

ELECTRICAL NOTES

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Jignesh.Parmar

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Note: All Notes/Abstract s are based on some electrical References. All References are mentions at the end of Note.

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Electrical	Length	Area
1HP=0.746KW	1Foot=30.48 cm	1 Sq.mt=1.19560 Sq.yard
1KW=1.36HP	1Foot=12 inch	1 Sq.mt=10.763 Sq.Foot
1Watt=0.846 KJ/Hr	1Meter= 0.304 Feet	1 Sq.cm=0.155 Sq.inch
1Watt=3.41 BTU/Hr	1Meter= 1.094 Yard	1 Sq.mt
1KWH=3.6 MJ	1Meter= 3.33 Feet	1 Sq.mt
1Cal=4.186 J	1Meter= 39.3 Inch	1 Sq.mt
1Tone= 3530 BTU	1Mile= 1.60 Km	1 Sq.mt
1Tone= 12000 BTU/Hr	1 Km=0.62137 Mile	
1Tone= 3.5 KW	1inch= 2.54 cm	
85 Sq.ft Floor Area=1200 BTU	1cm=0.0328 Foot	
1Kcal=4186 Joule	1cm=0.394 inch	
1KWH=860 Kcal	1mm=0.0328 inch	
1Cal=4.183 Joule	1km=0.62137 mile	
	1Yard=3 feet	
	1Yard=36 inch	
Star Connection	1Yard=91.4 cm	Temp
Line Voltage= $\sqrt{3}$ Phase Voltage	1Gaj=36 inch	$C^{\circ}=5/9(F^{\circ}-32)$
Line Current=Phase Current	1cm=1000 micron	$K^{\circ}=C^{\circ}+273.15$
Delta Connection		
Line Voltage=Phase Voltage		
Line Current= $\sqrt{3}$ Phase Current		

Power Factor (CosØ)	=KW / KVA
Motor In Put Power (KW)	=HPx0.746 / Efficiency (%)
KVA	= $\sqrt{3} \times V \times I / 1000$
KVA	= $\sqrt{(kW \times kW) + (kvar \times kvar)}$
Kvar	= $2 \times 3.14 \times f \times c \times (kv \times kv) / 1000$
Kvar	= $\sqrt{(kvar \times kvar) + (kW \times kW)}$
Capacitance (c)	=(Kvarx1000) / ($2 \times 3.14 \times f \times (kv \times kv)$)
Luminance (E) Lux	=Phi / Area (Sq.Meter)
Lux	=Lumens / Area (sq meter)
Sinusoidal Current Form Factor	=RMS Value/Average Value=1.11
Sinusoidal Current Peak Factor	=Max Value/RMS Value =1.414
Average Value of Sinusoidal Current (Iav)	=0.637xIm (Im= Max.Value)
RMS Value of Sinusoidal Current (Irms)	=0.707xIm (Im= Max.Value)
A.C Current=	D.C Current / 0.636
Phase Difference between Phase	=360 / No of Phase (1 Phase=360/1=360°, 2 Phase=360/2=180°)
Short Circuit Level of Cable in KA (Isc)	=0.094xCable Dia in Sq.mm) / $\sqrt{\text{Short Circuit Time (Sec)}}$
Maximum Cross Section Area of Earthing Strip(mm²)	= $\sqrt{(\text{Fault Current} \times \text{Fault Current} \times \text{Operating Time of Disconnected Device})} / K$ Where K=Material Factor, K for Cu=159, K for Alu=105, K for steel=58, K for GI=80
Most Economical Voltage at given Distance	= $5.5 \times \sqrt{((\text{km}/1.6) + (kW/100))}$
Cable Voltage Drop (%)	=($1.732 \times \text{current} \times (R \cos \phi + j \sin \phi) \times 1.732 \times \text{Length (km)} \times 100$) / (Volt(L-L) x Cable Run.
Spacing of Conductor in Transmission Line (mm)	= $500 + 18 \times (P-P \text{ Volt}) + (2 \times (\text{Span in Length}) / 50)$
Protection radius of LightingArrestor	= $\sqrt{h \times (2D-h) + (2D+L)}$ Where h= height of L.A, D-distance of equipment (20, 40, 60 Meter), L=Vxt (V=1m/ms, t=Discharge Time)
Size of Lighting Arrestor	=1.5x Phase to Earth Voltage or 1.5x (System Voltage/1.732)
Maximum Voltage of the System	=1.1xRated Voltage (Ex. 66KV=1.1x66=72.6KV)
Load Factor	=Average Power / Peak Power If Load Factor is 1 or 100% = This is best situation for System and Consumer both. If Load Factor is Low (0 or 25%) =you are paying maximum amount of KWH consumption. Load Factor may be increased by switching or use of your Electrical Application.

Demand Factor	=Maximum Demand / Total Connected Load (Demand Factor <1) Demand factor should be applied for Group Load
Diversity Factor	=Sum of Maximum Power Demand / Maximum Demand ,(Demand Factor >1) Diversity factor should be consider for individual Load
Plant Factor(Plant Capacity)	=Average Load / Capacity of Plant
Fusing Factor	=Minimum Fusing Current / Current Rating (Fusing Factor>1)
Voltage Variation (1 to 1.5%)	=(Average Voltage-Min Voltage)x100 / Average Voltage Ex: 462V, 463V, 455V, Voltage Variation= ((460-455) x100)/455=1.1%
Current Variation (10%)	=(Average Current-Min Current)x100 / Average Current. Ex:30A,35A,30A, Current Variation=((35- 31.7)x100)/31.7=10.4%
Fault Level at TC Secondary	=TC (VA) x100 / TC Secondary (V) x Impedance (%)
Motor Full Load Current	=Kw /1.732xKVxP.FxEfficiency
HV/LV Distribution Transformer Size (In Radial System)	=1.2xPeak Electrical Power / No of Transformer x cosØ
Voltage Rise in Transformers due to Capacitor Bank in Distribution Line	% Voltage Rise in Transformer=(Kvar / Kva)x Z Where ,Kvar =Applied Kvar ,Kva = Kva of the transformer ,z = Transformer Reactance in % Example: 300 Kvar bank connected to 1200 KVA transformer with 5.75% reactance.% Voltage Rise in Transformer=(300/1200)x 5.75 =1.43%
Number of Lighting Fixtures	=Illumination x area / Lamp per fixture x lumens x cu x mf
Area per Lighting Fixture	=lamp per fixture x lumens per lamp x cu x mf / Illumination
Street illumination level in Lux (E)	=Al x cu x mf / w x d Where, E = The illumination in Lux, w = Width of the Roadway, d = Distance between luminaries, cu = Coefficient of utilization. mf = maintenance factor (Normally 0.8 to 0.9) , Al = Average lumens, Al = (E x w x d) / Cu x mf The typical value of Al is 20500 lumens for 400 watts,11500 lumens for 250 watts,5400 lumens for 125 watts
Allowed illumination time in T (Hr)	=kx.tx1000/E Where: k = extension factor, t = permissible time in hours at 1000 lux, unfiltered daylight ,E = luminance (lx)
Running cost of Lamp	=Cost of electricity in \$/kWh x wattage of lamp x lifetime in hours
Cross Section area of Cable (mm2)	= I x √t / K Where, t = fault duration (S), I = effective short circuit current (kA), K = 0.094 for aluminum conductor insulated with XLPE
Electrical Line Ground Clearance (Meter)	= 5.812 + 0.305 X K Where K= (Volt-33)/33
Economical Voltage for Power Transmission (kV line to line)	= 5.5x√0.62 L + kVA /150 (Indian Practice) = 5.5x√0.62 L + kVA /150 (American Practice) Where L is length of transmission line in km

For Cu Wire Current Capacity (Up to 30 Sq.mm)	=6X Size of Wire in Sq.mm Example for 2.5 Sq.mm=6x2.5=15 A, For 1 Sq.mm=6x1=6 A, 1.5 Sq.mm=6x1.5=9 A
For Cable Current Capacity	=4X Size of Cable in Sq.mm , Example for 2.5 Sq.mm=4x2.5=9 Amp
1 Phase Motor draws Current	=7 Amp/HP.
3 Phase Motor draws Current	=1.25 Amp/HP.
Diesel Generator Set Produces	=3.87 Units (KWH) in 1 Litter of Diesel.
Requirement Area for Diesel Generator	for 25KW to 48KW=56 Sq.meter, 100KW=65 Sq.meter
DG noise levels to be less than	75dBA @ 1meter
DG Set must be Required in a canopy	<= 1000kVA DG set
DG Set can either be in a canopy or skid mounted in an acoustically treated room	>= 1000kVA DG set
DG fuel storage tanks	Should be a maximum of 990 Litter per unit Storage tanks above this level will trigger more stringent explosion protection provision.
Earthing Resistance =	Single Pit =5Ω , Earthing Grid=0.5Ω
As per NEC 1985 Earthing Resistance	<5Ω.
Voltage between Neutral and Earth	<=2 Volts
Resistance between Neutral and Earth	<=1Ω
Creepage Distance=	18 to 22mm/KV (Moderate Polluted Air) or
Creepage Distance=	25 to 33mm/KV (Highly Polluted Air)
Minimum Bending Radius for LT Power Cable	=12xDia of Cable.
Min. Bending Radius for HT Cable	=20xDia of Cable.
Min. Bending Radius for Control Cable	=10xDia of Cable.
Insulation Resistance for Rotating Machine	=(KV+1) MΩ.
Insulation Resistance for Motor (IS 732)	=((20xVoltage (L-L)) / (1000+ (2xKW))).
Insulation Resistance for Equipment (<1KV)	=Minimum 1 MΩ
Insulation Resistance for Equipment (>1KV)	=KV 1 MΩ per 1KV
Insulation Resistance Value for Panel	=2 x KV rating of the panel.
Min Insulation Resistance Value (Domestic)	=50 MΩ / No of Points. (All Electrical Points with Electrical fitting & Plugs). Should be less than 0.5 MΩ
Min Insulation Resistance Value (Commercial)	=100 MΩ / No of Points. (All Electrical Points without fitting & Plugs).Should be less than 0.5 MΩ.
Test Voltage (A.C) for Meggering	=(2X Name Plate Voltage) +1000
Test Voltage (D.C) for Meggering	=(2X Name Plate Voltage).
Submersible Pump Take	=0.4 KWH of extra Energy at 1 meter drop of Water
Arrestor have Two Rating	(1) MCOV=Max. Continuous Voltage (Line to Ground Operating Voltage).

	(2) Duty Cycle Voltage. (Duty Cycle Voltage>MCOV)
Nomenclature for cable Rating	= U_o/U , where U_o =Phase-Ground Voltage, U =Phase-Phase Voltage, U_m =Highest Permissible Voltage
Current Rating of Transformer	= $KVA \times 1.4$
Short Circuit Current of T.C /Generator	=Current Rating / % Impedance
No Load Current of Transformer	<2% of Transformer Rated current
Full Load Current of 3 Phase Motor	= $HP \times 1.5$
Full Load Current of 1 Phase Motor	= $HP \times 6$
No Load Current of 3 Phase Motor	=30% of FLC
KW Rating of Motor	= $HP \times 0.75$
Approximate Current	= $1.39 \times KVA$ (for 3 Phase 415V)olt)
Approximate Current	= $1.74 \times KW$ (for 3 Phase 415V)olt)
Capacitor Current (Ic)	= $KVAR / 1.732 \times Volt$ (Phase-Phase)
For LT metered supplies the maximum connected load will be	=150kW
The diversity for apartments	=60%
Earthing for each Transformer	2No. for body and 2No. for neutral earthing
Clearances around TC allow for transformer movement for replacement	Approximate 1000mm
Nomenclature of CT: Ratio, VA Burden, Accuracy Class, Accuracy Limit Factor.	Ratio: input / output current ratio
	Burden (VA): total burden including pilot wires. (2.5, 5, 10, 15 and 30VA.)
	Accuracy Class: Accuracy required for operation (Metering: 0.2, 0.5, 1 or 3, Protection: 5, 10, 15, 20, 30)
	Accuracy Limit Factor:
Example CT 1600/5, 15VA 5P10	Ratio=1600/5, Burden=15VA, Accuracy Class=5P, ALF=10
As per IEEE Metering CT=	0.3B0.1 rated Metering CT is accurate to 0.3 percent if the connected secondary burden if impedance does not exceed 0.1 ohms
As per IEEE Relaying (Protection) CT=	2.5C100 Relaying CT is accurate within 2.5 percent if the secondary burden is less than 1.0 ohm (100 volts/100A)
Rating of Lighting Arrestor=	= $1.5 \times \text{Phase to Earth Voltage}$ OR = $1.5 \times \text{system Voltage} / 1.732$ OR = $0.81 \times \text{highest System Voltage}$
Lighting Arrestor Protection Radius(Rp)=	= $\sqrt{H \times (2D-H) + L(2D+L)}$ H= Actual Height of L.A D= 20 meter, 40 meter or 60 meter L= $V \times T$ (T=Discharge Time & V= 1m/ms)
Cree page Distance=	=18 to 22 mm /KV for Moderate Polluted Air. =25 to 33 mm /KV for Heavily Polluted Air. =In HVDC System The value is double from above value

Cable Coding (IS 1554) : (A2XFY / A2XWY / A2XY / FRLS / FRPVC / FRLA / PILC)	
A	Aluminium
2X	XLPE
F	Flat Armoured
W	Wire Armoured
Y	Outer PVC Insulation Sheath
W	Steel Round Wire
WW	Steel double round wire Armoured
YY	Steel double Strip Armoured
FR	Fire Retardation
LS	Low Smoke
LA	Low Acid Gas Emission
WA	Non Magnetic round wire Armoured
FA	Non Magnetic Flat wire Armoured
FF	Double Steel Round Wire Armoured
Example: A2XFY= Aluminium Conductor, XLPE Insulation, Flat Armoured, Outer PVC Insulation	

Earthed / Unearthed Cable Nomenclature (Uo/U)	
Voltage Grade (Uo/U)	Where Uo is Phase to Earth Voltage & U is Phase to Phase Voltage.
Earthed system has insulation grade of KV / 0.686 x KV	For Earthed System (Uo/U): 1.9/3.3 kV, 3.8/6.6 kV, 6.35/11 kV, 12.7/22 kV and 19/33 kV
Unearthed system has insulation grade of KV / KV	For Unearthed System (Uo/U): 3.3/3.3 kV and 11/11 kV
Thumb Rule	6.6KV unearthed cable is equal to 11kV earthed cable i.e. 6.6/6.6kV Unearthed cable can be used for 6.6/11kV earthed system.

1.1Kv PVC Flexible Wire / Cable (Make: Havells)

Nominal Conductor Area (Sq.mm)	Aluminium		Copper		Aluminium	Copper	Overall Dia mm	Overall Weight Kg/Km	Short Circuit Current K.Amp
	Resi	React	Resi	React	Current	Current			
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp			
1cX0.5			39	0		4	2.1		0.400
1cX0.75			26	0		7	2.3		0.400
1cX1			19.5	0		11	2.7		0.400
1cX1.5			13.3	0		15	3		0.400
1cX2.5			7.98	0		19	3.6		0.400
1cX4			4.95	0		26	4.1		0.460
1cX6			3.3	0		35	4.6		0.690
1cX10			1.91	0		46	6.1		1.150
1cX16			1.21	0		62	7		1.84
1cX25			0.78	0		80	8.6		2.88
1cX35			0.554	0		102	9.7		4.03
1cX50			0.386	0		138	11.5		5.75
1cX70			0.272	0		214	13		8.05
1cX95			0.206	0		254	14.9		10.90
1cX120			0.161	0		300	16.4		13.80
2cX0.5			39	0		4	6.2		0.400
2cX0.75			26	0		7	6.6		0.400
2cX1			19.5	0		11	6.9		0.400
2cX1.5			13.3	0		15	7.4		0.500
2cX2.5			7.98	0		19	8.8		0.500
2cX4			4.95	0		26	10.2		0.500
3cX0.5			39	0		4	6.6		0.400
3cX0.75			26	0		7	6.9		0.500
3cX1			19.5	0		11	7.3		0.400
3cX1.5			13.3	0		15	7.8		0.500
3cX2.5			7.98	0		19	9.4		0.500
3cX4			4.95	0		26	10.9		0.500

1.1 KV PVC Insulated Cable (Ref: IS 1554) (Make: Havells) ,AYY/YY

Conduct or Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Overall Dia	Overall Weight	Short Circuit Current Rating for 1Sec	
	Resi	React	Resi	React	Ground	Duct	Air	Ground	Duct	Air			Alu	Cu
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp	Amp	Amp	Amp	Amp			K.A	K.A
1cX4	8.8	0.158	5.52	0.015	—	—	—	39	38	35	9	150	0.30	0.46
1cX6	5.53	0.148	3.69	0.148	39	37	35	49	48	44	10	180	0.45	0.69
1cX10	3.7	0.138	2.19	0.138	51	51	47	65	64	60	11	230	0.76	1.15
1cX16	2.29	0.128	1.38	0.128	66	65	64	85	83	82	11	370	1.22	1.84
1cX25	1.44	0.12	0.87	0.12	86	84	84	110	110	110	12	460	1.90	2.88
1cX35	1.04	0.114	0.627	0.114	100	100	105	130	125	130	13	460	2.66	4.03
1cX50	0.77	0.11	0.463	0.11	120	115	130	155	150	165	15	610	3.80	5.75
1cX70	0.53	0.103	0.321	0.103	140	135	155	190	175	205	17	800	5.32	8.05
1cX95	0.38	0.101	0.231	0.101	175	155	190	220	200	245	19	1100	7.22	10.90
1cX120	0.3	0.096	0.184	0.096	195	170	220	250	220	280	21	1350	9.12	13.80
1cX150	0.25	0.094	0.149	0.094	220	190	250	280	245	320	23	1650	11.4	17.30
1cX185	0.2	0.092	0.12	0.092	240	210	290	305	260	370	25	2000	14.10	21.30
1cX240	0.15	0.09	0.091	0.09	270	225	335	345	285	425	27	2550	18.20	27.30
1cX300	0.12	0.088	0.074	0.088	295	245	380	375	310	475	30	3200	22.8	34.50
1cX400	0.094	0.088	0.059	0.088	325	275	435	400	335	550	34	4000	30.40	46.00
1cX 500	0.072	0.087	0.046	0.087	345	295	480	425	355	590	38	5100	38.00	57.50
1cX 630	0.056	0.086	0.037	0.086	390	320	550	470	375	660	43	6550	47.90	72.50
1cX800	0.044	0.083	0.031	0.083	450	380	610	530	425	725	46	8220	60.80	92.00
1cX1000	0.034	0.082	0.03	0.082	500	415	680	590	740	870	50	10150	76.00	115.0
2cX1.5	21.72	0.126	14.5	0.126	18	16	16	23	20	20			0.3	0.4
2cX2.5	14.52	0.119	8.87	0.119	16	21	21	32	27	27			0.3	0.4
2cX4	8.89	0.116	5.52	0.116	32	27	27	41	35	35	14	320	0.30	0.46
2cX 6	5.53	0.11	3.69	0.11	40	34	35	50	44	45	16	370	0.45	0.69
2cX10	3.7	0.1	2.19	0.1	55	45	47	70	58	60	18	520	0.76	1.15
2cX16	2.29	0.097	1.38	0.097	70	58	59	90	75	78	18	550	1.22	1.84
2cX25	1.44	0.097	0.87	0.097	90	76	78	115	97	105	20	800	1.90	2.88
2cX35	1.04	0.097	0.627	0.097	110	92	99	140	120	125	22	980	2.660	4.03
2cX50	0.77	0.094	0.463	0.094	135	115	125	165	145	155	24	1300	3.800	5.75
2cX70	0.53	0.09	0.321	0.09	160	140	150	205	180	195	26	1700	5.320	8.05
2cX95	0.38	0.09	0.231	0.09	190	170	185	240	215	230	30	2300	7.220	10.9
2cX120	0.3	0.087	0.184	0.087	210	190	210	275	235	265	32	2750	9.120	13.8
2cX150	0.25	0.087	0.149	0.087	240	210	240	310	270	305	34	3350	11.40	17.30
2cX185	0.2	0.087	0.12	0.087	275	240	275	350	300	350	37	4150	14.10	21.28
2cX240	0.15	0.087	0.091	0.087	320	275	325	405	345	410	42	5350	18.20	27.60
2cX300	0.12	0.086	0.073	0.086	355	305	365	450	385	465	46	6650	22.80	34.50
2cX400	0.09	0.086	0.059	0.086	385	345	420	490	485	530	52	8450	30.40	46.00
2cX500	0.09	0.086	0.059	0.086	425	380	475	540	460	605	58	10700	38.00	57.50
2cX630	0.09	0.086	0.059	0.086	465	415	540	640	550	785	65	13800	47.90	72.55
3cX1.5	21.72	0.126	14.5	0.126	16	14	13	21	17	17			0.3	0.4
3cX2.5	14.52	0.119	8.87	0.119	21	18	18	27	24	24			0.3	0.4
3cX4	8.89	0.116	5.52	0.116	28	23	23	36	30	30	15	360	0.304	0.460
3cX 6	5.53	0.11	3.69	0.11	35	30	30	45	38	39	16	450	0.456	0.690

3cX 10	3.7	0.1	2.19	0.1	46	39	40	60	50	52	18	620	0.760	1.150
3cX 16	2.29	0.097	1.38	0.097	60	50	51	77	64	66	19	740	1.220	1.840
3cX 25	1.44	0.097	0.87	0.097	76	63	70	99	81	90	22	1100	1.900	2.880
3cX 35	1.04	0.097	0.627	0.097	92	77	86	120	99	110	24	1400	2.660	4.030
3cX 50	0.77	0.094	0.463	0.094	110	95	105	145	125	135	27	1800	3.800	5.750
3cX 70	0.53	0.09	0.321	0.09	135	115	130	175	150	165	30	2500	5.320	8.050
3cX 95	0.38	0.9	0.231	0.09	165	140	155	210	175	200	34	3300	7.220	10.90
3cX 120	0.3	0.087	0.184	0.087	185	155	180	240	195	230	36	4000	9.120	13.80
3cX 150	0.25	0.087	0.149	0.087	210	175	205	270	225	265	40	4900	11.40	17.30
3cX 185	0.2	0.087	0.12	0.087	235	200	240	300	255	305	44	6065	14.10	21.30
3cX 240	0.15	0.087	0.091 2	0.087	275	235	280	345	295	355	50	7850	18.20	27.60
3cX 300	0.12	0.086	0.074	0.086	305	260	315	385	335	400	55	9750	22.80	34.50
3cX 400	0.09	0.086	0.059	0.086	335	290	375	425	360	435	62	12400	30.40	46.00
3cX 500	0.09	0.086	0.059	0.086	370	320	425	470	390	520	70	15800	38.00	57.50
3cX 630	0.09	0.086	0.059	0.086	405	350	480	555	470	675	78	20200	47.90	72.50
3.5X16	1.44	0.097	0.73	0.097	70	65	62	99	81	90			1.8	2.5
3.5X25	0.77	0.094	0.387	0.094	76	63	70	99	81	90	23	1250	1.90	2.88
3.5X35	0.53	0.09	0.268	0.09	92	77	86	120	99	110	26	1600	2.66	4.03
3.5X50	0.38	0.09	0.193	0.09	110	95	105	145	125	135	28	2100	3.80	5.75
3.5X70	0.3	0.087	0.153	0.087	135	115	130	175	150	165	32	2850	5.32	8.05
3.5X95	0.2	0.087	0.099	0.087	165	140	155	210	175	200	37	3800	7.22	10.90
3.5X120	0.15	0.087	0.075	0.087	185	155	180	240	195	230	40	4750	9.12	13.80
3.5X150	0.12	0.086	0.06	0.086	210	175	205	270	225	265	44	5650	11.40	17.30
3.5X185	0.09	0.086	0.047	0.086	235	200	240	300	255	305	48	7050	14.10	21.30
3.5X240	0.08	0.085	0.046	0.085	275	235	280	345	295	355	55	9150	18.20	27.60
3.5X300	0.08	0.085	0.046	0.085	305	260	315	385	335	400	60	11300	22.80	34.50
3.5X400	0.08	0.084	0.045	0.084	335	290	375	425	360	435	68	14300	30.40	46.00
3.5X500	0.08	0.084	0.045	0.084	370	320	425	470	390	520	77	18300	38.00	57.50
3.5X630	0.08	0.084	0.045	0.084	405	350	480	555	470	675	87	23300	47.90	72.50
4cX 1.5	21.72	0.126	14.5	0.126	16	14	13	21	17	17			0.3	0.4
4cX 2.5	14.52	0.119	8.87	0.119	21	18	18	27	24	24			0.3	0.4
4cX4	8.89	0.116	5.52	0.116	28	23	23	36	30	30	16	430	0.304	0.46
4cX 6	5.53	0.11	3.69	0.11	35	30	30	45	38	39	18	540	0.456	0.69
4cX 10	3.7	0.1	2.19	0.1	46	39	40	60	50	52	20	750	0.760	1.15
4cX16	2.29	0.097	1.38	0.097	60	50	51	77	64	66	21	950	1.220	1.84
4cX 25	1.44	0.097	0.87	0.097	76	63	70	99	81	90	24	1400	1.900	2.88
4cX35	1.04	0.097	0.62	0.097	92	77	86	120	99	110	26	1750	2.660	4.03
4cX 50	0.77	0.094	0.46	0.094	110	95	105	145	125	135	30	2350	3.800	5.75
4cX70	0.53	0.09	0.32	0.09	135	115	130	175	150	165	33	3150	5.320	8.05
4cX 95	0.38	0.09	0.23	0.09	165	140	155	210	175	200	38	4300	7.220	10.90
4cX 120	0.3	0.087	0.18	0.087	185	155	180	240	195	230	41	5250	9.120	13.80
4cX 150	0.25	0.087	0.14	0.087	210	175	205	270	225	265	45	6450	11.40	17.30
4cX 185	0.2	0.087	0.12	0.087	235	200	240	300	255	305	50	8000	14.10	21.30
4cX 240	0.15	0.087	0.091	0.087	275	235	280	345	295	355	57	10350	18.20	27.60
4cX 300	0.12	0.086	0.073	0.086	305	260	315	385	335	400	63	12900	22.80	34.50
4cX 400	0.09	0.086	0.059	0.086	335	290	375	425	360	435	71	16300	30.40	46.00
4cX 500	0.09	0.086	0.059	0.086	370	320	425	470	390	520	80	20900	38.00	57.50
4cX 630	0.09	0.086	0.059	0.086	405	350	480	555	470	675	90	26600	47.90	72.50

1.1 KV XLPE Insulated Cable (Ref: IS 1554) (Make: Havells), AYY/YY

Conduct or Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Over all Dia	Over all Weight	Short Circuit Current Rating for 1Sec.duration in K. Amps	
	Resi	React	Resi	React	Gro und	Duct	Air	Gro und	Duct	Air			Alu	Cu
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp	Amp	Amp	Amp	Amp			K.A	K.A
1cX4	1.555	0.102	1.555	0.102	—	—	—	48	47	45	9	150	0.376	0.572
1cX6	1.553	0.102	1.553	0.102	48	45	45	60	59	57	10	180	0.564	0.858
1cX10	1.553	0.102	1.553	0.102	62	62	61	80	78	77	11	230	0.940	1.430
1cX16	1.54	0.102	1.540	0.102	81	80	83	104	102	106	11	370	1.504	2.288
1cX25	1.54	0.102	0.930	0.102	99	90	115	130	115	145	12	460	2.350	3.575
1cX35	1.11	0.097	0.671	0.097	117	110	135	155	140	175	13	460	3.290	5.005
1cX50	0.82	0.092	0.495	0.092	138	125	170	185	165	215	15	610	4.700	7.150
1cX70	0.56	0.088	0.343	0.088	168	155	210	225	200	270	17	800	6.580	10.01
1cX95	0.41	0.085	0.247	0.085	204	185	255	265	235	330	19	1100	8.930	13.59
1cX120	0.32	0.082	0.196	0.082	230	210	300	300	265	380	21	1350	11.28	17.16
1cX150	0.265	0.082	0.159	0.082	265	230	342	335	300	430	23	1650	14.10	21.45
1cX185	0.211	0.082	0.127	0.082	295	260	385	380	335	495	25	2000	17.39	26.46
1cX240	0.162	0.079	0.097	0.079	340	300	450	435	385	590	27	2550	22.56	34.32
1cX300	0.13	0.078	0.077	0.078	390	335	519	490	430	670	30	3200	28.20	42.90
1cX400	0.102 3	0.077	0.061	0.077	450	380	605	550	480	780	34	4000	37.60	57.20
1cX 500	0.080 8	0.076	0.047	0.076	500	430	700	610	530	900	38	5100	47.00	71.50
1cX 630	0.064 8	0.075	0.036	0.075	555	485	809	680	590	1020	43	6550	59.22	90.09
1cX800	0.053	0.075	0.028	0.075	625	530	935	740	630	1140	46	8220	75.20	114.40
1cX1000	0.044 4	0.068	0.023	0.068	690	570	1065	780	660	1250	50	10150	94.00	143.00
2cX1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2cX2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2cX4	1.555	0.097	1.555	0.097	34	28	30	44	37	39	14	320	0.376	0.572
2cX 6	1.553	0.097	1.553	0.097	43	37	40	55	47	50	16	370	0.564	0.858
2cX10	1.553	0.085	1.553	0.085	57	48	53	74	61	67	18	520	0.940	1.430
2cX16	1.54	0.080	1.540	0.08	78	61	70	94	78	85	18	550	1.50	2.29
2cX25	1.54	0.080	0.930	0.08	95	80	99	120	100	125	20	800	2.35	3.58
2cX35	1.11	0.080	0.671	0.08	116	94	117	145	120	155	22	980	3.29	5.01
2cX50	0.082	0.078	0.495	0.078	140	110	140	170	145	190	24	1300	4.70	7.15
2cX70	0.57	0.077	0.343	0.077	170	140	176	210	175	235	26	1700	6.58	10.01
2cX95	0.41	0.074	0.247	0.074	200	165	221	250	210	290	30	2300	8.93	13.59
2cX120	0.33	0.072	0.196	0.072	225	185	258	285	240	330	32	2750	11.28	17.16
2cX150	0.27	0.072	0.159	0.072	255	210	294	315	270	375	34	3350	14.10	21.45
2cX185	0.21	0.072	0.127	0.072	285	235	339	355	300	435	37	4150	17.39	26.46
2cX240	0.16	0.072	0.097	0.072	325	270	402	410	350	510	42	5350	22.56	34.32
2cX300	0.13	0.071	0.077	0.071	370	305	461	460	390	590	46	6650	28.20	42.90
2cX400	0.1	0.070	0.060	0.07	435	350	542	520	440	670	52	8450	37.60	57.20
2cX500	0.1	0.070	0.060	0.07	481	405	624	580	480	750	58	10700	47.00	71.50

2cX630	0.1	0.070	0.060	0.07	537	470	723	680	575	875	65	13800	59.22	90.09
3cX1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3cX2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3cX4	1.581	0.097	1.581	0.097	34	28	30	44	37	39	15	360	0.376	0.572
3cX 6	1.57	0.097	1.570	0.097	43	37	40	55	47	50	16	450	0.564	0.858
3cX 10	1.55	0.080	1.550	0.08	57	48	53	74	61	67	18	620	0.940	1.430
3cX 16	1.557	0.080	1.557	0.08	78	61	70	94	78	85	19	740	1.50	2.29
3cX 25	1.54	0.080	0.930	0.08	95	80	99	120	100	125	22	1100	2.35	3.58
3cX 35	1.11	0.080	0.671	0.08	116	94	117	145	120	155	24	1400	3.29	5.01
3cX 50	0.82	0.780	0.495	0.078	140	110	140	170	145	190	27	1800	4.70	7.15
3cX 70	0.57	0.077	0.343	0.077	170	140	176	210	175	235	30	2500	6.58	10.01
3cX 95	0.41	0.074	0.247	0.074	200	165	221	250	210	290	34	3300	8.93	13.59
3cX 120	0.33	0.072	0.196	0.072	225	185	258	285	240	330	36	4000	11.28	17.16
3cX 150	0.27	0.072	0.159	0.072	255	210	294	315	270	375	40	4900	14.10	21.45
3cX 185	0.21	0.072	0.127	0.072	285	235	339	355	300	435	44	6065	17.39	26.46
3cX 240	0.16	0.072	0.097	0.072	325	270	402	410	350	510	50	7850	22.56	34.32
3cX 300	0.13	0.071	0.077	0.071	370	305	461	460	390	590	55	9750	28.20	42.90
3cX 400	0.1	0.070	0.060	0.07	435	350	542	520	440	670	62	12400	37.60	57.20
3cX 500	0.1	0.070	0.060	0.07	481	405	624	580	480	750	70	15800	47.00	71.50
3cX 630	0.1	0.070	0.060	0.07	537	470	723	680	575	875	78	20200	59.22	90.09
3.5X16	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3.5X25	1.54	0.080	0.930	0.08	95	80	99	120	100	125	23	1250	2.35	3.58
3.5X35	1.11	0.080	0.671	0.08	116	94	117	145	120	155	26	1600	3.29	5.01
3.5X50	0.82	0.078	0.050	0.078	140	110	140	170	145	190	28	2100	4.70	7.15
3.5X70	0.57	0.077	0.343	0.077	170	140	176	210	175	235	32	2850	6.58	10.01
3.5X95	0.41	0.074	0.247	0.074	200	165	221	250	210	290	37	3800	8.93	13.59
3.5X120	0.33	0.072	0.196	0.072	225	185	258	285	240	330	40	4750	11.28	17.16
3.5X150	0.27	0.072	0.159	0.072	255	210	294	315	270	375	44	5650	14.10	21.45
3.5X185	0.21	0.072	0.127	0.072	285	235	339	355	300	435	48	7050	17.39	26.46
3.5X240	0.16	0.072	0.097	0.072	325	270	402	410	350	510	55	9150	22.56	34.32
3.5X300	0.13	0.071	0.077	0.071	370	305	461	460	390	590	60	11300	28.20	42.90
3.5X400	0.1	0.070	0.060	0.07	435	350	542	520	440	670	68	14300	37.60	57.20
3.5X500	0.1	0.070	0.060	0.07	481	405	624	580	480	750	77	18300	47.00	71.50
3.5X630	0.1	0.070	0.060	0.07	537	470	723	680	575	875	87	23300	59.22	90.09
4cX 1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4cX 2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4cX4	5.53	0.110	3.690	0.11	34	28	30	44	37	39	16	430	0.376	0.572
4cX 6	3.7	0.100	2.190	0.1	43	37	40	55	47	50	18	540	0.564	0.858
4cX 10	2.29	0.097	1.380	0.097	57	48	53	74	61	67	20	750	0.940	1.430
4cX16	2.45	0.080	1.470	0.08	78	61	70	94	78	85	21	950	1.50	2.29
4cX 25	1.54	0.080	0.930	0.08	95	80	99	120	100	125	24	1400	2.35	3.58
4cX35	1.11	0.080	0.671	0.08	116	94	117	145	120	155	26	1750	3.29	5.01
4cX 50	0.082	0.078	0.495	0.078	140	110	140	170	145	190	30	2350	4.70	7.15
4cX70	0.57	0.077	0.343	0.077	170	140	176	210	175	235	33	3150	6.58	10.01
4cX 95	0.41	0.074	0.247	0.074	200	165	221	250	210	290	38	4300	8.93	13.59
4cX 120	0.33	0.072	0.196	0.072	225	185	258	285	240	330	41	5250	11.28	17.16
4cX 150	0.27	0.072	0.159	0.072	255	210	294	315	270	375	45	6450	14.10	21.45
4cX 185	0.21	0.072	0.127	0.072	285	235	339	355	300	435	50	8000	17.39	26.46
4cX 240	0.16	0.072	0.097	0.072	325	270	402	410	350	510	57	10350	22.56	34.32

4cX 300	0.13	0.071	0.077	0.071	370	305	461	460	390	590	63	12900	28.20	42.90
4cX 400	0.1	0.070	0.060	0.07	435	350	542	520	440	670	71	16300	37.60	57.20
4cX 500	0.1	0.070	0.060	0.07	481	405	624	580	480	750	80	20900	47.00	71.50
4cX 630	0.1	0.070	0.060	0.07	537	470	723	680	575	875	90	26600	59.22	90.09

3.8 / 6.6 KV (3.8Kv Un-Earthed / 6.6 KV Earthed) AL/COPPER COND, XLPE INSULATED CABLES (Ref: IS 7098) (Make: Havells) , A2XFY/2XFY, A2XWY/2XWY														
Conduct or Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Over all Dia	Over all Weigh ht	Short Circuit Current Rating for 1Sec.duration in K. Amps	
	Resi	React	Resi	React	Grou nd	Duct	Air	Gro und	Duct	Air			Alu	Cuer
	Ω/km	Ω/km	Ω/km	Ω/km	Amp	Amp	Amp	Amp	Amp	Amp			K.A	K.A
1cX25	1.1	0.129	1.1	0.129	100	90	120	130	115	155	21	700	2.35	3.58
1cX35	1.1	0.129	1.1	0.129	120	105	145	155	140	185	22	720	3.29	5.00
1cX50	0.822	0.129	0.822	0.129	140	125	170	185	160	220	23	1000	4.70	7.15
1cX70	0.568	0.120	0.568	0.120	175	155	215	225	195	275	25	1200	6.58	10.01
1cX95	0.411	0.113	0.411	0.113	205	180	260	265	235	340	27	1500	8.93	13.59
1cX120	0.325	0.109	0.325	0.109	235	205	305	300	265	390	28	1750	11.28	17.16
1cX150	0.265	0.106	0.265	0.106	260	230	345	335	295	440	30	2050	14.10	21.45
1cX185	0.211	0.103	0.211	0.103	295	260	395	380	330	510	31	2450	17.39	26.46
1cX240	0.161	0.101	0.161	0.101	340	300	470	435	380	600	35	3100	22.56	34.32
1cX300	0.13	0.099	0.13	0.099	385	335	540	490	425	680	37	3700	28.20	42.90
1cX400	0.102	0.096	0.102	0.096	0.57	440	380	630	550	480	41	4650	790	37.60
1cX 500	0.08	0.094	0.08	0.094	0.60	495	430	730	610	530	46	5800	910	47.00
1cX 630	0.063	0.092	0.063	0.092	0.67	560	480	840	680	580	50	7200	1030	59.22
1cX800	0.052	0.090	0.052	0.090	0.76	620	530	960	740	630	55	9100	1140	75.20
1cX1000	0.043	0.088	0.043	0.088	0.82	680	580	1070	790	670	60	11200	1250	94.00
3cX 25	1.1	0.134	1.1	0.134	95	82	105	120	105	135	38	2850	2.35	3.58
3cX 35	1.1	0.134	1.1	0.134	115	97	125	145	125	165	40	3300	3.29	5.01
3cX 50	0.822	0.136	0.822	0.136	130	115	150	170	150	195	44	3900	4.70	7.15
3cX 70	0.568	0.124	0.568	0.124	160	140	190	210	180	240	47	4700	6.58	10.01
3cX 95	0.411	0.117	0.411	0.117	190	165	230	250	215	295	52	6100	8.93	13.59
3cX 120	0.325	0.113	0.325	0.113	220	190	260	280	240	335	55	7150	11.28	17.16
3cX 150	0.265	0.110	0.265	0.110	245	210	295	310	270	380	59	8200	14.10	21.45
3cX 185	0.211	0.107	0.211	0.107	275	240	335	350	305	430	62	9550	17.39	26.46
3cX 240	0.161	0.104	0.161	0.104	315	275	395	400	350	500	69	12300	22.56	34.32
3cX 300	0.13	0.100	0.13	0.100	355	310	450	445	390	570	75	14700	28.20	42.90
3cX 400	0.102	0.097	0.102	0.097	400	350	520	500	440	650	86	19200	37.60	57.20

6.6 /11 KV(6.6KV Un-Earthed / 11KV Earthed) AL/COPPER COND, XLPE INSULATED CABLES
(Ref: IS 7098) (Make: Havells) ,A2XFY/2XFY, A2XWY/2XWY

Conduct or Area (Sq.mm)	Aluminium		Copper		Aluminum			Copper			Over all Dia	Over all Weig ht	Short Circuit Current Rating for 1Sec.duration in K. Amps	
	Resi	React	Resi	React	Gro und	Duct	Air	Gro und	Duct	Air			Alu	Cu
	ohm/km	ohm/km	ohm/km	ohm/km	Amp	Amp	Amp	Amp	Amp	Amp			K.A	K.A
1cX25	1.1	0.134	1.1	0.134	100	90	120	130	115	155	23	800	2.35	3.58
1cX35	1.1	0.134	1.1	0.134	120	105	145	155	140	185	24	900	3.29	5.00
1cX50	0.822	0.136	0.822	0.136	140	125	170	185	160	220	25	1050	4.70	7.15
1cX70	0.568	0.124	0.568	0.124	175	155	215	225	195	275	27	1300	6.58	10.01
1cX95	0.411	0.117	0.411	0.117	205	180	260	265	235	340	28	1550	8.93	13.59
1cX120	0.325	0.113	0.325	0.113	235	205	305	300	265	390	30	1850	11.28	17.16
1cX150	0.265	0.110	0.265	0.110	260	230	345	335	295	440	31	2150	14.10	21.45
1cX185	0.211	0.107	0.211	0.107	295	260	395	380	330	510	34	2600	17.39	26.46
1cX240	0.161	0.104	0.161	0.104	340	300	470	435	380	600	36	3200	22.56	34.32
1cX300	0.13	0.100	0.13	0.100	385	335	540	490	425	680	38	3800	28.20	42.90
1cX400	0.102	0.097	0.102	0.097	440	380	630	550	480	790	42	4650	37.60	57.20
1cX 500	0.08	0.094	0.08	0.094	495	430	730	610	530	910	47	5850	47.00	71.50

BASIC DATA FOR ALL ALUMINIUM CONDUCTORS STEEL REINFORCED (IS 398)

CODE WORD	Aluminum Area Sqmm		Total Sectional Area Sq mm	Stranding and Wire Diameter				Overall Dia. (mm) approx	WEIGHT MASS			Resistance at 20 degC Ohms/Km (MAX)	Ultimate Breaking Load (KN)
				Conductor (AL)		Conductor (ST)							
	NO.	DIA		NO	DIA								
		(mm)			(mm)								
MOLE	10	10.60	12.37	6	1.50	-	1.50	4.50	43	29	14	2.780	3.97
ROSE	18	18.10	21.12	6	1.96	1	1.96	5.88	73	49.5	23.5	1.618	6.74
SQUIRREL	20	20.98	24.48	6	2.11	1	2.11	6.33	85	58	27	1.394	7.61
WEASEL	30	31.61	36.88	6	2.59	1	2.59	7.77	128	87	41	0.9289	11.12
RABBIT	50	52.88	61.70	6	3.35	1	3.53	10.05	214	145	69	0.5524	18.25
RACCOON	80	78.83	91.97	6	4.09	1	4.09	12.27	318	215	103	0.3712	26.91
DOG	100	105.0	118.5	6	4.72	7	1.57	14.15	394	288.3	105.7	0.2792	32.41
WOLF	150	158.1	194.9	30	2.59	7	2.59	18.13	727	438	289	0.1871	67.34
PANTHER	200	212.1	261.5	30	3.00	7	3.00	21.00	976	588.5	387.5	0.1390	89.67
KUNDAH	400	404.1	425.2	42	3.50	7	1.96	26.88	1282	1119	163	0.07311	88.79
ZEBRA	420	428.9	484.5	54	3.18	7	3.18	28.62	1621	1182	439	0.06868	130.32
MOOSE	520	528.5	597.0	54	3.53	7	3.53	31.77	1998	1463	535	0.05595	159.60
MORCULLA	560	562.7	591.7	42	4.13	7	2.30	31.68	1781	1553	228	0.05231	120.16
GOPHER	16	25.90	30.62	6	2.36	1	2.36	7.08	106	72	34	1.0980	952
FERRET	25	41.87	49.98	6	3.00	1	3	9	171	116	55	0.6795	1503
MINK	40	63.32	73.65	6	3.66	1	3.66	10.98	255	173	82	0.4565	2207
HORSE	42	71.58	116.20	12	2.75	7	2.79	13.95	542	204	338	0.3977	6108
BEAVER	45	74.07	87.53	6	3.99	1	3.99	11.97	303	205	98	0.3841	2613
OTTER	50	82.85	97.91	6	4.22	1	4.22	12.66	339	230	109	0.3434	2923
CAT	55	94.21	111.30	6	4.5	7	4.50	13.50	385	261	124	0.3020	3324
LEOPARD	80	129.70	148.40	6	5.28	7	1.76	15.48	493	360	133	0.2193	4137
COYOTE	80	128.50	151.60	26	2.54	7	1.90	15.86	521	365	156	0.2214	4638
TIGER	80	128.10	161.80	30	2.36	7	2.36	16.52	604	363	241	0.2221	5758
LYNX	110	179.00	226.20	30	2.79	7	2.79	19.53	844	506	338	0.1589	7950
LION	140	232.50	293.90	30	3.18	7	3.18	22.26	1097	659	438	0.1223	10210
BEAR	160	258.10	326.10	30	3.35	7	3.35	23.45	1219	734	485	0.1102	11310
GOAT	185	316.5	400	30	3.71	7	3.71	25.97	1492	896	596	0.0898	13780
SHEEP	225	366.1	462.6	30	3.99	7	3.99	27.93	1726	1036	690	0.0777	15910
DEER	260	419.3	529.8	30	4.27	7	4.27	29.89	1977	1188	789	0.0678	18230
FLK	300	465.7	588.4	30	4.5	7	4.5	31.5	2196	1320	876	0.0611	20240
CAMEL	300	464.5	537.7	54	3.35	7	3.35	30.15	1804	1318	486	0.0612	14750
SPARROW	20	33.16	39.22	6	2.67	7	2.67	8.01	135	92	43	0.8578	1208
FOX	22	36.21	42.92	6	2.79	7	2.79	8.37	149	101	48	0.7857	1313
GUINEA	49	78.56	127.2	12	2.92	7	2.92	14.6	590	224	366	0.362	6664
LARK	125	196.1	247.8	30	2.92	7	2.92	20.44	922	556	366	0.1451	8559

Load in Multi-storied Building (Madhyanchal Vidyut Vitran Nigam)		
Type of Load	Calculation	Diversity
Domestic (Without Common Area)	50 watt / sq. meters	0.5
Commercial (Without Common Area)	150 watt / sq. meters	0.75
Lift, Water Pump, Streetlight ,Campus Lighting ,Common Facilities,	Actual load shall be calculated	0.75

Load in Multi-storied Building (Noida Power Company Limited)		
Type of Load	Calculation	Diversity
Domestic (Constructed area)	15 watt / sq. Foot	0.4
Commercial(Constructed area)	30 watt / sq. Foot	0.8
Industrial (Constructed area)	100 watt/ 1 sq. Foot	0.5
Lift, Water Pump, Streetlight ,Campus Lighting ,Common Facilities,	0.5Kw / Flat	
Voltage Drop:	2% Voltage drop from Transformer to Consumer end.	
T&D Losses:	2% T&D Losses from Transformer to Consumer end.	

Approximate % Cost or Sq.Foot Cost		
Project Item	% of Total Project Cost	Rs per Sq.Foot
Articheture (Consultancy)	0.7%	13.1 Rs / Sq.Foot
Structural (Consultancy)	1.2%	21.8 Rs / Sq.Foot
Service Design (Consultancy)	0.4%	7.2 Rs / Sq.Foot
Fire Fighting Work	1.3%	23 Rs / Sq.Foot
Electrical Work	4.1%	76 Rs / Sq.Foot
Lift Work	4.4%	82 Rs / Sq.Foot

Street Light Cost (CPWD-2012)	
Fluorescent Lamp	95 Rs/Sq.Meter
With HPMV Lamp	130 Rs/Sq.Meter
With HPSV Lamp	165 Rs/Sq.Meter
Electrical Signage	85 Rs/Sq.Meter

Solar / HVAC Cost	
Solar Light	10 Watt/Sq.Foot
Solar Power Installation	1.5 Lacs Rs/1Kw
HVAC	18 Watt/Sq.Foot

Rate Analysis Rs per Sq. Meter (CPWD-2012)				
Work	Office/College/Hospital	School	Hostel	Residence
Fire Fighting (with Wet Riser)	500	500	500	500
Fire Fighting (with Sprinkler)	750	750	750	750
Fire Alarm (Manually)	-	-	-	300
Fire Alarm (Automatic)	500	500	500	500
Pressurized Ventilation	650	650	650	650

Rate Analysis % of Total Project Cost (CPWD-2012)				
Work	Office/College/Hospital	School	Hostel	Residence
Internal Water Supply & Sanitary	4%	10%	5%	12%
Internal Electrical Installation	12.5%	12.5%	12.5%	12.5%

Approximate Load as per Sq.ft Area (As per DHBVN)	
Sq.ft Area	Required Load (Connected)
< 900 Sq.ft	8 KW
901 Sq.ft to 1600 Sq.ft	16 KW
1601 Sq.ft to 2500 Sq.ft	20 KW
> 2500 Sq.ft	24 KW
For Flats :	100 Sq.foot / 1 KW
For Flats USS /TC:	100 Sq.foot / 23 KVA

Contracted Load in case of High-rise Building:	
For Domestic Load	500 watt per 100 Sq. foot of the constructed area.
For Commercial	1500 watt per 100 Sq. foot of the constructed area
Other Common Load	For lift, water lifting pump, streetlight if any, corridor/campus lighting and other common facilities, actual load shall be calculated
Staircase Light	11 Watt/Flat Ex: 200Flat=200x11=2.2KW
Sanctioned Load for Building	
Up to 50 kW	The L.T. existing mains shall be strengthened.
50 kW to 450 kW (500 kVA)	11 kV existing feeders shall be extended if spare capacity is available otherwise, new 11 kV feeders shall be constructed.
450 kW to 2550 kW (3000 kVA)	11 kV feeder shall be constructed from the nearest 33 kV or 110 kV substation
2550 kW to 8500 kW (10,000 kVA)	33kV feeder from 33 kV or 110 kV sub station
8500 kW (10,000 kVA)	110 kV feeder from nearest 110 kV or 220 kV sub-station

Approximate Load as per Sq.Foot Area:		
Type of Load	Load/Sq.Ft	Diversity Factor
Industrial	1000 Watt/Sq.Ft	0.5
Commercial	30 Watt/Sq.Ft	0.8
Domestic	15 Watt/Sq.Ft	0.4
Lighting	15 Watt/Sq.Ft	0.8

Size of Ventilation Shaft:		
Building Height (Mt)	Size of ventilation shaft (sq meter)	Minimum size of shaft (Mt)
9.0	1.5	1.0
12.5	3.0	1.2
15 and above	4.0	1.5

Distribution Losses (Gujarat Electricity Board)		
Voltage (Point of Injection)	At 11 KV	Point of Energy Delivered
11KV / 22KV / 33KV	10%	1082%
400 Volt	-	16.77%

Lift Speed (Indian Army Manual)	
No of Floor	Lift Speed
4 to 5	0.5 to 0.7 meter/Sec
6 to 12	0.75 to 1.5 meter/Sec
3 to 20	1.5 to 2.5 meter/Sec
Above 20	Above 2.5 meter/Sec

Lift Details (CPWD-2012)						
Type of Lift	Persons	Weight	Speed(M/Sec)	Travel	Price	Add Rs /Floor
Passenger Lift	8 Person	544 Kg	1.0	G+4	18 Lacs	1.25 Lacs
Passenger Lift	13 Person	844 Kg	1.5	G+4	22 Lacs	1.25 Lacs
Passenger Lift	16 Person	1088 Kg	1.0	G+4	28 Lacs	1.50 Lacs
Passenger Lift	20 Person	1360 Kg	1.5	G+4	30 Lacs	1.50 Lacs

MCB Class according to Appliances			
Appliance	Capacity / watt	MCB Rating	MCB Class
Air Conditioner	1.0 Tone	10A	C Class
	1.5 Tone	16A	C Class
	2.0 Tone	20A	C Class
Freeze	165 Liter	3 A	C Class
	350 Liter	4 A	C Class
Oven /Grill	4500 Watt	32 A	B Class
	1750Watt	10 A	B Class
Oven / Hotplate	750Watt	6 A	B Class
	2000Watt	10 A	B Class
Room Heater	1000Watt	6 A	B Class
	2000Watt	10 A	B Class
Washing Machine	300Watt	2 A	C Class
	1300Watt	8 A	C Class
Water Heater	1000Watt	6 A	B Class
	2000Watt	10 A	B Class
	3000Watt	16 A	B Class
	6000Watt	32 A	B Class
Iron	750Watt	6 A	B Class
	1250Watt	8 A	B Class
Toaster	1200 Watt	8 A	B Class
	1500 Watt	10 A	B Class

Voltage Limit for Electrical Load (As per CPWD & Kerala Electricity Board):

Voltage	Total Load
240V	< 5 KW
415V	<100 KVA
11KV	<3 MVA
22KV	<6 MVA
33KV	<12 MVA
66KV	<20 MVA
110KV	<40 MVA
220KV	>40 MVA

Economic generation voltage (CBIP Manual):

Total Load	Economical Voltage
Up to 750 KVA	415 V
750 KVA to 2500 KVA	3.3 KV
2500 KVA to 5000 KVA	6.6 KV
Above 5000 KVA	11 KV or Higher

Economic Voltage for Power Transmission:

Required Power Transfer (MW)	Distance (KM)	Economical Voltage Level (KM)
3500	500	765
500	400	400
120	150	220
80	50	132

Voltage Variation:

> 33 KV	(-) 12.5% to (+) 10%
< 33 KV	(-) 9% to (+) 6%
Low Voltage	(-) 6% to (+) 6%

Insulation Class:	
Insulation	Temperature
Class A	105°C
Class E	120°C
Class B	130°C
Class F	155°C
Class H	180°C
Class N	200°C

Standard Voltage Limit:			
Voltage	IEC (60038)	IEC (6100:3.6)	Indian Elect. Rule
ELV	< 50 V		
LV	50 V to 1 KV	<=1 KV	< 250 V
MV		<= 35 KV	250 V to 650 V
HV	> 1KV	<= 230 KV	650 V to 33 KV
EHV		> 230 KV	> 33 KV

Electrical Wire Ground Clearance	
Voltage Level	Ground Clearance
<=33KV	5.2 Meter
66KV	5.49 Meter
132KV	6.10 Meter
220KV	7.0 Meter
400KV	8.84 Meter

Standard Electrical Connection / HT Connection (As per GERC):	
As per Type of Connection	
Connection	Voltage
LT Connection	<=440V
HT connection	440V to 66KV
EHT connection	>= 66KV
As per Electrical Load Demand	
Up 6W Load demand	1 Phase 230V Supp
6W to 100KVA(100KW)	3 Phase 440V Sup
100KVA to 2500KVA	11KV,22KV,33KV
Above 2500KVA	66KV
HT Connection Earthing	
H.T Connection's Earthing Strip	20mmX4mm Cu. Strip
CT & PT bodies	2Nos
PT Secondary	1Nos
CT Secondary	1Nos
I/C and O/G Cable+ Cubicle Body	2Nos

Standard Meter Room Size (As per GERC):	
Meter Box Height	Upper level does not beyond 1.7 meter and Lower level should not below 1.2 meter from ground.
Facing of Meter Box	Meter Box should be at front area of Building at Ground Floor.
Meter Room / Closed Shade	4 meter square Size

Sub Station Capacity & Short Circuit Current Capacity:(GERC)		
Voltage	Sub Station Capacity	Short Circuit Current
400 KV	Up to 1000 MVA	40 KA (1 to 3 Sec)
220 KV	Up to 320 MVA	40 KA (1 to 3 Sec)
132 KV	Up to 150 MVA	32 KA (1 to 3 Sec)
66 KV	Up to 80 MVA	25 KA (1 to 3 Sec)
33 KV	1.5 MVA to 5 MVA	35 KA (Urban) (1 to 3 Sec)

11 KV	150 KVA to 1.5 MVA	25 KA (Rural) (1 to 3 Sec)
415 V	6 KVA to 150 KVA	10 KA (1 to 3 Sec)
220 V	Up to 6 KVA	6 KA (1 to 3 Sec)

Sub Station Capacity:(Central Electricity Authority)

Voltage	Sub Station Capacity	Short Circuit Current
765 KV	4500 MVA	31.5 KA for 1 Sec
400 KV	1500 MVA	31.5 KA for 1 Sec
220 KV	500 MVA	40 KA for 1 Sec
110/132 KV	150 MVA	40 KA or 50 KA for 1 Sec
66 KV	75 MVA	40 KA or 50 KA for 1 Sec

Minimum Ground Clearance and Fault Clearing Time:

Voltage	Min. Ground Clearance	Fault Clear Time
400 KV	8.8 Meter	100 mille second
220 KV	8.0 Meter	120 mille second
132 KV	6.1 Meter	160 mille second
66 KV	5.1 Meter	300 mille second
33 KV	3.7 Meter	
11 KV	2.7 Meter	

Bus bar Ampere Rating:

For Phase Bus bar	Aluminium 130 Amp / Sq.cm or 800Amp / Sq.inch.
For Phase Bus bar	Copper 160 Amp / Sq.cm or 1000Amp / Sq.inch
For Neutral Bus bar	Same as Phase Bus bar up to 200 Amp than Size of Neutral Bus bar is at least half of Phase Bus bar.

Bus bar Spacing:

Between Phase and Earth	26mm (Min)
Between Phase and Phase	32mm (Min)
Bus bar Support between Two Insulator	250mm.

Insulation Resistance Value of Transformer:

Voltage	30°C	40°C	50°C
>66KV	600MΩ	300MΩ	150MΩ
22KV to 33KV	500MΩ	250MΩ	125MΩ
6.6KV to 11KV	400MΩ	200MΩ	100MΩ
<6.6KV	200MΩ	100MΩ	50MΩ
415V	100MΩ	50MΩ	20MΩ

Span of Transmission Line (As per Central Electricity Authority):

Voltage	Normal Span
765 KV	400 to 450 Meter
400 KV	400 Meter
220 KV	335,350,375 Meter
132 KV	315,325,335 Meter
66 KV	240,250,275 Meter

Overhead Conductor /Cable Size:

Voltage	Overhead Conductor	Cable Size
33 KV	ACSR-Panther/Wolf/Dog , AAAC	150,185,300,400,240 mm2 Cable
11 KV	ACSR-Dog/Recon/Rabbit , AAAC	120, 150,185,300 mm2 Cable
LT	ACSR-Dog/Recon/Rabbit , AAC,AAAC	95,120, 150,185,300 mm2 Cable

Transmission / Distribution Line:

Span	Height of Tower
400KV=400 Meter	400KV=30Meter (Base 8.8 Meter)
220KV=350 Meter	220KV=23Meter (Base 5.2 Meter)
132KV=335 Meter	220KV Double Circuit=28 Meter
66KV=210 Meter	66KV=13Meter
Conductor Ampere	Voltage wise Conductor
Dog=300Amp	400KV=Moose ACSR=500MVA Load
Panther=514Amp	220KV=Zebra ACSR=200MVA Load
Zebra=720Amp	132KV=Panther ACSR=75MVA Load
Rabbit=208Amp	66KV=Dog ACSR=50MVA Load
Moose=218Amp	

Type of Transmission Tower:		
Type	Used	Angle/Deviation
A	Suspension Tower	Up to 2°
B	Small Angle Tower	2° to 15°
C	Medium Angle Tower	15° to 30°
D	Large Angle / Dead End Tower	30° to 60° & Dead End

Tower Swing Angle Clearance (Metal Part to Live Part):				
Swing Angle	Live Part to Metal Part Clearance (mm)			
	66KV	132KV	220KV	400KV
0°	915mm	1530mm	2130mm	3050mm
15°	915mm	1530mm	2130mm	-
22°	-	-	-	3050mm
30°	760mm	1370mm	1830mm	-
44°	-	-	-	1860mm
44°	610mm	1220mm	1675mm	-

Standard Size of MCB/MCCB/ELCB/RCCB/SFU/Fuse:	
MCB	Up to 63 Amp (80Amp and 100 Amp as per Request)
MCCB	Up to 1600 Amp (2000 Amp as per Request)
ACB	Above 1000 Amp
MCB Rating	6A,10A,16A,20A,32A,40A,50A,63A
MCCB Rating	0.5A,1A,2A,4A,6A,10A,16A,20A,32A,40A,50A,63A,80A,100 A (Domestic Max 6A)
RCCB/ELCB	6A,10A,16A,20A,32A,40A,50A,63A,80A,100A
Sen. of ELCB	30ma (Domestic),100ma (Industrial),300ma
DPIC (Double Pole Iron Clad) main switch	5A,15A,30 A for 250V
TPIC (Triple Pole Iron Clad) Switch	30A, 60A, 100A, 200 A For 500 V
DPMCB	5A, 10A, 16A, 32A and 63 A for 250V
TPMCCB	100A,200A, 300Aand 500 A For 660 V
TPN main switch	30A, 60A, 100A, 200A, 300 A For 500 V
TPNMCB	16A, 32A,63A For 500 V, beyond this TPN MCCB: 100A, 200A, 300A, 500 A For 660 V
TPN Fuse Unit (Rewirable)	16A,32A,63A,100A,200A
Change over switch (Off Load)	32A,63A,100A,200A,300A,400A,630A,800A
SFU (Switch Fuse Unit)	32A,63A,100A,125A,160A,200A,250A,315A,400A,630A
HRC Fuse TPN (Bakelite)	125A,160A,200A,250A,400A.630A
HRC Fuse DPN (Bakelite)	16A,32A,63A
MCB/MCCB/ELCB Termination Wire / Cable	
Up to 20A MCB	Max. 25 Sq.mm
20A to 63A MCB	Max. 35 Sq.mm
MCCB	Max. 25 Sq.mm
6A to 45A ELCB	16 Sq.mm
24A to 63A ELCB	35 Sq.mm
80A to 100A ELCB	50 Sq.mm

Current Density	
Surface Current Density(mA/m ²)	Health Effect
<1	Absence of any established effects.
1 To 10	Minor biological effects.
10 To 100	Well established effects (a) Visual effect. (b) Possible nervous system effect
100 To 1000	Changes in central nervous System
>1000	Ventricular Fibrillation (Heart Condition 0. Health hazards.

Type of Distribution System	
As per IEC 60364-3	
Unearthed System	Earthed System
IT	TT / TN (TN-S, TN-C, TN-C-S)
First Letter =The neutral point in relation to earth: T= directly earthed neutral (from the French word Terre) I =unearthed or high impedance-earthed neutral (e.g. 2,000 Ω)	
Second letter=Exposed conductive parts of the electrical installation in relation to earth: T =directly earthed exposed conductive parts N =exposed conductive parts directly connected to the neutral conductor	

Capacities of PVC conduits				
Nominal conductorSize mm	16 mm	20 mm	25 mm	32 mm
	Number of Cables (maximum)			
1.0	6	5	19	30
1.5	5	4	15	24
2.5	3	3	11	17
4	2	2	8	13
6	2	-	6	10
10	-	-	4	6
16	-	-	3	4
25	-	-	2	3
35	-	-	-	2

System Highest and Lower Voltage		
Ref: NEC(India) :2011		
System Voltage	Highest Voltage	Lowest Voltage
240 V	264 V	216 V
415 V	457 V	374 V
3.3 kV	3.6 kV	3.0 kV
6.6 kV	7.2 kV	6.0 kV
11 kV	12 kV	10 kV
22 kV	24 kV	20 kV
33 kV	36 kV	30 kV
66 kV	72.5 kV	60 kV
66 kV	72.5 kV	60 kV
132 kV	145 kV	120 kV
220	kV 245 kV	200 kV
400 kV	420 kV	380 kV

Number of Points for Dwelling Unit						
Ref: NEC(India) :2011						
No.	Description	Area for the Main Dwelling Unit (m2)				
		35 mm2	45 mm2	55 mm2	85 mm2	140 mm2
1	Light points	7 No	8 No	10 No	12 No	17 No
2	Ceiling fans Pont	2 No	3 No	4 No	5 No	7 No
3	Ceiling fans No's	2 No	2 No	3 No	4 No	5 No
4	6A Socket outlets	2 No	3 No	4No	5 No	7 No
5	16A Socket outlets	-	1 No	2 No	3 No	4No
6	Call-bell (buzzer)	-	-	1 No	1 No	1 No

Recommended Schedule of Socket-Outlets		
Ref: NEC(India) :2011		
Description	Number of Socket	
	6A Socket	16A Socket
Bedroom	2	1
Living room	2	2
Kitchen	1	2
Dining room	2	1
Garage	1	1
For refrigerator	-	1
For air-conditioner	-	1 for each
Veranda	1 per 10mter2	1
Bathroom	1	1

Power requirements of the building		
Ref: NEC(India) :2011		
Part of ElectricalInstallation	Part of the Total Power Requirement in %	Diversity Factor
Ventilation, heating (air-conditioning)	45%	1.0
Power plant (drives)	52%	0.65
Lighting	30%	0.95
Lifts	20%	1.0
Kitchen	10%	0.6
Laundry	5%	0.6

Lift Car Speed		
Ref: NEC(India) :2011		
Occupancy	No. of Floors Served	Car Speed m/s
Office building	4 to 5	0.5 to 0.75 m/sec
Office building	6 to 12	0.75 to 1.5 m/sec
Shops and departmental stores	13 to 20	More than 1.5 m/sec
Passenger lifts for low and medium lodging houses	-	0.5 m/sec
Hotels	4 to 5	0.5 to 0.75 m/sec
Normal load carrying lifts	-	2.0 to 2.5 m/sec
Hospital passenger Lift	4 to 5	0.5 to 0.75 m/sec
Hospital passenger Lift	13 to 20	More than 1.5 m/sec
Hospital bed lifts (Short travel lifts insmall hospitals)	-	0.25 m/sec
Hospital bed lifts (Normal)	-	0.5 m/sec
Hospital bed lifts (Long travel lifts inGeneral hospitals)		0.6 to 1.5 m/sec

Approximate Fuel Consumption for Diesel Generator Set				
Generator Size (KVA) @0.8 PF	1/4 Load (Liter/Hr)	1/2 Load (Liter/Hr)	3/4 Load (Liter/Hr)	Full Load (Liter/Hr)
25	2.27	3.41	4.92	6.06
38	4.92	6.82	9.09	10.98
50	6.06	8.71	12.12	15.15
75	6.82	10.98	14.39	18.18
94	9.09	12.88	17.42	23.11
125	9.85	15.53	21.97	28.03
156	11.74	18.94	26.89	34.47
169	12.50	20.45	28.79	37.12
188	13.64	22.35	31.82	41.29
219	15.53	25.76	36.74	48.11
250	17.80	29.17	41.67	54.55
288	20.08	33.33	47.35	62.88
313	21.59	35.98	51.52	68.18
375	25.76	42.80	60.98	81.44
438	29.92	49.62	70.83	95.08
500	33.71	56.44	80.68	108.33
625	41.67	70.08	100.00	135.23
750	50.00	83.33	119.32	162.12
938	61.74	103.79	148.86	202.27
1250	81.82	137.88	197.35	269.32
1563	101.89	171.59	246.21	336.36
1875	121.97	205.68	294.70	403.41
2188	142.05	239.39	343.56	470.45
2500	162.12	273.48	392.05	537.50
2813	182.20	307.20	440.91	604.55

Approximate Current Rating of Diesel Generator Set @ 0.8 PF										
KVA	kW	220V	240V	400V	440V	450V	480V	600V	2400V	3300V
8	6.3	16.5	15.2	9.1	8.3	8.1	7.6	6.1		
9.4	7.5	24.7	22.6	13.6	12.3	12	11.3	9.1		
12.5	10	33	30.1	18.2	16.6	16.2	15.1	12		
18.7	15	49.5	45	27.3	24.9	24.4	22.5	18		
25	20	66	60.2	36.4	33.2	30.1	24	6	4.4	3.5
31.3	25	82.5	75.5	45.5	41.5	40.5	37.8	30	7.5	5.5
37.5	30	99	90.3	54.6	49.8	48.7	45.2	36	9.1	6.6
50	40	132	120	73	66.5	65	60	48	12.1	8.8
62.5	50	165	152	91	83	81	76	61	15.1	10.9
75	60	198	181	109	99.6	97.5	91	72	18.1	13.1
93.8	75	247	226	136	123	120	113	90	22.6	16.4
100	80	264	240	146	133	130	120	96	21.1	17.6
125	100	330	301	182	166	162	150	120	30	21.8
156	125	413	375	228	208	204	188	150	38	27.3
187	150	495	450	273	249	244	225	180	45	33
219	175	577	527	318	289	283	264	211	53	38
250	200	660	601	364	332	324	301	241	60	44
312	250	825	751	455	415	405	376	300	75	55
375	300	990	903	546	498	487	451	361	90	66
438	350	1155	1053	637	581	568	527	422	105	77
500	400	1320	1203	730	665	650	602	481	120	88
625	500	1650	1504	910	830	810	752	602	150	109
750	600	1980	1803	1090	996	975	902	721	180	131
875	700	2310	2104	1274	1162	1136	1052	842	210	153
1000	800	2640	2405	1460	1330	1300	1203	962	241	176

1125	900	2970	2709	1640	1495	1460	1354	1082	271	197
1250	1000	3300	3009	1820	1660	1620	1504	1202	301	218
1563	1250	4130	3765	2280	2080	2040	1885	1503	376	273
1875	1500	4950	4520	2730	2490	2440	2260	1805	452	327
2188	1750		5280	3180	2890	2830	2640	2106	528	380
2500	2000		6020	3640	3320	3240	3015	2405	602	436
2812	2250		6780	4095	3735	3645	3400	2710	678	491

Approximate Fuel Consumption of D.G Set As per Bureau of Energy Efficiency

D.G Set (Kw)	Average Load as % of De rated Capacity	Specific Fuel Cons. Lit/kWh	Specific Lube Oil Cons. Lit/kWh
480	89	0.335	0.007
480	110	0.334	0.024
292	84	0.356	0.006
200	89	0.325	0.003
200	106	0.338	0.003
292	79	0.339	0.006
292	81	0.362	0.005
292	94	0.342	0.003
292	88	0.335	0.006
292	76	0.335	0.005
292	69	0.353	0.006
400	75	0.334	0.004
400	65	0.349	0.004
880	85	0.318	0.007
400	70	0.335	0.004
400	80	0.337	0.004
880	78	0.345	0.007
800	74	0.324	0.002
800	91	0.290	0.002
880	96	0.307	0.002
920	77	0.297	0.002

Starting Current for D.G set

Type of Load	Starting Current
Motors over 50 HP	6 X motor rated current
Variable frequency drive motors	2 X motor rated current
Uninterruptible power supply (UPS) loads	1.5 X UPS rated current
Battery charger loads	2.5 X Charger rated current
Non-Linear Load	1.5 to 2.5 X rated current
Medical imaging loads	1.1 X Rated current
Soft Starter Motor	1.2 X motor rated current
DOL Starter	4 X motor rated current
Star-Delta Starter	3 X motor rated current
Auto Transformer Starter	1.5 X motor rated current
Most generators are capable of delivering 300% of the rated current for 10 seconds	

Stand by D.G Permission As per PSEB

D.G Set Capacity	Permission	Remarks
Up to 10 KW(11 KVA)	No permission is required. Also prior sanction of CEI is not required.	
10 KW (11 KVA) to 250 KVA		
250 KVA to 1 MVA		
1 MVA to 2.5 MVA	Permission is required. Also prior sanction of CEI is required	The capacity of D.G Set should not exceed 1.2 times of the sanctioned Load.
2.5 MVA to 5 MVA		
Exceeding 5 MVA		

Sound Level of Diesel Generator (ANSI 89.2&NEMA 51.20):	
KVA	Max. Sound Level
<9 KVA	40 DB
10 KVA to 50 KVA	45 DB
51 KVA to 150 KVA	50 DB
151 KVA to 300 KVA	55 DB
301 KVA to 500 KVA	60 DB

Exhaust Stack Height:

Up to 1000KVA D.G Set:

- Total Height of stack (Meter) = (Height of Building Where D.G Installed +0.2) X $\sqrt{\text{D.G Capacity in KVA}}$

More than 1000KVA D.G Set:

- 30 Meter height or more than 3 meter height of building which is higher.

Height of stack (Meter)	
Generator Sets	Total Height of Stack in Meters.
000 to 050 KVA	Height of Building + 1.5 Meter
050 to 100 KVA	Height of Building + 2.0 Meter.
100 to 150 KVA	Height of Building + 2.5 Meter
150 to 200 KVA	Height of Building + 3.0 Meter
200 to 250 KVA	Height of Building + 3.5 Meter
250 to 300 KVA	Height of Building + 4.0 Meter.

D.G Room Air Requirement	
D.G Set	Air Requirement
275 KVA	605 Cu. Meter / Min
320 KVA	625 Cu. Meter / Min
400 KVA	854 Cu. Meter / Min
500 KVA	1065 Cu. Meter / Min
600 KVA	1286 Cu. Meter / Min

Noise Limit of D.G Set As per CPWD, India

- Up to 1000 KVA (manufactured after 2005) =75 dB(A) at 1 meter from the enclosure surface.
- The acoustic enclosure or acoustic treatment of the room shall be designed for minimum 25 dB(A) insertion loss or for meeting the ambient noise standards, whichever is on the higher side.
- The measurement for insertion loss may be done at different points at 0.5 m from the acoustic enclosure / room, and then averaged.
- The DG set shall be provided with proper exhaust muffler with insertion loss of minimum 25 dB(A).

Harmonic Distortion As per Central Electricity Authority ,India		
System Voltage (kV)	Total Harmonic Distortion (%)	Individual Harmonic of any Particular Frequency (%)
765	1.5	1
400	2	1.5
220	2.5	2
33 to 132	5	3

Air Condition Capacity Application wise	
Application	Average Load
Residence	400 to 600 sq. ft. floor area per ton
Apartment (1 or 2 room)	400 sq. ft. of floor area per ton
Office Building	190 to 360 sq. ft. floor area per ton
Office Building Large Interior	340 Sq Foot Floor Area / Ton
Office Building Large Exterior	250 Sq Foot Floor Area / Ton
Restaurant	200 Sq Foot Floor Area / Ton
Bar or Tavern	9 people per ton
Cocktail Lounge	175 Sq Foot Floor Area / Ton
Computer Room	50 – 150 Sq Foot Floor Area / Ton
Bank (main area)	225 Sq Foot Floor Area / Ton
Barber Shop	250 Sq Foot Floor Area / Ton
Beauty Shop	180 Sq Foot Floor Area / Ton
School Classroom	250 Sq Foot Floor Area / Ton
Bowling Alley	1.5 – 2.5 tons per alley
Motel	400 Sq Foot Floor Area / Ton
Groceries – Supermarket	350 Sq Foot Floor Area / Ton
Hospital Room	280 Sq Foot Floor Area / Ton
Hotel Public Spaces	220 Sq Foot Floor Area / Ton
Drug Store	150 Sq Foot Floor Area / Ton
Factory (precision manufacturing)	275 Sq Foot Floor Area / Ton
Small Shop	225 Sq Foot Floor Area / Ton
Department Store	400 Sq Foot Floor Area / Ton
School Classroom	250 Sq Foot Floor Area / Ton

Air Condition Capacity Range		
Air Conditioner Machine	Capacity Range	Suitable for
Room air conditioner	0.5 to 2 TR per unit	Up to 1000 Sq Foot Floor Area
Packaged unit integral air-cooled condenser	3 to 50 TR	1000 to 10000 Sq Foot Floor Area
Split system with outdoor air-cooled condenser	0.5 to 50 TR,	100 to 10000 Sq Foot Floor Area
Central air-conditioning chilled water system with air cooled condensers	20 to 400 TR	More than 4000 Sq Foot Floor Area
Central air-conditioning chilled water systems with outdoor water cooled condenser	20 to 2000 TR	More than 4000 Sq Foot Floor Area

Air Supply Requirement (For Heating & Cooling Load)	
Equipment	Appro. Airflow Rate
Gas/Oil Furnace	1 CFM per 100 Btu/hr
Electric Furnace	50 – 70 CFM per kW input
Electric Air-conditioning	400 CFM per ton
Precision Air Conditioning	500 CFM/ton
Comfort Cooling Air Conditioning	400 CFM/ton
Dehumidification	200 CFM/ton
Heat Pump	450 CFM per ton

HVAC Chiller Selection	
Type of Chiller	Ton
Reciprocating	Up to 25 tons (88kW)
Reciprocating or Screw	25 to 80 tons (88 to 280kW)
Reciprocating, Screw or Centrifugal	80 to 200 tons (280 to 700kW)

Screw or Centrifugal	200 to 800 tons (700 to 2800kW)
Centrifugal	Above 800 tons (2800 kW)
Air-cooled chilled water system	40 to 200 TR
Water-cooled chilled water system	200 TR and above

Ventilation Requirement		
Application	Occupancy (people/1000ft ²)	CFM/person
Food and Beverage Service		
Dining rooms	70	20
Cafeteria, fast food	100	20
Bars, cocktail lounges	100	30
Kitchen (cooking)	20	15
Offices		
Office space	7	20
Reception areas	60	15
Conference rooms	50	20
Public Spaces		
Smoking lounge	70	60
Elevators	70	60
Showrooms		
Basement & Street	30	
Upper floors	20	
Malls and arcades	20	
Smoking lounges	70	60
Beauty shops	25	25
Hardware stores	8	15
Sports Area		
Spectator areas	150	15
Games rooms	70	25
Playing rooms	30	20
Ballrooms and discos	100	25
Theatres		
Classroom	50	15
Music rooms	50	15
Libraries	20	15
Auditoriums	150	15
Hotels, Resorts		
Bedrooms		
Living rooms		
Lobbies	30	15
Conference rooms	50	20
Assembly rooms	120	15
Dry cleaning, laundry	30	30
Hospitals		
Operating rooms	20	30
Patient rooms	10	25
Laboratories	30	20
Procedure rooms	20	15
Pharmacies	20	15
Physical therapy	20	15

Motor Earthing Wire / Strip Size:	
Size of Motor	Body Earthing
< 5.5 KW	85 SWG GI Wire
5.5 KW to 22 KW	25x6 mm GI Strip
22 KW to 55 KW	40x6 mm GI Strip
>55 KW	50x6 mm GI Strip

Earthing Resistance value: (As per USAID)	
Power Station	0.5 Ω
Sub Station Major	1.0 Ω
Sub Station Minor	2.0 Ω
Distribution Transformer	5.0 Ω
Transmission Line	10 Ω
Single Isolate Earth Pit	5.0 Ω
Earthing Grid	0.5 Ω
As per NEC Earthing Resistance should be <5.0 Ω	

Panel Earthing Wire / Strip Size:	
Type of Panel	Body Earthing
Lighting & Local Panel	25x6 mm GI Strip
Control & Relay Panel	25x6 mm GI Strip
D.G & Exciter Panel	50x6 mm GI Strip
D.G & T/C Neutral	50x6 mm Cu Strip

Electrical Equipment Earthing:	
Equipment	Body Earthing
LA (5KA,9KA)	25x3 mm Cu Strip
HT Switchgear	50x6 mm GI Strip
Structure	50x6 mm GI Strip
Cable Tray	50x6 mm GI Strip
Fence / Rail Gate	50x6 mm GI Strip

Earthing Wire (As per BS 7671)	
Cross Section Area of Phase, Neutral Conductor(S) mm ²	Minimum Cross Section area of Earthing Conductor (mm ²)
$S \leq 16$	S (Not less than 2.5 mm ²)
$16 < S \leq 35$	16
$S > 35$	$S/2$

GI Earthing Conductor sizes for various Equipments	
Equipments	Earth Strip Size
HT switchgear, structures, cable trays & fence, rails, gate and steel column	55 X 6 mm (GI)
Lighting Arrestor	25 X 3 mm (Copper)
PLC Panel	25 X 3 mm (Copper)
DG & Transformer Neutral	50X6 mm (Copper)
Transformer Body	50X6 mm (GI)
Control & Relay Panel	25 X 6 mm (GI)
Lighting Panel & Local Panel	25 X 6 mm (GI)
Distribution Board	25 X 6 mm (GI)
Motor up to 5.5 kw	4 mm ² (GI)
Motor 5.5 kw to 55 kw	25 X 6 mm (GI)
Motor 22 kw to 55 kw	40 X 6 mm (GI)
Motor Above 55 kw	55 X 6 mm (GI)

Size of Plate /Pipe/Strip for Earthing	
GI Plate	600 mm x600 mm x6 mm
CI Plate	600 mm x600 mm x12 mm.
Copper Plate	600 mm x 600 mm x 3.15 mm
GI Pipe	75 mm diameter, 10 feet long
GI Strip	30 mm X 10 mm

Size of Earthing Conductor (IS 3043 & Handbook on BS 7671)		
Area of Phase Conductor S (mm ²)	Area of Earthing conductor (mm ²) When It is Same Material as Phase Conductor	Area of Earthing conductor (mm ²) When It is Not Same Material as Phase Conductor
S < 16 mm ²	S	SX(k ₁ /k ₂)
16 mm ² < S < 35 mm ²	16 mm ²	16X(k ₁ /k ₂)
S > 35 mm ²	S/2	SX(k ₁ /2k ₂)
K ₁ is value of Phase conductor, k ₂ is value of earthing conductor		
Value of K for GI=80, Alu=126, Cu=205 for 1 Sec		

Weight per Meter for GI Earthing Strip:	
Size (mm ²)	Weight
20 x 3	500 gm Per meter
25 x 3	600 gm Per meter
25 x 6	1/200 Kg Per meter
32 x 6	1/600 Kg Per meter
40 x 6	2 Kg Per meter
50 x 6	2/400 Kg Per meter
65 x 10	5/200 Kg Per meter
75 x 12	7/200 Kg Per meter

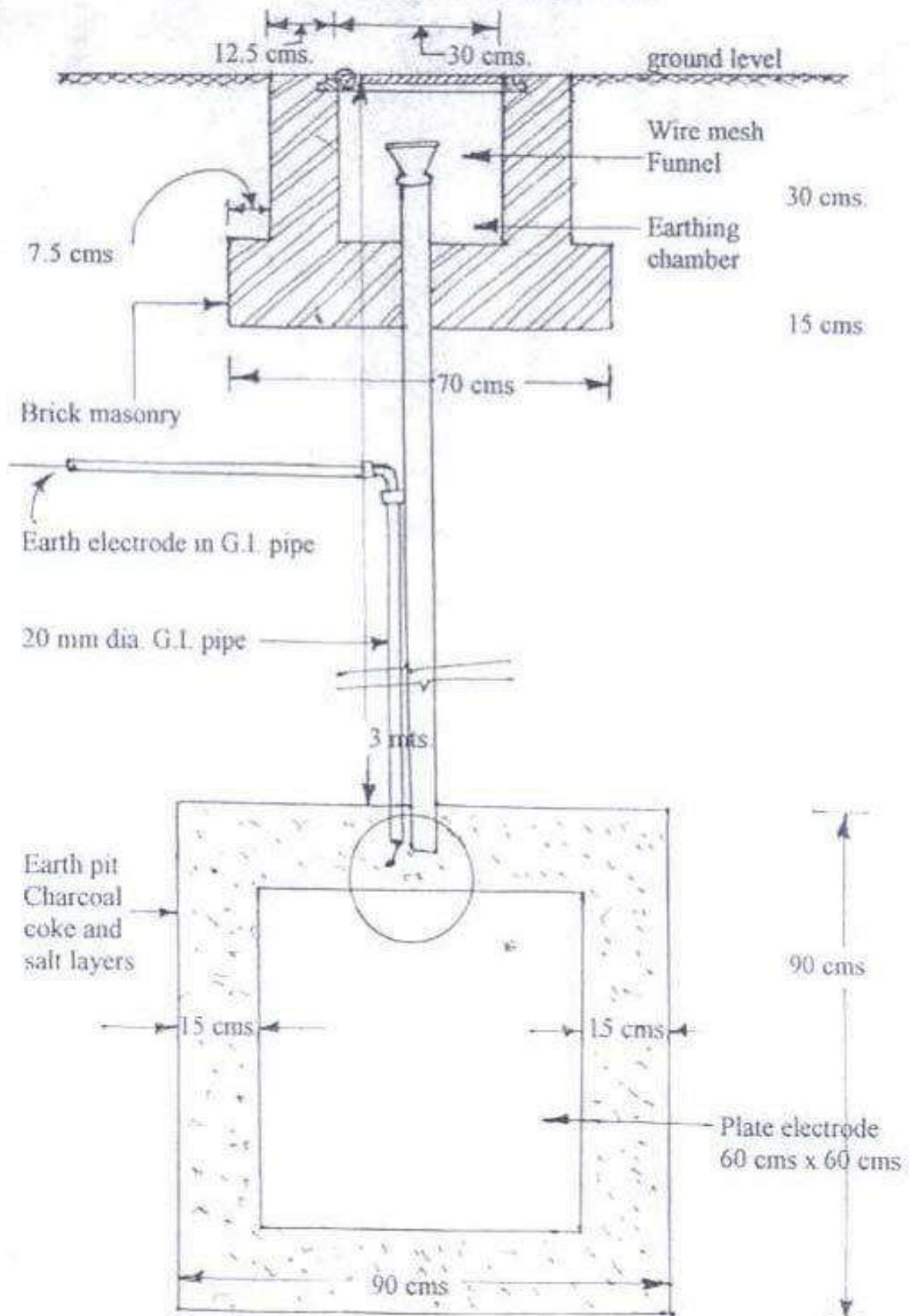
Weight per Meter for GI Earthing Plate:	
Plate	Weight
600 x 600 x 3 mm	10 Kg App.
600 x 600 x 4 mm	12 Kg App.
600 x 600 x 5 mm	15 Kg App.
600 x 600 x 6 mm	18 Kg App.
600 x 600 x 12 mm	36 Kg App.
1200 x 1200 x 6 mm	70 Kg App.
1200 x 1200 x 12 mm	140 Kg App.

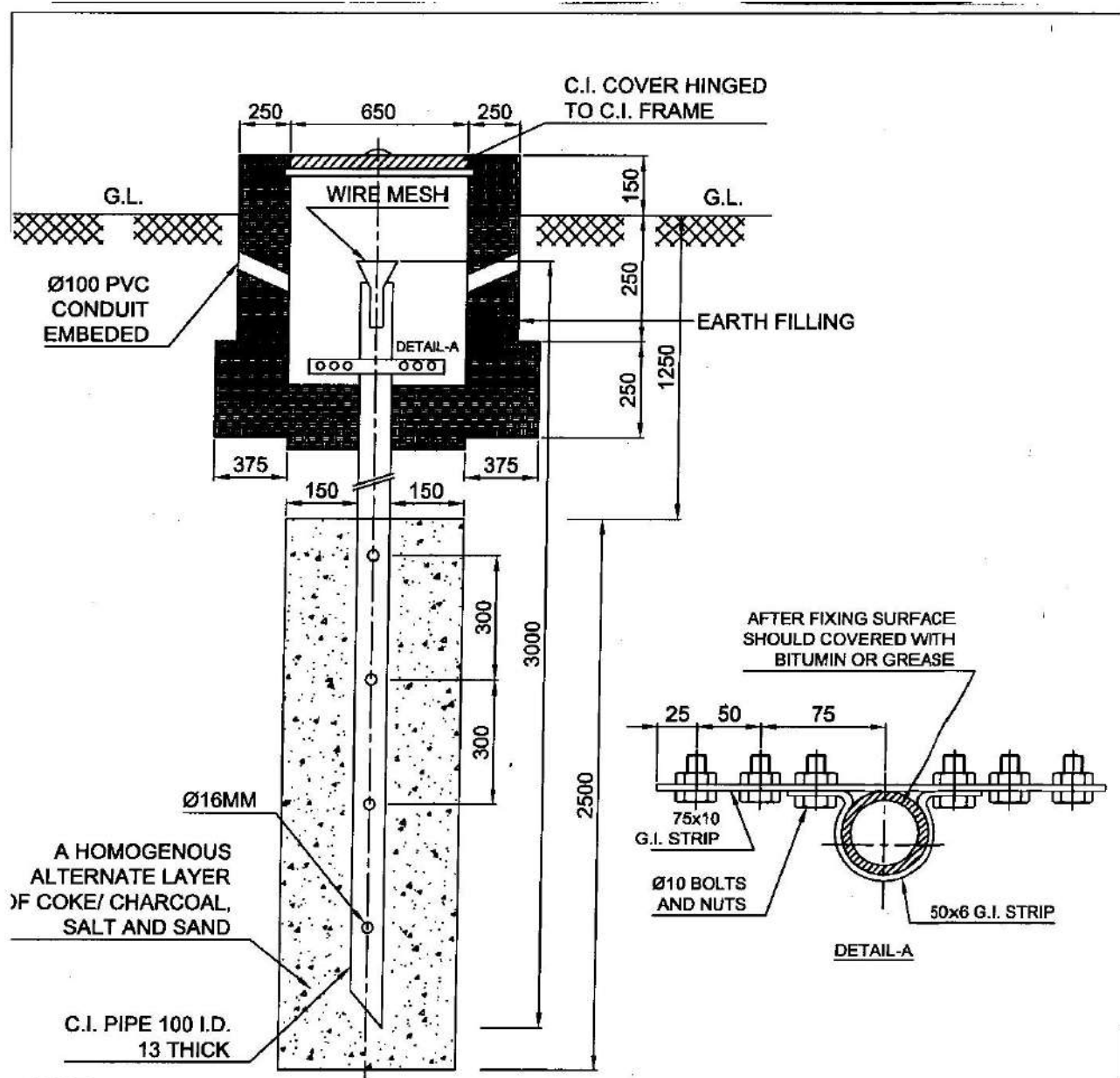
Weight of GI Earthing Pipe:	
Pipe	Weight
3 meter Long BISE	5 Kg App.
3 meter r Long BISE	9 Kg App.
4.5 meter (15' Long BISE)	5 Kg App.
4.5 meter (15' Long BISE)	9 Kg App.
4.5 meter (15' Long BISE)	14 Kg App

Weight of GI Earthing Wire:	
Plate	Weight
6 Swg	5 meter in 1 Kg
8 Swg	9 meter in 1 Kg

Transformer Earthing Wire / Strip Size:		
Size of T.C or DG	Body Earthing	Neutral Earthing
<315 KVA	25x3 mm Cu / 40x6 mm GI Strip	25x3 mm Cu Strip
315 KVA to 500 KVA	25x3 mm Cu / 40x6 mm GI Strip	25x3 mm Cu Strip
500 KVA to 750 KVA	25x3 mm Cu / 40x6 mm GI Strip	40x3 mm Cu Strip
750 KVA to 1000 KVA	25x3 mm Cu / 40x6 mm GI Strip	50x3 mm Cu Strip

PLATE EARTHING





Size and Practice of Plate / Pipe Earthing	
Plate Earthing Electrode	For copper = 600X600X31mm and For Hot dip GI =600X600X63mm.
Pipe Earthing Electrode.	Earthing electrode shall consist of a GI pipe (class B of approved make), not less than 40 mm dia. and 3 meters long. CL pipe electrode shall be cut tapered at the bottom and provided with holes of 12 mm dia. drilled at 75 mm interval up to 2.5 meters length from bottom The electrode shall be buried vertically in the ground as far as practicable below permanent moisture level, but in any case not less than 3 meters below ground level The electrode shall be in one piece and no joints shall be allowed in the electrode.
Size of Excavation:	Size of 1 meter diameter and 3 meter length shall be excavated after depth of 3 meter the size of excavation shall be 900X300X900mm depth. Plate / Pipe Electrode shall be in vertical position. GI/PVC pipe for Watering shall be used of 40mm Diameter, length of 3 meter (contain hole of 12mm Diameter in Zigzag manner starting from 15cm away from bottom to 2 meter height). At bottom 150mm layer of Salt and charcoal power shall be installed than Plate shall be installed. Alternate layer of 150mm of Salt and charcoal power shall be used up to 2.5 meter. Min 120kg of charcoal power and 120kg of salt shall be used for each earthing pit. The plate \ pipe electrode, as far as practicable, shall be buried below permanent moisture level but in no case not less than 2.5 M below finished ground level. The Copper plate earthing shall be buried deep in the ground with its face vertically and top not less than 3 meters below ground
Chamber & Frame	A cast iron/MS frame with cover having locking equipment shall be suitable embedded in the brick masonry to protect the watering arrangement (funnel with mesh and 20 mm diameter G.I. pipe of medium class quality fixed on the top of the electrode) and the earth pit from mechanical damages The brick masonry and closures should be not less than 30 cms X 30 cms X 30 cms. Layers of charcoal/coke and salt are to be made in the earth pit after putting the electrode in its place.
Earth Resistance	3. No earth electrode should have a resistance more 10 three ohms measured by an earth resistance meter. In rocky soil the resistance may be up to 8 ohms.
Plate Earthing	Earthing electrode shall consist of plate, not less than 600 mm x 600 mm x 12 mm thick . The plate electrode shall not be buried less than 3 meters below ground level. Earth electrodes shall not be installed in proximity to a metal fence. It shall be kept clear of the buildings foundations and in no case it shall be nearer than 2 meters from the outer face of the wall The earth plate shall be set vertically and surrounded with 150 mm thick layer of Charcoal dust and salt mixture. 20 mm GI pipe shall run from the top edge of the plate to the ground level. The top of the pipe shall be provided with a G.I. threaded cap for watering the earth through a pipe. The G.I. cap over the GI pipe shall be housed in a masonry chamber, approximately 300 mm x 300 mm x 300 mm deep. The masonry chamber shall be provided with a cast iron inspection cover resting over a GI frame, embedded in masonry.
Pipe Earthing	Earthing electrode shall consist of a CI pipe (class B), not less than 40 mm dia. and 3 meters long. CL pipe electrode shall be cut tapered at the bottom and provided with holes of 12 mm dia. drilled at 75 mm interval up to 2.5 meters length from bottom. The electrode shall be buried vertically in the ground but in any case not less than 3 meters below ground level. The electrode shall be in one piece and no joints. Earth electrode shall not be nearer than 2 meters from the outer face of the wall. The pipe earth electrode shall be kept vertically and surrounded with 150mm thick layer of charcoal dust and salt mixture up to a height of 2.5 meters from the bottom. At the top of the electrode a G.I. threaded cap shall be provided for watering the earth. The main earth conductors shall be connected to the electrode just below the G.I cap, with proper terminal lugs and check nuts. The G.I. cap over the CL pipe and earth connection shall be housed in a masonry chamber, approximately 300 mm length x 300 mm wide and 300 mm deep. The masonry chamber shall be provided with a cast iron inspection cover resting over a C.I. frame, embedded in masonry.

Standard Size of Transformer (IEEE/ANSI 57.120):			
Single Phase Transformer		Three Phase Transformer	
5KVA	1.25MVA	3KVA	1MVA
10KVA	1.66 MVA	5KVA	1.5 MVA
15KVA	2.5 MVA	9KVA	2 MVA
25KVA	3.33 MVA	15KVA	2.5 MVA
37.5KVA	5.0 MVA	30 KVA	3.7 MVA
50KVA	6.6 MVA	45 KVA	5 MVA
75KVA	8.3 MVA	75 KVA	7.5 MVA
100KVA	10 MVA	112.5 KVA	10 MVA
167KVA	12.5 MVA	150 KVA	12 MVA
250KVA	16.6 MVA	225 KVA	15 MVA
333KVA	20.8 MVA	300 KVA	20 MVA
500KVA	25 MVA	500 KVA	60 MVA
833KVA	33.33 MVA	750 KVA	75 MVA
			100 MVA

Standard Size of Transformer:	
Standard Size of Transformer	KVA
Power Transformer (Urban)	3,6,8,10,16
Power Transformer (Rural)	1,1.6,3,15,5
Distribution Transformer	25,50,63,100,250,315,400,500,630

Impedance of Transformer (As per IS 2026):	
MVA	% Impedance
< 1 MVA	5%
1 MVA to 2.5 MVA	6%
2.5 MVA to 5 MVA	7%
5 MVA to 7 MVA	8%
7 MVA to 12 MVA	9%
12 MVA to 30 MVA	10%
> 30 MVA	12.5%

% Impedance for Transformer (As per IS 2026)			
33KV Transformer		66KV Transformer	
MVA	%Impedance	MVA	%Impedance
1MVA	5%	6.3MVA	8.35%
1.6MVA	6.25%	8MVA	8.35%
3.15MVA	6.25%	10MVA	8.35%
4MVA	7.15%	12.5MVA	8.35%
5MVA	7.15%	20MVA	10%
6.3MVA	7.15%	16MVA	10%
8MVA	8.35%	25MVA	10%
10MVA	8.35%	31.5MVA	12.5%

% Impedance for Transformer	
MVA	%impedance
Less Than 1MVA	5%
1MVA To 2.5MVA	6%
2.5MVA To 5MVA	7%
5MVA To 7MVA	8%
7MVA To 12MVA	9%
12MVA To 30MVA	10%

More Than 30MVA	12.5%
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Losses in 11 kv Transformer at 75c (As per CBIP):			
Transformer	No Load Loss(kw)	Load Loss (kw)	% Impedance
3.15MVA	2.9	20	6.25
4MVA	3.2	27	7.15
5.3MVA	3.9	31	7.15
6.3MVA	4.5	37	7.15

Losses in 66 kv Transformer at 75c (As per CBIP):			
Transformer	No Load Loss(kw)	Load Loss (kw)	% Impedance
6.3MVA	6	40	8.35
8MVA	7.1	48	8.35
10MVA	8.4	57	8.35
12.5MVA	9.7	70	8.35
20MVA	13	102	10.0

Standard Rating of 66KV Transformer (As per CBIP)		
Transformer	KV	Type of Cooling
6.3MVA	66KV/11KV	ONAN
8MVA	66KV/11KV	ONAN
10MVA	66KV/11KV	ONAN
12.5MVA	66KV/11KV	ONAN / ONAF
20MVA	66KV/11KV	ONAN / ONAF

Area for Transformer Room: (As per NBC-2005):			
Transformer Size	Min. Transformer Room Area (M2)	Min. Total Sub Station Area(Incoming HV, LV Panel, T.C Roof) (M2)	Min. Space Width (Meter)
1X160	14	90	9
2X160	28	118	13.5
1X250	15	91	9
2X250	30	121	13.5
1X400	16.5	93	9
2X400	33	125	13.5
3X400	49.5	167	18
2X500	36	130	14.5
3X500	54	172	19
2X630	36	132	14.5
3X630	54	176	19
2X800	39	135	14.5
3X800	58	181	14
2X1000	39	149	14.5
3X1000	58	197	19

Transformer Mounting arrangements:	
Size of Transformer	Mounting Type
Up to 25KVA	Mounted direct on Pole.
From 25KVA to 250KVA	either on "H" Frame or Plinth
Above 250KVA	can be mounted Plinth only.
Above 100MVA	Shall be protected by Drop out Fuse or Circuit Breaker.

Requirement of Insulating Oil	
400KVA to 1600KVA	1.0 Litter / KVA
1600KVA to 8000KVA	0.6 Litter / KVA
Above 8000KVA	0.5 Litter / KVA

:Transformer Cooling Arrangement Code:	
Code	Description
A	Air Cooling
N	Natural Cooling by Convection
B	Cooling by Air Blast Fans
O	Oil (mineral) immersed cooling
W	Water Cooled
F	Forced Oil Circulation by Oil Pumps
S	Synthetic Liquid used instead of Oil
G	Gas Cooled (SF6 or N2)
D	Forced (Oil directed)
ONAF	Oil immersed Transformer with natural oil circulation and forced air external cooling
ONAN	Oil Immersed Natural cooled
ONAF	Oil Immersed Air Blast
ONWN	Oil Immersed Water Cooled
OFAF	Forced Oil Air Blast Cooled
OFAN	Forced Oil Natural Air Cooled
OFWF	Forced Oil Water Cooled
ODAF	Forced Directed Oil and Forced Air Cooling

Cable Size for Transformer (NPC Limited)	
Transformer Size	Cable
630kVA transformers	2 no x 1C x 630 Sq mm, Al, XLPE Cable
400kVA transformers	1 no x 1C x 630 Sq mm, Al, XLPE
250kVA transformers	3 ½ C x 400 Sq mm, Al, XLPE
160kVA transformers	3 ½ C x 300 Sq mm, Al, XLPE
100kVA transformers	3 ½ C x 150 Sq mm, Al, XLPE

Corona Ring Size:	
Voltage	Size
<170 KV	160mm Ring put at HV end
>170 KV	350mm Ring put at HV end
>275 KV	450mm Ring put at HV end & 350 mm Ring put at Earth end

Size of Cable on Secondary Side of Transformer (11KV/433V) (KSEI Handbook)				
Rating of T/C (KVA)	Primary current (Amp)	Secondary Current (Amp)	Min. Size of Neutral Earthing Conductor (mm2)	Minimum Size of Cable (mm2)
63	3.3	84	25X3	50mm2
100	5.25	133.3	25X3	95mm2 or (2x50 mm2)
160	8.4	213.3	25X3	185mm2 or (2x95 mm2)
200	10.49	266.6	25X3	300mm2 or (2x120 mm2)
250	13.12	333	25X3	2x185 mm2
315	16.53	420	31X3 or 25X4	(2x300 mm2) or (3x185 mm2)
400	21.80	533	38X3	(3x300 mm2) or (2x400 mm2)
500	26.20	666.5	25X6	(3x400 mm2) or (4x240 mm2)
630	33	840	31X6	4x400 mm2
750	39.36	1000	50X4	Bus Bar Trucking (min. Isc 50KA)
1000	52.50	1333	210mm2	Bus Bar Trucking (min. Isc 50KA)
1250	65.50	1667	290mm2	Bus Bar Trucking (min. Isc 50KA)
1600	83.98	2133	380mm2	Bus Bar Trucking (min. Isc 50KA)
2000	105.00	2666	450mm2	Bus Bar Trucking (min. Isc 50KA)

HT Fuse on Primary Side of Transformer (11KV/433V)				
Rating of T/C (KVA)	Primary current (Amp)	Secondary Current (Amp)	HT Fuse	
			Min (Amp)	Max(Amp)
63	3.3	84	10	16
100	5.25	133.3	16	25
160	8.4	213.3	16	40
200	10.49	266.6	25	40
250	13.12	333	32	40
315	16.53	420	40	63
400	21.80	533	40	63
500	26.20	666.5	50	100
630	33	840	63	100
750	39.36	1000	75	160
1000	52.50	1333	100	160
1250	65.50	1667	100	200
1600	83.98	2133	160	250
2000	105.00	2666	200	250

Application of Transformer according to Vector Group	
Star-Delta (Dyn11, Dyn 1, YNd1, YNd11)	- Common for distribution transformers. - Normally Dyn11 vector group using at distribution system. Because Generating Transformer are YNd1 for neutralizing the load angle between 11 and 1. - We can use Dyn1 at distribution system, when we are using Generator Transformer are YNd11. - In some industries 6 pulse electric drives are using due to this 5th harmonics will generate if we use Dyn1 it will be suppress the 5th harmonics. - Star point facilitates mixed loading of three phase and single phase consumer connections. - The delta winding carry third harmonics and stabilizes star point potential. - A delta-Star connection is used for step-up generating stations. If HV winding is star connected there will be saving in cost of insulation. - But delta connected HV winding is common in distribution network, for feeding motors and lighting loads from LV side.
Star-Star (Yy0 or Yy6)	- Mainly used for large system tie-up Transformer. - Most economical connection in HV power system to interconnect between two delta systems and to provide neutral for grounding both of them. - Tertiary winding stabilizes the neutral conditions. In star connected transformers, load can be connected between line and neutral, only if (a) the source side transformers is delta connected or (b) the source side is star connected with neutral connected back to the source neutral. - Insulation cost is highly reduced. Neutral wire can permit mixed loading. - Triple harmonics are absent in the lines. These triple harmonic currents cannot flow, unless there is a neutral wire. This connection produces oscillating neutral. - Three phase shell type units have large triple harmonic phase voltage. However three phase core type transformers work satisfactorily. - A tertiary mesh connected winding may be required to stabilize the oscillating neutral due to third harmonics in three phase banks.
Delta- Delta (Dd 0 or Dd 6)	- This is an economical connection for large low voltage transformers. - Large unbalance of load can be met without difficulty. - Delta permits a circulating path for triple harmonics thus attenuates the same. - It is possible to operate with one transformer removed in open delta or "V" connection meeting 58 percent of the balanced load. - Three phase units cannot have this facility. Mixed single phase loading is not possible due to the absence of neutral.
Star-Zig-zag or Delta-Zig-zag (Yz or Dz)	- These connections are employed where delta connections are weak. Interconnection of phases in zigzag winding effects a reduction of third harmonic voltages and at the same time permits unbalanced loading. - This connection may be used with either delta connected or star connected winding either for step-up or step-down transformers. In either case, the zigzag

	winding produces the same angular displacement as a delta winding, and at the same time provides a neutral for earthing purposes. • The amount of copper required from a zigzag winding is 15% more than a corresponding star or delta winding. This is extensively used for earthing transformer. • Due to zigzag connection (interconnection between phases), third harmonic voltages are reduced. • It also allows unbalanced loading. The zigzag connection is employed for LV winding. For a given total voltage per phase, the zigzag side requires 15% more turns as compared to normal phase connection. In cases where delta connections are weak due to large number of turns and small cross sections, then zigzag star connection is preferred. It is also used in rectifiers.
Zig- zag/ star (ZY1 or Zy11)	• Zigzag connection is obtained by inter connection of phases. 4-wire system is possible on both sides. Unbalanced loading is also possible. Oscillating neutral problem is absent in this connection. • This connection requires 15% more turns for the same voltage on the zigzag side and hence costs more. Hence a bank of three single phase transformers cost about 15% more than their 3-phase counterpart. Also, they occupy more space. But the spare capacity cost will be less and single phase units are easier to transport. • Unbalanced operation of the transformer with large zero sequence fundamental mmf content also does not affect its performance. Even with Yy type of poly phase connection without neutral connection the oscillating neutral does not occur with these cores. Finally, three phase cores themselves cost less than three single phase units due to compactness.
Yd5	• Mainly used for machine and main Transformer in large Power Station and Transmission Substation. • The Neutral point can be loaded with rated Current.
Yz-5	• For Distribution Transformer up to 250MVA for local distribution system. • The Neutral point can be loaded with rated Current.

Application of Transformer according to Uses	
Step up Transformer	It should be Yd1 or Yd11.
Step down Transformer	It should be Dy1 or Dy11.
Grounding purpose Transformer	It should be Yz1 or Dz11.
Distribution Transformer:	We can consider vector group of Dzn0 which reduce the 75% of harmonics in secondary side.
Power Transformer	Vector group is deepened on application for Example: Generating Transformer: Dyn1, Furnace Transformer: Ynyn0.

Convert One Group of T/C to Other Group by Changing External Connection	
Group I:	Example: Dd0 (no phase displacement between HV and LV). =The conventional method is to connect the red phase on A/a, Yellow phase on B/b, and the Blue phase on C/c. =Other phase displacements are possible with unconventional connections (for instance red on b, yellow on c and blue on a) By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd0 transformer can be changed either to a Dd4(-120°) or Dd8(+120°) connection. The same is true for internal connected Dd4 or Dd8 transformers
Group II:	Example: Dd6 (180° displacement between HV and LV). By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd6 transformer can be changed either to a Dd2(-60°) or Dd10(+60°) connection
Group III:	Example: Dyn1 (-30° displacement between HV and LV). =By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn1 transformer can be changed either to a Dyn5(-150°) or

	Dyn9(+90°) connection.
Group IV:	Example: Dyn11 (+30° displacement between HV and LV). =By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn11 transformer can be changed either to a Dyn7(+150°) or Dyn3(-90°) connection.
Point to be remembered	
For Group-III & Group-IV: By doing some unconventional connections externally on both sides of the Transformer, an internal connected Group-III or Group-IV transformer can be changed to any of these two groups. Thus by doing external changes on both sides of the Transformer an internal connected Dyn1 transformer can be changed to either a: Dyn3, Dyn5, Dyn7, Dyn9 or Dyn11 transformer, This is just true for star/delta or delta/star connections.	
For Group-I & Group-II: Changes for delta/delta or star/star transformers between Group-I and Group-III can just be done internally.	

Size of Capacitor for P.F Correction:	
For Motor	
Size of Capacitor = 1/3 Hp of Motor OR (0.12x KW of Motor)	
For Transformer	
< 315 KVA	5% of KVA Rating
315 KVA to 1000 KVA	6% of KVA Rating
>1000 KVA	8% of KVA Rating
Capacitor Bank should be automatic Type	>= 5MVA Substation

Size of Capacitor Bank	
System Voltage	Minimum rating of capacitor bank
3.3 KV , 6.6KV	75 Kvar
11 KV	200 Kvar
22 KV	400 Kvar
33 KV	600 Kvar

Capacitor Bank for Non Linear Load	
% Non Liner Load	Type of Capacitor
<=10%	Standard Duty
Up to 15%	Heavy Duty
Up to 20%	Super Heavy Duty
Up to 25%	Capacitor +Reactor (Detuned)
Above 30%	

Selection of capacitor for transformer no-load compensation	
KVA Rating of the Transformer	Kvar Required for compensation
Up to and including 315 KVA	5% of KVA Transformer Rating
315 to 1000 KVA	6% of KVA Transformer Rating
Above 1000 KVA	8% of KVA Transformer Rating

Capacitor Bank for Transformer	
Transformer	Required Capacitor (Kvar)
<= 315 KVA T.C	5% of KVA
315kVA To 1000 kVA	6% of KVA
>= 1000 kVA	8% of KVA

Capacitor Bank for Power Supply Voltage	
System Voltage	Minimum rating of capacitor bank
3.3 KV , 6.6KV	75 Kvar
11 KV	200 Kvar
22 KV	400 Kvar
33 KV	600 Kvar

Fuse for Capacitor Bank		
KVAr	HRC Fuse	Cable Amps
5	12 Amps	12 Amps
7.5	25 Amps	25 Amps
10	32 Amps	32 Amps
12.5	32 Amps	32 Amps
15	50 Amps	50 Amps
20	50 Amps	50 Amps

25	63 Amps	63 Amps
50	125 Amps	125 Amps
75	200 Amps	200 Amps
100	200 Amps	250 Amps

Capacitor Ratings at Rated Voltage						
Ref: NEC(India) :2011						
Motor Rating(Kw)	Capacitor Rating in kVAR for Motor Speed					
	3 000 rev/min	1 500 rev/min	1 000 rev/min	750 rev/min	600 rev/min	500 rev/min
2.25	1	1	1.5	2	2.5	2.5
3.7	2	2	2.5	3.5	4	4
5.7	2	3	3.5	4.5	5	5.5
7.5	3	4	4.5	5.5	6	6.5
11.2	4	5	6	7.5	8.5	9
15	5	6	7	9	11	12
18.7	6	7	9	10.5	13	14.5
22.5	7	8	10	12	15	17
37	11	12.5	16	18	23	25
57	16	17	21	23	29	32
75	21	23	26	28	35	40
102	31	33	36	38	45	55
150	40	42	45	47	60	67
187	46	50	53	55	68	76

Calculation for Required Capacitor:

- Suppose Actual P.F is 0.8, Required P.F is 0.98 and Total Load is 516KVA.
- Power factor = KW / KVA
- **KW = KVA x Power Factor**
- KW = 516 x 0.8 = 412.8
- **Required capacitor = kW x Multiplying Factor**
- Required capacitor= (0.8 x 516) x Multiplying Factor
- Required capacitor = 412.8 x 0.547 (See Table to find Value according to P.F 0.8 to P.F of 0.98)
- **Required capacitor = 225.80 KVAR**

Multiplying factor for calculating KVAR											
Target PF											
0.6	0.9	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1
0.6	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191	1.333
0.61	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.157	1.299
0.62	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.015	1.062	1.123	1.265
0.63	0.748	0.777	0.807	0.837	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.685	0.714	0.743	0.774	0.806	0.840	0.877	0.919	0.966	1.027	1.169
0.66	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996	1.138
0.67	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.966	1.108
0.68	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936	1.078
0.69	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.907	1.049
0.7	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878	1.020
0.71	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.452	0.481	0.510	0.541	0.573	0.608	0.645	0.686	0.733	0.794	0.936
0.74	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713	0.855
0.77	0.344	0.373	0.403	0.433	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.599	0.660	0.802
0.79	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.634	0.776
0.8	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608	0.750
0.81	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556	0.698
0.83	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.530	0.672
0.84	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85	0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86	0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451	0.593
0.87	0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88	0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89	0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370	0.512
0.9		0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342	0.484
0.91			0.030	0.060	0.093	0.127	0.164	0.205	0.253	0.313	0.456
0.92				0.031	0.063	0.097	0.134	0.175	0.223	0.284	0.426
0.93					0.032	0.067	0.104	0.145	0.192	0.253	0.395
0.94						0.034	0.071	0.112	0.160	0.220	0.363
0.95							0.037	0.078	0.126	0.186	0.329

Cable Gland Terminology		
First Letter of Gland	Description	Sealing
A1	Un armored cable	with an elastomeric or plastics outer sheath, where the function of the gland is to secure the outer sheath of the cable
A2	Un armored cable	As type A1, but with an IP66 seal between the outer sheath and gland.
A3	Un armored cable	As type A1, but with an electrical bond for the metallic inner sheath.
A4	Un armored cable	As type A2, but with an electrical bond for the metallic inner sheath.
B	Armored cable or wire braided cable, no sealing	The function of the gland is to secure the armor or metallic braid and to provide electrical continuity between such armor or braid and the threaded fixing component of the gland.
C	Armored cable or wire braided cable, sealing on outer sheath	As type B, but with an IP66 seal between outer sheath and gland.
D1	Armored cable or wire braided cable, sealing on inner sheath	As type B, but with an IP66 seal between the inner sheath and threaded fixing component.
D2	Armored cable or wire braided cable, sealing on inner sheath	As type D1, but with an electrical bond for The metallic inner sheath.
E1	Armored cable, sealing on both sheaths	An extruded elastomeric or plastics inner sheath and elastomeric or plastics outer sheath. As type B, but with IP66 seals between the outer sheath and gland and between the inner sheath and threaded fixing component
E2	Armored cable, sealing on both sheaths	As type E 1, but with an electrical bond for the metallic inner sheath.
Second Letter of Gland	Description	Sealing
W	Single wire armored	
X	Wire braided	
T	Pliable wire armored flexible	
Y	Aluminum strip armored	
Z	Double steel tape armored	
Example		
Type BW	An armored clamp without a watertight seal, for single wire armored cable.	
Type CT	A gland for pliable wire armored flexible cable, with an IP66 seal between the outer sheath and gland.	
Type E2X	gland for wire braided cable with an electrical bond for the metallic inner sheath	

Gland for 600/1000V STANDARD COPPER CONDUCTORS PVC INSULATED WITH STEEL WIRE ARMOUR AND PVC SHEATHED OVERALL														
Cable Size	Numbers of Cores													
(mm ²)	Neutral	1	2	3	31/2	4	5	7	10	12	19	27	37	48
1.5	-	-	16	16	-	20S	20S	20S	20	20	25	25	32	32
2.5	-	-	20S	20S	-	20S	20S	20	25	25	25	32	32	40
4	-	-	20S	20	-	20	20	25	25	25	32	40	-	-
6	-	-	20	20	-	20	-	-	-	-	-	-	-	-
10	-	-	25	25	-	25	-	-	-	-	-	-	-	-
16	-	-	25	25	-	25	-	-	-	-	-	-	-	-
25	16	-	25	32	32	32	-	-	-	-	-	-	-	-
35	16	-	32	32	32	40	-	-	-	-	-	-	-	-
50	25	25	32	32	32	40	-	-	-	-	-	-	-	-
70	35	25	32	40	40	40	-	-	-	-	-	-	-	-
95	50	25	40	40	50S	50S	-	-	-	-	-	-	-	-
120	70	32	40	50S	50	50	-	-	-	-	-	-	-	-
150	70	32	50S	50	50	63S	-	-	-	-	-	-	-	-
185	95	32	50	50	63S	63	-	-	-	-	-	-	-	-
240	120	40	50	63S	63	75S	-	-	-	-	-	-	-	-
300	150	40	63S	63	75S	75	-	-	-	-	-	-	-	-
300	185	40	63	63	75	75	-	-	-	-	-	-	-	-
400	185	50S	63	75S	75	75	-	-	-	-	-	-	-	-
500	-	50	-	-	-	-	-	-	-	-	-	-	-	-
630	-	50	-	-	-	-	-	-	-	-	-	-	-	-
800	-	63S	-	-	-	-	-	-	-	-	-	-	-	-
1000	-	63	-	-	-	-	-	-	-	-	-	-	-	-

Gland For 600 / 1000v stranded copper conductors XLPE/SWA/PVC cable and PVC sheathed overall. (BS 5467 : 1989)														
Cable Size	Numbers of Cores													
Area (mm ²)	Neutral	1	2	3	31/2	4	5	7	10	12	19	27	37	48
1.5	-	-	20S	20S	-	20S	20S	20S	20	25	25	32	32	32
2.5	-	-	20S	20S	-	20S	20S	20	25	25	32	32	40	40
4	-	-	20S	20S	-	20	20	25	25	25	32	40	40	50S
6	-	-	20	20	-	20	-	-	-	-	-	-	-	-
10	-	-	20	25	-	25	-	-	-	-	-	-	-	-
16	-	-	25	25	-	25	-	-	-	-	-	-	-	-
25	16	-	25	32	32	32	-	-	-	-	-	-	-	-
35	16	-	32	32	32	32	-	-	-	-	-	-	-	-
50	25	25	25	32	32	32	-	-	-	-	-	-	-	-
70	35	25	32	32	40	40	-	-	-	-	-	-	-	-
95	50	25	32	40	50S	50S	-	-	-	-	-	-	-	-
120	70	32	40	40	50	50	-	-	-	-	-	-	-	-
150	70	32	40	50S	50	50	-	-	-	-	-	-	-	-
185	95	32	50S	50	63S	63S	-	-	-	-	-	-	-	-
240	120	40	50	63S	63	63	-	-	-	-	-	-	-	-
300	150	40	63S	63	75S	75S	-	-	-	-	-	-	-	-
300	185	40	63S	63	75S	75	-	-	-	-	-	-	-	-
400	185	50S	63S	75S	75	75	-	-	-	-	-	-	-	-
500	-	50	-	-	-	-	-	-	-	-	-	-	-	-
630	-	50	-	-	-	-	-	-	-	-	-	-	-	-
800	-	63S	-	-	-	-	-	-	-	-	-	-	-	-
1000	-	63	-	-	-	-	-	-	-	-	-	-	-	-

Accuracy Class Letter of CT:	
Metering Class CT	
Accuracy Class	Applications
B	Metering Purpose
Protection Class CT	
C	CT has low leakage flux.
T	CT can have significant leakage flux.
H	CT accuracy is applicable within the entire range of secondary currents from 5 to 20 times the nominal CT rating. (Typically wound CTs.)
L	CT accuracy applies at the maximum rated secondary burden at 20 time rated only. The ratio accuracy can be up to four times greater than the listed value, depending on connected burden and fault current. (Typically window, busing, or bar-type CTs.)

Accuracy Class of Metering CT:	
Metering Class CT	
Class	Applications
0.1 To 0.2	Precision measurements
0.5	High grade kilowatt hour meters for commercial grade kilowatt hour meters
3	General industrial measurements
3 OR 5	Approximate measurements
0.15	High Accuracy Metering
0.15S	Special High Accuracy Metering
0.3	Revenue Metering
1.2	Indicating Instruments

Accuracy Class of Protection CT	
Class	Applications
10P5	Instantaneous over current relays & trip coils: 2.5VA
10P10	Thermal inverse time relays: 7.5VA
10P10	Low consumption Relay: 2.5VA
10P10/5	Inverse definite min. time relays (IDMT) over current
10P10	IDMT Earth fault relays with approximate time grading:15VA
5P10	IDMT Earth fault relays with phase fault stability or accurate time grading: 15VA

Protection CT			
Protective System	CT Secondary	VA	Class
Per current for phase & earth fault	1A	2.5	10P20 Or 5P20
	5A	7.5	10P20 Or 5P20
Unrestricted earth fault	1A	2.5	10P20 Or 5P20
	5A	7.5	10P20 Or 5P20
Sensitive earth fault	1A or 5A		Class PX use relay manufacturers formula
Distance protection	1A or 5A		Class PX use relay manufacturers formula
Differential protection	1A or 5A		Class PX use relay manufacturers formula
High impedance differential impedance	1A or 5A		Class PX use relay manufacturers formula
High speed feeder protection	1A or 5A		Class PX use relay manufacturers formula
Motor protection	1A or 5A	5	5P10

Burden of CT:	
VA	Applications
1 To 2 VA	Moving iron ammeter
1 To 2.5VA	Moving coil rectifier ammeter
2.5 To 5VA	Electrodynamics instrument
3 To 5VA	Maximum demand ammeter
1 To 2.5VA	Recording ammeter or transducer

Nomenclature of CT:	
Nomenclature of CT:	Ratio, VA Burden, Accuracy Class, Accuracy Limit Factor.
Ratio:	Input / output current ratio
Burden (VA):	Total burden including pilot wires. (2.5, 5, 10, 15 and 30VA.)
Class:	Accuracy required for operation (Metering: 0.2, 0.5, 1 or 3, Protection: 5, 10, 15, 20, 30).
Accuracy Limit Factor:	5, 10, 15, 20 and 30.
Dimensions:	maximum & minimum limits
Example:	1600/5, 15VA 5P10 (Ratio: 1600/5, Burden: 15VA, Accuracy Class: 5P, ALF: 10)
As per IEEE Metering CT:	0.3B0.1 rated Metering CT is accurate to 0.3 percent if the connected secondary burden if impedance does not exceed 0.1 ohms
As per IEEE Relaying (Protection) CT:	2.5C100 Relaying CT is accurate within 2.5 percent if the secondary burden is less than 1.0 ohm (100 volts/100A).

Sizing of CT for Building:

- **New construction:** size the CT to handle about 80% of the circuit breaker capacity. If the building is served by a 2000 amp breaker, use 1600 amp (2000 x 0.8) CT's.
- **Older buildings:** the peak demand can generally be determined from the power company or from past billings. In this case add 20 to 30% to the peak demand and size the CT's for this load. If the peak demand was 500 kW, the peak current on a 480/3/60 system would be **500,000 / (480 x 1.73 x 0.9 pf) = 669 amps**. This assumes a 0.9 power factor. (Peak current would be higher with a lower power Factor.) Use CT's about 20% larger. 800:5 CT's would be a good selection.
- For older buildings with no demand history, size the **CT's** the same as for new construction. Where possible, use multi-tap **CT's** so that the ratio can be reduced if the maximum load is much less than 80% of the breaker size.
- **CT's** that are used to monitor motor loads can be sized from the nameplate full load motor amps.

Chapter: 14 Electrical Reference Demand Factor / Diversity Factor

Demand Factor For Industrial Load(Design of Elect. Installation- Jain)	
Electrical Load	Demand Factor
1 No of Motor	1
Up to 10 No's of Motor	0.75
Up to 20 No's of Motor	0.65
Up to 30 No's of Motor	0.6
Up to 40 No's of Motor	0.5
Up to 50 No's of Motor	0.4

Demand Factor (Design of Elect. Installation- Jain)	
Utility	Demand Factor
Office ,School	0.4
Hospital	0.5
Air Port, Bank, Shops,	0.6
Restaurant, Factory,	0.7
Work Shop, Factory (24Hr Shift)	0.8
Arc Furnace	0.9
Compressor	0.5
Hand tools	0.4
Inductance Furnace	0.8

Demand Factor(Saudi Electricity Company Distribution)	
Utility	Demand Factor
Residential	0.6
Commercial	0.7
Flats	0.7
Hotel	0.75
Mall	0.7
Restaurant	0.7
Office	0.7
School	0.8
Common Area in building	0.8
Public Facility	0.75
Street Light	0.9
Indoor Parking	0.8
Outdoor Parking	0.9
Park / Garden	0.8
Hospital	0.8
Workshops	0.6
Ware House	0.7
Farms	0.9
Fuel Station	0.7
Factories	0.9

Demand Factor (Principal of Power System-V.K.Mehta)	
Utility	Demand Factor
Residence Load (<0.25 KW)	1
Residence Load (<0.5 KW)	0.6
Residence Load (>0.1 KW)	0.5
Restaurant	0.7
Theatre	0.6
Hotel	0.5
School	0.55

Small Industry	0.6
Store	0.7
Motor Load (up to 10HP)	0.75
Motor Load (10HP to 20HP)	0.65
Motor Load (20HP to 100HP)	0.55
Motor Load (Above 100HP)	0.50

Diversity Factor in distribution Network				
(Standard Handbook for Electrical Engineers" by Fink and Beaty)				
Elements of System	Residential	Commercial	General Power	Large Industrial
Between individual users	2.00	1.46	1.45	
Between transformers	1.30	1.30	1.35	1.05
Between feeders	1.15	1.15	1.15	1.05
Between substations	1.10	1.10	1.10	1.10
From users to transformers	2.00	1.46	1.44	
From users to feeder	2.60	1.90	1.95	1.15
From users to substation	3.00	2.18	2.24	1.32
From users to Generating station	3.29	2.40	2.46	1.45

Diversity Factor for Distribution Switchboards	
Number of circuits	Diversity Factor in % (ks)
Assemblies entirely tested 2 and 3	90%
4 and 5	80%
6 to 9	70%
10 and more	60%
Assemblies partially tested in every case choose	100%

Diversity Factor as per IEC 60439	
Circuits Function	Diversity Factor in % (ks)
Lighting	90%
Heating and air conditioning	80%
Socket-outlets	70%
Lifts and catering hoist	
For the most powerful motor	100%
For the second most powerful motor	75%
For all motors	80%

Diversity Factor for Apartment block	
Apartment	Diversity Factor in % (ks)
2 To 4	1
5To 19	0.78
10To 14	0.63
15To 19	0.53
20To 24	0.49
25To 29	0.46
30 To 34	0.44
35 To 39	0.42
40To 40	0.41
50 To Above	0.40

Diversity Factor (Principal of Power System-V.K.Mehta)			
Area	Residence Lighting	Commercial Lighting	Ind. Lighting
Between Consumer	3	1.5	1.5
Between Transformer	1.3	1.3	1.3
Between Feeder	1.2	1.2	1.2
Between S.S	1.1	1.1	1.1

Demand Factor & Load Factor		
Introduction to Power Requirement for Building - J. Paul Guyer,		
Utility	Demand Factor (%)	Load Factor (%)
Communications – buildings	60-65	70-75
Telephone exchange building	55-70	20-25
Air passenger terminal building	65-80	28-32
Aircraft fire and rescue station	25-35	13-17
Aircraft line operations building	65-80	24-28
Academic instruction building	40-60	22-26
Applied instruction building	35-65	24-28
Chemistry and Toxicology Laboratory	70-80	22-28
Materials Laboratory	30-35	27-32
Physics Laboratory	70-80	22-28
Electrical and electronics laboratory	20-30	3-7
Cold storage warehouse	70-75	20-25
General warehouse	75-80	23-28
Controlled humidity warehouse	60-65	33-38
Hazardous/flammable storehouse	75-80	20-25
Disposal, salvage, scrap building	35-40	25-20
Hospital	38-42	45-50
Laboratory	32-37	20-25
7-12 schools	65-70	12-17
Churches	65-70	5-25
Post Office	75-80	20-25
Retail store	65-70	25-32
Bank	75-80	20-25
Supermarket	55-60	25-30
Restaurant	45-75	15-25
Auto repair shop	40-60	15-20
Hobby shop, art/crafts	30-40	25-30
Bowling alley	70-75	10-15
Gymnasium	70-75	20-45
Skating rink	70-75	10-15
Indoor swimming pool	55-60	25-50
Theatres	45-55	8-13
Library	75-80	30-35
Golf clubhouse	75-80	15-20
Museum	75-80	30-35

Illumination Level	
Area	Lux Level
Very Bright Summer Day (Max)	Up to 100000 Lux
Very Bright Summer Day (Min)	20000 Lux
Nighttime Car Park	1 Lux
Nighttime Urban Street	10 Lux
Night Light on a Building	60 Lux
Machine shop	400 Lux
Offices	500 Lux
Kitchens (food preparation area)	400 Lux
Counters	240 Lux
Machine shop	700 Lux
Canteens	300 Lux
Waiting Rooms	80 Lux
Foyers	200 Lux
Entrance halls	160 Lux
Stairs	40 Lux
Warehouses	80 Lux
Passageways	80 Lux
Corridors	40 Lux

Illumination Level	
Ref: NEC(India) :2011	
Location	Illumination Level (Lux)
Residence	
Entrance / Hallways	100
Living room	300
Dining Room	150
Bed Room (General)	300
Bed Room (Dressing , Bed Heads)	200
Kitchen	200
Kitchen sink	300
Bathroom	100
Sewing	700
Workshop	200
Staircase	100
Garage	70
Study Room	300
Office Building	
Entrance hall / Reception	150
Conference Room / Executive Office	300
General Office Space	300
Business Machinery Operation	450
Drawing Office	450
Corridors	70
Stairs	100
Lift landing	150
Hospital Building	
Reception & Waiting	150
General ward	100
Bed Side	150
Toilet	70
Stairs	100
Operation Theatre (General)	300
Operation Theatre (Operation Table)	Special

Laboratories	300
Radiology	100
Causality	150
Dispensaries	300
Laundry	200
Dry Cleaning	200
Ironing	300
General Office	450
Kitchen	200
Assembly & Concert Halls	
Foyers	100 to 150
Auditoria	100 to 150
Platform	450
Corridors	70
Stairs	100
Cinema Halls	
Foyers	150
Auditoria	50
Corridors	70
Stairs	100
Theatres	
Foyers	150
Auditoria	70
Corridors	70
Stairs	100
School / College Building	
Assembly Halls	
General	150
Examination center	300
Platform	300
Classes	
Desktop	300
Blackboard	200 to 300
Libraries	
Shelves	70 to 150
Reading Room	150 to 300
Reading Table	300 to 700
Cataloguing	150 to 300
General	
Office	300
Staff Room	150
Corridors	70
Stairs	100

Lamp's Lumen Data		
Rating (Watt)	Life (Hours)	Initial Lumens
Incandescent Lamp		
60	1000	870
100	750	1750
150	2000	1740
200	2000	2300
500	2000	6500
Fluorescent Lamp		
18	7000	1120
20	7000	1020
36	7000	2800
40	7000	2700
2X40	7000	4000
Compact Fluorescent Lamp		

5	10000	220
7	7000	380
11	7000	560
13	7000	680
15	7000	810
18	7000	1050
23	7000	1500
26	7000	1800
32	7000	2400
Mercury Vapour Lamp		
100	18000	3700
175	24000	8600
250	24000	12100
400	24000	22500
1000	24000	57000
Metal Halide Lamp		
50	15000	3400
70	15000	5600
100	15000	9000
150	10000	13500
175	10000	15000
250	10000	20500
400	20000	36000
1000	12000	110000
High Pressure Sodium Vapour Lamps		
35	16000	2250
50	24000	4000
70	24000	5800
100	24000	9500
150	24000	16000
250	24000	27500
400	24000	47500
1000	24000	140000
Pulse Start Metal Halide Lamp		
50	15000	3400
70	15000	5600
100	15000	9000
150	15000	15000
175	15000	17500
200	15000	21000
250	15000	26300
320	20000	34000
400	20000	44000
450	20000	50000

Illuminance for Various Roadway Types (ANSI/IES RP-8)	
Road Type	Illuminance Lux
Urban Freeway	10
Freeway Interchange	14
Commercial Arterial	20
Residential Collector	8
Local	6

Light levels as per IS 1944				
Classification of road	Type of road	Average level of illumination (lux)	Min:Avg	Min:Max (%)
Group A1	Important traffic routes carrying fast traffic	30	0.4	33

Group A2	Other main roads carrying mixed traffic, like main city streets, arterial roads, throughways etc	15	0.4	33
Group B1	Secondary roads with considerable traffic like principal local traffic routes, shopping streets etc	8	0.3	20
Group B2	Secondary roads with light traffic. important traffic routes carrying fast traffic	4	0.3	20

Minimum Level of illumination in Lux			
Road	Residential	Industrial	Commercial
Arterial Roads	10.0	13.0	17
Collector Road	6.0	10.0	13.0
Local Roads	4.0	7.0	9.0
Walkways & Pathways	4.0		
Lanes	4.0	2.0	2.0

Recommended Levels of Illumination (BIS, 1981)Table 6			
Road Characteristics	Avg Illumination (Lux)	Min / Avg Illumination (Lux)	Type of Luminaries Preferred
Important traffic routes carrying fast traffic	30	0.4	Cutoff
Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways	15	0.4	Cutoff
Secondary roads with considerable traffic like local traffic routes, shopping streets	8	0.3	Cutoff or semi-cutoff
Secondary roads with light traffic	4	0.3	Cutoff or semi-cutoff

Recommended Average Horizontal Illumination level in Lux				
Pedestrian Traffic	Vehicular traffic Classification			
	Very light	Light	Medium	Heavy to Heaviest
Heavy	9.68	12.91	16.14	12.52
Medium	6.46	8.61	10.26	12.91
Light	2.15	4.30	6.46	9.68

Classification Roadway Traffic		
Classification Number	Number of Vehicles per Hour	
	Maximum Night Hour	Both Direction
Very light traffic	Under	150
Light traffic	150	500
Medium traffic	500	1200
Heavy traffic	1200	2400
Very heavy traffic	2400	4000
Heavy traffic	Over	4000

Classification of Pedestrian Traffic	
Light or No Traffic	Residential, warehouse areas on express / elevated depressed roadways
Medium Traffic	Secondary business streets and some industrial roads
Heavy Traffic	Business streets.

Lamp Comparison Chart (Bureau of Energy Efficiency, Delhi)					
Lamp Type	Lamp (Watts)	Efficacy (Lumens/ Watt)	Color Render	Lamp Life (Hr)	Remarks
Incandescent (GLF) Lamps:					
(Incandescent bulbs)	15,25,40,60,75,100, 150,200, 300,500 (no ballast)	8 to 17	100	1000	
Tungsten Halogen	75,100,150,500,1000,2000 (no ballast)	13 to 25	100	2000	
Fluorescent Tube lights (Argon filled)	20,40,65, (32,51,79)	31 to 58	67 to 77	5000	
Fluorescent Tubular Lamp (T5)	18,20,36,40,58,65	100 to 120	Very Good	15,000 to 20,000	Energy-efficient, long lamp life, only available in low wattages
Compact Fluorescent Lamps (CFLs)	5,7,9,11,18,24,36	26 to 64	85	8000	
HID Lamps:					
High Pressure Mercury Vapor (HPMV)	80,125,250,400,1000,2000	25 to 60	45 (Fair)	16,000 to 24,000	High energy use, Poor lamp life
High Pressure Metal Halide Lamps (HPMH)	70,150,250,400,1000,2000	62 to 72	70 (Excellent)	8000 to 12000	High luminous efficacy, Poor lamp life
High Pressure Sodium Vapor Lamps (HPSV)	70,150,250,400,1000	69 to 108	25 to 60 (Fair)	15000 to 24000	Energy-efficient, poor color rendering
Low Pressure Sodium Vapor Lamps (LPSV)	35,55,135	90 to 133	Very Poor	18000 to 24000	Energy-efficient, very poor color rendering
Low Pressure Mercury Fluorescent Tubular Lamps (T8 & T12)	35,55,135	30 to 90	Good	5000 to 10000	Poor lamp life, Medium energy use, only available in low wattages
LED Lamps					
Light Emitting Diode (LED)		70 to 160	Good	40,000 to 90,000	High energy savings, low maintenance, long life, no mercury. High investment cost

Savings by Use of More Efficient Lamps (Bureau of Energy Efficiency)		
Existing Lamp	Replace by	Energy Savings
GLS (Incandescent)	Compact Fluorescent Lamp (CFL)	35 to 60 %
	High Pressure Mercury Vapor (HPMV)	40 to 50 %
	Metal Halide	65 %
	High Pressure Sodium Vapor (HPSV)	65 to 75%
Tungsten Halogen	High Pressure Mercury Vapor (HPMV)	50 to 60 %
	Metal Halide	40 to 70 %
	High Pressure Sodium Vapor (HPSV)	40 to 80 %
High Pressure Mercury Vapor	Metal Halide	35 %

(HPMV)	High Pressure Sodium Vapor (HPSV)	35 to 60 %
	Low Pressure Sodium Vapor (HPSV)	60 %
Metal Halide	High Pressure Sodium Vapor (HPSV)	30 %
	Low Pressure Sodium Vapor (HPSV)	40 %
High Pressure Sodium Vapor (HPSV)	Low Pressure Sodium Vapor (HPSV)	40 %

Variation in Light Output and Power Consumption (BEE, India)

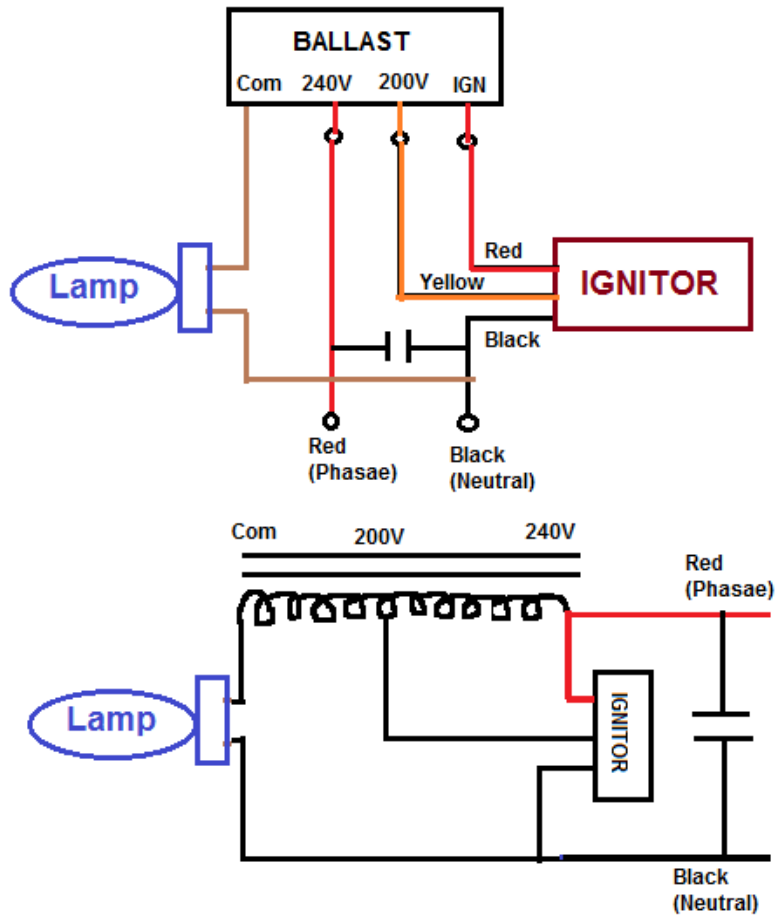
Type of Lamp	10% lower voltage		10% Higher voltage	
	Light Out Put	Power Out Put	Light Out Put	Power Out Put
Fluorescent lamps	Decreased 9%	Decreased 15%	Increased 9%	Increased 15%
HPMV lamps	Decreased 20%	Decreased 16%	Increased 20%	Increased 17%
Mercury Blended lamps	Decreased 24%	Decreased 20%	Increased 30%	Increased 20%
Metal Halide lamps	Decreased 30%	Decreased 20%	Increased 30%	Increased 20%
HPSV lamps	Decreased 28%	Decreased 20%	Increased 30%	Increased 26%
LPSV lamps	Decreased 4%	Decreased 8%	Increased 2%	Increased 3%

Height of Pole	Application
6 Meter	For streets ,alleys, public gardens and parking lots
8 Meter	Urban traffic route, multiplicity of road junctions,
	Narrow roads such as local access roads in residential areas in which a mounting height between 10 M or 12 M and 5 M or 6 M is required.
10 Meter	Urban traffic route, For wide heavily used routes where a large number of intersection, bends can lead to a short spacing making the use of 12 M mounting height uneconomical.
12 Meter	Wide or heavily used routes where advantage can be taken of a longer spacing of luminaries.
18 Meter and above	High mast lighting poles shall be installed at large-scale area such as airports, dockyards, large industrial areas, sports areas and road intersections

Illuminance Levels for different Areas of Activity

	Illuminance level (lux)	Examples of Area of Activity
General Lighting for rooms and areas used either infrequently and/or casual or simple visual tasks	20	Minimum service illuminance in exterior circulating areas, outdoor stores , stockyards
	50	Exterior walkways & platforms.
	70	Boiler house.
	100	Transformer yards, furnace rooms etc.
	150	Circulation areas in industry, stores and stock rooms.
General lighting for interiors	200	Minimum service illuminance on the task
	300	Medium bench & machine work, general process in chemical and food industries, casual reading and filing activities.
	450	Hangers, inspection, drawing offices, fine bench and machine assembly, color work, critical drawing tasks.
	1500	Very fine bench and machine work, instrument & small precision mechanism assembly; electronic components, gauging & inspection of small intricate parts (may be partly provided by local task lighting)
Additional localized lighting for visually exacting tasks	3000	Minutely detailed and precise work, e.g. very small parts of instruments, watch making, engraving

Circuit for Ballast-Ignitor-Capacitor-Lamp



IP Rating Digits			
IP Rating	First Digit Solid Objects Protection	Second Digit Liquids Protection	Third Digit (Optional) Mechanical impacts
0	No special protection	No protection.	No protection.
1	Protected against solid objects greater than 50mm in diameter (such as large part of the body like hand)	Protection against vertically falling drops of water e.g. condensation.	Protects against impact of 0.225 joule (150 g weight falling from 15 cm height)
2	Protected against solid objects over 12 mm in diameter (person's fingers)	Protection against direct sprays of water up to 15° from the vertical.	Protected against impact of 0.375 joule (250 g weight falling from 15 cm height)
3	Protected against solid objects not greater than 80mm in length and 12mm in diameter (tools and wires).	Protected against direct sprays of water up to 60° from the vertical.	Protected against impact of 0.500 joule (250 g weight falling from 20 cm height)
4	Protected against solid objects larger than 1 mm diameter (tools, wires, and small wires).	Protection against water sprayed from all directions (limited ingress permitted).	Protected against impact of 2.0 joule (500 g weight falling from 40 cm height)
5	Protected against dust limited ingress (no harmful deposit).	Protected against low pressure jets of water from all directions (limited ingress).	Protected against impact of 6.0 joule (1.5 kg weight falling from 40 cm height)
6	Totally dust tight.	Protected against temporary flooding of water, e.g. for use on ship decks (limited ingress permitted).	Protected against impact of 20.0 joule (5 kg weight falling from 40 cm height)
7	N/A	Protected against the effect of immersion between 15 cm and 1 m.	N/A
8	N/A	Protects against long periods of immersion under pressure.	N/A

Example:

- **IP65 Enclosure:** IP rated as protection against dust (5) and protection from low water pressure (6).
- **IP66 Enclosure :** IP rated as protection against dust (5) and protected against heavy seas or powerful jets of water (6)

Types of Over Load Relay:	
Class	Tripping Time
Class 10	Would Trip after 10 seconds.
Class 20	Would Trip after 20 seconds.
Class 30	Would Trip after 30 seconds.
Class 10 is faster than Class 20 and Class 30 over Load Relay	
Over Load Relay should be set 115% to 130% of Motor Full Load Current	

Approximate RPM of Motor	
HP	RPM
< 10 HP	750 RPM
10 HP to 30 HP	600 RPM
30 HP to 125 HP	500 RPM
125 HP to 300 HP	375 RPM

Standard Size of Motor:	
1 HP	200 HP
1.5 HP	250 HP
3 HP	300 HP
5 HP	450 HP
7.5 HP	500 HP
10 HP	600 HP
15 HP	700 HP
20 HP	800 HP
30 HP	900 HP
40 HP	1000 HP
50 HP	1250 HP
60 HP	1050 HP
75 HP	1750 HP
100 HP	2000 HP
125 HP	2250 HP
150 HP	3000 HP
	3500 HP
	4000 HP

Motor Line Voltage:	
Motor (KW)	Line Voltage
< 250 KW	440 V (LV)
150 KW to 3000KW	2.5 KV to 4.1 KV (HV)
200 KW to 3000KW	3.3 KV to 7.2 KV (HV)
1000 KW to 1500KW	6.6 KV to 13.8 KV (HV)

Motor Starting Current:		
Supply	Size of Motor	Max. Starting Current
1 Phase	< 1 HP	6 X Motor Full Load Current
1 Phase	1 HP to 10 HP	3 X Motor Full Load Current
3 Phase	10 HP	2 X Motor Full Load Current
3 Phase	10 HP to 15 HP	2 X Motor Full Load Current
3 Phase	> 15 HP	1.5 X Motor Full Load Current

Max. Lock Rotor Amp for Single Phase 230 V Motor (NEMA)	
HP	Amp
1 HP	45 Amp
1.5 HP	50 Amp
2 HP	65 Amp
3 HP	90 Amp
5 HP	135 Amp
7.5 HP	200 Amp
10 HP	260 Amp

Three Phase Motor Code (NEMA)	
HP	Code
<1 HP	L
1.5 to 2.0 HP	L,M
3 HP	K
5 HP	J
7 to 10 HP	H
>15 HP	G

Service Factor of Motor:							
HP	Synchronous Speed (RPM)						
	3600 RPM	1800 RPM	1200 RPM	900 RPM	720 RPM	600 RPM	514 RPM
1 HP	1.25	1.15	1.15	1.15	1	1	1
1.5 to 1.25 HP	1.15	1.15	1.15	1.15	1.15	1.15	1.15
150 HP	1.15	1.15	1.15	1.15	1.15	1.15	1
200 HP	1.15	1.15	1.15	1.15	1.15	1	1
> 200 HP	1	1.15	1	1	1	1	1

Motor Starting Current:	
Size of Motor	Limit of maximum starting current
Up to 5 H.P	Direct on line starting permitted.
5 H.P to 20 H.P	2 times full load current
20 H.P to 100 H.P	1.5 times full load current
Above 100 H.P	1.25 times full load current

:Maximum Current Demand for Motor:		
Ref: NEC(India) :2011		
Nature of supply	Size of installation	Maximum current demand
Single phase or Three phase	Up to and including 0.75 kW	Six times the full load current
	Above 0.75 kW and up to 7.5 kW	Three times the full load current
	Above 7.5 kW up to and up to 11 kW	Two times the full load current
	Above 11 kW	One and half times the full load current

Motor Starter:			
Starter	HP or KW	Starting Current	Torque
DOL	<13 HP(11KW)	7 X Full Load Current	Good
Star-Delta	13 HP to 48 HP	3 X Full Load Current	Poor
Auto TC	> 48 HP (37 KW)	4 X Full Load Current	Good/ Average
VSD		0.5 to 1.5 X Full Load Current	Excellent
Motor > 2.2KW Should not connect direct to supply voltage if it is in Delta winding			

Type of Contactor:	
Type	Application
AC1	Non Inductive Load or Slightly Inductive Load
AC2	Slip Ring Motor, Starting, Switching OFF
AC3	Squirrel Cage Motor
AC4,AC5,AC5a,AC5b,AC6a	Rapid Start & Rapid Stop
AC 5a	Auxiliary Control circuit
AC 5b	Electrical discharge Lamp
AC 6a	Electrical Incandescent Lamp
AC 6b	Transformer Switching
AC 7a	Switching of Capacitor Bank
AC 7b	Slightly Inductive Load in Household
AC 5a	Motor Load in Household
AC 8a	Hermetic refrigerant compressor motor with Manual Reset O/L Relay
AC 8b	Hermetic refrigerant compressor motor with Automatic Reset O/L Relay
AC 12	Control of Resistive Load & Solid State Load
AC 13	Control of Resistive Load & Solid State Load with Transformer Isolation
AC 14	Control of small Electro Magnetic Load (<72 VA)
AC 15	Control of Electro Magnetic Load (>72 VA)

Contactor Coil:	
Coil Voltage	Suffix
24 Volt	T
48 Volt	W
110 to 127 Volt	A
220 to 240 Volt	B
277 Volt	H
380 to 415 Volt	L

Size of over Load Relay:	
Size	Amp Capacity
S00	0.1 To 0.4
	0.4 To 0.6
	1.6 To 6
	3 To 12
S0	3 To 12
	6 To 25
S2	6 To 25
	13 To 50
S3	13 To 50
	25 To 100
S6	50 To 200
	55 To 250
S10 & S12	200 To 540
	300 To 630

Contactor Coil:	
Coil Voltage (40 To 50 Hz)	Suffix
24V	T
48V	W
110V To 127V	A
220V To 240V	B
277V	H
380V To 415V	L

Making and Breaking Capacity of Contactor:		
Contactor	Making Capacity(Amp)	Breaking Capacity (Amp)
AC1	1.5 X motor rated current	1.5 X motor rated current
AC2	4 X motor rated current	4 X motor rated current
AC3	10 X motor rated current	8 X motor rated current
AC4	12 X motor rated current	10 X motor rated current
AC5a	3 X motor rated current	3 X motor rated current
AC5b	1.5 X motor rated current	1.5 X motor rated current
AC6a	12 X motor rated current	10 X motor rated current
AC6b	12 X motor rated current	10 X motor rated current
AC7a	1.5 X motor rated current	1.5 X motor rated current
AC7b	8 X motor rated current	8 X motor rated current
AC8a	6 X motor rated current	6 X motor rated current
AC8b	6 X motor rated current	6 X motor rated current
AC12		
AC13	10 X motor rated current	1.1 X motor rated current
AC14	6 X motor rated current	6 X motor rated current
AC15	10 X motor rated current	10 X motor rated current

Contactor Status		
Contactor Status	Continuity Between Pins (N/C)	Non Continuity Between Pins (N/O)
Power Not Applied	32 and 33	21 and 22
		11 and 12
		A1 and A2
		B1 and B2
Power Applied	21 and 22	32 and 33
	11 and 12	
	A1 and A2	
	B1 and B2	

Rated Current of Contactor(Thermal and Intermittent Duty)	
A.C	6,10,16,25,63,100,160,200,315,400,630,800 Amp
D.C	16,20,80,160,315,1250,8000 Amp

Voltage Level		
Main Circuit Voltage	A.C	240V,415V
	D.C	230V,460V,600V
Contactor's Coil Voltage	A.C	40V,220V,240V,415V
	D.C	24V(For PLC),110V,230V,460V

Locked Rotor Current		
Code	Min	Max
A	1	3.14
B	3.15	3.54
C	3.55	3.99

D	4	4.49
E	4.5	4.99
F	5	2.59
G	2.6	6.29
H	6.3	7.09
I	7.1	7.99
K	8	8.99
L	9	9.99
M	10	11.19
N	11.2	12.49
P	12.5	13.99
R	14	15.99
S	16	17.99
T	18	19.99
U	20	22.39
V	22.4	

DOL STARTER								
H.P	KW	FLC	Contactor Size (Amp)	Relay setting		Fuse	Cable (mm2)	
				Min	Max		Cu	Allu
0.5	0.37	1	-	0.8	1.17	4	1	1.5
0.75	0.55	1.3	9	1	1.5	4	1	1.5
1	0.74	1.9	9	1.6	2.3	6	1.5	2.5
1.5	1.11	2.6	9	2	3	6	1.5	2.5
2	1.49	3.7	9	2.5	3.7	10	1.5	2.5
3	2.2	4.8	9	4	5.9	16	1.5	2.5
5	3.73	7.8	9	6.3	9.4	20	1.5	2.5
7	5.22	11.2	12	8	11.7	25	2.5	4
10	7.46	16	16	12.5	18.7	25	4	6
12.5	9.32	19	32	16	23.4	32	4	6
15	11.19	20.8	32	16	23.4	50	6	10
20	14.92	28	32	20	30	50	6	10
25	18.65	34	38	32	37.4	63	10	16
30	22.38	40	45	32	47	80	16	25
40	29.84	53	63	50	59	100	25	35
50	37.3	65	70	57	65.5	125	25	50
60	44.76	78	85	70	88.9	125	25	50
75	55.95	96	110	85	98.2	160	50	70
100	74.6	131	140	115	168	200	70	95
125	93.25	156	170	115	168	250	120	150
150	111.9	189	205	160	234	315	150	240
180	134.28	227	250	160	234	355	185	300
215	160.39	271	300	200	299	400	-	-
270	201.42	339	400	250	374	500	-	-
335	249.91	338	475	320	468	500	-	-

Selection of Motor Starter -Contactor-Relay- Fuse -Cable										
Motor Rating (3 Phase,415 V)		Full Load Current (Amp)	Phase Current (Amp)	Contactor Capacity (Amp)		Relay Scale (Amp)		Back up Fuse HRC (Amp)	Cable Size (Sq.mm)	
HP	KW			Main/Delta	Star	Min	Max		Supply Side	Motor Side
3	2.25	5	2.88	12	12	1.5	4	10	1.5/2.5	1.5/2.5
5	3.75	7.5	4.32	12	12	3	6	20	1.5/2.5	1.5/2.5
7.5	5.5	11	6.34	12	12	6	10	25	2.5	1.5/2.5

10	7.5	14	8.1	16	16	6	12	25	4	1.5/2.5
12.5	9.3	18	10.02	16	16	8	12	35	4	2.5
15	11	21	12.1	16	16	11	16	50	6	2.5
20	15	28	16	30	30	14	20	63	10	4
25	18.5	35	20.2	30	30	17	25	63	16	6
30	22	40	23	30	30	17	25	100	16	6
35	26	47	27	38	30	22	32	100	25	10
40	30	55	30.3	38	30	22	32	100	25	16
45	33.5	60	34.6	70	30	25	40	125	35	16
50	37	66	35	70	70	25	40	125	35	16
60	45	80	45	70	70	38	63	125	50	25
65	28.5	87	50	70	70	38	63	160	70	35
70	52	94	54	70	70	38	63	160	70	35
75	56	100	57.5	70	70	38	63	160	70	35
90	67.5	120	69	105	70	50	90	200	95	50
100	75	135	78	105	70	50	90	200	95	50
125	90	165	95	160	70	70	110	250	120	70
150	112	200	115	170	170	90	135	250	185	70
175	132	230	133	170	170	90	135	300	225	120
200	150	275	159	300	170	140	170	350	300/400	150
240	175	320	184.5	400	170	140	170	400	300/400	185
250	187.5	323	185	400	170	140	200	400	400	185
275	204	360	206	400	170	175	250	400	500	185
300	225	385	222	400	400	210	300	500	500	225
400	300	500	390	400	400	280	400	700	625	300/400

Relay Range & Back up Fuse for DOL Starter

H.P	KW	Full Load Current (amp)	Relay Rang(Amp)	Back Up Fuse	
				Min	Max
10	7.5	13.6	13 To 20	25	50
12.5	9.3	17	13 To 20	25	50
15	11.2	20	20 To 30	35	80
20	14.9	28	20 To 30	60	80
25	18.7	35	30 To 45	60	100
30	22.4	40	30 To 45	80	100
35	26.1	47	45 To 63	80	125

Relay Range & Back up Fuse for Star / Delta Starter

H.P	KW	Full Load Current (amp)	Relay Rang(Amp)	Back Up Fuse	
				Min	Max
20	14.9	28	13 To 20	60	60
25	18.7	35	20 To 30	60	100
30	22.4	40	20 To 30	60	100
35	26.1	47	20 To 30	80	100
40	29.8	55	30 To 35	80	125
50	37.3	66	30 To 35	100	125
60	44.8	80	45 To 63	100	160
75	55.95	95	45 To 63	125	160

Circuit Breaker as per NEC 430-52		
Type of Motor	Instantaneous Trip	Inverse Time
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

Size of each part of Star-Delta starter:

(1) Size of Over Load Relay:

- For a star-delta starter there is a possibility to place the overload protection in two positions, in the line or in the windings.
- Overload Relay in Line:** In the line is the same as just putting the overload before the motor as with a DOL starter.
- The rating of Overload (In Line) = FLC of Motor.**
- Disadvantage: If the overload is set to FLC, then it is not protecting the motor while it is in delta (setting is $\times 1.732$ too high).
- Overload Relay in Winding:** In the windings means that the overload is placed after the point where the wiring to the contactors are split into main and delta. The overload then always measures the current inside the windings.
- The setting of Overload Relay (In Winding) = $0.58 \times \text{FLC}$ (line current).**
- Disadvantage: We must use separate short circuit and overload protections.

(2) Size of Main and Delta Contractor:

- There are two contactors that are close during run, often referred to as the main contractor and the delta contractor. These are AC3 rated at 58% of the current rating of the motor.

- Size of Main Contractor = $\text{IFL} \times 0.58$**

(3) Size of Star Contractor:

- The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is $1/\sqrt{3} = (58\%)$ of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.
- Size of Star Contractor = $\text{IFL} \times 0.33$**

Calculate Size of Contactor, Fuse, C.B, O/L Relay of DOL Starter:

(1) Basic Calculation of Motor Torque & Current:

- Motor Rated Torque (Full Load Torque) = $5252 \times \text{HP} \times \text{RPM}$
- Motor Rated Torque (Full Load Torque) = $9500 \times \text{KW} \times \text{RPM}$
- If Motor Capacity is less than 30 KW than Motor Starting Torque is $3 \times \text{Motor Full Load Current}$ or $2 \times \text{Motor Full Load Current}$.
- Motor Starting Torque = $3 \times \text{Motor Full Load Current}$.
- Motor Lock Rotor Current = $1000 \times \text{HP} \times \text{figure from Chart} / 1.732 \times 415$
- Motor Full Load Current (Line) = $\text{KW} \times 1000 / 1.732 \times 415$
- Motor Full Load Current (Phase) = $\text{Motor Full Load Current (Line)} / 1.732$
- Motor Starting Current = 6 to $7 \times \text{Full Load Current}$.

(2) Size of Fuse:

- Maximum Size of Time Delay Fuse = $300\% \times \text{Full Load Line Current}$.
- Maximum Size of Non Time Delay Fuse = $1.75\% \times \text{Full Load Line Current}$.

(3) Size of Circuit Breaker:

- Maximum Size of Instantaneous Trip Circuit Breaker = $800\% \times \text{Full Load Line Current}$.
- Maximum Size of Inverse Trip Circuit Breaker = $250\% \times \text{Full Load Line Current}$.

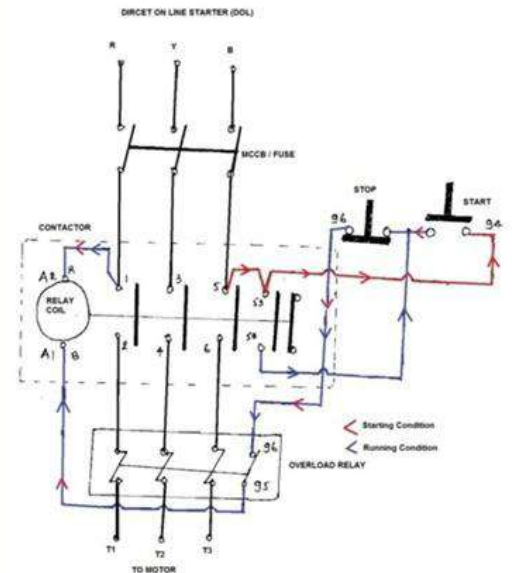
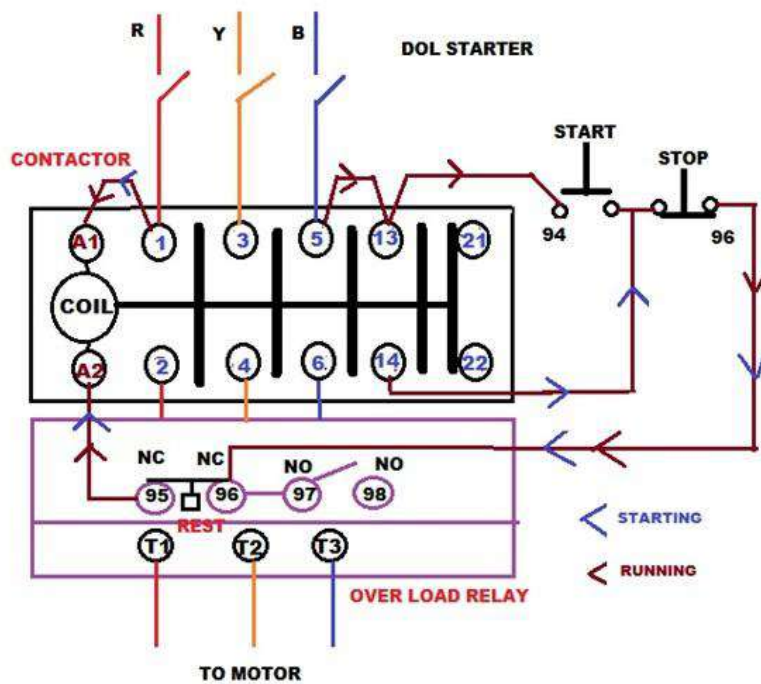
(4) Thermal over Load Relay:

- Thermal over Load Relay (Phase):
- Min Thermal Over Load Relay setting = $70\% \times \text{Full Load Current(Phase)}$
- Max Thermal Over Load Relay setting = $120\% \times \text{Full Load Current(Phase)}$
- Thermal over Load Relay (Phase):
- Thermal over Load Relay setting = $100\% \times \text{Full Load Current (Line)}$.

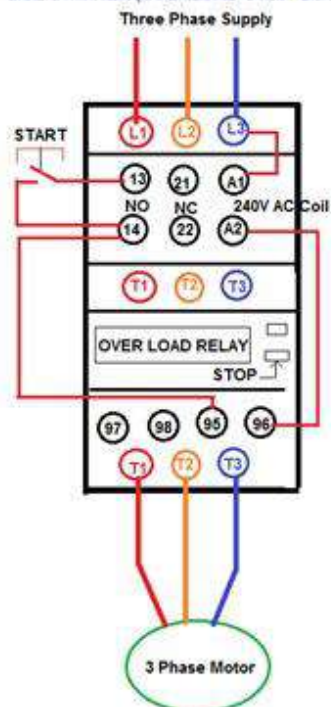
(5) Size and Type of Contactor:

- Size of Main Contactor = $100\% \times \text{Full Load Current (Line)}$.
- Making/Breaking Capacity of Contactor = Value above Chart $\times \text{Full Load Current (Line)}$.

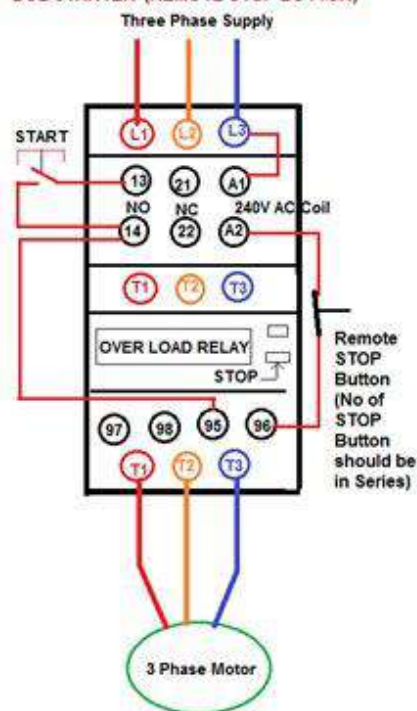
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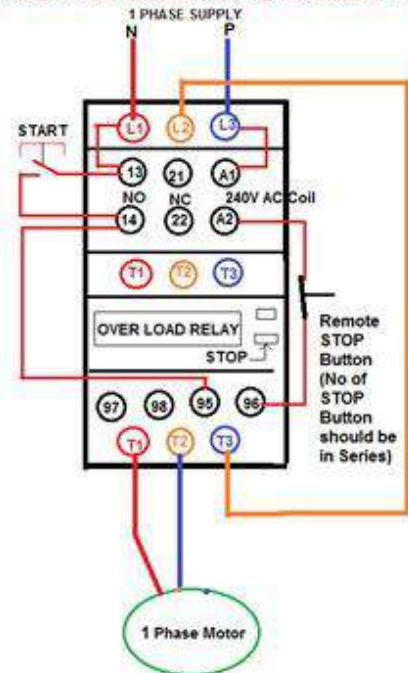
DOL STARTER (OVERLOAD STOP BUTTON)

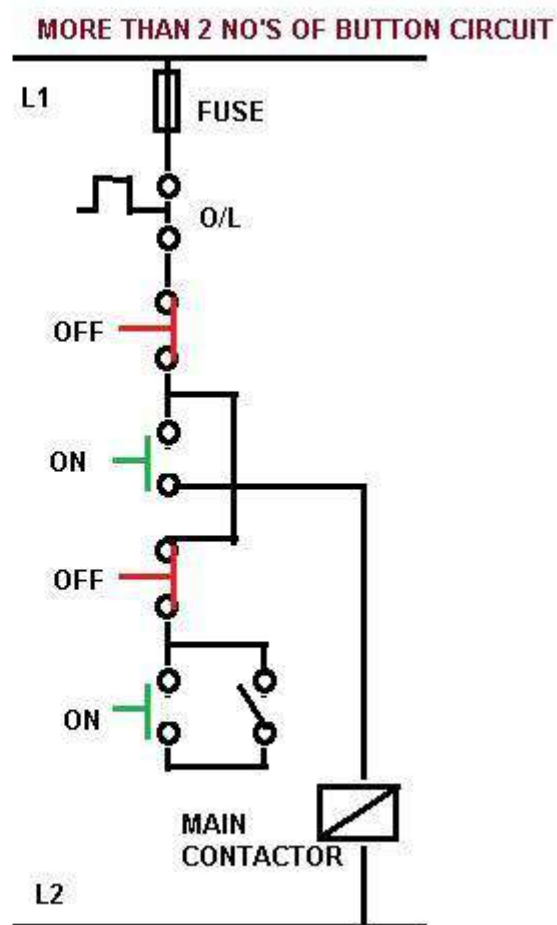
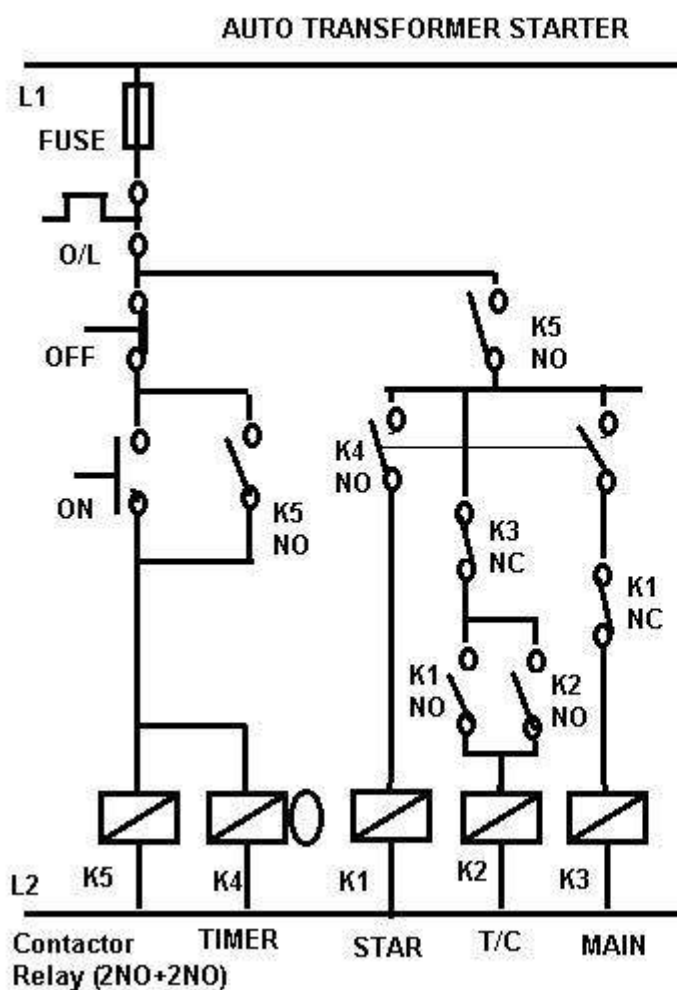
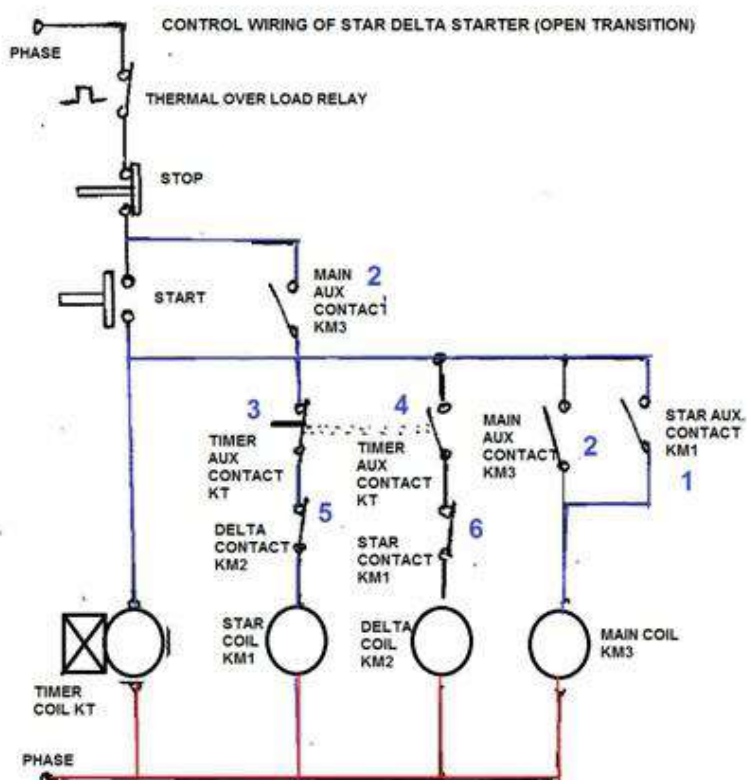
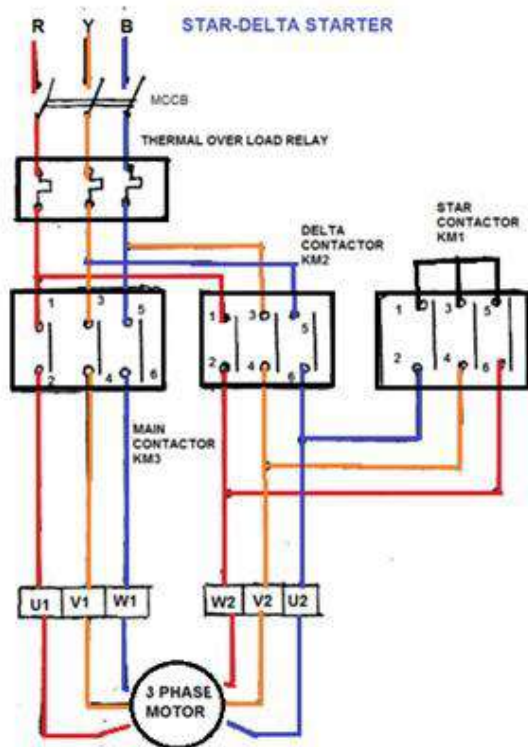


DOL STARTER (REMOTE STOP BUTTON)

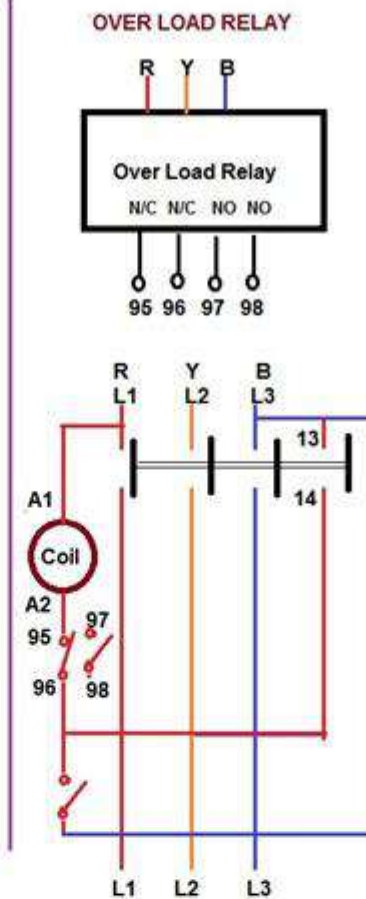
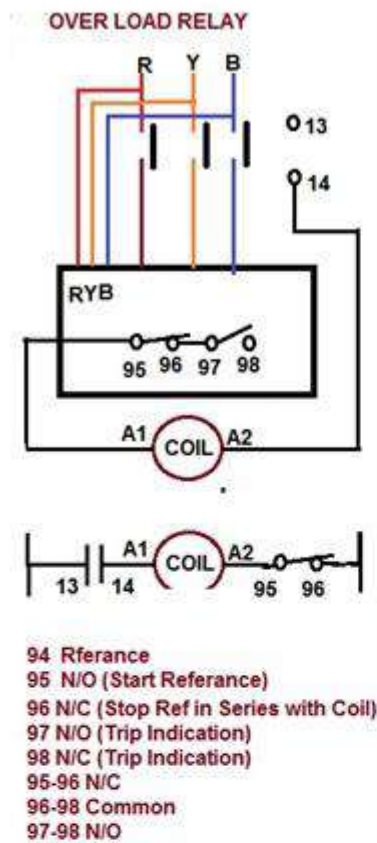


THREE PHASE DOL STARTER USE FOR SINGLE PHASE MOTOR



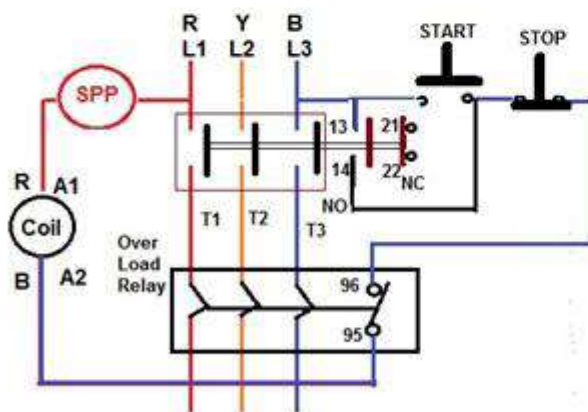


OVER LOAD RELAY

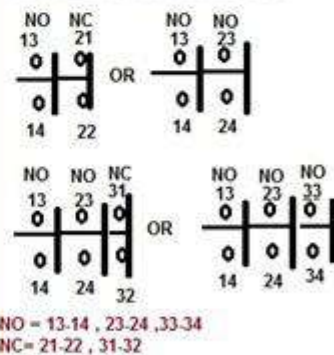


OVERLOAD RELAY CIRCUIT DIAGRAM

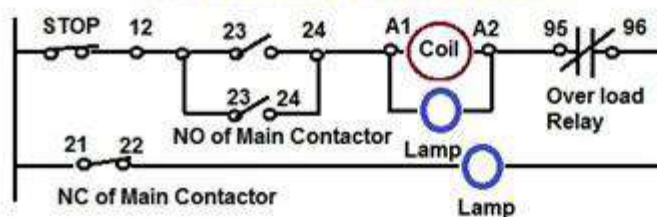
OVER LOAD RELAY CIRCUIT DIAGRAM



AUXILIARY CONTACTOR



OVER LOAD RELAY CIRCUIT DIAGRAM



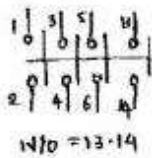
TYPE OF MAIN & AUXILIARY CONTACTOR

CONTACTOR

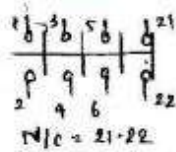
MAIN CONTACTOR: 1-2,3-4,5-6.

AUXILIARY CONTACTOR

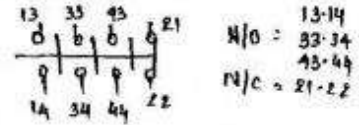
1 NO



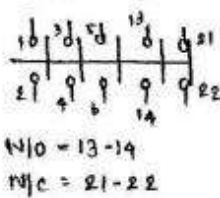
1 NC



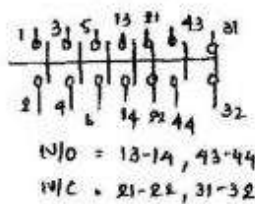
3 NO + 1 NC



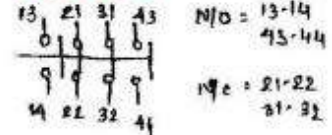
1 NO + 1 NC



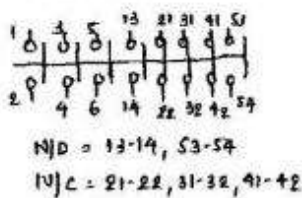
2 NO + 1 NC



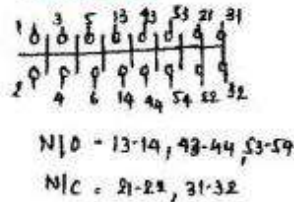
2 NO + 2 NC



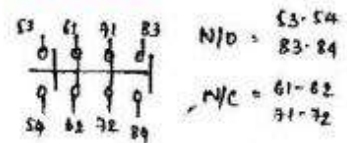
2 NO + 3 NC



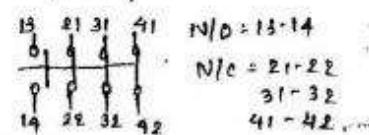
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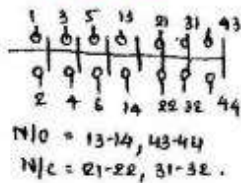
2 NO + 2 NC



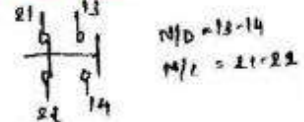
1 NO + 3 NC



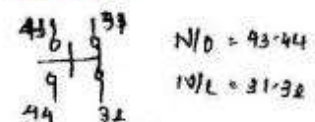
2 NO + 2 NC



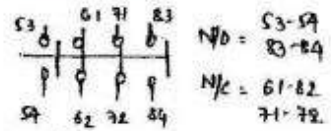
1 NO + 1 NC



1 NO + 1 NC



2 NO + 2 NC



SUMMARY OF MAIN / NO / NC CONTACTOR

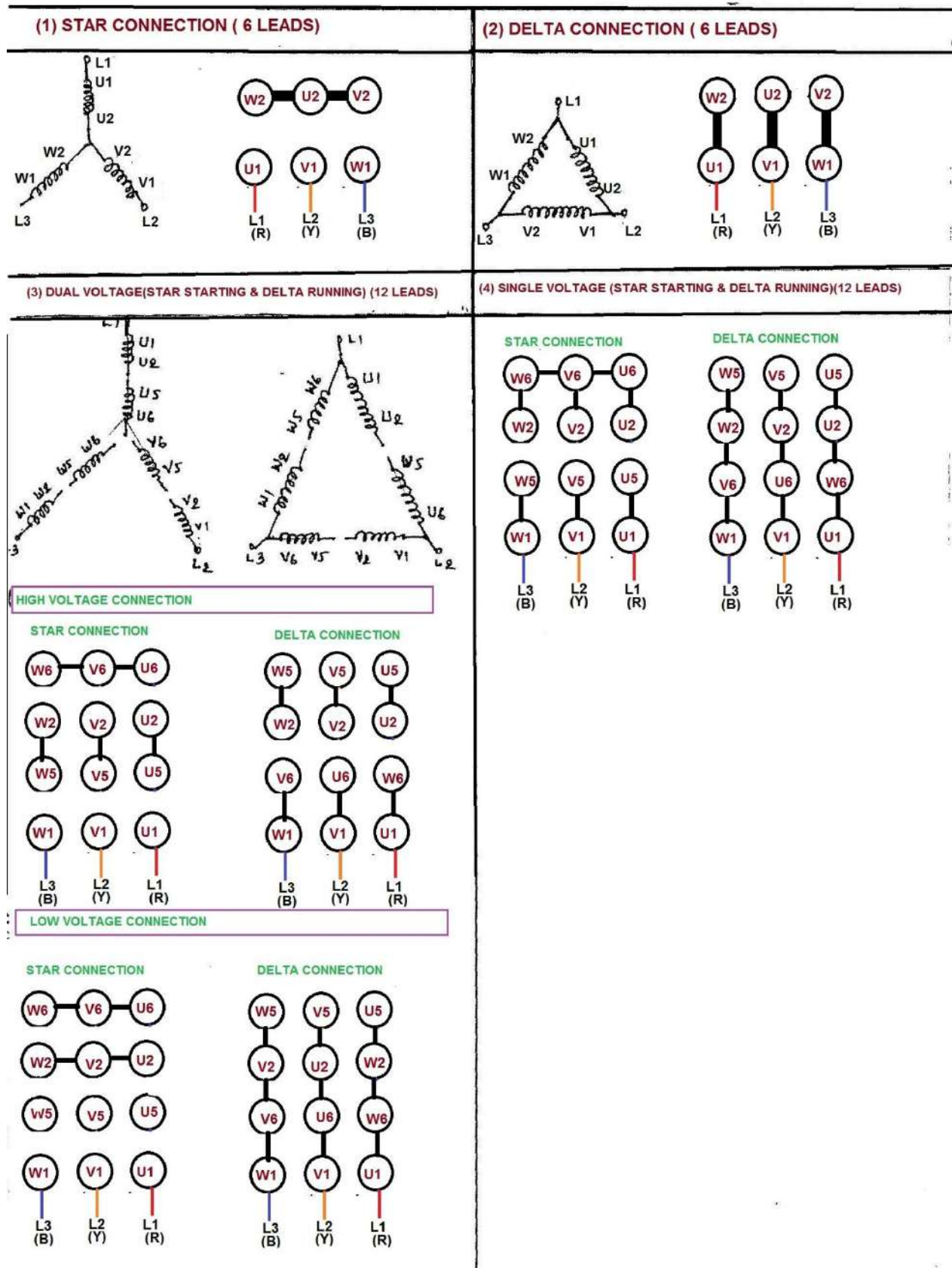
MAIN CONTACTOR:= 1-2, 3-4, 5-6.

NO CONTACTOR:= 13-14, 33-34, 43-44, 53-54, 83-84

NC CONTACTOR:= 21-22, 31-32, 41-42, 61-62, 71-72

N.B: You can easily identify whether The Contactor is NO or NC from above Summary.

ELECTRICAL MOTOR CONNECTION(6/9/12 Leads)



Change Rotation in Clockwise Direction:						
No	Present Motor Connection:			Change Direction in Clockwise		
1	R Phase Connected to	U1	W2	R Phase Connected to	U1	V2
	Y Phase Connected to	V1	U2	Y Phase Connected to	V1	W2
	B Phase Connected to	W1	V2	B Phase Connected to	W1	U2
2	R Phase Connected to	W1	V2	R Phase Connected to	W1	U2
	Y Phase Connected to	U1	W2	Y Phase Connected to	U1	V2
	B Phase Connected to	V1	U2	B Phase Connected to	V1	W2
3	R Phase Connected to	V1	U2	R Phase Connected to	V1	W2
	Y Phase Connected to	W1	V2	Y Phase Connected to	W1	U2
	B Phase Connected to	U1	W2	B Phase Connected to	U1	V2

Change Rotation in Anticlockwise Direction:						
No	Present Motor Connection:			Change Direction in Clockwise		
1	R Phase Connected to	U1	V2	R Phase Connected to	U1	W2
	Y Phase Connected to	W1	U2	Y Phase Connected to	W1	V2
	B Phase Connected to	V1	W2	B Phase Connected to	V1	U2
2	R Phase Connected to	W1	U2	R Phase Connected to	W1	V2
	Y Phase Connected to	V1	W2	Y Phase Connected to	V1	U2
	B Phase Connected to	U1	V2	B Phase Connected to	U1	W2
3	R Phase Connected to	V1	W2	R Phase Connected to	V1	U2
	Y Phase Connected to	U1	V2	Y Phase Connected to	U1	W2
	B Phase Connected to	W1	U2	B Phase Connected to	W1	V2

Thumb Rule (If Phase sequence is R-Y-B):

- Check Phase Winding Starting Phase and Connected ending Connection of That Phase winding to the one Phase after the Phase where Phase winding Starting lead is connected.
- (Example If U1 is connected to R Phase than Connect U2 to B Phase, If V1 is connected to Y Phase than V2 should be connected to R Phase)

Standard: Qatar General Electricity and Water Corporation:

Minimum Safety Clearance of Pipeline from Electrical Tower:		
Description	Voltage	
	33KV/66KV/132KV	220KV/400KV
The right of way (ROW) (widths on either side of the centre line of overhead transmission lines)	25 Meter	50 Meter
Other than the roadways and boundary fences of security establishments any temporary or permanent structures / buildings, parapet walls,	Not within 25 Meter	Not within 50 Meter
With All Underground services crossing the way leave (from the nearest tower foundation)	35 Meter (Min)	50 Meter (Min)
The nearest side of the road reservation to the nearest tower foundation	25 Meter	35 Meter, 50 Meter
The pipelines (water, oil/gas etc.) crossing (respectively away from the nearest base of tower leg). Pipe-lines shall not be laid parallel to the overhead line within the limits of a way leave (ROW).	25 Meter (Min)	35 Meter (Min) , 50 Meter (Min)
Cables crossing the transmission lines way leave (ROW) respectively away from the nearest base of tower leg.	25 Meter	35 Meter, 50 Meter
Foundations and civil structures (Temporary or permanent) will not be permitted in the close proximity to the cable circuit. A minimum horizontal distance from such structures to the nearest edge of the cable trench shall be observed	Min 1.5 Meter	Min 1.5 Meter

Clearance among Electrical Line, Telephone, Water, Sewerage & Gas Services	
Service	Vertical Clearance (Min)
Water Line (to cross below EHV cable level)	0.5 Meter
Sewerage Mains (to cross below EHV cable level)	1.0 Meter
Drainage Mains (to cross below EHV cable level)	0.5 Meter
Gas pipes	0.6 Meter
Telephone lines	0.5 Meter
LV / 11kV cables	0.5 Meter

Excavation:	
Type of Excavation	Distance
Use of heavy mechanical excavators (other than hand operated pneumatic jack hammers) or driving sheet piles	Not less than 3 Meter from the edge of cable, cover, cable joint
Heavy machinery engaged in the civil construction or road works	operating load/thrust/ weight will not be applied directly on the cable installation
Trench excavations parallel to the cable installations	Minimum separation of 1 Meter to the nearest edge of cable tile
Laying of metal pipes over a long distance parallel to cable	Not permitted unless the Step and Touch Potentials at any point of the pipe line do not exceed 65 Volts.

(A) Inside Towns

Distance between Tower's foundation to Pipeline in parallel and intersections	
Voltage	Min Distance
380/220V	0.5 Meter
20KV	2 Meter
63KV	7 Meter
132KV	10 Meter
230KV and Above	20 Meter

Distance between underground power cables to wall of gas pipelines in parallel		
Voltage	Min Horizontal Distance	Min Vertical Distance
380/220V	1 Meter	0.5 Meter
20KV	2 Meter	1 Meter
63KV	3 Meter	1.5 Meter

(B) Outside of Towns:

Distance between Tower's foundation to Pipeline in parallel and intersections		
KV	Min Distance in Parallel Route (Up to 5 Km)	Min Distance in Parallel Route (Above 5 Km)
20KV	20 Meter	30 Meter
63KV	30 Meter	40 Meter
132KV	40 Meter	50 Meter
230KV	50 Meter	60 Meter
400KV	60 Meter	60 Meter

Distance between overhead lines to gas pipelines at intersections	
KV	Min Distance
20KV	8 Meter
63KV	9 Meter
132KV	10 Meter
230KV	11 Meter
400KV	12 Meter

Distance between Tower's foundations to gas pipelines at intersections	
KV	Min Distance
20KV	20 Meter
63KV and Higher	30 Meter

Right Of Way (R.O.W) From Roads:	
Highway	Distance
High Way : (38 meter from one side of Central Line of Highway)	76 Meter
First Class State Road :(22.5 meter from one side of Central Line of Highway)	45 Meter
Second Class State Road:(17.5 meter from one side of Central Line of Highway)	35 Meter
Third Class State Road :(12.5 meter from one side of Central Line of Highway)	25 Meter
Forth Class State Road:(7.5 meter from one side of Central Line of Highway)	15 Meter

General Clearance		
KV	Description	Distance
Up to 11 KV	At points where the lines cross roads or railways	Min 6 Meter Height
Up to 11 KV	parallel to roads the	Min 5.5 Meter Height
Up to 11 KV	lines cross totally desert regions where no traffic is possible	Min 5.5 Meter Height
20 KV to 66 KV	All Location	Min 6 Meter Height
Up to 11 KV	Conductor Joint	No joint shall be closer than 3 meters to a point of support
33 KV & 66 KV	Conductor Joint	No tension joints shall be used unless specially approved.

Standard: Indian Electricity Rules/ Central Electricity Authority:

Right of Way Clearance (As per GETCO Standard):	
KV	Minimum Right of Way ROW
66 KV	18 Meter
132 KV	27 Meter
220 KV	35 Meter
400KV	52 Meter (Single Circuit)
400 KV	48 Meter (Double Circuit)

Minimum clearances between Electrical Lines crossing each other:				
Voltage	66 KV	132 KV	220 KV	400 KV
66 KV	2.4 Meter	3 Meter	4.5 Meter	5.4 Meter
132 KV	3 Meter	3 Meter	4.5 Meter	5.4 Meter
220 KV	4.5 Meter	4.5 Meter	4.5 Meter	5.4 Meter
400 KV	4.5 Meter	5.4 Meter	5.4 Meter	5.4 Meter

Permissible Min ground Clearance of Electrical Line:		
KV	Ground Clearance	Over National Highway
66 KV	6.1 Meter	8.0 Meter
132 KV	6.1 Meter	8.6 Meter
220 KV	7.0 Meter	9.8 Meter
400KV	8.8 Meter	10.8 Meter

Clearance for Telephone line Crossings Power Line:	
KV	Clearance (Min)
66 KV	2.4 Meter
132 KV	2.7 Meter
220 KV	3.0 Meter

Vertical Clearance between Electrical Line and railway tracks	
KV	Clearance (Min)
66 KV	14 Meter
132 KV	14.6 Meter
220 KV	15.4 Meter
400 KV	17.9 Meter

Clearance from Buildings to low, medium & high voltage lines:		
Voltage	Description	Distance
Low & Medium Voltage	Flat roof, open balcony, verandah roof ,When the line passes above the building a vertical clearance from the highest point	2.5 Meter
Low & Medium Voltage	Line passes adjacent to the building a horizontal clearance from the nearest point	1.2 Meter
Low & Medium Voltage	Line passes above the building a vertical clearance	2.5 Meter
Low & Medium Voltage	Line passes adjacent the building a Horizontal clearance	1.2 Meter
11 KV to 33 KV	Line passes above or adjacent to any building or part of a building	3.7 Meter
Above 33 KV	Line passes above or adjacent to any building or part of a building	3.7+(0.3 for every additional 33 KV)
Up to 11 KV	The horizontal clearance between the nearer conductor and any part of such building	1.2 Meter
11 KV to 33 KV	The horizontal clearance between the nearer conductor and any part of such building	2.0 Meter
Above 33 KV	The horizontal clearance between the nearer conductor	2.0 + (0.3 for every

	and any part of such building	additional 33 KV)
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Clearance above ground at the lowest conductor		
Voltage	Description	Distance
Low & Medium Voltage	Across a street	5.8 Meter
High Voltage	Across a street	6.1 Meter
Low & Medium Voltage	Along a street	5.5 Meter
High Voltage	Along a street	5.8 Meter
Low & Medium Voltage	Elsewhere than along or across any street	4.0 Meter
High Voltage	Elsewhere than along or across any street	5.2 Meter
33 KV & EHV	Clearance above ground (Add 0.3 Meter for every 33 KV Volts in 5.2 Meter)	Min 6.1 Meter

Vertical Clearance at Middle of Span:	
Span	Vertical Clearance (At Middle of Span)
200 Meter	4.0 Meter
300 Meter	5.5 Meter
400 Meter	7.0 Meter
500 Meter	8.5 Meter

Safety Clearance from Live Part in Outdoor Substation:	
KV	Safety Working Clearance
12 KV	2.6 Meter
36 KV	2.8 Meter
72.5 KV	3.1 Meter
145 KV	3.7 Meter
220 KV	4.3 Meter
400KV	6.4 Meter
800 KV	10.3 Meter

Lying of Telecommunication Cables with Power Cables (>33 kV)	
Cable	Min. Distance
Power cable of voltage exceeding 33 kV shall be laid	Min 1.2 Meter depth
Underground telecommunication cable shall be with underground power cable of voltage exceeding 33 kV.	Min 0.6 Meter Separate from Power Cable

Safe approach limits for people:						
Voltage	214V to 415 KV	11KV	33KV	66KV	132KV	275KV
Person using manually operated tool	1.3 Meter	2.0 Meter	3.0 Meter	4.0 Meter	5.0 Meter	6.0 Meter
Person using power operated tool	3.0 Meter	3.0 Meter	3.0 Meter	4.0 Meter	5.0 Meter	6.0 Meter

Minimum Ground Clearance As Per IE-1956(Rule 77)	
Voltage in KV	To ground in mm
132	6.10
220	7.00
400	8.84
800	12.40

Minimum Height above Railway As Per IE-1957	
Voltage	Broad Meter & Narrow Gauges
Above 66KV up to 132KV	14.60 Meter
Above 132KV up to 220KV	15.40 Meter
Above 220KV up to 400KV	17.90 Meter

Above 400KV up to 500KV	19.30 Meter
Above 500KV up to 800KV	23.40 Meter

Clearances from Buildings of HT and EHT voltage lines IE Rule 80	
Vertical Distance	
High voltage lines up to 33KV	3.7 Meter
Extra High Voltage	3.7 Meter + Add 0.3 meter for every additional 33KV
Horizontal clearance between the conductor and Building	
High Voltage Up to 11 KV	1.2 Meter
11KV To 33KV	2.0 Meter
Extra High Voltage	2.0 Meter + Add 0.3 meter for every additional 33KV

Minimum Clearance between Lines Crossing Each Other (IE-1957)				
System Voltage	132KV	220KV	400KV	800KV
Low & Medium	3.05	4.58	5.49	7.94
11-66KV	3.05	4.58	5.49	7.94
132KV	3.05	4.58	5.49	7.94
220KV	4.58	4.58	5.49	7.94
400KV	5.49	5.49	5.49	7.94
800KV	7.94	7.94	7.94	7.94

Various Air clearances to be provided as per IE rule 64					
Voltage KV	33KV	66KV	110KV	220KV	400KV
BIL (Kvp)	170	325	550	1050	1425
P-E (cm)	30	63	115	240	350
P-P(cm)	40	75	135	210	410
P-G (Meter)	3.7	4.0	4.6	5.5	8.0
Section Clearance(Mt)	2.8	3.0	3.5	4.3	6.5

Clearance above ground of the lowest conductor As per IE Rule 77	
Over head Line Across Street	
Low and Medium Voltage	5.8 Meter
High Voltage	6.1 Meter
Over head Line Along Street (Parallel To Street)	
Low and Medium Voltage	5.5 Meter
High Voltage	5.8 Meter
Over head Line Without Across or Along Street	
Low/Medium /HT line up to 11KV If Bare Conductor	4.6 Meter
Low/Medium /HT line up to 11KV If Insulated Conductor	4.0 Meter
Above 11 KV Line	5.2 Meter
Above 33KV Line	5.8 Meter + Add 0.3 meter for every additional 33KV
Clearance between conductors and Trolley / Tram wires (IE Rule 78)	
Low and Medium Voltage	1.2 Meter
High Voltage Line Up to 11KV	1.8 Meter
High Voltage Line Above to 11KV	2.5 Meter
Extra High Voltage Line	3.0 Meter

Clearances from Buildings of low & medium voltage lines(IE Rule 79)	
For Flat roof, Open Balcony, Verandah Roof and lean to Roof	
Line Passes Over Building Vertical Clearance	2.5 Meter
Line Passes Adjustment of Building Horizontal Clearance	1.2 Meter
For pitched Roof	
Line Passes Over Building Vertical Clearance	2.5 Meter
Line Passes Adjustment of Building Horizontal Clearance	1.2 Meter

Standard: Northern Ireland Electricity (NIE), 6/025 ENA

Clearances to Ground and Roads						
Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Line conductor to any point not over road	5.2 Mt	6.1 Mt	6.4 Mt	6.4 Mt	7.0 Mt	7.0 Mt
Line conductor to road surface	5.8 Mt	6.1 Mt	6.4 Mt	6.4 Mt	7.4 Mt	8.1 Mt
Line conductor to road surface of high load routes	6.9 Mt	6.9 Mt	6.9 Mt	7.2 Mt	8.5 Mt	9.2 Mt
Bare live metalwork (transformer terminals, jumper connections, etc)	4.6 Mt	4.6 Mt	4.6 Mt	-	-	-

Electrical Clearances to Objects:					
Description of Clearance	<11 KV	33 KV	110KV	220KV	400 KV
Line conductor or bare live metalwork to any object that is normally accessible (including permanently mounted ladders and access platforms) or to any surface of a building	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
Line conductor or bare live metalwork to any object to which access is not required AND on which a person cannot stand or lean a ladder	0.8 Meter	0.8 Meter	1.2 Meter	2.4 Meter	3.1 Meter
Line conductors to irrigators, slurry guns and high-pressure hoses	30 Meter	30 Meter	30 Meter	30 Meter	30 Meter
Line conductors to playing fields	8.5 Meter	8.5 Meter	8.5 Meter	8.5 Meter	8.5 Meter
Line conductors to Caravan Sites	9.0 Meter	9.0 Meter	9.0 Meter	9.0 Meter	9.0 Meter
Horizontal clearances to wells	15.0 Meter	15Meter	15Meter	15Meter	15 Meter

Clearances to Trees and Hedges:					
Description of Clearance	<11 KV	33 KV	110KV	220KV	400 KV
Line conductor or bare live metalwork to trees or hedges unable to support a ladder or being climbed.	0.8 Meter	0.8 Meter	1.2 Meter	2.4 Meter	3.1 Meter
Line conductor or bare live metalwork to trees or hedges capable of supporting a ladder or being climbed.	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
Line conductor or bare live metalwork to trees falling towards the overhead line with the line conductors hanging vertically.	0.8 Meter	0.8 Meter	1.2 Meter	2.4 Meter	3.1 Meter
Line conductors to trees in Orchards	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Mt

Clearances to Street Lighting:						
Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Line conductor to Lantern on same pole	1.0 Meter	-	-	-	-	-
Bare line conductor to lantern or column below	1.5 Meter	-	-	-	-	-
Insulated line conductor to column	0.3 Meter	-	-	-	-	-
Insulated line conductor to lantern	1.0 Meter	-	-	-	-	-
Column to nearest LV pole	1.5 Meter	-	-	-	-	-
Line conductor to street lighting column with						
(i) Column in normal upright position.	-	1.7 Mt	1.7 Mt	2.3 Mt	3.3 Mt	4.0 Mt
(ii) Column falling towards line with line conductor hanging vertically only	-	1.7 Mt	1.7 Mt	2.3 Mt	3.3 Mt	4.0 Mt

(iii) Column falling towards line	-	0.4 Mt	0.4 Mt	0.8 Mt	1.4 Mt	1.9 Mt
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Clearances to Waterways:						
Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Navigable Waters: Lower bank to conductor or earth wire	10.5 Meter	10.5 Meter	10.5 Meter	10.5 Meter	10.5 Meter	10.5 Meter
Minor Watercourses : Lower bank to conductor or earth wire	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter

Clearances to Railways:						
Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Line conductor to ground level	6.1 Mt	6.1 Mt	6.1 Mt	6.7 Mt	7.0 Mt	7.6 Mt
Line conductor to ground level on or across vehicle parks	7.6 Mt	8.5 Mt	8.5 Mt	9.1 Mt	9.4 Mt	10.1 Mt
Line conductor to ground level at roads and yards, where road mobile cranes are likely to be employed	10.7 Mt	10.7 Mt	10.7 Mt	11.2 Mt	11.5 Mt	12.2 Mt
Line conductor to Rail level	7.3 Mt	7.3 Mt	7.3 Mt r	8.0 Mt	8.2 Mt	8.8 Mt
Line conductor to the level of buildings, gantries or other structures (including those carrying traction wires) on which a man may be	3.0 Mt	3.0 Mt	3.0 Mt	3.7 Mt	4.6 Mt	6.1 Mt
Line conductor to poles and other projections.	2.4 Mt	2.7 Mt	2.7 Mt	3.0 Mt	3.7 Mt	5.5 Mt
Line conductor to any other wire other than traction wires.	1.8 Mt	1.8 Mt	1.8 Mt	2.4 Meter	3.0 Mt	3.7 Mt

Clearances to Fuel Tanks:						
Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Horizontal clearance from line conductors to petrol tanks and vents	15 Meter	15 Meter	15 Meter	15 Meter	15 Meter	15 Meter
Horizontal clearance from line conductors to liquid gas tanks						
(1) 459 to 2273 litre capacity	3.0 Meter	3.0 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
(2) 2274 to 9092 litre capacity	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter	7.6 Meter
(3) More than 9093 litre.	15Meter	15Meter	15 Meter	15Meter	15Meter	15Meter
Vertical clearance from line conductors to fuel oil tanks	Please refer Clearances to Objects					

Clearances to other Power Lines:						
Description of Clearance	0.4 KV	11 KV	33KV	110KV	220 KV	400KV
Lowest line conductor or earth wire of upper line to highest line conductor of lower line.	1.0 Meter	1.8 Meter	2.0 Meter	2.5 Meter	3.7 Meter	4.4 Meter
Lowest line conductor or earth wire of upper line to earth wire of lower line where erected.	0.7 Meter	1.4 Meter	1.6 Meter	2.5 Meter	3.7 Meter	4.4 Meter
Lowest line conductor or earth wire of upper line to any point on a support of the lower line on which a person may stand.	2.7 Meter	2.8 Meter	3.0 Meter	3.4 Meter	4.6 Meter	5.3 Meter
Support of upper line and any conductor of lower line.	7.5 Meter	7.5 Meter	7.5 Meter	15 Meter	15 Meter	15 Meter

Vertical Passing Clearance (sites where vehicles will pass below the lines):				
Description of Clearance	<33 KV	110KV	220KV	400 KV
Passing clearance: fixed height loads	0.8 Meter	1.4 Meter	2.4 Meter	3.1 Meter
Passing Clearance: variable height loads.	2.3 Meter	3.2 Meter	4.1 Meter	5.0 Meter

Horizontal Clearance (where there will be no work / passage of plant under lines)				
Description of Clearance	<33 KV	110KV	220KV	400 KV
Minimum horizontal distances to safety barriers	6.0 Meter	9.0 Meter	12.0 Meter	14.0 Meter

Distance between Conductors of Same/Different Circuit (On Same Support):		
Higher Voltage of either Circuit	Lower Voltage of either Circuit	Distance between Circuits
< 33 KV	< 1 KV	1.0 Meter
< 33 KV	> 1 KV	1.2 Meter
33 KV to 110 KV	< 1 KV	1.5Meter
33 KV to 110 KV	> 1 KV	2.0 Meter
Above 110 KV	All	2.5 Meter

Vertical Distance between Conductors of different Circuit (On Different Support):	
Higher Voltage of either Circuit	Distance between Circuits
< 1 KV	0.6 Meter
1 KV to 33 KV	1.2 Meter
33 KV to 66 KV	1.8 Meter
110 KV	2.4 Meter
220 KV	2.8 Meter

Distance between Conductors (down from Pole to other Support, on Transformer)	
Voltage	Distance between Circuits
11 KV & LV Line	0.60 Meter
22 KV & LV Line	0.75 Meter
33 KV & LV Line	0.90 Meter

Horizontal Distance of Telecommunication Line & Overhead Line:	
Description of Clearance	Distance
Telecommunication Line(Not insulated) to HV Line	Min 1.6 Meter
Telecommunication Line (Bare) to LV (Bare) Line	Min 1.2 Meter
Telecommunication Line (Covered) to LV (Bare) Line	Min 0.6 Meter
Telecommunication Line (Bare) to Stay (Bare) Wire	Min 0.3 Meter

Passage Way for Metal clad Switchgear:	
Description of Clearance	Distance
Clean &unobstructed Passages at the front of any Low/High Voltage Switchgear.	1.0 Meter wide & 2.5 Meter high
Clean &unobstructed Passages at side or under any earthed enclosure containing Bare Conductor	0.8 Meter wide & 2.2 Meter high

Safe approach distance for Person from Exposed Live Parts:	
Circuit Voltage	Distance
< 1 KV	0.5 Meter
11 KV	1.5 Meter
22 KV	2.0 Meter
33 KV	2.5 Meter
66 KV	3.0 Meter
110 KV	4.0 Meter
>220 KV	6.0 Meter

Standard: ETSA Utilities

Vertical Clearances between Services:		
Service	LV Cable	HV Cable
Common Pipe	0.100 Meter	0.100 Meter
Gas Pipe	0.200 Meter	0.200 Meter
Sewer Pipe	0.300 Meter	0.300 Meter
Water Pipe	0.600 Meter	0.600 Meter

Horizontal Clearances between Services:		
Service	LV Cable	HV Cable
Common Pipe	0.100 Meter	0.100 Meter
Gas Pipe	0.200 Meter	0.200 Meter
Sewer Pipe	1.0 Meter	1.0 Meter
Water Pipe	0.600 Meter	0.600 Meter

Minimum Electrical Clearance as per BS: 162.

INDOOR		
Voltage in KV	Phase to earth in mm	Phase to phase in mm
0.415	15.8	19.05
0.600	19.05	19.05
3.3	50.8	50.8
6.6	63.5	88.9
11	76.2	127.0
15	101.6	165.1
22	139.7	241.3
33	222.25	355.6
OUTDOOR		
Voltage in KV	Phase to earth in mm	Phase to phase in mm
6.6	139.7	177.8
11	177.8	228.6
22	279.4	330.2
33	381	431.8
66	685.8	787.4
110	863.6	990.6
132	1066.8	1219.2
220	1778	2057.4

Minimum working Clearance : OUTDOOR Switchyard		
Voltage in KV	To ground in mm	Between section(mm)
11	2750	2500
33	3700	2800
66	4000	3000
132	4600	3500
220	5500	4500

Standard: UK Power Networks - EI 02-0019

Cable Installation Depths:		
Voltage	Area	Depth (min)
Low Voltage	Footways, grass verges or private property	0.450 Meter
	Carriageways (including road crossings)	0.600 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
11 KV to 20 KV	Footways, grass verges or private property	0.600 Meter
	Carriageways (including road crossings)	0.750 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
33 KV to 132 KV	Footways, grass verges or private property	0.900 Meter
	Carriageways (including road crossings)	0.900 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
Auxiliary Multi-core & Multi-pair Cables	Footways, grass verges or private property	0.450 Meter
	Carriageways (including road crossings)	0.600 Meter
	Normal agricultural land (not deep ploughing)	1.0 Meter
	Agricultural land subject to deep ploughing	1.2 Meter
On Cable Ladder for LV to HV	The Horizontal clearance between cables on cable ladders	2X Dia of Cable of Largest Cable or min 150 mm
	The clearance from a supporting wall	20 mm
	The vertical clearance between cables is greater	150 mm
	If the number of cables > 4, they are to be installed in a horizontal	

Minimum Approach Distance of Crane or Moving Part from Live Conductor:			
Voltage	Without Safety Observation		For ordinary Person
	Un insulated portions	Insulated portions	
Upto1KV	2 Meter	1.0 Meter	3.0 Meter
11 KV	2 Meter	1.4 Meter	3.0 Meter
22 KV	2.4 Meter	2 Meter	3.0 Meter
33 KV	2.4 Meter	2 Meter	3.0 Meter
66 KV	2.8 Meter	2 Meter	3.0 Meter
132 KV	3.0 Meter	3.0 Meter	3.0 Meter
220 KV	4.8 Meter	4.8 Meter	6.0 Meter
330 KV	6.0 Meter	6.0 Meter	6.0 Meter
500 KV	8.0 Meter	8.0 Meter	8.0 Meter

Minimum Fixed Clearances for Electrical Apparatus (Isolation Points):	
Voltage	Fixed Clearance
Up to 11Kv	0.320 Meter
11KV to 33KV	0.320 Meter
33KV to 66KV	0.630 Meter
66KV to 132KV	1.1 Meter

Standard: New Zealand Electrical Code:**Min Safe Distance between Buildings and Overhead Line:**

Voltage	Pole	Tower
11 kV to 33 kV	2 Meter	2 Meter
33 kV to 66 kV	6 Meter	6 Meter
66 kV and Above	8 Meter	8 Meter

Min Safe Distance for excavation near Overhead Line:

Description of Clearance	From Pole (Min)	From Tower (min)
Excavation in land more than 750mm depth	8 Meter	12 Meter
Excavation in land up to 750mm depth	2.2 to 5 Meter	6 to 12 Meter
Excavation in land up to 300mm depth	2.2 Meter	6 Meter
Construction near 11KV to 33KV Line	2.2 Meter	6 Meter
Construction near 33KV to 66KV Line	6 Meter	9 Meter
Construction near 66KV and more	8 Meter	12 Meter
Wire Fence near 1KV to 66KV Line	2.2 Meter	2.2 Meter
Wire Fence near 66KV and more	5 Meter	5 Meter

Min Safe Distance for Tower Crain near Electrical Tower:

Description of Clearance	Distance (Min)
Mobile Crain movement	4.0 Meter
Tower Crain movement	4.0 Meter
Crain movement	4.0 Meter
Moving Activity above height of Tower	4.0 Meter
Hedge Cutter movement	4.0 Meter

Min Safe Vertical Distance above Railway Track:

Description of Clearance	Distance (Min)
Earthed conductors	5.5 Meter
Stay wires	5.5 Meter
Conductors up to 33 kV	6.5 Meter
Conductors above 33 kV to 220 kV	7.5 Meter
Conductors above 220 kV.	8 Meter

Min Distance between two Conductors on Same Supports:

High Voltage Circuit	High Voltage Circuit	Distance between circuits(min)
Up to 33 KV	Up to 1KV	1.0 Meter
Up to 33 KV	More than 1KV	1.2 Meter
33 KV to 110 KV	Up to 1KV	1.5 Meter
33 KV to 110 KV	More than 1KV	2.0 Meter
More than 110 KV	All	2.5 Meter

Min Distance between two Conductors on Different Supports:

High Voltage Circuit	Distance (min)
Up to 1 KV	0.6 Meter
1 KV to 33 KV	1.2 Meter
33 KV to 66 KV	1.8 Meter
110 KV	2.4 Meter
More than 220 KV	2.8 Meter

Min Safety Distance from Electrical Apparatuses:	
Description of Clearance	Distance (min)
Passage In front of Metal Clad Switchgear (UP to HV)	1.0 Meter wide 2.5 Height
Passage In rear or side of Metal Clad Switchgear (UP to HV)	1.0 Meter wide 2.2 Height
Passage at any side of Metal Clad Switch gear containing Bare conductor (UP to HV)	0.8 Meter wide 2.2 Height

Min Approach Distance for Non-Competent Person near exposed Live Parts:	
Voltage	Distance (min)
Below 110 kV	4.0 Meter
220 kV and above	6.0 Meter

Min Approach Distance for Competent Person near exposed Live Parts:	
Voltage	Distance (min)
Below 1 kV	0.5 Meter
11 kV	1.5 Meter
22 kV	2.0 Meter
33 kV	2.5 Meter
66 kV	3.0 Meter
110 kV	4.0 Meter
220 kV and above	6.0 Meter

Standard: Western Power Company.

Water Safety Clearance on Electrical Fires:	
Voltage	Minimum distances between a nozzle producing a fog stream of fresh water and a live conductor
Up to 750 V	1.5 Meter
750 V to 15 KV	4.0 Meter
15 KV to 230 KV	5.0 Meter

Minimum Approach Distance for Authorized Person:	
Voltage	Distance (min)
Up to 1 KV	0.7 Meter
1 V to 6.6 KV	0.7 Meter
6.6 KV to 11 KV	0.7 Meter
11 KV to 22 KV	0.7 Meter
22 KV to 33 KV	1.0 Meter
33 KV to 66 KV	1.0 Meter
66 KV to 132 KV	1.2 Meter
132 KV to 220 KV	1.8 Meter
220 KV to 330 KV	3.0 Meter

Minimum Approach Distance for Ordinary Person:	
Voltage	Distance (min)
Up to 1 KV	3.0 Meter
1 V to 6.6 KV	3.0 Meter
6.6 KV to 11 KV	3.0 Meter
11 KV to 22 KV	3.0 Meter
22 KV to 33 KV	3.0 Meter
33 KV to 66 KV	3.0 Meter
66 KV to 132 KV	3.0 Meter
132 KV to 220 KV	4.5 Meter
220 KV to 330 KV	6.0 Meter

Minimum Approach Distance for Vehicle & Plant for Ordinary Person:		
Voltage	Distance (min)	
	Mobile Plant	Vehicle
Up to 1 KV	3.0 Meter	0.6 Meter
1 V to 6.6 KV	3.0 Meter	0.9Meter
6.6 KV to 11 KV	3.0 Meter	0.9Meter
11 KV to 22 KV	3.0 Meter	0.9Meter
22 KV to 33 KV	3.0 Meter	0.9Meter
33 KV to 66 KV	3.0 Meter	2.1 Meter
66 KV to 132 KV	3.0 Meter	2.1 Meter
132 KV to 220 KV	3.0 Meter	2.9 Meter
220 KV to 330 KV	6.0 Meter	3.4 Meter

Working Space around Indoor Panel/Circuit Board (NES 312.2):			
Voltage	Exposed live parts to Not live parts(or grounded parts)	Exposed live parts to Grounded parts (concrete, brick, and walls).	Exposed live parts on both sides
Up to 150 V	0.914 Meter (3 Ft)	0.914 Meter (3 Ft)	0.914 Meter (3 Ft)
150 V to 600 V	0.914 Meter (3 Ft)	1.07 Meter (3'6")	1.22 Meter (4 Ft)

Clearance around an Indoor electrical panel (NES 110.26)	
Description of Clearance	Distance (min)
Left to Right the minimum clearance	0.9 Meter (3 Ft)
Distance between Panel and wall	1.0 Meter
Distance between Panel and Ceiling	0.9 Meter
Clear Height in front of Panel > 480V	2.0 Meter
Clear Height in front of Panel < 480V	0.9 Meter (3 Ft)
Clearance When Facing Other Panels < 480V	0.9 Meter (3 Ft)
The width of the working space in front of the Panel	The width of Panel or 0.762 Meter which is Greater.
Headroom of working spaces for panel boards (Up to 200Amp)	Up to 2 Meter
Headroom of working spaces for panel boards (More than 200Amp & Panel height is max 2 Meter)	Up to 2 Meter (If Panel height is max 2 Meter)
Headroom of working spaces for panel boards (More than 200Amp & Panel height is more than 2 Meter)	If Panel height is more than 2 Meter than clearance should not less than panel Height
Entrance For Panel (More than 1200 Amp and over 1.8 m Wide)	One entrance required for working space (Not less than 610 mm wide and 2.0 m high)
Personal Door For Panel (More than 1200 Amp)	Personnel door(s) intended for entrance to and egress from the working space less than 7.6 m from the nearest edge of the working space
Dedicated Electrical Space	Required Space is width and depth of the Panel and extending from the floor to a height of 1.8 m (6 ft) above the equipment or to the structural ceiling, whichever is lower
The door(s) shall open in the direction of egress and be equipped with panic bars, pressure plates, or other devices that are normally latched but open under simple pressure	
the work space shall permit at least a 90 degree opening of equipment doors or hinged panels	

Clearance for Conductor Entering in Panel (NES 408.5):	
Description of Clearance	Distance (min)
Spacing between The conductor raceways(including their end fittings) and Bottom of Enclosure	> than 75 mm (3 in) above the bottom of the enclosure
Spacing Between Bottom of Enclosure and Insulated bus bars, their supports,	200 mm
Spacing Between Bottom of Enclosure and Non insulated bus bars	200 mm

Clearance between Bare Metal Bus bar in Panel (NES 408.5):			
Voltage	Opposite Polarity Mounted on Same Surface	Opposite Polarity Where Held Free in Air	Live Parts to Ground
Up to 125 V	19.1 mm	12.7 mm	12.7 mm
125 V to 250 V	31.8 mm	19.1 mm	12.7 mm
250 V to 600 V	50.8 mm	25.4 mm	25.4 mm

Clearance of Outdoor electrical panel to Fence/Wall (NES 110.31):	
Voltage	Distance (min)
600 V to 13.8 KV	3.05 Meter
13.8 K V to 230 KV	4.57 Meter
Above 230 KV	5.49 Meter

Working Space around Indoor Panel/Circuit Board (NES 110.34):			
Voltage	Exposed live parts to Not live parts(or grounded parts)	Exposed live parts to Grounded parts (concrete, brick, and walls).	Exposed live parts on both sides
601 V to 2.5 K V	0.914 Meter (3 Ft)	1.2 Meter (4 Ft)	1.5 Meter (5 Ft)
2.5 K V to 9.0 K V	1.2 Meter (4 Ft)	1.5 Meter (5 Ft)	1.8 Meter (6 Ft)
9.0 K V to 25 K V	1.5 Meter (5 Ft)	1.8 Meter (6 Ft)	2.5 Meter (8 Ft)
25 K V to 75 K V	1.8 Meter (6 Ft)	2.5 Meter (8 Ft)	3.0 Meter (10 Ft)
Above 75 KV	2.5 Meter (8 Ft)	3.0 Meter (10 Ft)	3.7 Meter (12 Ft)

Clearance around an Outdoor electrical panel (NES 110.31):	
Description of Clearance	Distance (min)
Clear work space:	Not less than 2.0 Meter high(Measured vertically from the floor or platform) or not less than 914 mm (3 ft) wide (Measured parallel to the equipment).
Entrance For Panel: (More than 1200 Amp and over 1.8 m Wide)	One entrance required for working space (Not less than 610 mm wide and 2.0 m high)
Entrance For Panel: On Large panels exceeding 1.8 Meter in width	One Entrance at each end of the equipment.
Nonmetallic or Metal-enclosed Panel in general public and the bottom of the enclosure is less than 2.5 m (8 ft) above the floor or grade level	Enclosure door or hinged cover shall be kept locked.

Elevation of Unguarded Live Parts above Working Space (NES 110.34E)	
Voltage	Elevation (min)
600 V to 7.5 KV	2.8 Meter
7.5 K V to 35 KV	2.9 Meter
Above 35 KV	2.9 Meter + 9.5 mm/KV

Working Space for Panel (Code Georgia Power Company):			
Voltage	Exposed live parts to Not live parts(or grounded parts)	Exposed live parts to Grounded parts (concrete, brick, and walls).	Exposed live parts on both sides
Up to 150 V	3.0 Meter	3.0 Meter	3.0 Meter
150 V to 600 V	3.0 Meter	3.5 Meter	4.0 Meter
600 V to 2.5 KV	3.0 Meter	4.0 Meter	5.0 Meter
2.5 KV to 9 KV	3.0 Meter	5.0 Meter	6.0 Meter
9 KV to 25 KV	5.0 Meter	6.0 Meter	6.0 Meter

Clearance of Outdoor Liquid Insulated Transformers and Buildings (NEC):

Liquid	Liquid Volume (m3)	Fire Resistant Wall	Non-Combustible Wall	Combustible Wall	Vertical Distance
Less Flammable	NA	0.9 Meter	0.9 Meter	0.9 Meter	0.9 Meter
	<38 m3	1.5 Meter	1.5 Meter	7.6 Meter	7.6 Meter
	>38 m3	4.6 Meter	4.6 Meter	15.2 Meter	15.2 Meter
Mineral Oil	<1.9 m3	1.5 Meter	4.6 Meter	7.6 Meter	7.6 Meter
	1.9 m3 to 19 m3	4.6 Meter	7.6 Meter	15.2 Meter	15.2 Meter
	> 19 m3	7.6 Meter	15.2 Meter	30.5 Meter	30.5 Meter

Clearance between Two Outdoor Liquid Insulated Transformers (NEC)

Liquid	Liquid Volume (m3)	Distance
Less Flammable	NA	0.9 Meter
	<38 m3	1.5 Meter
	>38 m3	7.6 Meter
Mineral Oil	<1.9 m3	1.5 Meter
	1.9 m3 to 19 m3	7.6 Meter
	> 19 m3	15.2 Meter

Dry Type Transformer Indoor Installation (NES 420.21)

Voltage	Distance (min)
Up to 112.5 KVA	300 mm (12 in.) from combustible material unless separated from the combustible material by a heat-insulated barrier.
Above 112.5 KVA	Installed in a transformer room of fire-resistant construction.
Above 112.5 KVA with Class 155 Insulation	separated from a fire-resistant barrier not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically

Dry Type Transformer Outdoor Installation (NES 420.22):

Voltage	Distance (min)
Above 112.5 KVA with Class 155 Insulation	separated from a fire-resistant barrier not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically

Non Flammable Liquid-Insulated Transformer Indoor Installation (NES 420.21):

Voltage	Distance (min)
Over 35KV	Installed indoors Vault (Having liquid confinement area and a pressure-relief vent for absorbing any gases generated by arcing inside the tank, the pressure-relief vent shall be connected to a chimney or flue that will carry such gases to an environmentally safe area)
Above 112.5 KVA	Installed in a transformer room of fire-resistant construction.
Above 112.5 KVA (Class 155 Insulation)	separated from a fire-resistant barrier not less than 1.83 m (6 ft) horizontally and 3.7 m (12 ft) vertically

Oil Insulated Transformer Indoor Installation (NES 420.25)

Voltage	Distance (min)
Up to 112.5 KVA	Installed indoors Vault (With construction of reinforced concrete that is not less than 100 mm (4 in.) thick.
Up to 10 KVA & Up to 600V	Vault shall not be required if suitable arrangements are made to prevent a transformer oil fire from igniting
Up to 75 KVA & Up to 600V	Vault shall not be required if where the surrounding Structure is classified as fire-resistant construction.
Furnace transformers (Up to 75 kVA)	Installed without a vault in a building or room of fire resistant construction

Transformer Clearance from Building (IEEE Stand):	
Transformer	Distance from Building (min)
Up to 75 KVA	3.0 Meter
75 KVA to 333 KVA	6.0 Meter
More than 333 KVA	9.0 Meter

Transformer Clearance Specifications (Stand: Georgia Power Company):	
Description of Clearance	Distance (min)
Clearance in front of the transformer	3.0 Meter
Between Two pad mounted transformers (including Cooling fin)	2.1 Meter
Between Transformer and Trees, shrubs, vegetation(for unrestricted natural cooling	3.0 Meter
The edge of the concrete transformer pad to nearest the building	4.2 Meter
The edge of the concrete transformer pad to nearest building wall, windows, or other openings	3.0 Meter
Clearance from the transformer to edge of (or Canopy) building (3 or less stories)	3.0 Meter
Clearance in front of the transformer doors and on the left side of the transformer, looking at it from the front. (For operation of protective and switching devices on the unit.)	3.0 Meter
Gas service meter relief vents.	0.9 Meter
Fire sprinkler valves, standpipes and fire hydrants	1.8 Meter
The water's edge of a swimming pool or any body of water.	4.5 Meter
Facilities used to dispense hazardous liquids or gases	6.0 Meter
Facilities used to store hazardous liquids or gases	3.0 Meter
Clear vehicle passageway at all times, immediately adjacent of Transformer	3.6 Meter
Fire safety clearances can be reduced by building a suitable masonry fire barrier wall (2.7 Meter wide and 4.5 Meter Tall) 0.9 Meter from the back or side of the Pad Mounted Transformer to the side of the combustible wall	
Front of the transformer must face away from the building.	

Clearance of Transformer-Cable-Overhead Line (Stand: Georgia Power Company)			
Description of Clearance	Horizontal Distance (mm)		
	to pad-mounted transformers	to buried HV cable	to overhead HV Line
Fuel tanks	7.5 Meter	1.5 Meter	7.5 Meter
Granaries	6.0 Meter	0.6 Meter	15 Meter
Homes	6.0 Meter	0.6 Meter	15 Meter
Barns, sheds, garages	6.0 Meter	0.6 Meter	15 Meter
Water wells	1.5 Meter	1.5 Meter	15 Meter
Antennas	3.0 Meter	0.6 Meter	Height of Antenna + 3.0 Meter

Minimum Clearance in Substation:							
Voltage	Highest Voltage	Lighting Impulse Level (Kvp)	Switching Impulse Level (Kvp)	Minimum Clearance		Safety Clearance (Mt)	Ground Clearance (Mt)
				Phase-Earth	Phase-Phase (Mt)		
11KV	12KV	70		0.178	0.229	2.600	3.700
33KV	36KV	170		0.320	0.320	2.800	3.700
132KV	145KV	550		1.100	1.100	3.700	4.600
		650		1.100	1.100	2.700	4.600
220KV	245KV	950		1.900	1.900	4.300	5.500
		1050		1.900	1.900	4.300	5.500
400KV	420KV	1425	1050(P-E)	3.400	4.200	6.400	8.000

Electrical Clearance in Substation:						
Voltage	Height of I Bay From Ground	Height of II Bay From Ground	Bay Width	Phase-Phase	Between Equipment	Earth Wire From Ground
132KV (Single)	8 Mt	-	11.0 Mt	3 Mt	3 Mt	10.5 Mt
220KV (Single)	12.5 Mt	-	18 Mt	4.5 Mt	4.5 Mt	15.5 Mt
220KV (Double)	18.5 Mt	25 Mt	25 Mt	4.5 Mt	4.5 Mt	28.5 Mt
400KV	15.6 Mt	22 Mt	22 Mt	7 Mt	>6 Mt	30 Mt

Standard Bay Widths in Meters:	
Voltage	Bay Width (Meter)
11KV	4.7 Meter
33KV	4.7 Meter
66KV	7.6 Meter
132KV	12.2 Meter
220KV	17 Meter
400KV	27 Meter

Standard Bus and Equipment Elevation:				
Voltage	Equipment live Terminal Elevation (Meter)	Main Bus		Take of Elevation (Meter)
		Low	High	
11 KV/33KV	2.8To 4	5.5 To6.5	9	6.5To8.5
66KV	2.8To 4	6To8	9To 10.5	9.5
132KV	3.7To5	8To9.5	13.5To14.5	12To12.5
220KV	4.9To5.5	9To13	18.5	15To18.5
400KV	8.0	15.5	-	23

Phase spacing for strung Bus:	
Voltage	Clearance
11KV	1300 mm
33KV	1300 mm
66KV	2200 mm
132KV	3000 mm
220KV	4500 mm
400KV	7000 mm

Minimum Clearance of Live Parts from Ground:		
Voltage	Minimum Clearance to Ground (Mt)	Section Clearance (Mt)
11KV	3.700	2.600
33KV	3.700	2.800
66KV	4.600	3.000

132KV	4.600	3.500
220KV	5.500	4.300
400KV	8.000	7.000

Insulator String:				
Voltage	No of Suspension String	Length (mm)	No of Disc for Tension String	Length in (mm)
66KV	5	965	6	1070
132KV	9	1255	10	1820
220KV	14	1915	15	2915
400KV	23	3850	2 X 23	5450

Nominal Span:	
Voltage	Normal Span (Meter)
66KV	240-250-275
132KV	315-325-335
220KV	315-325-335
400KV	315-325-335

Minimum Ground Clearance:	
Voltage	Ground (Meter)
66KV	5.5
132KV	6.1
220KV	7.0
400KV	8.0
800KV	12.4

Indoor Substation Minimum Clearances:	
Distance	Descriptions
0.9 Meter	Horizontally between any item of equipment and the substation wall
0.6 Meter	Horizontally between any Two items of equipment
1.2 Meter	Horizontally in front of any HV switchgear

Clearance of Conductor on Tower:				
Voltage	Tower Type	Vertical Space (Mt)	Horizontal Space(Mt)	Total Height From Ground(Mt)
66KV	A	1.03	4.0	15.91
	B	1.03	4.27	15.42
	C	1.22	4.88	16.24
132KV	A	7.140	2.17	23.14
	B	4.2	6.29	22.06
	C	4.2	7.15	22.68
	D	4.2	8.8	24.06
220KV	A	5.2	8.5	28.55
	B	5.25	10.5	29.08
	C	6.7	12.6	31.68

Norms of Protection for EHV Class Power Transformers:			
Voltage ratio & capacity	HV Side	LV Side	Common relays
132/33/11KV up to 8 MVA	3 O/L relays + 1 E/L relay	2 O/L relays + 1 E/L relay	Buchholz, OLTC Buchholz, OT, WT
132/33/11KV above 8 MVA and below 31.5 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Buchholz, OLTC Buchholz, OT, WT
132/33KV, 31.5 MVA & above	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Over flux, Buchholz, OLTC PRV, OT,

220/33 KV, 31.5MVA & 50MVA 220/132KV, 100 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 dir. relay	WT Differential, Over flux, Buchholz, OLTC PRV, OT, WT
400/220KV 315MVA	3 directional O/L relays (with dir. High set) +1 directional E/L relays. Restricted E/F relay + 3 Directional O/L relays for action	3 directional O/L relays (with dir. High set)+1 directional E/L relays. Restricted E/F relay	Differential, Over flux, Buchholz, OLTC PRV, OT, WT and overload (alarm) relay

The bottom most portion of any insulator or bushing in service should be at a minimum height of 2500 mm above ground level.

Location of L.A (From T.C Bushing):		
Voltage	BIL KV Peak	Distance (Mt)
11KV	75	12
33KV	200	15
66KV	325	24
132KV	550	35
220KV	900 To 1050	Close To T.C
400KV	1425 To 1550	

Lighting Arrestor Rating:		
Rated Voltage	Highest Voltage	L.A Rating
132kv	145kv	120kv To 132kv
220kv	245kv	198kv To 216kv
400kv	420kv	336kv

Location of Lighting Arrestor:	
Rated Voltage	Max Distance from Equipment
132kv	35 meter To 45 meter
220kv	Closed To Transformer
400kv	Closed To Transformer

Size of Corona Ring:	
Rated Voltage	Size of Corona Ring
Less than 170 KV	160mm Ring Put on HV end
170KV To 275KV	350mm Ring Put on HV end
More than 275KV	450mm Ring Put on HV end
More than 275KV	350mm Ring Put on HV end

Capacity of Sub Station as per GERC:	
Size of S/S	Electrical Load
66 KV	80 MVA
132 KV	150 MVA
220 KV	320 MVA
400 KV	1000 MVA

Breaking / Short Circuit Capacity of Sub Station:	
Size of S/S	Short Circuit Current
66 KV	25 KAmper for 1 or 3 sec
132 KV	31.5 KAmper for 1 or 3 sec
220 KV	40 KAmper for 1 or 3 sec
400 KV	40 KAmper for 1 or 3 sec

Fault Clear Time:	
Size of S/S	Fault Clear Time
66 KV	300 mili Sec
132 KV	160 mili Sec
220 KV	120 mili Sec
400 KV	100 mili Sec

Normal Type of Conductors:		
Voltage	Main Bus	Auxiliary Bus
11KV	Twin ACSR Zebra	ACSR Zebra
33KV	ACSR Zebra	ACSR Zebra
132KV	ACSR Zebra	ACSR Panthers
220KV	Twin ACSR Zebra	ACSR Zebra
400KV	1/14.2 mm Dia Alu Pipe	Twin ACSR Moose

Number of Disc Insulator:		
System	Number	Strength (KN)
11KV	4	120KN
33KV	4	120KN
132KV	10	120KN
220KV	14	70KN
220KV (Anti Fog)	2 X 15	120KN
400KV (Anti Fog)	2 X 25	120KN

Minimum Clearance:			
Voltage	Phase to Earth Wire	Phase to Phase	Section Clearance
2.2KV	28cm	33cm	27.45cm
33KV	380cm	43cm	27.7cm
132KV	107cm	12cm	25cm
220KV	178cm	20.6cm	42.8cm
400KV	350cm	40cm	65cm

Ground Clearance:	
Voltage	Meter
33KV	3.7meter
66 KV	6.1meter
132 KV	6.1meter
220 KV	7.0meter
400 KV	8.8meter

Conductor Spacing:						
Voltage	Highest Voltage	Lighting Impulse Level (Kvp)	Min Clearance		Ground Clearance	Safety working Clearance
			Phase to Earth	Phase to Phase		
11KV	12kv	70	178mm	229mm	3700mm	2600mm
33KV	36kv	170	320mm	320mm	3700mm	2800mm
132 KV	145kv	550	1300mm	1300mm	4600mm	3700mm
220 KV	245kv	950	2100mm	2100mm	5500mm	4300mm
400 KV	420kv	1425	3400mm	4200mm	8000mm	6400mm

Earthing Resistance Value (As per USAID):	
Particular	Max Earthing Resistance
Power Station	0.5Ω
EHT Sub Station	1Ω
33KV Sub Station	2Ω
Double Pole Structure	5Ω
Tower foot Resistance	10Ω
Distribution Transformer	5Ω
220KV Sub Station	1Ω To 2Ω
400KV Sub Station	0.5Ω

Bus bar Materials:	
Description	Bus Bar and Jumper Material
400 kV Main Bus	114.2 mm dia. Aluminum pipe
400 kV equipment interconnection	114.2 mm dia. Aluminum pipe
400 kV overhead bus & droppers in all bays.	Twin ACSR Moose
220 kV Main Bus	Quadruple / Twin ACSR Zebra / Twin AAC
220 kV Auxiliary Bus	ACSR Zebra
220 kV equipment interconnection	Twin ACSR Zebra / Single ACSR Zebra
220 kV overhead bus & droppers in all bays.	Twin ACSR Zebra / Single ACSR Zebra
132 kV Main Bus	ACSR Zebra
132 kV Auxiliary Bus	ACSR Panther
132 kV equipment interconnection	ACSR Zebra / ACSR Panther
132 kV overhead bus & droppers in all bays.	ACSR Panther
33 kV Main Bus	ACSR Zebra
33 kV Auxiliary Bus	ACSR Zebra
33 kV equipment interconnection, overhead bus and droppers:	
(i) Bus coupler & transformer bay	ACSR Zebra
(ii) Feeder bay.	ACSR Panther
11 kV Main Bus	Twin ACSR Zebra
11 kV Auxiliary Bus	ACSR Zebra
11 kV equipment interconnection, overhead bus and droppers:	
(i) Transformer bay	Twin ACSR Zebra / Single ACSR Zebra
(ii) Bus coupler	ACSR Zebra

Transformer / Reactor:			
No	Equipment / test data	Permissible limits	Reference
A)	Transformer oil		
	a) BDV		
	-At the time of first charging	600 kV (Gap – 2.5 mm) – Minimum	IS – 1866
	-During O&M	50 kV (Gap – 2.5 mm) – Minimum	IS – 1867
	b) Moisture content		IS – 1868
	-At the time of first charging	15 PPM (Max.)	IS – 1869
	-During O&M	25 PPM (Max.)	IS – 1870
	c) Resistivity at 90 degree C	0.1-1012 Ohm-CM (Min.)	IS – 1871
	d) Acidity	0.2 mg KOH/gm (Max.)	IS – 1872
	e) IFT at 27 degree C	0.018 N/M (Min.)	IS – 1873
B)	f) Tan delta at 90 degree C	0.20 (Max.)	IS – 1874
	g) Flash point	126 Deg. C (Min.)	IS – 1875
	Vibration level for reactors	200 Microns (Peak to Peak)	IS – 1876
C)		60 Microns (Average)	IS – 1877
C)	Tan delta for bushing at 20 Deg. C	0.007*	IEC – 137
D)	Capacitance for bushing	+ 5% variation	IEC – 138
E)	IR value for winding	1000 M-Ohm By 5.0/10.0 kV Megger	IEC – 139
F)	Tan delta for windings at 20 Deg. C	0.007*	IEEE/C57.12.90.1980
G)	Contact resistance of bushing terminal connectors	10 M. Ohm / Connector	NGC.UK Recommendations
H)	Turret Neutral CT ratio errors	39	IS – 2705

Circuit Breakers			
No	Equipment / test data	Permissible limits	Reference
A)	Dew point of SF6 gas	Dew point values as per Annexure – II	
B)	Dew point of operating air	-45 Deg. C at ATM. Pressure	
C)	CB Operating timings	400 kV 220KV	
	a) Closing time (Max.)	150 MS 200MS	
	b) Trip time (Max.)	25 MS 35MS	
	c) Close/trip time, Pole discrepancy		
	– Phase to Phase (Max.)	3.33 MS 3.33MS	
D)	-Break to break (Max.) of same phase	2.5 MS 2.5MS	
	PIR time		
	BHEL make	12-16 MS	Mfgs. Recomm
	ABB make	8-12 MS	Mfgs. Recomm
	NGEF make	8-12 MS	Mfgs. Recomm
	M&G make	8-12 MS	Mfgs. Recomm
	TELK make	8-12 MS	Mfgs. Recomm
E)	ABB make (HVDC)	8-12 MS	Mfgs. Recomm
	PIR opening time prior to opening of main contacts (ABB, CGL, NGEF make CBs)	5 MS (Min.) at rated pressure	Mfgs. Recomm
F)	Pir and main contacts overlap time [BHEL, M&G, ABB (imported) make CBs]	6 MS (Min.) at rated pressure	Mfgs. Recomm
G)	Tan delta of grading capacitors	0.007 at 20 Deg. C	
H)	Capacitance of grading capacitors	Within + 10% / -5% of the rated value	IEC 359
I)	Contact resistance of CB	150 M. Ohm	
J)	Contact resistance of CB terminal connector	10 M. Ohm per connector	UK Recomm
K)	IR value:		

	1. Phase – earth	1000 M Ohm (Min.) by 5.0 / 10.0 kV Megger	
	2. Across open contacts	1000 M Ohm (Min.) by 5.0/10.0 kV Megger	
	3. Control cables	50 M Ohm (Min.) by 0.5 kV Megger	
L)	Pressure switch settings		
	-SF6 gas pressure switches	Within + 0.1 Bar of set value	
	-Operating air pr. Switches	Within + 0.1 Bar of set value	
	-Operating oil pr. Switches	Within + 0.1 Bar of set value	
M)	BDV of oil used for MOCB		
	-At the time of filling	40 kV at 2.5 mm Gap (Min.)	Mfgs. Recomm
	-During O&M	20 kV at 2.5 mm Gap. (Min.)	Mfgs. Recomm

Current Transformer			
No	Equipment / test data	Permissible limits	Reference
A)	IR value		
	1. Primary – earth	1000 M – Ohm (Min.) by 5.0/10.0 kV Megger	
	2. Secondary – earth	50 M – Ohm (Min.) by 0.5 kV Megger	
	3. Control cables	50 M-Ohm (Min.) by 0.5 kV Megger	
B)	Tan delta value	0.007* at 20 Deg. C	
C)	Terminal Connector	10 M-Ohm per connector	NGC, UK Recommend
D)	CT ratio errors	+ 3% -Protection cores	IS – 2705
D)	CT ratio errors	+ 1% -Metering cores	IS – 2706

Capacitive Voltage			
No	Equipment / test data	Permissible limits	Reference
A)	Tan Delta	0.007* at 20 Deg. C	
B)	Capacitance	Within +10%/-5% of the rated value	IEC – 358
C	Contact resistance of terminal connector	10 M-Ohm per connector	NGC, UK Recommendations
D)	IR Value	IR Value	
	1. Primary – earth	1000 M – Ohm (Min.) by 5.0/10.0 kV Megger	
	2. Secondary – earth	50 M – Ohm (Min.) by 0.5 kV Megger	
	3. Control cables	50 M-Ohm (Min.) by 0.5 kV Megger	
E)	EMU tank oil parameters	EMU tank oil parameters	
	a) BDV (Min.)	30 kV (Gap. –2.5 mm)	IS – 1866
	b) Moisture content (Max.)	35 ppm	-do-
	c) Resistivity at 90 Deg. C	0.1 – 1012 Ohm. – CM	-do-
	d) Acidity	0.5 mg KOH /gm (Max.)	-do-
	e) IFT at 27 Deg. C	0.018 N/M (Min.)	-do-
	f) Tan delta at 90 Deg. C	1.0 Max.	-do-
F)	g) Flash point	125 Deg. C (Min.)	-do-
	CVT voltage ratio errors	+ 5% protection cores	IEEE/C93.1.1990
F)	CVT voltage ratio errors	+ 0.5% metering cores	IEC 186

Isolators			
No	Equipment / test data	Permissible limits	Reference
A)	Contact resistance	300 MΩ. (Max.)	
B)	Contact resistance of terminal connector	10 MΩ per connector	UK Recommendations
C)	IR value		
	1. Phase – earth	1000 MΩ (Min.) by 5.0/10.0 kV Megger	UK Recommendations
	2. Across open contacts	1000 MΩ (Min.) by 5.0/10.0 kV Megger	UK Recommendations
	3. Control cables	50 MΩ (Min.) by 0.5 kV Megger	

Surge Arrester			
No	Equipment / test data	Permissible limits	Reference
A)	Leakage current	500 M-Amp. (Resistive)	Hitachi, Japan Recom.
B)	IR value	1000 MΩ (Min.)	Hitachi, Japan Recom.

Miscellaneous			
No.	Equipment / test data	Permissible limits	Reference
A)	Station earth resistance	1.0 Ohm (Max.)	
B)	Thermo vision scanning		
	Temp. up to 15 Deg. C (above ambient)	Normal	
	Temp. above 15-50 Deg. C (above ambient)	Alert	
	Temp. above 50 Deg. C (above ambient)	To be immediately attended	
C)	Terminal connectors – Contact resistance	10 M-Ohm per connector	HGC, UK Recommendations
D)	IR values		
	1. All electrical motors	50 M-Ohm (Min.) by 0.5 kV Megger	
	2. Control cables	50 M-Ohm (Min) by 0.5 kV Megger	
	3. Lt. Transformers	100 M.-Ohm (Min.) by Megger	
	4. Lt. Switchgears	100 M – Ohm (Min.) by 0.5 kV Megger	

Batteries			
No.	Equipment / test data	Permissible limits	Reference
A)	Terminal connector resistance	10 M – Ohm + 20%	ANSI/IEEE – 450 1989
B)	Specific gravity	1200 + 5 GM/L at 27 Deg. C	

Temperature Correction Factor for Tan Delta Measurement		
Sr. No.	Oil temperature Deg. C	Correction factor(K)
1	10	0.8
2	15	0.9
3	20	1.0
4	25	1.12
5	30	1.25
6	35	1.40
7	40	1.55
8	45	1.75
9	50	1.95
10	55	2.18
11	60	2.42
12	65	2.70
13	70	3.00
If Tan Delta of bushing/winding/CVT/CT is measured at oil temperature T Deg. C. Then Tan Delta at 20 Deg. C shall be as given below		
Tan Delta at 20 Deg. C = Tan Delta at Temp T Deg. C / Factor K		

Dew Point Limits for SF6 Gas in EHV Circuit Breakers

No	Make of C.B	Dew point at rated Pr. Deg. C	Corresponding dew point at Atmospheric Press	Remarks
1	BHEL	-15	-36	At the time of commissioning
		-7	-29	During O&M
		-5	-27	Critical
2	M&G	--	-39	At the time of commissioning
			-32	During O&M
3	CGL	-15	-35	At the time of commissioning
		-10	-31	During O&M
4	ABB	-15	-35	At the time of commissioning
		-5	-26	During O&M
5	NGEF	-15	-36	At the time of commissioning
		-7	-29	During O&M

Note: Dew point of SF6 gas varies with pressure at which measurement is carried out. So it is to be ensured that if measurement is done at pressure other than atmospheric pressure, it needs to be converted to the atmospheric pressure.

Particular	11 kV	33 kV	132 kV	220 kV
Highest System Voltage (kV rms)	12	36	145	245
CT ratio.	2000-1000/1-1	800-400/1-1	400/1-1	800/1-1
	1600-800/1-1	600-300/1-1		
	1200-600/1-1	400-200/1-1		
	800-400/1-1	300-150/1-1		
	600-300/1-1	100-50/1-1		
	400-200/1-1			
	300-150/1-1			
	150-75/1-1			
Number of metering cores	Two Nos	Two Nos	Two Nos	Two Nos
Rated continuous thermal current.	120% of rated primary current	120% of rated primary current	120% of rated primary current	120% of rated primary current
Rated short time thermal current of primary for 1 sec. (kA)	25	25	31.5	40
CT characteristics : a) Rated primary current (Amps.)	2000-1000	800-400	400	800
	1600-800	600-300		
	1200-600	400-200		
	800-400	300-150		
	600-300	100-50		
	400-200			
	300-150			
	150-75			
(b) Rated Secondary current (Amps.)	1	1	1	1
(c) Class of accuracy.	0.2	0.2	0.2	0.2
(d) Max. instrument security factor	5	5	5	5
(e) Rated burden (VA).	30	30	30	40

Minimum Acceptable Specification of Voltage Transformer for Metering:

No	Particulars	245 kV CVTs	145 kV CVTs
1	Highest System Voltage (kV)	245 kV	145 kV
2	Rated Capacitance (pF)	4400 pf with tolerance + 10% and – 5%	
3	For low voltage terminal over entire carrier frequency range.		
	(a) Stray capacitance	Shall not exceed 200 pf	
	(b) Stray conductance	Shall not exceed 20 us	
4	(a) High frequency capacitance for entire carrier frequency	within 80% to 150% of rated capacitance	
	(b) Equivalent series resistance over the entire frequency	less than 40 Ohms	
5	No. of secondary windings for potential device.	Two	Two
6	Transformation ratio:		
	(i) Winding –I	20 kV- V3/110 -V3V	
	(ii) Winding –II	20 kV- V3/110 -V3V	
7	Rated secondary burden		
	(i)Winding –I (VA)	50 VA	50 VA
	(ii) Winding –II (VA)	50 VA	50 VA
8	Accuracy Class :		
	(i)Winding –I (VA)	0.2 for metering	
	(ii) Winding –II (VA)	0.2 for metering	
9	Voltage factor for winding – I Voltage factor for winding – II	1.2 Cont. & 1.5 for 30 secs. 1.2 Cont. & 1.5 for 30 secs.	
10	IS to which CVTs conform.	IS 3156 with latest amendment	
11	IS to which Insulating Oil conform.	IS 335 with latest amendment	

Minimum Acceptable Specification of Single Phase Voltage Transformer for Metering			
No	Particulars	33 kV	11 kV
1	Highest System Voltage (kV rms)	36	12
2	Transformation ratio.	33kV/ $\sqrt{3}$ / 110/ $\sqrt{3}$	11 kV/110 V
3	Number of windings.	Two	Two
4	Rated output/ burden (VA) per winding /phase.	50	50
5	Accuracy class. (At 10 to 100% of VA burden)	0.2	0.2
6	Rated voltage factor and duration.	1.2 continuous & 1.5 for 30 secs.	
7	IS to which PT conforms.	3156 with latest amendment	

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Selection of IR Testers (Megger):	
Insulation testers with test voltage of 500, 1000, 2500 and 5000 V are available	
Voltage Level	IR Tester
650V	500V DC
1.1KV	1KV DC
3.3KV	2.5KV DC
66Kv and Above	5KV DC

Test Voltage for Meggering:	
When AC Voltage is used, Rule of Thumb is Test Voltage (A.C) = (2X Name Plate Voltage) +1000	
When DC Voltage is used (Most used in All Megger), Test Voltage (D.C) = (2X Name Plate Voltage)	
Equipment / Cable Rating	DC Test Voltage
24V To 50V	50V To 100V
50V To 100V	100V To 250V
100V To 240V	250V To 500V
440V To 550V	500V To 1000V
2400V	1000V To 2500V
4100V	1000V To 5000V

Measurement Range of Megger:	
Test voltage	Measurement Range
250V DC	0MΩ to 250GΩ
500V DC	0MΩ to 500GΩ
1KV DC	0MΩ to 1TΩ
2.5KV DC	0MΩ to 2.5TΩ
5KV DC	0MΩ to 5TΩ

Precaution while Meggering:

Before Meggering:

- Make sure that all connections in the test circuit are tight.
- Test the megger before use, whether it gives **INFINITY** value when not connected, and ZERO when the two terminals are connected together and the handle is rotated.

During Meggering:

- Make sure when testing for earth, that the far end of the conductor is not touching, otherwise the test will show faulty insulation when such is not actually the case.
- Make sure that the earth used when testing for earth and open circuits is a good one otherwise the test will give wrong information
- Spare conductors should not be meggered when other working conductors of the same cable are connected to the respective circuits.

After completion of cable Meggering:

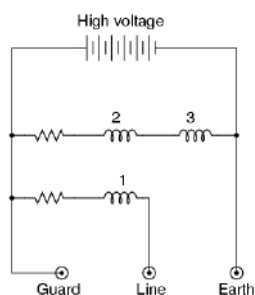
- Ensure that all conductors have been reconnected properly.
- Test the functions of Points, Tracks & Signals connected through the cable for their correct response.
- In case of signals, aspect should be verified personally.
- In case of points, verify positions at site. Check whether any polarity of any feed taken through the cable has got earthed inadvertently.

Safety Requirements for Meggering:

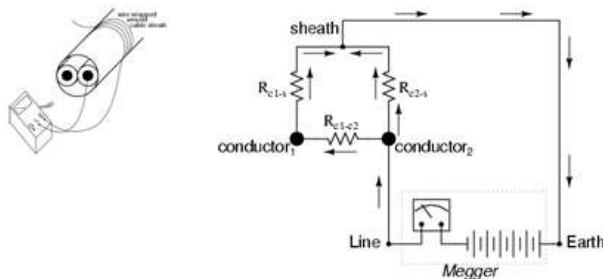
- All equipment under test **MUST** be disconnected and isolated.
- Equipment should be discharged (shunted or shorted out) for at least as long as the test voltage was applied in order to be absolutely safe for the person conducting the test.
- Never use Megger in an explosive atmosphere.
- Make sure all switches are blocked out and cable ends marked properly for safety.
- Cable ends to be isolated shall be disconnected from the supply and protected from contact to supply, or ground, or accidental contact.
- Erection of safety barriers with warning signs, and an open communication channel between testing personnel.
- Do not megger when humidity is more than 70 %.
- Good Insulation: Megger reading increases first then remain constant.
- Bad Insulation: Megger reading increases first and then decreases.
- Expected IR value gets on Temp. 20 to 30 degree centigrade.
- If above temperature reduces by 10 degree centigrade, IR values will increased by two times.
- If above temperature increased by 70 degree centigrade IR values decreases by 700 times.

How to use Megger:

- Meggers is equipped with three connection terminals, Line Terminal (L), Earth Terminal (E) and Guard Terminal (G).

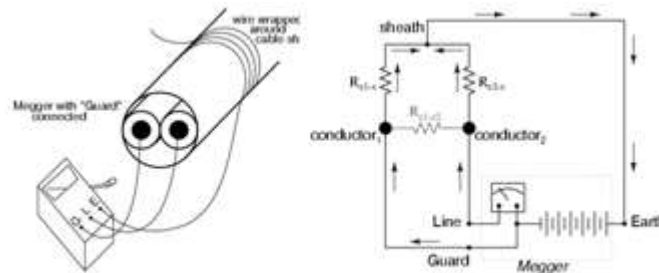


- Resistance is measured between the Line and Earth terminals, where current will travel through coil 1. **The "Guard" terminal is provided for special testing situations where one resistance must be isolated from another.** Let's us check one situation where the insulation resistance is to be tested in a two-wire cable.
- To measure insulation resistance from a conductor to the outside of the cable, we need to connect the "Line" lead of the megger to one of the conductors and connect the "Earth" lead of the megger to a wire wrapped around the sheath of the cable:

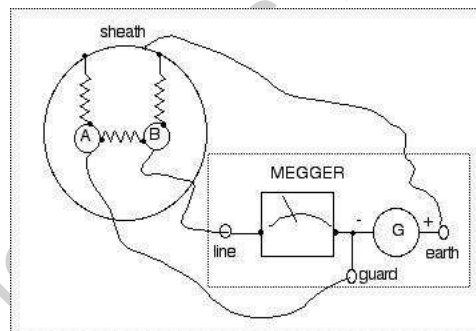


- In this configuration the Megger should read the resistance between one conductor and the outside sheath.

- We want to measure Resistance between Conductor- 2To Sheaths but Actually Megger measure resistance in parallel with the series combination of conductor-to-conductor resistance (R_{c1-c2}) and the first conductor to the sheath (R_{c1-s}).
- If we don't care about this fact, we can proceed with the test as configured. If we desire to measure *only* the resistance between the second conductor and the sheath (R_{c2-s}), then we need to use the megger's "Guard" terminal:



- **Connecting the "Guard" terminal to the first conductor places the two conductors at almost equal potential.** With little or no voltage between them, the insulation resistance is nearly infinite, and thus there will be no current *between* the two conductors. Consequently, the Megger's resistance indication will be based exclusively on the current through the second conductor's insulation, through the cable sheath, and to the wire wrapped around, not the current leaking through the first conductor's insulation.
- The guard terminal (if fitted) acts as a shunt to remove the connected element from the measurement. In other words, it allows you to be selective in evaluating certain specific components in a large piece of electrical equipment. For example consider a two core cable with a sheath. As the diagram below shows there are three resistances to be considered.



- If we measure between core B and sheath without a connection to the guard terminal some current will pass from B to A and from A to the sheath. Our measurement would be low. By connecting the guard terminal to A the two cable cores will be at very nearly the same potential and thus the shunting effect is eliminated.

(1) IR Test Values Electrical Apparatus and Systems:

IR Value (PEARL Standard / NETA MTS-1997 Table 10.1)		
Max.Voltage Rating Of Equipment	Megger Size	Min.IR Value
250 Volts	500 Volts	25 MΩ
600 Volts	1,000 Volts	100 MΩ
5 KV	2,500 Volts	1,000 MΩ
8 KV	2,500 Volts	2,000 MΩ
15 KV	2,500 Volts	5,000 MΩ
25 KV	5,000 Volts	20,000 MΩ
35 KV	15,000 Volts	100,000 MΩ
46 KV	15,000 Volts	100,000 MΩ
69 KV	15,000 Volts	100,000 MΩ

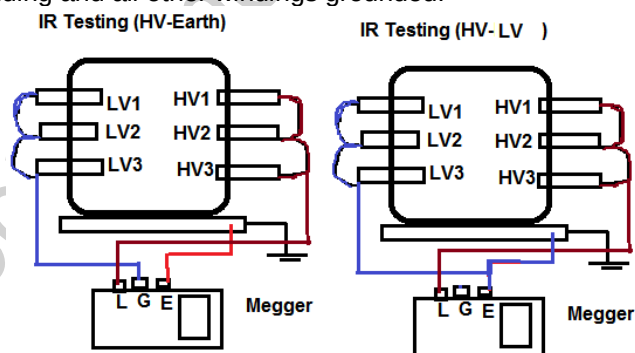
IR Value for Equipment (One Meg ohm Rule):	
Equipment Rating	IR Value
<1KV	= 1 MΩ minimum
>1KV	1 MΩ per KV

IR Value for Equipment (As per IE Rules-1956):	
Equipment Rating	IR Value
Medium and Low Voltage Installations	At a pressure of 500 V applied between each live conductor and earth for a period of one minute, the insulation resistance of medium and low voltage installations shall be at least 1 Mega ohm or as specified by the Bureau of Indian Standards] from time to time.
HV installations	At a pressure of 1000 V applied between each live conductor and earth for a period of one minute the insulation resistance of HV installations shall be at least 1 Mega ohm or as specified by the Bureau of Indian Standards

IR Value (As per CBIP):	
Acceptable IR value= 2 MΩ per KV	

(2) IR Value for Transformer:

- Insulation resistance tests are made to determine insulation resistance from individual windings to ground or between individual windings. Insulation resistance tests are commonly measured directly in megohms or may be calculated from measurements of applied voltage and leakage current.
- The recommended practice in measuring insulation resistance is to always ground the tank (and the core). Short circuit each winding of the transformer at the bushing terminals. Resistance measurements are then made between each winding and all other windings grounded.



- Windings are never left floating for insulation resistance measurements. Solidly grounded winding must have the ground removed in order to measure the insulation resistance of the winding grounded. If the ground cannot be removed, as in the case of some windings with solidly grounded neutrals, the insulation resistance of the winding cannot be measured. Treat it as part of the grounded section of the circuit.
- We need to test winding to winding and winding to ground (E). For three phase transformers, We need to test winding (L1,L2,L3) with substitute Earthing for Delta transformer or winding (L1,L2,L3) with earthing (E) and neutral (N) for wye transformers.

IR Value for Transformer (Guide to TC Maintenance by. JJ. Kelly. S.D Myer)	
Transformer	Formula
1 Phase Transformer	IR Value (MΩ) = C X E / (√KVA)
3 Phase Transformer (Star)	IR Value (MΩ) = C X E (P-n) / (√KVA)
3 Phase Transformer (Delta)	IR Value (MΩ) = C X E (P-P) / (√KVA)
Where C= 1.5 for Oil filled T/C with Oil Tank, 30 for Oil filled T/C without Oil Tank or Dry Type T/C.	

Temperature correction Factor (Base 20°C):		
°C	°F	Correction Factor
0	32	0.25
5	41	0.36
10	50	0.50
15	59	0.720
20	68	1.00
30	86	1.98
40	104	3.95
50	122	7.85
- Example: For 1600KVA, 20KV/400V, Three Phase Transformer - IR Value at HV Side= $(1.5 \times 20000) / \sqrt{1600} = 16000 / 40 = 750 \text{ M}\Omega$ at 20°C - IR Value at LV Side = $(1.5 \times 400) / \sqrt{1600} = 320 / 40 = 15 \text{ M}\Omega$ at 20°C - IR Value at 300C = $15 \times 1.98 = 29.7 \text{ M}\Omega$		

Insulation Resistance of Transformer Coil			
Transformer Coil Voltage	Megger Size	Min.IR Value Liquid Filled T/C	Min.IR Value Dry Type T/C
0 - 600 V	1KV	100 MΩ	500 MΩ
600 V To 5KV	2.5KV	1,000 MΩ	5,000 MΩ
5KV To 15KV	5KV	5,000 MΩ	25,000 MΩ
15KV To 69KV	5KV	10,000 MΩ	50,000 MΩ

IR Value of Transformers:			
Voltage	Test Voltage (DC) LV side	Test Voltage (DC) HV side	Min IR Value
415V	500V	2.5KV	100MΩ
Up to 6.6KV	500V	2.5KV	200MΩ
6.6KV to 11KV	500V	2.5KV	400MΩ
11KV to 33KV	1000V	5KV	500MΩ
33KV to 66KV	1000V	5KV	600MΩ
66KV to 132KV	1000V	5KV	600MΩ
132KV to 220KV	1000V	5KV	650MΩ

Steps for measuring the IR of Transformer:

- Shut down the transformer and disconnect the jumpers and lightning arrestors.
- Discharge the winding capacitance.
- Thoroughly clean all bushings
- Short circuit the windings.
- Guard the terminals to eliminate surface leakage over terminal bushings.
- Record the temperature.
- Connect the test leads (avoid joints).
- Apply the test voltage and note the reading. The IR. Value at 60 seconds after application of the test voltage is referred to as the Insulation Resistance of the transformer at the test temperature.
- The transformer Neutral bushing is to be disconnected from earth during the test.
- All LV surgediverter earth connections are to be disconnected during the test.
- Due to the inductive characteristics of transformers, the insulation resistancereading shall not be taken until the test current stabilizes.
- Avoid meggering when the transformer is under vacuum.

Test Connections of Transformer for IR Test (Not Less than 200 MΩ)		
Type of Transformer	Megger Connection	
	Megger (L)	Megger (E)
Two winding transformer	(HV + LV)	GND
	HV	(LV + GND)
	LV	(HV + GND)
Three winding transformer	HV	(HV + TV + GND)
	LV	(HV + LV + GND)

	(HV +LV+ TV)	GND
	TV	(HV + LV + GND)
Auto transformer (two winding)	(HV + LV) - GND	GND
	HV + LV)	(TV + GND)
Auto transformer (three winding)	(HV + LV + TV)	GND
	TV	(HV + LV + GND)
For any installation, the insulation resistance shall not be less than:		
=HV to Earth 200 M Ω		
=LV to Earth 100 M Ω		
=HV to LV 200 M Ω		

Factors affecting on IR value of Transformer

The IR value of transformers are influenced by

- surface condition of the terminal bushing
- quality of oil
- quality of winding insulation
- temperature of oil
- duration of application and value of test voltage

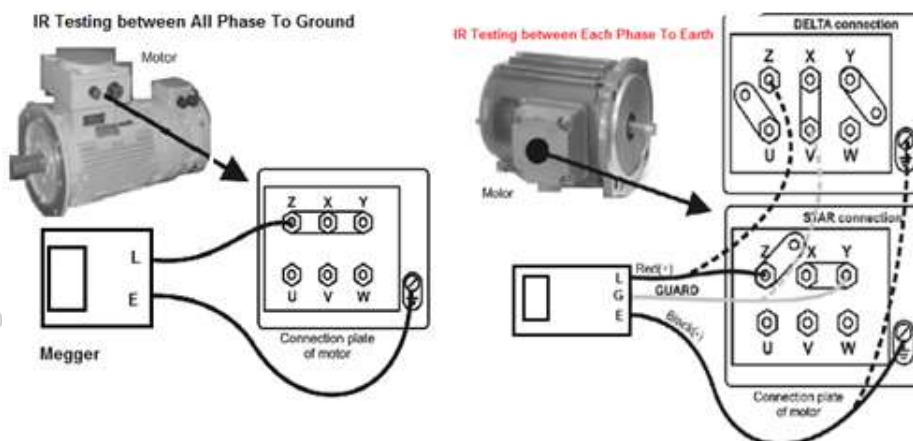
(3) IR Value for Tap Changer (Off-circuit/On-load tap changer)

- IR between HV and LV as well as windings to earth.
- Minimum IR value for Tap changer is **1000 ohm per volt service voltage**

(4) IR Value for Electric motor

For electric motor, we used a insulation tester to measure the resistance of motor winding with earthing (E).

- For rated voltage below 1KV, measured with a 500VDC Megger.
- For rated voltage above 1KV, measured with a 1000VDC Megger.
- In accordance with IEEE 43, clause 9.3, the following formula should be applied.
- **Min IR Value (For Rotating Machine) = (Rated voltage (v) /1000) + 1**



As per IEEE 43 Standard 1974,2000	
IR Value in MΩ	
IR (Min) = kV+1	For most windings made before about 1970, all field windings, and others not described below
IR (Min) = 100 M Ω	For most dc armature and ac windings built after about 1970 (form wound coils)
IR (Min) = 5 M Ω	For most machines with random -wound stator coils and form-wound coils rated below 1kV
• Example-1: For 11KV, Three Phase Motor. • IR Value =11+1=12 MΩ but as per IEEE43 It should be 100 MΩ • Example-2: For 415V, Three Phase Motor	

- IR Value = $0.415 + 1 = 1.41 \text{ M}\Omega$ but as per IEEE43 It should be $5 \text{ M}\Omega$.
- As per IS 732 Min IR Value of Motor = $(20 \times \text{Voltage (p-p)} / (1000 + 2 \times \text{KW}))$

IR Value of Motor as per NETA ATS 2007. Section 7.15.1

Motor Name Plate (V)	Test Voltage	Min IR Value
250V	500V DC	25 M Ω
600V	1000V DC	100M Ω
1000V	1000V DC	100M Ω
2500V	1000V DC	500M Ω
5000V	2500V DC	1000M Ω
8000V	2500V DC	2000M Ω
15000V	2500V DC	5000M Ω
25000V	5000V DC	20000M Ω
34500V	15000V DC	100000M Ω

IR Value of Submersible Motor

Motor Out off Well (Without Cable)	IR Value
New Motor	20 M Ω
A used motor which can be reinstalled	10 M Ω
Motor Installed in Well (With Cable)	
New Motor	2 M Ω
A used motor which can be reinstalled	0.5 M Ω

(5) IR Value for Electrical cable and wiring:

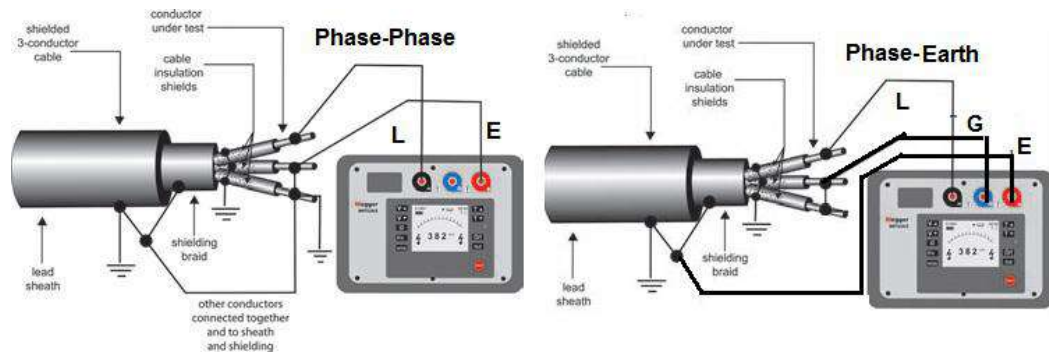
- For insulation testing, we need to disconnect from panel or equipment and keep them isolated from power supply. The wiring and cables need to test for each other (phase to phase) with a ground (E) cable. The Insulated Power Cable Engineers Association (IPCEA) provides the formula to determine minimum insulation resistance values.
- **$R = K \times \log_{10} (D/d)$**
- R = IR Value in M Ω s per 1000 feet (305 meters) of cable.
- K = Insulation material constant. (Varnished Cambric=2460, Thermoplastic Polyethylene=50000, Composite Polyethylene=30000)
- D = Outside diameter of conductor insulation for single conductor wire and cable
- ($D = d + 2c + 2b$ diameter of single conductor cable)
 - d – Diameter of conductor
 - c – Thickness of conductor insulation
 - b – Thickness of jacket insulation

HV test on new XLPE cable (As per ETSA Standard)

Application	Test Voltage	Min IR Value
New cables – Sheath	1KV DC	100 M Ω
New cables – Insulation	10KV DC	1000 M Ω
After repairs – Sheath	1KV DC	10 M Ω
After repairs - Insulation	5KV DC	1000M Ω

11kV / 33kV Cables between Cores and Earth (As per ETSA Standard)

Application	Test Voltage	Min IR Value
11KV New cables – Sheath	5KV DC	1000 M Ω
11KV After repairs – Sheath	5KV DC	100 M Ω
33KV no TF's connected	5KV DC	1000 M Ω
33KV with TF's connected.	5KV DC	15M Ω



IR Value Measurement (Conductors to conductor (Cross Insulation))

- The first conductor for which cross insulation is being measured shall be connected to Line terminal of the megger. The remaining conductors looped together (with the help of crocodile clips) i. e. Conductor 2 and onwards, are connected to Earth terminal of megger. Conductors at the other end are left free.
- Now rotate the handle of megger or press push button of megger. The reading of meter will show the cross Insulation between conductor 1 and rest of the conductors. Insulation reading shall be recorded.
- Now connect next conductor to Line terminal of the megger & connect the remaining conductors to earth terminal of the megger and take measurements.

IR Value Measurement (Conductor to Earth Insulation)

- Connect conductor under test to the Line terminal of the megger.
- Connect earth terminal of the megger to the earth.
- Rotate the handle of megger or press push button of megger. The reading of meter will show the insulation resistance of the conductors. Insulation reading shall be recorded after applying the test voltage for about a minute till a steady reading is obtained.

IR Value Measurements:

- If during periodical testing, insulation resistance of cable is found between **5 and 1 MΩ/km** at buried temperature, the subject cable should be programmed for replacement.
- If insulation resistance of the cable is found between **1000 to 100 KΩ/km**, at buried temperature, the subject cable should be replaced urgently within a year.
- If the insulation resistance of the cable is found less than **100 KΩ /km**, the subject cable must be replaced immediately on emergency basis.

(6) IR Value for Transmission / Distribution Line:

Equipment.	Megger Size	Min IR Value
S/S Equipments	5 KV	5000MΩ
EHV Lines.	5 KV	10MΩ
H.T.Lines.	1 KV	5MΩ
LT / Service Lines.	0.5 KV	5MΩ

(7) IR Value for Panel Bus:

- **IR Value for Panel = 2 x KV rating of the panel.**
- Example, for a 5 KV panel, the minimum insulation is $2 \times 5 = 10 \text{ M}\Omega$.

(8) IR Value for Substation Equipment:

Typical IR Value of S/S Equipments			
Equipment		Megger Size	IR Value(Min)
Circuit Breaker	(Phase-Earth)	5KV, 10 KV	1000 MΩ
	(Phase-Phase)	5KV, 10 KV	1000 MΩ
	Control Circuit	0.5KV	50 MΩ
CT/PT	(Pri-Earth)	5KV, 10 KV	1000 MΩ
	(Sec-Phase)	5KV, 10 KV	50 MΩ

	Control Circuit	0.5KV	50 MΩ
Isolator	(Phase-Earth)	5KV,10 KV	1000 MΩ
	(Phase-Phase)	5KV,10 KV	1000 MΩ
	Control Circuit	0.5KV	50 MΩ
L.A	(Phase-Earth)	5KV,10 KV	1000 MΩ
Electrical Motor	(Phase-Earth)	0.5KV	50 MΩ
LT Switchgear	(Phase-Earth)	0.5KV	100 MΩ
LT Transformer	(Phase-Earth)	0.5KV	100 MΩ

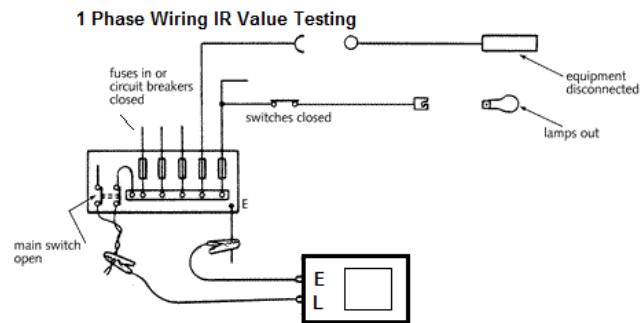
IR Value of S/S Equipments As per DEP Standard			
Equipment	Meggering	IR Value at Commissioning Time (MΩ)	IR Value at Maintenance Time(MΩ)
Switchgear	HV Bus	200 MΩ	100 MΩ
	LV Bus	20 MΩ	10 MΩ
	LV wiring	5 MΩ	0.5 MΩ
Cable(min 100 Meter)	HV & LV	(10XKV) / KM	(KV) / KM
Motor & Generator	Phase-Earth	10(KV+1)	2(KV+1)
Transformer Oil immersed	HV & LV	75 MΩ	30 MΩ
Transformer Dry Type	HV	100 MΩ	25 MΩ
	LV	10 MΩ	2 MΩ
Fixed Equipments/Tools	Phase-Earth	5KΩ / Volt	1KΩ / Volt
Movable Equipments	Phase-Earth	5 MΩ	1MΩ
Distribution Equipments	Phase-Earth	5 MΩ	1MΩ
Circuit Breaker	Main Circuit	2 MΩ / KV	
	Control Circuit	5MΩ	
Relay	D.C Circuit-Earth	40MΩ	
	LT Circuit-Earth	50MΩ	
	LT-D.C Circuit	40MΩ	
	LT-LT	70MΩ	

(9) IR Value for Domestic /Industrial Wiring:

- A low resistance between phase and neutral conductors, or from live conductors to earth, will result in a leakage current. This cause deterioration of the insulation, as well as involving a waste of energy which would increase the running costs of the installation.
- The resistance between Phase-Phase-Neutral-Earth must **never be less than 0.5 M Ohms** for the usual supply voltages.
- In addition to the leakage current due to insulation resistance, there is a further current leakage in the reactance of the insulation, because it acts as the dielectric of a capacitor. This current dissipates no energy and is not harmful, but we wish to measure the resistance of the insulation, **so DC Voltage is used to prevent reactance from being included in the measurement.**

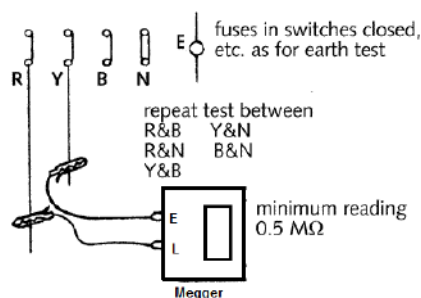
1 Phase Wiring:

- The IR test between Phase-Natural to earth must be carried out on the complete installation with the main switch off, with phase and neutral connected together, with lamps and other equipment disconnected, but with fuses in, circuit breakers closed and all circuit switches closed.
- Where two-way switching is wired, only one of the two stripper wires will be tested. To test the other, both two-way switches should be operated and the system retested. If desired, the installation can be tested as a whole, when a value of at least 0.5 M Ohms should be achieved.



3 Phase Wiring:

- In the case of a very large installation where there are many earth paths in parallel, the reading would be expected to be lower. If this happens, the installation should be subdivided and retested, when each part must meet the minimum requirement.



- The IR tests must be carried out between Phase-Phase-Neutral-Earth with a minimum acceptable value for each test of 0.5 M Ohms.

IR Testing for Low voltage		
circuit voltage	Test voltage	IR Value(Min)
Extra Low Voltage	250V DC	0.25MΩ
Up to 500 V except for above	500 V DC	0.5MΩ
500 V To 1KV	1000 V DC	1.0MΩ

- Min IR Value= 50MΩ / No of Electrical outlet. (All Elect. Points with fitting & Plugs).**
- Min IR Value = 100MΩ / No of Electrical outlet. (All Elect. Points without fitting & Plugs).**

Required Precautions:

- Electronic equipment like electronic fluorescent starter switches, touch switches, dimmer switches, power controllers, delay timers could be damaged by the application of the high test voltage should be disconnected.
- Capacitors and indicator or pilot lamps must be disconnected or an inaccurate test reading will result.
- Where any equipment is disconnected for testing purposes, it must be subjected to its own insulation test, using a voltage which is not likely to result in damage. The result must conform with that specified in the British Standard concerned, or be at least 0.5 M Ohms if there is no Standard.

IR Value on New HT Cable		
Application	Test Voltage	Criteria
New cables – Sheath	1kV Megger 1 minute	100 meg-ohms min.
New cables – Insulation	10kV DC 15 minute	1.0 μA (micro-amps) max
New cables – Insulation	10kV DC 15 minute	1000 meg-ohms min.

IR Value of Cable		
Application	Test Voltage	Criteria
11kV new cables	5kV Megger 1 minute	100 meg-ohms.
11kV after repairs	5kV Megger 1 minute	100 meg-ohms.
33kV - no TF's connected	5kV Megger 1 minute	1000 meg-ohms.
33kV - with TF's connected	5kV Megger 1 minute	15 meg-ohms.

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Item	IS No.	Makes
Transformer	IS: 2026	Crompton Greaves, NGEF, Kirloskar, BHEL, Andrewyule, Bharat Bijlee, Alsthom, ABB, Voltamp, Siemens, GEC, Voltas, TELK
11 kV/HT Vacuum Circuit Breaker, SF-6/11kV gas filled Circuit Breaker	IS: 3427 for VCB	GEC, Siemens, Andrew yule, Crompton Greave, Alsthom(Areva), Jyoti, ABB, BHEL, Alind, L&T, Schneider, Biecco Lawrie.
ACB(11kV)	IS: 13118	Siemens, L&T, Crompton Greave, Schneider, Jyoti, GEC, MEI, ABB, Merlin Gerin, Moeller, Biecco Lawrie.
MCCBs, MCBs, ELCBS, RCCBs, DB, ICTPN, TP, HRC fuse, Changing over switch, Switch Fuse Unit	IS: 8828 for MCB	L&T, Crompton Greave, Siemens, Legrand, Jyoti, GEC, Andrew yule, BCH, Schneider, ABB, Moeller, Merlin Gerin
	IS:13947 for MCCB	
	IS:12640 for RCCB	
	IS:13703 for HRC fuse	
	IS:13947 for SFU	
XLPE Cable 11/33kV grade	IS:7098(Part-2)	Asian, NICCO, Universal, CCI, Torrent, Fort Gloster, INCAB, Industrial Cable, Polycab
PVC/XLPE Power Cables up to 1.1kV grade	IS: 694 for PVC cable	CCI, Universal Cable, Polycab, NICCO, Torrent, Asian, Fort Gloster, Finolex, Incab, Industrial Cable
	IS: 1554 for heavy duty PVC cable	
	IS:7098 for XLPE cable	
Instrument Voltmeter, Ammeter, PF meter	IS:1248 for Analog	Automatic Electric, Meco, Industrial Meter, Motwani, Toshniwal, L&T, Siemens, Rishab, IMP, Shanti, Moeller(HPL).
11kV Cable End Termination & Jointing kits	IS: 13573/92	Raychem, M-Seal, Safe system, Xicon brand of CCI, Hari consolidated(Cable seal brand), Densons(Yamuna)
Relays	IS: 3231/65	Siemens, L&T, Alsthom, EA SUN REY Roll, ABB, BHEL, Jyoti, Alind, GE, BCH, Minilec, Enercon
Luminaries, MH, HPSV, T-5 fittings, CFL & related accessories	IS: 9974 for HPSV	Phillips, Crompton, Bajaj, GE, Osram, Wipro.
	IS:10322 for Luminaries	
	IS:15111 for CFL	
PVC insulated Elect. Wires Sheathed/ unsheathed, PVC flexible LT cable, multi core, single core, Flat cable for submersible pumps	IS: 694 for PVC cable	Finolex, Asian, Fort Gloster, CCI, NICCO, Universal, Incab, Torrent, Uniflex, RPG, Polycab, ICL, Unistar
Current Transformer	IS: 2705	Automatic Electric, CGL, C&S, MECO, KAPPA, Siemens, L&T, Schneider
On line UPS, Servo Stabilizer, Inverter, CVT	IS:13314 for Inverter	AEI, BHEL, Hind Rectifier, L&T, NGEF, Siemens, Hi-rel, Autometer, Enertech, Pyramid, APC, Dubas, Luminous, Microtech, TATA Libert
	IS:11260 for voltage Stabilizer	
Rotary Switches. Selector Switches	Relevant IS	Kaycee, L&T, Salzer, GE, ABB, C&S, Siemens, HPL, Moeller
Exhaust fan/Air Circulator/ Bracket & Pedestal fans/Ceiling fan	IS: 374 for ceiling fan	Crompton, Khaitan, GEC, Usha, Philips, Bajaj, Polar, Orient, Almonarda.
	IS: 2312 for Exhaust fan	
	IS: 875, BSTN-10025/1993, CPE III TRT/1996 of ILE UK.	
	Octagonal Pole S355JO.	
	Galvanization	
	IS: 2629	
	BSEN ISO-1461	
Electronic Energy Meter	IS:13779/1999	L&T, IMP,HPL, Secure, ABB, Enercon,
	IEC:62053-21	
Central Air Conditioning	IS: 8148 for package	Voltas, Blue Star, Sidwal, Fedder Lloyd, Videocon,

Plants & Package type plant	type. IS: 1391 for Room Air Conditioners.	Amtrex, Carrier, Frick, Shriram, Hitachi, O General, Mitsubhisi
Capacitors- PF correction for Electrical General Services	IS:13340 IS:13341	ABB, BHEL, Indian Capacitors, Khatau Junker, Shreem, Unistar, WS Insulators, L&T, Hind Rectifier, Voltas, Siemens, Schneider, Indian Condenser, EPCOS
DG Sets- Portable	IS: 13364 for Alternator IS:1001 for Diesel Engine	Birla Yamaha, CGL, Shriram Honda
DG Engine	IS:13364	Cummins, Kirloskar, Caterpillar, Ashok Leyland, Penta-volvo
Alternator for DG set	IS:4722 IS:4728	KEC, CGL, Stampford, Leroy-somer, Kirloskar-Green
Induction Motor	IS:235 IS:12615	Bharat Bijlee, BHEL, CGL, GE, Jyoti, Kirloskar, Siemens, ABB, NGEF, Alsthom
LT Switchgear & control gears- Contactors & motor starters, Energy Efficient Soft Starter panel/ Earthing Switch, Single phase preventer	IS:13947 IS:13947	ABB, CGL, Jyoti, L&T, MEI, NGEF, Siemens, Telemecanique & control (India) (TC), Legrand(MDS), BCH, Standard, GEC, BHEL, Minilec, Enercon, Andrewyule, C&S, N.N. Planner, Power Boss, Schneider.
Pumps- Submersible	IS: 8034 for submersible pump sets IS: 9283 for motors of submersible pump sets IS: 14220 for open well submersible pump sets	Calama, CGL, Jyoti, Kirloskar, KSB, TEXMO, SABAR
Timers- electronic solid state	Relevant IS	ABB, BHEL, GE, Jyoti, L&T, BCH, Siemens, Minilec, Legrand
Water Coolers	IS: 1475	Blue Star, Fedders, Kelvinator, Shriram, Sidwal, Voltas
Electrical accessories (Piano switch, Plugs & sockets, ceiling rose, Angle holder, holders,)	IS: 3854 for switches IS: 1293 for plugs& sockets IS: 371 for ceiling rose IS: 1258 for lamp holder Bakelite	SSK(Top line), Anchor(Penta-or-net), Precision(Prime), Vinay(Clair-30), CONA(Nice-Indian), Leader, Legrand, ABB
Bell Buzzer	IS:2268 or latest	CONA, MAX, Anchor, Leader, SSK
Electronic fan regulator	IS:11037	Anchor, Usha, ERIK, Rider
Solar cell/Module system	Relevant IS	TATA BP, BEL, BHEL, REIL, MOSER BEAR, CEL, Sharp Business Systems (India) Ltd.
Solar Lighting system	Relevant IS	DGS&D approved vendors on RC
GI/MS Pipe	IS: 1239	TATA, Jindal, TT Swastik, Prakash Surya
Geysers	IS:2082/93	Bajaj, Usha, Crompton, Spherohot, Recold, Venus.
Lifts & Escalators	IS:14665	OTIS, Thysson Krup, Shindler, KONE, Mitsubhisi.
LEDs	Relevant IS	BHEL, Indo Asian Fusegear Ltd., Switch control (India), Siemens, GE, ABB, L&T, Moeller.
Solar Water Heaters	Relevant IS	As per MNES approved sources.
Solar Distilled Water Plants	Relevant IS	Makes can be approved on the recommendation of divisions.
Air Cooling Plants	Relevant IS for its concern equipments	Voltas, Blue Star, Carrier
Battery Charger for other than battery room for Train Lighting	IS:2026 / IS:3895	Hind Rectifier, Usha Rectifier, Suresh Electrical, Pyramid, Automatic Electric, Delta Elect., Trinity Elect., Universal Ind. Products, Venus Engg., RS Power.
Battery Charger for battery room		Amar Raja, Exide, RS Power
PVC Conduit pipe & Casing capping for electrical wiring	IS:9537/93	Precision, A.K.G., Polycab, Finolex, Prestoplast

Aluminum Ladders	IS:4571/1977	Sumer, Beatfire
LT Panels	As per Relevant IEC	From CPRI tested firms.
Air Curtain	Relevant IS	Aircon, ALMONARD, Technocrate, Thermadyne, Mitzwak
Lighting Arrestor	IS:5621 with latest amendment/ revision (specification for hollow insulators for use in electrical equipment)	(a) Jayshree Make – JSI (b) WSI (c) Shesashayee (d) BHEL (e) Luster Ceramics (f) Shakti make (g) Oblum make. Any other make approved by the PGVCL/GUVNL. Creepage Distance : 11KV – 320 mm. 22KV – 600 mm.
Power transformer		BHEL, Bharat Bijlee, EMCO, Kanohar
66KV Circuit Breaker		ABB, Siemens, AREVA
66KV Isolator		ABB, AREVA.
66KV Current Transformer		ABB, CGL, BHEL, TELK
66KV CVT		ABB, TELK, CGL, BHEL
66KV LA		ABB, CGL
Control and Relay Panel		ABB, AREVA, Siemens
1.1KV Grade control and power Cable		Universal, KEI, GEMSCAB, Polycab, Paramount, CCI, Torrent, Krishna, HVPL
Batteries		Exide, Amco, Amaraja, HBL nife
Battery Charger		Chhabi, HBL, Caldyne, Masstech, DUBAS, Statcon
Station Transformer		CGL, Kotson, Voltamp, Kanohar, EMCO, AREVA
Fire Protection system		Vijay, unitech, Technofab, Mather & Platt, Steelage.
11KV switchgear		ABB, AREVA, Siemens

Circuits:	
Topic	Abstracts
Lighting Circuit	Per Circuit Not more than 10 Points of Lighting or Total 800Watt which is less
Power Circuit	For Residential Per Circuit Less than 2 No of 5A/15A Plug Socket
Power Circuit	For Non Residential Per Circuit Less than 1 No of 5A/15A Plug Socket
Plug Socket	In Residential wiring ,wiring of Socket outlet shall be done by copper Cable only
Min Size of Wire	For Lighting Circuit Smallest size of conductor shall be 1.5 Sq.mm
Min Size of Wire	For Power Circuit Smallest size of conductor shall be 4 Sq.mm
Plug Socket	
Plug Socket	5A/6A or 15A/16A Socket shall be installed at following heights: For Non Residential building 23cm above Floor, For Kitchen 23cm above Platform, For Bathroom not Socket is provided in bathroom MCB/IC will be 2.1 mt from fixed appliance and at least 1 mt away from Shower
Switch Board / D.B	
Operating Rod	Operating Rod/Handle of Distribution Board at the height of min 2mt
D.B Clearance	Clear Distance in front of Switch Board/D.B shall be min 1 mt.
D.B Clearance	If there may be bare connection at back of Switch Board than space behind S/W shall be either less than 20cm or more than 75cm
D.B Clearance	No fuse Body shall be mounted within 2.5 cm edge of D.B or Panel
D.B Clearance	Clearance between 2.5 cm is maintained between opposite polarity
Switch Box	Switch Box or Regular Box shall be mounted normally 1.25 mt from floor level.
Fan Hook	
Fan Hook	For Fan Hook in concrete roof 12mm dia MS Rod in 'U' Shape, horizontally Leg at Top at least 19 cm on either side.
Connection between adjustment Building (Out House, Garages)	
Safety Clearance	If the distance with adjustment building is less than 3 mt and there is no any Road interval than GI pipe of suitable size shall be installed. This pipe shall be exposed on wall at height of not less than 2.5 mt.
Safety Clearance	If the distance with adjustment building is more than 3 mt and there is any Road interval than GI pipe of suitable size shall be installed. This pipe shall be exposed on wall at height of not less than 4 mt.
Conduit	
Metallic Conduit	Shall be used for Industrial wiring, Heavy mechanical Stress, shall be ISI marked, The Thickness shall not be less than 1.6mm(16SWG) for conduits up to 32mm Dia and not less than 2mm (14SWG) for conduit above 32mm Dia.
Metallic Conduit	No steel conduit less than 20 mm Diameter shall be used.
Metallic Conduit	For rigid Conduit IS:2509/IS:3419 and For Flexible Conduit IS:6946.
Metallic Accessories	All Metallic conduit accessories shall be threaded type (Not pin grip, clamp grip)
Metallic Accessories	Saddle for surface conduit work on wall shall not less than 0.55mm(24 gauge) for conduit up to 25mm Dia not less than 0.9mm (20 gauge) for larger Dia
Metallic Outlets	Fore Cast Boxes: Wall thickness shall be at least 3mm. For Welded mild Steel Box: Wall thickness shall not be less than 1.2mm (18 gauge) for Boxes up to size 20cmX30cm. Above This size 1.6mm(16guage)thick MS Boxes shall be used.
Metallic Outlets	Clear depth of Out less Box shall not be less than 60mm. This will be increased as per mounting of Fan regulator
Bends in Conduits	Bending radius not less than 7.5 cm
Fixating Conduits on Surface	Conduits shall be fixed by saddles not less than 1mt interval but in case of coupler/Bends in either side of saddles, The saddle shall be fitted 30 cm from fitting.
Non Metallic Accessories	Normally grip Type.
Non Metallic Outlet(PVC Box)	PVC Box IS:5133(PartII) thickness not less than 2mm, Clear depth of PVC Boxes not less than 60mm.
Non Metallic Surface Conduit	Conduits shall be fixed by saddles not less than 60cm interval but in case of coupler/Bends in either side of saddles, The saddle shall be fitted 15 cm from

	fitting.
Junction Box	
Junction Box	Depth of Junction Box shall be min 65mm as per IS: 2667.
Fish Wire	
Fish Wire	GI fish wire of 1.6mm/1.2mm (16SWG) shall be used.
Bulbar	
Bulbar	Bulbar shall be 100A,200A,300A,400A,500A,600A,800A
Bulbar	The Cross-section area of Bus bar shall be same as Phase Bus bar (Up to 200A) for higher Capacity Neutral Bus bar must be not less than half cross section areas of Phase Bus bar.
Bulbar	Bus bar shall be suitably installed with PVC sleeve/Tap.
Bulbar	Bus bar Chamber shall be fabricated with MS angle for Frame work and sheet steel of thickness not less than 1.5mm.
Bulbar	Minimum clearance between phase to earth shall be 26mm and phase to phase shall be 32mm.
Bus bar Trucking	
Bus bar Trucking	Bus bar Trucking are generally used for interconnection between T/C over 500KVA/D.G set over 500KVA and their switch Board Panel.
Bus bar Trucking	Bus bar Trucking enclosure sheet steel of min 2mm thickness
Earthing	
Earthing	Type of earthing are Pipe earthing/Plate earthing/Strip earthing.
Earthing	Length of Buried strip shall not be less than 15mt.
Earthing	Two copper strip, each size 50mmX5mm shall be provided as each bus bar in 11KV S/S or D.G generally.
Earthing	Each strip should be connected separately to earth.
Earthing	Two no of Body earthing of T/C,Panel,D.G are connected to earth Bus.
Earthing	Neutral Leads of T/C,D.G shall not be connected to earth Bus.
Earthing	The minimum Cross-section are of protective conductor (Not contained within cable or wire) 2mm Dia(14SWG) for Copper, 2.5mm Dia(12SWG) for G.I, 2.24mm Dia(13SWG) for Aluminum.
Earthing	Earthing Pit shall not be closer than 1.5mt from Building.
Earthing	Top of Pipe earthing electrode shall not be less than 20cm below the ground
Earthing	Plate electrode shall be buried in ground with face vertical and it's Top not less than 3mt below ground level.
Earthing	The strip of earthing electrode shall be buried in trench not less than 0.5m deep.
Earthing	If strip electrode cannot be laid in straight length. It may be Zigzag with deviation up to 45 Degree from axis of strip.
Earthing	In Plate Earthing Dia of water pipe shall not be less than 20mm and in Pipe earthing reducer of 40mmX20mm shall be used.
Earthing	Earthing Pit Size shall be not less than 30cmX30cmX30cm.
Earthing	Thickness of MS cover of earthing pit shall be not less than 6mm and having locking arrangements.
Earthing	Earthing resistance of each electrode shall be less than 5Ω and for Rocky Soil not less than 8Ω
Earthing	Earthing conduit for earthing wire shall be Medium class 15mm Dia GI pipe and for Earthing Strip shall be medium class 40mm Dia GI Pipe.
Conductor Clearance(min)	
Cable crossing	The horizontal and vertical distance between Power and Communication cable shall not be less than 60cm.
Railway crossing	After taking approval of railway authority, Cable under railway track shall be min 1mt from bottom of sleeper under RCC or cast Iron Pipe.
Railway crossing	Cable in parallel to Railway track shall be min 3mt far away from centre of nearest Track.
Cable Laying in Pipe	For Single Conductor Shall be min 10cm Dia and more than Two Cable shall be min 15cm Dia.
Cable in Road Crossing	In Road Crossing Cable shall be laid min 1 mt below Road in Pipe.
Cable trench	
Cable trench	For single cable: For below 11Kv.Min length of Trench shall be 35cm and depth shall be min 75cm (with sand cushioning of 8cm at bottom +Cable+ protective covering/Sand cushioning of 17cm above Cable) and without Cushioning Depth

	shall be 75cm+25cm.																
Cable trench	For single cable: For above 11Kv.Min length of Trench shall be 35cm and depth shall be min 1.2mt (with sand cushioning and protective covering).																
Cable trench	For multi cable in horizontal level: Min distance between two cable shall be 20cm and min distance between cable and edge of trench on both side shall be 15cm																
Cable trench	For multi cable in Vertical level: Min distance between two cable shall be 30cm.(min Sand cushioning at bottom of trench shall be 8cm +Cable+min Sand cushioning of 30cm+Cable+protective covering/Sand cushioning of 17cm above Cable)																
Cable trench	For LV/MV cable cushioning is not required where there is no possibility of mechanical damages.																
Cable trench	Extra loop of cable at end shall be 3mt for cable termination/Joints.																
Cable Route																	
Cable Route Marker	Cable Route Marker shall be min 0.5mt away from cable trench at the interval not exceeding 100mt parallel.																
Cable Route Marker	Plate Type Cable Route Marker shall be made of 100mmX5mm GI/Aluminum Plate welded/Bolted on 35mmX35mmX6mm Iron angle of 60cm Long.																
Cable Route Marker	Cement Concrete(C.C) type marker shall be made in formation of 1:2:4.																
Cable Bending Radius																	
Cable Bending Radius	<table><tr><td>Voltage</td><td>1Core</td><td>Unarmoured(Multi core)</td><td>Armoured(Multi core)</td></tr><tr><td>11KV</td><td>20D</td><td>15D</td><td>12D</td></tr><tr><td>22KV</td><td>20D</td><td>20D</td><td>15D</td></tr><tr><td>33KV</td><td>20D</td><td>25D</td><td>20D</td></tr></table>	Voltage	1Core	Unarmoured(Multi core)	Armoured(Multi core)	11KV	20D	15D	12D	22KV	20D	20D	15D	33KV	20D	25D	20D
Voltage	1Core	Unarmoured(Multi core)	Armoured(Multi core)														
11KV	20D	15D	12D														
22KV	20D	20D	15D														
33KV	20D	25D	20D														
Cable Tray (Perforated)																	
Cable Tray (Perforated)	Cable Tray may be fabricated by two angle irons of 50mmX50mmX6mm as two longitudinal members with cross bracing between them 50mmX5mm welded/Bolted at angle and 1 mt spacing of 2mm thick MS sheet.																
Overhead Line																	
Steel Tubular Pole	1/6 length of Steel Tubular Pole + 30 cm from base shall be coated with Black Bituminous paint on both internally and externally. The remaining portion of the pole shall be painted with Red oxide.																
Cross arm	LV/MV Line: MS angle iron of size not less than 50mmX50mmX6mm(4.5kg/mt) 11KV Line: MS angle iron of size not less than 65mmX65mmX6mm(5kg/mt)																
Cross arm	LV/MV Line: MS Chanel iron of size not less than 75mmX40mmX4.8mm(7.14kg/mt) 11KV Line: MS Chanel iron of size not less than 75mmX40mmX4.8mm(7.14kg/mt)																
Cross arm	For LV/MV Line: Min distance shall be 5cm between centre of insulation pin and end of cross arm. For 11KV Line: Min distance shall be 10cm between center of insulation pin and end of cross arm.																
Cross arm Length.	<table><tr><td>Voltage</td><td>No of Horizontal Conductor</td><td>Length of Cross Arm</td></tr><tr><td>LV/MV</td><td>2 Conductors</td><td>55cm</td></tr><tr><td>LV/MV</td><td>4 Conductors</td><td>115cm</td></tr><tr><td>LV/MV</td><td>4 Conductors Guard</td><td>175cm</td></tr><tr><td>11KV</td><td>3 Conductors</td><td>225cm</td></tr></table>	Voltage	No of Horizontal Conductor	Length of Cross Arm	LV/MV	2 Conductors	55cm	LV/MV	4 Conductors	115cm	LV/MV	4 Conductors Guard	175cm	11KV	3 Conductors	225cm	
Voltage	No of Horizontal Conductor	Length of Cross Arm															
LV/MV	2 Conductors	55cm															
LV/MV	4 Conductors	115cm															
LV/MV	4 Conductors Guard	175cm															
11KV	3 Conductors	225cm															
Struts	The Pit for Struts shall be located not less than 1.8mt from pole side. The depth of Pit shall be at least 1.2mt																
Danger board	All Support carrying HV Line shall be fitted with Danger Board(IS:2551) at height of 3mt.																
Anti Climbing Device	For HV Line(IS:278-1978) having 4Point Barbs 75mm+12mm apart weight 128/125 gm/mt shall be wrapped helically with pitch of 75mm around Limb of Pole height of 3.5mt to 5 to 6 mt.																
Insulator	For LV/MV Overhead Line: Pin/Shackle Insulator and For 11KV Line Pin/Disc Insulator																
Insulator	For Pin Insulator for LV/MV line: Stalk Length 135mm Shank Length 125 mm , min Load 2KN. For Pin Insulator for 11KV line: Stalk Length 165mm Shank Length 150 mm ,min Load 2KN.																
D Clamp	D clamp shall be made of MS Flat size of 50mmX6mm,height of 75mm																

	Galvanized and only used for vertical configuration for LV/MV Line only.
Pole Top Clamp	Pole Top clamp made from Flat iron 50mmX8mm.
Stay wire Rod	Stay wire Rod shall not be less than 1.8 m Long and 19mm Dia. Ankor Plate shall not be less than 45mmX45mmX7.5mm.
Overhead Conductor (min)	For LV Line : AAC(All Alu.Cond) 7/1/2.21mm, ACSR 6/1/1/2.11mm, AAAC(All Alu.Alloy Cond) 7/2.09mm(20Sgmm) For 11KV/33KV Line : AAC(All Alu.Cond) N/A, ACSR 6/1/1/2.11mm, AAAC(All Alu.Alloy Cond) 7/2.56mm(30Sgmm)
Binding Wire	Binding Wire with insulator shall be with 2.6mm(12SWG) soft aluminum wire.
Earthing in Overhead Line	Earthing wire shall not be less than 4mm(8SWG) and min 3 earthing Pit per KM shall be required. If there is no Continuous wire for earthing in overhead line than each pole should be earthed.
Overhead Line Conductor Clearance(min)	
Same Support	For LV/MV Line on Same Support Vertical distance: Between Phase to Earth shall be min 30cm and Between Phase to Phase min 20cm
Same Support	For LV/MV Line on Same Support Horizontal distance: Between Live wire on either side of support shall be 45cm.
Same Support	For LV/MV Line on Same Support Horizontal distance: Between Live wire on same side of support shall be 30cm.
Same Support	For LV/MV Line on Same Support Horizontal distance: Between central of pin insulator to end of cross Arm shall be 05cm.
Same Support	For HV Line In Triangular Configuration for 11KV/33KV Line shall be min 1.5mt.
Different Voltage	When Two conductor of different Voltage are erected on same support min clearance between LV/MV and 11KV shall be min 1mt.
Different Support	A Clearance not less than height of tallest support may be maintained between parallel overhead line on Different support.
Different Support	When Two overhead line cross each other vertical clearance between LV/MV and 11KV shall not be less than 1.25mt and for LV/MV and 33KV line shall be not less than 2mt.
Across Road	Min Conductor Clearance across Road: For LV/MV Line is 5.8mt and for HV Line 6.1mt
Along Road	Min Conductor Clearance along Road: For LV/MV Line is 5.5mt and for HV Line 5.8mt
Along/Across	Min Conductor Clearance along/across Road: For LV/MV/HV up to 11Kv (Bare Cond) Line is 4.6mt. Min Conductor Clearance along/across Road: For LV/MV/HV up to 11Kv (Insulated Cond) Line is 4.0mt. Min Conductor Clearance along/across Road: For HV (11Kv To 33Kv) Line is 5.2mt. Min Conductor Clearance along/across Road: For EHV (above 33Kv) is 5.2mt + 0.3 mt for every 33KV(Not Less than 6.1).
From Building	Min Conductor Vertical Clearance above Building: For LV/MV Line is 2.5mt from highest Point. Min Conductor Horizontal Clearance near Building: For LV/MV Line is 1.5mt from nearest Point. Min Conductor Vertical Clearance above Building: For MV/EHV(up to 33KV) Line is 3.7mt from highest Point. Min Conductor Vertical Clearance above Building: For MV/EHV(above 33KV) Line is 3.7mt + 0.3mt for every 33KV Min Conductor Horizontal Clearance above Building: For MV/EHV(Up to 11KV) Line is 1.2mt. Min Conductor Horizontal Clearance above Building: For EHV(Up to 33KV) Line is 02mt. Min Conductor Horizontal Clearance above Building: For EHV(above 33KV) Line is 2mt + 0.3mt for every 33KV
Looping Box	
Looping Box	Looping Bus shall be fabricated from MS Sheet of 1.6mm(16SWG) thickness, Min Size 250mmX200mmX100mm for single cable entry and for

	250mmX300mmX100mm for more than two cable entry
Feeder Pillar	
Feeder Pillar	Feeder Pillar shall be fabricated min 2mm thick MS sheet and hinged type double door at front side. If width of Pillar shall be less than 60cm than single hinged type door shall be permitted.
Feeder Pillar	Min height of Pedestal of Feeder Pillar shall be not less than 45cm and 1 to 2 mt height from Road Level.
Feeder Pillar	Each Feeder Pillar shall be earthed with 2 no of Earthing electrode.
Substation	
Area of S/S	S/S TC Room Area Total S.S Area(T.C,HT/LT Panel, without DG)
	2X500KVA 36 Sqmeter 130 Sqmeter
	3X500KVA 54 Sqmeter 172 Sqmeter
	2X800KVA 39 Sqmeter 135 Sqmeter
	3X800KVA 58 Sqmeter 181 Sqmeter
	2X1000KVA 39 Sqmeter 149 Sqmeter
	2X1000KVA 58 Sqmeter 197 Sqmeter

IER-61-2.	Only one connection with earth has been provided for the frame of A B switch. One more Separate and Distinct connection with earth should be provided for frame of the A B switch.
IER-61-2.	Only one connection with earth has been providing for the frame of the H G fuse. One more Separate and distinct connection with earth should be provided for the frame of HG fuse.
IER -29&5b	Metal cover of the transformer (top cover) on which the HV and or LV bushing are Housed should be Looped to earth to avoid any fault current passing through fastening bolts
IE R-9 2	The earthling lead of the HV lighting arrester is not kept separate but it mixed with other Connections. The earthling lead from the HV lighting arrester should not be used for earthling Any other gear and should be taken to a separate electrodes
IER-51-1 b & 61-3	The GI pipe enclosing the MV circuits on the secondary side of the transformer are Not earthed. This should be earthed.
IER- 29&9 2	The earth lead from the HV lighting arrester is taken through GI pipe. The above earth lead Should not Pass through any iron steel pipes.
IER 29&51b	The AB switch handle has not been earthed. The same should be earthed effectively.
IER-29	Masonry through are not provided for the earth electrodes. Masonry through should be Provided for the Earth electrodes
IER -29	No name board has been provided for the substation. A name board with all particulars Should be providing.
IER 50 1 b.	There is no fuse control on the secondary side of the transformer but only the outgoing Feeders are provided with fuse control. Porcelain fuse unit of adequate capacity should be Provided for the transformer on the secondary side and only from these fuse unit supply to the outgoing feeders should be tapped
IE R-29	The handle of the AB switch has been fixed at a height of about 4-5 feet's for easy operation.
IER 29	The UN supported length of jumper in the transformer structure is more than 5 feet. The same Should be restricted to a length of 5 feet
IER 51 1a & b	All the open wiring on the secondary side of the transformer should be closed in conduits.
IER 29	The secondary control of porcelain fuse carrier is not housed in distribution box. They should Be housed in the distribution box No breather has been provided for the transformer a breather should be provided for the transformer.
IER 29	Some of the fuse units are broken. The broken fuse units should be replaced by fresh unit
IER 51 1a & b	The feeders emanating from the secondary fuse control are not provided with separate fuse Unit individually. Further one feeder is tapped from another. There should not be any tapping In the feeder and the entire emanating feeder should be provided with fuse units individually
IER 51 -1b	The providing pipe of the AB switch has not been earthed. The same should be earthed Effectively.
IER 91	Earthed called guarding has not been provided at the place where the HV/MV lines are Crossing the road. Suitable earthed cradle guarding should be provided for the road crossing.
IER 29	The metal parts of the DP structure distribution box have rusted badly and requires Repainting. Repainting should be carried out to the above structure and should be maintained Properly
IER 29	All the routine maintenance work on the transformer like testing of transformer oil etc should Be periodically and the result obtained should be recorded up to date in a separate register
IER 29 & 61 b	The earth electrodes provided should be tested periodically for satisfactory results and Results obtained should be recorded up to date in a separated register
IER 29.	The HV jumpers connected on the tension side are to be connected to the slack side or U Loop connection on the line
IER 29	No HV LA is provided for the protection of the transformer which should Be provided
IER 51 -1b	The metallic fittings of the insulators, strain dishes are to be looped to earth leads of Structure
IER 29	Bushes are not provided for the ends of conduit pipes enclosing MV wires on the secondary Sides. Bushes are to be provides for the ends of conduit pipes
IER 29	The insulated wires on the secondary side of the transformer are deteriorated and they

	Should be replaced by healthy wire
IER 35	Danger notices have been provided the transformer section. Danger notice is to be provided For the transformer section.
IER 29	Oil leak in the LV bushing of the transformer should be attended
IER 29	The position of the HV/LV is to be shifted to the other side so that the clearance between The live jumper and earthed metal parts should not less than 12 inches
IER 29	The transformer base channel from ground is less than 7 feet and the clearance to HV live Point from ground is less than 12 feet. The above clearances are to be provided.
IER 61-1a	The transformer neutral is provided with only one earthy. The neutral should be provided With one more earth connection
IER 61-1a	The transformer neutral earth lead is looped with body. The neutral earth leads should be Separated from the transformer body
IER 61 -2	The transformer body is earthed with signal earth connection. The transformer body should Be provided with two separate and distinct earth locations

Earthing Separation	All medium voltage equipment shall be earthed by two separate and distinct connections with earth. In the case of high.
Neutral Earthing	And extra high voltage the neutral points shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station or substation and may be earthed at any other point provided 'no interference is caused by such earthing.
	If necessary, the neutral may be earthed through suitable impedance.
	Earthed or earthed neutral conductor and the live conductors shall be inserted on any supply system. This however does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.
	In cases where direct earthing may prove harmful rather than provide safety (for example, high frequency and main frequency coreless induction furnaces). Relaxation may be obtained from the competent authority.
Visibility of Earthing	As far as possible, all earth connections shall be visible for inspection.
Cut Out / Link	No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the link
Grounding	Grounding is not likely to reduce the total magnitude of over-voltage produced by lightning or switching surges. It can, however, distribute the voltage between phases and reduce the possibility of excessive voltage stress on the phase-to-ground insulation of a particular phase.
Plate Earthing	Plate electrodes shall be of the size at least 60 cm X 60 cm, plates are generally of cut iron not less than 12 mm thick and preferably ribbed. The earth connection should be joined to the plate at not less than two separate points. Plate electrodes, when made of GI or steel, shall be not less than 6 mm in thickness.
	Plate electrodes of Cu shall be not less than 3.15 mm in thickness.
	Plate electrodes shall be buried such that ii. Top edge is at a depth not less than 150 mm from the surface of the ground. However, the depth at which plates are set should be such as to ensure that the surrounding soil is always damp
Pipe Earthing	Pipes may be of cast iron of not less than 100 mm diameter, 2.5 to 3 m long and 13 mm thick. Such pipes cannot be driven satisfactorily and may, therefore, be more expensive to install than plates for the same effective area. Water pipes shall not be used as consumer earth electrodes.
Under fault conditions	Under fault conditions, the earth electrode is raised to a potential with respect to the general mass of the earth that can be calculated from the prospective fault current and the earth resistance of the electrode. The results in the existence of voltage. In the soil around the electrode, that may be injurious to telephone and pilot cables, whose cores are substantially at earth potential, owing to the voltage to which the sheaths of such cables are raised
The voltage gradient	The voltage gradient at the surface of the ground may also constitute a danger to life, especially where cattle are concerned. The former risk arises mainly in connection with large electrode systems as at power stations and substation.
Earth electrodes	Earth electrodes, other than the used for the earthing of the fence itself, should not be installed in proximity to a metal fence to avoid the possibility of the fence becoming live and thus dangerous at points remote from the substation. The materials used for making connections have to be compatible with the earth rod and the copper earthing conductor so that galvanic corrosion is minimized. In all cases, the connections have to be mechanically strong.
cross-sectional	The cross-sectional area of every protective conductor which does not form part of the supply cable or cable enclosure shall be in any case, not less than 2.5 mm² , if mechanical protection is provided and 4 mm² , if mechanical protection is not provided.
	Joints of protective conductors shall be accessible for inspection and testing except in compound-filled or encapsulated joints.
	No switching device shall be inserted in the protective conductor, but joints which can be disconnected for test purposes by use of a tool may be provided.
	In TN systems, for cables in fixed installations having a cross sectional area not less than 10 mm ² for copper and 16 mm ² for aluminum, a single conductor may serve both as protective conductor and neutral conductor, provided that the part of the installation concerned is not protected by a residual current-operated device. However, the minimum cross sectional area of a PEN conductor may be 4 mm ² ,

	provided that the cable is of a concentric type conforming to Indian Standards and that duplicate continuity connections exist at all joints and terminations in the run of the concentric conductors.
Auxiliary earth electrode	An auxiliary earth electrode shall be provided electrically independent of all other earthed metal, for example, constructional metalwork, pipers, or metal-sheathed cables. This requirement is considered to be fulfilled if the auxiliary earth electrode is installed at a specified distance from all other earthed metal (value of distance under consideration).
	The earthing conductor leading to the auxiliary earth electrode shall be isolated to avoid contact with the protective conductor or any of the parts connected thereto or extraneous conductive parts which are, or may be, in contact with them
Earthing Strip	Size of GI Strip: 300mmX10mm Size of GI Pipe: 2.5" Diameter
IR Value	Minimum 1Ω Resistance should be available at a distance of 15mt. IR value of Earth resistance is less than 10Ω. Earthing Res. of earthing rod is very from 0.3Ω to 0.8Ω between summer to winter
	If ground resistance is less than plate earthing (if hard rock) than Pipe earthing shall be used. Resistance between two earthing pit is negligible. Earthing of lighting protection should not mix with power system earthing. Lighting protection earthing should be 10 time stronger than normal earthing (use copper bus strip instead of wire) Joining of earthing strip shall be overlap of min 50mm and for earthing wire overlapping shall be min 40mm
Distance between two Earthing Pit	Distance between two earthing pit is 2 X Length of earthing electrode.
Plate Size	GI/Copper Plate Size: 500mmX500mmX10mm. Wood coal powder and salt are in same quantity.
RCD	RCD's Having Minimum Operating Currents Greater Than 30 mA - These devices are intended to give indirect shock risk protection. The neutral points of each separate electricity system which has to be earthed at the power station or substation.

Size of Plate / Pipe Earthing	
Plate Earthing Electrode	For copper = 600X600X31mm and
	For Hot dip GI = 600X600X63mm.
Pipe Earthing Electrode.	Earthing electrode shall consist of a GI pipe (class B of approved make), not less than 40 mm dia. and 3 meters long.
	CL pipe electrode shall be cut tapered at the bottom and provided with holes of 12 mm dia. drilled at 75 mm interval up to 2.5 meters length from bottom
	The electrode shall be buried vertically in the ground as far as practicable below permanent moisture level, but in any case not less than 3 meters below ground level
	The electrode shall be in one piece and no joints shall be allowed in the electrode.
Size of Excavation:	Size of 1 meter diameter and 3 meter length shall be excavated after depth of 3 meter the size of excavation shall be 900X300X900mm depth.
	Plate / Pipe Electrode shall be in vertical position.
	GI/PVC pipe for Watering shall be used of 40mm Diameter, length of 3 meter (contain hole of 12mm Diameter in Zigzag manner starting from 15cm away from bottom to 2 meter height).
	At bottom 150mm layer of Salt and charcoal power shall be installed than Plate shall be installed.
	Alternate layer of 150mm of Salt and charcoal power shall be used up to 2.5 meter.
	Min 120kg of charcoal power and 120kg of salt shall be used for each earthing pit.
	The plate \ pipe electrode, as far as practicable, shall be buried below permanent moisture level but in no case not less than 2.5 M below finished ground level.

Abstract of IS:5039 for Distribution Pillar (<1KV AC&DC)	
Distribution pillars	Distribution pillars are used by a number of distributing agencies to interconnect, terminate, control, protect and sectionalize distribution feeders.
	They are generally located on public footpaths abutting the building line or along the kerb line of footpaths.
	The distribution pillars covered by this standard are intended to incorporate HRC type fuses/links only and of current rating not exceeding 630 amperes.
	This standard covers distribution pillars for voltages not exceeding 1 000 V ac or 1 200 V dc, the current rating in each outgoing or incoming circuit not exceeding 630 A, for use on ac or dc systems, in outdoor conditions.
Rating of Individual Circuits:	The rated current of the outgoing or incoming circuits shall be as follows: 160, 200, 250, 400 and 630 amperes.
	NOTE 1: These ratings correspond to those of fuse-bases.
	NOTE 2 : All the incoming circuits of the same distribution pillar shall have the
	Same current rating and similarly all the outgoing circuits of the same distribution pillar shall have the same current rating. Unless otherwise specified the sum of the rated current of the incoming circuits shall be fixed at the 2/3 of the sum of the current ratings of outgoing circuits, rounded up to the nearest higher value of the preferred current
Rated Diversity Factor:	The rated diversity factor of the distribution pillar having several incoming and outgoing circuits is the ratio of the maximum sum at any one time, of the assumed circuits of all the circuits involved, to the sum of the rated currents of all the circuits of the distribution pillar.
	NUMBER OF FUSE-WAYS
	DIVERSITY FACTOR
	2 and 3 0.9
	4 and 5 0.8
Enclosure:	6 to 9 inclusive 0.7
	10 and above 0.6
	It shall be in all respect suitable for outdoor installations. It shall be made from a suitable material to withstand rough usage and weather. If fabricated out of MS sheets the thickness of the sheet shall be at least 3.15 mm
Doors:	Distribution pillars shall have a set of double hinged doors at the front. Similar doors shall be provided at the back also; if specified.
	The doors shall be so fitted as to provide the interior with maximum protection from atmospheric conditions. The hinges shall be of such construction that the doors can be swung open by not less than 150°.
	In addition the hinged design shall permit doors being completely removed when necessary. The base horizontal member shall be completely removable to facilitate cable jointing
Canopy:	The top of the pillar shall be fitted with a sloping canopy design of which shall be such that rain water shall not accumulate on the top.
Aprons:	If required, an apron (two if there are doors at the rear also) shall be provided below the door level of the pillar. They shall be easily removable. The apron shall be made from a suitable material to withstand rough usage. If made from sheet steel, the thickness of the sheet shall be at least 3.15 mm.
Pillar Lighting:	A bayonet lamp holder complying with IS : 1258-1987, with a tumbler switch, competing with IS : 3854-1988†, a three pin plug and socket complying with IS : 1293-1988 with necessary fuses and wiring shall be provided inside the pillar.
	Unless otherwise agreed between the manufacturers and user, on TPN fuse boards, terminals for the neutral conductor shall allow the connection of aluminium conductors having a current carrying capacity:
	(a) equal to half the current carrying capacity of the phase conductor with a minimum of 25 mm ² , if the size of the phase conductor exceeds 25 mm ²
	(b) equal to the full current carrying capacity of the phase conductor if the size of the latter is less than or equal to 25mm ² .
Bus-bar	Suitable barriers shall be provided between bus-bars
Earthing	The distribution pillar shall be provided with two separate earthing terminals and the framework shall be metallically connected with the casing.

Abstract IS 694 (Cable)	
Cable Sheath (Up to 1.1KV)	The color of the sheath shall be black or any other color as agreed to between the purchaser and the supplier. For weatherproof cables, the color of sheath shall be black only.
	The difference between maximum and minimum measured values of overall diameter of sheathed circular cables shall not exceed 15 percent of the maximum measured value at the same cross-section.
Cable Construction (Up to 1.1KV)	Copper Cable up to 6mm ² =Solid/Stranded ,
	Copper Cable up to 10mm ² =Solid/Stranded
	Copper Cable above 6mm ² =Stranded ,
	Copper Cable above 10mm ² =Stranded
Cable-Testing (Up to 1.1KV)	The core(s) shall be carefully removed from a sample approximately 3 m long from the finished cable. They shall be so immersed in a water-bath at 60±3°C that their ends protrude at least 200 mm above the water-level. After 24 hours, a voltage of 3 kV (rms) shall be applied between conductors and water. This voltage shall be raised to 6 kV (rms) within 10 seconds and held constant at this value for 5 minutes. If the sample fails in this test, one more sample shall be subjected to this test, which should pass.
	The cores which have passed the preliminary test given in 16.2.1 shall be subsequently tested with a dc voltage of 1.2 kV in the same water-bath at the same temperature. The conductors shall be connected to the negative pole and water to the positive pole of dc supply by means of a copper electrode.
	The core shall withstand this dc voltage test for 240 hours without breakdown.
	The voltage shall be applied continuously, but if there are any unavoidable interruptions during the 4 hours period, that period shall be increased by the time of interruptions. The total of such interruptions shall not exceed 1 hour otherwise the test shall be started again.
	The cables and cords shall withstand without breakdown an ac voltage of 3 kV (rms) or a dc voltage of 7.2 kV applied for a period of 5 min for each test connection
	Single-core cables shall be immersed in water at ambient temperature one hour before the testing and the test voltage shall be applied between conductor and water for the specified period.

Abstract of IS 1554	
Insulation Color (up to 11 KV)	For reduced neutral conductors, the insulation color shall be black
Arrangement of Marking (up to 11 KV)	For cables having more than 5 cores, the core identification may be done by numbers. In that case, the insulation of cores shall be of the same color and numbered sequentially, starting with number 1 for the inner layer. The numbers shall be printed in Hindu-Arabic numerals on the outer surface of the cores. All the numbers shall be of the same color which shall contrast with the color of the insulation. The numerals shall be legible.
	When the number is a single numeral, a dash shall be placed underneath it. If the number consists of two numerals, these shall be disposed one below the other and a dash placed below the lower numeral. The spacing between consecutive numbers shall not exceed 50 mm.
Type of Armor (up to 11 KV)	Where the calculated diameter below armoring does not exceed 13 mm, the armor shall consist of galvanized round steel wires. Where the calculated diameter below armoring is greater than 13 mm, the armor shall consist of either galvanized round steel wires or galvanized steel strips.
Cable Identification/ Marking (up to 11 KV)	Type of Cable Legend: (i) Improved fire performance or Category C1 FR (Cables in constrained areas, Does not propagate fire even when installed

	in groups in vertical ducts),(ii) Improved fire performance for Category C2 FR—LSH (Cables in constrained areas with limited human activity and/or presence of sophisticated systems)																				
	Aluminum conductor= A, PVC insulation=Y, Steel round wire armor= W, Steel strip armor= F, Steel double round wire armor= WW, Steel double strip armor =FF, PVC outer sheath= Y																				
Insulating Rubber Mat	Four classes of mats, covered under this standard nd differing in electrical characteristics for different use voltages are designated																				
Insulating Rubber Mat	<table><tr><th>Class</th><th>AC (Rms)KV</th><th>DC(V)</th><th>Thickness(mm)</th></tr><tr><td>A</td><td>3.3</td><td>240</td><td>2.0</td></tr><tr><td>B</td><td>11</td><td>240</td><td>2.5</td></tr><tr><td>C</td><td>33</td><td>240</td><td>3.0</td></tr><tr><td>D</td><td>66</td><td>240 3.5</td><td></td></tr></table>	Class	AC (Rms)KV	DC(V)	Thickness(mm)	A	3.3	240	2.0	B	11	240	2.5	C	33	240	3.0	D	66	240 3.5	
Class	AC (Rms)KV	DC(V)	Thickness(mm)																		
A	3.3	240	2.0																		
B	11	240	2.5																		
C	33	240	3.0																		
D	66	240 3.5																			
Insulating Rubber Mat	Most of all classes hall be resistant to acid and oil and low temperagre and shall be identified by the respective class symbol. However a category with special property of resistance to extreme 'low' ternperature will be identified by a subscript's 'to, the 'respective "c" Class symbol																				
Insulating Rubber Mat	Roll of Mat shall be in multiple Length of of 5000mm and ion width of 1000mm.Standard Shape in length of 1000, 2000, 3000mm.																				
Insulating Rubber Mat	Leakage current for all Class of Mat shall not be more than 10 Micro Amp.																				

Abstract of IS:11892	
Maximum external Diameter of Cable (dc)=	$=k_c \times d$ where d= Nominal dia of conductor standards. $k_c=1$ for solid cable. For stranded cable $k_c=3$ (up to 7 stranded). More than 7 stranded $k_c=1.16 \times \text{sq.root}(n_1)$, n_1 =Number of stranded

Abstract of IS: 15652 for Insulating Mat				
Insulating Rubber Mat	Class	AC Voltage	DC Voltage	Thicknes
	Class A	AC (Rms)KV=3.3	DC(V) =240	2.0mm
	Class B	AC (Rms)KV=11	DC(V) =240	2.5mm
	Class C	AC (Rms)KV=33	DC(V) =240	3.0mm
	Class D	AC (Rms)KV=66	DC(V) =240	3.5mm
	Class A	AC (Rms)KV=3.3	DC(V) =240	2.0mm
Resistance	Most of all classes hall be resistant to acid and oil and low temperature and shall be identified by the respective class symbol. However a category with special property of resistance to extreme 'low' ternperature will be identified by a subscript 'S' to, the 'respective "C" Class symbol.			
Length	Roll of Mat shall be in multiple Length of 5000mm and ion width of 1000mm.Standard Shape in length of 1000, 2000, 3000mm.			
	In Case of Mat in Roll It shall be min 1m X 1m.			
Leakage current	Leakage current for all Class of Mat shall not be more than 10 Micro Amp.			

Abstract of IS:11171 for Transformer			
Transformer Temperature Rise Limit	Part	Type of Insulation	Degree (Centigrade)
	Part=Winding	Type of Insulation=A	50 Centigrade
	Part=Winding	Type of Insulation=E	65 Centigrade
	Part=Winding	Type of Insulation=B	70 Centigrade
	Part=Winding	Type of Insulation=F	90 Centigrade
	Part=Winding	Type of Insulation=H	115 Centigrade
	Part=Winding	Type of Insulation=G	140 Centigrade
Transformer Cooling Method indication	Part= Core, MetallicPart	Type of Insulation=-	Not rise to damage core or metallic part
	Type of cooling Medium: A=Air		
	First Letter= Type of Cooling Medium (Contact with Winding)		
	Second Letter = Kind of Circulation(Contact with Winding)		
Transformer Reduce Temperature Rise Limit	Third Letter= Type of Cooling Medium (Contact with external cooling System)		
	Forth Letter = Kind of Circulation (Contact with external cooling System)		
Transformer Parallel operation Condition	TRANSFORMER designed for operation at an altitude greater than 1 000 m but tested at normal altitudes the limits of temperature rise are reduced by the following amounts for each 500 m by which the intended working altitude exceeds 1000Meter		
	(a) Natural-air-cooled Transformers 2.5 %		
	(b) Forced-air-cooled Transformers %		
	(1)Rated power (kVA);		
	(2) Rated voltage ratio;		
	(3) Voltage ratios corresponding to tappings other than the principal tapping.		
	(4) Rated power (kVA); Rated voltage ratio; Voltage ratios corresponding to tapings other than the principal tapping.		
Transformer Parallel operation Condition	(5) Load loss at rated current on the principal tapping, corrected to the appropriate reference temperature.		
	(6) Impedance voltage at rated current (on the principal tapping).		
	(7) Short-circuit impedances, at least on the extreme tappings, if the tapping. Range of the tapped winding exceeds + or – 5 %.		

Abstract of IS: 1678 for Pole			
PCC Pole	Class of Pole	Length of Pole	Min Ultimate Transverse Load
	Class 1	17 Meter	3000 Kg
	Class 2	17 Meter	2300 Kg
	Class 3	17 Meter	1800 Kg
	Class 4	17 Meter	1400 Kg
	Class 5	16 Meter	1100 Kg
	Class 6	12.5 Meter	1000 Kg
	Class 7	12 Meter	800 Kg
	Class 8	12 Meter	700 Kg
	Class 9	11 Meter	450 Kg
	Class 10	9 Meter	300 Kg
	Class 11	7.5 Meter	200 Kg
PCC Pole Tolerance	Tolerance: The tolerance of overall length of the poles shall be + 15 mm.		
	The tolerance on cross-sectional dimensions shall be + 3 mm.		
	The tolerance on cross-sectional dimensions shall be + 3 mm.		
	The tolerance on uprightness of the pole shall be 0.5 per cent		
PCC Pole depth in Ground:	Length of Pole		Min depth in ground
	6 Meter To 7.5 Meter		1.2 Meter
	8 Meter To 9 Meter		1.5 Meter
	9.5 Meter To 11 Meter		1.8 Meter
	11.5 Meter To 13 Meter		2.0 Meter
	13.5 Meter To 14.5 Meter		2.2 Meter
	15 Meter To 16.5 Meter		2.3 Meter
	17 Meter		2.4 Meter

Abstract of IS:1445 for Porcelain Insulator		
Porcelain Insulator	Type A	An insulator unit in which the lengths of the shortest puncture patch through solid insulating material is at least equal to half the length of the shortest flash over path through air outside the insulator
	Type B	An insulator or an insulator unit in which the length of the shortest puncture patch through solid insulating material is less than half the length of the shortest flash over path through air outside the insulator.

Abstract of IS :1255 for Instalation of Cable	
Cable Route Indicator (Up to 33KV)	Power cable route indicators should be provided at an interval not exceeding 200 M and also at turning points of the power cable route wherever practicable
Cable Corrosion (Up to 33KV)	Electrolytic corrosion: Where the possibility of electrolytic corrosion exists, for example, adjacent to dc traction system, the potential gradient along the pipe-line and the cable sheath should be specified.
Neutral (Up to 33KV)	The neutral point is earthed in such a manner that during a line-to-earth fault the highest rms voltage to earth of a sound phase(s) expressed as a percentage of the highest line-to-line voltage, does not exceed 80 percent, irrespective of the fault location,
Earthing (Up to 33KV)	The neutral point is not earthed but a device is installed which automatically and instantly cuts out any part of the system which becomes accidentally earthed,
Earthing (Up to 33KV)	In case of ac systems only, the neutral point is earthed through an arc suppression coil with arrangement for isolation within one hour for the non-radial field cables and within 8 hours for radial field cables, of occurrence of the fault provided that the total of such periods in a year does not exceed 125 hours.
Cable Tensile Strength (Up to 33KV)	PVC and XLPE insulated armored power cables $P = 9 D^2$, P =Pulling Strength(N), D =Outer Dia of Cable(mm)
Cable Tensile Strength (Up to 33KV)	PVC and XLPE insulated unarmored power cables $P = 5 D^2$
Cable Tensile Strength (Up to 33KV)	Paper insulated armoured power cables $P = 5 D^3$
Cable Pulling (Up to 33KV)	For Cables Pulled by Pulling Eye : If the cables are pulled by gripping the conductor directly with pulling eye, the maximum permissible tensile stress depends on the material of the conductor and on their cross-section as given below: For aluminum conductors 30 N/mm ² and For copper conductors 50 N/mm ²
Cable Pulling (Up to 33KV)	Expected Pulling Force When Pulling Cables by Winch : The following values of pulling force are expected = (approximately percentage of cable weight): In trenches without large bends 15-20 % In trenches with 1 or 2 bends of 90° each 20-40 % In trenches with 3 bends of 90° each (assuming the use of easy-running support and corner rollers) 50-60 % In ducts with bends totalling 360° Up to 100 %
Cable Laying Direct in Ground (Up to 33KV)	This method involves digging a trench in the ground and laying cable(s) on a bedding of minimum 75 mm riddled soil or sand at the bottom of the trench, and covering it with additional riddled soil or sand of minimum 75 mm and protecting it by means of tiles, bricks
Cable Laying Direct in Ground (Up to 33KV)	Depth : The desired minimum depth of laying from ground surface to the top of cable is as follows: High voltage cables, 3.3 kV to 11 kV rating = 0.9 m High voltage cables, 22 kV, 33 kV rating = 1.05 m Low voltage and control cables = 0.75 m Cables at road crossings = 1.00 m Cables at railway level crossings (measured from bottom of sleepers to the top of pipe)=1.00m
Cable Clearance (Up to 33KV)	Clearances :The desired minimum clearances are as follows: Power cable to power cable = Clearance not necessary; however, larger the clearance, better would be current carrying capacity Power cable to control cables = 0.2 m Power cable to communication cable = 0.3 m Power cable to gas/water main = 0.3 m Inductive influence on sensitive control cable on account of nearby power cables should be checked
Cable Clearance (Up to 33KV)	The power cable should not be laid above the telecommunication cable, to avoid danger to life of the person, digging to attend to the fault in the Telecommunication cable.
Crossing (Up to 33KV)	Cables Laid Across Roads, Railway Tracks and Water Pipe Lines: Steel, cast

	iron, plastics, cement or earthenware ducts, or cable ducting blocks should be used where cables cross roads and railway tracks. Spare ducts for future extensions should be provided. Spare duct runs should be sealed off. Buried ducts or ducting blocks should project into footpath or up to the edge of road, where there is no footpath, to permit smooth entry of cable without undue bending
Diameter of Pipe (Up to 33KV)	The diameter of the cable conduit or pipe or duct should be at least 1.5 times the outer diameter of cable. The ducts/pipes should be mechanically strong to withstand forces due to heavy traffic when they are laid across road/railway tracks.
Bending Radius (Up to 33KV)	The bending radius of steel or plastics ducts should not be less than 1.5 m.
Cable on Over Bridge (Up to 33KV)	Cable Over Bridges : On bridges, the cables are generally supported on steel cable hooks or clamped on steel supports at regular intervals. While designing a cable layout on a bridge; expansion of bridge due to changes in atmospheric temperature should be taken into account. On most of the rail-cum-road bridges, the cables are subjected to vibrations. For such conditions, round wire armoured and lead alloy 'B' sheathed cables are preferred. Cables can be laid on bridges duly suspended from catenary wire at regular intervals
Cable on Railway Crossing (Up to 33KV)	Cables Below Railway Crossing : When the cables are laid under railway tracks the cables should be laid in reinforced spun concrete or cast iron or steel pipes at such depths as may be specified by the railway authorities but not less than 1 m measured from the bottom of sleepers to the top of the pipe.
Cable on Duct (Up to 33KV)	On long run ducts, it is desirable to apply lubrication to the lead or serving/outer sheath as it enters the duct. Petroleum jelly or graphite powder or a combination of both is effective for this purpose and through lubrication will reduce the pulling tension by about 40 percent.
Laying on Racks in Air (Up to 33KV)	Lying on Racks in Air-The vertical distance between the two racks should be minimum 0.3 m and the clearance between the first cable and the wall (if racks are mounted on wall) should be 25 mm. The width of the rack should not exceed 0.75 m in order to facilitate installation of cables.
Laying on Racks in Air (Up to 33KV)	Ungalvanized steel work of cable racking/trays should be painted with a coat of primer and thereafter finished with suitable anti-corrosive paint.
Laying on Racks in Air (Up to 33KV)	Only single-core cables laid on horizontal racks need be clamped at suitable intervals. Multi-core cables need not be clamped. The distance between the vertical clamps should not be more than 2 m.
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	Laying Cables on Racks Inside a Tunnel: Horizontal distance between Two cable is min Diameter of Cable and vertical distance between two cable row is 30cm. In cable tunnel, the head room should not be less than 2 m and width sufficient to leave a free passage of at least 600 to 800 mm either from one side or in the middle.
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	With temperatures below 3°C, the cables should be warmed before the laying out, since otherwise the bending would damage the insulation and protective coverings of cables. The cable laying must be carried out swiftly, so that the cable does not cool down too much
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	Identification strips/tags of metal or plastics should be attached to the cables, particularly if several are laid in parallel, 8 to 10 m apart. Identification tags should also be attached at every entry point into the buildings and at the cable end termination
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	The spacing between three cables laid in one plane should be not less than the cable diameter.
Laying Cables on Racks Inside a Tunnel(Up to 33KV)	When the cable run is several kilometres long, the cables should be transposed at one-third and at two-thirds of the total lengths.
Trefoil arrangement in ducts (Up to 33KV)	If several single-core cables are laid per phase, these should be arranged as follows to ensure balanced current distribution in Horizontal direction : R-Y-B-Distance-B-Y-R, (Distance=2 X Diameter of Cable) , vertical distance shall be 6 X Diameter of Cable

Abstract of IS : 5613 for HV Line	
Overhead Line	Pole Foundation hole should be drilled in the ground with the use of earth-augers. However, if earth-augers are not available a dog pit of the size 1.2 x 0.6 m should be made in the direction of the line. The depth of the pit shall be in accordance-with the length of the pole to be planted in the ground as given in respective Indian Standards.
Tublar Pole	Steel Tubular Poles, Rolled Steel Joists and Rails - A suitable pad of cement concrete, stone or steel shall be provided at the bottom of the pit, before the metallic pole is erected. Where metal works are likely to get corroded (points where the pole emerges out of the ground), a cement concrete muff, 20 cm above and 20 cm below the ground with sloping top shall be provided.
RCC Pole	RCC poles generally have larger cross-section than the PCC poles and, therefore, the base plates or muffing are usually not provided for these types of poles. However, for PCC poles, a base plate (40 x 40 x 7 cm concrete block) shall be provided. Cement concrete muff with sloping top may also be provided, 20 cm above and 20 cm below-the ground level, when the ground or local conditions call for the same.
H.V Line (120m To 160m Span)	The insulators should be attached to the poles directly with the help of 'D' type or other suitable clamps in case of vertical configuration of conductors or be attached to the cross arms with the help of pins in case of horizontal configuration.
H.V Line (120m To 160m Span)	Pin insulator and recommended for use on straight runs and up to maximum of 10' deviation.
H.V Line (120m To 160m Span)	The disc insulators are intended for use a pole positions having more than 30' angle or for dead ending of 11 kV lines.
H.V Line (120m To 160m Span)	For lines having=A bend of 10" to 30', either double cross arms or disc insulators should be used for HT lines up to 11 kV. For low and medium voltage line, shackle insulators should be used
H.V Line (120m To 160m Span)	For Vertical configuration for Conductor erection: Distance between Pole's Top to Disc insulation=200mm. Between Disc insulator to Disc Insulator=1000mm. Between Disc insulator to Guy Wire=500mm.
Stay Wire Angle with Pole	Overhead lines supports at angles and terminal positions should be well stayed with stay wire, rod, etc. The angle between the pole and the wire should be about 45" and in no case should be less than 30". If the site conditions are such that an angle or more than 30" between the pole and the stay wire cannot be obtained, special stays such as, foot stay, flying stay or struts may be used
Stay Wire	Hard drawn galvanized steel wires should be used as stay wires. The tensile strength of these wires shall not be less than 70 kgf/mm ² . Only standard wires should be used for staying purpose.
Stay Rod	Mild steel rods should be used for stay rods. The tensile strength of these rods shall not be less than 42 kgf/mm ²
Stay Anchor	Stays should be anchored either by providing base plates of suitable dimensions or by providing angle iron or rail anchors of suitable dimensions and lengths.
Guy Insulator	Stay wires and rods should be connected to the pole with a porcelain guy insulator. Wooden insulators should not be used. Suitable clamps should be used to coMeCt stay wires and rods to its anchor. For low and -medium voltage lines a porcelain guy insulator should be inserted in the stay wire at a height of 3 m vertically above the ground level. For high voltage lines, however, the stays may be directly anchored.
Stay Setting	The inclination of stay relative to the ground is roughly determined before making the hole for excavation. This enables the position of the stay hole to be fixed so - that when the stay is set, the stay rod will have the correct inclination and will come out of the ground at the correct distance from the pole. The stay rods should be securely fixed to the ground by means of a suitable anchor
O/H Conductor Drum	In loading, transportation and unloading conductor drums should be protected against injury. The conductor drums should never be dropped and may be Trolled

	only as indicated by the arrow on the drum side. The drums should be distributed along the route at distance approximately equal to the length of the conductor wound on the drum.
Binding of O/H Conductor	The insulators should be bound with the line conductors with the help of copper binding wire in case of copper conductors, galvanized iron binding wire for galvanized iron conductors and aluminum binding wire or tape for aluminum and steel reinforced aluminum conductors (ACSR). The size of the binding wire shall not be 'less than 2 mm'
Different Voltage on Same Support	Where conductors forming parts of systems at different voltages are erected on the same supports. Adequate clearance and guarding shall be provided to guard against the danger to linemen and others from the lower voltage system being charged above its normal working voltage by leakage from or contact with the higher voltage system. The clearance between the bottom most conductor of the system placed at the top and the top most conductor of the other system should not be less than 1.2m.
Jumper	Jumpers from dead end points on one side of the pole to the dead end side on the other side of the pole should be made with conductor of same material and current carrying capacity as that of the line conductor. The jumpers should be tied with the line conductor with a suitable clamp. If the material of the jumper wire is different from that of the line conductor, suitable bimetallic clamps should be used. If copper and aluminium bimetallic clamps are to be used, it should be ensured that the aluminium conductor is situated above the copper conductor so that no copper contaminated water comes in contact with aluminium.
Jumper Clearance	For high voltage lines the jumpers should be so arranged that there is minimum clearance of 0.3 m under maximum deflection condition due to wind between the live jumpers and other metallic parts. This may involve erection of insulators and dead weights specially for fixing the jumpers.
Binding of O/H Line	Length of Binding wire on Insulator (From outer surface of Insulator to end of binding wire) should be $6D$ (Where D =Diameter of O/H Conductor)
O/H Patrolling	All overhead lines should be patrolled periodically at intervals not exceeding 3 months from the ground when the line is live.
Pole Earthing	All metal poles including reinforced cement concrete and pre-stressed cement concrete poles shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected with earth ordinarily at 3 points in every kilometre, the spacing between the points being as nearly equidistant as possible. Alternatively each pole, and metallic fitting attached thereto shall be efficiently earthed.
Stay wire Earthing	All stay wires of low and medium voltage lines other than those which are connected with earth by means of a continuous earth wire shall have an insulator inserted at a height of not less than 3 m from the ground.
Earthing Wire Size	The cross-sectional area of the earth conductor shall not be less than 16 mm ² if of copper, and 25 mm ² if of galvanized iron or steel.
Conductor Clearance	Fixing Cross Arm in Low and Medium Voltage in Horizontal Configuration:
P-P-N Clearance	Up to 650V Horizontal "V" Shape Cross arm(P-P(Street Light)-Neutral): Phase to Neutral=750mm, Phase to Phase(Streetlight at Top of Pole)=325mm, Last Phase-Cross Arm end=80mm
P-P-N Clearance	650V to 11KV Horizontal Cross arm(P-P(Street Light)-N) : Phase-Phase=300mm, Phase-Phase(Street Light)=300mm, Phase-Neutral=300mm, Last Phase-Cross Arm end=80mm
P-P-N Clearance	Low and Medium Voltage Line (Horizontal Configuration): Less than 75cm Sag =P-P 30cm 76cm To 120cm Sag =P-P 45cm 121cm To 145cm Sag =P-P 60cm
P-P-N Clearance	Low and Medium Voltage Line (Vertical Configuration): Less than 70m Sag =P-P 20cm 71m To 100m Sag =P-P 30cm
P-P-N Clearance	High Voltage Line (Horizontal Configuration): Up to 120m Sag =Phase to Phase= 40cm 140m To 225m Sag =Phase to Phase= 65cm
P-P-N Clearance	Double Circuit on Same Pole at different level : Distance between Two Circuit is 120cm.
O/H Conductor	Choice of Conductors: The physical and electrical properties of different

	conductors shall be in accordance with relevant Indian Standards. All conductors shall have a breaking strength of not less than 350 kg. However, for low voltage lines with spans less than 15 m and installed either on owner's or consumer's premises, conductors with breaking strength of not less than 140 kg may be used.		
Voltage Variation	In accordance with the Indian Electricity Rules voltage variation for low voltage lines should not be more than ± 6 percent and for high voltage lines should not be more than ± 6 percent to ± 9 percent		
Span (Up to 11KV)	Recommended Span Lengths: The recommended span lengths for lines up to 11 kV are 45, 60, 65, 75, 90, 105 and 120 meters		
Span (Up to 11KV)	There are no fixed rules for spacing arrangement of overhead line conductors. However, the following formula gives an economical spacing of conductors: $D=500+18U+(L*L/50)$ Where D=Spacing between conductor(mm), U=Voltage(p-p in kv), L=Span in meter		
Clearance(Up to 11KV)	Min height of any conductor of an overhead line across any street (Low Medium Voltage)=5.8m		
Clearance(Up to 11KV)	Min height of any conductor of an overhead line across any street (High Voltage)=6.1m		
Clearance(Up to 11KV)	Minimum height of any conductor of an overhead line along any street(Low &Medium Voltage)=5.5m		
Clearance(Up to 11KV)	Minimum height of any conductor of an overhead line along any street(High Voltage)=5.8m		
Clearance(Up to 11KV)	Minimum height of any conductor (bare) of an overhead line erected elsewhere(Low &Medium Voltage)=4.6m		
Clearance(Up to 11KV)	Minimum height of any conductor (bare) of an overhead line erected elsewhere(High Voltage)=4.6m		
Clearance(Up to 11KV)	Minimum height of any conductor (insulated) of an overhead line erected elsewhere(Low &Medium Voltage)=4.0m		
Clearance(Up to 11KV)	Minimum height of any conductor (insulated) of an overhead line erected elsewhere(High Voltage)=4.0m		
Clearance(Up to 11KV)	Minimum clearance of overhead line conductor from buildings(Low & Medium Voltage)=2.5m		
Clearance(Up to 11KV)	Minimum clearance of overhead line conductor from buildings(High Voltage)=3.7m		
Span(11KV To 220KV)	System Voltage 33KV (over Pole) 33KV 33KV 66KV 66KV 220KV 220KV	Number Of Circuit Single Single Double Single Double Single Double	Span (Meter) 90 To 135 Meter 180 To 305 Meter 180 To 305 Meter 204 To 305 Meter 240 To 320 Meter 320 To 380 Meter 320 To 380 Meter
Danger Plate(11KV To 220KV)	Danger and number plates are located on Face (Feeding End (S/S))of pole		
Anti Climbing Device(11KV To 220KV)	Leg 1 (Right End Leg (Feeding End (S/S)) represents the leg with step bolts and anti-climb device gate if any. If two legs with step bolts are required, the next is No. 3 leg (Dignotical opposite of Leg1)		
Clearance(11KV To 220KV)	Voltage 33KV (over Pole) 33KV 66KV 110KV 220KV	Circuit Single Single/Double Single/Double Single/Double Single/Double	P-P Vertical 1.5 Meter 1.5 Meter 2.0 Meter 3.2 Meter 4.9 Meter P-P Horizontal 1.5 Meter 1.5 Meter 3.5 Meter 5.5 Meter 8.4 Meter
Clearance(11KV To 220KV)	In case triangular formation has to be adopted, the conductor lying below an upper one shall be staggered out by a distance of $X=V/150$ Where V=System Voltage, X=staggered distance in meters		
Clearance(11KV To 220KV)	The earth wire sag shall be not more than 90 percent of the corresponding sag of power conductor under still air conditions for the entire specified temperature range		
Clearance(11KV To 220KV)	Line Voltage(KV) 33KV 66KV	Spacing between P-E (m) 1.5meter 3.0meter	

	110KV 132KV 220KV	4.5meter 6.1meter 8.5meter
Earthing(11KV To 220KV)	All metal supports and all reinforced and prestressed cement concrete supports of overhead lines and metallic fittings attached thereto, shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected with earth ordinarily at 3 points in every kilometer, the spacing between the points being as nearly equidistant as possible. Alternatively, each support and metallic fittings attached thereto shall be efficiently earthed.	
Earthing(11KV To 220KV)	Each stay-wire shall be similarly earthed unless an insulator has been placed in it at a height not less than 3.0 meters from the ground	
Tower Height (up to 400KV)	The transmission lines and transmission line structures of height 45 m and above shall be notified to the Directorate of Flight Safety (DFS), Air Headquarters (Air HQ), New Delhi.	
Tower Height (up to 400KV)	For construction of any transmission line/structure or a portion thereof, falling within a radius of 20 km around the Defence aerodromes and air to firing ranges provisions of the Aircraft Act 1934, Section 9A as amplified by the associated Gazette Notification SO 988 Part II, Section 3,	
Tower Height (up to 400KV)	Within a radius of 10 km around aerodromes and air to ground firing ranges, all transmission lines and structures of height 45 meters or more shall be provided with day and night visual aids.	
Line Marker (up to 400KV)	Line Markers :Colored globules of 40-50 cm diameter made of reinforced fiber glass or any other suitable material, weighing not more than 4.5 kg each with suitable clamping arrangement and drainage holes shall be installed on the earth wire(s) in such a manner that the top of the marker is not below the level of the earth wire. Up to 400-metre span, one globule shall be provided in the middle of the span on the highest earth wire. In case of double earth wires, the globule may be provided on any one of them. For span greater than 400-metres, one additional globule may be provided for every additional 200-metre span or part thereof. Half orange and half white colored globule should be used.	
Structure Marking (up to 400KV)	Structure Marking: The structure portion excluding cross-arms above 45 m height shall be painted in alternate bands of international orange and white colours. The bands shall be perpendicular to the vertical axis and the top and bottom bands shall be orange. There shall be an odd number of bands. The maximum height of each band shall be 5 m.	
Span(up to 400KV)	Minimum ground clearance from lowest point of power conductor shall be 8 840 mm.	
Span(up to 400KV)	Minimum mid-span vertical clearance between power conductor and ground wire in still air at normal design span shall be 9 000 mm.	
Clearance (up to 400KV)	Vertical clearances above Railway Track : 220KV To 400KV =19.3 Meter	
Shield Angle (400KV)	For 440KV :Shielding Angle= 20°	
Clearance (400KV)	For 440KV :Maximum Length of Suspension Strings from Shackle Attachment at Hanger to Centre Line of Conductor =3 850 mm	
Clearance (400KV)	For 440KV :Maximum Length of Tension Strings from Tower Attachment to Compression Dead-End Attachment=5600mm	
Clearance (400KV)	For 440KV :Minimum Ground Clearance from Lowest Point of Power Conductor=8400mm	
Clearance (400KV)	For 440KV :Minimum Mid-Span Vertical Clearance Between Power Conductor end Ground Wire in Still Air=9000mm	
Clearance (400KV)	For 440KV :Right-of-way and transport requirements of maintenance, the following right-of-way width for 400 kV lines are recommended: Single/Double Circuit=50meter	
Clearance (400KV)	For 400KV Road Crossing: At all important crossings, the towers shall be fitted with normal suspension or tension insulator strings depending on the type of towers but the ground clearance at the roads under maximum temperature and in still air shall be such that even with conductor bundle broken in adjacent span, the ground clearance of the conductor from the road surface shall not be less than 8.84 meters. At all national highways tension towers shall be used. The crossing span, however, shall not exceed 25 meters in any case.	

Phase-Phase-Neutral Conductor Clearance (As per IS:5613)		
Voltage	Description	Distance
Up to 650V	Horizontal "V" Shape Cross arm: (P-P(Street Light)-Neutral)	Phase to Neutral=750mm , Phase to Phase(Streetlight at Top of Pole)=325mm, Last Phase-Cross Arm end=80mm
650V to 11KV	Horizontal Cross arm: (P-P(Street Light)-N)	Phase-Phase=300mm, Phase-Phase(Street Ltg)=300mm, Phase-Neutral=300mm, Last Phase-Cross Arm end=80mm
Low and Medium Voltage Line	(Horizontal Configuration):	Less than 75cm Sag(P-P) =30 cm 76cm to 120 cm Sag (P-P)=45 cm 121cm to 145 cm Sag (P-P)=60 cm
Low and Medium Voltage Line	(Vertical Configuration):	Less than 70cm Sag(P-P) =20 cm 71cm to 100 cm Sag (P-P)=30 cm
High Voltage Line	(Horizontal Configuration):	Up to 120cm Sag(P-P) =40 cm 140cm to 225cm Sag (P-P)=65 cm Double Circuit on Same Pole at Different Level: Distance between two Circuit=120 cm

Min Overhead conductor Clearance (Up to 11KV) (As per IS:5613)	
Type of Crossing	Clearance
Across any street (Low Medium Voltage)	5.8 Meter
Across any street (High Voltage)	6.1 Meter
Along with street (Low Medium Voltage)	5.5 Meter
Along with street (High Voltage)	5.8 Meter
Line(Bare) erected elsewhere(Low &Medium Voltage)	4.6 Meter
Line(Bare) erected elsewhere(High Voltage)	4.6 Meter
Line(Insulated) erected elsewhere(Low &Medium Voltage)	4.0 Meter
Line(Insulated) erected elsewhere(High Voltage)	4.0 Meter
Line conductor from buildings(Low &Medium Voltage)	2.5 Meter
Line conductor from buildings(High Voltage)	3.7 Meter

Span of Overhead Conductor (As per IS:5613)		
System Voltage	Number Of Circuit	Span
33 KV (over Pole)	Single	90 Meter to 135 Meter
33 KV	Single	180 Meter to 305 Meter
33 KV	Double	180 Meter to 305 Meter
66 KV	Single	204 Meter to 305 Meter
66 KV	Double	240 Meter to 320 Meter
220 KV	Single	320 Meter to 380 Meter
220 KV	Double	320 Meter to 380 Meter

Clearance (11KV to 220KV) (As per IS:5613)			
Voltage	Number Of Circuit	P-P Vertical Clearance	P-P Horizontal Clearance
33KV	Single	1.5 Meter	1.5 Meter
33KV	Single/Double	1.5 Meter	1.5 Meter
66KV	Single/Double	2.0 Meter	3.5 Meter
110KV	Single/Double	3.2 Meter	5.5 Meter
220KV	Single/Double	4.9 Meter	8.4 Meter

Phase to Earth wire Clearance (As per IS:5613)	
Line Voltage(KV)	Spacing between P-E
33 KV	1.5 Meter
66 KV	3.0 Meter
110 KV	4.5 Meter
132 KV	6.1 Meter
220 KV	8.5 Meter

Cut-out on consumer's premises	The supplier shall provide a suitable cut-out in each conductor of every service-line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable within a consumer's premises, in an accessible position. Such cut-out shall be contained within an adequately enclosed fireproof receptacle.
	Where more than one consumer is supplied through a common service-line, each such consumer shall be provided with an independent cut-out at the point of junction to the common service
	Every electric supply line other than the earth or earthed neutral conductor of any system or the earthed external conductor of a concentric cable shall be protected by a suitable cut-out by its owner
	No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:(a) A link for testing purposes, or (b) A switch for use in controlling a generator or transformer.
Danger Notices:	The owner of every medium, high and extra-high voltage installation shall affix permanently in a conspicuous position a danger notice in Hindi or English and the local language of the district, with a sign of skull and Bones on
	(a) Every motor, generator, transformer and other electrical plant and equipment together with apparatus used for controlling or regulating the same
	(b) All supports of high and extra-high voltage overhead lines which can be easily climb-upon without the aid of ladder or special appliances.
Cables :	Flexible cables shall not be used for portable or transportable motors, generators, transformer rectifiers, electric drills, electric sprayers, welding sets or any other portable or transportable apparatus unless they are heavily insulated and adequately protected from mechanical injury.
	Where the protection is by means of metallic covering, the covering shall be in metallic connection with the frame of any such apparatus and earth.
	The cables shall be three core type and four-core type for portable and transportable apparatus working on single phase and three phases supply respectively and the wire meant to be used for ground connection shall be easily Identifiable
	Where A.C. and D.C. circuits are installed on the same support they shall be so arranged and protected that they shall not come into contact with each other when live.
Safety:	Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places in every generating station with capacity of 5 MW and above and enclosed sub-station with transformation capacity of 5 MVA and above for use in the event of fire or smoke.
	Provide that where more than one generator with capacity of 5 MW and above is installed in a power station, each generator would be provided with at least two separate gas masks in accessible and conspicuous position.
High Voltage Equipments installations	High Voltage equipments shall have the IR value as the Indian Standard.
	At a pressure of 1000 V applied between each live conductor and earth for a period of one minute the insulation resistance of HV installations shall be at least 1 Mega ohm Medium and Low Voltage Installations- At a pressure of 500 V applied between each live conductor and earth for a period of one minute, the insulation resistance of medium and low voltage installations shall be at least 1 Mega ohm
switchboard	A clear space of not less than 1 meter in width shall be provided in front of the switchboard;
	If there are any attachments or bare connections at the back of the switchboard, the space (if any) behind the switchboard shall be either less than 20 centimetres or more than 75 centimetres in width, measured from the farthest outstanding part of any attachment or conductor;
	If the space behind the switchboard exceeds 75 centimetres in width, there shall

	be a passage-way from either end of the switchboard clear to a height of 1.8 meters.
Declared voltage	In the case of low or medium voltage, by more than 6 per cent, or In the case of high voltage, by more than 6 per cent on the higher side or by more than 9 per cent on the lower side, or In the case of extra-high voltage, by more than 10 per cent on the higher side or by more than 12.5 per cent on the lower side
Declared frequency	Except with the written consent of the consumer or with the previous sanction of the State Government a supplier shall not permit the frequency of an alternating current supply to vary from the declared frequency by more than 3 per cent
Meters, maximum demand indicators and other apparatus on consumer's premises	Any meter or maximum demand indicator or other apparatus placed upon a consumer's premises in accordance with section 26 shall be of appropriate capacity and shall be deemed to be correct if its limits of error are within the limits specified in the relevant Indian Standard Specification and where no such specification exists, the limits of error do not exceed 3 per cent above or below absolute accuracy at all loads in excess of one tenth of full load and up to full load Connection with earth Neutral conductor of a phase, 4 wire system and the middle conductor of a 2 phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes of such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station. The earth electrodes so provided, may be interconnected to reduce earth resistance. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises
	In the case of a system comprising electric supply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.
	The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.
	All metal castings or metallic coverings containing or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connection throughout their whole length.
Transformer:	Where transformer or transformers are used, suitable provision shall be made, either by connecting with earth a point of the circuit at the lower voltage or otherwise, to guard against danger by reason of the said circuit becoming Accidentally charged above its normal voltage by leakage from or contact with the circuit at the higher voltage
	A sub-station or a switch station with apparatus having more than 2000 litres of oil shall not be located in the basement where proper oil draining arrangement cannot be provided.
	Where a sub-station or a switch station with apparatus having more than 2000 litres of oil is installed, whether indoor or out-doors, the following measures shall be taken, namely: The baffle walls 4[of 4 hour fire rating] shall be provided between the apparatus in the following cases: -
	(1) Single phase banks in the switch-yards of generating stations and substations, (2) On the consumer premises, (3) Where adequate clearance between the units is not available.
	Provisions shall be made for suitable oil soakpit and where use of more than 9000 litres of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tanks receptacles or chambers containing the same.
	The transformer shall be protected by an automatic high velocity water spray system or by carbon dioxide or BCF (Bromo chlorodi feuromethane) or BTM (Bromo tri fluoromethane) fixed installation system; and
	Oil filled transformers installed indoors shall not be on any floor above the ground or below the first basement.
	Isolators and the corresponding earthing switches shall be interlocked so that no earthing switch can be closed unless and until the corresponding isolator is in open position.
	When two or more transformers are operated in parallel, the system shall be so arranged as to trip the secondary breaker of a transformer in case the primary breaker of that transformer trips.

	Where two or more generators operate in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.
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	The transformer shall be protected by an automatic high velocity water spray system or by carbon dioxide or BCF (Bromo chlorodi feuromethane) or BTM (Bromo tri fluomethane) fixed installation system; and
	Oil filled transformers installed indoors shall not be on any floor above the ground or below the first basement.
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	Where two or more generators operate in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.
	Gas pressure type protection to given alarm and tripping shall be provided on all transformers of ratings 1000 KVA and above.
	Transformers of capacity 10 MVA and above shall be protected against incipient faults by differential protection; and All generators with rating of 100 KVA and above shall be protected against earth fault/leakage. All generators of rating 1000KVA and above shall be protected against faults within the generator winding using restricted earth fault protection or differential protection or by both
Connection with earth	In case of the delta connected system the neutral point shall be obtained by the insertion of a grounding transformer and current limiting resistance or impedance wherever considered necessary at the commencement of a system.
	Where the earthing lead and earth connection are used only in connection with earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage relays of a type and setting approved by the Inspector, the resistance shall not exceed 25 ohms.
Clearance above ground of the lowest conductor	No conductor of an overhead line, including service lines, erected across a street shall at any part thereof be at a height of less than: For low and medium voltage lines 5.8 meters (b) For high voltage lines 6.1 metres No conductor of an overhead line, including service lines, erected along any street shall at any part thereof be at a height less than: For low and medium voltage lines 5.5 metres For high voltage lines 5.8 metres No conductor of in overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than: For low, medium and high voltages lines=4.6 meters. For low, medium and high voltage=4.0 meters. For high voltage lines above 11,000 volts=5.2 meters. For extra-high voltage lines the clearance above ground shall not be less than 5.2 metres plus 0.3 meter for every 33,000 volts or part thereof by which the voltage of the line exceeds 33,000 volts.

Electrical Clearance As per IE Rules:

Voltage	Ground clearance	Sectional clearance
11KV	2.75 Meter	2.6 Meter
33KV	3.7 Meter	2.8 Meter
66KV	4.0 Meter	3.0 Meter
132KV	4.6 Meter	3.5 Meter
220KV	5.5 Meter	4.3 Meter
400KV	8.0 Meter	6.5 Meter

PART-2

Electrical Calculation:

Introduction:

- Number of Earthing Electrode and Earthing Resistance depends on the resistivity of soil and time for fault Current to pass through (1 sec or 3 sec). If we divide the area for earthing required by the area of one earth plate gives the no of Earth pits required.
- There is no general rule to calculate the exact no of earth Pits and Size of Earthing Strip, But discharging of leakage current is certainly dependent on the cross section area of the material so for any equipment **the earth strip size is calculated on the current to be carried by that strip**. First the leakage current to be carried is calculated and then size of the strip is determined.
- For most of the Electrical equipments like Transformer, DG set etc., the General concept is to have 4 no earth pits. 2 no's for body earthing With 2 separate strips with the pits shorted and 2 nos for Neutral with 2 separate strips with the pits shorted.
- **The Size of Neutral Earthing Strip should be Capable to carry neutral current of that equipment. The Size of Body Earthing should be capable to carry half of neutral Current.**
- For example for 100kVA transformer, the full load Current is around 140A. The strip connected should be Capable to carry at least 70A (neutral current) which means a Strip of GI 25x3mm should be enough to carry the current And for body a strip of 25x3 will do the needful.
- Normally we consider the strip size that is generally used as Standards. However a strip with lesser size which can carry a current of 35A can be used for body earthing. The reason for using 2 earth pits for each body and neutral and then shorting them is to serve as back up. If one strip gets Corroded and cuts the continuity is broken and the other Leakage current flows through the other run thereby completing the circuit. Similarly for panels the no of pits should be 2 nos. The size can be decided on the main incomer Breaker.
- For example if main incomer to breaker is 400A, then Body earthing for panel can have a strip size of 25x6 mm Which can easily carry 100A.
- Number of earth pits is decided by considering the total Fault current to be dissipated to the ground in case of Fault and the current that can be dissipated by each earth Pit.
- Normally the density of current for GI strip can be roughly 200 amps per square cm. Based on the length and dia of the Pipe used the Number of Earthing Pits can be finalized.

(1) Calculate Numbers of Pipe Earthing:**(A) Earthing Resistance & No of Rod for Isolated Earth Pit (Without Buried Earthing Strip):**

- **The Earth Resistance of Single Rod or Pipe electrode is calculated as per BS 7430:**
- **$R = \rho / 2 \times 3.14 \times L (\log_e (8 \times L / d) - 1)$**
- Where ρ = Resistivity of Soil (Ω Meter),
- L = Length of Electrode (Meter),
- D = Diameter of Electrode (Meter)
- **Example:** Calculate Isolated Earthing Rod Resistance. The Earthing Rod is 4 Meter Long and having 12.2mm Diameter, Soil Resistivity 500 Ω Meter.
- $R = 500 / (2 \times 3.14 \times 4) \times (\log_e (8 \times 4 / 0.0125) - 1) = 156.19 \Omega$.
- **The Earth Resistance of Single Rod or Pipe electrode is calculated as per IS 3040:**
- **$R = 100 \times \rho / 2 \times 3.14 \times L (\log_e (4 \times L / d))$**
- Where ρ = Resistivity of Soil (Ω Meter),
- L = Length of Electrode (cm),
- D = Diameter of Electrode (cm)
- **Example:** Calculate Number of CI Earthing Pipe of 100mm diameter, 3 Meter length. System has Fault current 50KA for 1 Sec and Soil Resistivity is 72.44 Ω -Meters.
- **Current Density At The Surface of Earth Electrode (As per IS 3043):**
- **Max. Allowable Current Density $I = 7.57 \times 1000 / (\sqrt{\rho \times t})$ A/m²**
- Max. Allowable Current Density = $7.57 \times 1000 / (\sqrt{72.44 \times 1}) = 889.419$ A/m²
- Surface area of one 100mm dia. 3 meter Pipe = $2 \times 3.14 \times r \times L = 2 \times 3.14 \times 0.05 \times 3 = 0.942$ m²
- **Max. current dissipated by one Earthing Pipe = Current Density x Surface area of electrode**
- Max. current dissipated by one Earthing Pipe = $889.419 \times 0.942 = 837.83$ A say **838 Amps**
- Number of Earthing Pipe required = Fault Current / Max. current dissipated by one Earthing Pipe.

- Number of Earthing Pipe required= $50000/838 = 59.66$ Say **60 No's.**
- **Total Number of Earthing Pipe required = 60 No's.**
- **Resistance of Earthing Pipe (Isolated) $R=100\rho/2\pi \times 3.14 \times L \times (\log_e (4XL/d))$**
- Resistance of Earthing Pipe (Isolated) $R=100 \times 72.44 / 2\pi \times 3.14 \times 300 \times (\log_e (4 \times 300 / 10)) = 7.99 \Omega/\text{Pipe}$
- Overall resistance of 60 No of Earthing Pipe = $7.99/60 = 0.133 \Omega$.

(B) Earthing Resistance & No of Rod for Isolated Earth Pit (With Buried Earthing Strip):

- **Resistance of Earth Strip(R) As per IS 3043= $\rho/2\pi \times 3.14 \times L \times (\log_e (2xLxL/wt))$.**
- **Example:** Calculate GI Strip having width of 12mm , length of 2200 Meter buried in ground at depth of 200mm, Soil Resistivity is 72.44 Ω -Meter
- Resistance of Earth Strip(R_e) = $72.44 / 2\pi \times 3.14 \times 2200 \times (\log_e (2 \times 2200 \times 2200 / .2 \times 0.12)) = 0.050 \Omega$
- From above Calculation Overall resistance of 60 No of Earthing Pipe (R_p) = **0.133 Ω** . And it connected to bury Earthing Strip. Here Net Earthing Resistance = $(R_p \times R_e) / (R_p + R_e)$
- Net Earthing Resistance = $(0.133 \times 0.05) / (0.133 + 0.05) = 0.036 \Omega$

(C) Total Earthing Resistance & No of Electrode for Group of Electrode (Parallel):

- In cases where a single electrode is not sufficient to provide the desired earth resistance, more than one electrode shall be used. The separation of the electrodes shall be about 4 M.
- The combined resistance of parallel electrodes is a complex function of several factors, such as the number and configuration of electrode the array.
- **The Total Resistance of Group of Electrode in different configurations as per BS 7430:**
- **$R_a = R (1 + \lambda a/n)$ Where $a = \rho / 2\pi \times 3.14 \times R \times S$**
- Where S= Distance between adjustment Rod (Meter),
- λ =Factor Given in Table,
- n= Number of Electrode,
- ρ =Resistivity of Soil (Ω Meter),
- R=Resistance of Single Rod in Isolation (Ω)

Factors for parallel electrodes in line (BS 7430)	
Number of electrodes (n)	Factor (λ)
2	1.0
3	1.66
4	2.15
5	2.54
6	2.87
7	3.15
8	3.39
9	3.61
10	3.8

- For electrodes equally spaced around a hollow square, e.g. around the perimeter of a building, the equations given above are used with a value of λ taken from following Table.
- For three rods placed in an equilateral triangle, or in an L formation, a value of $\lambda = 1.66$ may be assumed.

Factors for electrodes in a hollow square(BS 7430)	
Number of electrodes (n)	Factor (λ)
2	2.71
3	4.51
4	5.48
5	6.13
6	6.63
7	7.03
8	7.36
9	7.65
10	7.9
12	8.3
14	8.6
16	8.9

18	9.2
20	9.4

- For Hollow Square Total Number of Electrode (N) = (4n-1).
- The rule of thumb is that rods in parallel should be spaced at least twice their length to utilize the full benefit of the additional rods.
- If the separation of the electrodes is much larger than their lengths and only a few electrodes are in parallel, then the resultant earth resistance can be calculated using the ordinary equation for resistances in parallel.
- In practice, the effective earth resistance will usually be higher than Calculation. Typically, a 4 spike array may provide an improvement 2.5 to 3 times. An 8 spike array will typically give an improvement of maybe 5 to 6 times.
- The Resistance of Original Earthing Rod will be lowered by Total of 40% for Second Rod, 60% for third Rod, 66% for forth Rod
- **Example:** Calculate Total Earthing Rod Resistance of 200 Number arranges in Parallel having 4 Meter Space of each and if it connects in Hollow Square arrangement. The Earthing Rod is 4 Meter Long and having 12.2mm Diameter, Soil Resistivity 500 Ω .
- First Calculate Single Earthing Rod Resistance
- $R = 500 / (2 \times 3.14 \times 4) \times (\text{Loge } (8 \times 4 / 0.0125) - 1) = 136.23 \Omega$.
- Now Calculate Total Resistance of Earthing Rod of 200 Number in Parallel condition.
- $a = 500 / (2 \times 3.14 \times 136 \times 4) = 0.146$
- $R_a (\text{Parallel in Line}) = 136.23 \times (1 + 10 \times 0.146 / 200) = 1.67 \Omega$.
- If Earthing Rod is connected in Hollow Square than Rod in Each side of Square is $200 = (4n-1)$ so $n = 49$ No.
- $R_a (\text{In Hollow Square}) = 136.23 \times (1 + 9.4 \times 0.146 / 200) = 1.61 \Omega$.

(2) Calculate Numbers of Plate Earthing:

- The Earth Resistance of Single Plate electrode is calculated as per IS 3040:
- **$R = \rho / A \sqrt{3.14/A}$**
- Where ρ = Resistivity of Soil (Ω Meter),
- A = Area of both side of Plate (m^2),
- **Example:** Calculate Number of CI Earthing Plate of 600x600 mm, System has Fault current 65KA for 1 Sec and Soil Resistivity is 100 Ω -Meters.
- **Current Density At The Surface of Earth Electrode (As per IS 3043):**
- **Max. Allowable Current Density $I = 7.57 \times 1000 / (\sqrt{\rho \times t})$ A/m²**
- Max. Allowable Current Density = $7.57 \times 1000 / (\sqrt{100 \times 1}) = 757$ A/m²
- Surface area of both side of single 600x600 mm Plate = $2 \times l \times w = 2 \times 0.06 \times 0.06 = 0.72$ m²
- **Max. current dissipated by one Earthing Plate = Current Density x Surface area of electrode**
- Max. current dissipated by one Earthing Plate = $757 \times 0.72 = 545.04$ Amps
- **Resistance of Earthing Plate (Isolated) $(R) = \rho / A \sqrt{3.14/A}$**
- Resistance of Earthing Plate (Isolated) $(R) = 100 / 0.72 \times \sqrt{3.14 / 0.72} = 290.14 \Omega$
- Number of Earthing Plate required = Fault Current / Max. current dissipated by one Earthing Pipe.
- Number of Earthing Plate required = $65000 / 545.04 = 119$ No's.
- **Total Number of Earthing Plate required = 119 No's.**
- Overall resistance of 119 No of Earthing Plate = $290.14 / 119 = 2.438 \Omega$.

Calculating Resistance of Bared Earthing Strip / Wire:

1) Calculation for earth resistance of buried Strip/Conductor (As per IEEE):

- The Earth Resistance of Single Strip of Rod buried in ground is
- **$R = \rho / P \times 3.14 \times L (\log_e (2 \times L \times L / W \times h) + Q)$**
- Where ρ = Resistivity of Soil (Ω Meter),
- h = Depth of Electrode (Meter),
- w = Width of Strip or Diameter of Conductor (Meter)
- L = Length of Strip or Conductor (Meter)
- P and Q are Coefficients

2) Calculation for earth resistance of buried Strip/Conductor (As per IS 3043):

- The Earth Resistance of Single Strip of Rod buried in ground is
- **$R = 100 \rho / 2 \times 3.14 \times L (\log_e (2 \times L \times L / W \times t))$**
- Where ρ = Resistivity of Soil (Ω Meter),
- L = Length of Strip or Conductor (cm)
- w = Width of Strip or Diameter of Conductor (cm)
- t = Depth of burial (cm)
- **Example:** Calculate Earthing Resistance of Earthing strip/wire of 36mm Diameter, 262 meter long buried at 500mm depth in ground, soil Resistivity is 65 Ω Meter.
- Here R = Resistance of earth rod in W.
- ρ = Resistivity of soil (Ω Meter) = 65 Ω Meter
- L = length of the rod (cm) = 262m = 26200 cm
- d = internal diameter of rod (cm) = 36mm = 3.6cm
- h = Depth of the buried strip/rod (cm) = 500mm = 50cm
- Resistance of Earthing Strip/Conductor (R) = $\rho / 2 \times 3.14 \times L (\log_e (2 \times L \times L / W \times t))$
- Resistance of Earthing Strip/Conductor (R) = $65 / 2 \times 3.14 \times 26200 \times \ln(2 \times 26200 \times 26200 / 3.6 \times 50)$
- Resistance of Earthing Strip/Conductor (R) = **1.7 Ω**

Calculate Minimum Cross Section area of Earthing Conductor:

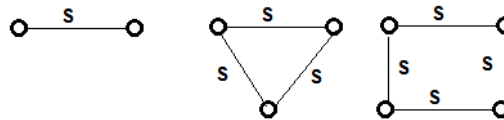
- **Cross Section Area of Earthing Conductor As per IS 3043 (A) = $(I_f \times \sqrt{t}) / K$**
- Where t = Fault current Time (Second).
- K = Material Constant.
- **Example:** Calculate Cross Section Area of GI Earthing Conductor for System has 50KA Fault Current for 1 second. Corrosion will be 1.0 % Per Year and No of Year for Replacement is 20 Years.
- Cross Section Area of Earthing Conductor (A) = $(I_f \times \sqrt{t}) / K$
- Here I_f = 50000 Amp
- T = 1 Second
- K = 80 (Material Constant, For GI=80, copper K =205, Aluminium K =126).
- Cross Section Area of Earthing Conductor (A) = $(50000 \times 1) / 80$
- Cross Section Area of GI Earthing Conductor (A) = 625 Sq.mm
- Allowance for Corrosion = 1.0 % Per Year & Number of Year before replacement say = 20 Years
- Total allowance = $20 \times 1.0\% = 20\%$
- Safety factor = 1.5
- Required Earthing Conductor size = Cross sectional area $\times$ Total allowance $\times$ Safety factor
- Required Earthing Conductor size = 1125 Sq.mm say 1200 Sq.mm
- **Hence, Considered 1Nox12x100 mm GI Strip or 2Nox6 x 100 mm GI Strips**

Thumb Rule for Calculation of Earth Resistance & Number of Earthing Rod:

- The approximate earth resistance of the Rod/Pipe electrodes can be calculated by
- **Earth Resistance of the Rod/Pipe electrodes $R = K \times \rho / L$**
- Where ρ = Resistivity of earth in Ohm-Meter
- L = Length of the electrode in Meter.
- d = Diameter of the electrode in Meter.
- $K = 0.75$ if $25 < L/d < 100$.
- $K = 1$ if $100 < L/d < 600$
- $K = 1.2$ if $600 < L/d < 3000$
- **Number of Electrode if find out by Equation of $R(d) = (1.5/N) \times R$**
- Where $R(d)$ = Desired earth resistance
- R = Resistance of single electrode
- N = No. of electrodes installed in parallel at a distance of 3 to 4 Meter interval.
- **Example:** Calculate Earthing Pipe Resistance and Number of Electrode for getting Earthing Resistance of 1 Ω , Soil Resistivity of ρ = 40, Length = 2.5 Meter, Diameter of Pipe = 38 mm.
- Here $L/d = 2.5 / 0.038 = 65.78$ so $K = 0.75$
- The Earth Resistance of the Pipe electrodes $R = K \times \rho / L = 0.75 \times 40 / 2.5 = 12 \Omega$
- One electrode the earth resistance is 12 Ω .
- To get Earth resistance of 1 Ω the total Number of electrodes required = $(1.5 \times 12) / 1 = 18$ No

Calculating Resistance & Number of Earthing Rod:

- **Reference:** As per EHV Transmission Line Reference Book page: 290 and Electrical Transmission & Distribution Reference Book Westinghouse Electric Corporation, Section-I Page: 570-590.
- **Earthing Resistance of Single Rods:** $R = \frac{\rho x [\ln (2L/a) - 1]}{2 \times 3.14 \times L}$
- **Earthing Resistance of Parallel Rods:** $R = \frac{\rho x [\ln (2L/A)]}{2 \times 3.14 \times L}$
- Where L = length of rod in ground Meter,
- a = radius of rod Meter
- ρ = ground resistivity, ohm- Meter
- $A = \sqrt{(axS)}$
- S = Rod separation Meter



Earthing Rod Arrangement

Factor affects on Ground resistance:

- The NEC code requires a minimum ground electrode length of 2.5 meters (8.0 feet) to be in contact with the soil. But, there are some factor that affect the ground resistance of a ground system:
- **Length / Depth of the ground electrode:** double the length, reduce ground resistance by up to 40%.
- **Diameter of the ground electrode:** double the diameter, lower ground resistance by only 10%.
- **Number of ground electrodes:** for increased effectiveness, space additional electrodes at least equal to the depth of the ground electrodes.
- **Ground system design:** single ground rod to ground plate.

The GI Earthing Conductor sizes for various Equipments:

No	Equipments	Earth Strip Size
1	HT switchgear, structures, cable trays & fence, rails, gate and steel column	55 X 6 mm (GI)
2	Lighting Arrestor	25 X 3 mm (Copper)
3	PLC Panel	25 X 3 mm (Copper)
4	DG & Transformer Neutral	50X6 mm (Copper)
5	Transformer Body	50X6 mm (GI)
6	Control & Relay Panel	25 X 6 mm (GI)
7	Lighting Panel & Local Panel	25 X 6 mm (GI)
8	Distribution Board	25 X 6 mm (GI)
9	Motor up to 5.5 kw	4 mm ² (GI)
10	Motor 5.5 kw to 55 kw	25 X 6 mm (GI)
11	Motor 22 kw to 55 kw	40 X 6 mm (GI)
12	Motor Above 55 kw	55 X 6 mm (GI)

Selection of Earthing System:

Installations/ Isc Capacity	IR Value Required	Soil Type/ Resistivity	Earth System
House hold earthing/3kA	8 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Single Electrode
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
Commercial premises, Office / 5kA	2 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
Transformers, substation earthing, LT line equipment/ 15kA	less than 1 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
LA, High current	less than	Normal Soil/ up to 50 ohm-meter	Single Electrode

Equipment./ 50kA	1 Ω	Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes
PRS, UTS, RTUs, Data processing centre etc./5KA	less than 0.5 Ω	Normal Soil/ up to 50 ohm-meter	Single Electrode
		Sandy Soil/ between 50 to 2000 ohm- meter	Multiple Electrodes
		Rocky Soil/ More than 2000 ohm- meter	Multiple Electrodes

Size of Earthing Conductor:

- Ref IS 3043 & Handbook on BS 7671: The IEE Wiring Regulations by Trevor E. Marks.

Size of Earthing Conductor		
Area of Phase Conductor S (mm ²)	Area of Earthing conductor (mm ²) When It is Same Material as Phase Conductor	Area of Earthing conductor (mm ²) When It is Not Same Material as Phase Conductor
$S < 16 \text{ mm}^2$	S	$SX(k_1/k_2)$
$16 \text{ mm}^2 < S < 35 \text{ mm}^2$	16 mm ²	$16X(k_1/k_2)$
$S > 35 \text{ mm}^2$	$S/2$	$SX(k_1/2k_2)$
K ₁ is value of Phase conductor, k ₂ is value of earthing conductor		
Value of K for GI=80, Alu=126, Cu=205 for 1 Sec		

Standard Earthing Strip/Plate/Pipe/wire Weight:

GI Earthing Strip:

Size (mm ²)	Weight
20 x 3	500 gm Per meter
25 x 3	600 gm Per meter
25 x 6	1/200 Kg Per meter
32 x 6	1/600 Kg Per meter
40 x 6	2 Kg Per meter
50 x 6	2/400 Kg Per meter
65 x 10	5/200 Kg Per meter
75 x 12	7/200 Kg Per meter

GI Earthing Plate:

Plate	Weight
600 x 600 x 3 mm	10 Kg App.
600 x 600 x 4 mm	12 Kg App.
600 x 600 x 5 mm	15 Kg App.
600 x 600 x 6 mm	18 Kg App.
600 x 600 x 12 mm	36 Kg App.
1200 x 1200 x 6 mm	70 Kg App.
1200 x 1200 x 12 mm	140 Kg App.

GI Earthing Pipe:

Pipe	Weight
3 meter Long BISE	5 Kg App.
3 meter r Long BISE	9 Kg App.
4.5 meter (15' Long BISE)	5 Kg App.
4.5 meter (15' Long BISE)	9 Kg App.
4.5 meter (15' Long BISE)	14 Kg App

GI Earthing Wire:

Plate	Weight
6 Swg	5 meter in 1 Kg
8 Swg	9 meter in 1 Kg

NEC Code 430.22 (Size of Cable for Single Motor):

- Size of Cable for Branch circuit which has Single Motor connection is **125% of Motor Full Load Current Capacity**.
- **Example:** what is the minimum rating in amperes for Cables supplying 1 No of 5 hp, 415-volt, 3-phase motor at 0.8 Power Factor. Full-load currents for 5 hp = 7Amp.
- **Min Capacity of Cable= (7X125%) =8.75 Amp.**

NEC Code 430.6(A) (Size of Cable for Group of Motors or Elect. Load).

- Cables or Feeder which is supplying more than one motors other load(s), shall have an ampacity not less than 125 % of the full-load current rating of the highest rated motor plus the sum of the full-load current ratings of all the other motors in the group, as determined by 430.6(A).
- For Calculating minimum Ampere Capacity of Main feeder and Cable is **125% of Highest Full Load Current + Sum of Full Load Current of remaining Motors**.
- **Example:** what is the minimum rating in amperes for Cables supplying 1 No of 5 hp, 415-volt, 3-phase motor at 0.8 Power Factor, 1 No of 10 hp, 415-volt, 3-phase motor at 0.8 Power Factor, 1 No of 15 hp, 415-volt, 3-phase motor at 0.8 Power Factor and 1 No of 5hp, 230-volt, single-phase motor at 0.8 Power Factor?
- Full-load currents for 5 hp = 7Amp.
- Full-load currents for 10 hp = 13Amp.
- Full-load currents for 15 hp = 19Amp.
- Full-load currents for 10 hp (1 Ph) = 21Amp.
- Here Capacity wise Large Motor is 15 Hp but Highest Full Load current is 21Amp of 5hp Single Phase Motor so 125% of Highest Full Load current is $21 \times 125\% = 26.25 \text{ Amp}$
- **Min Capacity of Cable= (26.25+7+13+19) =65.25 Amp.**

NEC Code 430.24 (Size of Cable for Group of Motors or Electrical Load).

- As specified in 430.24, conductors supplying two or more motors must have an ampacity not less than 125 % of the full-load current rating of the highest rated motor + the sum of the full-load current ratings of all the other motors in the group or on the same phase.
- It may not be necessary to include all the motors into the calculation. It is permissible to balance the motors as evenly as possible between phases before performing motor-load calculations.
- **Example:** what is the minimum rating in amperes for conductors supplying 1 No of 10 hp, 415-volt, 3-phase motor at 0.8 P.F and 3 No of 3 hp, 230-volt, single-phase motors at 0.8 P.F.
- The full-load current for a 10 hp, 415-volt, 3-phase motor is **13** amperes.
- The Full-load current for single-phase 3 hp motors is **12 amperes**.
- Here for Load Balancing one Single Phase Motor is connected on R Phase Second in B Phase and third is in Y Phase. Because the motors are balanced between phases, the full-load current on each phase is 25 amperes ($13 + 12 = 25$).
- Here multiply 13 amperes by 125 % ($13 \times 125\% = 16.25 \text{ Amp}$). Add to this value the full-load currents of the other motor on the same phase ($16.25 + 12 = 28.25 \text{ Amp}$).
- The minimum rating in amperes for conductors supplying these motors is 28 amperes.

NEC 430/32 Size of Overload Protection for Motor:

- Overload protection (Heater or Thermal cut out protection) would be a device that thermally protects a given motor from damage due to heat when loaded too heavy with work.
- All continuous duty motors rated more than 1HP must have some type of an approved overload device.
- An overload shall be installed on each conductor that controls the running of the motor rated more than one horsepower. NEC 430/37 plus the grounded leg of a three phase grounded system must contain an overload also. This Grounded leg of a three phase system is the only time you may install an overload or over – current device on a grounded conductor that is supplying a motor.
- To Find the motor running overload protection size that is required, you must multiply the F.L.C. (full load current) with the minimum or the maximum percentage ratings as follows;

Maximum Overload

- Maximum overload = F.L.C. (full load current of a motor) X allowable % of the maximum setting of an overload,
- 130% for motors, found in NEC Article 430/34.
- Increase of 5% allowed if the marked temperature rise is not over 40 degrees or the marked service factor is not less than 1.15.

Minimum Overload

- Minimum Overload = F.L.C. (full load current of a motor) X allowable % of the minimum setting of an overload,
- 115% for motors found in NEC Article 430/32/B/1.
- Increase of 10% allowed to 125% if the marked temperature rise is not over 40 degrees or the marked service factor is not less than 1.15

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NEC, Code 450.4: (Calculate over current Protection on the Primary)

- According to NEC 450.4, "each transformer 600 volts, nominal, or less shall be protected by an individual over current device installed in series with each ungrounded input conductor.
- Such over current device shall be rated or set at not more than **125%** of the rated full-load input current of the auto transformer.
- Further, according to NEC Table 450.3(B), if the primary current of the transformer is less than 9 amps, an over current device rated or set at not more than **167%** of the primary current shall be permitted. Where the primary current is less than 2 amps, an over current device rated or set at not more than **300%** shall be permitted.
- Example: Decide Size of circuit breaker (over current protection device) is required on the primary side to protect a **75kva** 440v-230v 3Ø transformer.
- $75\text{kva} \times 1,000 = 75,000\text{va}$
- $75,000\text{va} / (440\text{V} \times \sqrt{3}) = 98.41 \text{ amps.}$
- The current (amps) is more than 9 amps so use 125% rating.
- $123 \text{ amps} \times 1.25 = 112.76 \text{ amps}$
- Use **125amp 3-pole circuit breaker** (the next highest fuse/fixed-trip circuit breaker size per NEC 240.6).
- The over current device on the primary side must be sized based on the transformer KVA rating and not sized based on the secondary load to the transformer.

NEC, Code 450.3B:(Calculate over current Protection on the Secondary)

- According to NEC Table 450.3(B), where the secondary current of a transformer is 9 amps or more and **125%** of this current does not correspond to a standard rating of a fuse or circuit breaker, the next higher standard rating shall be required. Where the secondary current is less than 9 amps, an over current device rated or set at not more than **167%** of the secondary current shall be permitted.
- Example: Decide Size of circuit breaker (over current protection device) is required on the *secondary* side to protect a **75kva** 440v-230v 3Ø transformer.
- We have Calculate the secondary over current protection based on the size of the transformer, not the total connected load.
- $75\text{kva} \times 1,000 = 75,000\text{va}$
- $75,000\text{va} / (230\text{V} \times \sqrt{3}) = 188.27 \text{ amps.}$ (Note: 230V 3Ø is calculated)
- The current (amps) is more than 9 amps so use 125% rating.
- $188.27 \text{ amps} \times 1.25 = 235.34 \text{ amps.}$
- Therefore: Use **300amp 3-pole circuit breaker** (per NEC 240.6).

NEC, Section 450-3(a):(Transformers over 600 volts, Nominal)

- For primary and secondary protection with a transformer impedance of 6% or less, the primary fuse must not be larger than **300%** of primary Full Load Amps (F.L.A.) and the secondary fuse must not be larger than **250%** of secondary F.L.A.

NEC, Section 450-3(b):(Transformers over 600 volts, Nominal)

- For primary protection only, the primary fuse must not be larger than **125%** of primary F.L.A.
- For primary and secondary protection the primary feeder fuse must not be larger than 250% of primary F.L.A. if the secondary fuse is sized at **125%** of secondary F.L.A.

NEC, Section 450-3(b):(Potential (Voltage) Transformer)

- These shall be protected with primary fuses when installed indoors or enclosed

NEC, Section 230-95(Ground-Fault Protection of Equipment).

- This section show that 277/480 volt “wye” only connected services, **1000 amperes** and larger, must have ground fault protection in addition to conventional over current protection.
- The ground fault relay (or sensor) must be set to pick up ground faults which are 1200 amperes or more and actuate the main switch or circuit breaker to disconnect all ungrounded conductors of the faulted circuit.

NEC, Section 110-9 – Interrupting Capacity.

- Any device used to protect a low voltage system should be capable of opening all fault currents up to the maximum current available at the terminal of the device.
- Many over current devices, today, are used in circuits that are above their interrupting rating.
- By using properly sized Current Limiting Fuses ahead of these devices, the current can usually be limited to a value lower than the interrupting capacity of the over current devices.

NEC, Section 110-10 – Circuit Impedance and Other Characteristics.

- The over current protective devices, along with the total impedance, the component short-circuit withstand ratings, and other characteristics of the circuit to be protected shall be so selected and coordinated so that the circuit protective devices used to clear a fault will do so without the occurrence of extensive damage to the electrical components of the circuit.
- In order to do this we must select the over current protective devices so that they will open fast enough to prevent damage to the electrical components on their load side.

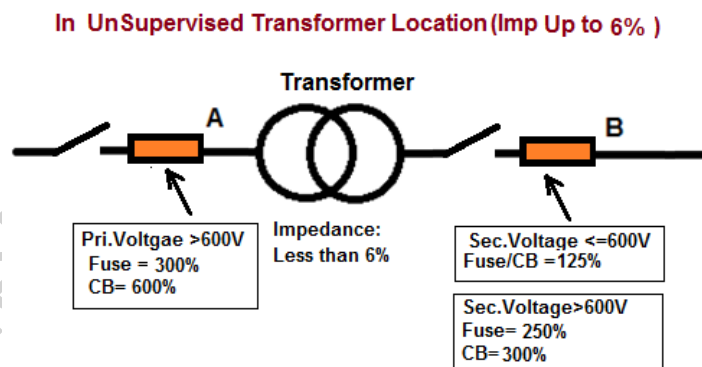
Chapter: 47 Calculate Transformer O/C Protection (NEC 450.3)

Introduction:

- The over current protection required for transformers is consider for Protection of Transformer only. Such over current protection will not necessarily protect the primary or secondary conductors or equipment connected on the secondary side of the transformer.
- When voltage is switched on to energize a transformer, the transformer core normally saturates. This results in a large inrush current which is greatest during the first half cycle (approximately 0.01 second) and becomes progressively less severe over the next several cycles (approximately 1 second) until the transformer reaches its normal magnetizing current.
- To accommodate this inrush current, fuses are often selected which have time-current withstand values of at least 12 times transformer primary rated current for 0.1 second and 25 times for 0.01 second. Some small dry-type transformers may have substantially greater inrush currents.
- To avoid using oversized conductors, over current devices should be selected at about 110 to 125 percent of the transformer full-load current rating. And when using such smaller over current protection, devices should be of the time-delay type (on the primary side) to compensate for inrush currents which reach 8 to 10 times the full-load primary current of the transformer for about 0.1 s when energized initially.
- Protection of secondary conductors has to be provided completely separately from any primary-side protection.
- A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons will monitor and service the transformer installation.
- Over current protection for a transformer on the primary side is typically a circuit breaker. In some instances where there is not a high voltage panel, there is a fused disconnect instead.
- It is important to note that the over current device on the primary side must be sized based on the transformer KVA rating and not sized based on the secondary load to the transformer

Over current Protection of Transformers (dry-type, liquid-filled) > 600 V (NEC 450.3 (A))

1) Unsupervised Location of Transformer (Transformer Impedance <6%)

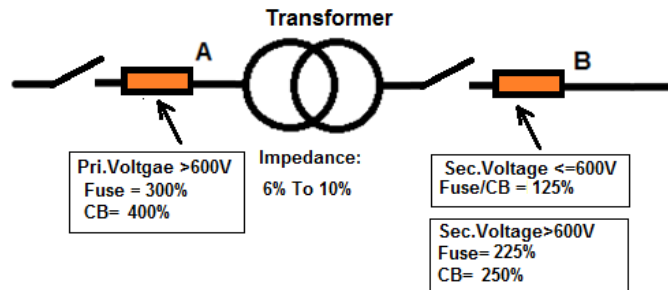


- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A = 300% of Pri. Full Load Current or Next higher Standard size. or
- Rating of Pri. Circuit Breaker at Point A = 600% of Pri. Full Load Current or Next higher Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage ≤ 600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B = 125% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage > 600V):**
- Rating of Sec. Fuse at Point B = 250% of Sec. Full Load Current or Next higher Standard size. or
- Rating of Sec. Circuit Breaker at Point B = 300% of Sec. Full Load Current.

Example: 750KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 5%

- Full Load Current At Primary side= $750000/(1.732 \times 11000)=39A$
 - Rating of Primary Fuse = $3 \times 39A = 118A$, So Standard Size of Fuse =125A.
 - OR Rating of Primary Circuit Breaker = $6 \times 39A=236A$, So Standard Size of Circuit Breaker =250A.
 - Full Load Current at Secondary side= $750000/ (1.732 \times 415) =1043A$.
 - Rating of Secondary of Fuse / Circuit Breaker = $1.25 \times 1043A=1304A$, So Standard Size of Fuse =1600A.
- 2) Unsupervised of Transformer (Transformer Impedance 6% to 10 %)**

In UnSupervised Transformer Location (Imp 6% to 10%)



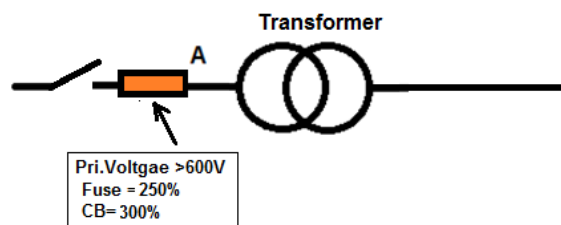
- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Primary Full Load Current or Next higher Standard size.
- Rating of Pri. Circuit Breaker at Point A= 400% of Primary Full Load Current or Next higher Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage ≤600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B= 125% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuse at Point B= 225% of Sec. Full Load Current or Next higher Standard size.
- Rating of Sec. Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next higher Standard size.

Example: 10MVA, 66KV/11KV 3Phase Transformer, Impedance of Transformer is 8%

- Full Load Current At Primary side= $10000000/(1.732 \times 66000)=87A$
- Rating of Pri. Fuse = $3 \times 87A = 262A$, So Next Standard Size of Fuse =300A.
- OR Rating of Pri. Circuit Breaker = $6 \times 87A=525A$, So Next Standard Size of Circuit Breaker =600A.
- Full Load Current at Secondary side= $10000000/ (1.732 \times 11000) =525A$.
- Rating of Sec. Fuse = $2.25 \times 525A=1181A$, So Next Standard Size of Fuse =1200A.
- OR Rating of Sec. Circuit Breaker = $2.5 \times 525A=1312A$, So Next Standard Size of Circuit Breaker =1600A.

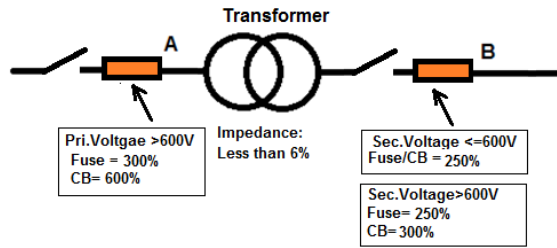
3) Supervised Location in Only Primary side of Transformer:

In Primary Supervised Transformer Location



- **Over Current Protection at Primary Side (Primary Voltage >600V):**
 - Rating of Pri. Fuse at Point A= 250% of Primary Full Load Current or Next higher Standard size.
 - Rating of Pri. Circuit Breaker at Point A= 300% of Primary Full Load Current or Next higher Standard size.
- 4) Supervised Location of Transformer (Transformer Impedance Up to 6%):**

In Supervised Transformer Location (Imp Up to 6%)



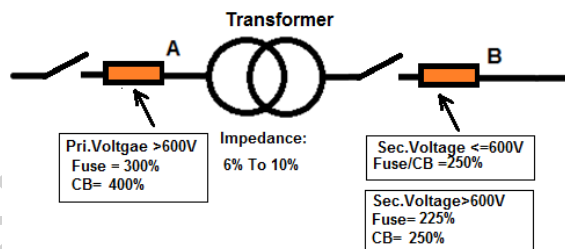
- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Pri. Full Load Current or Next Lower Standard size.
- Rating of Pri.Circuit Breaker at Point A= 600% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage ≤600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuse at Point B= 250% of Sec. Full Load Current or Next Lower Standard size.
- Rating of Sec.Circuit Breaker at Point B= 300% of Sec. Full Load Current or Next Lower Standard size.

Example: 750KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 5%

- Full Load Current At Primary side = $750000 / (1.732 \times 11000) = 39A$
- Rating of Primary Fuse = $3 \times 39A = 118A$, So Next Lower Standard Size of Fuse = 110A.
- OR Rating of Primary Circuit Breaker = $6 \times 39A = 236A$, So Next Lower Standard Size of Circuit Breaker = 225A.
- Full Load Current at Secondary side = $750000 / (1.732 \times 415) = 1043A$.
- Rating of Secondary of Fuse / Circuit Breaker = $2.5 \times 1043A = 2609A$, So Standard Size of Fuse = 2500A.

5) Supervised Location of Transformer (Transformer Impedance 6% to 10%):

In Supervised Transformer Location (Imp 6% to 10%)



- **Over Current Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 300% of Pri. Full Load Current or Next Lower Standard size.
- Rating of Pri.Circuit Breaker at Point A= 400% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage ≤600V):**
- Rating of Sec. Fuse / Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next higher Standard size.
- **Over Current Protection at Secondary Side (Secondary Voltage >600V):**
- Rating of Sec. Fuse at Point B= 225% of Sec. Full Load Current or Next Lower Standard size.
- Rating of Sec.Circuit Breaker at Point B= 250% of Sec. Full Load Current or Next Lower Standard size.

Example: 750KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 8%

- Full Load Current At Primary side = $750000 / (1.732 \times 11000) = 39A$
- Rating of Primary Fuse = $3 \times 39A = 118A$, So Next Lower Standard Size of Fuse = 110A.

- OR Rating of Primary Circuit Breaker = $4 \times 39A = 157A$, So Next Lower Standard Size of Circuit Breaker = $150A$.
- Full Load Current at Secondary side = $750000 / (1.732 \times 415) = 1043A$.
- Rating of Secondary of Fuse / Circuit Breaker = $2.5 \times 1043A = 2609A$, So Standard Size of Fuse = $2500A$.

Difference in Selection of C.B between Supervised Locations and Unsupervised Location

- Here we see two notable conditions while we select Fuse / Circuit Breaker in Supervised Location and Unsupervised Location.
- First notable Condition is Primary Over current Protection. In Unsupervised Location Fuse in Primary side is 300% of Primary Current or **Next Higher Standard size** and in Supervised Location is 300% of Primary Current or **Next Lower Standard size**. Here Primary Over current Protection is same in both conditions (300%) But Selecting Size of Fuse/Circuit Breaker is Different.
- Let's us Check with the Example for 750KVA, 11KV/415V 3Phase Transformer.
- Full Load Current At Primary side = $750000 / (1.732 \times 11000) = 39A$
- In Unsupervised Location: **Rating of Primary Fuse = $3 \times 39A = 118A$, So Next Higher Standard Size = $125A$**
- In Supervised Location: **Rating of Primary Fuse = $3 \times 39A = 118A$, So Next Lower Standard Size = $110A$**
- Second notable Condition is Secondary Over current Protection increased from 125% to 250% for unsupervised to Supervised Location.

Summary of over current Protection for more than 600V:

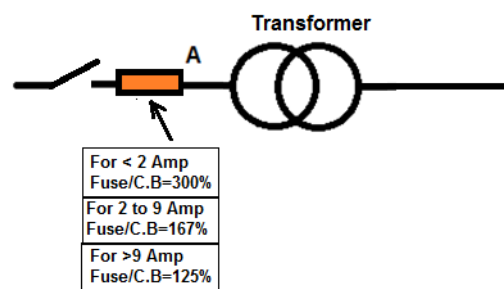
Maximum Rating of Over current Protection for Transformers more than 600 Volts						
Location Limitations	Transformer Rated Impedance	Primary Protection (More than 600 Volts)		Secondary Protection		
				More than 600 Volts		Less than 600 Volts
		Circuit Breaker	Fuse Rating	Circuit Breaker	Fuse Rating	C.B or Fuse
Any location	Less than 6%	600%(NH)	300%(NH)	300 % (NH)	250%(NH)	125%(NH)
	6% To 10%	400%(NH)	300%(NH)	250%(NH)	225%(NH)	125%(NH)
Supervised locations only	Any	300%(NH)	250%(NH)	Not required	Not required	Not required
	Less than 6%	600%	300%	300%	250%	250%
	6% To 10%	400%	300%	250%	225%	250%

NH: Next Higher Standard Size.

Over current Protection of Transformers (dry-type, liquid-filled) for < 600 V (NEC 450.3 (B))

1) Only Primary side Protection of Transformer:

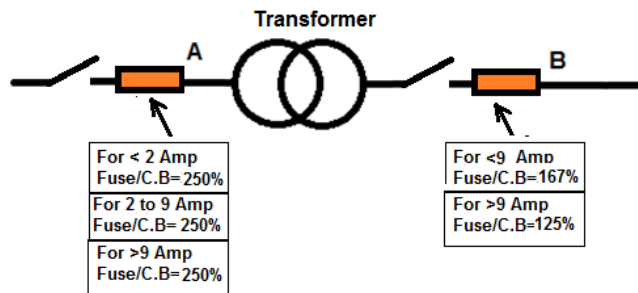
Primary side Protection of Transformer Less than 600 Volt



- **Over Current Protection at Primary Side (Less than 2A):**
- Rating of Pri. Fuse / C.B at Point A = 300% of Pri. Full Load Current or Next Lower Standard size.
- **Example:** 1KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side = $1000 / (1.732 \times 480) = 1A$

- Rating of Primary Fuse = $3 \times 1\text{A} = 3\text{A}$, So Next Lower Standard Size of Fuse = 3A .
 - **Over Current Protection at Primary Side (2A to 9A):**
 - Rating of Sec. Fuse / C.B at Point A = 167% of Pri. Full Load Current or Next Lower Standard size.
 - **Example:** 3KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side = $3000 / (1.732 \times 480) = 4\text{A}$
 - Rating of Primary Fuse = $1.67 \times 4\text{A} = 6\text{A}$, So Next Lower Standard Size of Fuse = 6A .
 - **Over Current Protection at Primary Side (More than 9A):**
 - Rating of Pri. Fuse / C.B at Point A = 125% of Pri. Full Load Current or Next Higher Standard size.
 - **Example:** 15KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side = $15000 / (1.732 \times 480) = 18\text{A}$
 - Rating of Primary Fuse = $1.25 \times 18\text{A} = 23\text{A}$, So Next Higher Standard Size of Fuse = 25A .
- 2) **Primary and Secondary side Protection of Transformer:**

Over Current Protection of Transformer Less than 600 Volt



- **Over Current Protection at Primary Side (Less than 2A):**
- Rating of Pri. Fuse / C.B at Point A = 250% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection at Primary Side (2A to 9A):**
- Rating of Sec. Fuse / C.B at Point A = 250% of Pri. Full Load Current or Next Lower Standard size.
- **Over Current Protection at Primary Side (More than 9A):**
- Rating of Pri. Fuse / C.B at Point A = 250% of Pri. Full Load Current or Lower Higher Standard size.
- **Example:** 25KVA, 480/230 3Phase Transformer, Full Load Current at Pri. Side = $125000 / (1.732 \times 480) = 30\text{A}$
- Rating of Primary Fuse = $2.50 \times 30\text{A} = 75\text{A}$, So Next Lower Standard Size of Fuse = 70A .
- **Over Current Protection at Secondary Side (Less than 9A):**
- Rating of Pri. Fuse / C.B at Point B = 167% of Sec. Full Load Current or Lower Standard size.
- **Example:** 3KVA, 480/230 3Phase Transformer, Full Load Current at Sec. Side = $3000 / (1.732 \times 230) = 8\text{A}$
- Rating of Primary Fuse = $1.67 \times 8\text{A} = 13\text{A}$, So Next Lower Standard Size of Fuse = 9A .
- **Over Current Protection at Secondary Side (More than 9A):**
- Rating of Pri. Fuse / C.B at Point A = 125% of Pri. Full Load Current or Higher Standard size.
- **Example:** 15KVA, 480/230 3Phase Transformer, Full Load Current at Sec. Side = $15000 / (1.732 \times 230) = 38\text{A}$
- Rating of Primary Fuse = $1.25 \times 38\text{A} = 63\text{A}$, So Next Higher Standard Size of Fuse = 70A .

Summary of over current Protection for Less than 600V:

Maximum Rating of Over current Protection for Transformers Less than 600 Volts					
Protection Method	Primary Protection			Secondary Protection	
	More than 9A	2A to 9A	Less than 2A	More than 9A	Less than 9A
Primary only protection	125%(NH)	167%	300%	Not required	Not required
Primary and secondary protection	250%	250%	250%	125%(NH)	167%

NH: Next Higher Standard Size.

Chapter: 48 Calculate Size of Contactor / Fuse / CB / OL

Relay of DOL Starter

- Calculate Size of each Part of DOL starter for The System Voltage 415V ,5HP Three Phase House hold Application Induction Motor ,Code A, Motor efficiency 80%,Motor RPM 750 ,Power Factor 0.8 , Overload Relay of Starter is Put before Motor.

Basic Calculation of Motor Torque & Current:

- Motor Rated Torque (Full Load Torque) = $5252 \times \text{HP} \times \text{RPM}$**
- Motor Rated Torque (Full Load Torque) = $5252 \times 5 \times 750 = 35 \text{ lb-ft.}$
- Motor Rated Torque (Full Load Torque) = $9500 \times \text{KW} \times \text{RPM}$**
- Motor Rated Torque (Full Load Torque) = $9500 \times (5 \times 0.746) \times 750 = 47 \text{ Nm}$
- If Motor Capacity is less than 30 KW than Motor Starting Torque is 3xMotor Full Load Current or 2X Motor Full Load Current.
- Motor Starting Torque = 3xMotor Full Load Current.**
- Motor Starting Torque = $3 \times 47 = 142 \text{ Nm.}$
- Motor Lock Rotor Current = $1000 \times \text{HP} \times \text{figure from below Chart} / 1.732 \times 415$**

Locked Rotor Current		
Code	Min	Max
A	1	3.14
B	3.15	3.54
C	3.55	3.99
D	4	4.49
E	4.5	4.99
F	5	5.59
G	6	6.59
H	7	7.99
I	8	8.99
K	9	9.99
L	10	11.19
M	11.2	12.49
N	12.5	13.99
P	14	15.99
R	16	17.99
S	18	19.99
T	20	22.39
U	22.4	
V		

- As per above chart Minimum Locked Rotor Current = $1000 \times 5 \times 1 / 1.732 \times 415 = 7 \text{ Amp}$
- Maximum Locked Rotor Current = $1000 \times 5 \times 3.14 / 1.732 \times 415 = 22 \text{ Amp.}$
- Motor Full Load Current (Line) = $\text{KW} \times 1000 / 1.732 \times 415$**
- Motor Full Load Current (Line) = $(5 \times 0.746) \times 1000 / 1.732 \times 415 = 6 \text{ Amp.}$
- Motor Full Load Current (Phase) = Motor Full Load Current (Line) / 1.732**
- Motor Full Load Current (Phase) = $6 / 1.732 = 4 \text{ Amp}$
- Motor Starting Current = 6 to 7xFull Load Current.**
- Motor Starting Current (Line) = $7 \times 6 = 42 \text{ Amp}$

(1) Size of Fuse:

Fuse as per NEC 430-52		
Type of Motor	Time Delay Fuse	Non-Time Delay Fuse
Single Phase	300%	175%
3 Phase	300%	175%
Synchronous	300%	175%
Wound Rotor	150%	150%
Direct Current	150%	150%

- Maximum Size of Time Delay Fuse = $300\% \times \text{Full Load Line Current.}$**
- Maximum Size of Time Delay Fuse = $300\% \times 6 = 18 \text{ Amp.}$
- Maximum Size of Non Time Delay Fuse = $175\% \times \text{Full Load Line Current.}$**

- Maximum Size of Non Time Delay Fuse = $1.75 \times 6 = 11$ Amp.

(2) Size of Circuit Breaker:

Circuit Breaker as per NEC 430-52		
Type of Motor	Instantaneous Trip	Inverse Time
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

- Maximum Size of Instantaneous Trip Circuit Breaker = $800\% \times \text{Full Load Line Current}$.**
- Maximum Size of Instantaneous Trip Circuit Breaker = $800\% \times 6 = 52$ Amp.
- Maximum Size of Inverse Trip Circuit Breaker = $250\% \times \text{Full Load Line Current}$.**
- Maximum Size of Inverse Trip Circuit Breaker = $250\% \times 6 = 16$ Amp.

(3) Thermal over Load Relay:

- Thermal over Load Relay (Phase):**
- Min Thermal Over Load Relay setting = $70\% \times \text{Full Load Current (Phase)}$**
- Min Thermal Over Load Relay setting = $70\% \times 4 = 3$ Amp
- Max Thermal Over Load Relay setting = $120\% \times \text{Full Load Current (Phase)}$**
- Max Thermal Over Load Relay setting = $120\% \times 4 = 4$ Amp
- Thermal over Load Relay (Line):**
- Thermal over Load Relay setting = $100\% \times \text{Full Load Current (Line)}$.**
- Thermal over Load Relay setting = $100\% \times 6 = 6$ Amp

(4) Size and Type of Contactor:

Application	Contactor	Making Cap
Non-Inductive or Slightly Inductive ,Resistive Load	AC1	1.5
Slip Ring Motor	AC2	4
Squirrel Cage Motor	AC3	10
Rapid Start / Stop	AC4	12
Switching of Electrical Discharge Lamp	AC5a	3
Switching of Electrical Incandescent Lamp	AC5b	1.5
Switching of Transformer	AC6a	12
Switching of Capacitor Bank	AC6b	12
Slightly Inductive Load in Household or same type load	AC7a	1.5
Motor Load in Household Application	AC7b	8
Hermetic refrigerant Compressor Motor with Manual O/L Reset	AC8a	6
Hermetic refrigerant Compressor Motor with Auto O/L Reset	AC8b	6
Control of Restive & Solid State Load with upto coupler Isolation	AC12	6
Control of Restive Load and Solid State with T/C Isolation	AC13	10
Control of Small Electro Magnetic Load (<72VA)	AC14	6
Control of Small Electro Magnetic Load (>72VA)	AC15	10

- As per above Chart
- Type of Contactor = AC7b**
- Size of Main Contactor = $100\% \times \text{Full Load Current (Line)}$.**
- Size of Main Contactor = $100\% \times 6 = 6$ Amp.
- Making/Breaking Capacity of Contactor = Value above Chart x Full Load Current (Line).**
- Making/Breaking Capacity of Contactor = $8 \times 6 = 52$ Amp.

Chapter: 49

Calculate Size of Contactor / Fuse / CB / OL Relay of Star-Delta Starter

- Calculate Size of each Part of Star-Delta starter for 10HP, 415 Volt Three Phase Induction Motor having Non Inductive Type Load, Code A, Motor efficiency 80%, Motor RPM 600, Power Factor 0.8. Also Calculate Size of Overload Relay if O/L Relay Put **in the windings** (overload is placed after the Winding Split into main and delta Contactor) or **in the line** (Putting the overload before the motor same as in DOL).

Basic Calculation of Motor Torque & Current:

- Motor Rated Torque (Full Load Torque) = $5252 \times \text{HP} \times \text{RPM}$**
- Motor Rated Torque (Full Load Torque) = $5252 \times 10 \times 600 = 88 \text{ lb-ft}$.
- Motor Rated Torque (Full Load Torque) = $9500 \times \text{KW} \times \text{RPM}$**
- Motor Rated Torque (Full Load Torque) = $9500 \times (10 \times 0.746) \times 600 = 119 \text{ Nm}$
- If Motor Capacity is less than 30 KW than Motor Starting Torque is 3x Motor Full Load Current or 2X Motor Full Load Current.
- Motor Starting Torque = 3x Motor Rated Torque (Full Load Torque).**
- Motor Starting Torque = $3 \times 119 = 356 \text{ Nm}$.
- Motor Lock Rotor Current = $1000 \times \text{HP} \times \text{figure from below Chart} / 1.732 \times 415$**

Locked Rotor Current		
Code	Min	Max
A	1	3.14
B	3.15	3.54
C	3.55	3.99
D	4	4.49
E	4.5	4.99
F	5	5.59
G	5.6	6.29
H	6.3	7.09
I	7.1	7.99
K	8	8.99
L	9	9.99
M	10	11.19
N	11.2	12.49
P	12.5	13.99
R	14	15.99
S	16	17.99
T	18	19.99
U	20	22.39
V	22.4	

- As per above chart Minimum Locked Rotor Current = $1000 \times 10 \times 1 / 1.732 \times 415 = 14 \text{ Amp}$
- Maximum Locked Rotor Current = $1000 \times 10 \times 3.14 / 1.732 \times 415 = 44 \text{ Amp}$.
- Motor Full Load Current (Line) = $\text{KW} \times 1000 / 1.732 \times 415$**
- Motor Full Load Current (Line) = $(10 \times 0.746) \times 1000 / 1.732 \times 415 = 13 \text{ Amp}$.
- Motor Full Load Current (Phase) = Motor Full Load Current (Line) / 1.732.**
- Motor Full Load Current (Phase) = $13 / 1.732 = 7 \text{ Amp}$.
- Motor Starting Current (Star-Delta Starter) = 3x Full Load Current.**
- Motor Starting Current (Line) = $3 \times 13 = 39 \text{ Amp}$

(5) Size of Fuse:

Fuse as per NEC 430-52		
Type of Motor	Time Delay Fuse	Non-Time Delay Fuse
Single Phase	300%	175%
3 Phase	300%	175%
Synchronous	300%	175%
Wound Rotor	150%	150%
Direct Current	150%	150%

- **Maximum Size of Time Delay Fuse = $300\% \times \text{Full Load Line Current}$.**
- Maximum Size of Time Delay Fuse = $300\% \times 13 = 39$ Amp.
- **Maximum Size of Non Time Delay Fuse = $1.75\% \times \text{Full Load Line Current}$.**
- Maximum Size of Non Time Delay Fuse = $1.75\% \times 13 = 23$ Amp.

(6) Size of Circuit Breaker:

Circuit Breaker as per NEC 430-52		
Type of Motor	Instantaneous Trip	Inverse Time
Single Phase	800%	250%
3 Phase	800%	250%
Synchronous	800%	250%
Wound Rotor	800%	150%
Direct Current	200%	150%

- **Maximum Size of Instantaneous Trip Circuit Breaker = $800\% \times \text{Full Load Line Current}$.**
- Maximum Size of Instantaneous Trip Circuit Breaker = $800\% \times 13 = 104$ Amp.
- **Maximum Size of Inverse Trip Circuit Breaker = $250\% \times \text{Full Load Line Current}$.**
- Maximum Size of Inverse Trip Circuit Breaker = $250\% \times 13 = 32$ Amp.

(7) Thermal over Load Relay:

Thermal over Load Relay (Phase):

- **Min Thermal Over Load Relay setting = $70\% \times \text{Full Load Current (Phase)}$**
- Min Thermal Over Load Relay setting = $70\% \times 7 = 5$ Amp
- **Max Thermal Over Load Relay setting = $120\% \times \text{Full Load Current (Phase)}$**
- Max Thermal Over Load Relay setting = $120\% \times 7 = 9$ Amp

Thermal over Load Relay (Line):

- For a star-delta starter we have the possibility to place the overload protection in two positions, in the line or in the windings.
- **If O/L Relay Placed in Line:** (Putting the O/L before the motor same as in DOL). Supply > Over Load Relay > Main Contactor
- If Over Load Relay supply the entire motor circuit and are located ahead of where the power splits to the Delta and Star contactors, so O/L Relay size must be based upon the entire motor Full Load Current.
- **Thermal over Load Relay setting = $100\% \times \text{Full Load Current (Line)}$.**
- Thermal over Load Relay setting = $100\% \times 13 = 13$ Amp
- Disadvantage: O/L Relay will not give Protection while Motor runs in Delta (Relay Setting is too High for Delta Winding)
- **If O/L Relay Placed In the windings:** (overload is placed after the Winding Split into main and delta Contactor). Supply > Main Contactor > Delta Contactor > O/L Relay
- If overload is placed after the Point where the wiring Split into main and delta Contactor, Size of over load relay at 58% ($1/\sqrt{3}$) of the motor Full Load Current because we use 6 leads going to the motor, and only 58% of the current goes through the main set of conductors (connected to the main contactor).
- The overload then always measures the current inside the windings, and is thus always correct. The setting must be $\times 0.58$ FLC (line current).
- **Thermal over Load Relay setting = $58\% \times \text{Full Load Current (Line)}$.**
- Thermal over Load Relay setting = $58\% \times 13 = 8$ Amp.
- Disadvantage: We must use separate short-circuit and overload protections

(8) Size and Type of Contactor:

- **Main and Delta Contactor:**
- The Main and Delta contactors are smaller compared to single contactor used in a Direct on Line starter because they Main and Delta contactors in star delta starter are controlling winding currents only. **The currents through the winding are $1/\sqrt{3}$ (58%) of the current in the line.** These two contactors (Main contactor and Delta Contactor) are close during run. These rated at 58% of the current rating of the motor.
- **Star Contactor:**
- The third contactor is the star contactor and that only carries star current while the motor is connected in star in starting. The current in star winding is $1/\sqrt{3} = (58\%)$ of the current in delta, so this contactor can be rated at $1/3$ (33%) of the motor rating. Star contactor can be selected smaller than the others, providing the star contactor pulls first before the main contactor. Then no current flows when third contactor pulls.

- In star connection at start, the motor draws and delivers 1/3 of its full rated power.
- When the starter switches over to Delta, the motor draws full power, but since the contactors and the overload relay are usually wired within the Delta, you need to use contactors and relay which are only rated $1/\sqrt{3} = 58\%$ of the full rated power of the motor.

Application	Contactors	Making Cap
Non-Inductive or Slightly Inductive ,Resistive Load	AC1	1.5
Slip Ring Motor	AC2	4
Squirrel Cage Motor	AC3	10
Rapid Start / Stop	AC4	12
Switching of Electrical Discharge Lamp	AC5a	3
Switching of Electrical Incandescent Lamp	AC5b	1.5
Switching of Transformer	AC6a	12
Switching of Capacitor Bank	AC6b	12
Slightly Inductive Load in Household or same type load	AC7a	1.5
Motor Load in Household Application	AC7b	8
Hermetic refrigerant Compressor Motor with Manual O/L Reset	AC8a	6
Hermetic refrigerant Compressor Motor with Auto O/L Reset	AC8b	6
Control of Restive & Solid State Load with opto coupler Isolation	AC12	6
Control of Restive Load and Solid State with T/C Isolation	AC13	10
Control of Small Electro Magnetic Load (<72VA)	AC14	6
Control of Small Electro Magnetic Load (>72VA)	AC15	10

- As per above Chart
- **Type of Contactor= AC1**
- **Making/Breaking Capacity of Contactor= Value above Chart x Full Load Current (Line).**
- Making/Breaking Capacity of Contactor= $1.5 \times 13 = 19$ Amp.
- **Size of Star Contactor (Starting Condition) = $33\% \times$ Full Load Current (Line).**
- Size of Star Contactor $= 33\% \times 13 = 4$ Amp.
- **Size of Main Contactor (Starting-Transition-Running) = $58\% \times$ Full Load Current (Line).**
- Size of Main Contactor $= 58\% \times 13 = 8$ Amp.
- **Size of Delta Contactor (Running Condition) = $58\% \times$ Full Load Current (Line).**
- Size of Delta Contactor $= 58\% \times 13 = 8$ Amp.

Summary:

- **Type of Contactor= AC1**
- **Making/Breaking Capacity of Contactor=19 Amp.**
- **Size of Star Contactor =4 Amp.**
- **Size of Main Contactor = 8 Amp.**
- **Size of Delta Contactor =8 Amp.**

Chapter: 50 Calculate Size of Transformer & Voltage Drop due to Starting of Single Large Motor

- Calculate Voltage drop in Transformer ,1000KVA,11/0.480KV,impedance 5.75%, due to starting of 300KW,460V,0.8 Power Factor, Motor code D(kva/hp).Motor Start 2 times per Hour and The allowable Voltage drop at Transformer Secondary terminal is 10%.

Motor current / Torque:

- Motor Full Load Current= $(Kw \times 1000) / (1.732 \times \text{Volt (L-L)} \times \text{P.F})$**
- Motor Full Load Current= $300 \times 1000 / 1.732 \times 460 \times 0.8 = 471 \text{ Amp}$.
- Motor Locked Rotor Current = Multiplier x Motor Full Load Current**

Locked Rotor Current (Kva/Hp)		
Motor Code	Min	Max
A	3.15	
B	3.16	3.55
C	3.56	4
D	4.1	4.5
E	4.6	5
F	5.1	5.6
G	5.7	6.3
H	6.4	7.1
J	7.2	8
K	8.1	9
L	9.1	10
M	10.1	11.2
N	11.3	12.5
P	12.6	14
R	14.1	16
S	16.1	18
T	18.1	20
U	20.1	22.4
V	22.5	

- Min Motor Locked Rotor Current (L1)= $4.10 \times 471 = 1930 \text{ Amp}$
- Max Motor Locked Rotor Current (L2) = $4.50 \times 471 = 2118 \text{ Amp}$
- Motor inrush Kva at Starting (I_{rm})= Volt x locked Rotor Current x Full Load Current x 1.732 / 1000**
- Motor inrush Kva at Starting (I_{rm})= $460 \times 2118 \times 471 \times 1.732 / 1000 = 1688 \text{ Kva}$

Transformer:

- Transformer Full Load Current= $Kva / (1.732 \times \text{Volt})$**
- Transformer Full Load Current= $1000 / (1.732 \times 480) = 1203 \text{ Amp}$.
- Short Circuit Current at TC Secondary (I_{sc}) = Transformer Full Load Current / Impedance.**
- Short Circuit Current at TC Secondary= $1203 / 5.75 = 20919 \text{ Amp}$
- Maximum Kva of TC at rated Short Circuit Current (Q1) = $(\text{Volt} \times I_{sc} \times 1.732) / 1000$.**
- Maximum Kva of TC at rated Short Circuit Current (Q1)= $480 \times 20919 \times 1.732 / 1000 = 17391 \text{ Kva}$.
- Voltage Drop at Transformer secondary due to Motor Inrush (V_d)= $(I_{rm}) / Q1$**
- Voltage Drop at Transformer secondary due to Motor Inrush (V_d) = $1688 / 17391 = 10\%$
- Voltage Drop at Transformer Secondary is 10% which is within permissible Limit.
- Motor Full Load Current <= 65% of Transformer Full Load Current**
- $471 \text{ Amp} <= 65\% \times 1203 \text{ amp} = 471 \text{ Amp} <= 781 \text{ Amp}$
- Here Voltage Drop is within Limit and Motor Full Load Current <= TC Full Load Current.
- Size of Transformer is Adequate.**

Chapter: 51 Calculate Size of Transformer & Voltage Drop **due to Starting of Multiple No of Motor**

- Calculate Voltage drop in Transformer, 1000KVA, 11/0.480KV, impedance 5.75%, due to starting of 300KW Three Phase Motor and 5KW Single Phase Motor, 460V (Line-Line), 0.8 Power Factor, Locked Rotor Current is 450% and The allowable Voltage drop at Transformer Secondary terminal is 10%.

Motor current / Torque:

- **Motor Full Load Current= $(Kw \times 1000) / (1.732 \times \text{Volt (L-L)} \times \text{P.F})$**
- Motor Full Load Current = $300 \times 1000 / 1.732 \times 460 \times 0.8 = 471 \text{ Amp.}$
- **Motor Full Load Current= $(Kw \times 1000) / (\text{Volt (L-P)} \times \text{P.F})$**
- Motor Full Load Current = $10 \times 1000 / (460 / 1.732) \times 0.8 = 24 \text{ Amp.}$
- Total Motor Full Load Current = $471 + 24 = 494 \text{ Amp}$
- **Motor inrush Kva at Starting (I_{rsm}) = Volt x locked Rotor Current x Full Load Current x 1.732 / 1000**
- Motor inrush Kva at Starting (I_{rsm}) = $460 \times 2118 \times 494 \times 1.732 / 1000 = 1772 \text{ Kva}$

Transformer:

- **Transformer Full Load Current= $Kva / (1.732 \times \text{Volt})$**
- Transformer Full Load Current = $1000 / (1.732 \times 480) = 1203 \text{ Amp.}$
- **Short Circuit Current at TC Secondary (I_{sc}) = Transformer Full Load Current / Impedance.**
- Short Circuit Current at TC Secondary = $1203 / 5.75 = 20919 \text{ Amp}$
- **Maximum Kva of TC at rated Short Circuit Current (Q₁) = $(\text{Volt} \times I_{sc} \times 1.732) / 1000$.**
- Maximum Kva of TC at rated Short Circuit Current (Q₁) = $480 \times 20919 \times 1.732 / 1000 = 17391 \text{ Kva.}$
- **Voltage Drop at Transformer secondary due to Motor Inrush (V_d) = $(I_{rsm}) / Q_1$**
- Voltage Drop at Transformer secondary due to Motor Inrush (V_d) = $1772 / 17391 = 10.2\%$
- **Motor Full Load Current ≤ 65% of Transformer Full Load Current**
- $494 \text{ Amp} \leq 65\% \times 1203 \text{ amp} = 781 \text{ Amp}$
- Here Motor Full Load Current ≤ TC Full Load Current but Voltage Drop is High (10.20%) so Size of Transformer is Not Adequate.
- **Required to increase the size of Transformer.**

Chapter: 52 Calculate Voltage Regulation of 11KV / 22KV / 33KV Overhead Line (As per REC)

- **% Voltage Regulation** = $(1.06 \times P \times L \times PF) / (LDF \times RC \times DF)$
- Where
- P = Total Power in KVA
- L = Total Length of Line from Power Sending to Power Receiving in KM.
- PF = Power Factor in p.u
- RC = Regulation Constant (KVA-KM) per 1% drop.
- $RC = (KV \times KV \times 10) / (R \cos \Phi + X \sin \Phi)$
- LDF = Load Distribution Factor.
- LDF = 2 for uniformly distributed Load on Feeder.
- LDF > 2 If Load is skewed toward the Power Transformer.
- LDF = 1 To 2 If Load is skewed toward the Tail end of Feeder.
- DF = Diversity Factor in p.u

Permissible Voltage Regulation (As per REC):

Maximum Voltage Regulation at any Point of Distribution Line			
Part of Distribution System	Urban Area (%)	Suburban Area (%)	Rural Area (%)
Up to Transformer	2.5	2.5	2.5
Up to Secondary Main	3	2	0.0
Up to Service Drop	0.5	0.5	0.5
Total	6.0	5.0	3.0

Required Size of Capacitor:

- Size of capacitor for improvement of the Power Factor from $\cos \phi_1$ to $\cos \phi_2$ is
- **Required size of Capacitor (Kvar) = $KVA_1 (\sin \phi_1 - [\cos \phi_1 / \cos \phi_2] \times \sin \phi_2)$**
- Where KVA1 is Original KVA.

Optimum location of capacitors:

- **$L = [1 - (KVARC / 2 KVARL) \times (2n-1)]$**
- Where,
- L = distance in per unit along the line from sub-station.
- KVARC = Size of capacitor bank
- KVARL = KVAR loading of line
- n = relative position of capacitor bank along the feeder from sub-station if the total capacitance is to be divided into more than one Bank along the line. If all capacitance is put in one Bank than values of n=1.

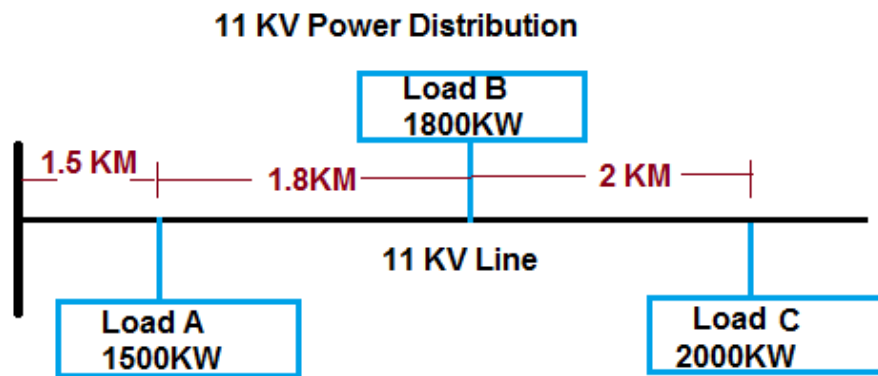
Voltage Rise due to Capacitor installation:

- **% Voltage Rise = $(KVAR(Cap) \times L \times X) / 10 \times V \times 2$**
- Where,
- KVAR(Cap) = Capacitor KVAR
- X = Reactance per phase
- L = Length of Line (mile)
- V = Phase to phase voltage in kilovolts

Calculate % Voltage Regulation of Distribution Line at Trail end:

- Calculate Voltage drop and % Voltage Regulation at Trail end of following 11 KV Distribution system , System have ACSR DOG Conductor (AI 6/4.72, GI7/1.57), Current Capacity of ACSR Conductor

=205Amp, Resistance =0.2792Ω and Reactance =0 Ω, Permissible limit of % Voltage Regulation at Trail end is 5%.



Method-1 (Distance Base):

- **Voltage Drop** = $(\sqrt{3} \times (R \cos \Phi + X \sin \Phi) \times I) / (\text{No of Conductor/Phase} \times 1000) \times \text{Length of Line}$
- Voltage drop at Load A
- Load Current at Point A (I) = KW / 1.732 x Volt x P.F
- Load Current at Point A (I) = 1500 / 1.732 x 11000 x 0.8 = 98 Amp.
- Required No of conductor / Phase = 98 / 205 = 0.47 Amp = 1 No
- Voltage Drop at Point A = $(\sqrt{3} \times (R \cos \Phi + X \sin \Phi) \times I) / (\text{No of Conductor/Phase} \times 1000) \times \text{Length of Line}$
- Voltage Drop at Point A = $((1.732 \times (0.272 \times 0.8 + 0 \times 0.6) \times 98) / 1 \times 1000) \times 1500 = 57 \text{ Volt}$
- Receiving end Voltage at Point A = Sending end Volt - Voltage Drop = (1100 - 57) = 10943 Volt.
- % Voltage Regulation at Point A = $((\text{Sending end Volt} - \text{Receiving end Volt}) / \text{Receiving end Volt}) \times 100$
- % Voltage Regulation at Point A = $((11000 - 10943) / 10943) \times 100 = 0.52\%$
- **% Voltage Regulation at Point A = 0.52 %**
- Voltage drop at Load B
- Load Current at Point B (I) = KW / 1.732 x Volt x P.F
- Load Current at Point B (I) = 1800 / 1.732 x 11000 x 0.8 = 118 Amp.
- Distance from source = 1500 + 1800 = 3300 Meter.
- Voltage Drop at Point B = $(\sqrt{3} \times (R \cos \Phi + X \sin \Phi) \times I) / (\text{No of Conductor/Phase} \times 1000) \times \text{Length of Line}$
- Voltage Drop at Point B = $((1.732 \times (0.272 \times 0.8 + 0 \times 0.6) \times 98) / 1 \times 1000) \times 3300 = 266 \text{ Volt}$
- Receiving end Voltage at Point B = Sending end Volt - Voltage Drop = (1100 - 266) = 10734 Volt.
- % Voltage Regulation at Point B = $((\text{Sending end Volt} - \text{Receiving end Volt}) / \text{Receiving end Volt}) \times 100$
- % Voltage Regulation at Point B = $((11000 - 10734) / 10734) \times 100 = 2.48\%$
- **% Voltage Regulation at Point B = 2.48 %**
- Voltage drop at Load C
- Load Current at Point C (I) = KW / 1.732 x Volt x P.F
- Load Current at Point C (I) = 2000 / 1.732 x 11000 x 0.8 = 131 Amp
- Distance from source = 1500 + 1800 + 2000 = 5300 Meter.
- Voltage Drop at Point C = $(\sqrt{3} \times (R \cos \Phi + X \sin \Phi) \times I) / (\text{No of Conductor/Phase} \times 1000) \times \text{Length of Line}$
- Voltage Drop at Point C = $((1.732 \times (0.272 \times 0.8 + 0 \times 0.6) \times 98) / 1 \times 1000) \times 5300 = 269 \text{ Volt}$
- Receiving end Voltage at Point C = Sending end Volt - Voltage Drop = (1100 - 269) = 10731 Volt.
- % Voltage Regulation at Point C = $((\text{Sending end Volt} - \text{Receiving end Volt}) / \text{Receiving end Volt}) \times 100$
- % Voltage Regulation at Point C = $((11000 - 10731) / 10731) \times 100 = 2.51\%$
- **% Voltage Regulation at Point C = 2.51 %**

Here Trail end Point % Voltage Regulation is 2.51% which is in permissible limit.

Method-2 (Load Base):

- **% Voltage Regulation = $(I \times (R \cos \phi + X \sin \phi) \times \text{Length}) / \text{No of Cond.per Phase} \times V (P-N) \times 100$**

Voltage drop at Load A

- Load Current at Point A (I) = KW / 1.732xVoltxP.F
- Load Current at Point A (I) = 1500 / 1.732x11000x0.8 = 98 Amp.
- Distance from source= 1.500 Km.
- Required No of conductor / Phase = 98 / 205 = 0.47 Amp = 1 No
- Voltage Drop at Point A = $(I \times (R \cos \phi + X \sin \phi) \times \text{Length}) / V (\text{Phase-Neutral}) \times 100$
- Voltage Drop at Point A = $((98 \times (0.272 \times 0.8 + 0 \times 0.6) \times 1.5) / 1 \times 6351) = 0.52\%$
- **% Voltage Regulation at Point A = 0.52 %**

Voltage drop at Load B

- Load Current at Point B (I) = KW / 1.732xVoltxP.F
- Load Current at Point B (I) = 1800 / 1.732x11000x0.8 = 118 Amp.
- Distance from source= 1500+1800=3.3Km.
- Required No of conductor / Phase = 118 / 205 = 0.57 Amp = 1 No
- Voltage Drop at Point B = $(I \times (R \cos \phi + X \sin \phi) \times \text{Length}) / V (\text{Phase-Neutral}) \times 100$
- Voltage Drop at Point B = $((118 \times (0.272 \times 0.8 + 0 \times 0.6) \times 3.3) / 1 \times 6351) = 1.36\%$
- **% Voltage Regulation at Point A = 1.36 %**

Voltage drop at Load C

- Load Current at Point C (I) = KW / 1.732xVoltxP.F
- Load Current at Point C (I) = 2000 / 1.732x11000x0.8 = 131Amp.
- Distance from source= 1500+1800+2000=5.3Km.
- Required No of conductor / Phase = 131/205 = 0.64 Amp = 1 No
- Voltage Drop at Point C = $(I \times (R \cos \phi + X \sin \phi) \times \text{Length}) / V (\text{Phase-Neutral}) \times 100$
- Voltage Drop at Point C = $((131 \times (0.272 \times 0.8 + 0 \times 0.6) \times 5.3) / 1 \times 6351) = 2.44\%$
- **% Voltage Regulation at Point A = 2.44 %**
- **Here Trail end Point % Voltage Regulation is 2.44% which is in permissible limit.**

- There are two types of Losses in distribution Line. (1) Technical Losses and (2) Commercial Losses.
- Distribution Company should calculate technical and commercial losses so that Commercial losses are not implemented to all consumers.
- Technical Losses of the Distribution line mostly depend upon Electrical Load, type and size of conductor, length of line etc.
- Let's try to calculate Technical Losses of one of the 11 KV Distribution Line which have following parameter.
- Main length of 11 KV Line is 6.18 Kms.
- Total nos. of Distribution Transformer on Feeder 25 KVA= 3 No, 63 KVA =3 No, 100KVA=1No.
- 25KVA Transformer Iron Losses = 100 W, Copper Losses= 720 W, Average LT Line Loss= 63W.
- 63KVA Transformer Iron Losses =200 W, Copper Losses=1300 W, Average LT Line Loss=260W.
- 100KVA Transformer Iron Losses =290 W, Copper Losses=1850 W, LT Line Loss=1380W.
- Maximum Amp is 12 Amps.
- Unit sent out during to feeder is 490335 Kwh
- Unit sold out during from Feeder is 353592 Kwh
- Normative Load diversity Factor for Urban feeder is 1.5 and for Rural Feeder is 2.0

Calculation:

Total Connected Load=No's of Connected Transformer.

- Total Connected Load= (25x3) + (63x3) + (100x1).
- Total Connected Load=364 KVA.

Peak Load = 1.732 x Line Voltage x Max Amp

- Peak Load = 264 / 1.732x11x12
- Peak Load =228

Diversity Factor (DF) = Connected Load (In KVA) / Peak Load.

- Diversity Factor (DF) = 364 /228
- Diversity Factor (DF) =1.15

Load Factor (LF)= Unit Sent Out (In Kwh) / 1.732 x Line Voltage x Max Amp. x P.F. x 8760

- Load Factor (LF)=490335 / 1.732x11x12x0.8x8760
- Load Factor (LF)=0.3060

Loss Load Factor (LLF)= (0.8 x LFX LF)+ (0.2 x LF)

- Loss Load Factor (LLF)= (0.8 x 0.3060 x 0.3060) + (0.2 x 0.306)
- Loss Load Factor (LLF)= 0.1361

Calculation of Iron losses:

- **Total Annual Iron loss in Kwh =Iron Loss in Watts X Nos of TC on the feeder X8760 / 1000**
- Total Annual Iron loss (25KVA TC)=100x3x8760 /1000 =2628 Kwh
- Total Annual Iron loss (63KVA TC)=200x3x8760 /1000 =5256 Kwh
- Total Annual Iron loss (100KVA TC)=290x3x8760 /1000 =2540 Kwh
- Total Annual Iron loss =2628+5256+2540 =10424Kwh

Calculation of Copper losses:

- **Total Annual Copper loss in Kwh =Cu Loss in Watts XNos of TC on the feeder LFX LF X8760 / 1000**
- Total Annual Copper loss (25KVA TC)=720x3x0.3x0.3x8760 /1000 =1771 Kwh
- Total Annual Copper loss (63KVA TC)=1300x3x0.3x0.3x8760 /1000 =3199 Kwh
- Total Annual Copper loss (100KVA TC)=1850x1x0.3x0.3x8760 /1000 =1458 Kwh
- Total Annual Copper loss =1771+3199+1458=6490Kwh

HT Line Losses (Kwh)=0.105 x (Conn. Load x 2) x Length x Resistance x LLF / (LDF x DF x DF x 2)

- HT Line Losses= 1.05 x(265x2) x 6.18 x 0.54 x 0.1361 /1.5 x 1.15 x1.15 x 2
- HT Line Losses = 831 Kwh

Peak Power Losses= (3 x Total LT Line Losses) / (PPLxDFxDFx 1000)

- Peak Power Losses= $3 \times (3 \times 63 + 3 \times 260 + 1 \times 1380) / 1.15 \times 1.15 \times 1000$
- Peak Power Losses= 3.0

LT Line Losses (Kwh)= (PPL.) x (LLF) x 8760

- LT Line Losses = $3 \times 0.1361 \times 8760$
- LT Line Losses = 3315 Kwh

Total Technical Losses= (HT Line Losses + LT Line Losses + Annual Cu Losses + Annual Iron Losses)

- Total Technical Losses = (831+ 3315 + 10424 + 6490)

• **Total Technical Losses = 21061 Kwh**

% Technical Loss= (Total Losses) / (Unit Sent Out Annually) x 100

- % Technical Loss= $(21061/490335) \times 100$
- **% Technical Loss=4.30%**

- **Calculate Voltage Drop and Size of Electrical cable for following data.**
- **Electrical Details:** Electrical Load of 80KW, Distance between Source and Load is 200Meter, System Voltage 415V Three Phase, Power Factor is 0.8, Permissible Voltage drop is 5%, Demand Factor is 1,
- **Cable Laying Detail:** Cable is directed buried in Ground in trench at the depth of 1 meter. Ground Temperature is approximate 35 Deg. No of Cable per Trench is 1. No of Run of Cable is 1 Run.
- **Soil Details:** Thermal Resistivity of Soil is not known. Nature of Soil is Damp Soil.

Calculation:

- **Consumed Load= Total Load x Demand Factor**
- Consumed Load in KW= $80 \times 1 = 80\text{KW}$
- **Consumed Load in KVA= KW/P.F**
- Consumed Load in KVA = $80/0.8 = 100\text{KVA}$
- **Full Load Current= $(\text{KVA} \times 1000) / (1.732 \times \text{Voltage})$**
- Full Load Current= $(100 \times 1000) / (1.732 \times 415) = 139\text{Amp.}$
- **Calculating Correction Factor of Cable from following data :**
- **Temperature Correction Factor (K1) When Cable is in Air is**

Temperature Correction Factor in Air :K1		
Ambient Temp°C	Insulation	
	PVC	XLPE/EPR
10	1.22	1.15
15	1.17	1.12
20	1.12	1.08
25	1.06	1.04
35	0.94	0.96
40	0.87	0.91
45	0.79	0.87
50	0.71	0.82
55	0.61	0.76
60	0.5	0.71
65	0	0.65
70	0	0.58
75	0	0.5
80	0	0.41

- **Ground Temperature Correction Factor (K2):**

Ground Temperature Correction Factor:K2		
Ground Temp°C	Insulation	
	PVC	XLPE/EPR
10	1.1	1.07
15	1.05	1.04
20	0.95	0.96
25	0.89	0.93
35	0.77	0.89
40	0.71	0.85
45	0.63	0.8
50	0.55	0.76
55	0.45	0.71
60	0	0.65
65	0	0.6
70	0	0.53

75	0	0.46
80	0	0.38

- **Thermal Resistance Correction Factor (K4) for Soil (When Thermal Resistance of Soil is known):**

Ther.Resi Correction Factor: K4	
Soil Thermal Resistivity: 2.5 KM/W	
Resistivity	K3
1	1.18
1.5	1.1
2	1.05
2.5	1
3	0.96

- **Soil Correction Factor(K4) of Soil (When Thermal Resistance of Soil is not known):**

Soil Correction Factor:K4	
Nature of Soil	K3
Very Wet Soil	1.21
Wet Soil	1.13
Damp Soil	1.05
Dry Soil	1
Very Dry Soil	0.86

- **Cable Depth Correction Factor (K5):**

Cable Depth Factor (K5)	
Laying Depth(Meter)	Rating Factor
0.5	1.1
0.7	1.05
0.9	1.01
1	1
1.2	0.98
1.5	0.96

- **Cable Distance correction Factor (K6):**

Cable Distance Correction Factor(K6)					
No of Circuit	Nil	cable Diameter	0.125m	0.25m	0.5m
1	1	1	1	1	1
2	0.75	0.8	0.85	0.9	0.9
3	0.65	0.7	0.75	0.8	0.85
4	0.6	0.6	0.7	0.75	0.8
5	0.55	0.55	0.65	0.7	0.8
6	0.5	0.55	0.6	0.7	0.8

- **Cable Grouping Factor (No of Tray Factor) (K7):**

No of Cable/Tray	(Cable Grouping factor K7)=No of Tray					
	1	2	3	4	6	8
1	1	1	1	1	1	1
2	0.84	0.8	0.78	0.77	0.76	0.75
3	0.8	0.76	0.74	0.73	0.72	0.71
4	0.78	0.74	0.72	0.71	0.7	0.69
5	0.77	0.73	0.7	0.69	0.68	0.67
6	0.75	0.71	0.7	0.68	0.68	0.66
7	0.74	0.69	0.675	0.66	0.66	0.64
8	0.73	0.69	0.68	0.67	0.66	0.64

- According to above Detail correction Factors are
- Ground Temperature Correction Factor (K2) =0.89
- Soil Correction Factor (K4)=1.05

- Cable Depth Correction Factor (K5)=1.0
- Cable Distance correction Factor (K6)=1.0
- **Total De rating Factor= $k1 \times k2 \times k3 \times K4 \times K5 \times K6 \times K7$**
- Total De rating Factor= 0.93

Selection of Cable:

- For selection of Proper Cable following Conditions should be satisfied
- (1) Cable De rating Amp should be higher than Full Load Current of Load.
- (2) Cable Voltage Drop should be less than Defined Voltage drop.
- (3) Cable Short Circuit Capacity should be higher than System S.C Capacity at that Point.
- **Selection of Cable Case (1):**
- Let's Select 3.5Core 70 Sq.mm cable for Single run.
- Current Capacity of 70 Sq.mm cable is 170Amp, Resistance=0.57 Ω /Km and Reactance=0.077 mho/Km
- Total De rating Current of 70 Sq.mm Cable= 170x0.93 =159 Amp.
- **Voltage Drop of Cable= $(1.732 \times \text{Full Load Current} \times (R \cos \phi + j \sin \phi) \times \text{Cable Length} \times 100) / (\text{Line Voltage} \times \text{No of Run} \times 1000)$**
- Voltage Drop of Cable= $(1.732 \times 139 \times (0.57 \times 0.8 + 0.077 \times 0.6) \times 200 \times 100) / (415 \times 1 \times 1000) = 5.8\%$
- **Voltage Drop of Cable=5.8%**
- Here Voltage drop for 70 Sq.mm Cable (5.8%) is higher than Define Voltage drop (5%) so either select higher size of cable or Increase no of Cable Runs.
- If we Select 2 No's of Run than Voltage drop is 2.8% which is within limit (5%) but to use 2 no's of Run of cable of 70 Sq.mm Cable is not economical so It is necessary to use next higher size of Cable.
- **Selection of Cable Case (2):**
- Let's Select 3.5Core 95 Sq.mm cable for Single run, S.C Capacity =8.2KA.
- Current Capacity of 95 Sq.mm cable is 200Amp, Resistance=0.41 Ω /Km and Reactance=0.074 mho/Km
- Total De rating Current of 70 Sq.mm Cable= 200x0.93 =187 Amp.
- Voltage Drop of Cable= $(1.732 \times 139 \times (0.41 \times 0.8 + 0.074 \times 0.6) \times 200 \times 100) / (415 \times 1 \times 1000) = 2.2\%$
- **Voltage Drop of Cable=2.2%**
- To decide 95Sq.mm Cable, Cable selection condition should be checked.
- (1) Cable De rating Amp (187 Amp) is higher than Full Load Current of Load (139 Amp) =O.K
- (2) Cable Voltage Drop should (2.2%) is less than Defined Voltage drop (5%) =O.K
- (3) Cable S.C Capacity (8.2KA) is higher than System S.C Capacity at that Point (6.0KA) =O.K
- **95 Sq.mm Cable satisfied all three condition so It is advisable to use 3.5 Core 95 Sq.mm cable**

Chapter: 55 Calculate IDMT Over Current Relay Setting (50/51)

- Calculate setting of IDMT over Current Relay for following Feeder and CT Detail
- **Feeder Detail:** Feeder Load Current 384 Amp, Feeder Fault current Min11KA and Max 22KA.
- **CT Detail:** CT installed on feeder is 600/1 Amp. Relay Error 7.5%, CT Error 10.0%, CT over shoot 0.05 Sec, CT interrupting Time is 0.17 Sec and Safety is 0.33 Sec.
- **IDMT Relay Detail:**
- **IDMT Relay Low Current setting:** Over Load Current setting is 125%, Plug setting of Relay is 0.8 Amp and Time Delay (TMS) is 0.125 Sec, Relay Curve is selected as Normal Inverse Type.
- **IDMT Relay High Current setting :** Plug setting of Relay is 2.5 Amp and Time Delay (TMS) is 0.100 Sec, Relay Curve is selected as Normal Inverse Type

Calculation of Over Current Relay Setting:

(1) Low over Current Setting: (I>)

- **Over Load Current (In) = Feeder Load Current X Relay setting = 384 X 125% = 480 Amp**
- **Required Over Load Relay Plug Setting= Over Load Current (In) / CT Primary Current**
- Required Over Load Relay Plug Setting = 480 / 600 = 0.8
- **Pick up Setting of Over Current Relay (PMS) (I>)= CT Secondary Current X Relay Plug Setting**
- Pick up Setting of Over Current Relay (PMS) (I>)= 1 X 0.8 = 0.8 Amp
- **Plug Setting Multiplier (PSM) = Min. Feeder Fault Current / (PMS X (CT Pri. Current / CT Sec. Current))**
- Plug Setting Multiplier (PSM) = 11000 / (0.8 X (600 / 1)) = 22.92
- Operation Time of Relay as per it's Curve
- Operating Time of Relay for Very Inverse Curve (t) = 13.5 / ((PSM)-1).
- Operating Time of Relay for Extreme Inverse Curve (t) = 80 / ((PSM)² -1).
- Operating Time of Relay for Long Time Inverse Curve (t) = 120 / ((PSM) -1).
- Operating Time of Relay for Normal Inverse Curve (t) = 0.14 / ((PSM) 0.02 -1).
- Operating Time of Relay for Normal Inverse Curve (t) = 0.14 / ((22.92)0.02-1) = 2.17 Amp
- Here Time Delay of Relay (TMS) is 0.125 Sec so
- **Actual operating Time of Relay (t>) = Operating Time of Relay X TMS = 2.17 X 0.125 = 0.271 Sec**
- **Grading Time of Relay = (((2XRelay Error)+CT Error)XTMS)+ Over shoot+ CB Interrupting Time+ Safety**
- Total Grading Time of Relay = (((2X7.5)+10)X0.125)+0.05+0.17+0.33 = 0.58 Sec
- **Operating Time of Previous upstream Relay = Actual operating Time of Relay+ Total Grading Time**
Operating Time of Previous up Stream Relay = 0.271 + 0.58 = 0.85 Sec

(2) High over Current Setting: (I>>)

- **Pick up Setting of Over Current Relay (PMS) (I>>)= CT Secondary Current X Relay Plug Setting**
- Pick up Setting of Over Current Relay (PMS) (I>)= 1 X 2.5 = 2.5 Amp
- **Plug Setting Multiplier (PSM) = Min. Feeder Fault Current / (PMS X (CT Pri. Current / CT Sec. Current))**
- Plug Setting Multiplier (PSM) = 11000 / (2.5 X (600 / 1)) = 7.33
- Operation Time of Relay as per it's Curve
- Operating Time of Relay for Very Inverse Curve (t) = 13.5 / ((PSM)-1).
- Operating Time of Relay for Extreme Inverse Curve (t) = 80 / ((PSM)² -1).
- Operating Time of Relay for Long Time Inverse Curve (t) = 120 / ((PSM) -1).
- Operating Time of Relay for Normal Inverse Curve (t) = 0.14 / ((PSM) 0.02 -1).
- **Operating Time of Relay for Normal Inverse Curve (t)=0.14 / ((7.33)0.02-1) = 3.44 Amp**
- Here Time Delay of Relay (TMS) is 0.100 Sec so
- **Actual operating Time of Relay (t>) = Operating Time of Relay X TMS = 3.44 X 0.100 = 0.34 Sec**
- **Grading Time of Relay = (((2XRelay Error)+CT Error)XTMS)+ Over shoot+ CB Interrupting Time+ Safety**
- Total Grading Time of Relay = (((2X7.5)+10)X0.100)+0.05+0.17+0.33 = 0.58 Sec

- **Operating Time of Previous upstream Relay = Actual operating Time of Relay+ Total Grading Time.**
- Operating Time of Previous up Stream Relay = $0.34 + 0.58 = 0.85$ Sec

Conclusion of Calculation:

- Pickup Setting of over current Relay (PMS)($I_{>}$) should be satisfied following Two Condition.
- **(1) Pickup Setting of over current Relay (PMS)($I_{>}$) $\geq$ Over Load Current (I_n) / CT Primary Current**
- **(2) $TMS \leq$ Minimum Fault Current / CT Primary Current**
- For Condition (1) $0.8 \geq (480/600) = 0.8 \geq 0.8$, Which found **OK**
- For Condition (2) $0.125 \leq 11000/600 = 0.125 \leq 18.33$, Which found **OK**
- **Here Condition (1) and (2) are satisfied so**
- **Pickup Setting of Over Current Relay = OK**
- **Low Over Current Relay Setting: ($I_{>}$) = 0.8A XIn Amp**
- **Actual operating Time of Relay ($t_{>}$) = 0.271 Sec**
- **High Over Current Relay Setting: ($I_{>>}$) = 2.5A XIn Amp**
- **Actual operating Time of Relay ($t_{>>}$) = 0.34 Sec**

Chapter: 56

Calculate Size of Capacitor Bank / Annual Saving & Payback Period

- Calculate Size of Capacitor Bank Annual Saving in Bills and Payback Period for Capacitor Bank.
- Electrical Load of (1) 2 No's of 18.5KW, 415V motor, 90% efficiency, 0.82 Power Factor, (2) 2 No's of 7.5KW, 415V motor, 90% efficiency, 0.82 Power Factor, (3) 10KW, 415V Lighting Load. The Targeted Power Factor for System is 0.98.
- Electrical Load is connected 24 Hours, Electricity Charge is 100Rs/KVA and 10Rs/KW.
- Calculate size of Discharge Resistor for discharging of capacitor Bank. Discharge rate of Capacitor is 50v in less than 1 minute.
- Also Calculate reduction in KVAR rating of Capacitor if Capacitor Bank is operated at frequency of 40Hz instead of 50Hz and If Operating Voltage 400V instead of 415V.
- Capacitor is connected in star Connection, Capacitor voltage 415V, Capacitor Cost is 60Rs/Kvar. Annual Deprecation Cost of Capacitor is 12%.

Calculation:

- For Connection (1):
- Total Load KW for Connection(1) = $Kw / \text{Efficiency} = (18.5 \times 2) / 90 = 41.1 \text{ KW}$
- Total Load KVA (old) for Connection(1) = $KW / \text{Old Power Factor} = 41.1 / 0.82 = 50.1 \text{ KVA}$
- Total Load KVA (new) for Connection(1) = $KW / \text{New Power Factor} = 41.1 / 0.98 = 41.9 \text{ KVA}$
- Total Load KVAR = $KWX[(\sqrt{1-(\text{old p.f})^2}) / \text{old p.f}] - [(\sqrt{1-(\text{New p.f})^2}) / \text{New p.f}]$
- Total Load KVAR1 = $41.1 \times [(\sqrt{1-(0.82)^2}) / 0.82] - [(\sqrt{1-(0.98)^2}) / 0.98]$
- **Total Load KVAR1 = 20.35 KVAR**
- OR
- $\tan \phi 1 = \text{Arcos}(0.82) = 0.69$
- $\tan \phi 2 = \text{Arcos}(0.98) = 0.20$
- Total Load KVAR1 = $KWX(\tan \phi 1 - \tan \phi 2) = 41.1(0.69 - 0.20) = 20.35 \text{ KVAR}$
- For Connection (2):
- Total Load KW for Connection(2) = $Kw / \text{Efficiency} = (7.5 \times 2) / 90 = 16.66 \text{ KW}$
- Total Load KVA (old) for Connection(1) = $KW / \text{Old Power Factor} = 16.66 / 0.83 = 20.08 \text{ KVA}$
- Total Load KVA (new) for Connection(1) = $KW / \text{New Power Factor} = 16.66 / 0.98 = 17.01 \text{ KVA}$
- Total Load KVAR2 = $KWX[(\sqrt{1-(\text{old p.f})^2}) / \text{old p.f}] - [(\sqrt{1-(\text{New p.f})^2}) / \text{New p.f}]$
- Total Load KVAR2 = $20.35 \times [(\sqrt{1-(0.83)^2}) / 0.83] - [(\sqrt{1-(0.98)^2}) / 0.98]$
- **Total Load KVAR2 = 7.82 KVAR**
- For Connection (3):
- Total Load KW for Connection(2) = $Kw = 10 \text{ KW}$
- Total Load KVA (old) for Connection(1) = $KW / \text{Old Power Factor} = 10 / 0.85 = 11.76 \text{ KVA}$
- Total Load KVA (new) for Connection(1) = $KW / \text{New Power Factor} = 10 / 0.98 = 10.20 \text{ KVA}$
- Total Load KVAR3 = $KWX[(\sqrt{1-(\text{old p.f})^2}) / \text{old p.f}] - [(\sqrt{1-(\text{New p.f})^2}) / \text{New p.f}]$
- Total Load KVAR3 = $20.35 \times [(\sqrt{1-(0.85)^2}) / 0.85] - [(\sqrt{1-(0.98)^2}) / 0.98]$
- **Total Load KVAR1 = 4.17 KVAR**
- **Total KVAR = KVAR1 + KVAR2 + KVAR3**
- Total KVAR = $20.35 + 7.82 + 4.17$
- **Total KVAR = 32 Kvar**

Size of Capacitor Bank:

- **Site of Capacitor Bank = 32 Kvar.**
- **Leading KVAR supplied by each Phase = Kvar / No of Phase**
- Leading KVAR supplied by each Phase = $32 / 3 = 10.8 \text{ Kvar / Phase}$
- **Capacitor Charging Current (Ic) = (Kvar / Phase x 1000) / Volt**
- Capacitor Charging Current (Ic) = $(10.8 \times 1000) / (415 / \sqrt{3})$
- Capacitor Charging Current (Ic) = 44.9 Amp
- **Capacitance of Capacitor = Capacitor Charging Current (Ic) / Xc**
- $Xc = 2 \times 3.14 \times f \times v = 2 \times 3.14 \times 50 \times (415 / \sqrt{3}) = 75362$
- Capacitance of Capacitor = $44.9 / 75362 = 5.96 \mu\text{F}$
- **Required 3 No's of 10.8 Kvar Capacitors and**

- **Total Size of Capacitor Bank is 32Kvar**

Protection of Capacitor Bank

Size of HRC Fuse for Capacitor Bank Protection:

- **Size of the fuse =165% to 200% of Capacitor Charging current.**
- Size of the fuse=2x44.9Amp
- Size of the fuse=90Amp

Size of Circuit Breaker for Capacitor Protection:

- **Size of the Circuit Breaker =135% to 150% of Capacitor Charging current.**
- Size of the Circuit Breaker=1.5x44.9Amp
- Size of the Circuit Breaker=67Amp
- Thermal relay setting between 1.3 and 1.5 of Capacitor Charging current.
- Thermal relay setting of C.B=1.5x44.9 Amp
- Thermal relay setting of C.B=67 Amp
- Magnetic relay setting between 5 and 10 of Capacitor Charging current.
- Magnetic relay setting of C.B=10x44.9Amp
- Magnetic relay setting of C.B=449Amp

Sizing of cables for capacitor Connection:

- Capacitors can withstand a permanent over current of 30% +tolerance of 10% on capacitor Current.
- Cables size for Capacitor Connection= 1.3 + 1.1 x nominal capacitor Current
- **Cables size for Capacitor Connection = 1.43 x nominal capacitor Current**
- Cables size for Capacitor Connection=1.43x44.9Amp
- Cables size for Capacitor Connection=64 Amp

Maximum size of discharge Resistor for Capacitor:

- Capacitors will be discharge by discharging resistors.
- After the capacitor is disconnected from the source of supply, discharge resistors are required for discharging each unit within 3 min to 75 V or less from initial nominal peak voltage (according IEC-standard 60831-1 + 2).
- Discharge resistors have to be connected directly to the capacitors. There shall be no switch, fuse cut-out or any other isolating device between the capacitor unit and the discharge resistors.
- **Max. Discharge resistance Value (Star Connection) = $C_t / C_n \times \log (U_n \times \sqrt{2} / D_v)$.**
- **Max. Discharge resistance Value (Delta Connection)= $C_t / 1/3 \times C_n \times \log (U_n \times \sqrt{2} / D_v)$**
- Where C_t =Capacitor Discharge Time (sec)
- C_n =Capacitance μ Farad.
- U_n = Line Voltage
- D_v =Capacitor Discharge voltage.
- Maximum Discharge resistance =60 / ((5.96/1000000)x log (415x $\sqrt{2}$ /50)
- **Maximum Discharge resistance=4087 K Ω**

Effect of Decreasing Voltage & Frequency on Rating of Capacitor:

- The kvar of capacitor will not be same if voltage applied to the capacitor and frequency changes
- Reduced in Kvar size of Capacitor when operating 50 Hz unit at 40 Hz
- Actual KVAR = Rated KVAR x(Operating Frequency / Rated Frequency)
- Actual KVAR = Rated KVAR x(40/50)
- Actual KVAR = 80% of Rated KVAR
- **Hence 32 Kvar Capacitor works as 80%x32Kvar= 26.6Kvar**

- Reduced in Kvar size of Capacitor when operating 415V unit at 400V
- Actual KVAR = Rated KVAR x (Operating voltage / Rated voltage)²
- Actual KVAR = Rated KVAR x (400/415)²
- Actual KVAR = 93% of Rated KVAR
- Hence 32 Kvar Capacitor works as 93% x 32 Kvar = 230.6 Kvar

Annual Saving and Pay Back Period

Before Power Factor Correction:

- **Total electrical load KVA (old) = KVA1 + KVA2 + KVA3**
- Total electrical load = 50.1 + 20.08 + 11.76
- Total electrical load = 82 KVA
- Total electrical Load KW = kW1 + kW2 + kW3
- Total electrical Load KW = 37 + 15 + 10
- Total electrical Load KW = 62 kW
- Load Current = KVA/V = 80 x 1000 / (415 / 1.732)
- Load Current = 114.1 Amp
- KVA Demand Charge = KVA X Charge
- KVA Demand Charge = 82 x 60 Rs
- KVA Demand Charge = 8198 Rs
- Annual Unit Consumption = KW x Daily uses x 365
- Annual Unit Consumption = 62 x 24 x 365 = 543120 Kwh
- Annual charges = 543120 x 10 = 5431200 Rs
- Total Annual Cost = 8198 + 5431200
- **Total Annual Cost before Power Factor Correction = 5439398 Rs**

After Power Factor Correction:

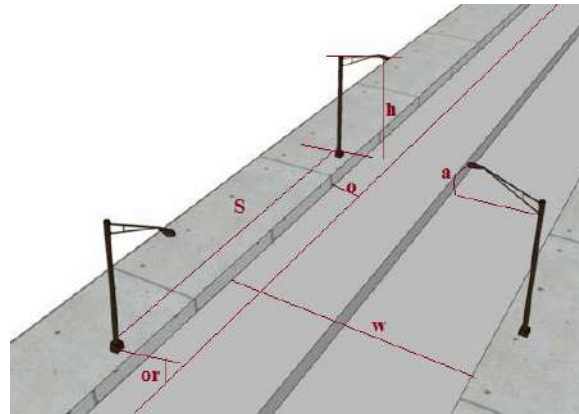
- **Total electrical load KVA (new) = KVA1 + KVA2 + KVA3**
- Total electrical load = 41.95 + 17.01 + 10.20
- Total electrical load = 69 KVA
- Total electrical Load KW = kW1 + kW2 + kW3
- Total electrical Load KW = 37 + 15 + 10
- Total electrical Load KW = 62 kW
- Load Current = KVA/V = 69 x 1000 / (415 / 1.732)
- Load Current = 96.2 Amp
- KVA Demand Charge = KVA X Charge
- KVA Demand Charge = 69 x 60 Rs = 6916 Rs-----(1)
- Annual Unit Consumption = KW x Daily uses x 365
- Annual Unit Consumption = 62 x 24 x 365 = 543120 Kwh
- Annual charges = 543120 x 10 = 5431200 Rs----- (2)
- Capital Cost of capacitor = Kvar x Capacitor cost / Kvar = 82 x 60 = 4919 Rs---(3)
- Annual Interest and Deprecation Cost = 4919 x 12% = 590 Rs----(4)
- Total Annual Cost = 6916 + 5431200 + 4919 + 590
- **Total Annual Cost After Power Factor Correction = 5438706 Rs**

Pay Back Period:

- Total Annual Cost before Power Factor Correction = 5439398 Rs
- Total Annual Cost After Power Factor Correction = 5438706 Rs
- Annual Saving = 5439398 - 5438706 Rs
- **Annual Saving = 692 Rs**
- Payback Period = Capital Cost of Capacitor / Annual Saving
- Payback Period = 4919 / 692
- **Payback Period = 7.1 Years**

Typical Calculation of Road Lighting:

- Luminaries are properly selected and mounted on a location most feasible and effective with minimum cost. For a 230 volts system, a voltage drop of 5% is allowed although in extreme cases 15% voltage drop is sometimes tolerated.



Street Lighting Features (BIS, 1981)
 A: Angle of Tilt Or: Outreach S: Spacing
 W: Width H: Mounting Height O: Overhang

- Street illumination level in Lux (E) = $(AI \times (cu \times mf)) / (w \times d)$**
- E = The illumination in Lux
- w = Width of the roadway
- d = Distance between luminaries
- cu = Coefficient of utilization. Which is dependent on the type of fixture, mounting height, width of roadway and the length of mast arm of outreach?
- AI = Average lumens, $AI = (E \times w \times d) / Cu \times mf$**
- The typical value of AI is
- 20500 lumens for 400 watts
- 11500 lumens for 250 watts
- 5400 lumens for 125 watts
- The value of AI varies depending upon the type of lamp specified.
- mf** : It is the maintenance factor (Normally 0.8 to 0.9)

(1) Calculate Lamp watt for street Light Pole:

- Calculate Lamp Lumen for street Light Pole having Road width of 7 meter, distance between two Pole is 50 meter, Maintenance factor is 0.9, Coefficient of utilization factor is 0.29, light pedestrian traffic is medium and Vehicular traffic is very light and Road is concrete road.
- Solution:**
- From Above table Recommended of illumination (E) in Lux is 6.46 per sq. meter.
- w = 7.00 meters, d = 50 meters, mf = 0.9, cu = 0.29
- To decide Lamp Watt It is necessary to calculate Average Lumens of Lamp (AI).
- Average Lumen of Lamp (AI) = $(E \times w \times d) / Cu \times mf$**
- $AI = (6.46 \times 7 \times 50) / (0.29 \times 0.9) = 8662.83$ Average lumens
- Lamp lumen of a 250 watts lamp is 11,500 lm which is the nearest value to 8662.83 lumens. Therefore, a 250 watts lamp is acceptable.
- Let's Computing for the actual illumination E for 250 Watt Lamp
- illumination (E) = $(AI \times (cu \times mf)) / (w \times d)$**
- $E = (11500 \times 0.29 \times 0.9) / (7 \times 50) = 8.57$ lumens per sq meter.
- Conclusion:**
- Actual illumination (E) for 250 Watt is 8.57 lumens per sq meter which is higher than recommended illumination (E) 6.46.
- Hence 250 watt gives adequately lighting.**

(2) Calculate Spacing between two Light Poles:

- Calculate Space between Two Pole of Street Light having Fixture Watt is 250W , Lamp output of the Lamp (LL) is 33200 lumens , Required Lux Level (E) is 5 lux , Width of the road (W) = 11.48 feet (3.5 M), Height of the pole (H) = 26.24 feet (8 M) ,Coefficient of utilization (CU) = 0.18, Lamp Lumen Depreciation Factor (LLD) = 0.8 ,Luminaries dirt Depreciation Factor (LDD) = 0.9
- Solution:**
- Luminaries Spacing (S) = $(LL \times CU \times LLD \times LDD) / (E \times W)$**
- Luminaries Spacing (S) = $(33200 \times 0.18 \times 0.9 \times 0.8) / (5 \times 11.48)$
- Luminaries Spacing (S) = 75 feet (23 Meters)**

(3) Calculation of the allowed illumination time:

- The allowed illumination time in hours $T = k \cdot t \cdot 1000 / E$.**
- Where: k = extension factor
- t = permissible time in hours at 1000 lux, unfiltered daylight
- E = luminance (lx)

Extension Factor	
Lamp	Extension Factor
Incandescent lamps,	2.7 to 3.2
Halogen reflector lamps	2.5 to 3.5
Halogen capsules	2.5 to 3.5
High-pressure metal-halide	1.1 to 2.1
High-pressure sodium lamps	4
Fluorescent lamps	1.9 to 2.7

- Example:**
- In sunlight (100000 lux) and extension factor 1: The permissible illumination time (T) = $1 \times 70 \times 1000 / 100000 = 0.7$ hour.
- In halogen light (200 lux) and extension factor 2.3: The permissible illumination time (T) = $2.3 \times 70 \times 1000 / 200 = 805$ hours.
- In UV-filtered halogen light (200 lux) and extension factor 3.5: The permissible illumination time (T) = $3.5 \times 70 \times 1000 / 200 = 1225$ hours.

(4) Calculate Uniformity Ratio:

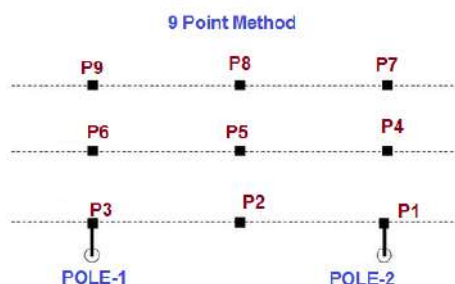
- Once luminaries spacing has been decided It is necessary to check the uniformity of light distribution and compare this value to the selected lighting
- Uniformity Ratio (UR) = E_{av} / E_{min}**
- E_{av} = average maintained horizontal luminance
- E_{min} = maintained horizontal luminance at the point of minimum illumination on the pavement

(5) Energy Saving Calculations:

- At a simplistic level, the cost of running a light is directly related to the wattage of the globe plus any associated ballast or transformer. The higher the wattage, the higher the running cost and it is a straightforward calculation to work out the running cost of lamp over its lifetime:
- Running cost = cost of electricity in \$/kWh x wattage of lamp x lifetime in hours.**

Calculate Lux Level for Street Lighting

- The Average Lux Level of Street Light is measured by 9 point method. Make two equal quadrants between two Street light poles. on the lane of light poles(one side pole to road).
- We have 3 points P1,P2 and P3 under the light pole then P4 & P7 are points opposite pole 1 or Point P3 same is applicable for P6 and P9 for Pole 2.
- The average lux = $[(P1+P3+P7+P9)/16] + [(P2+P6+P8+P4)/8] + [P5/4]$**



Chapter: 58

Calculate Number Lighting Fixture / Lumen for Indoor Lighting

- An office area is 20meter (Length) x 10meter (width) x 3 Meter (height). The ceiling to desk height is 2 meters. The area is to be illuminated to a general level of 250 lux using twin lamp 32 watt CFL luminaires with a SHR of 1.25. Each lamp has an initial output (Efficiency) of 85 lumens per watt. The lamps Maintenance Factor (MF) is 0.63 ,Utilization Factor is 0.69 and space height ratio (SHR) is 1.25

Calculation:

Calculate Total Wattage of Fixtures:

Total Wattage of Fixtures= No of Lamps X each Lamp's Watt.

- Total Wattage of Fixtures= $2 \times 32 = 64$ Watt.

Calculate Lumens per Fixtures:

- Lumens per Fixtures = Lumen Efficiency(Lumen per Watt) x each Fixture's Watt**
- Lumens per Fixtures= $85 \times 64 = 5440$ Lumen

Calculate No's of Fixtures:

- Required No of Fixtures = Required Lux x Room Area / MFxUFx Lumen per Fixture**
- Required No of Fixtures = $(250 \times 20 \times 10) / (0.63 \times 0.69 \times 5440)$
- Required No of Fixtures = 21 No's**

Calculate Minimum Spacing Between each Fixture:

- The ceiling to desk height is 2 meters and Space height Ratio is 1.25 so
- Maximum spacing between Fixtures = $2 \times 1.25 = 2.25$ meter.

Calculate No of Row Fixture's Row Required along with width of Room:

- Number of Row required = width of Room / Max. Spacing= $10 / 2.25$
- Number of Row required=4.

Calculate No of Fixture's required in each Row:

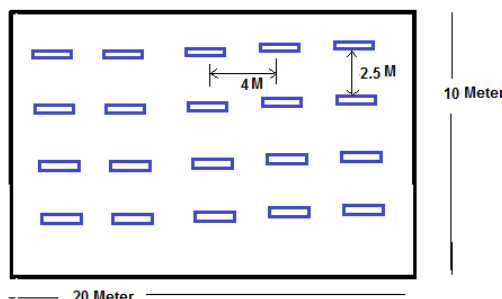
- Number of Fixture Required in each Row = Total Fixtures / No of Row = $21 / 4$
- Number of Fixture Required in each Row = 5 No's:

Calculate Axial Spacing between each Fixture:

- Axial Spacing between Fixtures = Length of Room / Number of Fixture in each Row
- Axial Spacing between Fixtures = $20 / 5 = 4$ Meter

Calculate Transverse Spacing between each Fixture:

- Transverse Spacing between Fixtures = width of Room / Number of Fixture's row
- Transverse Spacing between Fixtures = $10 / 4 = 2.5$ Meter.



Conclusion:

- No of Row for Lighting Fixture's= 4 No**
- No of Lighting Fixtures in each Row= 5 No**
- Axial Spacing between Fixtures= 4.0 Meter**
- Transverse Spacing between Fixtures= 2.5 Meter**
- Required No of Fixtures = 21 No's**

Chapter: 59 Calculate Street Light Pole Watt / Area & Distance

Calculate Distance between each Street Light Pole:

- **Example:** Calculate Distance between each streetlight pole having following Details,
- Road Details: The width of road (W) is 11.5 Foot.
- Pole Details: The height of Pole is 26.5 Foot.
- Luminaries of each Pole: Wattage of Luminaries is 250 Watt, Lamp Out Put (LL) is 33200 Lumen, Required Lux Level (Eh) is 5 Lux, Coefficient of Utilization Factor (Cu) is 0.18, Lamp Lumen Depreciation Factor (LLD) is 0.8, Lamp Lumen Depreciation Factor (LLD) is 0.9.
- Space Height Ratio should be less than 3.

Calculation:

- **Spacing between each Pole** $= (LL * CU * LLD * LDD) / Eh * W$
- Spacing between each Pole $= (33200 * 0.18 * 0.8 * 0.9) / (5 * 11.5)$
- Spacing between each Pole = 75 Foot.
- Space Height Ratio = Distance between Pole / Road width
- Space Height Ratio = 3. Which is less than define value.
- **Spacing between each Pole is 75 Foot.**

Calculate Street Light Luminas Watt:

- **Example:** Calculate Streetlight Watt of each Laminar of Street Light Pole having following Details,
- Road Details: The width of road (W) is 7 Meter. Distance between each Pole (D) is 50 Meter.
- Required Illumination Level for Street Light (L) is 6.46 Lux per Square Meter. Luminous efficacy is 24 Lumen/Watt. Maintenance Factor (mf) 0.29, Coefficient of Utilization Factor (Cu) is 0.9.

Calculation:

- **Average Lumen of Lamp (Al)** = 8663 Lumen.
- **Average Lumen of Lamp (Al)** $= (L * W * D) / (mf * cu)$
- Average Lumen of Lamp (Al) $= (6.46 * 7 * 50) / (0.29 * 0.9)$
- Average Lumen of Lamp (Al) = 8663 Lumen.
- **Watt of Each Street Light Laminar** = Average Lumen of Lamp / Luminous efficacy
- Watt of Each Street Light Laminar = 8663 / 24
- **Watt of Each Street Light Luminas = 361 Watt**

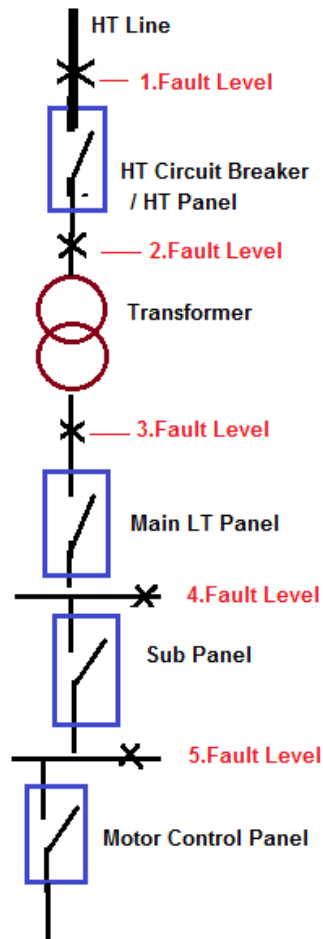
Calculate Required Power for Street Light Area:

- **Example:** Calculate Streetlight Watt of following Street Light Area,
- Required Illumination Level for Street Light (L) is 6 Lux per Square Meter.
- Luminous efficacy (En) is 20 Lumen per Watt.
- Required Street Light Area to be illuminated (A) is 1 Square Meter.

Calculation:

- **Required Streetlight Watt** = (Lux per Sq.Meter X Surface Area of Street Light) / Lumen per Watt.
- Required Streetlight Watt = $(6 * 1) / 20$.
- **Required Streetlight Watt = 0.3 watt per Square Meter.**

- **Example:** Calculate Fault current at each stage of following Electrical System SLD having details of.
- Main Incoming HT Supply Voltage is 6.6 KV.
- Fault Level at HT Incoming Power Supply is 360 MVA.
- Transformer Rating is 2.5 MVA.
- Transformer Impedance is 6%.



Calculation:

- Let's first consider Base KVA and KV for HT and LT Side.
- Base KVA for HT side (H.T. Breaker and Transformer Primary) is 6 MVA
- Base KV for HT side (H.T. Breaker and Transformer Primary) is 6.6 KV
- Base KVA for LT side (Transformer Secondary and down Stream) is 2.5 MVA
- Base KV for LT side (Transformer Secondary and down Stream) is 415V

Fault Level at HT Side (Up to Sub-station):

(1) Fault Level from HT incoming Line to HT Circuit Breaker

- HT Cable used from HT incoming to HT Circuit Breaker is 5 Runs , 50 Meter ,6.6KV 3 Core 400 sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω /Km and Reactance of Cable is 0.0990 Ω /Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.05X0.1230) / 5
- Total Cable Resistance=0.001023 Ω

- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.05X0.0990) / 5
- Total Cable Reactance =0.00099Ω
- **Total Cable Impedance (Zc1)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc1)=0.0014235 Ω------(1)
- **P.U Reactance at H.T. Breaker Incoming Terminals (X Pu)= Fault Level / Base KVA**
- P.U Reactance at H.T. Breaker Incoming Terminals (X Pu)= 360 / 6
- P.U. Reactance at H.T. Breaker Incoming Terminals(X Pu)= 0.01666 PU------(2)
- **Total Impedance up to HT Circuit Breaker (Z Pu-a)= (Zc1)+ (X Pu)=(1)+(2)**
- Total Impedance up to HT Circuit Breaker(Z Pu-a)=0.001435+0.01666
- Total Impedance up to HT Circuit Breaker (Z Pu-a)=0.0181Ω.------(3)
- **Fault MVA at HT Circuit Breaker= Base MVA / Z Pu-a.**
- Fault MVA at HT Circuit Breaker= 6 / 0.0181
- **Fault MVA at HT Circuit Breaker= 332 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 332 / 6.6
- **Fault Current at HT Circuit Breaker = 50 KA**

(2) Fault Level from HT Circuit Breaker to Primary Side of Transformer

- HT Cable used from HT Circuit Breaker to Transformer is 3 Runs , 400 Meter ,6.6KV 3 Core 400 sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0990 Ω/Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.4X0.1230) / 3
- Total Cable Resistance=0.01364Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.4X0.0990) / 5
- Total Cable Reactance =0.01320Ω
- **Total Cable Impedance (Zc2)=√(RXR)+(XxX)**
- Total Cable Impedance (Zc2)=0.01898 Ω------(4)
- **P.U Impedance at Primary side of Transformer (Z Pu)= (Zc2 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Primary side of Transformer (Z Pu)=(0.01898X6) /(6.6x6.6x1000)
- P.U Impedance at Primary side of Transformer (Z Pu)=0.0026145 PU------(5)
- Total Impedance(Z Pu)=(4) + (5)
- Total Impedance(Z Pu)=0.01898+0.0026145
- Total Impedance(Z Pu)=0.00261------(6)
- **Total Impedance up to Primary side of Transformer (Z Pu-b)= (Z Pu)+(Z Pu-a) =(6)+(3)**
- Total Impedance up to Primary side of Transformer (Z Pu-b)=0.00261+0.0181
- Total Impedance up to Primary side of Transformer (Z Pu-b)=0.02070Ω.------(7)
- **Fault MVA at Primary side of Transformer= Base MVA / Z Pu-b.**
- Fault MVA at Primary side of Transformer = 6 / 0.02070
- **Fault MVA at Primary side of Transformer= 290 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 290 / 6.6
- **Fault Current at Primary side of Transformer= 44 KA**

(3) Fault Level from Primary Side of Transformer to Secondary side of Transformer:

- Transformer Rating is 2.5 MVA and Transformer Impedance is 6%.
- **% Reactance at Base KVA = (Base KVA x % impedance at Rated KVA) /Rated KVA**

- % Reactance at Base KVA = $(2.5 \times 6) / 2.5$
- % Reactance at Base KVA = 6%
- **P.U. Reactance of the Transformer(Z Pu) = % Reactance / 100**
- P.U. Reactance of the Transformer(Z Pu) = $6 / 100 = 0.06 \Omega$ -----(8)
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c) = (Z Pu) + (Z Pu-b) = (7) + (8)
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c) = $0.06 + 0.02070$
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c) = 0.0807Ω -----(9)
- **Fault MVA at Transformer Secondary Winding = Base MVA / Z Pu-c**
- Fault MVA at Transformer Secondary Winding = $2.5 / 0.0807$
- **Fault MVA at Transformer Secondary Winding = 31 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = $31 / (1.732 \times 0.415)$
- **Fault Current at Transformer Secondary Winding = 43 KA**

Fault Level at LT Side (Sub-station to Down stream):

(4) Fault Level from Transformer Secondary to Main LT Panel

- LT Cable used from Transformer Secondary to Main LT Panel is 13 Runs , 12 Meter , 1.1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable $0.1230 \Omega/\text{Km}$ and Reactance of Cable is $0.0618 \Omega/\text{Km}$.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance = $(0.012 \times 0.1230) / 13$
- Total Cable Resistance = 0.00009Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance = $(0.012 \times 0.0618) / 13$
- Total Cable Reactance = 0.00006Ω
- **Total Cable Impedance (Zc3)= $\sqrt{(R \times R) + (X \times X)}$**
- Total Cable Impedance (Zc3) = 0.00011Ω ----- (10)
- **P.U Impedance at Main LT Panel (Z Pu)= (Zc3 X Base KVA) / (Base KV x Base KV x 1000)**
- P.U Impedance at Main LT Panel (Z Pu) = $(0.00011 \times 2.5 \times 1000) / (0.415 \times 0.415 \times 1000)$
- P.U Impedance at Main LT Panel (Z Pu) = 0.001601Ω ----- (11)
- **Total Impedance up to Main LT Panel(Z Pu-d)= (Zc3)+ (Z Pu-c)=(11)+(9)**
- Total Impedance up to Main LT Panel (Z Pu-d) = $0.001601 + 0.0807$
- Total Impedance up to Main LT Panel (Z Pu-d) = 0.082306Ω ----- (12)
- **Fault MVA at Main LT Panel= Base MVA / Z Pu-a.**
- Fault MVA at Main LT Panel = $2.5 / 0.082306$
- **Fault MVA at Main LT Panel= 30 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = $30 / (1.732 \times 0.415)$
- **Fault Current at Main Lt Panel = 42 KA**

(5) Fault Level from Main LT Panel to Sub Panel:

- LT Cable used from Main LT Panel to Sub Panel is 2 Runs , 160 Meter , 1.1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable $0.1230 \Omega/\text{Km}$ and Reactance of Cable is $0.0618 \Omega/\text{Km}$.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance = $(0.160 \times 0.1230) / 2$
- Total Cable Resistance = 0.008184Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance = $(0.160 \times 0.0618) / 2$
- Total Cable Reactance = 0.004944Ω

- **Total Cable Impedance (Zc4)= $\sqrt{(RXR)+(XxX)}$**
- Total Cable Impedance (Zc4)=0.0095614 Ω -----(13)
- **P.U Impedance at Sub Panel (Z Pu)= (Zc4 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Sub Panel(Z Pu)=(0.0095614 X2.5x1000)/(0.415x0.415X1000)
- PP.U Impedance at Sub Panel(Z Pu)=0.13879 Ω -----(14)
- **Total Impedance up to Sub Panel (Z Pu-e)= (Zc4)+ (Z Pu-d)=(14)+(12)**
- Total Impedance up to Sub Panel(Z Pu-e)=0.13879+0.082306
- Total Impedance up to Sub Panel(Z Pu-e)=0.2211 Ω -----(15)
- **Fault MVA at Sub Panel = Base MVA / Z Pu-a.**
- Fault MVA at Sub Panel= 2.5 / 0.2211
- **Fault MVA at Sub Panel = 11 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 11 / (1.732X0.415)
- **Fault Current at Sub Panel= 16 KA**

(6) Fault Level from Sub Panel to Motor Control Panel:

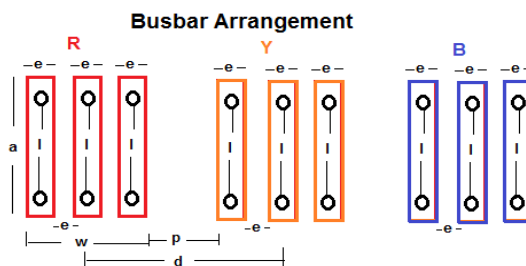
- LT Cable used from Sub Panel to Motor Control Panel is 6 Runs , 150 Meter ,1.1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω /Km and Reactance of Cable is0.0739 Ω /Km.
- **Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.**
- Total Cable Resistance=(0.150X0.1230) / 6
- Total Cable Resistance=0.003075 Ω
- **Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.**
- Total Cable Reactance=(0.150X0.0739) / 6
- Total Cable Reactance =0.0018475 Ω
- **Total Cable Impedance (Zc5)= $\sqrt{(RXR)+(XxX)}$**
- Total Cable Impedance (Zc4)=0.003587 Ω -----(16)
- **P.U Impedance at Motor Control Panel (Z Pu)= (Zc5 X Base KVA) / (Base KV xBase KVx1000)**
- P.U Impedance at Motor Control Panel(Z Pu)=(0.003587 X2.5x1000)/(0.415x0.415X1000)
- PP.U Impedance at Motor Control Panel(Z Pu)=0.05207 Ω -----(17)
- **Total Impedance up to Motor Control Panel(Z Pu-f)= (Zc5)+ (Z Pu-e)=(17)+(15)**
- Total Impedance up to Motor Control Panel(Z Pu-e)=0.13879+0.2211
- Total Impedance up to Motor Control Panel(Z Pu-e)=0.27317 Ω -----(15)
- **Fault MVA at Motor Control Panel= Base MVA / Z Pu-a.**
- Fault MVA at Motor Control Panel= 2.5 / 0.27317
- **Fault MVA at Motor Control Panel = 9 MVA**
- **Fault Current = Fault MVA / Base KV**
- Fault Current = 9 / (1.732X0.415)
- **Fault Current at Motor Control Panel= 13 KA**

Summary of Calculation:

Sr.No	Fault Location	Fault MVA	Fault Current (KA)
1	At HT Circuit Breaker	332	50
2	At Primary Side of Transformer	290	44
3	At Secondary Side of Transformer	31	43
4	At Main LT Panel	30	42
5	At Sub Main Panel	11	16
6	At Motor Control Panel	9	13

Example: Calculate Size of Bus bar having Following Details

- **Bus bar Current Details:**
- Rated Voltage = 415V, 50Hz ,
- Desire Maximum Current Rating of Bus bar = 630Amp.
- Fault Current (I_{sc}) = 50KA
- Fault Duration (t) = 1sec.
- **Bus bar Temperature details:**
- Operating Temperature of Bus bar (θ) = 85°C.
- Final Temperature of Bus bar during Fault (θ_1) = 185°C.
- Temperature rise of Bus Bar Bar during Fault ($\theta_t = \theta_1 - \theta$) = 100°C.
- Ambient Temperature (θ_n) = 50°C.
- Maximum Bus Bar Temperature Rise = 55°C.
- **Enclosure Details:**
- Installation of Panel = Indoors (well Ventilated)
- Altitude of Panel Installation on Site = 2000 Meter
- Panel Length = 1200 mm , Panel width = 600 mm, Panel Height = 2400 mm
- **Bus bar Details:**
- Bus bar Material = Copper
- Bus bar Strip Arrangements = Vertical
- Current Density of Bus Bar Material = 1.6
- Temperature Co efficient of Material Resistance at 20°C (α_{20}) = 0.00403
- Material Constant (K) = 1.166
- Bus bar Material Permissible Strength = 1200 kg/cm²
- Bus bar Insulating Material = Bare
- Bus bar Position = Edge-mounted bars
- Bus bar Installation Media = Non-ventilated ducting
- Bus bar Artificial Ventilation Scheme = without artificial ventilation
- **Bus bar Size Details:**
- Busbar Width (e) = 75 mm
- Busbar Thickness (s) = 10 mm
- Number of Bus Bar per Phase (n) = 2 No
- Busbar Length per Phase (a) = 500 mm
- Distance between Two Bus Strip per Phase (e) = 75 mm
- Busbar Phase Spacing (p) = 400 mm
- Total No of Circuit = 3 No.
- **Busbar Support Insulator Detail:**
- Distance between insulators on Same Phase (l) = 500 mm
- Insulator Height (H) = 100 mm
- Distance from the head of the insulator to the busbar centre of gravity (h) = 5 mm
- Permissible Strength of Insulator (F') = 1000 Kg/cm²



Calculation:

(1) De rating Factor for Bus bar:

- **(1) Per Phase Bus Strip De rating Factor (K1):**
- Bus bar Width(e) is 75mm and Bus bar Length per Phase(a) is 500mm so e/a is $75/500=0.15$
- No of Bus bar per phase is 2 No's.
- From following table value of de rating factor is 1.83

Number of Bus Bar Strip per Phase (K1)			
e/a	No of Bus Bar per Phase		
	1	2	3
0.05	1	1.63	2.4
0.06	1	1.73	2.45
0.08	1	1.76	2.5
0.1	1	1.8	2.55
0.12	1	1.83	2.6
0.14	1	1.85	2.63
0.16	1	1.87	2.65
0.18	1	1.89	2.68
0.2	1	1.91	2.7

- **(2) Busbar Insulating Material Derating Factor (K2)**
- Bus bar having No insulating material. It is Bare so following Table
- De rating Factor is 1.

Bus Bar Insulating Material (K2):	Derating Factor
Bare	1
PVC Sleeving	1.2
Painted	1.5

- **(3) Busbar Position Derating Factor (K3)**
- Bus bar Position is Edge-mounted bars so following Table
- De rating Factor is 1

Bus Bar Position(K3):	Derating Factor
Edge-mounted bars	1
1 bar base-mounted	0.95
several base-mounted bars	0.75

- **(4) Busbar Installation Media Derating Factor (K4)**
- Bus bar Installation Media is Non-ventilated ducting so following Table
- De rating Factor is 0.8

Bus Bar Installation Media(K4):	Derating Factor
Calm indoor atmosphere	1
Calm outdoor atmosphere	1.2
Non-ventilated ducting	0.8

- **(5) Bus bar Artificial Ventilation De rating Factor (K5)**

- Bus bar Installation Media is Non-ventilated ducting so following Table
- Derating Factor is 0.9

Bus Bar Artificial Ventilation Scheme (K5):	Derating Factor
without artificial ventilation	0.9
with artificial ventilation	1

- **(6) Enclosure & Ventilation Derating Factor (K6)**
- Bus bar Area per Phase = Bus width X Bus Thickness X Length of Bus X No of Bus bar per Phase
- Bus bar Area per Phase = $75 \times 10 \times 500 \times 2 = 750000 \text{ mm}$
- Total Bus bar Area for Enclosure = No of Circuit X (No of Phase + Neutral) X Bus bar Area per Phase
- Here we used Size of Neutral Bus is equal to Size of Phase Bus
- Total Bus bar Area for Enclosure = $3 \times (3+1) \times 750000 \text{ mm}$
- Total Bus bar Area for Enclosure = 9000000 Sq.mm
- Total Enclosure Area = width X Height X Length
- Total Enclosure Area = $1200 \times 600 \times 2400 = 1728000000 \text{ Sq.mm}$
- Total Bus bar Area for Enclosure / Total Enclosure Area = $9000000 / 1728000000$
- Total Bus bar Area for Enclosure / Total Enclosure Area = 0.53%
- Bus bar Artificial Ventilation Scheme is without artificial ventilation so following Table
- Derating Factor is 0.95

Volume of Enclosure & Ventilation Derating Factor (K6)			
cross Section area of Busbar/Total Bus Bar Area	Indoors (Panel is well Ventilated)	Indoors (Panel is Poorly Ventilated)	Outdoor
0%	0.95	0.85	0.65
1%	0.95	0.85	0.65
5%	0.9	0.7	0.6
10%	0.85	0.65	0.5

- **(7) Proxy Effect Derating Factor (K7)**
- Bus bar Phase Spacing (p) is 400mm.
- Bus bar Width (e) is 75mm and Space between each bus of Phase is 75mm so
- Total Bus length of Phase with spacing (w) = $75 + 75 + 75 + 75 + 75 = 225 \text{ mm}$
- Bus bar Phase Spacing (p) / Total Bus length of Phase with spacing (w) = $400 / 225 = 2$
- From following Table Derating factor is 0.82

Proxy Effect (K7):	Derating Factor
1	0.82
2	0.82
3	0.82
4	0.89
5	0.95
6	0.99
7	1

- **(8) Altitude of Bus Bar installation Derating Factor (K8)**
- Altitude of Panel Installation on Site is 2000 meter so following Table
- Derating Factor is 0.88

Altitude of installation site (Meter) (K8)	Derating Factor
2200	0.88
2400	0.87
2500	0.86
2700	0.85
2900	0.84
3000	0.83
3300	0.82
3500	0.81
4000	0.78
4500	0.76
5000	0.74

- Total De rating Factor= $K1 \times K2 \times K3 \times K4 \times K5 \times K6 \times K7 \times K8$
- Total De rating Factor = $1.83 \times 1 \times 1 \times 0.8 \times 0.9 \times 0.95 \times 0.82 \times 0.88$
- Total De rating Factor = 0.90

(2) Bus bar Size Calculation:

- Desire Current Rating of Busbar (I2) = 630 Amp
- Current Rating of Busbar after Derating Factor (I1) = I2 X De rating Factor or I2 / De rating Factor
- Current Rating of Busbar after Derating Factor (I1) = 630×0.9
- **Current Rating of Bus bar after De rating Factor (I1) = 697 Amp**
- Busbar Cross Section Area as per Current = Current Rating of Bus bar / Current Density of Material
- Busbar Cross Section Area as per Current = $697 / 1.6$
- **Bus bar Cross Section Area as per Current = 436 Sq.mm**
- Busbar Cross Section Area as per Short Circuit = $I_{sc} \times \sqrt{(K/(\theta \times 100)) \times (1 + \alpha_{20} \times \theta) \times t}$
- Busbar Cross Section Area as per Short Circuit = $50000 \times \sqrt{((1.166/(100 \times 100)) \times (1 + 0.00403 \times 85)) \times 1}$
- **Bus bar Cross Section Area as per Short Circuit = 626 Sq.mm**
- **Select Higher Size for Bus bar Cross section area between 436 Sq.mm and 626 Sq.mm**
- **Final Calculated Bus Bar Cross Section Area = 626 Sq.mm**
- Actual Selected Bus bar size is 75x10=750 Sq.mm
- We have select 2 No's of Bus bar per Phase hence.
- Actual Bus bar cross section Area per Phase = $750 \times 2 = 1500$ Sq.mm
- **Actual Cross Section Area of Bus bar = 1500 Sq.mm**
- **Actual Bus bar Size is Less than calculated Bus bar size.**

(3) Forces generated on Bus Bar due to Short Circuit Current

- Peak electro-magnetic forces between phase conductors (F1) = $2 \times (I/d) \times (2.5 \times I_{sc})^2 / 100000000$
- Total width of Bus bar per Phase (w) = $75 + 75 + 75 = 225$ mm = 2.25 cm
- Bus bar Phase to Phase Distance (d) = $400 + 225 = 625$ mm = 6.25 cm
- Peak electro-magnetic forces between phase conductors (F1) = $2 \times (50/63) \times (2.5 \times 50000)^2 / 100000000$
- Peak electro-magnetic forces between phase conductors (F1) = 250 Kg /cm²
- Peak electro-magnetic forces between phase conductors (F1) = 2.5 Kg /mm²
- Actual Forces at the head of the Supports or Bus Bar (F) = $F1 \times (H + h/H)$
- Actual Forces at the head of the Supports or Bus Bar (F) = $2.5 \times (100 + 5/100)$
- **Actual Forces at the head of the Supports or Bus Bar (F) = 3 Kg /mm²**
- **Permissible Strength of Insulator (F') is 10 Kg/mm²**
- Actual Forces at the head of the Supports or Bus Bar is less than Permissible Strength
- **Forces on Insulation is in within Limits**

(4) Mechanical strength of the busbars

- Mechanical strength of the busbars= $(F \times I / 12) \times (1 / \text{Modulus of inertia of a busbar})$

Value of Modulus of inertia of a busbar or of a set of busbars (i/v)		
No of Bus Strip per Phase	Vertical Bus Bar (cm ³)	Horizontal Bus Bar (cm ³)
1	1.66	16.66
2	14.45	33.33
3	33	50

- From above table Value of Modulus of inertia of a busbar=14.45
- Mechanical strength of the bus bars= $(250 \times 50 / 12) \times (1 / 14.45)$
- Mechanical strength of the bus bars= 72 Kg/cm²
- **Mechanical strength of the bus bars= 0.72 Kg/mm²**
- **Permissible Bus bar Strength is 12 Kg/mm²**
- Actual Mechanical Strength is less than Permissible Strength
- **Mechanical strength of Bus bar is in within Limit**

(5) Temperature Rise Calculation

- **Specified Maximum Temperature Rise (T₁) is 35°C**
- Calculated Maximum Temperature Rise (T₂)= $T / (\log(I_1 / I_2) 1.64)$
- Calculated Maximum Temperature Rise (T₂)= $35 / (\log(697 / 630) 1.64)$
- **Calculated Maximum Temperature Rise (T₂)= 30°C**
- Calculated Bus bar Temperature rise is less than Specified Max Temperature rise
- **Temperature Rise is in within Limit**

Results:

- **Size of Bus bar = 2 No's 75x10mm per Phase.**
- **Total No of Feeder =3 No's**
- **Total No's of Bus bar = 6 No's 75x10mm for Phase and 1 No's 75x10mm for Neutral.**
- **Forces at the head of the Supports or Bus Bar (F)= 3kg/mm²**
- **Mechanical strength of the bus bars= 0.7 Kg/mm²**
- **Maximum Temperature Rise=30°C**

- Calculate Size of Cable Tray for Following Cable Schedule. Cable Tray should be perforated and 20% spare Capacity. Distance between each Cable is 10mm. Cable are laying in Single Layer in Cable Tray.

- (1) 2 No's of 3.5Cx300 Sq.mm XLPE Cable having 59.7mm Outer Diameter and 5.9 Kg/Meter weight
- (2) 2 No's of 3.5Cx400 Sq.mm XLPE Cable having 68.6mm Outer Diameter and 6.1 Kg/Meter weight
- (3) 3 No's of 3.5Cx25 Sq.mm XLPE Cable having 25mm Outer Diameter and 0.5 Kg/Meter weight

Calculation:

Total Outer Diameter of all Cable Passing in to Cable Tray:

- Diameter of 300Sq.mm Cable = No of Cable X Outer Diameter of Each Cable
- Diameter of 300Sq.mm Cable = $2 \times 59.7 = 119.4 \text{ mm}$
- Diameter of 400Sq.mm Cable = No of Cable X Outer Diameter of Each Cable
- Diameter of 400Sq.mm Cable = $2 \times 68.6 = 137.2 \text{ mm}$
- Diameter of 25Sq.mm Cable = No of Cable X Outer Diameter of Each Cable
- Diameter of 25Sq.mm Cable = $3 \times 25 = 75 \text{ mm}$
- Total Diameter of All Cables laying in Tray = $(119.4 + 137.2 + 75) \text{ mm}$
- **Total Diameter of All Cables laying in Tray = 340.6mm**

Total Weight of Cables Passing in to Cable Tray:

- Weight of 300Sq.mm Cable = No of Cable X Weight of Each Cable
- Weight of 300Sq.mm Cable = $2 \times 5.9 = 11.8 \text{ Kg/Meter}$
- Weight of 400Sq.mm Cable = No of Cable X Weight of Each Cable
- Weight of 400Sq.mm Cable = $2 \times 6.1 = 12.2 \text{ Kg/Meter}$
- Weight of 25Sq.mm Cable = No of Cable X Weight of Each Cable
- Weight of 25Sq.mm Cable = $3 \times 0.5 = 1.5 \text{ Kg/Meter}$
- Total Weight of All Cables laying in Tray = $(11.8 + 12.2 + 1.5) \text{ Kg/Meter}$
- **Total Weight of All Cables laying in Tray = 25.5 Kg/Meter**

Total Width of all Cables:

- Total Width of all Cables = (Total No of Cable X Distance between Each Cable) + Total Cable Outer Diameter
- Total Width of all Cables = $(7 \times 10) + 340.6$
- Total Width of all Cables = 410.6 mm
- Taking 20% Spare Capacity of Cable Tray
- Final Width of all Cables = $1.2\% \times 4106.6$
- **Calculated Width of All Cables = 493 mm**

Total Area of Cable:

- Total Area of Cable = Final width of Cables X Maximum Height Cable
- Total Area of Cable = $493 \times 69.6 = 28167 \text{ Sq.mm}$
- Taking 20% Spare Capacity of Cable Tray
- Final Area of all Cables = $1.2\% \times 28167$
- **Calculated Area of all Cable = 33801 Sq.mm**

CASE-(I):

- Considering Single Run of Cable Tray having Size of 300X100mm, 120Kg/Meter Weight Capacity
- Area of Cable Tray = Width of Cable Tray X Height of Cable Tray
- Area of Cable Tray = $300 \times 100 = 3000 \text{ Sq.mm}$

Checking Width of Cable Tray

- Calculated Width of Cable Tray as per Calculation=No of Layer of Cable X No of Cable Tray Run X Width of Cables
- Width of Cable Tray as per Calculation=1X1X493 =493 mm

Checking Depth of Cable Tray

- Actual depth of Cable Tray = No of Layer of Cable X Maximum Diameter of Cable
- Actual depth of Cable Tray=1X68.6 =68.6mm

Checking Weight of Cable Tray

- Actual Weight of Cables=25.5 Kg/Meter

Results:

- Calculated Cable Tray width (493mm)> Actual Cable Tray width (300mm) = **Faulty Selection**
- Calculated depth of Cable Tray (68.6mm)< Actual Depth of Cable Tray (100mm) = **O.K**
- Calculated Weight of all Cables (25.5Kg/Mt) < Actual Weight of Cable Tray (125.5 Kg/Mt) =**O.K**
- **Required to select higher size Cable Tray due to small Cable Tray width.**

CASE-(II):

- Considering Single Run of Cable Tray having Size of 600X100mm, 120Kg/Meter Weight Capacity
- Area of Cable Tray =Width of Cable Tray X Height of Cable Tray
- Area of Cable Tray =600X100 = 6000 Sq.mm

Checking Width of Cable Tray

- Width of Cable Tray as per Calculation=No of Layer of Cable X No of Cable Tray Run X Width of Cables
- Width of Cable Tray as per Calculation=1X1X493 =493 mm

Checking Depth of Cable Tray

- Actual depth of Cable Tray = No of Layer of Cable X Maximum Diameter of Cable
- Actual depth of Cable Tray=1X68.6 =68.6mm

Checking Weight of Cable Tray

- Actual Weight of Cables=25.5 Kg/Meter

Results:

- Calculated Cable Tray width (493mm)< Actual Cable Tray width (600mm) = **O.K**
- Calculated depth of Cable Tray (68.6mm)< Actual Depth of Cable Tray (100mm) = **O.K**
- Calculated Weight of all Cables (25.5Kg/Mt) < Actual Weight of Cable Tray (125.5 Kg/Mt) =**O.K**
- Remaining Cable Tray width Area =100%-(Calculated Cable tray width/ Actual Cable Tray Width)
- Remaining Cable Tray width Area =100%-(493/600)% =**17.9%**
- Remaining Cable Tray Area =100%-(Calculated Cable tray Area/ Actual Cable Tray Area)
- Remaining Cable Tray Area =100%-(33801/60000) =**43.7%**
- **Selection of 600X100 Cable Tray is O.K**

Conclusion

- **Size of Cable Tray= 600X100mm**
- **Type of Cable Tray=Perforated**
- **No of Cable Tray Run= 1No**
- **No of layer of Cables in Cable Tray=1 Layer**
- **Remaining Cable Tray width Area =17.9%**
- **Remaining Cable Tray Area =43.7%**

Calculate Size of Diesel Generator having following Electrical Load. Consider Future Expansion ratio is 10%. Average use of Equipment is 0.8 (1 is Full Time Use)

- 4 No's of 1Ph, 230V, 80Watt CFL Bulbs, Diversity Factor is 0.8; Starting & Running P.F is 0.8.
- 2 No's of 1Ph, 230V, 3000Watt Air Condition, Diversity Factor is 1, Starting & Running P.F is 0.8.
- 2 No's of 1Ph, 230V, 500Watt Halogen Lights Diversity Factor is 0.8 Starting & Running P.F is 0.8.
- 1 No's of 1Ph, 230V, 10KW Motor with Y-D Starter, Diversity Factor is 0.8, Starting P.F is 0.7 & Running P.F is 0.8
- 1 No's of 3Ph, 430V, 130KW Motor with Soft Starter, Diversity Factor is 0.8, Starting P.F is 0.7 & Running P.F is 0.8

Calculation:

Type of Load	Equipment	Starting Current
Linear Load	General Equipments	100% of Full Load Current
Non-Linear Load	UPS, Inverter, Computer, Ballast	160% of Full Load Current

Type of Starter	Starting Current
DOL	6 X Full Load Current
Star-Delta	4 X Full Load Current
Auto Transformer	3 X Full Load Current
Soft Starter	2 X Full Load Current
VFD	1.5 X Full Load Current

Load Calculation-1:

- Full Load KW of CFL Bulb = $(\text{No} \times \text{Watt} \times \text{Diversity Factor}) / 1000$
- Full Load KW of CFL Bulb = $(4 \times 80 \times 0.8) / 1000 = 0.3 \text{ KW}$
- Full Load KVA of CFL Bulb = $\text{KW} / \text{P.F}$
- **Full Load KVA of CFL Bulb = $0.3 / 0.8 = 0.4 \text{ KVA}$ ------(H)**
- Full Load current of CFL Bulb = $(\text{No} \times \text{Watt} \times \text{Diversity Factor}) / (\text{Volt} \times \text{P.F})$
- **Full Load current of CFL Bulb = $(4 \times 80 \times 0.8) / (230 \times 0.8) = 2 \text{ Amp}$ -----(M)**
- Type of Load = Linear
- Starting KVA of CFL Bulb = $1 \times (\text{KW} / \text{Starting P.F})$
- **Starting KVA of CFL Bulb = $0.3 / 0.8 = 0.4 \text{ KVA}$ ------(1)**
- Starting Current = 100% of Full Load Current.
- **Starting Current = $1 \times 2 = 2 \text{ Amp}$ ------(A)**

Load Calculation-2:

- Total Full Load KW of A.C = $(\text{No} \times \text{Watt} \times \text{Diversity Factor}) / 1000$
- Total Full Load KW of A.C = $(2 \times 3000 \times 0.8) / 1000 = 4.8 \text{ KW}$
- Total Full Load KVA of A.C = $\text{KW} / \text{P.F}$
- **Total Full Load KVA of A.C = $4.8 / 0.8 = 6 \text{ KVA}$ ------(I)**
- Total Full Load current of A.C = $(\text{No} \times \text{Watt} \times \text{Diversity Factor}) / (\text{Volt} \times \text{P.F})$
- **Total Full Load current of A.C = $(2 \times 3000 \times 0.8) / (230 \times 0.8) = 26 \text{ Amp}$ ------(N)**
- Type of Load = Non Linear
- Starting KVA of A.C = $1.6 \times (\text{KW} / \text{Starting P.F})$

- **Starting KVA of A.C = $1.6 \times (4.8 / 0.8) = 9.6 \text{ KVA}$ ------(2)**
- Starting Current=160% of Full Load Current.
- **Starting Current= $1.6 \times 26 = 42 \text{ Amp.}$ -----(B)**

Load Calculation-3:

- Full Load KW of Halogen Bulb=(No X Watt X Diversity Factor) /1000
- Full Load KW of Halogen Bulb= $(2 \times 500 \times 0.8) / 1000 = 0.8 \text{ KW}$
- Full Load KVA of Halogen Bulb=KW / P.F
- **Full Load KVA of Halogen Bulb= $0.8 / 0.8 = 1 \text{ KVA}$ ------(J)**
- Full Load current of Halogen Bulb=(No X Watt X Diversity Factor) / (Volt x P.F)
- **Full Load current of Halogen Bulb= $(2 \times 500 \times 0.8) / (230 \times 0.8) = 4 \text{ Amp}$ -----(O)**
- Type of Load=Non Linear
- Starting KVA of Halogen Bulb = $1.6 \times (\text{KW} / \text{Starting P.F}) / \text{Starting P.F}$
- **Starting KVA of Halogen Bulb = $1.6 \times (0.8 / 0.8) = 1.6 \text{ KVA}$ ------(3)**
- Starting Current=160% of Full Load Current.
- **Starting Current= $1.6 \times 4 = 7 \text{ Amp}$.------(C)**

Load Calculation-4:

- Full Load KW of Motor=(No X Watt X Diversity Factor) /1000
- Full Load KW of Motor = $(1 \times 10000 \times 0.8) / 1000 = 8 \text{ KW}$
- Full Load KVA of Motor =KW / P.F
- **Full Load KVA of Motor = $8 / 0.8 = 10 \text{ KVA}$ ------(K)**
- Full Load current of Motor =(No X Watt X Diversity Factor) / (Volt x P.F)
- **Full Load current of Motor = $(1 \times 10000 \times 0.8) / (230 \times 0.8) = 43 \text{ Amp}$ -----(P)**
- Type of Starter=Star-Delta
- Starting KVA of Motor = $4 \times (\text{KW} / \text{Starting P.F})$
- **Starting KVA of Motor= $4 \times (8 / 0.7) = 45.7 \text{ KVA}$ ------(4)**
- Starting Current=4 X Full Load Current
- **Starting Current= $4 \times 11.4 = 174 \text{ Amp.}$ ------(D)**

Load Calculation-5:

- Full Load KW of Motor=(No X Watt X Diversity Factor) /1000
- Full Load KW of Motor = $(1 \times 120000 \times 0.8) / 1000 = 96 \text{ KW}$
- Full Load KVA of Motor =KW / P.F
- **Full Load KVA of Motor = $96 / 0.8 = 120 \text{ KVA}$ ------(L)**
- Full Load current of Motor =(No X Watt X Diversity Factor) / (Volt x P.F)
- **Full Load current of Motor = $(1 \times 120000 \times 0.8) / (1.732 \times 430 \times 0.8) = 167 \text{ Amp}$ -----(Q)**
- Type of Starter=Auto Transformer
- Starting KVA of Motor = $3 \times (\text{KW} / \text{Starting P.F})$
- **Starting KVA of Motor= $3 \times (96 / 0.7) = 411.4 \text{ KVA}$ ------(5)**
- Starting Current=3 X Full Load Current
- **Starting Current= $3 \times 167 = 501 \text{ Amp.}$ ------(E)**

Total Load Calculation:

- **Total Starting KVA = (1) + (2) + (3) + (4) + (5)**
- **Total Starting KVA = $0.4 + 9.6 + 1.6 + 45.7 + 411.4 = 468.7 \text{ KVA}$**
- **Total Starting Current = (A) + (B) + (C) + (D) + E**
- **Total Starting Current = $2 + 42 + 7 + 174 + 501 = 725 \text{ Amp}$**
- **Total Running KVA = (H) + (I) + (J) + (K) + (L)**

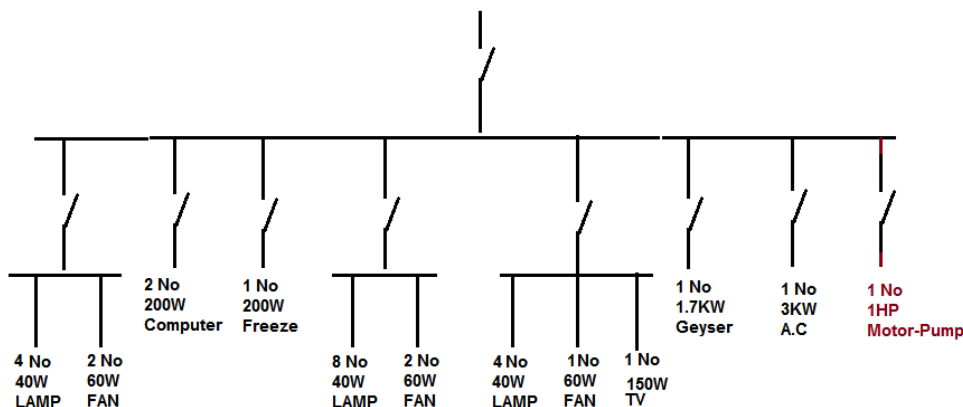
- **Total Running KVA** $=0.4+6+1+10+120= 137\text{KVA}$
- **Total Running Current** $=(M)+(N)+(O)+(P)+(Q)$
- **Total Running Current** $=2+26+4+43+167= 242 \text{ Amp}$
- **Size of Diesel Generator= Starting KVA X Future Expansion X Average Use of Equipments**
- **Size of Diesel Generator** $=468 \times 1.1 \times 0.8$
- **Size of Diesel Generator= 412 KVA**

Summary:

- **Total Starting KVA** $=468.7 \text{ KVA}$
- **Total Starting Current** $=725 \text{ Amp}$
- **Total Running KVA** $= 137\text{KVA}$
- **Total Running Current** $= 242 \text{ Amp}$
- **Size of Diesel Generator= 412 KVA**

Chapter: 64 Calculate Size of Main ELCB / Branch MCB of Distribution Box

- Design Distribution Box of one House and Calculation of Size of Main ELCB and branch Circuit MCB as following Load Detail. Power Supply is 430V (P-P), 230 (P-N), 50Hz. Consider Demand Factor 0.6 for Non Continuous Load & 1 for Continuous Load for Each Equipment.
- Branch Circuit-1:** 4 No of 1Ph, 40W, Lamp of Non Continues Load + 2 No's of 1Phas 60W, Fan of Non Continues Load.
- Branch Circuit-2:** 2 No of 1Ph, 200W, Computer of Non Continues Load.
- Branch Circuit-3:** 1 No of 1Ph, 200W, Freeze of Continues Load.
- Branch Circuit-4:** 8 No of 1Ph, 40W, Lamp of Non Continues Load + 2 No's of 1Phas 60W, Fan of Non Continues Load.
- Branch Circuit-5:** 4 No of 1Ph, 40W, Lamp of Non Continues Load + 1 No's of 1Ph, 60W, Fan of Non Continues Load.+ 1 No's of 1Ph, 150W, TV of Continues Load
- Branch Circuit-6:** 1 No of 1Ph, 1.7KW, Geyser of Non Continues Load.
- Branch Circuit-7:** 1 No of 1Ph, 3KW, A.C of Non Continues Load.
- Branch Circuit-8:** 1 No of 3Ph, 1HP, Motor-Pump of Non Continues Load.



Fault Current (TABLE-A)	
Voltage	Fault Current
230V	6KA
430V	10KA
11KV	25KA

Class of MCB/ELCB/RCCB (TABLE-B)		
Type of Load	Class	Sensitivity
Lighting	B Class	$I\Delta n:30ma$
Heater	B Class	$I\Delta n:30ma$
Drive	C Class	$I\Delta n:100ma$
A.C	C Class	$I\Delta n:30ma$
Motor	C Class	$I\Delta n:100ma$
Ballast	C Class	$I\Delta n:30ma$
Induction Load	C Class	$I\Delta n:100ma$
Transformer	D Class	$I\Delta n:100ma$

Size of MCB/ELCB (TABLE-C)		
Current (Amp)	Lighting Load MCB/ELCB (Amp)	Heating/Cooling/Motor-Pump Load MCB/ELCB (Amp)
1.0 to 4.0	6	16
6.0	10	16

10.0	16	16
16.0	20	20
20.0	25	25
25.0	32	32
32.0	40	40
40.0	45	45
45.0	50	50
50.0	63	63
63.0	80	80
80.0	100	100
100.0	125	125
125.0	225	225
225.0	600	600
600.0	800	800
800.0	1600	1600
1600.0	2000	2000
2000.0	3000	3000
3000.0	3200	3200
3200.0	4000	4000
4000.0	5000	5000
5000.0	6000	6000
6000.0	6000	6000

Calculation:

Size of MCB for Branch Circuit-1:

- Load Current of Lamp= (No X Watt X Demand Factor)/Volt = $(4 \times 40 \times 0.6)/230 = 0.40\text{Amp}$
- Load Current of Fan= (No X Watt X Demand Factor)/Volt = $(2 \times 60 \times 0.6)/230 = 0.31\text{Amp}$
- **Branch Circuit-1 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-1 Current as per NEC = $(0.4+0.31)+125\%(0) = 0.73\text{Amp}$
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-2:

- Load Current of Computer = (No X Watt X Demand Factor)/Volt = $(2 \times 200 \times 0.6)/230 = 1.04\text{Amp}$
- **Branch Circuit-2 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-2 Current as per NEC = $(1.04)+125\%(0) = 1.04\text{Amp}$
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-3:

- Load Current of Freeze= (No X Watt X Demand Factor)/Volt = $(1 \times 200 \times 0.6)/230 = 0.87\text{Amp}$
- **Branch Circuit-3 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-3 Current as per NEC = $(0.87)+125\%(0) = 0.87\text{Amp}$
- Type of Load=Lighting Type

- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-4:

- Load Current of Lamp= (No X Watt X Demand Factor)/Volt $= (8 \times 40 \times 0.6) / 230 = 0.83 \text{ Amp}$
- Load Current of Fan= (No X Watt X Demand Factor)/Volt $= (2 \times 60 \times 0.6) / 230 = 0.31 \text{ Amp}$
- **Branch Circuit-4 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-4 Current as per NEC $= (0.83 + 0.31) + 125\%(0) = 1.15 \text{ Amp}$
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-5:

- Load Current of Lamp= (No X Watt X Demand Factor)/Volt $= (4 \times 40 \times 0.6) / 230 = 0.42 \text{ Amp}$
- Load Current of Fan= (No X Watt X Demand Factor)/Volt $= (1 \times 60 \times 0.6) / 230 = 0.16 \text{ Amp}$
- Load Current of TV = (No X Watt X Demand Factor)/Volt $= (1 \times 150 \times 1) / 230 = 0.65 \text{ Amp}$
- **Branch Circuit-5 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-5 Current as per NEC $= (0.42 + 0.16) + 125\%(0.65) = 0.57 + 0.82 = 1.39 \text{ Amp}$
- Type of Load=Lighting Type
- Class of MCB=B Class
- Size of MCB=6 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-6:

- Load Current of Geyser= (No X Watt X Demand Factor)/Volt $= (1 \times 1700 \times 0.6) / 230 = 4.43 \text{ Amp}$
- **Branch Circuit-6 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-6 Current as per NEC $= (4.43) + 125\%(0) = 4.43 \text{ Amp}$
- Type of Load=Heating & Cooling Type
- Class of MCB=C Class
- Size of MCB=16 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-7:

- Load Current of A.C= (No X Watt X Demand Factor)/Volt $= (1 \times 3000 \times 0.6) / 230 = 7.83 \text{ Amp}$
- **Branch Circuit-7 Current as per NEC = Non Continues Load+125% Continues Load**
- Branch Circuit-7 Current as per NEC $= (7.83) + 125\%(0) = 7.83 \text{ Amp}$
- Type of Load=Heating & Cooling Type
- Class of MCB=C Class
- Size of MCB=16 Amp
- Breaking Capacity: 6KA
- No of Pole of MCB=Single Pole

Size of MCB for Branch Circuit-8:

- Load Current of Motor-Pump = $(No \times Watt \times Demand \text{ Factor}) / (1.732 \times Voltage)$
 $= (1 \times 746 \times 0.6) / (1.732 \times 430) = 0.60 \text{ Amp}$
- **Branch Circuit-8 Current as per NEC = Non Continuous Load + 125% Continuous Load**
- Branch Circuit-8 Current as per NEC = $(0.60) + 125\%(0) = 0.60 \text{ Amp}$
- Type of Load = Motor-Pump Type
- Class of MCB = C Class
- Size of MCB = 16 Amp
- Breaking Capacity: 10KA
- No of Pole of MCB = Three Pole

Size of Main ELCB/RCCB:

- Total Branch Circuit Load & MCB Detail is

Branch Circuit	Total Current (Amp)	Size of MCB (Amp)	Class of MCB	Breaking Capacity of MCB	Pole of MCB
Branch circuit-1	0.73	6 Amp	B Class	6KA	SP
Branch circuit-2	1.04	6 Amp	B Class	6KA	SP
Branch circuit-3	0.87	6 Amp	B Class	6KA	SP
Branch circuit-4	1.15	6 Amp	B Class	6KA	SP
Branch circuit-5	1.39	6 Amp	B Class	6KA	SP
Branch circuit-6	4.43	16 Amp	C Class	6KA	SP
Branch circuit-7	7.83	16 Amp	C Class	6KA	SP
Branch circuit-8	0.63	16 Amp	C Class	10KA	TP
Total	18.04				

- Total Load Current as per NEC = 18.04 Amp ----- (A)
- Max Size of Branch circuit MCB = 16 Amp
- **Total Load Current of Panel as per Branch Circuit = 2X Max Size of Branch circuit MCB**
- Total Load Current of Panel as per Branch Circuit = $2 \times 16 = 32 \text{ Amp}$ ----- (B)
- Total Load Current of Panel as per NEC = Maximum of (A) and (B)
- Total Load Current of Panel as per NEC = 32 Amp
- **Min Size of ELCB/RCCB as per NEC = 40 Amp**
- Class of ELCB/RCCB = B or C Class
- No of Pole of ELCB/RCCB = TP or FP
- Sensitivity ($I_{\Delta n}$) = 30ma
- Breaking Capacity = 10KA

Size of Distribution Board:

- No of Single Pole Branch Circuit MCB (SP) = 7 No's
- No of Three Pole Branch Circuit MCB (TP) = 1 No's
- Main ELCB (TP) = 1 No's
- Total No of Way of D.B (SPN) = $(SP) + 3 \times (TP) = 7 + (3 \times 2) = 13 \text{ Way SPN}$
- Total No of Way of D.B (TPN) = $(SP)/3 + (TP) = (7/3) + (2) = 4 + 2 = 6 \text{ Way SPN}$
- Select Either 14Way SPN or 6 Way TPN

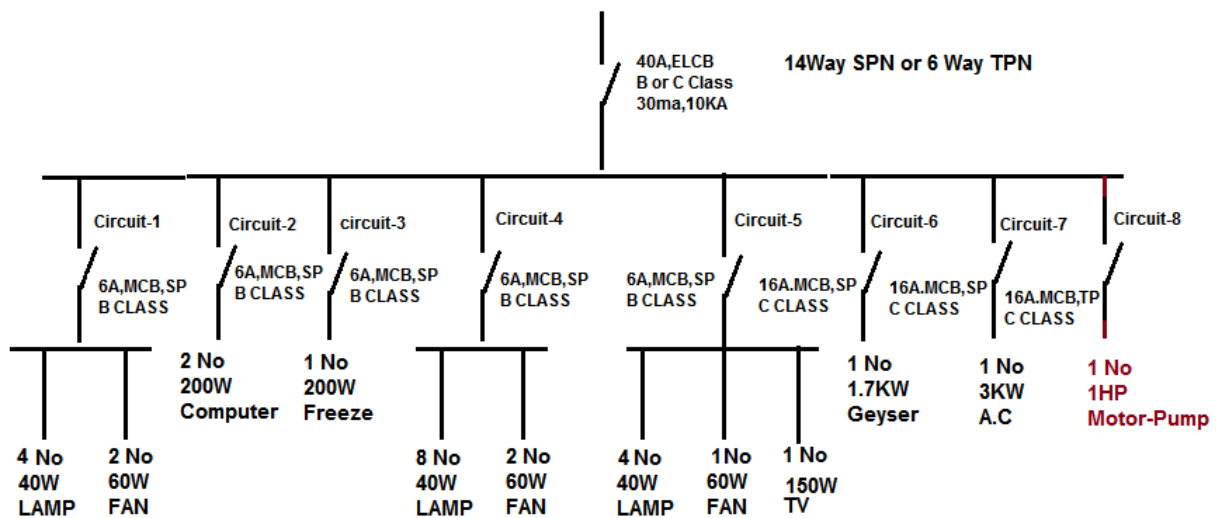
Load Balancing of Distribution Board:

- To Balance Load We need to try distribute Single Phase load on each Phase.
- Suppose We connect Branch Circuit load on following Phase

Branch Circuit	Current (Amp)	Type of Load	Connection on
Branch circuit-1	0.73	Single Phase	Y Phase

Branch circuit-2	1.04	Single Phase	B Phase
Branch circuit-3	0.87	Single Phase	Y Phase
Branch circuit-4	1.15	Single Phase	B Phase
Branch circuit-5	1.39	Single Phase	Y Phase
Branch circuit-6	4.43	Single Phase	B Phase
Branch circuit-7	7.83	Single Phase	R Phase
Branch circuit-8	0.63	Three Phase	RYB Phase
Summary of Load			
R Phase Load	8.5	Amp	
Y Phase Load	3.5	Amp	
B Phase Load	7.23	Amp	
Total Load	18.04	Amp	

Summary of Distribution Box:



- **Size of Distribution Box :** 14Way SPN or 6 Way TPN
- **Size of Main ELCB:** 40A,B or C Class,30ma,10KA
- **Size & No of Branch MCB:** 5 No's of 6A,SP, B Class,6KA
- **Size & No of Branch MCB:** 2 No's of 16A,SP, C Class,6KA
- **Size & No of Branch MCB:** 1 No's of 16A,TP, C Class,10KA

- Calculate Size of Solar Panel, No of Solar Panel and Size of Inverter for following Electrical Load

Electrical Load Detail:

- 1 No's of 100W Computer use for 8 Hours/Day
- 2 No's of 60W Fan use for 8 Hours/Day
- 1 No's of 100W CFL Light use for 8 Hours/Day

Solar System Detail:

- Solar System Voltage (As per Battery Bank) = 48V DC
- Loose Wiring Connection Factor = 20%
- Daily Sunshine Hour in Summer = 6 Hours/Day
- Daily Sunshine Hour in Winter = 4.5 Hours/Day
- Daily Sunshine Hour in Monsoon = 4 Hours/Day

Inverter Detail:

- Future Load Expansion Factor = 10%
- Inverter Efficiency = 80%
- Inverter Power Factor = 0.8

Calculation:

Step-1: Calculate Electrical Usages per Day

- Power Consumption for Computer = No x Watt x Use Hours/Day
- Power Consumption for Computer = $1 \times 100 \times 8 = 800 \text{ Watt Hr/Day}$
- Power Consumption for Fan = No x Watt x Use Hours/Day
- Power Consumption for Fan = $2 \times 60 \times 8 = 960 \text{ Watt Hr/Day}$
- Power Consumption for CFL Light = No x Watt x Use Hours/Day
- Power Consumption for CFL Light = $1 \times 100 \times 8 = 800 \text{ Watt Hr/Day}$
- Total Electrical Load = $800 + 960 + 800 = 2560 \text{ Watt Hr/Day}$

Step-2: Calculate Solar Panel Size

- Average Sunshine Hours = Daily Sunshine Hour in Summer+ Winter+ Monsoon /3
- Average Sunshine Hours = $6 + 4.5 + 4 / 3 = 4.8 \text{ Hours}$
- Total Electrical Load = 2560 Watt Hr/Day
- Required Size of Solar Panel = (Electrical Load / Avg. Sunshine) X Correction Factor
- Required Size of Solar Panel = $(2560 / 4.8) \times 1.2 = 635.6 \text{ Watt}$
- **Required Size of Solar Panel = 635.6 Watt**

Step-3: Calculate No of Solar Panel / Array of Solar Panel

If we Use 250 Watt, 24V Solar Panel in Series-Parallel Type Connection

- In Series-Parallel Connection Both Capacity (watt) and Volt are increases
- No of String of Solar Panel (Watt) = Total Size of Solar Panel / Capacity of Each Panel
- No of String of Solar Panel (Watt) = $635.6 / 250 = 2.5$ No's Say **3 No's**
- **No of Solar Panel in Each String= Solar System Volt / Each Solar Panel Volt**
- No of Solar Panel in Each String= $48/24 = 2 \text{ No's}$
- Total No of Solar Panel = No of String of Solar Panel x No of Solar Panel in Each String

- Total No of Solar Panel = $3 \times 2 = 6$ No's
- **Total No of Solar Panel = 6 No's**

Step-4: Calculate Electrical Load:

- Load for Computer = No x Watt
- Load for Computer = $1 \times 100 = 100$ Watt
- Load for Fan = No x Watt
- Load for Fan = $2 \times 60 = 120$ Watt
- Load for CFL Light = No x Watt
- Load for CFL Light = $1 \times 100 = 100$ Watt
- Total Electrical Load = $100 + 120 + 100 = 320$ Watt

Step-5: Calculate Size of Inverter:

- Total Electrical Load in Watt = 320 Watt
- **Total Electrical Load in VA = Watt / P.F**
- Total Electrical Load in VA = $320 / 0.8 = 400$ VA
- **Size of Inverter = Total Load x Correction Factor / Efficiency**
- Size of Inverter = $320 \times 1.2 / 80\% = 440$ Watt
- Size of Inverter = $400 \times 1.2 / 80\% = 600$ VA
- **Size of Inverter = 440 Watt or 600 VA**

Summary:

- Required Size of Solar Panel = 635.6 Watt
- Size of Each Solar Panel = 250 Watt. 12 V
- No of String of Solar Panel = 3 No's
- No of Solar Panel in Each String = 2 No's
- **Total No of Solar Panel = 6 No's**
- **Total Size of Solar Panel = 750 Watt**
- **Size of Inverter = 440 watt or 600 VA**

Calculate Size of Inverter for following Electrical Load .Calculate Size of Battery Bank and decide Connection of Battery.

Electrical Load detail:

- 2 No of 60W,230V, 0.8 P.F Fan.
- 1 No of 200W,230V, 0.8 P.F Computer.
- 2 No of 30W,230V, 0.8 P.F Tube Light.

Inverter / Battery Detail:

- Additional Further Load Expansion (Af)=20%
- Efficiency of Inverter (Ie) = 80%
- Required Battery Backup (Bb) = 2 Hours.
- Battery Bank Voltage = 24V DC
- Loose Connection/Wire Loss Factor (LF) = 20%
- Battery Efficiency (n) = 90%
- Battery Aging Factor (Ag) =20%
- Depth of Discharge (DOD) =50%
- Battery Operating Temp =46°C

Temp. °C	Factor
80	1.00
70	1.04
60	1.11
50	1.19
40	1.30
30	1.40
20	1.59

Calculation:

Step 1: Calculate Total Load:

- Fan Load= No x Watt =2x60=**120 Watt**
- Fan Load=(No x Watt)/P.F=(2x60)/0.8= **150VA**
- Computer Load= No x Watt =1x200=**200 Watt**
- Computer Load=(No x Watt)/P.F =(1x200)/0.8= **250VA**
- Tube Light Load= No x Watt =2x30=**60 Watt**
- Tube Light Load=(No x Watt)/P.F =(2x30)/0.8= **75VA**
- **Total Electrical Load=120+200+60 =380 Watt**
- **Total Electrical Load=150+250+75= 475VA**

Step 2: Size of Inverter:

- Size of Inverter=Total Load+(1+Af) / Ie VA
- Size of Inverter= 475+(1+20%) / 80%
- **Size of Inverter= 712 VA**

Step 3: Size of Battery:

- Total Load of Battery Bank= (Total Load x Backup Capacity) / Battery Bank Volt
- Total Load of Battery Bank=(380 x 2) / 24 Amp Hr
- **Total Load of Battery Bank= 32.66 Amp Hr**

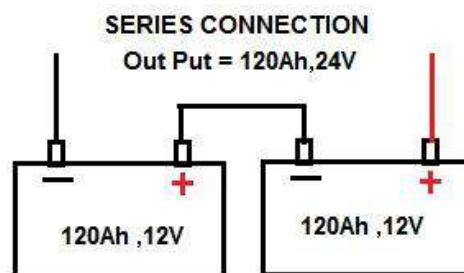
- Temperature Correction Factor for 46°C (Tp)=1
- Size of Battery Bank=[(Load) x (1+LF) x (1+Ag) x Tp] / [n x DOD] Amp/Hr
- Size of Battery Bank= (32.66 x (1+20%) x (1+20%) x 1) / (90% x 50%)
- **Size of Battery Bank= 101.3 Amp/Hr**

Step 4: Connection of Battery:

If We Select 120 Amp Hr , 12V DC Battery for Battery Bank:

Series Connection:

- Series configurations will add the voltage of the two batteries but keep the amperage rating (Amp Hours) same.
- Condition-I :
- **Selection of Battery for Voltage = Volt of Each Battery <= Volt of Battery Bank**
- Selection of Battery for Voltage =12< 24
- **Condition-I is O.K**
- No of Battery for Voltage = Volt of Battery Bank / Volt of Each Battery
- No of Battery for Voltage =24/12 = **2 No's**
- Condition-II :
- **Selection of Battery for Amp Hr = Amp Hr of Battery Bank <= Amp Hr of Each Battery**
- Selection of Battery for Amp Hr =101.3<=120
- **Condition-II is O.K**
- We can use Series Connection for Battery & No of Battery required 2 No's

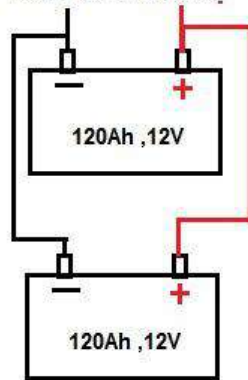


Parallel Configuration

- In Parallel connection, the current rating will increase but the voltage will be the same.
- More the number of batteries more will be the amp/hour. Two batteries will produce twice the amp/hour of a single battery.
- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Battery Bank / Amp Hr of Each Battery <=1
- Selection of Battery for Amp Hr =101/120 = 0.84=**1 No's**
- **Condition-I is O.K**
- Condition-II :
- **Selection of Battery for Voltage = Volt of Battery Bank = Volt of Each Battery**
- Condition-II :Selection of Battery for Voltage for Amp Hr = **24<=12**
- **Condition-II is Not Full Fill**
- We cannot use Parallel Connection for Battery as per our requirement But If We do Practically It is Possible and it will give more Hours of back

PARALLEL CONNECTION

Out Put= 240Ah, 12V



Series-Parallel Connection:

- Connecting the batteries up in series will increase both the voltage and the run time.
- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Each Battery $\leq$ Amp Hr of Battery Bank
- Selection of Battery for Amp Hr = $120 \leq 101$
- **Condition-I is Not Full Fill**
- Condition-II :
- Selection of Battery for Voltage = Volt of Each Battery $\leq$ Volt of Battery Bank
- Selection of Battery for Voltage = $12 \leq 24$
- **Condition-II is OK**
- We cannot use Parallel Connection for Battery

If We Select 60 Amp Hr , 12V DC Battery for Battery Bank:

Series Connection:

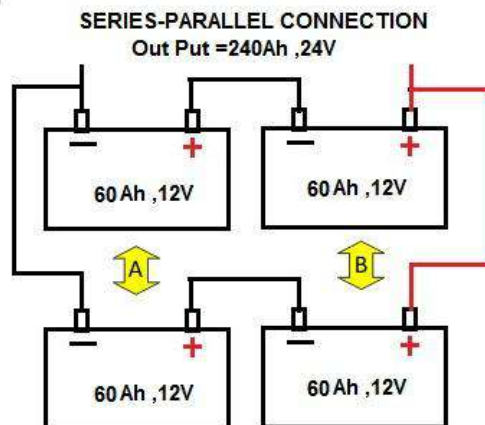
- **Selection of Battery for Voltage = Volt of Each Battery $\leq$ Volt of Battery Bank**
- Selection of Battery for Voltage = $12 < 24$
- **Condition-I is O.K**
- No of Battery for Voltage = Volt of Battery Bank / Volt of Each Battery
- No of Battery for Voltage = $24/12 = 2$ No's
- Condition-II :
- **Selection of Battery for Amp Hr = Amp Hr of Battery Bank $\leq$ Amp Hr of Each Battery**
- Selection of Battery for Amp Hr = $101.3 \leq 60$
- **Condition-II is Not Full Fill**
- We can use Series Connection for Battery

Parallel Configuration

- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Battery Bank / Amp Hr of Each Battery ≤ 1
- Selection of Battery for Amp Hr = $101/60 = 1.63 = 1$ No's
- **Condition-I is O.K**
- Condition-II :
- **Selection of Battery for Voltage = Volt of Battery Bank = Volt of Each Battery**
- Condition-II : Selection of Battery for Voltage for Amp Hr = $24 = 12$
- **Condition-II is Not Full Fill**
- We cannot use Parallel Connection for Battery as per our requirement.

Series-Parallel Connection:

- Condition-I :
- Selection of Battery for Amp Hr = Amp Hr of Each Battery $\leq$ Amp Hr of Battery Bank
- Selection of Battery for Amp Hr = $120 \leq 60$
- **Condition-I is OK**
- No of Battery for Amp Hr = Amp Hr of Battery Bank / Amp Hr of Each Battery
- No of Battery for Amp Hr = $120/60 = 1.68 = 2$ No's
- Condition-II :
- Selection of Battery for Voltage = Volt of Each Battery $\leq$ Volt of Battery Bank
- Selection of Battery for Voltage = $12 \leq 24$
- **Condition-II is OK**
- No of Battery for Voltage = Volt of Battery Bank / Volt of Each Battery
- No of Battery for Voltage = $24 / 12 = 2$ No's
- No of Battery Required = No of Battery Amp Hr x No of Battery for Voltage
- No of Battery Required = $2 \times 2 = 4$ No's
- We can use Series-Parallel Connection for Battery



Summary

- Total Electrical Load = 380 Watt
- Total Electrical Load = 475VA
- **Size of Inverter = 712 VA**
- **Size of Battery Bank = 101.3 Amp/Hr**
- For 120 Amp/Hr , 12V DC Battery : Series Connection & 2 No's of Battery or
- For 60 Amp/Hr , 12V DC Battery : Series-Parallel Connection & 4 No's of Battery

Chapter: 67

Calculate Cable Trunking Size

Example: Calculate PVC Trunking size for following Power Cables running through Trunking .Consider 10% as Future expansion

- (1) 30 No's of 1.5 Sq.mm Stranded Cables
- (2) 50 No's of 2.5 Sq.mm Stranded Cables
- (3) 20 No's of 4 Sq.mm Stranded Cables

Cable Factor for Trunking as per IEEE		
Type of Cable	Size of Cable	Factor
Solid	1.5	7.1
Solid	2.5	10.2
Stranded	1.5	8.1
Stranded	2.5	11.4
Stranded	4	15.2
Stranded	6	22.9
Stranded	10	36.3
Stranded	16	50.3
Stranded	25	75.4
Stranded	35	95
Stranded	50	132.7
Stranded	70	176.7
Stranded	95	227
Stranded	120	284
Stranded	150	346

Trunking Factor As per IEEE	
Trunking Size (mm)	Factor
75 X 25	738
50 X 37.5	767
100 X 50	993
50 x 50	1037
75 X 37.5	1146
100 X 37.5	1542
75 X 50	1555
100 X 50	2091
75 X 75	2371
150 X 50	3161
100 X 75	3189
100 X 100	4252
150 X 75	4787
150 X 100	6414
150 X 150	9575

Calculations:

- As per Table Cable Factor for 1.5 Sq.mm Stranded Cable=8.1
- As per Table Cable Factor for 2.5 Sq.mm Stranded Cable=11.4
- As per Table Cable Factor for 2.5 Sq.mm Stranded Cable=22.9
- **Total Cable Factor= No of Cables X Cable Factor**
- **Total Cable Factor=(30X8.1)+(50X11.4)+(20X22.9) =1271**
- **Total Cable Factor After 10% Future Expansion=1271+127 =1398**
- As per Table Suitable Size for PVC Trunking for Cable Factor 1398 is 100 X 37.5
- **Suitable PVC Trunking is 100 X 37.5 mm**

Example: Calculate Size of Conduit (Hume Pipe) for Following Size of Cables

- 1) 5 No's of 3.5 Core 50 Sq.mm XLPE Cable. Diameter of cable is 28mm
- 2) 3 No's of 3.5 Core 185 Sq.mm XLPE Cable. Diameter of cable is 54mm

% Fill Up Area of Conduit	
No of Cables	% Fill up Area of Conduit
Up to 2 No's	53%
2 No's	31%
More Than 2 No's	40%

Calculations:

- **Area of Cable = $3.14 \times (\text{Radius}/2)^2$**
- Area of 50 Cable = $3.14 \times (28/2)^2 = 615.44 \text{ Sq.mm}$
- Total Area of 50 Cable = No of Cable X Area of Each Cable
- Total Area of 50 Cable = $5 \times 615.44 = 3077.2$
- Area of 185 Cable = $3.14 \times (54/2)^2 = 2289 \text{ Sq.mm}$
- Total Area of 185 Cable = No of Cable X Area of Each Cable
- Total Area of 185 Cable = $3 \times 2289 = 6867.18$
- Total Area of Conductor = Total Area of 50 Cable + Total Area of 185 Cable
- Total Area of Conductor = $3077.2 + 6867.18$
- **Total Area of Conductor = 9944 Sq.mm**
- **Suppose We Select 150mm Diameter Hume Pipe**
- Total area of 150 mm Diameter Hume Pipe = $3.14 \times (\text{Radius}/2)^2 = 3.14 \times (150/2)^2$.
- Total area of 150 mm Diameter Hume Pipe = 17662 Sq.mm.
- % Fill up Area of Conduit due to Cables as per above Table is 40%
- Actual Fill up Area of Hume Pipe = $40\% \times \text{Area of Conduit} = 40\% \times 17662$
- Actual Fill up Area of Hume Pipe = 7065 Sq.mm
- **Required No of Conduit = Total Area of Cables / Actual Fill up Area of Conduit**
- Required No of Conduit = $9944 / 7065$
- **Required No of Conduit = 2 No's**
- **Suppose We Select 300mm Diameter Hume Pipe**
- Total area of 300 mm Diameter Hume Pipe = $3.14 \times (\text{Radius}/2)^2 = 3.14 \times (300/2)^2$.
- Total area of 150 mm Diameter Hume Pipe = 70650 Sq.mm.
- Actual Fill up Area of Hume Pipe = $40\% \times \text{Area of Conduit} = 40\% \times 70650$
- Actual Fill up Area of Hume Pipe = 28260 Sq.mm
- **Required No of Conduit = Total Area of Cables / Actual Fill up Area of Conduit**
- Required No of Conduit = $9944 / 28260$
- **Required No of Conduit = 1 No's**

Results:

- **Either We Select**
- **2 No's of 185 mm Diameter Conduit /Hume Pipe or**
- **1 No's 300 mm Diameter Conduit /Hume Pipe**

Chapter: 69 Calculate Cable Voltage Drop for Street Light Poles

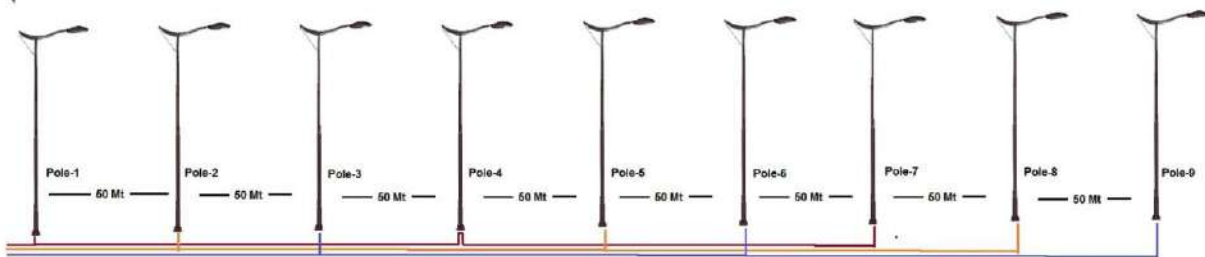
Example: Calculate Voltage drop of Cable for Street Light Pole. System Voltage is 230V (P-N), Power Factor=0.75. Allowable Voltage Drop = 4% .The Detail of Pole & cable are

Pole Detail:

- Section feeder Pillar is 50 meter away from Pole-1
- Distance between each Pole is 50 Meter Distance
- Luminar of Each Pole Fitting = 2 No's
- Luminar Watt =250 Watt

Cable Detail:

- Size of Cable= 4CX10 Sq.mm.
- First Pole is connected in R Phase Next Pole is connected in Y Phase Than Next Pole is connected in B Phase. Next Pole is connected again R Phase.
- Resistance of Cable=3.7 Ω /Km
- Reactance of Cable=0.1 Ω /Km



Calculation:

Load of Each Pole

- **Load of Each Pole = (Watt of Each Luminar X No of Luminar) / Volt X P.F**
- Load of Each Pole = (250X2) / (230X0.75)
- Load of Each Pole = 2.9 Amp

For Pole Pole-1:

- Pole Connected on "R" Phase
- Total Distance of Pole for "R" Phase =50 Meter ,
- **% Voltage drop of Cable= (Current X (Rcos ϕ + JSin ϕ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X50 / (230x1x1000)
- % Voltage drop of Cable= 0.18% -----(1)

For Pole Pole-2:

- Pole Connected on "Y" Phase
- Total Distance of Pole for "Y" Phase =50+50=100 Meter ,
- **% Voltage drop of Cable= (Current X (Rcos ϕ + JSin ϕ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= (2.9x(3.7x0.75+0.1x0.66)X100 / (230x1x1000)
- % Voltage drop of Cable= 0.36% -----(2)

For Pole Pole-3:

- Pole Connected on "B" Phase
- Total Distance of Pole for "B" Phase =50+50+50=150 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 150) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 0.54% -----(3)

For Pole Pole-4:

- Pole Connected on "R" Phase
- Total Distance of Pole for "R" Phase =150+50=200 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 200) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 0.72% -----(4)

For Pole Pole-5:

- Pole Connected on "Y" Phase
- Total Distance of Pole for "Y" Phase =200+50=250 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 250) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 0.9% -----(5)

For Pole Pole-6:

- Pole Connected on "B" Phase
- Total Distance of Pole for "B" Phase =250+50=300 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 300) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 1.07% -----(6)

For Pole Pole-7:

- Pole Connected on "R" Phase
- Total Distance of Pole for "R" Phase =300+50=350 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 350) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 1.25% -----(7)

For Pole Pole-8:

- Pole Connected on "Y" Phase
- Total Distance of Pole for "Y" Phase =350+50=400 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 400) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 1.43% -----(8)

For Pole Pole-9:

- Pole Connected on "B" Phase
- Total Distance of Pole for "B" Phase =400+50=450 Meter ,
- **% Voltage drop of Cable= (Current X (Rcosφ + JSinφ) X Distance) / (Volt X No of Cable X 1000)**
- % Voltage drop of Cable= $(2.9 \times (3.7 \times 0.75 + 0.1 \times 0.66) \times 450) / (230 \times 1 \times 1000)$
- % Voltage drop of Cable= 1.61% -----(9)

Total Voltage Drop:

- Voltage Drop in “R” Phase = $0.18+0.72+1.25 = 2.15 \%$
- Voltage Drop in “Y” Phase = $0.36+0.90+1.43 = 2.69 \%$
- Voltage Drop in “B” Phase = $0.54+1.07+1.61 = 3.22 \%$
- **% Voltage drop in each Phase is Max 3.22% Which is less than 4%**

Results:

Phase	No of Pole	Load (Amp)	Voltage Drop
R	3	9	2.15 %
Y	3	9	2.69 %
B	3	9	3.22 %
Total	9	9	2.55 %

Chapter:70 Calculate Lighting Protection for Building / Structure

Example: Calculate Whether Lighting Protection is required or not for following Building. Calculate No of Down Conductor for Lighting Protection

Area of Building / Structure:

- Length of Building (L) = 60 Meter.
- Width of Building (W) = 28 Meter.
- Height of Building (H) = 23 Meter.

Lighting Stock Flushing Density

- Number of Thunderstorm (N)= 80.00 Days/Year
- Lightning Flash Density (Ng)=69 km²/Year
- Application of Structure (A)= Houses & Buildings
- Type of Constructions (B)= Steel framed encased without Metal Roof
- Contexts or Consequential Effects (C)= Domestic / Office Buildings
- Degree of Isolations (D)= Structure in a large area having greater height
- Type of Country (E)= Flat country at any level
- Maximum Acceptable Overall Risk Factor =0.00000001

Reference Table As per IS:2309	
Thunder Storm Days / Year	Lightning Flash Density (Flashes to Ground /km ² /year)
5	0.2
10	0.5
20	1.1
30	1.9
40	2.8
50	3.7
60	4.7
80	6.9
100	9.2

Application of Structure	Factor
Houses & Buildings	0.3
Houses & Buildings with outside aerial	0.7
Factories / workshop/ Laboratories	1
Office blocks / Hotel	1.2
Block of Flats / Residences Building	1.2
Churches/ Hall / Theatres / Museums, Exhibitions	1.3
Departmental stores / Post Offices	1.3
Stations / Airports / Stadium	1.3
Schools / Hospitals / Children's Home	1.7
Others	1.2

Type of Constructions	Factor
Steel framed encased without Metal Roof	0.2
Reinforced concrete without Metal Roof	0.4
Steel framed encased with Metal Roof	0.8
Reinforced concrete with Metal Roof	1
Brick / Plain concrete or masonry without Metal Roof	1.4
Timber framed or clad without Metal Roof	1.7
Brick / Plain concrete or masonry with Metal Roof	2
Timber framed or clad with Metal Roof	

Contests or Consequential Effects	Factor
Domestic / Office Buildings	0.3
Factories / Workshop	0.3
Industrial & Agricultural Buildings	0.8
Power stations / Gas works	1
Telephone exchange / Radio Station	1
Industrial key plants, Ancient monuments	1.3
Historic Buildings / Museums / Art Galleries	1.3
Schools / hospitals / Children Homes	1.7

Degree of Isolations	Factor
Structure in a large area having greater height	0.4
Structure located in a area of the same height	1
Structure completely Isolated	2

Calculation:

Collection Area (Ac)=(L x W) + 2 (L x H) + 2(W x H) +(3.14 x H²)

- Collection Area (Ac) = (60x28)+2x(60x23)+2x(28x23)+(3.14x23x23)
- Collection Area (Ac) =7389 Meter²

Probable No of Strikes to Building / Structure (P)= Ac x Ng x 10⁻⁶ No's / Year

- Probable No of Strikes to Building / Structure (P)= 7389x69x10⁻⁶ No's / Year
- Probable No of Strikes to Building / Structure (P)= 0.05098 No's / Year

Overall Multiplying Factor (M) =A x B x C x D x E

- Application of Structure (A)= Houses & Buildings as per Table Multiplying Factor = 0.3
- Type of Constructions (B)= Steel framed encased without Metal Roof as per Table Multiplying Factor =0.2
- Contests or Consequential Effects (C)= Domestic / Office Buildings as per Table Multiplying Factor =0.3
- Degree of Isolations (D)= Structure in a large area having greater height as per Table Multiplying Factor =0.4
- Type of Country (E)= Flat country at any level so as per Table Multiplying Factor =0.3
- Overall Multiplying Factor (M) =0.3x0.2x0.3x0.4x0.3
- Overall Multiplying Factor (M) =0.00216

Overall Risk Factor Calculated (xc)= M x P

- Overall Risk Factor Calculated (xc)= 0.00216 x0.05098
- Overall Risk Factor Calculated (xc)= 0.000110127

Base Area of Structure (Ab) = (LxW)

- Base Area of Structure (Ab)=60x28
- Base Area of Structure (Ab)=1680 Meter²

Perimeter of Structure (P) =2x (L+W)

- Perimeter of Structure (P)=2x(60+28)
- Perimeter of Structure (P)=176 Meter

Lighting Protection Required or Not

- If Calculated Overall Risk Factor Calculated > Maximum Acceptable Overall Risk Factor than only **Lighting Protection Required**
- Here Calculated Overall Risk Factor is 0.000110127 > Max Acceptable Overall Risk Factor is 0.00000001
- **Lighting Protection is Required**

No of Down Conductor

- **Down Conductors As per Base Area of Structure (s) =1+(Ab-100)/300**
- Down Conductors As per Base Area of Structure (s) =1+(1680-100)/300
- Down Conductors As per Base Area of Structure (s) =6 No's
- **Down Conductors As per Perimeter of Structure (t)= P/30**
- Down Conductors As per Perimeter of Structure (t)= 176/30
- Down Conductors As per Perimeter of Structure (t)= 6 No's
- **Minimum No of Down Conductor is 6 No's**

Results:

- **Lighting Protection is Required**
- **Down Conductors As per Base Area of Structure (s) =6 No's**
- **Down Conductors As per Perimeter of Structure (t)= 6 No's**
- **Minimum No of Down Conductor is 6 No's**

PART-3

Electrical Notes:

Introduction:

- Different starting methods are employed for starting induction motors because Induction Motor draws more starting current during starting. To prevent damage to the windings due to the high starting current flow, we employ different types of starters.
- The simplest form of motor starter for the induction motor is the **Direct OnLine** starter. The DOL starter consist a MCCB or Circuit Breaker, Contactor and an overload relay for protection. Electromagnetic contactor which can be opened by the thermal overload relay under fault conditions.
- Typically, the contactor will be controlled by separate start and stop buttons, and an auxiliary contact on the contactor is used, across the start button, as a hold in contact. I.e. the contactor is electrically latched closed while the motor is operating.

Principle of DOL:

- To start, the contactor is closed, applying full line voltage to the motor windings. The motor will draw a very high inrush current for a very short time, the magnetic field in the iron, and then the current will be limited to the Locked Rotor Current of the motor. The motor will develop Locked Rotor Torque and begin to accelerate towards full speed.
- As the motor accelerates, the current will begin to drop, but will not drop significantly until the motor is at a high speed, typically about 85% of synchronous speed. The actual starting current curve is a function of the motor design, and the terminal voltage, and is totally independent of the motor load.
- The motor load will affect the time taken for the motor to accelerate to full speed and therefore the duration of the high starting current, but not the magnitude of the starting current.
- Provided the torque developed by the motor exceeds the load torque at all speeds during the start cycle, the motor will reach full speed. If the torque delivered by the motor is less than the torque of the load at any speed during the start cycle, the motor will stops accelerating. If the starting torque with a DOL starter is insufficient for the load, the motor must be replaced with a motor which can develop a higher starting torque.
- The acceleration torque is the torque developed by the motor minus the load torque, and will change as the motor accelerates due to the motor speed torque curve and the load speed torque curve. The start time is dependent on the acceleration torque and the load inertia.
- **DOL starting have a maximum start current and maximum start torque.** This may cause an electrical problem with the supply, or it may cause a mechanical problem with the driven load. So this will be inconvenient for the users of the supply line, always experience a voltage drop when starting a motor. But if this motor is not a high power one it does not affect much.

Parts of DOL Starters:

(1) Contactors & Coil.

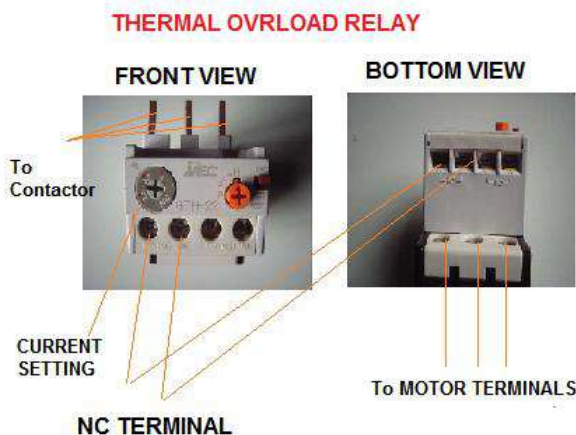
- Magnetic contactors are electromagnetically operated switches that provide a safe and convenient means for connecting and interrupting branch circuits.
- Magnetic motor controllers use electromagnetic energy for closing switches. The electromagnet consists of a coil of wire placed on an iron core. When a current flow through the coil, the iron of the magnet becomes magnetized, attracting an iron bar called the armature. An interruption of the current flow through the coil of wire causes the armature to drop out due to the presence of an air gap in the magnetic circuit.



- Line-voltage magnetic motor starters are electromechanical devices that provide a safe, convenient, and economical means of starting and stopping motors, and have the advantage of being controlled remotely. The great bulk of motor controllers sold are of this type.
- Contactors are mainly used to control machinery which uses electric motors. It consists of a coil which connects to a voltage source. Very often for Single phase Motors, 230V coils are used and for three phase motors, 415V coils are used. The contactor has three main NO contacts and lesser power rated contacts named as Auxiliary Contacts [NO and NC] used for the control circuit. A contact is conducting metal parts which completes or interrupt an electrical circuit.
- NO-normally open
- NC-normally closed

(2) Over Load Relay (Overload protection).

- Overload protection for an electric motor is necessary to prevent burnout and to ensure max operating life. Under any condition of overload, a motor draws excessive current that causes overheating. Since motor winding insulation deteriorates due to overheating, there are established limits on motor operating temperatures to protect a motor from overheating. Overload relays are employed on a motor control to limit the amount of current drawn.
- **The overload relay does not provide short circuit protection. This is the function of over current protective equipment like fuses and circuit breakers, generally located in the disconnecting switch enclosure.**
- The ideal and easiest way for overload protection for a motor is an element with current-sensing properties very similar to the heating curve of the motor which would act to open the motor circuit when full-load current is exceeded. The operation of the protective device should be such that the motor is allowed to carry harmless over-loads but is quickly removed from the line when an overload has persisted too long.
- Normally fuses are not designed to provide overload protection. Fuse is protecting against short circuits (over current protection). Motors draw a high inrush current when starting and conventional fuses have no way of distinguishing between this temporary and harmless inrush current and a damaging overload. Selection of Fuse is depend on motor full-load current, would "blow" every time the motor is started. On the other hand, if a fuse were chosen large enough to pass the starting or inrush current, it would not protect the motor against small, harmful overloads that might occur later.
- The overload relay is the heart of motor protection. It has inverse-trip-time characteristics, permitting it to hold in during the accelerating period (when inrush current is drawn), yet providing protection on small overloads above the full-load current when the motor is running. Overload relays are renewable and can withstand repeated trip and reset cycles without need of replacement. Overload relays cannot, however, take the place of over current protection equipment.
- The overload relay consists of a current-sensing unit connected in the line to the motor, plus a mechanism, actuated by the sensing unit, which serves, directly or indirectly, to break the circuit. Overload relays can be classified as being thermal, magnetic, or electronic.
- **(1) Thermal Relay:** As the name implies, thermal overload relays rely on the rising temperatures caused by the overload current to trip the overload mechanism. Thermal overload relays can be further subdivided into two types: melting alloy and bimetallic.
- **(2) Magnetic Relay:** Magnetic overload relays react only to current excesses and are not affected by temperature.
- **(3) Electronic Relay:** Electronic or solid-state overload relays, provide the combination of high-speed trip, adjustability, and ease of installation. They can be ideal in many precise applications.



Wiring of DOL Starter:

(1) Main Contact:

- Contactor is connecting among Supply Voltage, Relay Coil and Thermal Overload Relay.
- L1 of Contactor Connect (NO) to R Phase through MCCB
- L2 of Contactor Connect (NO) to Y Phase through MCCB
- L3 of Contactor Connect (NO) to B Phase through MCCB.

• NO Contact (-||-):

- (13-14 or 53-54) is a normally Open NO contact (closes when the relay energizes)
- Contactor Point 53 is connecting to Start Button Point (94) and 54 Point of Contactor is connected to Common wire of Start/Stop Button.

• NC Contact (-|/|-):

- (95-96) is a normally closed NC contact (opens when the thermal overloads trip if associated with the overload block)

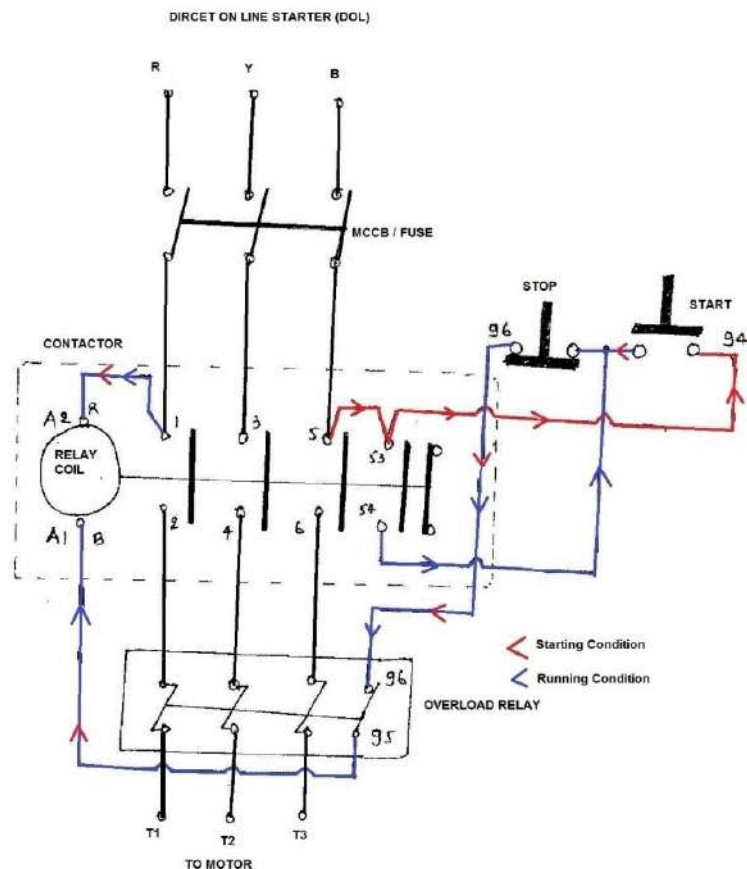
(2) Relay Coil Connection:

- A1 of Relay Coil is connecting to any one Supply Phase and A2 is connecting to Thermal over Load Relay's NC Connection (95).

(3) Thermal Overload Relay Connection:

- T1,T2,T3 are connect to Thermal Overload Relay
- Overload Relay is Connecting between Main Contactor and Motor
- NC Connection (95-96) of Thermal Overload Relay is connecting to Stop Button and Common Connection of Start/Stop Button.

Wiring Diagram of DOL Starter:



Control Circuit of DOL Starter:

- The main heart of DOL starter is Relay Coil. Normally it gets one phase constant from incoming supply Voltage (A1).when Coil gets second Phase relay coil energizes and Magnet of Contactor produce electromagnetic field and due to this Plunger of Contactor will move and Main Contactor of starter will

closed and Auxiliary will change its position NO become NC and NC become (shown Red Line in Diagram)

- **Pushing Start Button:**

- When We Push the start Button Relay Coil will get second phase from Supply Phase-Main contactor(5)-Auxiliary Contact(53)-Start button-Stop button-96-95-To Relay Coil (A2).Now Coil energizes and Magnetic field produce by Magnet and Plunger of Contactor move. Main Contactor closes and Motor gets supply at the same time Auxiliary contact become (53-54) from NO to NC .

- **Release Start Button:**

- Relay coil gets supply even though we release Start button. When We release Start Push Button Relay Coil gets Supply phase from Main contactor (5)-Auxiliary contactor (53) - Auxiliary contactor (54)-Stop Button-96-95-Relay coil (shown Red / Blue Lines in Diagram).

- In Overload Condition of Motor will be stopped by intermission of Control circuit at Point 96-95.

- **Pushing Stop Button:**

- When we push Stop Button Control circuit of Starter will be break at stop button and Supply of Relay coil is broken, Plunger moves and close contact of Main Contactor becomes Open, Supply of Motor is disconnected.

Motor Starting Characteristics on DOL Starter:

- Available starting current: 100%.
- Peak starting current: 6 to 8 Full Load Current.
- Peak starting torque: 100%

Advantages:

1. Most Economical and Cheapest Starter
2. Simple to establish, operate and maintain
3. Simple Control Circuitry
4. Easy to understand and trouble-shoot.
5. It provides 100% torque at the time of starting.
6. Only one set of cable is required from starter to motor.
7. Motor is connected in delta at motor terminals.

Disadvantages:

1. It does not reduce the starting current of the motor.
2. **High Starting Current:** Very High Starting Current (Typically 6 to 8 times the FLC of the motor).
3. **Mechanically Harsh:** Thermal Stress on the motor, thereby reducing its life.
4. **Voltage Dip:** There is a big voltage dip in the electrical installation because of high in-rush current affecting other customers connected to the same lines and therefore not suitable for higher size squirrel cage motors
5. **High starting Torque:** Unnecessary high starting torque, even when not required by the load, thereby increased mechanical stress on the mechanical systems such as rotor shaft, bearings, gearbox, coupling, chain drive, connected equipments, etc. leading to premature failure and plant downtimes.

Features of DOL starting

- For low- and medium-power three-phase motors
- Three connection lines (circuit layout: star or delta)
- High starting torque
- Very high mechanical load
- High current peaks
- Voltage dips
- Simple switching devices

DOL is Suitable for:

- A direct on line starter can be used if the high inrush current of the motor does not cause excessive voltage drop in the supply circuit. The maximum size of a motor allowed on a direct on line starter may be limited by the supply utility for this reason. For example, a utility may require rural customers to use reduced-voltage starters for motors larger than 10 kW.
- DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts.

DOL is not suitable for:

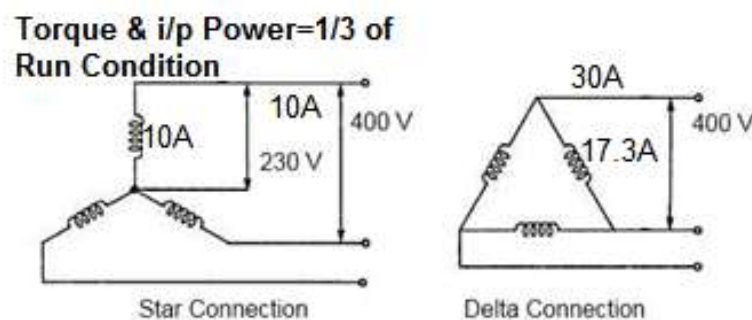
- The peak starting current would result in a serious voltage drop on the supply system
- The equipment being driven cannot tolerate the effects of very high peak torque loadings
- The safety or comfort of those using the equipment may be compromised by sudden starting as, for example, with escalators and lifts.

Introduction:

- Most induction motors are started directly on line, but when very large motors are started that way, they cause a disturbance of voltage on the supply lines due to large starting current surges. To limit the starting current surge, large induction motors are started at reduced voltage and then have full supply voltage reconnected when they run up to near rotated speed. Two methods are used for reduction of starting voltage are star delta starting and autotransformer starting.

**Working Principal of Star-Delta Starter:**

- This is the reduced voltage starting method. Voltage reduction during star-delta starting is achieved by physically reconfiguring the motor windings as illustrated in the figure below. During starting the motor windings are connected in star configuration and this reduces the voltage across each winding 3. This also reduces the torque by a factor of three. After a period of time the winding are reconfigured as delta and the motor runs normally.



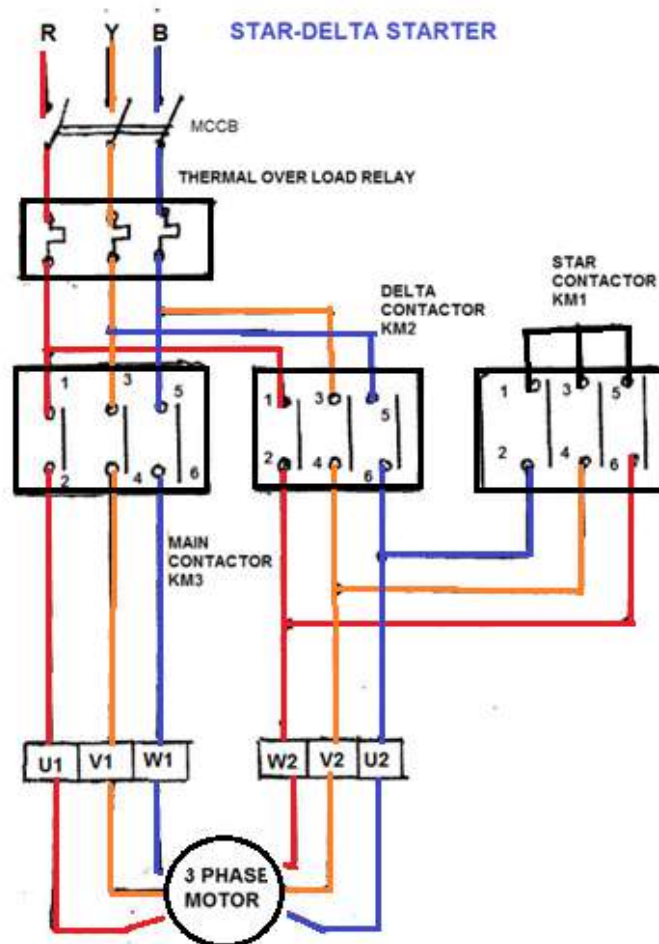
- Star/Delta starters are probably the most common reduced voltage starters. They are used in an attempt to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply.
- Traditionally in many supply regions, there has been a requirement to fit a reduced voltage starter on all motors greater than 5HP (4KW). The Star/Delta (or Wye/Delta) starter is one of the lowest cost electromechanical reduced voltage starters that can be applied.
- The Star/Delta starter is manufactured from three contactors, a timer and a thermal overload. The contactors are smaller than the single contactor used in a Direct on Line starter as they are controlling winding currents only. The currents through the winding are $1/\sqrt{3}$ (58%) of the current in the line.
- There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor. The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is one third of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.

Star-delta Starter Consists following units:

- 1) Contactors (Main, star and delta contactors) 3 No's (For Open State Starter) or 4 No's (Close Transient Starter).
- 2) Time relay (pull-in delayed) 1 No.
- 3) Three-pole thermal over current release 1No.
- 4) Fuse elements or automatic cut-outs for the main circuit 3 Nos.
- 5) Fuse element or automatic cut-out for the control circuit 1No.

Power Circuit of Star Delta Starter:

- The main circuit breaker serves as the main power supply switch that supplies electricity to the power circuit.
- The main contactor connects the reference source voltage R, Y, B to the primary terminal of the motor U1, V1, W1.
- In operation, the Main Contactor (KM3) and the Star Contactor (KM1) are closed initially, and then after a period of time, the star contactor is opened, and then the delta contactor (KM2) is closed. The control of the contactors is by the timer (K1T) built into the starter. The Star and Delta are electrically interlocked and preferably mechanically interlocked as well. In effect, there are four states:



- The star contactor serves to initially short the secondary terminal of the motor U2, V2, W2 for the start sequence during the initial run of the motor from standstill. This provides one third of DOL current to the motor, thus reducing the high inrush current inherent with large capacity motors at start-up.

Control Circuit of Star-Delta Starter (Open Transition):

- Controlling the interchanging star connection and delta connection of an AC induction motor is achieved by means of a star delta or wye delta control circuit. The control circuit consists of push button switches, auxiliary contacts and a timer.



- The **ON** push button starts the circuit by initially energizing Star Main Contactor (KM1) circuit.
- When Star Contactor Coil (KM1) energized, Star Main and Auxiliary Contactor Change its Position from NO To NC.
- When Star Auxiliary Contactor (1) (which is placed on Main Contactor Coil (KM3)) complete The Circuit of Main Contactor Coil (KM3) so Main Contactor Change its Position from NO To NC.
- After pushing the **ON** push button switch, the auxiliary contact connected in parallel across the ON push button will become NC. The main contactor coil activated which eventually maintains the circuit through the ON push button switch.
- When Star Main Contactor (KM1) close its connect Motor connection until Time Delay Auxiliary contact KT (3) become NC to NO.
- Once the time delay is reached its specified Time, the timer's auxiliary contact will change its position from NC to NO and at the Same Time Delta Contactor (4) change its Position from NO To NC so Delta coil energized. Now Motor terminal connection change from star to delta.
- A normally close auxiliary contact from both star and delta contactor coils, these interlocking contacts prevent

Open or Closed Transition Starting

- At some point during starting it is necessary to change from a star connected winding to a delta connected winding. Power and control circuits can be arranged to this in one of two ways - open transition or closed transition.

(1) Open Transition Starters.

- Discuss mention above is called open transition switching because there is an open state between the star state and the delta state.
- In open transition the power is disconnected from the motor while the winding are reconfigured via external switching.
- When a motor is driven by the supply, either at full speed or at part speed, there is a rotating magnetic field in the stator. This field is rotating at line frequency. The flux from the stator field induces a current in the rotor and this in turn results in a rotor magnetic field.
- When the motor is disconnected from the supply (open transition) there is a spinning rotor within the stator and the rotor has a magnetic field. Due to the low impedance of the rotor circuit, the time constant is quite long and the action of the spinning rotor field within the stator is that of a generator which generates voltage at a frequency determined by the speed of the rotor. When the motor is reconnected to the supply, it is reclosing onto an unsynchronized generator and **this result in a very high current and torque transient. The magnitude of the transient is dependent on the phase relationship between the generated voltage and the line voltage at the point of closure** can be much higher than DOL current and torque and can result in electrical and mechanical damage.
- Open transition starting is the easiest to implement in terms of cost and circuitry and if the timing of the changeover is good, this method can work well. In practice though it is difficult to set the necessary timing to operate correctly and disconnection/reconnection of the supply can cause significant voltage/current transients.
- In Open transition there are Four states:
 - OFF State:** All Contactors are open.
 - Star State:** The Main [KM3] and the Star [KM1] contactors are closed and the delta [KM2] contactor is open. The motor is connected in star and will produce one third of DOL torque at one third of DOL current.
 - Open State:** This type of operation is called open transition switching because there is an open state between the star state and the delta state. The Main contractor is closed and the Delta and Star contactors are open. There is voltage on one end of the motor windings, but the other end is open so no current can flow. The motor has a spinning rotor and behaves like a generator.
 - Delta State:** The Main and the Delta contactors are closed. The Star contactor is open. The motor is connected to full line voltage and full power and torque are available

(2) Closed Transition Star/Delta Starter.

- There is a technique to reduce the magnitude of the switching transients. This requires the use of a fourth contactor and a set of three resistors. The resistors must be sized such that considerable current is able to flow in the motor windings while they are in circuit.
- The auxiliary contactor and resistors are connected across the delta contactor. In operation, just before the star contactor opens, the auxiliary contactor closes resulting in current flow via the resistors into the star connection. Once the star contactor opens, current is able to flow round through the motor windings to the supply via the resistors. These resistors are then shorted by the delta contactor. If the resistance of the resistors is too high, they will not swamp the voltage generated by the motor and will serve no purpose.
- In closed transition the power is maintained to the motor at all time.** This is achieved by introducing resistors to take up the current flow during the winding changeover. A fourth contractor is required to place the resistor in circuit before opening the star contactor and then removing the resistors once the delta contactor is closed. These resistors need to be sized to carry the motor current. In addition to requiring more switching devices, the control circuit is more complicated due to the need to carry out resistor switching
- In Close transition there are Four states:
 - OFF State.** All Contactors are open
 - Star State.** The Main [KM3] and the Star [KM1] contactors are closed and the delta [KM2] contactor is open. The motor is connected in star and will produce one third of DOL torque at one third of DOL current.
 - Star Transition State.** The motor is connected in star and the resistors are connected across the delta contactor via the aux [KM4] contactor.
 - Closed Transition State.** The Main [KM3] contactor is closed and the Delta [KM2] and Star [KM1] contactors are open. Current flows through the motor windings and the transition resistors via KM4.
 - Delta State.** The Main and the Delta contactors are closed. The transition resistors are shorted out. The Star contactor is open. The motor is connected to full line voltage and full power and torque are available.

Effect of Change over Transient in Open Transient Star-Delta starter:

- It is Important the pause between star contactor switch off and Delta contactor switch is on correct. This is because Star contactor must be reliably disconnected before Delta contactor is activated. It is also important that the **switch over pause is not too long**.
- For 415v Star Connection voltage is effectively reduced to 58% or 240v. The equivalent of 33% that is obtained with Direct Online (DOL) starting.
- If Star connection has sufficient torque to run up to 75% or 80% of full load speed, then the motor can be connected in Delta mode.
- When connected to Delta configuration the phase voltage increases by a ratio of $\sqrt{3}$ or 173%. The phase currents increase by the same ratio. The line current increases three times its value in star connection.
- During transition period of switchover the motor must be free running with little deceleration. While this is happening "Coasting" it may generate a voltage of its own, and on connection to the supply this voltage can randomly add to or subtract from the applied line voltage. This is known as transient current. Only lasting a few milliseconds it causes voltage surges and spikes. Known as a changeover transient.

Size of each part of Star-Delta starter

(4) Size of Over Load Relay:

- For a star-delta starter there is a possibility to place the overload protection in two positions, in the line or in the windings.
- **Overload Relay in Line:** In the line is the same as just putting the overload before the motor as with a DOL starter.
- **The rating of Overload (In Line) = FLC of Motor.**
- Disadvantage: If the overload is set to FLC, then it is not protecting the motor while it is in delta (setting is $\times 1.732$ too high).
- **Overload Relay in Winding:** In the windings means that the overload is placed after the point where the wiring to the contactors are split into main and delta. The overload then always measures the current inside the windings.
- **The setting of Overload Relay (In Winding) = $0.58 \times \text{FLC}$ (line current).**
- Disadvantage: We must use separate short circuit and overload protections.

(5) Size of Main and Delta Contactor:

- There are two contactors that are close during run, often referred to as the main contractor and the delta contactor. These are AC3 rated at 58% of the current rating of the motor.

- **Size of Main Contactor = $\text{IFL} \times 0.58$**

(6) Size of Star Contactor:

- The third contactor is the star contactor and that only carries star current while the motor is connected in star. The current in star is $1/\sqrt{3}$ = (58%) of the current in delta, so this contactor can be AC3 rated at one third (33%) of the motor rating.
- **Size of Star Contactor = $\text{IFL} \times 0.33$**

Motor Starting Characteristics of Star-Delta Starter:

- Available starting current: 33% Full Load Current.
- Peak starting current: 1.3 to 2.6 Full Load Current.
- Peak starting torque: 33% Full Load Torque.

Advantages of Star-Delta starter:

- The operation of the star-delta method is simple and rugged
- It is relatively cheap compared to other reduced voltage methods.
- Good Torque/Current Performance.
- It draws 2 times starting current of the full load ampere of the motor connected

Disadvantages of Star-Delta starter:

- Low Starting Torque (Torque = (Square of Voltage) is also reduce).
- Break In Supply - Possible Transients
- Six Terminal Motor Required (Delta Connected).
- It requires 2 set of cables from starter to motor.
- It provides only 33% starting torque and if the load connected to the subject motor requires higher starting torque at the time of starting than very heavy transients and stresses are produced while changing from star to delta connections, and because of these transients and stresses many electrical and mechanical break-down occurs. In this method of starting initially motor is connected in star and then after change over the motor is connected in delta. The delta of motor is formed in starter and not on motor terminals.

- **High transmission and current peaks:** When starting up pumps and fans for example, the load torque is low at the beginning of the start and increases with the square of the speed. When reaching approx. 80-85 % of the motor rated speed the load torque is equal to the motor torque and the acceleration ceases. To reach the rated speed, a switch over to delta position is necessary, and this will very often result in high transmission and current peaks. In some cases the current peak can reach a value that is even bigger than for a D.O.L start.
- Applications with a load torque higher than 50 % of the motor rated torque will not be able to start using the start-delta starter.
- **Low Starting Torque:** The star-delta (wye-delta) starting method controls whether the lead connections from the motor are configured in a star or delta electrical connection. The initial connection should be in the star pattern that results in a reduction of the line voltage by a factor of $1/\sqrt{3}$ (57.7%) to the motor and the current is reduced to 1/3 of the current at full voltage, but the starting torque is also reduced 1/3 to 1/5 of the DOL starting torque. The transition from star to delta transition usually occurs once nominal speed is reached, but is sometimes performed as low as 50% of nominal speed which make transient Sparks.

Features of star-delta starting

- For low- to high-power three-phase motors.
- Reduced starting current
- Six connection cables
- Reduced starting torque
- Current peak on changeover from star to delta
- Mechanical load on changeover from star to delta

Application of Star-Delta Starter:

- The star-delta method is usually only applied to **low to medium voltage and light starting Torque** motors. The received starting current is about **30 %** of the starting current during direct on line start and the starting torque is reduced to about **25 %** of the torque available at a D.O.L start. This starting method only works when the application is light loaded during the start. If the motor is too heavily loaded, there will not be enough torque to accelerate the motor up to speed before switching over to the delta position.

General Terminology

(1) Service Factor:

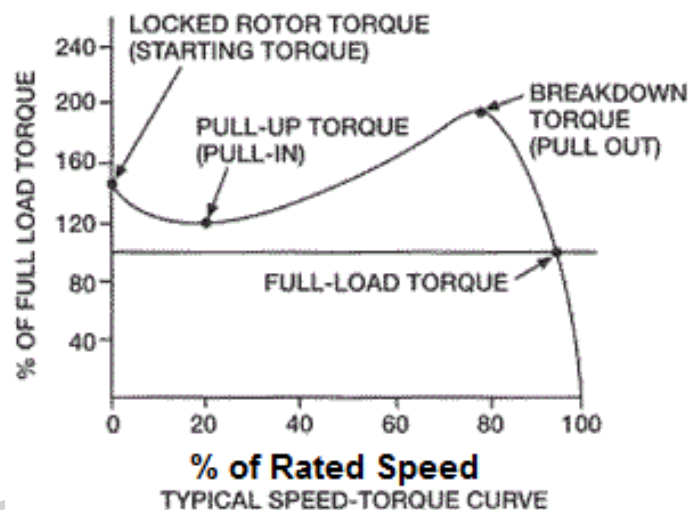
- The service factor is a multiplier that indicates the amount of overload a motor can be expected to handle. If a motor with a 1.15 service factor can be expected to safely handle intermittent loads amounting to 15% beyond its nameplate horsepower.
- For example, many motors will have a service factor of 1.15, meaning that the motor can handle a 15% overload. The service factor amperage is the amount of current that the motor will draw under the service factor load condition.

(2) Slip:

- Slip is used in two forms. One is the slip RPM which is the difference between the synchronous speed and the full load speed. When this slip RPM is expressed as a percentage of the synchronous speed, then it is called percent slip or just "slip". Most standard motors run with a full load slip of 2% to 5%.

(3) Synchronous Speed:

- This is the speed at which the magnetic field within the motor is rotating. It is also approximately the speed that the motor will run under no load conditions. For example, a 4 pole motor running on 60 cycles would have a magnetic field speed of 1800 RPM. The no load speed of that motor shaft would be very close to 1800, probably 1798 or 1799 RPM. The full load speed of the same motor might be 1745 RPM. The difference between the synchronous speed and the full load speed is called the slip RPM of the motor.



Motor Torque:

(1) Pull Up Torque:

- When the motor starts and begins to accelerate the torque in generally decrease until it reach a low point at a certain speed it called the pull-up torque.
- The Pull-up Torque is the minimum torque developed by the electrical motor when it runs from zero to full-load speed (before it reaches the break-down torque point).
- Pull-up torque is the minimum torque developed during the period of acceleration from locked-rotor to the speed at which breakdown torque occurs.
- Some motor designs do not have a value of pull up torque because the lowest point may occur at the locked rotor point. In this case, pull up torque is the same as **locked rotor torque**.
- For motors which do not have a definite breakdown torque (such as NEMA design D) pull-up torque is the minimum torque developed up to rated full-load speed. It is usually expressed as a percentage of full-load torque.

(2) Starting Torque (Locked Rotor Torque):

- The amount of torque the motor produces when it is energized at full voltage and with the shaft locked in place is called starting torque.
- The Locked Rotor Torque or Starting Torque is the torque the electrical motor develop when its starts at rest or zero speed.
- It is the amount of torque available when power is applied to break the load away and start accelerating it up to speed.
- A high Starting Torque is more important for application or machines hard to start - as positive displacement pumps, cranes etc. A lower Starting Torque can be accepted in applications as centrifugal fans or a pump where the start loads is low or close to zero.
- Operating a motor in a locked-rotor condition in excess of 20 seconds can result in insulation failure due to the excessive heat generated in the stator.

(3) Full Load Torque:

- Full load torque is the rated continuous torque that the motor can support without overheating within its time rating.
- In imperial units the Full-load Torque can be expressed as
- $T \text{ full-load torque (lb ft)} = (\text{Rated horsepower of Motor} \times 5252) / \text{Rated rotational speed (rpm)}$
- In metric units the rated torque can be expressed as
- **Full-load torque (Nm) = (Rated KW of Motor X 9550) / Rated rotational speed (rpm)**
- **Example :** The torque of a 60 hp motor rotating at 1725 rpm can be expressed as
- $T \text{ full-load torque} = 60 \times 5,252 / 1725 \text{ (rpm)}$
- $T \text{ full-load torque} = 182.7 \text{ lb ft}$

(4) Peak Torque:

- Many types of loads such as reciprocating compressors have cycling torques where the amount of torque required varies depending on the position of the machine.
- The actual maximum torque requirement at any point is called the peak torque requirement.
- Peak torques is involved in things such as punch presses and other types of loads where an oscillating torque requirement occurs.

(5) Pull out Torque (Breakdown Torque):

- Breakdown torque is the maximum torque the motor will develop with rated voltage applied at rated frequency without an abrupt drop in speed. Breakdown torque is usually expressed as a percentage of full-load torque
- The load is then increased until the maximum point is reached.

Motor Current:

(1) Full Load Amps:

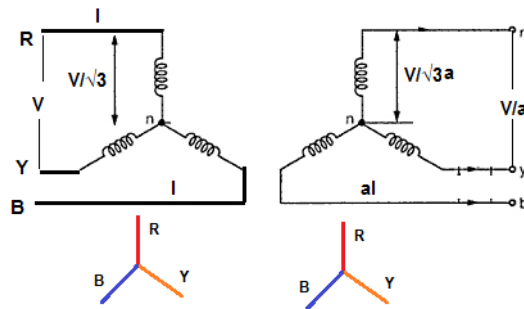
- The amount of current the motor can be expected to draw under full load (torque) conditions is called Full Load Amps. It is also known as nameplate amps.

(2) Locked Rotor Amps:

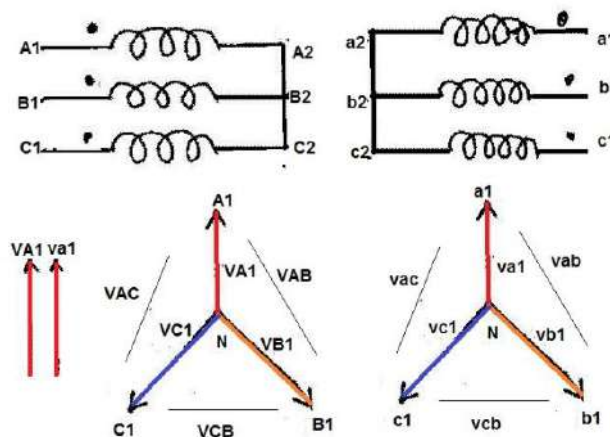
- Also known as starting inrush, this is the amount of current the motor can be expected to draw under starting conditions when full voltage is applied.
- **Code Letter:** The code letter is an indication of the amount of inrush or locked rotor current that is required by a motor when it is started

- The windings of three phase transformers may be connected in by Y or Δ in the same manner as for three single phase transformers. Since the secondary's may be connected either in Y or Δ regardless of which connection is used on the primaries, there must be four ways of connecting the windings of a 3-phase transformer for transformation of 3-phase voltages, namely Y-y, Δ - Δ , Y- Δ , and Δ -y. The inter-connections are made inside of the case so that only the terminal leads need to be brought outside the case
1. Star – Star Transformer (Yy0 or Yy6)
 2. Delta – Delta Transformer (Dd0 or Dd6)
 3. Delta – Star Transformer (Dy)
 4. Star – Delta Transformer Yd) (Grounding Transformer).
 5. Zig-zag Transformer (Yz, Dz) (Grounding Transformer)
 6. Scott ("T" Type) Transformer (Grounding Transformer).
 7. Auto Transformer.

(1) Star-Star(Y-y) Connection:



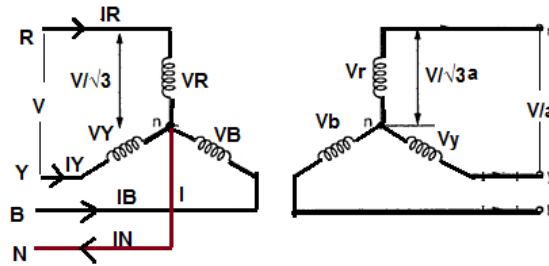
- In Primary Winding Each Phase is 120° electrical degrees out of phase with the other two phases.
- In Secondary Winding Each Phase is 120° electrical degrees out of phase with the other two phases.
- Each primary winding is magnetically linked to one secondary winding through a common core leg. Sets of windings that are magnetically linked are drawn parallel to each other in the vector diagram. In the Y-Y connection, each primary and secondary winding is connected to a neutral point.
- The neutral point may or may not be brought out to an external physical connection and the neutral may or may not be grounded



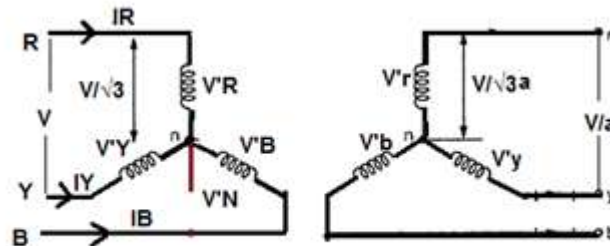
- Transformer magnetizing currents are not purely sinusoidal, even if the exciting voltages are sinusoidal. The magnetizing currents have significant quantities of odd-harmonic components. If three identical transformers are connected to each phase and are excited by 60 Hz voltages of equal magnitude, the 60 Hz fundamental components of the exciting currents cancel out each other at the neutral. This is because the 60 Hz fundamental currents of A, B, and C phase are 120° out of phase with one another and the vector sum of these currents is zero.
- The third, ninth, fifteenth and other so-called zero-sequence harmonic currents are in phase with each other; therefore, these components do not cancel out each other at the neutral but add in phase with one another to produce a zero-sequence neutral current, provided there is a path for the neutral current to flow.
- Due to the nonlinear shape of the B-H curve, odd-harmonic magnetizing currents are required to support sinusoidal induced voltages. If some of the magnetizing current harmonics are not present, then the induced voltages cannot be sinusoidal.

- **Y-Y Connection with Grounded Neutral :**

- Figure Show the situation where the primary neutral is returned to the voltage source in a four-wire three-phase circuit. Each of the magnetizing currents labeled I_R , I_Y , and I_B contain the 60 Hz fundamental current and all of the odd harmonic currents necessary to support sinusoidal induced voltages.



- The zero-sequence magnetizing currents combine to form the neutral current I_N , which returns these odd harmonics to the voltage source. Assuming that the primary voltage is sinusoidal, the induced voltages V_R , V_Y , and V_B (in both the primary and secondary) are sinusoidal as well.
- The connection of primary neutral to the neutral of generator has an add advantage that it eliminates distortion in the secondary phase voltages. If the flux in the core has sinusoidal waveform then it will give sinusoidal waveform for the voltage. But due to characteristic of iron, a sinusoidal waveform of flux requires a third harmonic component in the exciting current. As the frequency of this component is thrice the frequency of circuit at any given constant. It will try to flow either towards or away from the neutral point in the transformer windings. With isolated neutral, the triple frequency current cannot flow so the flux in the core will not be a sine wave and the voltages are distorted. If primary neutral is connected to generator neutral the triple frequency currents get the path to solve the difficulty. The alternative way of overcoming with this difficulty is the use of tertiary winding of low KVA rating. These windings are connected in delta and provide a circuit in which triple frequency currents can flow. Thus sinusoidal voltage on primary will give sinusoidal voltage on secondary side.
- This situation changes if the neutrals of both sets of the primary and secondary windings are not grounded.
- **Y-Y Connection without Grounded Neutral:** If the neutrals of both the primary and the secondary are open-circuited and so there is no path for the zero-sequence harmonic currents to flow and the induced voltages will not be sinusoidal.



- $V'R$, $V'Y$, and $V'B$ will not be sinusoidal. This results in distortions of the secondary voltages. The resulting voltage distortion is equivalent to a Y-Y transformer with zero-sequence currents allowed to flow in the primary neutral with an imaginary superimposed primary winding carrying only the zero-sequence currents 180° out of phase with the normal zero-sequence currents.
- Analysis of the voltages induced by the "primary windings" is greatly complicated by the fact that the core is highly nonlinear so that each of the individual zero-sequence harmonics currents carried by the phantom primary windings will induce even higher-order harmonic voltages as well.
- Fourier analysis can be used to arrive at an approximation of the secondary voltages with an open primary neutral. Taking one phase at a time, the normal magnetizing current for a sinusoidal exciting voltage is plotted from the B-H curve of the transformer. The normal magnetizing current is converted to a Fourier series and then it is reconstructed by removing all of the zero-sequence harmonics. The resulting exciting current will have a shape different from the normal exciting current, which is then used to construct an induced voltage using the B-H curve in there verse manner that was used to construct the original exciting current. This process is rather laborious, so suffice it to say that if a Y-Y transformer does not have a neutral path for zero-sequence exciting currents, there will be harmonic voltages induced in the secondary even if the exciting voltage is purely sinusoidal.

Advantage of Y-Y Connection:

- **No Phase Displacement:** The primary and secondary circuits are in phase; i.e., there are no phase angle displacements introduced by the Y-Y connection. This is an important advantage when transformers are used to interconnect systems of different voltages in a cascading manner. For example, suppose there are

four systems operating at 800, 440, 220, and 66 kV that need to be interconnected. Substations can be constructed using Y-Y transformer connections to interconnect any two of these voltages. The 800 kV systems can be tied with the 66 kV systems through a single 800 to 66 kV transformation or through a series of cascading transformations at 440, 220 and 66 kV.

- **Required Few Turns for winding:** Due to star connection, phase voltages is $(1/\sqrt{3})$ times the line voltage. Hence less number of turns is required. Also the stress on insulation is less. This makes the connection economical for small high voltage purposes.
- **Required Less Insulation Level:** If the neutral end of a Y-connected winding is grounded, then there is an opportunity to use reduced levels of insulation at the neutral end of the winding. A winding that is connected across the phases requires full insulation throughout the winding.
- **Handle Heavy Load:** Due to star connection, phase current is same as line current. Hence windings have to carry high currents. This makes cross section of the windings high. Thus the windings are mechanically strong and windings can bear heavy loads and short circuit current.
- **Use for Three phases Four Wires System:** As neutral is available, suitable for three phases four wire system.
- **Eliminate Distortion in Secondary Phase Voltage:** The connection of primary neutral to the neutral of generator eliminates distortion in the secondary phase voltages by giving path to triple frequency currents toward to generator.
- **Sinusoidal voltage on secondary side:** Neutral give path to flow Triple frequency current to flow Generator side thus sinusoidal voltage on primary will give sinusoidal voltage on secondary side.
- **Used as Auto Transformer:** A Y-Y transformer may be constructed as an autotransformer, with the possibility of great cost savings compared to the two-winding transformer construction.
- **Better Protective Relaying:** The protective relay settings will be protecting better on the line to ground faults when the Y-Y transformer connections with solidly grounded neutrals are applied.

Disadvantage of Y-Y Connection:

- **The Third harmonic issue:** The voltages in any phase of a Y-Y transformer are 120° apart from the voltages in any other phase. However, the third-harmonic components of each phase will be in phase with each other. Nonlinearities in the transformer core always lead to generation of third harmonic. These components will add up resulting in large (can be even larger than the fundamental component) third harmonic component.
- **Overvoltage at Lighting Load:** The presence of third (and other zero-sequence) harmonics at an ungrounded neutral can cause overvoltage conditions at light load. When constructing a Y-Y transformer using single-phase transformers connected in a bank, the measured line-to-neutral voltages are not 57.7% of the system phase-to-phase voltage at no load but are about 68% and diminish very rapidly as the bank is loaded. The effective values of voltages at different frequencies combine by taking the square root of the sum of the voltages squared. With sinusoidal phase-to-phase voltage, the third-harmonic component of the phase-to-neutral voltage is about 60%.
- **Voltage drop at Unbalance Load:** There can be a large voltage drop for unbalanced phase-to-neutral loads. This is caused by the fact that phase-to-phase loads cause a voltage drop through the leakage reactance of the transformer whereas phase-to-neutral loads cause a voltage drop through the magnetizing reactance, which is 100 to 1000 times larger than the leakage reactance.
- **Overheated Transformer Tank:** Under certain circumstances, a Y-Y connected three-phase trans- can produce severe tank overheating that can quickly destroy the transformer. This usually occurs with an open phase on the primary circuit and load on the secondary.
- **Over Excitation of Core in Fault Condition:** If a phase-to-ground fault occurs on the primary circuit with the primary neutral grounded, then the phase-to-neutral voltage on the un faulted phases increases to 173% of the normal voltage. This would almost certainly result in over excitation of the core, with greatly increased magnetizing currents and core losses
- If the neutrals of the primary and secondary are both brought out, then a phase-to-ground fault on the secondary circuit causes neutral fault current to flow in the primary circuit. Ground protection re- laying in the neutral of the primary circuit may then operate for faults on the secondary circuit
- **Neutral Shifting:** If the load on the secondary side unbalanced then the performance of this connection is not satisfactory then the shifting of neutral point is possible. To prevent this, star point of the primary is required to be connected to the star point of the generator.
- **Distortion of Secondary voltage:** Even though the star or neutral point of the primary is earthed, the third harmonic present in the alternator voltage may appear on the secondary side. This causes distortion in the secondary phase voltages.
- **Over Voltage at Light Load:** The presence of third (and other zero-sequence) harmonics at an ungrounded neutral can cause overvoltage conditions at light load.
- **Difficulty in coordination of Ground Protection:** In Y-Y Transformer, a low-side ground fault causes primary ground fault current, making coordination more difficult.

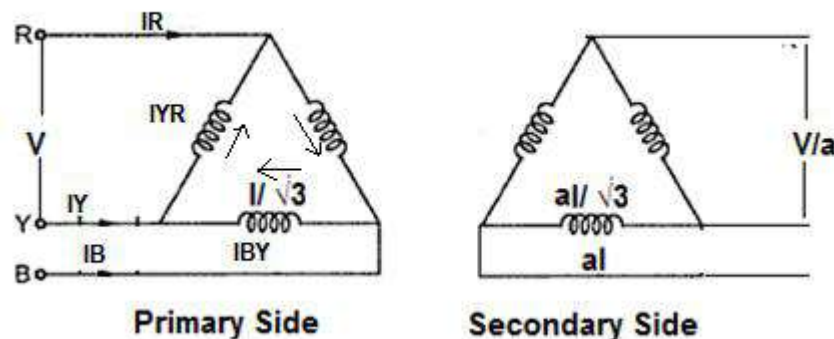
- **Increase Healthy Phase Voltage under Phase to ground Fault:** If a phase-to-ground fault occurs on the primary circuit with the primary neutral grounded, then the phase-to-neutral voltage on the UN faulted phase's increases to 173% of the normal voltage. If the neutrals of the primary and secondary are both brought out, then a phase-to-ground fault on the secondary circuit causes neutral fault current to flow in the primary circuit.
- **Trip the T/C in Line-Ground Fault:** All harmonics will propagate through the transformer, zero-sequence current path is continuous through the transformer, one line-to-ground fault will trip the transformer.
- **Suitable for Core Type Transformer:** The third harmonic voltage and current is absent in such type of connection with three phase wire system. or shell type of three phase units, the third harmonic phase voltage may be high. This type of connection is more suitable for core type transformers.

Application:

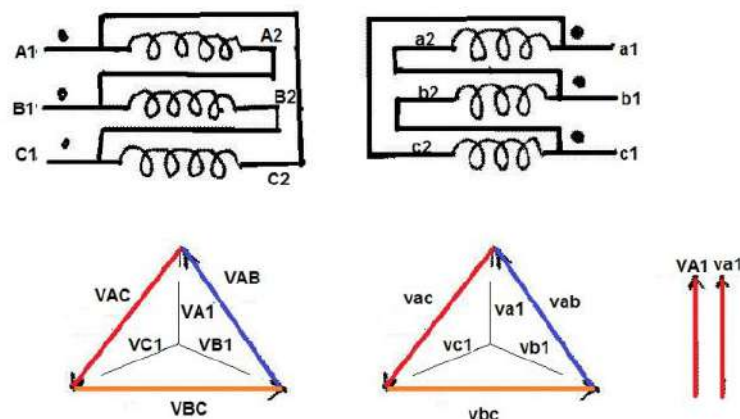
- This Type of Transformer is rarely used due to problems with unbalanced loads.
- It is economical for **small high voltage transformers** as the number of turns per phase and the amount of insulation required is less.

(2) Delta-Delta Connection:

- In this type of connection, both the three phase primary and secondary windings are connected in delta as shown in the Fig.



- The voltages on primary and secondary sides can be shown on the phasor diagram.



- This connection proves to be economical for large low voltage transformers as it increases number of turns per phase.

Key point:

- Primary Side Line Voltage = Secondary Side Line Voltage.
- Primary Side Phase Voltage= Secondary Side Phase Voltage.
- No phase shift between primary and secondary voltages

Advantage of Delta-Delta Connection:

- **Sinusoidal Voltage at Secondary:** In order to get secondary voltage as sinusoidal, the magnetizing current of transformer must contain a third harmonic component. The delta connection provides a closed path for circulation of third harmonic component of current. The flux remains sinusoidal which results in sinusoidal voltages.
- **Suitable for Unbalanced Load:** Even if the load is unbalanced the three phase voltages remains constant. Thus it suitable for unbalanced loading also.

- **Carry 58% Load if One Transfer is Faulty in Transformer Bank:** If there is bank of single phase transformers connected in delta-delta fashion and if one of the transformers is disabled then the supply can be continued with remaining two transformers of course with reduced efficiency.
- **No Distortion in Secondary Voltage:** there is no any phase displacement between primary and secondary voltages. There is no distortion of flux as the third harmonic component of magnetizing current can flow in the delta connected primary windings without flowing in the line wires. there is no distortion in the secondary voltages.
- **Economical for Low Voltage:** Due to delta connection, phase voltage is same as line voltage hence winding have more number of turns. But phase current is $(1/\sqrt{3})$ times the line current. Hence the cross-section of the windings is very less. This makes the connection economical for low voltages transformers.
- **Reduce Cross section of Conductor:** The conductor is required of smaller Cross section as the phase current is $1/\sqrt{3}$ times of the line current. It increases number of turns per phase and reduces the necessary cross sectional area of conductors thus insulation problem is not present.
- **Absent of Third Harmonic Voltage:** Due to closed delta, third harmonic voltages are absent.
- The absence of star or neutral point proves to be advantageous in some cases.

Disadvantage of Delta-Delta Connection:

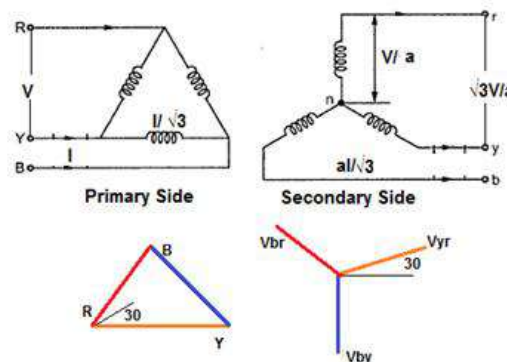
- Due to the absence of neutral point it is not suitable for three phase four wire system.
- More insulation is required and the voltage appearing between windings and core will be equal to full line voltage in case of earth fault on one phase.

Application:

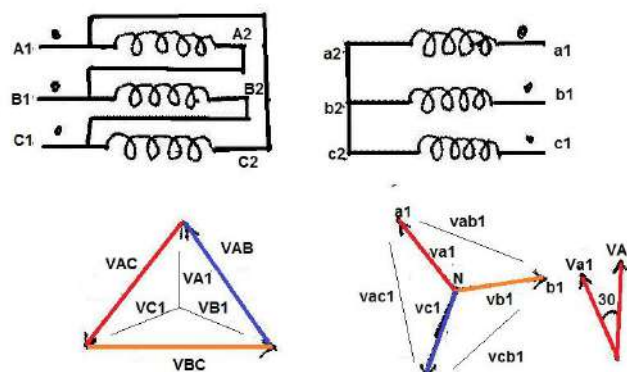
- Suitable for large, low voltage transformers.
- This Type of Connection is normally uncommon but used in some industrial facilities to reduce impact of SLG faults on the primary system
- It is generally used in systems where it need to be carry large currents on low voltages and especially when continuity of service is to be maintained even though one of the phases develops fault.

(3) Delta-Star Connection of Transformer

- In this type of connection, the primary connected in delta fashion while the secondary current is in star.



- The main use of this connection is to step up the voltage i.e. at the beginning of high tension transmission system. It can be noted that there is a phase shift of 30° between primary line voltage and secondary line voltage as leading.



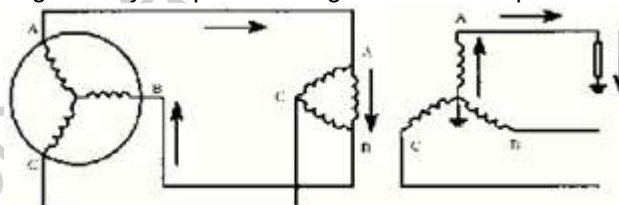
Key point:

- As primary in delta connected:
- Line voltage on primary side = Phase voltage on Primary side.
- Now Transformation Ratio (K) = Secondary Phase Voltage / Primary Phase Voltage

- Secondary Phase Voltage = $K \times \text{Primary Phase Voltage}$.
- As Secondary in Star connected
- Line voltage on Secondary side = $\sqrt{3} \times \text{Phase voltage on Secondary side}$. So,
- **Line voltage on Secondary side = $\sqrt{3} \times K \times \text{Primary Phase Voltage}$.**
- **Line voltage on Secondary side = $\sqrt{3} \times K \times \text{Primary Line Voltage}$.**
- **There is +30 Degree or -30 Degree Phase Shift between Secondary Phase Voltage to Primary Phase Voltage**

Advantages of Delta-Star Connection:

- **Cross section area of winding is less at Primary side:** On primary side due to delta connection winding cross-section required is less.
- **Used at Three phase four wire System:** On secondary side, neutral is available, due to which it can be used for 3-phase, 4 wire supply system.
- **No distortion of Secondary Voltage:** No distortion due to third harmonic components.
- **Handled large unbalanced Load:** Large unbalanced loads can be handled without any difficulty.
- **Grounding Isolation between Primary and Secondary:** Assuming that the neutral of the Y-connected secondary circuit is grounded, a load connected phase-to-neutral or a phase-to-ground fault produces two equal and opposite currents in two phases in the primary circuit without any neutral ground current in the primary circuit. Therefore, in contrast with the Y-Y connection, phase-to-ground faults or current unbalance in the secondary circuit will not affect ground protective relaying applied to the primary circuit. This feature enables proper coordination of protective devices and is a very important design consideration.
- The neutral of the Y grounded is sometimes referred to as a grounding bank, because it provides a local source of ground current at the secondary that is isolated from the primary circuit.
- **Harmonic Suppression:** The magnetizing current must contain odd harmonics for the induced voltages to be sinusoidal and the third harmonic is the dominant harmonic component. In a three-phase system the third harmonic currents of all three phases are in phase with each other because they are zero-sequence currents. In the Y-Y connection, the only path for third harmonic current is through the neutral. In the Δ -Y connection, however, the third harmonic currents, being equal in amplitude and in phase with each other, are able to circulate around the path formed by the Δ connected winding. The same thing is true for the other zero-sequence harmonics.
- **Grounding Bank:** It provides a local source of ground current at the secondary that is isolated from the primary circuit. For suppose an ungrounded generator supplies a simple radial system through Δ -Y transformer with grounded Neutral at secondary as shown Figure. The generator can supply a single-phase-to-neutral load through the -grounded Y transformer.
- Let us refer to the low-voltage generator side of the transformer as the secondary and the high-voltage load side of the transformer as the primary. Note that each primary winding is magnetically coupled to a secondary winding. The magnetically coupled windings are drawn in parallel to each other.



- Through the second transformer law, the phase-to-ground load current in the primary circuit is reflected as a current in the A-C secondary winding. No other currents are required to flow in the A-C or B-C windings on the generator side of the transformer in order to balance ampere-turns.
- **Easy Relaying of Ground Protection:** Protective relaying is MUCH easier on a delta-wye transformer because ground faults on the secondary side are isolated from the primary, making coordination much easier. If there is upstream relaying on a delta-wye transformer, any zero-sequence current can be assumed to be from a primary ground fault, allowing very sensitive ground fault protection. On a wye-wye, a low-side ground fault causes primary ground fault current, making coordination more difficult. Actually, ground fault protection is one of the primary advantages of delta-wye units.

Disadvantages of Delta-Star Connection:

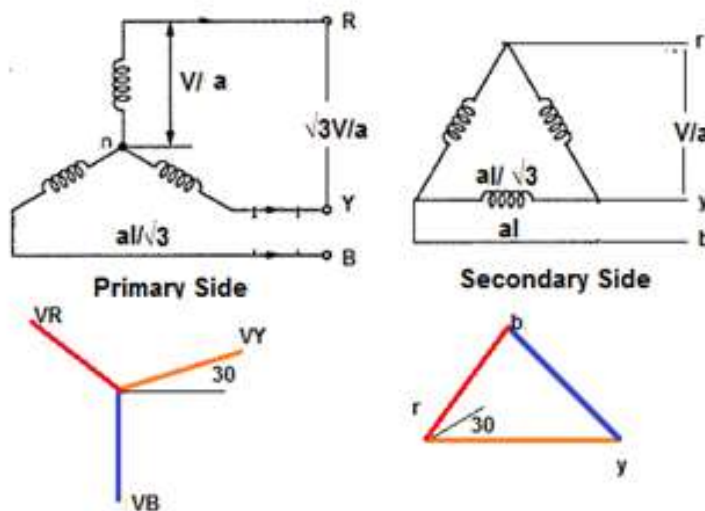
- In this type of connection, the secondary voltage is not in phase with the primary. Hence it is not possible to operate this connection in parallel with star-star or delta-delta connected transformer.
- One problem associated with this connection is that the secondary voltage is shifted by 30° with respect to the primary voltage. This can cause problems when paralleling 3-phase transformers since transformers secondary voltages must be in-phase to be paralleled. Therefore, we must pay attention to these shifts.
- If secondary of this transformer should be paralleled with secondary of another transformer without phase shift, there would be a problem.

Applications:

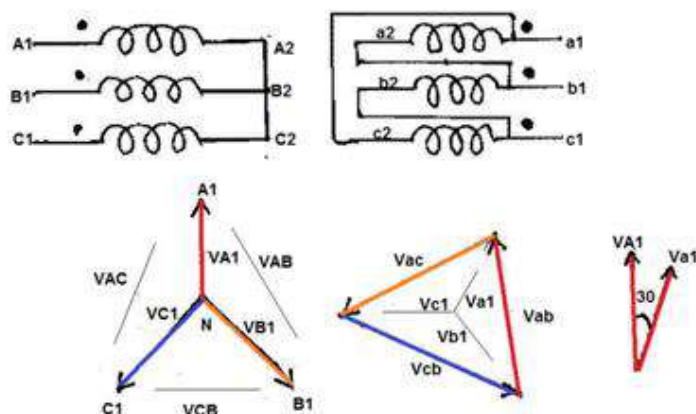
- **Commonly used in a step-up transformer:** As for example, at the beginning of a HT transmission line. In this case neutral point is stable and will not float in case of unbalanced loading. There is no distortion of flux because existence of a Δ -connection allows a path for the third-harmonic components. The line voltage ratio is $\sqrt{3}$ times of transformer turn-ratio and the secondary voltage leads the primary one by 30° . In recent years, this arrangement has become very popular for distribution system as it provides 3- ϕ , 4-wire system.
- **Commonly used in commercial, industrial, and high-density residential locations:** To supply three-phase distribution systems. An example would be a distribution transformer with a delta primary, running on three 11kV phases with no neutral or earth required, and a star (or wye) secondary providing a 3-phase supply at 400 V, with the domestic voltage of 230 available between each phase and an earthed neutral point.
- **Used as Generator Transformer:** The Δ -Y transformer connection is used universally for connecting generators to transmission systems because of two very important reasons. First of all, generators are usually equipped with sensitive ground fault relay protection. The Δ -Y transformer is a source of ground currents for loads and faults on the transmission system, yet the generator ground fault protection is completely isolated from ground currents on the primary side of the transformer. Second, rotating machines can literally be

(4) Star-Delta Connection:

- In this type of connection, then primary is connected in star fashion while the secondary is connected in delta fashion as shown in the Fig.



- The voltages on primary and secondary sides can be represented on the phasor diagram as shown in the Fig.



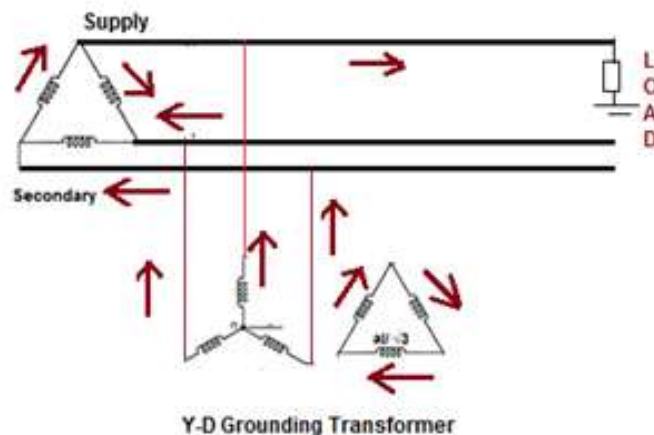
Key point:

- As Primary in Star connected
- Line voltage on Primary side = $\sqrt{3}$ X Phase voltage on Primary side. So
- Phase voltage on Primary side = Line voltage on Primary side / $\sqrt{3}$
- Now Transformation Ration (K) = Secondary Phase Voltage / Primary Phase Voltage
- Secondary Phase Voltage = K X Primary Phase Voltage.

- As Secondary in delta connected:
- Line voltage on Secondary side = Phase voltage on Secondary side.
- Secondary Phase Voltage = $K \times \text{Primary Phase Voltage}$. $= K \times (\text{Line voltage on Primary side} / \sqrt{3})$
- **Secondary Phase Voltage = $(K/\sqrt{3}) \times \text{Line voltage on Primary side}$.**
- **There is a +30 Degree or -30 Degree Phase Shift between Secondary Phase Voltage to Primary Phase Voltage**

Advantages of Star Delta Connection:

- The primary side is star connected. Hence fewer numbers of turns are required. This makes the connection economical for large high voltage step down power transformers.
- The neutral available on the primary can be earthed to avoid distortion.
- The neutral point allows both types of loads (single phase or three phases) to be met.
- Large unbalanced loads can be handled satisfactorily.
- The Y-D connection has no problem with third harmonic components due to circulating currents in D. It is also more stable to unbalanced loads since the D partially redistributes any imbalance that occurs.
- The delta connected winding carries third harmonic current due to which potential of neutral point is stabilized. Some saving in cost of insulation is achieved if HV side is star connected. But in practice the HV side is normally connected in delta so that the three phase loads like motors and single phase loads like lighting loads can be supplied by LV side using three phase four wire system.
- **As Grounding Transformer:** In Power System Mostly grounded Y- Δ transformer is used for no other purpose than to provide a good ground source in ungrounded Delta system. Take, for example, a distribution system supplied by Δ connected (i.e., un-grounded) power source. If it is required to connect phase-to-ground loads to this system a grounding bank is connected to the system, as shown in Figure



- This system a grounding bank is connected to the system, as shown in Figure. Note that the connected winding is not connected to any external circuit in Figure.
- With a load current equal to 3 times i , each phase of the grounded Y winding provides the same current i , with the Δ -connected secondary winding of the grounding bank providing the ampere-turns required to cancel the ampere-turns of the primary winding. Note that the grounding bank does not supply any real power to the load; it is there merely to provide a ground path. All the power required by the load is supplied by two phases of the ungrounded supply

Disadvantages of Star-Delta Connection:

- In this type of connection, the secondary voltage is not in phase with the primary. Hence it is not possible to operate this connection in parallel with star-star or delta-delta connected transformer.
- One problem associated with this connection is that the secondary voltage is shifted by 30° with respect to the primary voltage. This can cause problems when paralleling 3-phase transformers since transformers secondary voltages must be in-phase to be paralleled. Therefore, we must pay attention to these shifts.
- If secondary of this transformer should be paralleled with secondary of another transformer without phase shift, there would be a problem

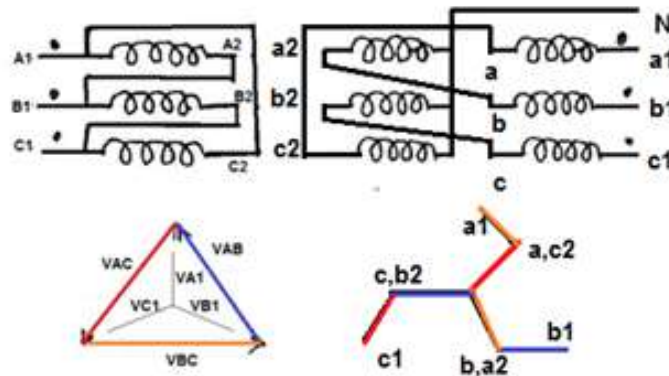
Application:

- It is commonly employed for power supply transformers.
- This type of connection is commonly employed at the substation end of the transmission line. The main use with this connection is to step down the voltage. The neutral available on the primary side is grounded. It can be seen that there is phase difference of 30° between primary and secondary line voltages.
- Commonly used in a step-down transformer, Y connection on the HV side reduces insulation costs the neutral point on the HV side can be grounded, stable with respect to unbalanced loads. As for example, at the end of a transmission line. The neutral of the primary winding is earthed. In this system, line voltage

ratio is $1/\sqrt{3}$ Times of transformer turn-ratio and secondary voltage lags behind primary voltage by 30° . Also third harmonic currents flow in the core to give a sinusoidal flux.

(5) The Zigzag Connection:

- The zigzag connection is also called the interconnected star connection. This connection has some of the features of the Y and the Δ connections, combining the advantages of both.
- The zigzag transformer contains six coils on three cores. The first coil on each core is connected contrariwise to the second coil on the next core. The second coils are then all tied together to form the neutral and the phases are connected to the primary coils. Each phase, therefore, couples with each other phase and the voltages cancel out. As such, there would be negligible current through the neutral pole and it can be connected to ground
- One coil is the outer coil and the other is the inner coil. Each coil has the same number of windings turns (Turns ratio=1:1) but they are wound in opposite directions. The coils are connected as follows:
 - The outer coil of phase a1-a is connected to the inner coil of phase c2-N.
 - The outer coil of phase b1-b is connected to the inner coil of phase a2-N.
 - The outer coil of phase c1-c is connected to the inner coil of phase b2-N.
 - The inner coils are connected together to form the neutral and are tied to ground
 - The outer coils are connected to phase's a1, b1, c1 of the existing delta system.



- If three currents, equal in magnitude and phase, are applied to the three terminals, the ampere-turns of the a2-N winding cancel the ampere-turns of the b1-b winding, the ampere-turns of the b2-N winding cancel the ampere turns of the c1-c winding, and the ampere-turns of the c2-N winding cancel the ampere turns of the a1-a winding. Therefore, the transformer allows the three in-phase currents to easily flow to neutral.
- If three currents, equal in magnitude but 120° out of phase with each other, are applied to the three terminals, the ampere-turns in the windings cannot cancel and the transformer restricts the current flow to the negligible level of magnetizing current. Therefore, the zigzag winding provides an easy path for in-phase currents but does not allow the flow of currents that are 120° out of phase with each other.
- Under normal system operation the outer and inner coil winding's magnetic flux will cancel each other and only negligible current will flow in the neutral of the zig-zag transformer.
- During a phase to ground fault the zig-zag transformer's coils magnetic flux are no longer equal in the faulted line. This allows zero sequence.
- If one phase, or more, faults to earth, the voltage applied to each phase of the transformer is no longer in balance; fluxes in the windings no longer oppose. (Using symmetrical components, this is $I_{a0} = I_{b0} = I_{c0}$.) Zero sequence (earth fault) current exists between the transformers' neutral to the faulting phase. Hence, the purpose of a zigzag transformer is to provide a return path for earth faults on delta connected systems. With negligible current in the neutral under normal conditions, engineers typically elect to under size the transformer; a short time rating is applied. Ensure the impedance is not too low for the desired fault limiting. Impedance can be added after the secondary's are summed (the $3I_0$ path)
- The neutral formed by the zigzag connection is very stable. Therefore, this type of transformer, or in some cases an auto transformer, lends itself very well for establishing a neutral for an ungrounded 3 phase system.
- Many times this type of transformer or auto transformer will carry a fairly large rating, yet physically be relatively small. This particularly applies in connection with grounding applications. The reason for this small size in relation to the nameplate KVA rating is due to the fact that many types of grounding auto transformers are rated for 2 seconds. This is based on the time to operate an over current protection device such as a breaker. Zigzag transformers used to be employed to enable size reductions in drive motor systems due to the stable wave form they present. Other means are now more common, such as 6 phase star.

Advantages of Zig-Zag Transformer:

- The Δ -zigzag connection provides the same advantages as the Δ -Y connection.
- **Less Costly for grounding Purpose:** It is typically the least costly than Y-D and Scott Transformer.
- **Third harmonic suppression:** The zigzag connection in power systems to trap triple harmonic (3rd, 9th, 15th, etc.) currents. Here, We install zigzag units near loads that produce large triple harmonic currents. The windings trap the harmonic currents and prevent them from traveling upstream, where they can produce undesirable effects.
- **Ground current isolation:** If we need a neutral for grounding or for supplying single-phase line to neutral loads when working with a 3-wire, ungrounded power system, a zigzag connection may be the better solution. Due to its composition, a zigzag transformer is more effective for grounding purposes because it has less internal winding impedance going to the ground than when using a Star type transformer.
- **No Phase Displacement:** There is no phase angle displacement between the primary and the secondary circuits with this connection; therefore, the Δ -zigzag connection can be used in the same manner as Y-Y and Δ - Δ transformers without introducing any phase shifts in the circuits.

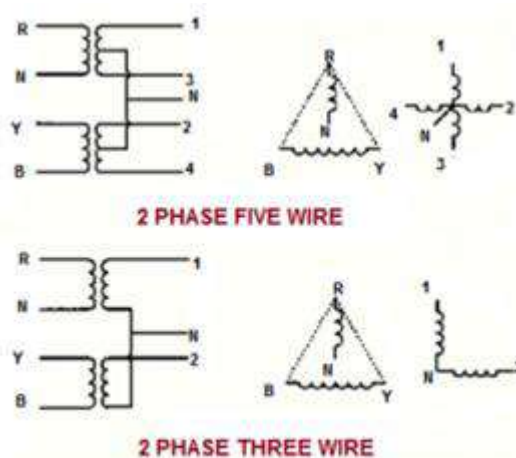
Application:

- **An Earthing Reference:** Occasionally engineers use a combination of YD and zigzag windings to achieve a vector phase shift. For example, an electrical network may have a transmission network of 220 kV/66 kV star/star transformers, with 66 kV/11 kV delta/star for the high voltage distribution network. If a transformation is required directly between the 220 kV/11 kV network the most obvious option is to use 220 kV/11 kV star/delta. The problem is that the 11 kV delta no longer has an earth reference point. Installing a zigzag transformer near the secondary side of the 220 kV/11 kV transformer provides the required earth reference point.
- **As a Grounding Transformer:** The ability to provide a path for in-phase currents enables us to use the zigzag connection as a grounding bank, which is one of the main applications for this connection.
- We rarely use zigzag configurations for typical industrial or commercial use, because they are more expensive to construct than conventional Star connected transformers. But zigzag connections are useful in special applications where conventional transformer connections aren't effective.
- D or Y / Zig-zag are used in unbalanced low voltage system – mostly with single phase appliances

(6) Scott-T Connection of Transformer:

Transforming 3 Phases to 2 Phases:

- There are two main reasons for the need to transform from three phases to two phases,
 1. To give a supply to an existing two phase system from a three phase supply.
 2. To supply two phase furnace transformers from a three phase source.
- Two-phase systems can have 3-wire, 4-wire, or 5-wire circuits. It is needed to be considering that a two-phase system is not 2/3 of a three-phase system. Balanced three-wire, two-phase circuits have two phase wires, both carrying approximately the same amount of current, with a neutral wire carrying 1.414 times the currents in the phase wires. The phase-to-neutral voltages are 90° out of phase with each other.
- Two phase 4-wire circuits are essentially just two ungrounded single-phase circuits that are electrically 90° out of phase with each other. Two phase 5-wire circuits have four phase wires plus a neutral; the four phase wires are 90° out of phase with each other.

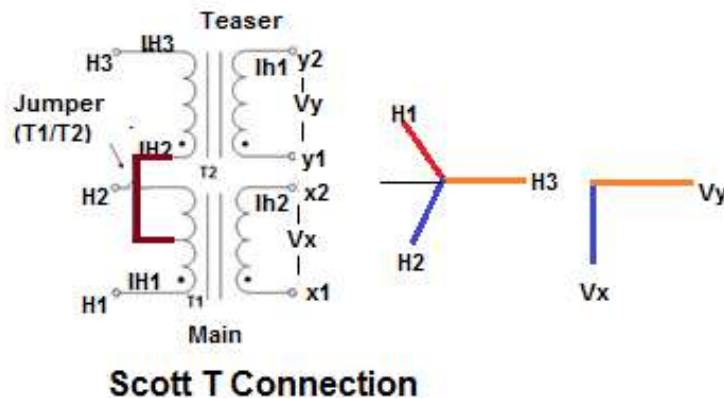


- The easiest way to transform three-phase voltages into two-phase voltages is with two conventional single-phase transformers. The first transformer is connected phase-to-neutral on the primary (three-phase) side and the second transformer is connected between the other two phases on the primary side.

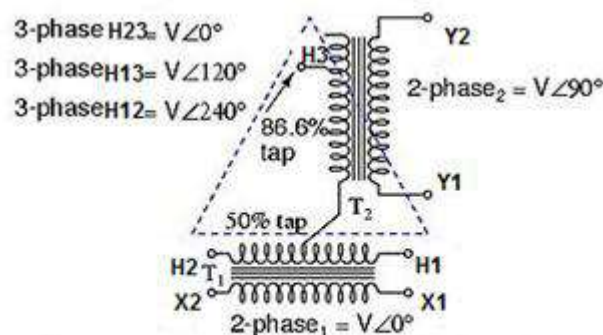
- The secondary windings of the two transformers are then connected to the two-phase circuit. The phase-to-neutral primary voltage is 90° out of phase with the phase-to-phase primary voltage, producing a two-phase voltage across the secondary windings. This simple connection, called the T connection, is shown in Figure
- The main advantage of the T connection is that it uses transformers with standard primary and secondary voltages. The disadvantage of the T connection is that a balanced two-phase load still produces unbalanced three-phase currents; i.e., the phase currents in the three-phase system do not have equal magnitudes, their phase angles are not 120° apart, and there is a considerable amount of neutral current that must be returned to the source.

The Scott Connection of Transformer:

- A Scott-T transformer (also called a Scott connection) is a type of circuit used to derive two-phase power from a three-phase source or vice-versa. The Scott connection evenly distributes a balanced load between the phases of the source.
- Scott T Transformers require a three phase power input and provide two equal single phase outputs called Main and Teaser. The MAIN and Teaser outputs are 90 degrees out of phase. The MAIN and the Teaser outputs must not be connected in parallel or in series as it creates a vector current imbalance on the primary side.
- MAIN and Teaser outputs are on separate cores. An external jumper is also required to connect the primary side of the MAIN and Teaser sections.
- The schematic of a typical Scott T Transformer is shown below

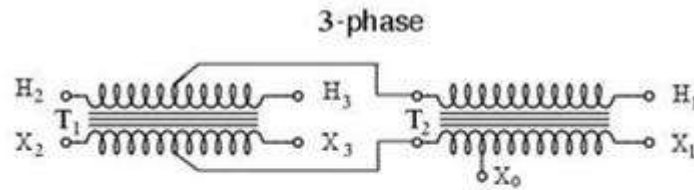


- Scott T Transformer is built with two single phase transformers of equal power rating. The MAIN and Teaser sections can be enclosed in a floor mount enclosure with MAIN on the bottom and Teaser on top with a connecting jumper cable. They can also be placed side by side in separate enclosures.
- Assuming the desired voltage is the same on the two and three phase sides, the Scott-T transformer connection consists of a center-tapped 1:1 ratio main transformer, T1, and an 86.6% ($0.5\sqrt{3}$) ratio teaser transformer, T2. The center-tapped side of T1 is connected between two of the phases on the three-phase side. Its center tap then connects to one end of the lower turn count side of T2, the other end connects to the remaining phase. The other side of the transformers then connects directly to the two pairs of a two-phase four-wire system.



- The Scott-T transformer connection may be also used in a back to back T to T arrangement for a three-phase to 3 phase connection. This is a cost saving in the smaller kVA transformers due to the 2 coil T connected to a secondary 2 coil T in-lieu of the traditional three-coil primary to three-coil secondary transformer. In this arrangement the Neutral tap is part way up on the secondary teaser transformer. The

voltage stability of this T to T arrangement as compared to the traditional 3 coil primary to three-coil secondary transformer is questioned



3-phase
SCOOT-T CONNECTION 3 PHASE to 3 PHASE

Key Point:

- If the main transformer has a turn's ratio of 1: 1, then the teaser transformer requires a turn's ratio of 0.866: 1 for balanced operation. The principle of operation of the Scott connection can be most easily seen by first applying a current to the teaser secondary windings, and then applying a current to the main secondary winding, calculating the primary currents separately and superimposing the results.

Load connected between phase Y1 and phase Y2 of the secondary:

- Secondary current from the teaser winding into phase X1 = $1.0 < 90^\circ$
- Secondary current from the teaser winding into phase X2 = $-1.0 < 90^\circ$
- Primary current from H3 phase into the teaser winding = $1.1547 < 90^\circ$
- Primary current from H2 phase into the main winding = $0.5774 < 90^\circ$
- Primary current from H1 phase into the main winding = $-0.5774 < 90^\circ$
- The reason that the primary current from H3 phase into the teaser winding is 1.1547 due to 0.866: 1 turn's ratio of the teaser, transforming $1/0.866 = 1.1547$ times the secondary current. This current must split in half at the center tap of the main primary winding because both halves of the main primary winding are wound on the same core and the total ampere-turns of the main winding must equal zero.

Load connected between phase X2 and phase X1 of the secondary:

- Secondary current from the main winding into phase X2 = $1.0 < 0^\circ$
- Secondary current from the main winding into phase X4 = $-1.0 < 0^\circ$
- Primary current from H2 phase into the main winding = $1.0 < 0^\circ$
- Primary current from H1 phase into the main winding = $-1.0 < 0^\circ$
- Primary current from H3 phase into the teaser winding = 0
- Superimpose the two sets of primary currents:
- $I_{H3} = 1.1547 < 90^\circ + 0 = 1.1547 < 90^\circ$
- $I_{H2} = 0.5774 < 90^\circ + 1.0 < 0^\circ = 1.1547 < 30^\circ$
- $I_{H1} = 0.5774 < 90^\circ + 1.0 < 0^\circ = 1.1547 < 210^\circ$
- Notice that the primary three-phase currents are balanced; i.e., the phase currents have the same magnitude and their phase angles are 120° apart. The apparent power supplied by the main transformer is greater than the apparent power supplied by the teaser transformer. This is easily verified by observing that the primary currents in both transformers have the same magnitude; however, the primary voltage of the teaser transformer is only 86.6% as great as the primary voltage of the main transformer. **Therefore, the teaser transforms only 86.6% of the apparent power transformed by the main.**
- We also observe that while the total real power delivered to the two phase load is equal to the total real power supplied from the three-phase system, the total apparent power transformed by both transformers is greater than the total apparent power delivered to the two-phase load.
- The apparent power transformed by the teaser is $0.866 \times I_{H1} = 1.0$ and the apparent power transformed by the main is $1.0 \times I_{H2} = 1.1547$ for a total of 2.1547 of apparent power transformed.
- The additional 0.1547 per unit of apparent power is due to parasitic reactive power owing between the two halves of the primary winding in the main transformer.
- Single-phase transformers used in the Scott connection are specialty items that are virtually impossible to buy "off the shelf" nowadays. In an emergency, standard distribution transformers can be used

Advantages of the Scott T Connection:

- If desired, a three phase, two phase, or single phase load may be supplied simultaneously
- The neutral points can be available for grounding or loading purposes

Disadvantages when used for 3 Phase Loading

- This type of asymmetrical connection (3 phases, 2 coils), reconstructs three phases from 2 windings. This can cause unequal voltage drops in the windings, resulting in potentially unbalanced voltages to be applied to the load.

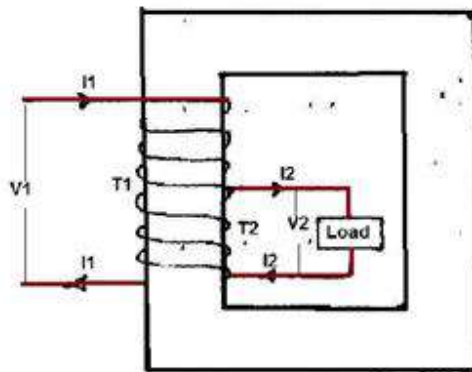
- The transformation ratio of the coils and the voltage obtained may be slightly unbalanced due to manufacturing variances of the interconnected coils.
- This design's neutral has to be solidly grounded. If it is not grounded solidly, the secondary voltages could become unstable.
- Since this design will have a low impedance, special care will have to be taken on the primary protection fault current capacity. This could be an issue if the system was designed for a Delta-Star connection.
- The inherent single phase construction and characteristics of this connection produces a comparatively bulky and heavier transformer when compared with a normal three phase transformer of the same rating.

Application:

- For Industrial Furnace Transformer.
- **For Traction Purpose:** The power is obtained from the 220 kV or 132 kV or 110 kV or 66 kV, three-phase, effectively earthed transmission network of the State Electricity Board, through single-phase transformers or Scott connected transformer installed at the Traction Substation. The primary winding of the single-phase transformer is connected to two phases of the transmission network or Where Scott-connected transformer is used, the primary windings are connected to the three phases of the transmission network.
- The single-phase transformers at a Traction Substation are connected to the same two phases of the transmission network (referred as single-phase connection), or alternatively to different pairs of phases- the three single phase transformers forming a delta-connection on the primary side. Out of three single-phase transformers, one transformer feeds the overhead equipment (OHE) on one side of the Traction Substation, another feeds the OHE on the other side of the Traction Substation, and the third remains as standby. Thus the two single-phase transformers which feed the OHE constitute an open-delta connection (alternatively, referred as V-connection) on the three-phase transformers network. The Scott-connected transformer and V-connected single-phase transformers are effective in reducing voltage imbalance on the transmission network. The spacing between adjacent substations is normally between 70 and 100 km.

(7) Auto Transformer Connection:

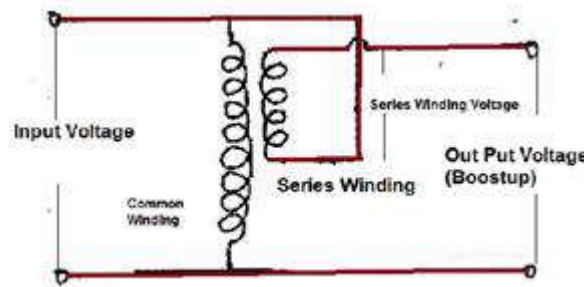
- An Ordinary Transformer consists of two windings called primary winding and secondary winding. These two windings are magnetically coupled and electrically isolated. But the transformer in which a part of windings is common to both primary and secondary is called Auto Transformer.
- In Auto Transformer two windings are not only magnetically coupled but also electrically coupled. The input to the transformer is constant but the output can be varied by varying the tapings.
- The autotransformer is both the most simple and the most fascinating of the connections involving two windings. It is used quite extensively in bulk power transmission systems because of its ability to multiply the effective KVA capacity of a transformer. Autotransformers are also used on radial distribution feeder circuits as voltage regulators. The connection is shown in Figure



- The primary and secondary windings of a two winding transformer have induced emf in them due to a common mutual flux and hence are in phase. The currents drawn by these two windings are out of phase by 180° . This prompted the use of a part of the primary as secondary. This is equivalent to common the secondary turns into primary turns.
- The common section need to have a cross sectional area of the conductor to carry $(I_2 - I_1)$ ampere.
- Total number of turns between A and C are T_1 . At point B a connection is taken. Section AB has T_2 turns. As the volts per turn, which is proportional to the flux in the machine, is the same for the whole winding, $V_1 : V_2 = T_1 : T_2$
- When the secondary winding delivers a load current of I_2 Ampere the demagnetizing ampere turns is $I_2 T_2$. This will be countered by a current I_1 flowing from the source through the T_1 turns such that, $I_1 T_1 = I_2 T_2$
- A current of I_1 ampere flows through the winding between B and C. The current in the winding between A and B is $(I_2 - I_1)$ ampere. The cross section of the wire to be selected for AB is proportional to this current assuming a constant current density for the whole winding. Thus some amount of material saving can be

achieved compared to a two winding transformer. The magnetic circuit is assumed to be identical and hence there is no saving in the same. To quantify the saving the total quantity of copper used in an auto transformer is expressed as a fraction of that used in a two winding transformer As

- copper in auto transformer / copper in two winding transformer = $((T_1 - T_2)I_1 + T_2(I_2 - I_1)) / (T_1I_1 + T_2I_2)$
- copper in auto transformer / copper in two winding transformer = $1 - (2T_2I_1 / (T_1I_1 + T_2I_2))$
- But $T_1I_1 = T_2I_2$ so
- The Ratio = $1 - (2T_2I_1 / 2T_1I_1) = 1 - (T_2/T_1)$
- This means that **an auto transformer requires the use of lesser quantity of copper given by the ratio of turns. This ratio therefore the savings in copper.**
- As the space for the second winding need not be there, the window space can be less for an auto transformer, giving some saving in the lamination weight also. The larger the ratio of the voltages, smaller is the savings. As T_2 approaches T_1 the savings become significant. Thus auto transformers
- become ideal choice for close ratio transformations



- The auto transformer shown in Figure is connected as a boosting auto transformer because the series winding boosts the output voltage. Care must be exercised when discussing “primary” and “secondary” voltages in relationship to windings in an auto transformer.
- In two-winding transformers, the primary voltage is associated with the primary winding, the secondary voltage is associated with the secondary winding, and the primary voltage is normally considered to be greater than the secondary voltage. In the case of a boosting autotransformer, however, the primary (or high) voltage is associated with the series winding, and the secondary (or low) voltage is associated with the common winding; but the voltage across the common winding is higher than across the series winding.

Limitation of the autotransformer

- One of the limitations of the autotransformer connection is that not all types of three-phase connections are possible. For example, the Δ -Y and Y- Δ connections are not possible using the autotransformer. The Y-Y connection must share a common neutral between the high-voltage and low-voltage windings, so the neutrals of the circuits connected to these windings cannot be isolated.
- A Δ - Δ autotransformer connection is theoretically possible; however, this will create a peculiar phase shift. The phase shift is a function of the ratio of the primary to secondary voltages and it can be calculated from the vector diagram. This phase shift cannot be changed or eliminated and for this reason, autotransformers are very seldom connected as Δ - Δ transformers.

Advantages of the autotransformer

- There are considerable savings in size and weight.
- There are decreased losses for a given KVA capacity.
- Using an autotransformer connection provides an opportunity for achieving lower series impedances and better regulation. Its efficiency is more when compared with the conventional one.
- Its size is relatively very smaller.
- Voltage regulation of autotransformer is much better.
- Lower cost
- Low requirements of excitation current.
- Less copper is used in its design and construction.
- In conventional transformer the voltage step up or step down value is fixed while in autotransformer, we can vary the output voltage as per our requirements and can smoothly increase or decrease its value as per our requirement.

Disadvantages of the autotransformer:

- The autotransformer connection is not available with certain three-phase connections.
- Higher (and possibly more damaging) short-circuit currents can result from a lower series impedance.
- Short circuits can impress voltages significantly higher than operating voltages across the windings of an autotransformer.
- For the same voltage surge at the line terminals, the impressed and induced voltages are greater for an autotransformer than for a two-winding transformer.

- Autotransformer consists of a single winding around an iron core, which creates a change in voltage from one end to the other. In other words, the self-inductance of the winding around the core changes the voltage potential, but there is no isolation of the high and low voltage ends of the winding. So any noise or other voltage anomaly coming in on one side is passed through to the other. For that reason, Autotransformers are typically only used where there is already some sort of filtering or conditioning ahead of it, as in electronic applications, or the downstream device is unaffected by those anomalies, such as an AC motor during starting

Applications:

- Used in both Synchronous motors and induction motors.
- Used in electrical apparatus testing labs since the voltage can be smoothly and continuously varied.
- They find application as boosters in AC feeders to increase the voltage levels.
- **Used in HV Substation due to following reasons.**
 1. If we use normal transformer the size of transformer will be very high which leads to heavy weight, more copper and high cost.
 2. The tertiary winding used in Auto transformer balances single phase unbalanced loads connected to secondary and it does not pass on these unbalanced currents to Primary side. Hence Harmonics and voltage unbalance are eliminated.
 3. Tertiary winding in the Auto Transformer balances amp turns so that Auto transformer achieves magnetic separation like two winding transformers.

Introduction:

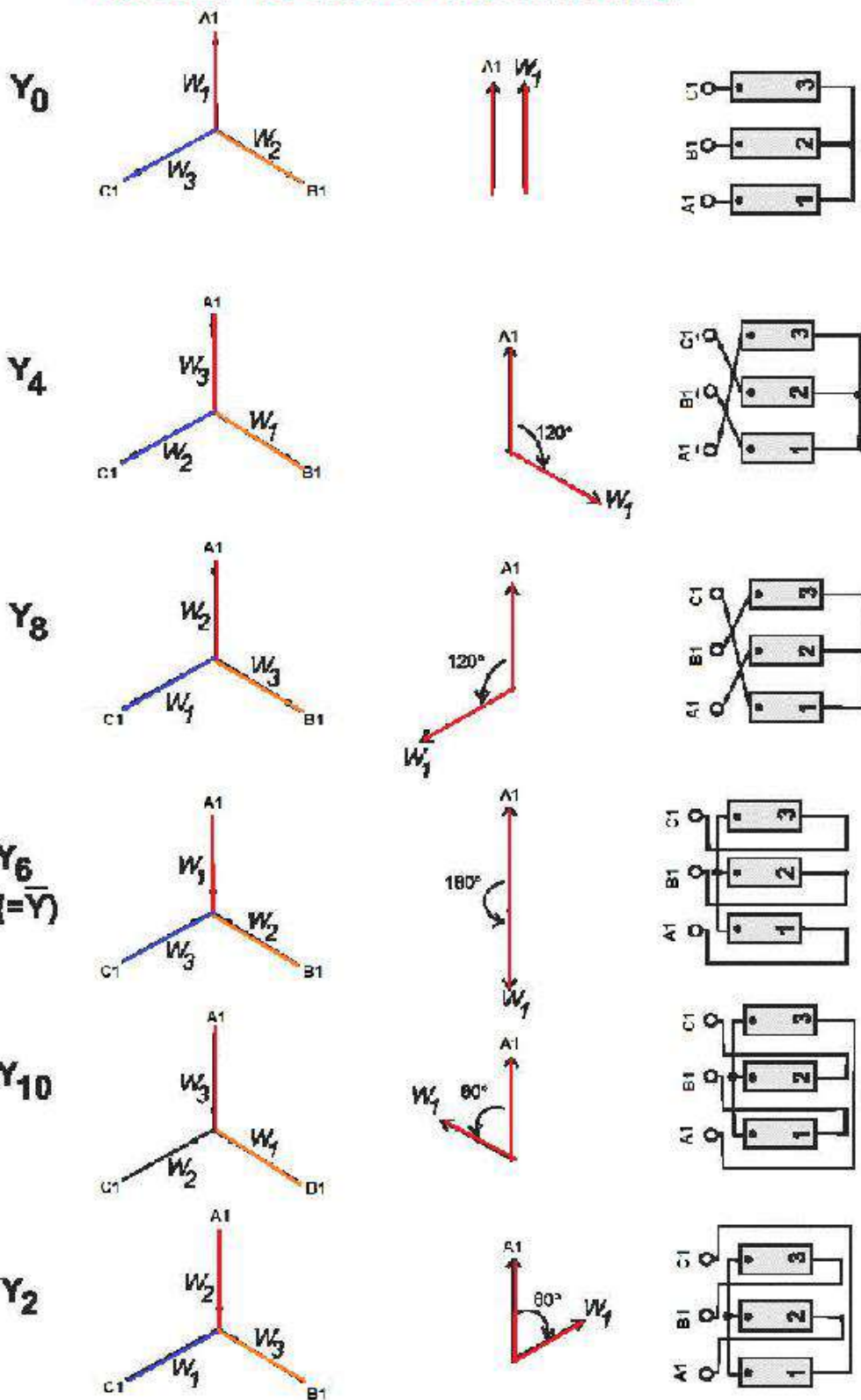
- Three phase transformer consists of three sets of primary windings, one for each phase, and three sets of secondary windings wound on the same iron core. Separate single-phase transformers can be used and externally interconnected to yield the same results as a 3-phase unit.
- The primary windings are connected in one of several ways. The two most common configurations are the delta, in which the polarity end of one winding is connected to the non-polarity end of the next, and the star, in which all three non-polarities (or polarity) ends are connected together. The secondary windings are connected similarly. This means that a 3-phase transformer can have its primary and secondary windings connected the same (delta-delta or star-star), or differently (delta-star or star-delta).
- It's important to remember that the secondary voltage waveforms are in phase with the primary waveforms when the primary and secondary windings are connected the same way. This condition is called "no phase shift." But when the primary and secondary windings are connected differently, the secondary voltage waveforms will differ from the corresponding primary voltage waveforms by 30 electrical degrees. This is called a 30 degree phase shift. When two transformers are connected in parallel, their phase shifts must be identical; if not, a short circuit will occur when the transformers are energized."

Basic Idea of Winding:

- An ac voltage applied to a coil will induce a voltage in a second coil where the two are linked by a magnetic path. The phase relationship of the two voltages depends upon which ways round the coils are connected. The voltages will either be in-phase or displaced by 180 deg
- When 3 coils are used in a 3 phase transformer winding a number of options exist. The coil voltages can be in phase or displaced as above with the coils connected in star or delta and, in the case of a star winding, have the star point (neutral) brought out to an external terminal or not.

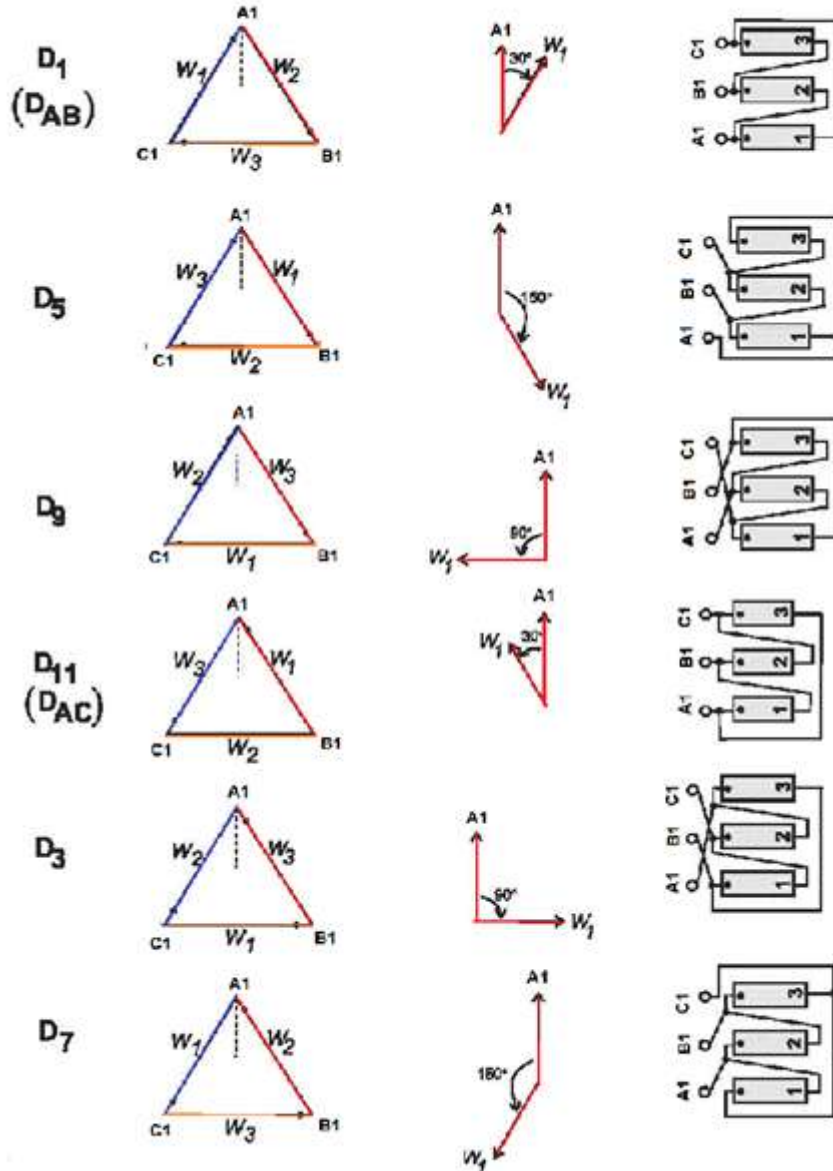
Six Ways to wire Star Winding:

SIX WAY TO WIRE STAR WINDING



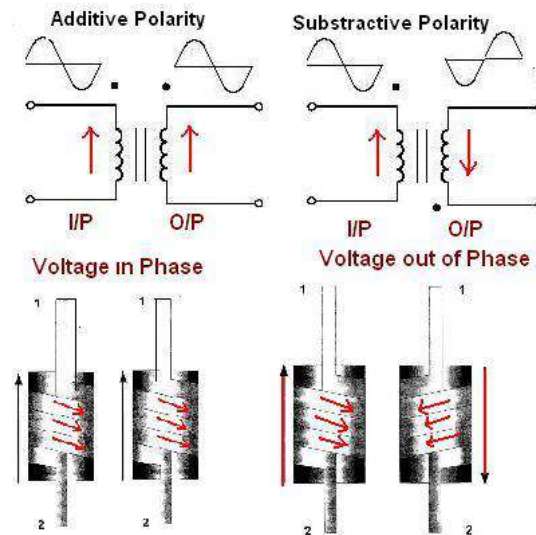
Six Ways to wire Delta Winding:

SIX WAY TO WIRE DELTA WINDING



Polarity:

- An ac voltage applied to a coil will induce a voltage in a second coil where the two are linked by a magnetic path. The phase relationship of the two voltages depends upon which way round the coils are connected. The voltages will either be in-phase or displaced by 180 deg.
- When 3 coils are used in a 3 phase transformer winding a number of options exist. The coil voltages can be in phase or displaced as above with the coils connected in star or delta and, in the case of a star winding, have the star point (neutral) brought out to an external terminal or not.



- When Pair of Coil of Transformer have same direction than voltage induced in both coil are in same direction from one end to other end.
- When two coil have opposite winding direction than Voltage induced in both coil are in opposite direction.

Winding connection designations:

- **First Symbol:** for **High Voltage:** Always capital letters.
- D=Delta, S=Star, Z=Interconnected star, N=Neutral
- **Second Symbol:** for **Low voltage:** Always Small letters.
- d=Delta, s=Star, z=Interconnected star, n=Neutral.
- **Third Symbol:** Phase displacement expressed as the clock hour number (1,6,11)
- **Example - Dyn11**
Transformer has a delta connected primary winding (**D**) a star connected secondary (**y**) with the star point brought out (**n**) and a phase shift of 30 deg leading (**11**).
- The point of confusion is occurring in notation in a step-up transformer. As the IEC60076-1 standard has stated, the notation is HV-LV in sequence. For example, a step-up transformer with a delta-connected primary, and star-connected secondary, is not written as 'dY11', but 'Yd11'. The 11 indicates the LV winding leads the HV by 30 degrees.
- Transformers built to ANSI standards usually do not have the vector group shown on their nameplate and instead a vector diagram is given to show the relationship between the primary and other windings.

Vector Group of Transformer:

- The three phase transformer windings can be connected several ways. Based on the windings' connection, the vector group of the transformer is determined.
- The transformer vector group is indicated on the Name Plate of transformer by the manufacturer. The vector group indicates the phase difference between the primary and secondary sides, introduced due to that particular configuration of transformer windings connection.
- The Determination of vector group of transformers is very important before connecting two or more transformers in parallel. If two transformers of different vector groups are connected in parallel then phase difference exist between the secondary of the transformers and large circulating current flows between the two transformers which is very detrimental.

Phase Displacement between HV and LV Windings:

- The vector for the high voltage winding is taken as the reference vector. Displacement of the vectors of other windings from the reference vector, with anticlockwise rotation, is represented by the use of clock hour figure.

- IS: 2026 (Part 1V)-1977 gives 26 sets of connections star-star, star-delta, and star zigzag, delta-delta, delta star, delta-zigzag, zigzag star, zigzag-delta. Displacement of the low voltage winding vector varies from zero to -330° in steps of -30° , depending on the method of connections.
- Hardly any power system adopts such a large variety of connections. Some of the commonly used connections with phase displacement of 0, -300 , -180° and -330° (clock-hour setting 0, 1, 6 and 11).
- Symbol for the high voltage winding comes first, followed by the symbols of windings in diminishing sequence of voltage. For example a 220/66/11 kV Transformer connected star, star and delta and vectors of 66 and 11 kV windings having phase displacement of 0° and -330° with the reference (220 kV) vector will be represented As **Yy0 - Yd11**.
- The digits (0, 1, 11 etc) relate to the phase displacement between the HV and LV windings using a clock face notation. The phasor representing the HV winding is taken as reference and set at 12 o'clock. Phase rotation is always anti-clockwise. (International adopted).
- Use the hour indicator as the indicating phase displacement angle. Because there are 12 hours on a clock, and a circle consists out of 360° , each hour represents 30° . Thus 1 = 30° , 2 = 60° , 3 = 90° , 6 = 180° and 12 = 0° or 360° .
- The minute hand is set on 12 o'clock and replaces the line to neutral voltage (sometimes imaginary) of the HV winding. This position is always the reference point.
- **Example:**
- Digit 0 = 0° that the LV phasor is in phase with the HV phasor
- Digit 1 = 30° lagging (LV lags HV with 30°) because rotation is anti-clockwise.
- Digit 11 = 330° lagging or 30° leading (LV leads HV with 30°)
- Digit 5 = 150° lagging (LV lags HV with 150°)
- Digit 6 = 180° lagging (LV lags HV with 180°)
- When transformers are operated in parallel it is important that any phase shift is the same through each. Paralleling typically occurs when transformers are located at one site and connected to a common bus bar (banked) or located at different sites with the secondary terminals connected via distribution or transmission circuits consisting of cables and overhead lines.

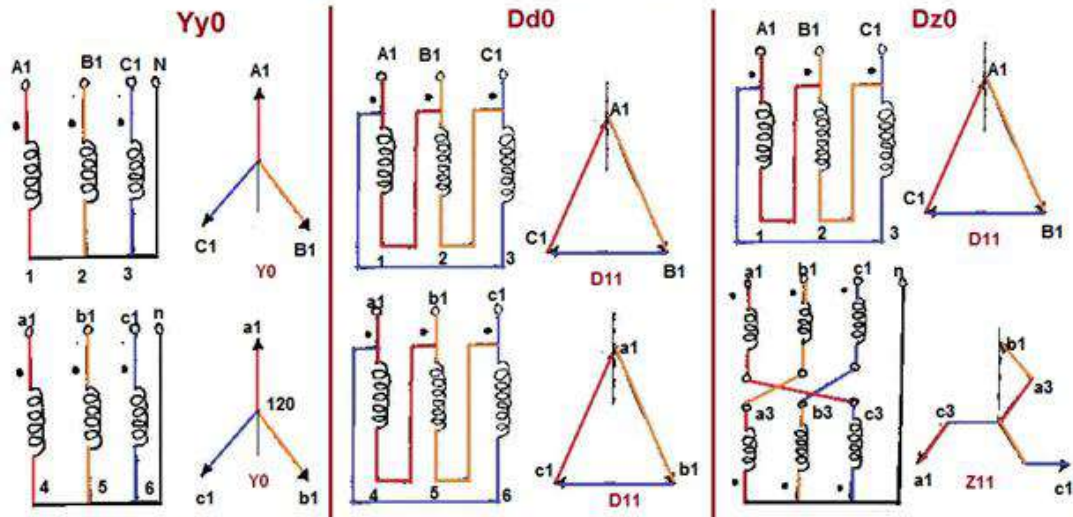
Phase Shift (Deg)	Connection		
0	Yy0	Dd0	Dz0
30 lag	Yd1	Dy1	Yz1
60 lag		Dd2	Dz2
120 lag		Dd4	Dz4
150 lag	Yd5	Dy5	Yz5
180 lag	Yy6	Dd6	Dz6
150 lead	Yd7	Dy7	Yz7
120 lead		Dd8	Dz8
60 lead		Dd10	Dz10
30 lead	Yd11	Dy11	Yz11

- The phase-bushings on a three phase transformer are marked either ABC, UVW or 123 (HV-side capital, LV-side small letters). Two winding, three phase transformers can be divided into four main categories

Group	O'clock	TC
Group I	0 o'clock, 0°	delta/delta, star/star
Group II	6 o'clock, 180°	delta/delta, star/star
Group III	1 o'clock, -30°	star/delta, delta/star
Group IV	11 o'clock, $+30^\circ$	star/delta, delta/star
Minus indicates LV lagging HV, plus indicates LV leading HV		

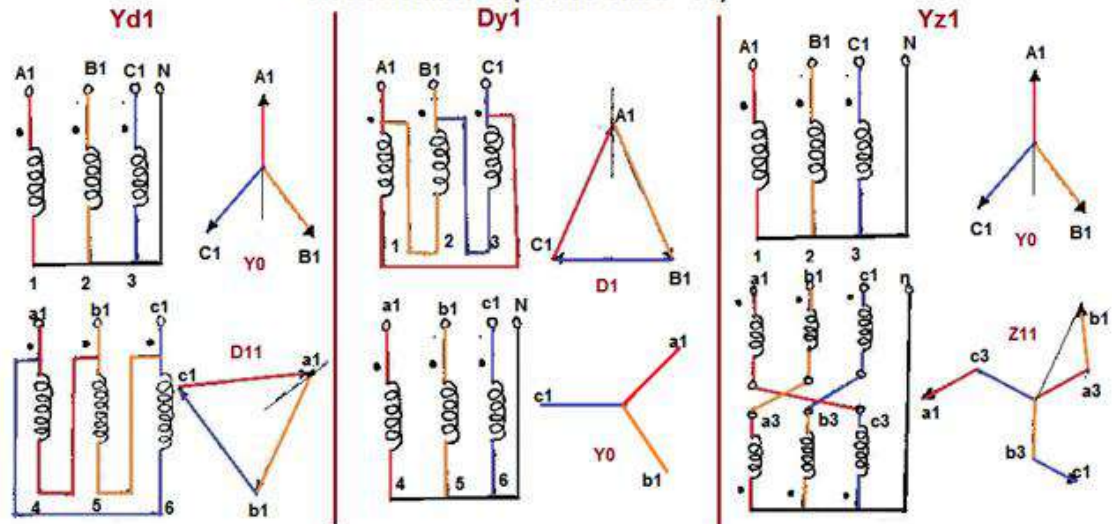
Clock Notation: 0

Clock Notation 0 (Phase shift 0)



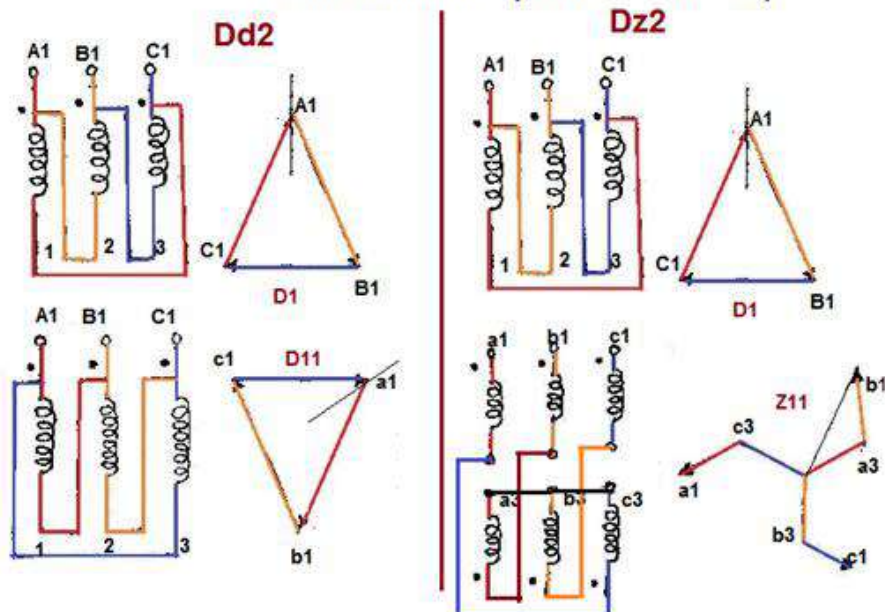
Clock Notation: 1

Clock Notation-1 (Phase Shift: -30)

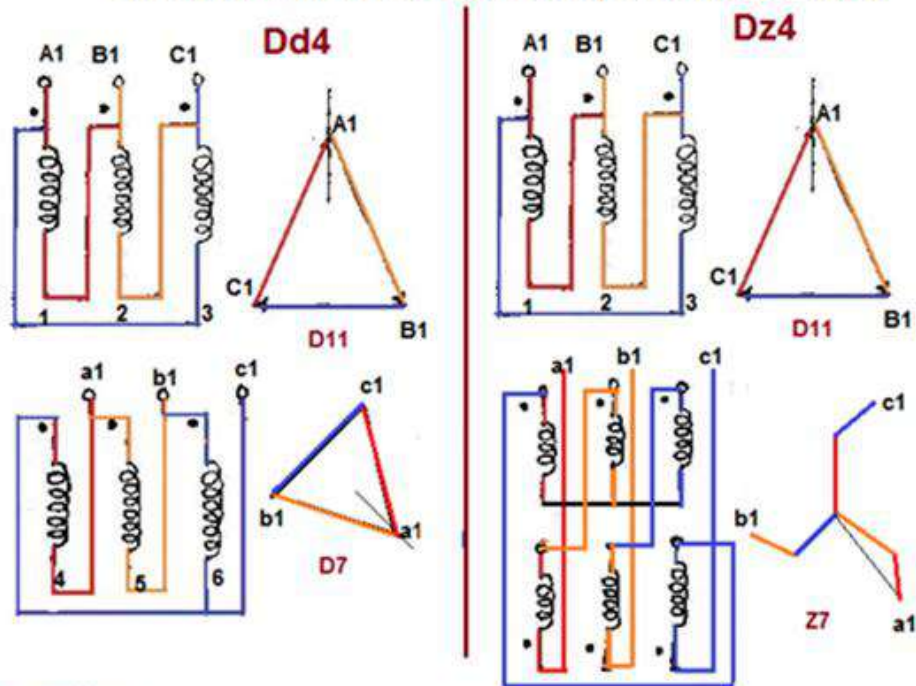


Clock Notation: 2

Clock Notation-2 (Phase Shift: -60)

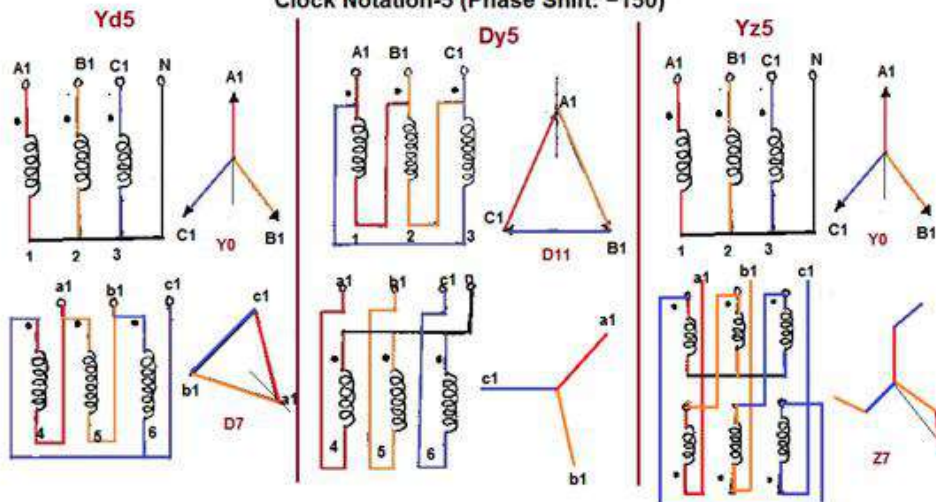


Clock Notation-4 (Phase Displacement -120°)



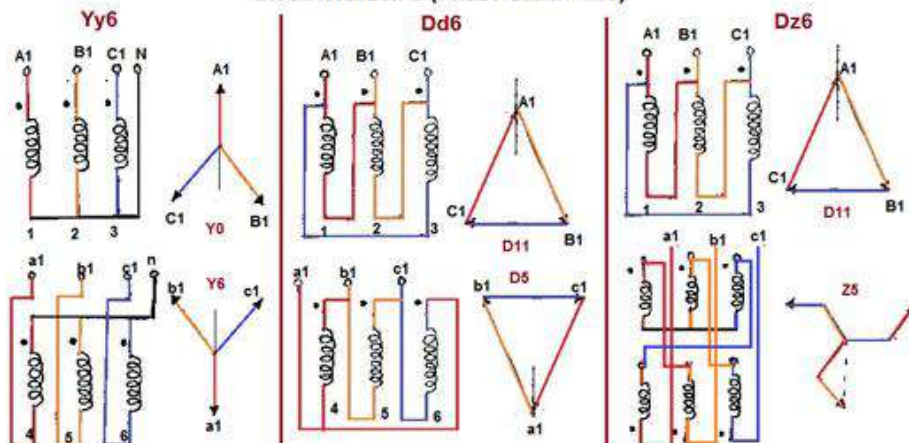
Clock Notation: 5

Clock Notation-5 (Phase Shift: -150°)



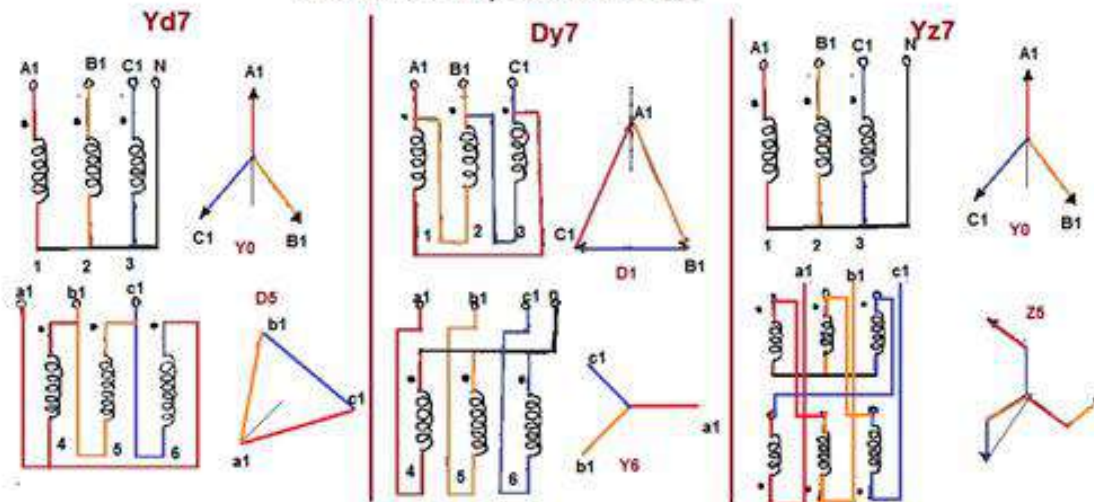
Clock Notation: 6

Clock Notation-6 (Phase Shift: +180°)



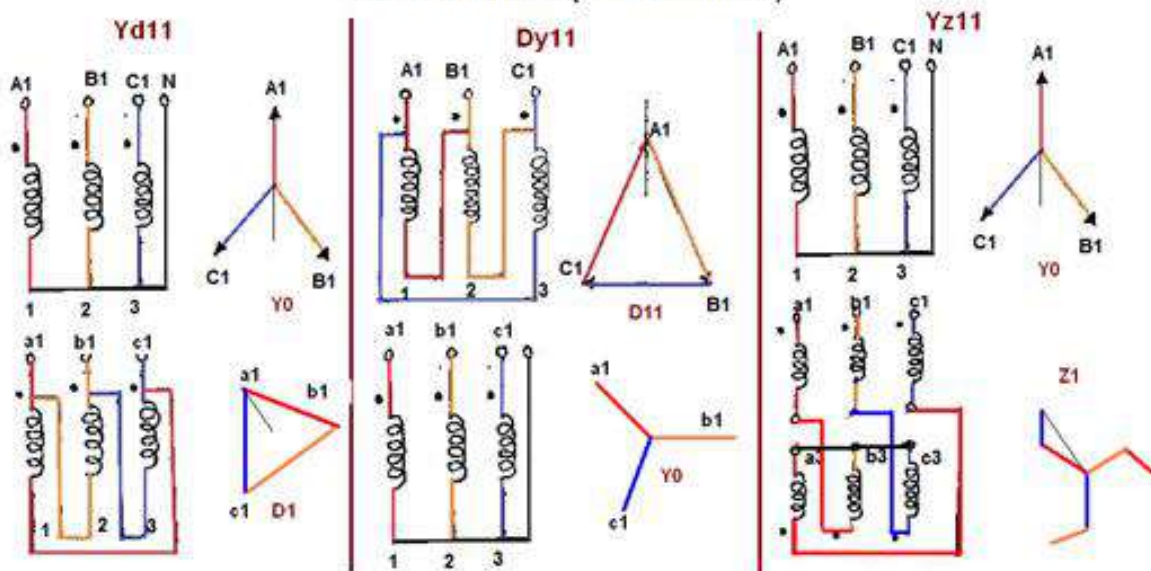
Clock Notation: 7

Clock Notation-7 (Phase Shift: +150)



Clock Notation: 11

Clock Notation 11 (Phase shift +30)



Points to be consider while Selecting of Vector Group:

- Vector Groups are the IEC method of categorizing the primary and secondary winding configurations of 3-phase transformers. Windings can be connected as delta, star, or interconnected-star (zigzag). Winding polarity is also important, since reversing the connections across a set of windings affects the phase-shift between primary and secondary. Vector groups identify the winding connections and polarities of the primary and secondary. From a vector group one can determine the phase-shift between primary and secondary.
- Transformer vector group depends upon
 - Removing harmonics:** Dy connection - y winding nullifies 3rd harmonics, preventing it to be reflected on delta side.
 - Parallel operations:** All the transformers should have same vector group & polarity of the winding.
 - Earth fault Relay:** A Dd transformer does not have neutral. to restrict the earth faults in such systems, we may use zig zag wound transformer to create a neutral along with the earth fault relay.

4. Type of Non Linear Load: systems having different types of harmonics & non linear Types of loads e.g. furnace heaters ,VFDS etc for that we may use Dyn11, Dyn21, Dyn31 configuration, wherein, 30 deg. shifts of voltages nullifies the 3rd harmonics to zero in the supply system.
5. **Type of Transformer Application:** Generally for Power export transformer i.e. generator side is connected in delta and load side is connected in star. For Power export import transformers i.e. in Transmission Purpose Transformer star star connection may be preferred by some since this avoids a grounding transformer on generator side and perhaps save on neutral insulation. Most of systems are running in this configuration. May be less harmful than operating delta system incorrectly. Yd or Dy connection is standard for all unit connected generators.
6. There are a number of factors associated with transformer connections and may be useful in designing a system, and the application of the factors therefore determines the best selection of transformers. For example:

For selecting Star Connection:

- A star connection presents a neutral. If the transformer also includes a delta winding, that neutral will be stable and can be grounded to become a reference for the system. A transformer with a star winding that does NOT include a delta does not present a stable neutral.
- Star-star transformers are used if there is a requirement to avoid a 30deg phase shift, if there is a desire to construct the three-phase transformer bank from single-phase transformers, or if the transformer is going to be switched on a single-pole basis (ie, one phase at a time), perhaps using manual switches.
- Star-star transformers are typically found in distribution applications, or in large sizes interconnecting high-voltage transmission systems. Some star-star transformers are equipped with a third winding connected in delta to stabilize the neutral.

For selecting Delta Connection:

- A delta connection introduces a 30 electrical degree phase shift.
- A delta connection 'traps' the flow of zero sequence currents.

For selecting Delta-Star Connection:

- Delta-star transformers are the most common and most generally useful transformers.
- Delta-delta transformers may be chosen if there is no need for a stable neutral, or if there is a requirement to avoid a 30 electrical degree phase shift. The most common application of a delta-delta transformer is as tan isolation transformer for a power converter.

For selecting Zig zag Connection:

- The Zig Zag winding reduces voltage unbalance in systems where the load is not equally distributed between phases, and permits neutral current loading with inherently low zero-sequence impedance. It is therefore often used for earthing transformers.
- Provision of a neutral earth point or points, where the neutral is referred to earth either directly or through impedance. Transformers are used to give the neutral point in the majority of systems. The star or interconnected star (Z) winding configurations give a neutral location. If for various reasons, only delta windings are used at a particular voltage level on a particular system, a neutral point can still be provided by a purpose-made transformer called a 'neutral earthing'.

For selecting Distribution Transformer:

- The first criterion to consider in choosing a vector group for a distribution transformer for a facility is to know whether we want a delta-star or star-star. Utilities often prefer star-star transformers, but these require 4-wire input feeders and 4-wire output feeders (i.e. incoming and outgoing neutral conductors).
- For distribution transformers within a facility, often delta-star are chosen because these transformers do not require 4-wire input; a 3-wire primary feeder circuit suffices to supply a 4-wire secondary circuit. That is because any zero sequence current required by the secondary to supply earth faults or unbalanced loads is supplied by the delta primary winding, and is not required from the upstream power source. The method of earthing on the secondary is independent of the primary for delta-star transformers.
- The second criterion to consider is what phase-shift you want between primary and secondary. For example, Dy11 and Dy5 transformers are both delta-star. If we don't care about the phase-shift, then either transformer will do the job. Phase-shift is important when we are paralleling sources. We want the phase-shifts of the sources to be identical.
- If we are paralleling transformers, then you want them to have the same the same vector group. If you are replacing a transformer, use the same vector group for the new transformer, otherwise the existing VTs and CTs used for protection and metering will not work properly.
- There is no technical difference between the one vector groups (i.e. Yd1) or another vector group (i.e. Yd11) in terms of performance. The only factor affecting the choice between one or the other is system phasing, ie whether parts of the network fed from the transformer need to operate in parallel with another source. It also matters if you have an auxiliary transformer connected to generator terminals. Vector matching at the auxiliary bus bar

Application of Transformer according to Vector Group:

(1) (Dyn11, Dyn1, YNd1, YNd11)

- Common for distribution transformers.
- Normally Dyn11 vector group using at distribution system. Because Generating Transformer are YNd1 for neutralizing the load angle between 11 and 1.
- We can use Dyn1 at distribution system, when we are using Generator Transformer are YNd11.
- In some industries 6 pulse electric drives are using due to this 5th harmonics will generate if we use Dyn1 it will be suppress the 5th harmonics.
- Star point facilitates mixed loading of three phase and single phase consumer connections.
- The delta winding carry third harmonics and stabilizes star point potential.
- A delta-Star connection is used for step-up generating stations. If HV winding is star connected there will be saving in cost of insulation.
- But delta connected HV winding is common in distribution network, for feeding motors and lighting loads from LV side.

(2) Star-Star (Yy0 or Yy6)

- Mainly used for large system tie-up Transformer.
- Most economical connection in HV power system to interconnect between two delta systems and to provide neutral for grounding both of them.
- Tertiary winding stabilizes the neutral conditions. In star connected transformers, load can be connected between line and neutral, only if
 - (a) the source side transformers is delta connected or
 - (b) the source side is star connected with neutral connected back to the source neutral.
- In This Transformers. Insulation cost is highly reduced. Neutral wire can permit mixed loading.
- Triple harmonics are absent in the lines. These triple harmonic currents cannot flow, unless there is a neutral wire. This connection produces oscillating neutral.
- Three phase shell type units have large triple harmonic phase voltage. However three phase core type transformers work satisfactorily.
- A tertiary mesh connected winding may be required to stabilize the oscillating neutral due to third harmonics in three phase banks.

(3) Delta - Delta (Dd 0 or Dd 6)

- This is an economical connection for large low voltage transformers.
- Large unbalance of load can be met without difficulty.
- Delta permits a circulating path for triple harmonics thus attenuates the same.
- It is possible to operate with one transformer removed in open delta or "V" connection meeting 58 percent of the balanced load.
- Three phase units cannot have this facility. Mixed single phase loading is not possible due to the absence of neutral.

(4) Star-Zig-zag or Delta-Zig-zag (Yz or Dz)

- These connections are employed where delta connections are weak. Interconnection of phases in zigzag winding effects a reduction of third harmonic voltages and at the same time permits unbalanced loading.
- This connection may be used with either delta connected or star connected winding either for step-up or step-down transformers. In either case, the zigzag winding produces the same angular displacement as a delta winding, and at the same time provides a neutral for earthing purposes.
- The amount of copper required from a zigzag winding is 15% more than a corresponding star or delta winding. This is extensively used for earthing transformer.
- Due to **zigzag** connection (interconnection between phases), third harmonic voltages are reduced. It also allows unbalanced loading. The zigzag connection is employed for LV winding. For a given total voltage per phase, the zigzag side requires 15% more turns as compared to normal phase connection. In cases where delta connections are weak due to large number of turns and small cross sections, then zigzag star connection is preferred. It is also used in rectifiers.

(5) Zig-zag/ star (ZY1 or Zy11)

- Zigzag connection is obtained by inter connection of phases. 4-wire system is possible on both sides. Unbalanced loading is also possible. Oscillating neutral problem is absent in this connection.
- This connection requires 15% more turns for the same voltage on the zigzag side and hence costs more. Hence a bank of three single phase transformers cost about 15% more than their 3-phase counterpart. Also, they occupy more space. But the spare capacity cost will be less and single phase units are easier to transport.

- Unbalanced operation of the transformer with large zero sequence fundamental mmf content also does not affect its performance. Even with Yy type of poly phase connection without neutral connection the oscillating neutral does not occur with these cores. Finally, three phase cores themselves cost less than three single phase units due to compactness.

(6) Yd5:

- Mainly used for machine and main Transformer in large Power Station and Transmission Substation.
- The Neutral point can be loaded with rated Current.

(7) Yz-5

- For Distribution Transformer up to 250MVA for local distribution system.
- The Neutral point can be loaded with rated Current.

Application of Transformer according according to Uses:

- **Step up Transformer:** It should be Yd1 or Yd11.
- **Step down Transformer:** It should be Dy1 or Dy11.
- **Grounding purpose Transformer:** It should be Yz1 or Dz11.
- **Distribution Transformer:** We can consider vector group of Dzn0 which reduce the 75% of harmonics in secondary side.
- **Power Transformer:** Vector group is deepen on application for Example : Generating Transformer : Dyn1 , Furnace Transformer: Ynyn0.

Convert One Group of Transformer to Other Group by Channing External Connection:

(1) Group I: Example: Dd0 (no phase displacement between HV and LV).

- The conventional method is to connect the red phase on A/a, Yellow phase on B/b, and the Blue phase on C/c.
- Other phase displacements are possible with unconventional connections (for instance red on b, yellow on c and blue on a) By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd0 transformer can be changed either to a Dd4(-120°) or Dd8(+120°) connection. The same is true for internal connected Dd4 or Dd8 transformers.

(2) Group II: Example: Dd6 (180° displacement between HV and LV).

- By doing some unconventional connections externally on one side of the Transformer, an internal connected Dd6 transformer can be changed either to a Dd2(-60°) or Dd10(+60°) connection.

(3) Group III: Example: Dyn1 (-30° displacement between HV and LV).

- By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn1 transformer can be changed either to a Dyn5(-150°) or Dyn9(+90°) connection.

(4) Group IV: Example: Dyn11 (+30° displacement between HV and LV).

- By doing some unconventional connections externally on one side of the Transformer, an internal connected Dyn11 transformer can be changed either to a Dyn7(+150°) or Dyn3(-90°) connection.

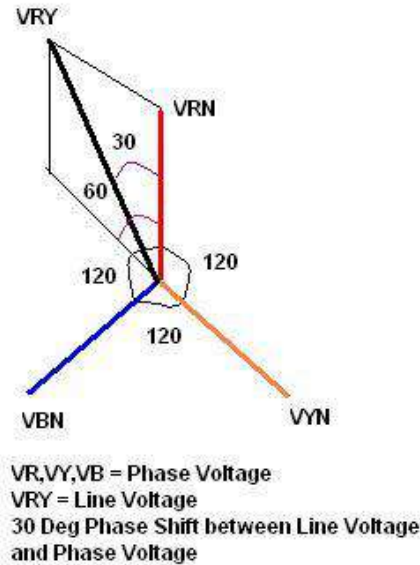
Point to be remembered:

- **For Group-III & Group-IV:** By doing some unconventional connections externally on both sides of the Transformer, an internal connected Group-III or Group-IV transformer can be changed to any of these two groups.
- Thus by doing external changes on both sides of the Transformer an internal connected Dyn1 transformer can be changed to either a: Dyn3, Dyn5, Dyn7, Dyn9 or Dyn11 transformer, This is just true for star/delta or delta/star connections.
- **For Group-I & Group-II:** Changes for delta/delta or star/star transformers between Group-I and Group-III can just be done internally.

Why 30° phase shift occur in star-delta transformer between primary and secondary?

- The phase shift is a natural consequence of the delta connection. The currents entering or leaving the star winding of the transformer are in phase with the currents in the star windings. Therefore, the currents in the delta windings are also in phase with the currents in the star windings and obviously, the three currents are 120 electrical degrees apart.
- But the currents entering or leaving the transformer on the delta side are formed at the point where two of the windings comprising the delta come together - each of those currents is the phasor sum of the currents in the adjacent windings.

- When you add together two currents that are 120 electrical degrees apart, the sum is inevitably shifted by degree



- The Main reason for this phenomenon is that the phase voltage lags line current by 30 degrees. Consider a delta/star transformer. The phase voltages in three phases of both primary and secondary. You will find that in primary the phase voltage and line voltages are same, let it be VRY (take one phase). But, the corresponding secondary will have the phase voltage only in its phase winding as it is star connected. The line voltage of star connected secondary and delta connected primary won't have any phase differences between them. So this can be summarized that "the phase shift is associated with the wave forms of the three phase windings."

Why Generating Transformer is Yd1 and Distribution Transformer is Dy11:

- This is the HV Side or the Switchyard side of the Generator Transformer is connected in Delta and the LV Side or the generator side of the GT is connected in Star, with the Star side neutral brought out. The LV side voltage will "lag" the HV side voltage by 30 degrees.
- Thus, in a generating station we create a 30 degrees lagging voltage for transmission, with respect to the generator voltage.
- As we have created a 30 degrees lagging connection in the generating station, it is advisable to create a 30 degrees leading connection in distribution so that the user voltage is "in phase" with the generated voltage. And, as the transmission side is Delta and the user might need three phase, four-wire in the LV side for his single phase loads, the distribution transformer is chosen as Dyn11.
- There is magnetic coupling between HT and LT. When the load side (LT) suffers some dip the LT current try to go out of phase with HT current, so 30 degree phase shift in Dyn-11 keeps the two currents in phase when there is dip.
- So the vector group at the generating station is important while selecting distribution Transformer.

Vector Group in Generating-Transmission-Distribution System:

- Generating TC is Yd1 transmitted power at 400KV, for 400KV to 220KV Yy is used and by using Yd between e.g. 220 and 66 kV, then Dy from 66 to 11 kV so that their phase shifts can be cancelled out. And for LV (400/230V) supplies at 50 Hz are usually 3 phase, earthed neutral, so a "Dyn" LV winding is needed. Here GT side -30lag (Yd1) can be nullify +30 by using distribution Transformer of Dy11.
- A reason for using Yd between e.g. 220 and 66 kV, then Dy from 66 to 11 kV is that their phase shifts can cancel out and it is then also possible to parallel a 220/11 kV YY transformer, at 11 kV, with the 66/11 kV (a YY transformer often has a third, delta, winding to reduce harmonics). If one went Dy11 - Dy11 from 220 to 11 kV, there would be a 60 degree shift, which is not possible in one transformer. The "standard" transformer groups in distribution avoid that kind of limitation, as a result of thought and experience leading to lowest cost over many years.

Generator TC is Yd1, Can we use Distribution TC Dy5 instead of Dy11.

- With regards to theory, there are no special advantages of Dyn11 over Dyn5.

- **In Isolation Application:** In isolated applications there is no advantage or disadvantage by using Dy5 or Dy11. If however we wish to interconnect the secondary sides of different Dny transformers, we must have compatible transformers, and that can be achieved if you have a Dyn11 among a group of Dyn5's and vice versa.
- **In Parallel Connection:** Practically, the relative places of the phases remain same in Dyn11 compared to Dyn5.
- If we use Yd1 Transformer on Generating Side and Distribution side Dy11 transformer than -30 lag of generating side (Yd1) is nullify by +30 Lead at Receiving side (Dy11) so no phase difference respect to generating Side and if we are on the HV side of the Transformer, and if we denote the phases as R- Y-B from left to right, the same phases on the LV side will be R- Y -B, but from left to Right.
- This will make the Transmission lines have same color (for identification) whether it is input to or output from the Transformer.
- If we use Yd1 Transformer on Generating Side and Distribution side Dy5 transformer than -30 lag of generating side (Yd1) is more lag by -150 Lag at Receiving side (Dy5) so Total phase difference respect to generating Side is 180 deg $(-30 + -150 = -180)$ and if we are on the HV side of the Transformer, and if we denote the phases as R- Y-B from left to right, the same phases on the LV side will be R- Y -B, but from Right to Left.
- This will make the Transmission lines have No same color (for identification) whether it is input to or output from the Transformer.
- The difference in output between the Dyn11 and Dny5 and is therefore 180 degrees.

Introduction:

- Power transformers are used in transmission network of higher voltages for step-up and step down application (400 kV, 200 kV, 110 kV, 66 kV, 33kV) and are generally rated above 200MVA.
- Distribution transformers are used for lower voltage distribution networks as a means to end user connectivity. (11kV, 6.6 kV, 3.3 kV, 440V, 230V) and are generally rated less than 200 MVA.

1) Transformer Size / Insulation Level:

- Power transformer is used for the transmission purpose at heavy load, high voltage greater than 33 KV & 100% efficiency. It also having a big in size as compare to distribution transformer, it used in generating station and Transmission substation .high insulation level.
- The distribution transformer is used for the distribution of electrical energy at low voltage as less than 33KV in industrial purpose and 440v-220v in domestic purpose. It work at low efficiency at 50-70%, small size, easy in installation, having low magnetic losses & it is not always fully loaded.

2) Iron Loss & Copper Loss:

- Power Transformers are used in Transmission network so they do not directly connect to the consumers, so load fluctuations are very less. These are loaded fully during 24 hr's a day, so cu losses & iron losses takes place throughout day the specific weight i.e. (iron weight)/(cu weight) is very less .the average loads are nearer to full loaded or full load and these are designed in such a way that maximum efficiency at full load condition. These are independent of time so in calculating the efficiency only power basis is enough.
- Power Transformers are used in Distribution Network so directly connected to the consumer so load fluctuations are very high. these are not loaded fully at all time so iron losses takes place 24hr a day and cu losses takes place based on load cycle. the specific weight is more i.e. (iron weight)/(cu weight).average loads are about only 75% of full load and these are designed in such a way that max efficiency occurs at 75% of full load.
- Power transformers are used for transmission as a step up devices so that the I²r loss can be minimized for a given power flow. These transformers are designed to utilize the core to maximum and will operate very much near to the knee point of B-H curve (slightly above the knee point value).This brings down the mass of the core enormously. Naturally these transformers have the matched iron losses and copper losses at peak load (i.e. the maximum efficiency point where both the losses match).
- Distribution transformers obviously cannot be designed like this. Hence the all-day-efficiency comes into picture while designing it. It depends on the typical load cycle for which it has to supply. Definitely Core design will be done to take care of peak load and as well as all-day-efficiency. It is a bargain between these two points.
- Power transformer generally operated at full load. Hence, it is designed such that copper losses are minimal. However, a distribution transformer is always online and operated at loads less than full load for most of time. Hence, it is designed such that core losses are minimal.
- In Power Transformer the flux density is higher than the distribution transformer.

3) Maximum Efficiency:

- The main difference between power and distribution transformer is distribution transformer is designed for maximum efficiency at 60% to 70% load as normally doesn't operate at full load all the time. Its load depends on distribution demand. Whereas power transformer is designed for maximum efficiency at 100% load as it always runs at 100% load being near to generating station.
- Distribution Transformer is used at the distribution level where voltages tend to be lower .The secondary voltage is almost always the voltage delivered to the end consumer. Because of voltage drop limitations, it is usually not possible to deliver that secondary voltage over great distances. As a result, most distribution systems tend to involve many 'clusters' of loads fed from distribution transformers, and this in turn means that the thermal rating of distribution transformers doesn't have to be very high to support the loads that they have to serve.
- All day efficiency = (Output in KWhr) / (Input in KWhr) in 24 hrs which is always less than power efficiency

Introduction:

- For supplying a load in excess of the rating of an existing transformer, two or more transformers may be connected in parallel with the existing transformer. The transformers are connected in parallel when load on one of the transformers is more than its capacity. The reliability is increased with parallel operation than to have single larger unit. The cost associated with maintaining the spares is less when two transformers are connected in parallel.
- It is usually economical to install another transformer in parallel instead of replacing the existing transformer by a single larger unit. The cost of a spare unit in the case of two parallel transformers (of equal rating) is also lower than that of a single large transformer. In addition, it is preferable to have a parallel transformer for the reason of reliability. With this at least half the load can be supplied with one transformer out of service.

Condition for Parallel Operation of Transformer:

- For parallel connection of transformers, primary windings of the Transformers are connected to source bus-bars and secondary windings are connected to the load bus-bars.
- Various conditions that must be fulfilled for the successful parallel operation of transformers:
 1. Same voltage Ratio & Turns Ratio (both primary and secondary Voltage Rating is same).
 2. Same Percentage Impedance and X/R ratio.
 3. Identical Position of Tap changer.
 4. Same KVA ratings.
 5. Same Phase angle shift (vector group are same).
 6. Same Frequency rating.
 7. Same Polarity.
 8. Same Phase sequence.
- Some of these conditions are convenient and some are mandatory.
- The convenient are: Same voltage Ratio & Turns Ratio, Same Percentage Impedance, Same KVA Rating, Same Position of Tap changer.
- The mandatory conditions are: Same Phase Angle Shift, Same Polarity, Same Phase Sequence and Same Frequency.
- When the convenient conditions are not met paralleled operation is possible but not optimal.

1. Same voltage Ratio & Turns Ratio (on each tap):

- If the transformers connected in parallel have slightly different voltage ratios, then due to the inequality of induced emfs in the secondary windings, a circulating current will flow in the loop formed by the secondary windings under the no-load condition, which may be much greater than the normal no-load current.
- The current will be quite high as the leakage impedance is low. When the secondary windings are loaded, this circulating current will tend to produce unequal loading on the two transformers, and it may not be possible to take the full load from this group of two parallel transformers (one of the transformers may get overloaded).
- If two transformers of different voltage ratio are connected in parallel with same primary supply voltage, there will be a difference in secondary voltages.
- Now when the secondary of these transformers are connected to same bus, there will be a circulating current between secondary's and therefore between primaries also. As the internal impedance of transformer is small, a small voltage difference may cause sufficiently high circulating current causing unnecessary extra I^2R loss.
- The ratings of both primaries and secondary's should be identical. In other words, the transformers should have the same turn ratio i.e. transformation ratio.

2. Same percentage impedance and X/R ratio:

- If two transformers connected in parallel with similar per-unit impedances they will mostly share the load in the ratio of their KVA ratings. Here Load is mostly equal because it is possible to have two transformers with equal per-unit impedances but different X/R ratios. In this case the line current will be less than the sum of the transformer currents and the combined capacity will be reduced accordingly.
- A difference in the ratio of the reactance value to resistance value of the per unit impedance results in a different phase angle of the currents carried by the two paralleled transformers; one transformer will be working with a higher power factor and the other with a lower power factor than that of the combined output. Hence, the real power will not be proportionally shared by the transformers.

- The current shared by two transformers running in parallel should be proportional to their MVA ratings.
- The current carried by these transformers are inversely proportional to their internal impedance.
- From the above two statements it can be said that impedance of transformers running in parallel are inversely proportional to their MVA ratings. In other words percentage impedance or per unit values of impedance should be identical for all the transformers run in parallel.
- When connecting single-phase transformers in three-phase banks, proper impedance matching becomes even more critical. In addition to following the three rules for parallel operation, it is also a good practice to try to match the X/R ratios of the three series impedances to keep the three-phase output voltages balanced.
- When single-phase transformers with the same KVA ratings are connected in a Y-Δ Bank, impedance mismatches can cause a significant load unbalance among the transformers
- Let's examine following different type of case among Impedance, Ratio and KVA.
- If single-phase transformers are connected in a Y-Y bank with an isolated neutral, then the magnetizing impedance should also be equal on an ohmic basis. Otherwise, the transformer having the largest magnetizing impedance will have a highest percentage of exciting voltage, increasing the core losses of that transformer and possibly driving its core into saturation.

Case 1: Equal Impedance, Ratios and Same kVA:

- The standard method of connecting transformers in parallel is to have the same turn ratios, percent impedances, and kVA ratings.
- Connecting transformers in parallel with the same parameters results in equal load sharing and no circulating currents in the transformer windings.
- **Example:** Connecting two 2000 kVA, 5.75% impedance transformers in parallel, each with the same turn ratios to a 4000 kVA load.
- Loading on the transformers-1 $= KVA1 = [(KVA1 / \%Z) / ((KVA1 / \%Z1) + (KVA2 / \%Z2))] \times KVA$
- $KVA1 = 348 / (348 + 348) \times 4000 \text{ kVA} = 2000 \text{ kVA}$.
- Loading on the transformers-2 $= KVA1 = [(KVA2 / \%Z) / ((KVA1 / \%Z1) + (KVA2 / \%Z2))] \times KVA$
- $KVA2 = 348 / (348 + 348) \times 4000 \text{ kVA} = 2000 \text{ kVA}$
- Hence $KVA1=KVA2=2000\text{KVA}$

Case 2: Equal Impedances, Ratios and Different kVA:

- This Parameter is not in common practice for new installations, sometimes two transformers with different KVAs and the same percent impedances are connected to one common bus. In this situation, the current division causes each transformer to carry its rated load. There will be no circulating currents because the voltages (turn ratios) are the same.
- **Example:** Connecting 3000 kVA and 1000 kVA transformers in parallel, each with 5.75% impedance, each with the same turn ratios, connected to a common 4000 kVA load.
- Loading on Transformer-1 $= KVA1 = 522 / (522 + 174) \times 4000 = 3000 \text{ kVA}$
- Loading on Transformer-1 $= KVA2 = 174 / (522 + 174) \times 4000 = 1000 \text{ kVA}$
- From above calculation it is seen that different kVA ratings on transformers connected to one common load, that current division causes each transformer to only be loaded to its kVA rating. The key here is that the percent impedance are the same.

Case 3: Unequal Impedance but Same Ratios & kVA:

- Mostly used this Parameter to enhance plant power capacity by connecting existing transformers in parallel that have the same kVA rating, but with different percent impedances.
- This is common when budget constraints limit the purchase of a new transformer with the same parameters.
- We need to understand is that the current divides in inverse proportions to the impedances, and larger current flows through the smaller impedance. Thus, the lower percent impedance transformer can be overloaded when subjected to heavy loading while the other higher percent impedance transformer will be lightly loaded.
- **Example:** Two 2000 kVA transformers in parallel, one with 5.75% impedance and the other with 4% impedance, each with the same turn ratios, connected to a common 3500 kVA load.
- **Loading on Transformer-1** $= KVA1 = 348 / (348 + 500) \times 3500 = 1436 \text{ kVA}$
- **Loading on Transformer-2** $= KVA2 = 500 / (348 + 500) \times 3500 = 2064 \text{ kVA}$
- It can be seen that because transformer percent impedances do not match, they cannot be loaded to their combined kVA rating. Load division between the transformers is not equal. At below combined rated kVA loading, the 4% impedance transformer is overloaded by 3.2%, while the 5.75% impedance transformer is loaded by 72%.

Case 4: Unequal Impedance & KVA Same Ratios:

- This particular of transformers used rarely in industrial and commercial facilities connected to one common bus with different kVA and unequal percent impedances. However, there may be that one situation where two single-ended substations may be tied together via bussing or cables to provide better voltage support when starting large Load.
- If the percent impedance and kVA ratings are different, care should be taken when loading these transformers.
- **Example:** Two transformers in parallel with one 3000 kVA (kVA1) with 5.75% impedance, and the other a 1000 kVA (kVA2) with 4% impedance, each with the same turn ratios, connected to a common 3500 kVA load.
- **Loading on Transformer-1** = $kVA1 = 522 / (522 + 250) \times 3500 = 2366 \text{ kVA}$
- **Loading on Transformer-2** = $kVA2 = 250 / (522 + 250) \times 3500 = 1134 \text{ kVA}$
- Because the percent impedance is less in the 1000 kVA transformer, it is overloaded with a less than combined rated load.

Case 5: Equal Impedance & KVA Unequal Ratios:

- Small differences in voltage cause a large amount of current to circulate. It is important to point out that paralleled transformers should always be on the same tap connection.
- Circulating current is completely independent of the load and load division. If transformers are fully loaded there will be a considerable amount of overheating due to circulating currents.
- The Point which should be Remember that circulating currents do not flow on the line, they cannot be measured if monitoring equipment is upstream or downstream of the common connection points.
- **Example:** Two 2000 kVA transformers connected in parallel, each with 5.75% impedance, same X/R ratio (8), transformer 1 with tap adjusted 2.5% from nominal and transformer 2 tapped at nominal. What is the percent circulating current (%IC)
- $\%Z1 = 5.75$, So $\%R' = \%Z1 / \sqrt{[(X/R)^2 + 1]} = 5.75 / \sqrt{(8)^2 + 1} = 0.713$
- $\%R1 = \%R2 = 0.713$
- $\%X1 = \%R \times (X/R) = \%X1 = \%X2 = 0.713 \times 8 = 5.7$
- Let %e = difference in voltage ratio expressed in percentage of normal and $k = kVA1 / kVA2$
- **Circulating current %IC = $\%e \times 100 / \sqrt{(\%R1 + k\%R2)^2 + (\%Z1 + k\%Z2)^2}$.**
- $\%IC = 2.5 \times 100 / \sqrt{(0.713 + (2000/2000) \times 0.713)^2 + (5.7 + (2000/2000) \times 5.7)^2}$
- $\%IC = 250 / 11.7 = 21.7$
- The circulating current is 21.7% of the full load current.

Case 6: Unequal Impedance, KVA & Different Ratios:

- This type of parameter would be unlikely in practice.
- If both the ratios and the impedance are different, the circulating current (because of the unequal ratio) should be combined with each transformer's share of the load current to obtain the actual total current in each unit.
- For unity power factor, 10% circulating current (due to unequal turn ratios) results in only half percent to the total current. At lower power factors, the circulating current will change dramatically.
- **Example:** Two transformers connected in parallel, 2000 kVA1 with 5.75% impedance, X/R ratio of 8, 1000 kVA2 with 4% impedance, X/R ratio of 5, 2000 kVA1 with tap adjusted 2.5% from nominal and 1000 kVA2 tapped at nominal.
- $\%Z1 = 5.75$, So $\%R' = \%Z1 / \sqrt{[(X/R)^2 + 1]} = 5.75 / \sqrt{(8)^2 + 1} = 0.713$
- $\%X1 = \%R \times (X/R) = 0.713 \times 8 = 5.7$
- $\%Z2 = 4$, So $\%R2 = \%Z2 / \sqrt{[(X/R)^2 + 1]} = 4 / \sqrt{(5)^2 + 1} = 0.784$
- $\%X2 = \%R \times (X/R) = 0.784 \times 5 = 3.92$
- Let %e = difference in voltage ratio expressed in percentage of normal and $k = kVA1 / kVA2$
- **Circulating current %IC = $\%e \times 100 / \sqrt{(\%R1 + k\%R2)^2 + (\%Z1 + k\%Z2)^2}$.**
- $\%IC = 2.5 \times 100 / \sqrt{(0.713 + (2000/2000) \times 0.713)^2 + (5.7 + (2000/2000) \times 5.7)^2}$
- $\%IC = 250 / 13.73 = 18.21$.
- The circulating current is 18.21% of the full load current.

3. Same polarity:

- Polarity of transformer means the instantaneous direction of induced emf in secondary. If the instantaneous directions of induced secondary emf in two transformers are opposite to each other when same input power is fed to the both of the transformers, the transformers are said to be in opposite polarity.
- The transformers should be properly connected with regard to their polarity. If they are connected with incorrect polarities then the two emfs, induced in the secondary windings which are in parallel, will act together in the local secondary circuit and produce a short circuit.

- Polarity of all transformers run in parallel should be same otherwise huge circulating current flows in the transformer but no load will be fed from these transformers.
- If the instantaneous directions of induced secondary emf in two transformers are same when same input power is fed to the both of the transformers, the transformers are said to be in same polarity.

4. Same phase sequence:

- The phase sequence of line voltages of both the transformers must be identical for parallel operation of three-phase transformers. If the phase sequence is an incorrect, in every cycle each pair of phases will get short-circuited.
- **This condition must be strictly followed for parallel operation of transformers.**

5. Same phase angle shift :(zero relative phase displacement between the secondary line voltages):

- The transformer windings can be connected in a variety of ways which produce different magnitudes and phase displacements of the secondary voltage. All the transformer connections can be classified into distinct vector groups.
- Group 1: Zero phase displacement (Yy0, Dd0, Dz0)
Group 2: 180° phase displacement (Yy6, Dd6, Dz6)
Group 3: -30° phase displacement (Yd1, Dy1, Yz1)
Group 4: +30° phase displacement (Yd11, Dy11, Yz11)
- In order to have zero relative phase displacement of secondary side line voltages, the transformers belonging to the same group can be paralleled. For example, two transformers with Yd1 and Dy1 connections can be paralleled.
- The transformers of groups 1 and 2 can only be paralleled with transformers of their own group. However, the transformers of groups 3 and 4 can be paralleled by reversing the phase sequence of one of them. For example, a transformer with Yd1 1 connection (group 4) can be paralleled with that having Dy1 connection (group 3) by reversing the phase sequence of both primary and secondary terminals of the Dy1 transformer.
- We can only parallel Dy1 and Dy11 by crossing two incoming phases and the same two outgoing phases on one of the transformers, so if we have a DY11 transformer we can cross B&C phases on the primary and secondary to change the +30 degree phase shift into a -30 degree shift which will parallel with the Dy1, assuming all the other points above are satisfied.

6. Same KVA ratings:

- If two or more transformer is connected in parallel, then load sharing % between them is according to their rating. If all are of same rating, they will share equal loads
- Transformers of unequal kVA ratings will share a load practically (but not exactly) in proportion to their ratings, providing that the voltage ratios are identical and the percentage impedances (at their own kVA rating) are identical, or very nearly so in these cases a total of than 90% of the sum of the two ratings is normally available.
- It is recommended that transformers, the kVA ratings of which differ by more than 2:1, should not be operated permanently in parallel.
- Transformers having different kva ratings may operate in parallel, with load division such that each transformer carries its proportionate share of the total load To achieve accurate load division, it is necessary that the transformers be wound with the same turns ratio, and that the percent impedance of all transformers be equal, when each percentage is expressed on the kva base of its respective transformer. It is also necessary that the ratio of resistance to reactance in all transformers be equal. For satisfactory operation the circulating current for any combinations of ratios and impedances probably should not exceed ten percent of the full-load rated current of the smaller unit.

7. Identical tap changer and its operation:

- The only important point to be remembered is the tap changing switches must be at same position for all the three transformers and should check and confirm that the secondary voltages are same. When the voltage tap need change all three tap changing switches should be operated identical for all transformers. The OL settings of the SF6 also should be identical. If the substation is operating on full load condition, tripping of one transformer can cause cascade tripping of all three transformers.
- In transformers Output Voltage can be controlled either by Off Circuit Tap Changer (Manual tap changing) or By On – Load Tap Changer-OLTC (Automatic Changing).
- In the transformer with OLTC, it is a closed loop system, with following components:
- (1) AVR (Automatic Voltage Regulator- an electronic programmable device). With this AVR we can set the Output Voltage of the transformers. The Output Voltage of the transformer is fed into the AVR through the

LT Panel. The AVR Compares the SET voltage & the Output Voltage and gives the error signals, if any, to the OLTC through the RTCC Panel for tap changing. This AVR is mounted in the RTCC.

- (2) RTCC (Remote Tap Changing Cubicle): This is a panel consisting of the AVR, Display for Tap Position, Voltage, and LEDs for Raise & Lower of Taps relays, Selector Switches for Auto Manual Selection... In AUTO MODE the voltage is controlled by the AVR. In manual Mode the operator can Increase / decrease the voltage by changing the Taps manually through the Push Button in the RTCC.
- (3) OLTC is mounted on the transformer. It consists of a motor, controlled by the RTCC, which changes the Taps in the transformers.
- Both the Transformers should have same voltage ratio at all the taps & when you run transformers in parallel, it should operate as same tap position. If we have OLTC with RTCC panel, one RTCC should work as master & other should work as follower to maintain same tap positions of Transformer.
- However, a circulating current can be flown between the two tanks if the impedances of the two transformers are different or if the taps of the on-load tap changer (OLTC) are mismatched temporarily due to the mechanical delay. The circulating current may cause the malfunction of protection relays.

Other necessary condition for parallel operation

1. All parallel units must be supplied from the same network.
2. Secondary cabling from the transformers to the point of paralling has approximately equal length and characteristics.
3. Voltage difference between corresponding phase must not exceed 0.4%
4. When the transformers are operated in parallel, the fault current would be very high on the secondary side. Supposing percentage impedance of one transformer is say 6.25 %, the short circuit MVA would be 25.6 MVA and short circuit current would be 35 kA.
5. If the transformers are of same rating and same percentage impedance, then the downstream short circuit current would be 3 times (since 3 transformers are in Parallel) approximately 105 kA. This means all the devices like ACBs, MCCBs, switch boards should withstand the short-circuit current of 105 kA. This is the maximum current. This current will get reduced depending on the location of the switch boards, cables and cable length etc. However this aspect has to be taken into consideration.
6. There should be Directional relays on the secondary side of the transformers.
7. The percent impedance of one transformer must be between 92.5% and 107.5% of the other. Otherwise, circulating currents between the two transformers would be excessive.

Summary of Parallel Operation of Transformer:

Transformer Parallel Connection Types	Equal Loading	Unequal Loading	Overloading Current	Circulating Current	Recomm. connection
Equal Impedance & Ratio ,Same KVA	Yes	No	No	No	Yes
Equal Impedance & Ratio But different KVA	No	Yes	No	No	Yes
Unequal Impedance But Same Ratio& KVA	No	Yes	Yes	No	No
Unequal Impedance & KVA But Same Ratio	No	Yes	Yes	No	No
Unequal Impedance & Ratio But Same KVA	Yes	No	Yes	Yes	No
Unequal Impedance & Ratio & different KVA	No	No	Yes	Yes	No

The combinations that will operate in parallel:

- Following Vector group of Transformer will operate in parallel.

Operative Parallel Operation		
Sr.No	Transformer-1	Transformer-2
1	$\Delta\Delta$	$\Delta\Delta$ or Yy
2	Yy	Yy or $\Delta\Delta$
3	Δy	Δy or $Y\Delta$
4	$Y\Delta$	$Y\Delta$ or Δy

- Single-phase transformers can be connected to form 3-phase transformer banks for 3-phase Power systems.
- Four common methods of connecting three transformers for 3-phase circuits are $\Delta\Delta$, $Y-Y$, $Y\Delta$, and ΔY connections.

- An advantage of Δ - Δ connection is that if one of the transformers fails or is removed from the circuit, the remaining two can operate in the open- Δ or V connection. This way, the bank still delivers 3-phase currents and voltages in their correct phase relationship. However, the capacity of the bank is reduced to 57.7 % (1/3) of its original value.
- In the Y-Y connection, only 57.7% of the line voltage is applied to each winding but full line current flows in each winding. The Y-Y connection is rarely used.
- The Δ -Y connection is used for stepping up voltages since the voltage is increased by the transformer ratio multiplied by 3.

The combinations that will not operate in parallel:

- Following Vector group of Transformer will not operate in parallel.

Inoperative Parallel Operation		
Sr.No	Transformer-1	Transformer-2
1	$\Delta\Delta$	Δy
2	Δy	$\Delta\Delta$
3	$Y\Delta$	Yy
4	Yy	$Y\Delta$

To check Synchronization of Transformers:

- Synchronization of Transformer can be checked by either of following steps:
- Checked by synchronizing relay & synchro scope.
- If Secondary of Transformer is not LT Then we must use check synchronizing relay & Commission the system properly. After connecting relay. Relay must be charges with only 1 supply & check that relay is functioning properly.
- Synchronizing should be checked of both the supply voltages. This can be checked directly with millimeter between L1 phases of Transformer 1 and L1 phase of Transformer 2. Then L2 Phase of Transformer 1 and L2 Phase of Transformer 2. Then L3 Phase of Transformer 1 and L3 Phase of Transformer 2. In all the cases MultiMate should show 0 voltages theoretically. These checks must be done at synchronizing breakers only. We have to also check that breaker out going terminals are connected in such a way that L1 Terminals of both the Breakers comes to same Main Bus bar of panel. Same for L2 & L3.
- Best way to check synchronization on LT is charge complete panel with 1 source up to outgoing terminals of another incoming breaker terminal. Then just measure Voltage difference on Incoming & out going terminals of Incoming Breaker. It should be near to 0.
- To check circulating current Synchronize both the transformer without outgoing load. Then check current. It will give you circulating current.

Advantages of Transformer Parallel Operation:

1) Maximize electrical system efficiency:

- Generally electrical power transformer gives the maximum efficiency at full load. If we run numbers of transformers in parallel, we can switch on only those transformers which will give the total demand by running nearer to its full load rating for that time.
- When load increases we can switch no one by one other transformer connected in parallel to fulfil the total demand. In this way we can run the system with maximum efficiency.

2) Maximize electrical system availability:

- If numbers of transformers run in parallel we can take shutdown any one of them for maintenance purpose. Other **parallel transformers** in system will serve the load without total interruption of power.

3) Maximize power system reliability:

- If nay one of the transformers run in parallel, is tripped due to fault other **parallel transformers** is the system will share the load hence power supply may not be interrupted if the shared loads do not make other transformers over loaded.

4) Maximize electrical system flexibility:

- There is a chance of increasing or decreasing future demand of power system. If it is predicted that power demand will be increased in future, there must be a provision of connecting transformers in system in parallel to fulfil the extra demand because it is not economical from business point of view to install a bigger rated single transformer by forecasting the increased future demand as it is unnecessary investment of money.
- Again if future demand is decreased, transformers running in parallel can be removed from system to balance the capital investment and its return.

Disadvantages of Transformer Parallel Operation:

- Increasing short-circuit currents that increase necessary breaker capacity.
- The risk of circulating currents running from one transformer to another Transformer. Circulating currents that diminish load capability and increased losses.
- The bus ratings could be too high.
- Paralleling transformers reduces the transformer impedance significantly, i.e. the parallel transformers may have very low impedance, which creates the high short circuit currents. Therefore, some current limiters are needed, e.g. reactors, fuses, high impedance buses, etc
- The control and protection of three units in parallel is more complex.
- It is not a common practice in this industry, since Main-tie-Main is very common in this industry.

Conclusions:

- Loading considerations for paralleling transformers are simple unless kVA, percent impedances, or ratios are different. When paralleled transformer turn ratios and percent impedances are the same, equal load division will exist on each transformer. When paralleled transformer kVA ratings are the same, but the percent impedances are different, then unequal load division will occur.
- The same is true for unequal percent impedances and unequal kVA. Circulating currents only exist if the turn ratios do not match on each transformer. The magnitude of the circulating currents will also depend on the X/R ratios of the transformers. Delta-delta to delta-wye transformer paralleling should not be attempted.

References

- Say, M.G. The performance and design of alternating current machines.
- Application Guide, Loading of Transformer, Nashville, TN, USA.
- Toro, V.D. Principles of electrical engineering.
- Stevenson, W.D. Elements of power system analysis.
- MIT Press, Magnetic circuits and transformers, John Wiley and Sons.

Introduction:

- There are various Test required on Transformer to conform performance of Transformer.
- Mainly two types of transformer are done by manufacturer before dispatching the transformer mainly (1) Type test of transformer and (2) Routine test.
- In addition some other tests are also carried out by the consumer at site before commissioning and also periodically in regular & emergency basis throughout its life.
- Transformer Testing mainly classified in
- **Transformer Tests done by Manufacturer**
- (A) Routine Tests
- (B) Type Tests
- (C) Special Tests
- **Transformer Tests done at Site**
- (D) Pre Commissioning Tests
- (E) Periodic/Condition Monitoring Tests
- (F) Emergency Tests

(A) Routine tests:

- A Routine test of transformer is mainly for confirming operational performance of individual unit in a production lot. Routine tests are carried out on every unit manufactured.
- All transformers are subjected to the following Routine tests:
 - (1) Insulation resistance Test.
 - (2) Winding resistance Test.
 - (3) Turns Ratio / Voltage ratio Test
 - (4) Polarity / Vector group Test.
 - (5) No-load losses and current Test.
 - (6) Short-circuit impedance and load loss Test.
 - (7) Continuity Test
 - (8) Magnetizing Current Test
 - (9) Magnetic Balance Test
 - (10) High Voltage Test.
 - (11) Dielectric tests
 - Separate source AC voltage.
 - Induced overvoltage.
 - Lightning impulse tests.
 - (12) Test on On-load tap changers, where appropriate.

(B) Type tests

- Type tests are tests made on a transformer which is representative of other transformers to demonstrate that they comply with specified requirements not covered by routine tests:
 - (1) Temperature rise test (IEC 60076-2).
 - (2) Dielectric type tests (IEC 60076-3).

(C) Special tests

- Special tests are tests, other than routine or type tests, agreed between manufacturer and purchaser.
 - (1) Dielectric special tests.
 - (2) Zero-sequence impedance on three-phase transformers.
 - (3) Short-circuit test.
 - (4) Harmonics on the no-load current.
 - (5) Power taken by fan and oil-pump motors.
 - (6) Determination of sound levels.
 - (7) Determination of capacitances between windings and earth, and between windings.
 - (8) Determination of transient voltage transfer between windings.
 - (9) Tests intended to be repeated in the field to confirm no damage during shipment, for example frequency response analysis (FRA).

(D) Pre commissioning Tests

- The Test performed before commissioning the transformer at site is called pre commissioning test of transformer. These tests are done to assess the condition of transformer after installation and compare the test results of all the low voltage tests with the factory test reports.
- All transformers are subjected to the following Pre commissioning tests:
 - (1) IR value of transformer and cables
 - (2) Winding Resistance
 - (3) Transformer Turns Ratio
 - (4) Polarity Test
 - (5) Magnetizing Current
 - (6) Vector Group
 - (7) Magnetic Balance
 - (8) Bushing & Winding Tan Delta (HV)
 - (9) Protective relay testing
 - (10) Transformer oil testing
 - (11) Hipot test

(A) Routine tests of Transformer

(1) Insulation Resistance Test:

Test Purpose:

- Insulation resistance test of transformer is essential to ensure the healthiness of overall insulation of an electrical power transformer.

Test Instruments:

- For LT System: Use 500V or 1000V Megger.
- For MV / HV System: Use 2500V or 5000V Megger.

Test Procedure:

- First disconnect all the line and neutral terminals of the transformer.
- Megger leads to be connected to LV and HV bushing studs to measure Insulation Resistance (IR) value in between the LV and HV windings.
- Megger leads to be connected to HV bushing studs and transformer tank earth point to measure Insulation Resistance IR value in between the HV windings and earth.
- Megger leads to be connected to LV bushing studs and transformer tank earth point to measure Insulation Resistance IR value in between the LV windings and earth.
- NB: It is unnecessary to perform insulation resistance test of transformer per phase wise in three phase transformer. IR values are taken between the windings collectively as because all the windings on HV side are internally connected together to form either star or delta and also all the windings on LV side are internally connected together to form either star or delta.
- Measurements are to be taken as follows:

Type of Transformer	Testing-1	Testing-2	Testing-3
Auto Transformer	HV-LV to LV	HV-IV to E	LV to E
Two Winding Transformer	HV to LV	HV to E	LV to E
Three Winding Transformers	HV to LV	LV to LV	HV to E & LV to E

- Oil temperature should be noted at the time of insulation resistance test of transformer. Since the IR value of transformer insulating oil may vary with temperature.
- IR values to be recorded at intervals of 15 seconds, 1 minute and 10 minutes.
- With the duration of application of voltage, IR value increases. The increase in IR is an indication of dryness of insulation.
- **Absorption Coefficient = 1 minute value / 15 second value.**
- **Polarization Index = 10 minutes value / 1 minute value**

Tests can detect:

- Weakness of Insulation.

(2) D.C. Resistance or Winding Resistance Test

Test Purpose:

- Transformer winding resistance is measured
- To check any abnormalities like Loose connections, broken strands and High contact resistance in tap changers
- To Calculation of the I²R losses in transformer.
- To Calculation of winding temperature at the end of temperature rise test of transformer.

Test Instrument:

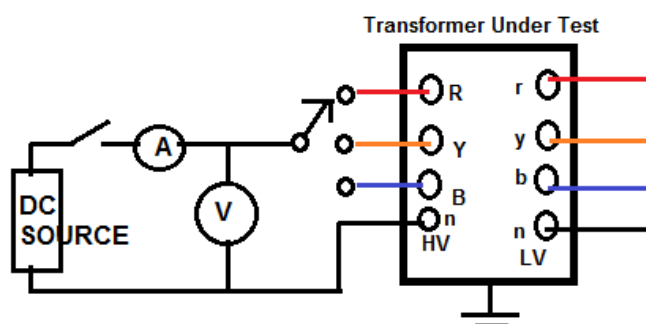
- The Resistance of HV winding LV winding between their terminals are to be measured with
- Precision milliohm meter/ micro ohm meter / Transformer Ohmmeter. OR
- Wheatstone bridge or DC resistance meter.

Method No: 1 (Kelvin Bridge Method for measurement of winding resistance)**Test Procedure:**

- The main principle of bridge method is based on comparing an unknown resistance with a known resistance.
- When electric currents flowing through the arms of bridge circuit become balanced, the reading of galvanometer shows zero deflection that means at balanced condition no electric current will flow through the galvanometer.



- Very small value of resistance (in milliohms range) can be accurately measured by Kelvin Bridge method whereas for higher value Wheatstone bridge method of resistance measurement is applied. In bridge method of measurement of winding resistance, the error is minimized.
- All other steps to be taken during transformer winding resistance measurement in these methods are similar to that of current voltage method of measurement of winding resistance of transformer

Method No: 2 (current voltage method of measurement of winding resistance)**DC Winding Resistance Test (Current-Volt Method)****Test Procedure:**

- The resistance of each transformer winding is measured using DC current and recorded at a ambient temp.
- In this test resistance of winding is measurement by applying a small DC voltage to the winding and measuring the current through the same
- The measured resistance should be corrected to a common temperature such as 75°C or 85°C using the formula: $RC = RM \times ((CF + CT) / (CF + WT))$
- where
- RC is the corrected resistance, RM is the measured resistance
- CF is the correction factor for copper (234.5) or aluminum (225) windings
- CT is the corrected temperature (75°C or 85°C)

- WT is the winding temperature (°C) at time of test
- Before measurement the transformer should be kept in OFF condition at least for 3 to 4 hours so in this time the winding temperature will become equal to its oil temperature.
- To minimize observation errors, polarity of the core magnetization shall be kept constant during all resistance readings.
- Voltmeter leads shall be independent of the current leads to protect it from high voltages which may occur during switching on and off the current circuit.
- The readings shall be taken after the electric current and voltage have reached steady state values. In some cases this may take several minutes depending upon the winding impedance.
- **The test current shall not exceed 15% of the rated current of the winding.** Large values may cause inaccuracy by heating the winding and thereby changing its resistance.
- For Calculating resistance, the corresponding temperature of the winding at the time of measurement must be taken along with resistance value.

Required Precaution:

- According to IEC 60076-1, in order to reduce measurement errors due to changes in temperature, some precautions should be taken before the measurement is made.
- **For Delta connected Winding:** for delta-connected transformer, the resistance should be measured for each phase (i.e. R-Y , Y-B & B-R) .Delta is composed of parallel combination of the winding under test and the series combination of the remaining winding .It is therefore recommended to make three measurements for each phase to-phase winding in order obtain the most accurate results.
- For Delta connected windings, such tertiary winding of auto-transformers measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the formula:
Resistance per Winding = 1.5 X Measured Value
- **For Star connected winding:** the neutral brought out, the resistance shall be measured between the line and neutral terminal (i.e. R-N , Y-N,B-N) and average of three sets of reading shall be the tested value. For Star connected auto transformers the resistance of the HV side is measured between HV terminal and IV terminal, then between IV terminal and the neutral.
- **For Dry type transformers:** the transformer shall be at rest in a constant ambient temperature for at least three hours.
- **For Oil immersed transformers:** the transformers should be under oil and without excitation for at least three hours. In case of tapped windings, above readings are recorded at each tap. In addition, it is important to ensure that the average oil temperature (average of the top and bottom oil temperatures) is approximately the same as the winding temperature. Average oil temperature is to be recorded. Measured values are to be corrected to required temperatures.
- As the measurement current increases, the core will be saturated and inductance will decrease. In this way, the current will reach the saturation value in a shorter time.
- After the current is applied to the circuit, it should be waited until the current becomes stationary (complete saturation) before taking measurements, otherwise, there will be measurement errors.
- The values shall be compared with original test an result which varies with the transformer ratings.

Test Acceptance criteria:

- DC Resistance Should be $\leq 2\%$ Factory Test.
- Test Current $< 10\%$ Rated Current

Test can detect:

- Short Turns
- Loose Connection of bushing
- Loose Connection or High Contact Resistance on Tap Changer.
- Broken winding stands

(3) Turns Ratio / Voltage Ratio Test:

Test Purpose:

- Turns Ratio Test / Voltage Ratio Test are done in Transformer to find out Open Circuited turns, Short Circuited turns in Transformer winding.
- The voltage ratio is equal to the turn's ratio in a transformer ($V_1/V_2 = N_1/N_2$). Using this principle, the turn's ratio is measured with the help of a turn's ratio meter. If it is correct , then the voltage ratio is assumed to be correct
- This test should be made for any new high-voltage power transformer at the time it is being installed.

- With use of Turns Ratio meter (TTR), turns Ratio between HV & LV windings at various taps to be measured & recorded.
- The turn's ratio is measure of the RMS voltage applied to the primary terminals to the RMS Voltage measured at the secondary terminals.
- **$R = N_p / N_s$**
- Where,
- R=Voltage ratio
- N_p =Number of turns at primary winding.
- N_s = Number of turns at secondary Winding.
- The voltage ratio shall be measured on each tapping in the no-load condition.

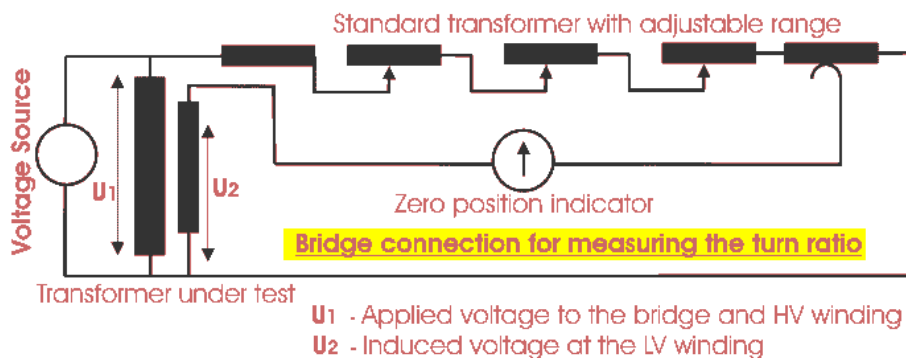
Test Instruments:

- Turns Ratio meter (TTR) to energise the transformer from a low-voltage supply and measure the HV and LV voltages.
- Wheatstone Bridge Circuit

Method No1 Turns Ratio Testing:

Test Procedure:

- **Transformer Turns Ratio Meter (TTR):**
- Transformer ratio test can be done by Transformer Turns Ratio (TTR) Meter. It has in built power supply, with the voltages commonly used being very low, such as 8, 10 V and 50 Hz.
- The HV and LV windings of one phase of a transformer (i.e. R-Y & r-n) are connected to the instrument, and the internal bridge elements are varied to produce a null indication on the detector.
- Values are recorded at each tap in case of tapped windings and then compared to calculated ratio at the same tap.
- The ratio meter gives accuracy of 0.1 per cent over a ratio range up to 1110:1. The ratio meter is used in a 'bridge' circuit where the voltages of the windings of the transformer under test are balanced against the voltages developed across the fixed and variable resistors of the ratio meter.
- Adjustment of the calibrated variable resistor until zero deflection is obtained on the galvanometer then gives the ratio to unity of the transformer windings from the ratio of the resistors.
- **Bridge Circuit:**
- A phase voltage is applied to the one of the windings by means of a bridge circuit and the ratio of induced voltage is measured at the bridge. The accuracy of the measuring instrument is < 0.1 %



- This theoretical turn ratio is adjusted on the transformer turn ratio tested or TTR by the adjustable transformer as shown in the figure above and it should be changed until a balance occurs in the percentage error indicator. The reading on this indicator implies the deviation of measured turn ratio from expected turn ratio in percentage.
- **Theoretical Turns Ratio = HV winding Voltage / LV Winding Voltage**
- **% Deviation = (Measured Turn Ratio – Expected Turns Ration) / Expected Turns Ration**
- Out-of-tolerance, ratio test of transformer can be due to shorted turns, especially if there is an associated high excitation current.
- Open turns in HV winding will indicate very low exciting current and no output voltage since open turns in HV winding causes no excitation current in the winding means no flux hence no induced voltage.
- But open turn in LV winding causes, low fluctuating LV voltage but normal excitation current in HV winding. Hence open turns in LV winding will be indicated by normal levels of exciting current, but very low levels of unstable output voltage.
- The turn ratio test of transformer also detects high resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge.

Test Caution:

- Disconnect all transformer terminals from line or load.
- Neutrals directly grounded to the grid can remain connected

Method No 2 Voltage Ratio Testing:

- This test is done to check both the transformer voltage ratio and tap changer.
- When "Turns Ratio meter" is not available, Voltage Ratio Test is done at various tap position by applying 3 phases LT (415V) supply on HT side of Power transformer. In order to obtain the required accuracy it is usual to use a ratio meter rather than to energise the transformer from a low-voltage supply and measure the HV and LV voltages.
- At Various taps applied voltage and Resultant voltages LV side between various Phases and phases & neutral measured with precision voltmeter & noted.

Test Procedure:

- With 415 V applied on high voltage side, measure the voltage between all phases on the low voltage side for every tap position.
- First, the tap changer of transformer is kept in the lowest position and LV terminals are kept open.
- Then apply 3-phase 415 V supply on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV and induced voltages at LV terminals simultaneously.
- After measuring the voltages at HV and LV terminals, the tap changer of transformer should be raised by one position and repeat test.
- Repeat the same for each of the tap position separately.
- At other taps values will be as per the percentage raise or lower at the respective tap positions.
- In case of Delta/Star transformers the ratio measure between RY-rn, YB-yn and BR-bn.
- Being Delta/Star transformers the voltage ratio between HV winding and LV winding in each phase limb at normal tap is 33 KV OR $33 \times \sqrt{3} = 5.196$, 11 KV / $\sqrt{3}$ 11
- At higher taps (i.e. high voltage steps) less number of turns is in circuit than normal. Hence ratio values increase by a value equal to $5.196 + \{5.196 \times (\text{no. of steps above normal}) \times (\% \text{ rise per each tap})\} 100$
- Similarly for lower taps than normal the ratio is equal to $5.196 - \{5.196 \times (\text{no. of steps above normal}) \times (\% \text{ rise per each tap})\} 100$

Test Acceptance Criteria:

- Range of measured ratio shall be equal to the calculated ratio $\pm 0.5\%$.
- Phase displacement is identical to approved arrangement and transformer's nameplate.
- The IEEE standard (IEEE Standard 62) states that when rated voltage is applied to one winding of the transformer, all other rated voltages at no load shall be correct within one half of one percent of the nameplate readings. It also states that all tap voltages shall be correct to the nearest turn if the volts per turn exceed one half of one percent desired voltage. The ratio test verifies that these conditions are met.
- The IEC60076-1 standard defines the permissible deviation of the actual to declared ratio
- Principal tapping for a specified first winding pair: the lesser $\pm 0.5\%$ of the declared voltage ratio
- or 0.1 times the actual short circuit impedance. Other taps on the first winding pair and other winding pair must be agreed upon, and must be lower than the smaller of the two values stated above.
- Measurements are typically made by applying a known low voltage across the high voltage winding so that the induced voltage on the secondary is lower, thereby reducing hazards while performing the test. For three phase delta/ye or ye/delta transformer, a three phase equivalency test is performed, i.e. the test is performed across corresponding single winding.

Test can detect:

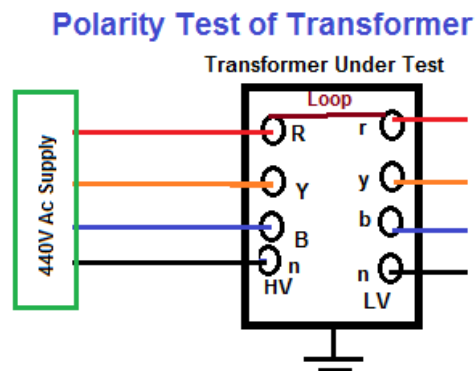
- Shorted turns or open circuits in the windings.
- Incorrect winding connections, and other internal faults or defects in tap changer

(4) Polarity / Vector group Test**Purpose of Test:**

- The vector group of transformer is an essential property for successful parallel operation of transformers. Hence every electrical power transformer must undergo through vector group test of transformer at factory site for ensuring the customer specified vector group of transformer.

Test Instruments:

- Ratio meter.
- Volt Meter. A Ratio meter may not always be available and this is usually the case on site so that the polarity may be checked by voltmeter.

Test Circuit Diagram:**Test Procedure:**

- The primary and secondary windings are connected together at one point.
- Connect neutral point of star connected winding with earth.
- Low-voltage three-phase supply (415 V) is then applied to the HV terminals.
- Voltage measurements are then taken between various pairs of terminals as indicated in the diagram and the readings obtained should be the phasor sum of the separate voltages of each winding under consideration.

Condition:(HV side R-Y-B-N and LV Side r-y-b-n)

- R and r should be shorted.
- Apply 415 Volt to R-Y-B
- Measure Voltage between Following Phase and Satisfy Following Condition

Vector Group	Satisfied Following Condition
Dyn1	$Rb = Rn + Bn$
	$Bb = By$
	$Yy < Yb$
Dyn11	$Ry = Rn + Yn$
	$Yb = Yy$
	$Bb < By$
Ynd1	$RN = Ry + Yn$
	$By = Yy$
	$Yy < Yb$
Ynyn0	$Bb = Yy$
	$Bn = Yn$
	$RN = Rn + Nn$

(5) Short Circuit Test**Test Purpose:**

- The value of the short circuit impedance $Z\%$ and the load (copper) losses (I^2R) are obtained.
- This test should be performed before the impulse test-if the later will be performed as a routine test- in order to avoid readings errors

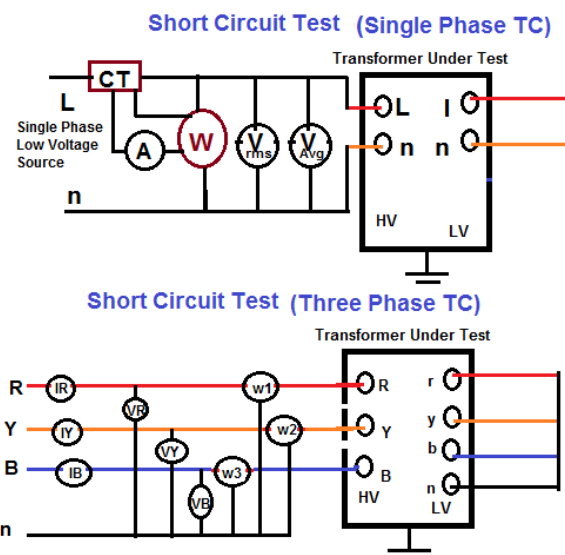
Test Instrument:

- Megger or
- Multi meter.

- CT ,PT

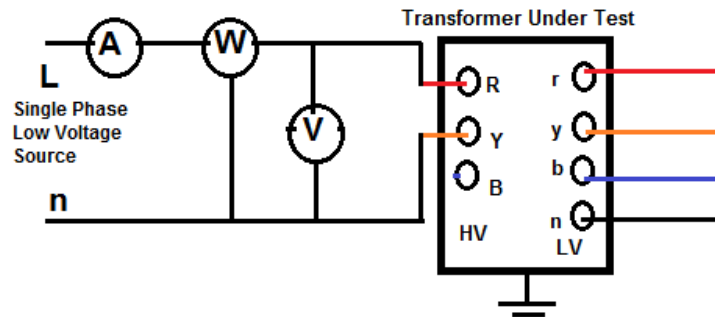
Test Procedure:

- Suitable Low Voltage (3-phase 415V, 50Hz)will be applied to the terminals of one winding (usually the H.V.) with the other winding short circuited with 50 sq. mm. Copper cable. (Usually the L.V.)
- The applied voltage is adjusted to pass the needed current in the primary/secondary. In order to simulate conditions nearest to full load, it is customary to pass 100%, 50% or at least 25% of full load current.
- Voltage to be increased gradually till the current in the energized winding reaches the required value (50% to 100% rated current).
- Measure the 3 Phase line currents at all tap position. If the tap-switch is an Off-Circuit tap-switch, the supply has to be disconnected before changing the tap. A consistent trend in the increase or decrease of current, as the case may be, confirms the healthiness of the transformer.
- If transformer is equipped with a tap changer, tapping regulations are applied.
- (1) If tapping range within $\pm 5\%$ and rated power less than 2500kAV, load loss guarantee refer to the principal tap only.
- (2) If tapping range exceeds $\pm 5\%$ or rated power above 2500kAV, it shall be stated for which tapping beside the principal tap the load losses will be guaranteed by the manufacturer.
- Three phase LT supply is applied on HV side of power transformer at normal tap with rated current on HV side and currents measured in all the phases on HV side and phases & neutral on LV side values noted.
- Readings to be taken as quickly as possible as the windings warm up and the winding resistance increases. Hence, the losses value will increase accordingly.
- Using appropriate instruments (conventional three wattmeter method or digital wattmeter with ammeters & voltmeters) measurements of voltage, currents and power can be recorded.



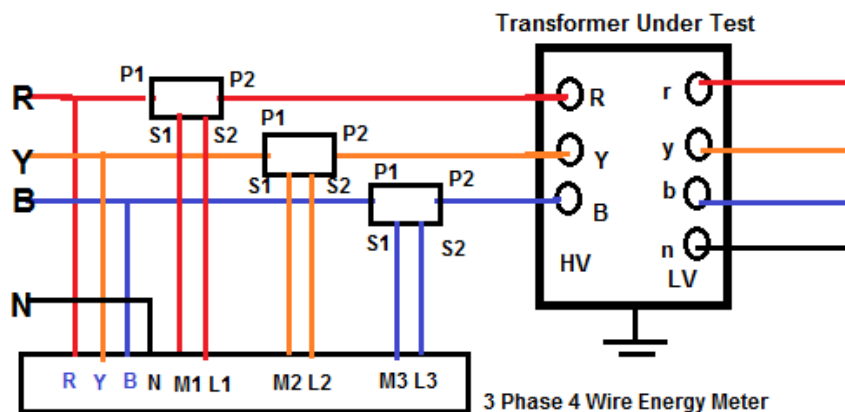
- **Short Circuit Test (Without using CT,PT)**
- To avoid CT's and PT's, this method can be used at current levels of 2 to 5 A and measurement of load losses is done at this condition. This measured load loss is then extrapolated to actual load currents to obtain load losses at the operating current.
- **Example:** - 11 kV/433 V, 1000 kVA transformer with 5% impedance, the voltage to be applied on H.V. side during load test is estimated below.
- H.V. side full load current (I_1) = $(KVA \times 1000 / 1.732 \times \text{Line Voltage})$
- H.V. side full load current (I_1) = $(1000 \times 1000 / 1.732 \times 11000) = 52.5$ Amp
- Line to line voltage to be applied on H.V side for getting 5 A on H.V. side,
- Line to line voltage to be applied on H.V side $V_{sc} = (\text{Line Voltage} \times 1000 \times Z \times 5 / 0.866 \times I_1 \times 100)$
- Line to line voltage to be applied on H.V side $V_{sc} = (11 \times 1000 \times 5 \times 0.005 / 0.866 \times 52.5 \times 100) = 60.5$ volts.
- Since the current drawn on H.V. side is only about 5A in this test, CT's can be avoided and hence phase angle error is not applicable.
-

Short Circuit Test (Without CT)



- Short Circuit Test (With using CT,PT)

Short Circuit Test (With CT)



Acceptance Criteria:

- Measured impedance to be within guaranteed value and nameplate value.
- Load losses to be within guaranteed values.

Test can detect:

- Winding deformation.
- Deviation in name plate value.

(6) Open Circuit / No Load Test

Test Purpose:

- In this test, the value of No-Load power (P_o) & the No-Load current (I_o) are measured at rated voltage & frequency.

Test Instruments:

- Watt meters.
- Ammeter , Voltmeter or
- Power analyser

Test Procedure:

- Test is performed at rated frequency.
- Three phase LT Voltage of 415 V applied on HV side of Power transformer keeping LT open
- Two voltmeters are connected to the energized winding, one is measuring the voltage mean value and the other is for the Voltage R.M.S value.
- Voltage applied to winding (usually to H.V. windings). It will be in a range from 90% of winding rated voltage to 110% of the same in steps, each of 5% (i.e. for a 33/11kV transformer, applied voltage values will be 29.7kV, 31.35kV, 36.3kV)

- Readings of watt meters, Voltmeters & Ammeters are recorded to obtain the values of V (r.m.s), V_{mean} , P_o and I_o at each voltage step.
- Test results are considered satisfactory if the readings of the two are equal within 3%. If it's more than 3%, the validity of the test is subjected to agreement.
- Measured value of power loss is corrected according to the following formula:
- $P_c = P_m (1+d)$
- $D = (V_{mean} - V_{r.m.s}) / V_{mean}$
- Measure the loss in all the three phases with the help of 3 watt meter method. Total no load loss or iron loss of the trf = $W_1 + W_2 + W_3$

Test Caution:

- This test should be performed before the impulse test-if the later will be performed as a routine test- in order to avoid readings errors

Acceptance Criteria:

- No Load losses to be within guaranteed values.

(7) Continuity test:

Purpose of Test:

- To know the continuity of windings of the transformer.

Test Instruments:

- Megger or
- Multi meter.

Test Procedure:

- Check Continuity of Transformer by using multi meter or by Megger between following Terminals

Transformer	P-P	P-P	P-P	Result
HV Side	R-Y	Y-B	B-R	Zero Mega ohm or continuity
LV Side	r-y	y-b	b-r	Zero Mega ohm or continuity

Test can detect:

- Open circuit / loose connection of winding

(8) Magnetic Current Test

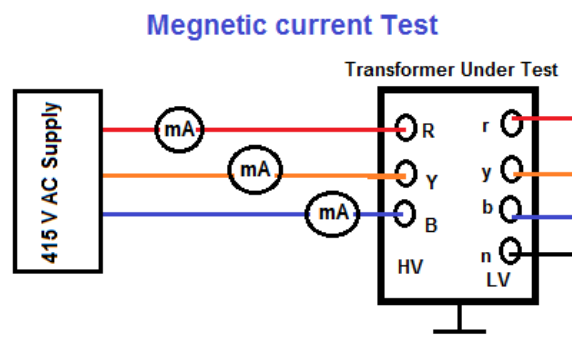
Test Purpose:

- Magnetizing current test of transformer locates the defects in the magnetic core structure, shifting of windings, failure in turn to turn insulation or problem in tap changers.
- These conditions change the effective reluctance of the magnetic circuit, thus affecting the electric current required to establish flux in the core.

Test Instrument:

- Multi meter.
- Mill Ammeter

Test Circuit Diagram:



- Three phases LT Voltage of 415 V applied on HV side of Power transformer and currents are to be measured with mill ammeter.
- The value shall be = (1 to 2 percent of rated full load current of TC / HT KV) X Voltage Applied

Test Procedure:

- First of all keep the tap changer in the lowest position and open all IV & LV terminals.
- Then apply three phase 415V supply on the line terminals for three phase transformers and single phase 230V supply on single phase transformers.
- Measure the supply voltage and electric current in each phase.
- Now repeat the magnetizing current test of transformer test with keeping tap changer in normal position.
- And repeat the test with keeping the tap at highest position.
- Generally there are two similar higher readings on two outer limb phases on transformer core and one lower reading on the centre limb phase, in case of three phase transformers.
- An agreement to within 30 % of the measured exciting current with the previous test is usually considered satisfactory. If the measured exciting current value is 50 times higher than the value measured during factory test, there is likelihood of a fault in the winding which needs further analysis.

Test Caution:

- This magnetizing current test of transformer is to be carried out before DC resistance measurement.

(9) Magnetic Balance Test

Test Purpose:

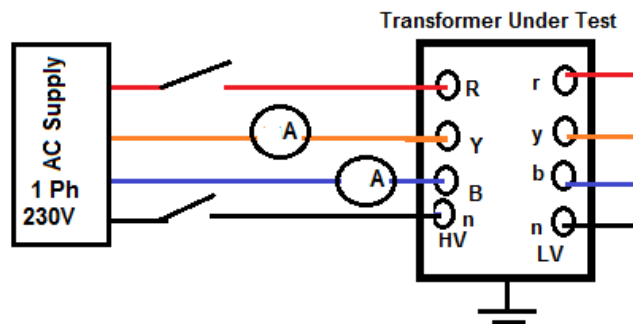
- Magnetic balance test of transformer is conducted only on three phase transformers to check the imbalance in the magnetic circuit.

Test Instrument:

- Multi meter.
- Mill Ammeter

Test Circuit Diagram:

Magnetic Balance Test



Test Procedure:

- First keep the tap changer of transformer in normal position.
- Now disconnect the transformer neutral from ground.
- Then apply single phase 230V AC supply across one of the HV winding terminals and neutral terminal.
- Measure the voltage in two other HV terminals in respect of neutral terminal.
- Repeat the test for each of the three phases.
- In case of auto transformer, magnetic balance test of transformer should be repeated for IV winding also.
- There are three limbs side by side in a core of transformer. One phase winding is wound in one limb. The voltage induced in different phases depends upon the respective position of the limb in the core.
- The voltage induced in different phases of transformer in respect to neutral terminals given in the table below.
- 415V, Two phase supply is to be applied to any two phases terminals on HV side of Power transformer and voltages in other two phase combination are to be measured with LT open.
- Sum of the Resultant two values shall be equal to the voltage applied.

Applied Voltage (415V)	Measured Voltage(V1)	Measured Voltage(V2)	Result
RY	YB	BR	$V=V1+V2$
YB	RY	BR	$V=V1+V2$
BR	YB	RY	$V=V1+V2$

(10) High Voltage tests on HV & LV Winding:

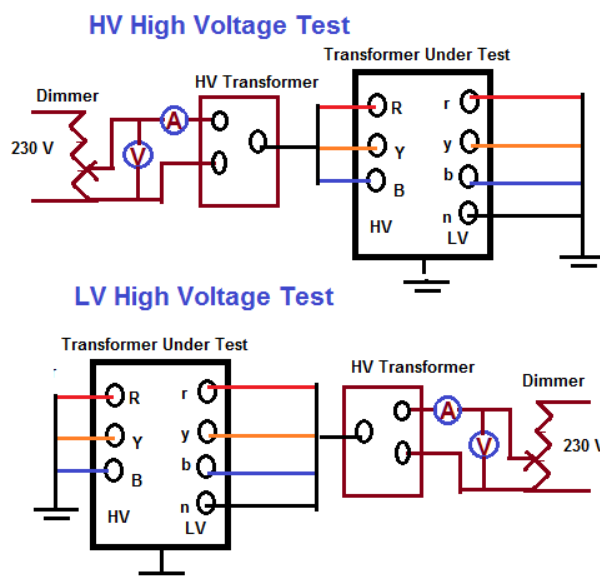
Purpose:

- To check the insulation property between Primary to earth, Secondary to earth and between Primary & Secondary.

Test Instrument:

- High Voltage tester (100KV & 3KV)

Test Circuit Diagram:



Test Procedure:

- HV high voltage test: LV winding connected together and earthed. HV winding connected together and given Following HV Supply for 1 minute.
- LV high Voltage test: HV winding connected together and earthed. LV winding connected together and given Following HV Supply for 1 minute.
- 433V Winding =3KV High Voltage
- 11KV Winding =28KV High Voltage
- 22KV Winding =50KV High Voltage
- 33KV Winding =70KV High Voltage.

(11) Di electrical Test:

Test Purpose:

- To check the ability of main insulation to earth and between winding
- To check the insulation property between Primary to earth, Secondary to earth and between Primary & Secondary.

Test Instruments:

- 3 Phase Variable Voltage & Frequency Source.
- Auto Transformer.

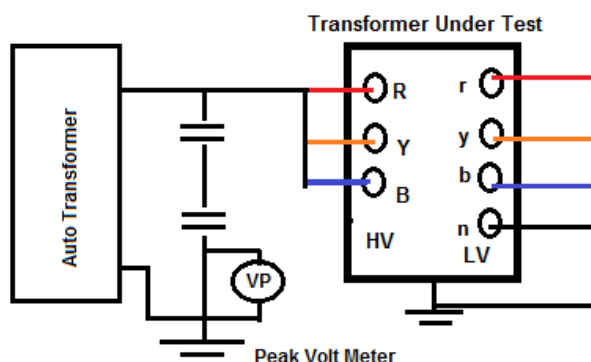
Test Procedure:

- The following Dielectric tests are performed in order to meet the transformer insulation strength expectations.
- **Switching impulse test:** to confirm the insulation of the transformer terminals and windings to the earthed parts and other windings, and to confirm the insulation strength in the windings and through the windings.
- **Lightning impulse test :** to confirm the transformer insulation strength in case of a lightning hitting the connection terminals
- **Separate source AC withstand voltage test:** to confirm the insulation strength of the transformer line and neutral connection terminals and the connected windings to the earthed parts and other windings.
- **Induced AC voltage test** (short duration ACSD and long duration ACLD) : to confirm the insulation strength of the transformer connection terminals and the connected windings to the earthed parts and other windings, both between the phases and through the winding.
- **Partial discharge measurement:** to confirm the “partial discharge below a determined level” property of the transformer insulation structure under operating conditions.

Method No 1 (separate source voltage withstand test)

- All the terminals of the winding under test should be connected together and the voltage should be applied.
- The secondary windings of bushing type current transformers should be connected together and earthed. The current should be stable during test and no surges should occur.

Dielectric Test (Separate Voltage Source withstand Test)

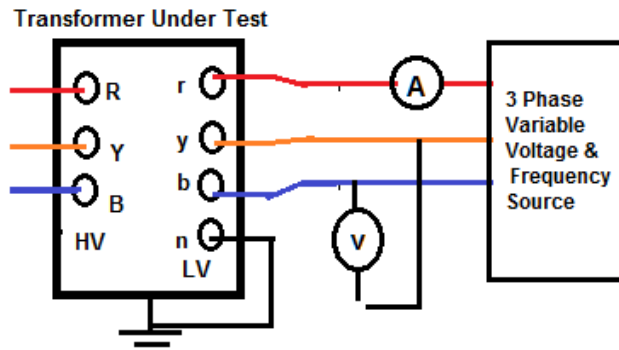


- A single phase power frequency voltage of shape approximately sinusoidal is applied for 60 seconds to the terminals of the winding under test.
- The test shall be performed on all the windings one by one.
- The test is successful if no breakdown in the dielectric of the insulation occurs during test.
- During the Separate source AC withstand voltage test, the frequency of the test voltage should be equal to the transformer's rated frequency or should be not less than 80% of this frequency. In this way, 60 Hz transformers can also be tested at 50 Hz. The shape of the voltage should be single phase and sinusoidal as far as possible.
- This test is applied to the star point (neutral point) of uniform insulated windings and gradual (non-uniform) insulation windings. Every point of the winding which test voltage has been applied is accepted to be tested with this voltage.
- The test voltage is measured with the help of a voltage divider. The test voltage should be read from voltmeter as peak value divided by 2. Test period is 1 minute.

Method No 2 (Induced source voltage withstand test)

- The aim of this test is to check the insulation both between phases and between turns of the windings and also the insulation between the input terminals of the graded insulation windings and earth

Dielectric Test(Induced Voltage Test)



- During test, normally the test voltage is applied to the low voltage winding. Meanwhile HV windings should be keeping open and earthed from a common point.
- Since the test voltage will be much higher than the transformer's rated voltage, the test frequency should not be less than twice the rated frequency value, in order to avoid oversaturation of the transformer core.
- The test shall start with a voltage lower than 1/3 the full test voltage and it shall be quickly increased up to desired value.
- The test voltage can either be measured on a voltage divider connected to the HV terminal or on a voltage transformer and voltmeter which have been set together with this voltage divider at the LV side. Another method is to measure the test voltage with a peak-value measuring instrument at the measuring-tap end of the capacitor type bushing (if any).
- Test period which should not be less than 15 seconds.
- It is calculated according ,Test period=120 seconds x (Rated frequency / Test frequency)
- The duration of the test shall be 60 second.
- The test is accepted to be successful if no surges, voltage collapses or extreme increases in the current have occurred.

Acceptance Criteria:

- The test is successful if no break down occurs at full test voltage during test.

Method No 3 Lighting Impulse Test:

- All the dielectric tests check the insulation level of the Transformer.
- Impulse generator is used to produce the specified voltage impulse wave of 1.2/50 micro seconds wave
- One impulse of a reduced voltage between 50 to 75% of the full test voltage and subsequent three impulses at full voltage.
- For a three phase transformer, impulse is carried out on all three phases in succession.
- The voltage is applied on each of the line terminal in succession, keeping the other terminals earthed.
- The current and voltage wave shapes are recorded on the oscilloscope and any distortion in the wave shape is the criteria for failure.

Standard Transformer Fittings:

1) Standard Fittings

1. Rating and terminal marking plate.
2. Tap Changing arrangement
3. Off – circuit tap changing switch
4. Off – circuit tap changing link
5. On Load tap changer
6. Two earthing terminals
7. Lifting Lugs
8. Drain – cum filter valve
9. Pressure Relief Device
10. Silica gel dehydrating breather.
11. Oil Level Indicator.
12. Thermometer Pocket.
13. Conservator with drain plug and filling hole.
14. Air Release plug.
15. Jacking lugs (above 1600 KVA)
16. Filter valve (top tank)
17. Under base unidirectional flat rollers.

2) Terminal Arrangement:

1. Bare Bushings or Cable box.
2. Compound filled for PVC cables (up to 33000 Volts) or Air filled for PVC cables (Upto 11000 Volts) or
3. Bus Duct (Bare bushing enclosed in housing upto 600 Volts)
4. Disconnection chamber between cable box and transformer tank.
5. Additional bare neutral terminal.

3) Optional Fittings:

1. These are optional fittings provided at an extra cost, if customer specifically orders them.
2. Winding temperature indicator
3. Oil temperature indicator
4. Gas and oil actuated (Buchholz) relay
5. Conservator drain valve
6. Shut off valve between conservator and tank.
7. Magnetic oil level gauge
8. Explosion vent
9. Filter valve (Bottom of tank)
10. Skid under base with haulage holes
11. Junction box.

Standard Transformer Accessories:

1) Thermometer Pockets:

- This pocket is provided to measure temperature of the top oil in tank with a mercury in glass type thermometer. It is essential to fill the pocket with transformer oil before inserting the thermometer, to have uniform and correct reading. One additional pocket is provided for dial type thermometer (OTI) with contacts

2) Air release plug:

- Air release plug is normally provided on the tank cover for transformer with conservator. Space is provided in the plug which allows air to be escaped without removing the plug fully from the seat. Plug should be unscrewed till air comes out from cross hole and as soon as oil flows out it should be closed. Air release plugs are also provided on radiator headers and outdoor bushings.

3) Winding temperature Indicator

- The windings temperature indicator indicates " Hot spot" temperature of the winding. This is a "Thermal Image type" indicator. This is basically an oil temperature indicator with a heater responsible to raise the

temperature equal to the "Hot spot" gradient between winding and oil over the oil temperature. Thus, this instrument indicates the "Hot Spot" temperature of the windings. Heater coil is fed with a current proportional to the windings current through a current transformer mounted on the winding under measurement. Heater coil is either placed on the heater bulb enveloping the sensing element of the winding temperature indicator immersed in oil or in the instrument. The value of the current fed to the heater is such that it raises the temperature by an amount equal to the hot spot gradient of the winding, as described above. Thus temperature of winding is simulated on the dial of the instrument. Pointer is connected through a mechanism to indicate the hot spot temperature on dial. WTI is provided with a temperature recording dial main pointer. Maximum pointer and re setting device and two sets of contacts for alarm and trip.

4) Oil Temperature Indicator

- Oil temperature indicator provides local temperature of top oil. Instruments are provided with temperature sensing bulb, temperature recording dial with the pointer and maximum reading pointer and resetting device. Electrical contacts are provided to give alarm or trip at a required setting (on capillary tube type thermometer).

5) Conservator Tank:

- It is an Expansion Vessel
- It maintains oil in the Transformer above a Minimum Level
- It has a Magnetic Oil Level Gage.
- It can give an alarm if the oil level falls below the limit
- A portion of the Tank is separated for use with OLTC.
- This usually has oil level indicators
- Main Conservator Tank can have a Bellow
- It has an oil filling provision
- It has an oil drain valve
- Provision is there for connecting a Breather

6) Silica Gel Breather:

- Prevents Moisture Ingress.
- Connected to Conservator Tank
- Silica Gel is Blue when Dry; Pink when moist
- Oil Seal provides a Trap for Moisture before passing thro Silica Gel

7) Cooling:

- ONAN. Oil Natural Air Natural
- ONAF. Oil Natural Air Forced
- OFWF. Oil Forced Water Forced
- ODWF. Oil directed Water Forced.
- By Forced Cooling, the Transformer capacity can be increased by more than 50%

8) Bushing:

• Manufacturing:

- Insulators and Bushings are built with the best quality Porcelain shells manufactured by wet process.
- For manufacture of electro porcelain, high quality indigenous raw materials viz, China Clay, Ball Clay, Quartz and Feldspar is used. Quartz and feldspar are ground to required finesses and then intimately mixed with ball and china clay in high speed blungers.
- They are then passed through electromagnetic separators, which remove iron and other magnetic impurities. The slip produced is passed to a filter press where extra water is removed under pressure and the resulting clay cakes are aged over a period. The aged cakes are extruded to required form viz, cylinders, on high vacuum de-airing pug mill. The extruded blanks or cylinders are given shapes of Insulators / Bushings which are conditioned and are shaped on copying lathes as the case may be.

• Testing, Assembly & packing:

- All insulators & bushings undergo routine electrical and mechanical tests. The tests before and after assembly are carried out according to IS Specifications, to ensure their suitability for actual conditions of use. Porosity tests are also carried out regularly on samples from every batch, to ensure that the insulators are completely vitrified.
- These insulators are then visually checked and sorted, before they are packed in sea worthy packing, to withstand transit conditions.

• Types of Insulators & Bushings:

- Bushing Insulators: Hollow Porcelain Bushings up to 33 KV
- Application : Transformers, Capacitors, Circuit Breakers
- Pin Insulators: Up to 33 KV

- Post type Insulators: Post type insulators, complete with metal fittings, generally IS Specifications and other International Standards up to 33 KV
- **Solid Core Insulators:**
 - Line Post
 - Long Rod
 - Support
- **Special Type Insulators**
 - C.T. up to 66 KV
 - P.T. up to 33 KV
 - Weather Casing
- **L.T. Insulators**
 - Shackel Type
 - Spool Type
 - Pin Type
 - Guy strain
- **H.V. Bushings (IS:3347)**

12 to 17.5 KV / 250 amps	24 KV / 1000 amps
12 to 17.5 KV / 630 amps	24 KV / 2000 to 3150 amps
12 to 17.5 KV / 1000 amps	36 KV / 250 amps
12 to 17.5 KV / 2000 to 3150 amps	36 KV / 630 amps
24 KV / 250 amps	36 KV / 1000 amps
24 KV / 630 amps	36 KV / 2000 to 3150 amps
- **L.V. Bushings (IS:3347)**

11 KV / 250 amps	1 KV / 2000 amps
1 KV / 630 amps	1 KV / 3150 amps
1 KV / 1000 amps	
- **H.V. Bushings (IS:8603)**

12KV / 250 amps	36 KV / 250 amps
12/ 630 amps	36 KV / 630 amps
12KV / 1000 amps	6 KV / 1000 amps
12KV / 2000 to 3150 amps	36 KV 3150 amps
- **C.T. Bushings (IS:5612)**

11 KV	1 KV / 2000 amps
1 KV / 630 amps	1 KV / 3150 amps
1 KV / 1000 amps	
- **Epoxy Bushing:**
- All Epoxy Resin Cast Components are made from hot setting resins cured with anhydrides; hence these provide class-F Insulation to the system. In an oxidizing atmosphere, certain amine cured Epoxy Resins can start to degrade at 150°C whereas the anhydride cured systems are stable at 200°C therefore our epoxy components are cured with anhydrides which gives them a longer life.

9) Buchholz Relay:

- The purpose of such devices is to disconnect faulty apparatus before large scale damage caused by a fault to the apparatus or to other connected apparatus. Such devices generally respond to a change in the current or pressure arising from the faults and are used for either signaling or tripping the circuits.
- Considering liquid immersed transformer, a near ideal protective device is available in the form of gas and oil operated relay described here. The relay operates on the well known fact that almost every type of electric fault in a liquid immersed transformer gives rise to a gas. This gas is collected in the body of the relay and is used in some way or the other to cause the alarm or the tripping circuit to operate.
- In the event of fault in an oil filled transformer gas is generated, due to which buchholz relay gives warning of developing fault. Buchholz relay is provided with two elements one for minor faults (gives alarm) and other for major faults (tripping). The alarm elements operate after a specific volume gets accumulated in the relay. Examples of incipient faults which will generate gas in oil are:- Buchholz Relay
 - i) Failure of core bolt insulation.
 - ii) Shorting of lamination and core clamp.
 - iii) Bad Electrical contact or connections.
 - iv) Excessive hot spots in winding.
- The alarm element will also operate in the event of oil leakage. The trip element operates due to sudden oil surge in the event of more serious fault such as: -
 - i) Earth fault due to insulation failure from winding to earth.
 - ii) Winding short circuit inter turn, interlayer, inter coil etc.

- iii) Short circuit between phases.
- iv) Puncture of bushing.
- The trip element will also operate if rapid loss of oil occurs. During the operation of transformer, if there is an alarm transformer should be isolated from lines and possible reasons, listed above for the operation of relay should be checked starting with simple reason such as loss of oil due to leaks, air accumulation in relay chamber which may be the absorbed air released by oil due to change in temperature etc. Rating of contacts: - 0.5 Amps. At 230 Volts AC or 220 Volts. DC.

Pre commissioning Inspection of Transformer:

- Sample of oil taken from the transformer to electric test (break down value) of 50KV (RMS) as per IS: 335.
- Release trapped air through air release plugs and valve fitted for the purpose on various fittings like radiators, bushing caps, tank cover, Bushing turrets etc.
- The float lever of the magnetic oil level indicator (if provided) should be moved up and down between the end positions to check that the mechanism does not stick at any point. If the indicator has signaling contact they should be checked at the same time for correct operation.
- Check whether gas operated relay (if provided) is mounted at angle by placing a spirit level on the top of the relay. See that the conservator is filled up to the filling oil level marked on plain oil gauge side and corresponding to the pointer reading in MOG side. Check the operation of the alarm and trip contacts of the relay independently by injecting air through the top cocks using a dry air bottle. The air should be released after the tests. Make sure that transformer oil runs through pet cock of Buchholz relay.
- Check alarm and trip contacts of WTIs, Dial type thermometer, magnetic oil gauge etc. (if provided).
- Ensure that off circuit switch handle is locked at the desired tap position with padlock.
- Make sure that all valves except drain, filter and sampling valves are opened (such as radiator valves, valves on the buchholz relay pipe line if Provided).
- Check the condition of silica gel in the breather to ensure that silica gel in the breather is active and colour is blue. Also check that the transformer oil is filled in the silica gel breather up to the level indicated.
- Check tightness of external electrical connections to bushings.
- Give a physical check on all bushing for any crack or any breakage of porcelain. Bushing with cracks or any other defects should be immediately replaced.
- Check the neutral earthing if specified.
- Make sure that neutrals of HV / LV are effectively earthed.
- Tank should be effectively earthed at two points.
- Check that the thermometer pockets on tank cover are filled with oil.
- If the oil temperature indicator is not working satisfactorily, loosen and remove the thermometer bulb from the pocket on the cover and place it with a standard thermometer in a suitable vessel filled with transformer oil. Warm the oil slowly while string it and take reading of the thermometers if an adjustment of the transformer thermometer is necessary the same may be done. Also check signaling contacts and set for the desired temperature.
- CT secondary terminals must be shorted and earthed if not in use.
- Check relief vent diaphragm for breakage. See that the Bakelite diaphragm at bottom and glass diaphragm at top are not ruptured.
- Check all the gasket joints to ensure that there is no leakage of transformer oil at any point.
- Clear off extraneous material like tools earthing rods, pieces of clothes, waste etc.
- Lock the rollers for accidental movement on rails.
- Touching of paint may be done after erection.

Parts of Transformer:

1) Transformer Oil

- Oil is used as coolant and dielectric in the transformer and keeping it in good condition will assist in preventing deterioration of the insulation, which is immersed in oil. Transformer oil is always exposed to the air to some extent therefore in the course of time it may oxidize and form sludge if the breather is defective, oil may also absorb moisture from air thus reducing dielectric strength.

2) Transformer Winding:

- The primary and secondary windings in a core type transformer are of the concentric type only, while in case of shell type transformer these could be of sand-witched type as well. The concentric windings are normally constructed in any of the following types depending on the size and application of the transformer.
 - (1) Cross over Type.
 - (2) Helical Type.
 - (3) Continuous Disc Type.
 - Distributed.
 - Spiral.
 - Interleaved Disc.
 - Shielded Layer
- a) Distributed Winding :**
- Used for HV windings of small Distribution Transformers where the current does not exceed 20 amps using circular cross section conductor .
- b) Spiral:**
- Used up to 33 KV for low currents using strip conductor. Wound closely on Bakelite or press board cylinders generally without cooling ducts. However, multi layer windings are provided with cooling ducts between layers. No Transposition is necessary.
- c) Interleaved Disc:**
- Used for voltages above 145 KV. Interleaving enables the winding withstand higher impulse voltages.
- d) Shielded Layer :**
- Used up to 132 KV in star connected windings with graded insulation. Comprises of a number of concentric spiral coils arranged in layers grading the layers.
 - The longest at the Neutral and the shortest at the Line Terminal. The layers are separated by cooling ducts. This type of construction ensures uniform distributed voltages.
- e) Cross-over type winding:**
- It is normally employed where rated currents are up-to about 20 Amperes or so.
 - In this type of winding, each coil consists of number of layers having number of turns per layer. The conductor being a round wire or strip insulated with a paper covering.
 - It is normal practice to provide one or two extra layers of paper insulation between layers. Further, the insulation between layers is wrapped round the end turns of the layers there by assisting to keep the whole coil compact.
 - The inside end of a coil is connected to the outside end of adjacent coil. Insulation blocks are provided between adjacent coils to ensure free circulation of oil.
- f) Helical winding:**
- Used for Low Voltage and high currents .The turns comprising of a number of conductors are wound axially. Could be single, double or multi layer winding. Since each conductor is not of the same length, does not embrace the same flux and of different impedances, and hence circulating currents, the winding is transposed.
 - The coil consists of a number of rectangular strips wound in parallel radially such that each separate turn occupies the total radial depth of the winding.
 - Each turn is wound on a number of key spacers which form the vertical oil duct and each turn or group of turns is spaced by radial keys sectors.
 - This ensures free circulation of oil in horizontal and vertical direction.
 - This type of coil construction is normally adopted for low voltage windings where the magnitude of current is comparatively large.
- Helical Disc winding:**
- This type of winding is also termed "interleaved disk winding."
 - Since conductors 1 – 4 and conductors 9 – 12 assume a shape similar to a wound capacitor, it is known that these conductors have very large capacitance. This capacitance acts as series capacitance of the winding to highly improve the voltage distribution for surge.
 - Unlike cylindrical windings, Helical disk winding requires no shield on the winding outermost side, resulting in smaller coil outside diameter and thus reducing Transformer dimension. Comparatively small in winding width and large in space between windings, the construction of this type of winding is appropriate for the winding, which faces to an inner winding of relatively high voltage.
 - Thus, general EHV or UHV substation Transformers employ Helical disk winding to utilize its features mentioned above.
- g) Continuous disc type of windings:**
- Used for 33kv and 132 KV for medium currents. The coil comprises of a number of sections axially. Cooling ducts are provided between each section.

- IT consists of number of Discs wound from a single wire or number of strips in parallel. Each disc consists of number of turns, wound radically, over one another.
- The conductor passing uninterruptedly from one disc to another. With multiple-strip conductor. Transpositions are made at regular intervals to ensure uniform resistance and length of conductor. The discs are wound on an insulating cylinder spaced from it by strips running the whole length of the cylinder and separated from one another by hard pressboard sectors keyed to the vertical strips.
- This ensures free circulation of oil in horizontal and vertical direction and provides efficient heat dissipation from windings to the oil.
- The whole coil structure is mechanically sound and capable of resisting the most enormous short circuit forces. This is the most general type applicable to windings of a wide range of voltage and current
- Rectangular wire is used where current is relatively small, while transposed cable Fig. (12) is applied to large current. When voltage is relatively low, a Transformer of 100MVA or more capacity handles a large current exceeding 1000A. In this case, the advantage of transposed cable may be fully utilized
- Since the number of turns is reduced, even conventional continuous disk construction is satisfactory in voltage distribution, thereby ensuring adequate dielectric characteristics. Also, whenever necessary, potential distribution is improved by inserting a shield between turns.
- **Arrangement of layers**
- According to the number of layers used the paper is applied as follows.
- Two layers: =Where there are two layers both of them are wound in opposite directions.
- More than two layers: =Where there are more than two layers all the layers are applied in the same direction, all, except the outermost layer is butt wound, and the outermost layer is overlap wound. Within each group of papers the position of the butt joints of any layer relative to the layer below is progressively displaced by approximately 30 percent of the paper width.
- Note: Overlapping can also be done as per customer requirements.
- **Grade of paper**
- The paper, before application, is ensured to be free from metallic and other injurious inclusions and have no deleterious effect on insulating oil.
- The thickness of paper used is between 0.025 mm to 0.075 mm.
- **Enamelled Conductor**
- Apart from paper covered conductors, we have all the facilities of producing enameled conductors as per customer specified requirements.
- Copper: Usually in 8 to 16mm rods is drawn to the required sizes and then insulated with paper etc..
- Annealing is done for softening and stress relieving in electrically heated annealing plant under vacuum upto 400-500°C. After 48hrs when the temperature reaches ambient, the vacuum is slowly released and the material is transferred to Insulation section.
- Conductors are one of the principal materials used in manufacturing of transformers. Best quality of copper rods are procured from indigenous as well as foreign sources. Normally 8 mm & 11 mm rods are procured. For each supply of input, test certificate from suppliers is obtained and at times.
- After the wires & strips are drawn as per clients requirements they are moved on to paper covering process.
- To prevent the inclusion of copper dust or other extraneous matter under paper covering the conductor is fully cleaned by felt pads or other suitable means before entering the paper covering machine. As per the customers' requirements DPC, TPC & MPC conductors are produced. It is ensured that each layer of paper is continuous, firmly applied and substantially free from creases.
- No bonding or adhesive material is used except to anchor the ends of paper. Any such bonding materials used to anchor the ends do not have deleterious effect on transformer oil, insulating paper or the electric strength of the covering. It is ensured that the overlapping percentage is not less than 25% of the paper width.
- The rectangular paper-covered copper conductor is the most commonly used conductor for the windings of medium and large power transformers.
- These conductors can be individual strip conductors, bunched conductors or continuously transposed cable (CTC) conductors.
- In low voltage side of a distribution transformer, where much fewer turns are involved, the use of copper or aluminum foils may find preference.
- To enhance the short circuit withstand capability, the work hardened copper is commonly used instead of soft annealed copper, particularly for higher rating transformers
- In the case of a generator transformer having high current rating, the CTC conductor is mostly used which gives better space factor and reduced eddy losses in windings. When the CTC conductor is used in transformers, it is usually of epoxy bonded type to enhance its short circuit strength.

3) Transformer Core:

- **Purpose of the core:**

- To reduce the magnetizing current. (For topologies such as Forward, Bridge etc we need the magnetizing current to be as small as possible. For fly-back topology, though the magnetizing current is used to transfer energy, the size of the transformer will be very large to get the required inductance if a core is not used.)
- To improve the linkage of the flux within windings if the windings are separated spatially.
- To contain the magnetic flux within a given volume
- In magnetic amplifier applications a saturable core is used as a switch.
- **Core Material:**
 - Different types of material used for cores
 - Iron-Silicon Steel- Nickel-Iron-Iron-Cobalt-Ferrite-Molybdenum-Met-glass
- **Salient characteristics of a core material:**
 - Permeability, Saturation flux density, Coercive force, Remnant flux, Losses due to Hysteresis & Eddy Current.
 - The power loss is a function of frequency and the ac flux swing and is given by the equation $P = K_1 \cdot (\text{frequency})^{K_2} \cdot (\text{Flux Density})^{K_3}$
 - Every transformer has a core, which is surrounded by windings. The core is made out of special cold rolled grain oriented silicon sheet steel laminations. The special silicon steel ensures low hysteresis losses. The silicon steel laminations also ensure high resistivity of core material which result in low eddy currents. In order to reduce eddy current losses, the laminations are kept as thin as possible. The thickness of the laminations is usually around 0.27 to 0.35 mm.
 - Transformer cores construction is of two types, viz, core type and shell type. In core type transformers, the windings are wound around the core, while in shell type transformers, the core is constructed around the windings. The shell type transformers provide a low reactance path for the magnetic flux, while the core type transformer has a high leakage flux and hence higher reactance.
 - The limb laminations in small transformers are held together by stout webbing tape or by suitably spaced glass fiber bends. The use of insulated bolts passing through the limb laminations has been discontinued due to number of instances of core bolt failures. The top and bottom mitered yokes are interleaved with the limbs and are clamped by steel sections held together by insulated yoke bolts. The steel frames clamping the top and bottom yokes are held together by vertical tie bolts.
 - Grain Oriented steel sheets namely ORIENTCORE, ORIENTCORE H1-B & ORIENTCORE HI-B.LS are some of the finest quality of core.
 - ORIENTCORE.HI-B is a breakthrough in that it offers higher magnetic flux density, lower core loss and lower magnetostriction than any conventional grain-oriented electrical steel sheet.
 - ORIENT.HI-B.LS is a novel type with marked lower core losses, produced by laser irradiation of the surface of ORIENTCORE.HI-B sheets.
- **Annealing of stacked electrical sheets**
 - Annealing is to be done at 760 to 845°C to
 - Reduce mechanical stress
 - Prevent contamination
 - Enhance insulation of lamination coating
 - Though ORIENTCORE and ORIENTCORE.HI-B are grain orient steel sheets with excellent magnetic properties, mechanical stress during such operations as cutting, punching and bending affect their magnetic properties adversely. When these stress are excessive, stress relief annealing is necessary.
 - Following method is observed for stress relief annealing
 1. Stacked electrical steel sheets are heated thoroughly in the edge-to-edge direction rather than in the face-to-face direction, because heat transfer is far faster in side heating.
 2. A cover is put over sheets stacked on a flat plate. Because ORIENTCORE and ORIENTCORE.HI-B have extremely low carbon content and very easily decarburized at annealing temperatures, the base, cover and other accessories used are of very low carbon content.
 3. To prevent oxidation so as to protect the coating on the sheets, a no oxidizing atmosphere free from carbon sources is used having less than 2% hydrogen or high-purity nitrogen gas. Due point of the atmosphere is maintained at 0°C or less.
 4. Care is taken to the flatness of annealing base, because an uneven base distorts cores, leading to possible distortion during assembly.
 5. Annealing temperature ranging from 780°C to 820°C is maintained for more than 2 hours or more. Cooling is done up to 350°C in about 15 hours or more.
- **Available Grades:**
 - ORIENTCORE:M1, M2, M3, M4, M5 & M6
 - ORIENTCORE.HI-B:23ZH90, 23ZH95, 27ZH95, 27ZH100, 30ZH100,M-0H, M-1H, M-2H, M-3H
 - ORIENTCORE.HI-B.LS: 23ZDKH90, 27ZDKH95

- Non-oriented silicon steel, hot rolled grain oriented silicon steel, cold rolled grain oriented (CRGO) silicon steel, Hi-B, laser scribed and mechanically scribed. The last three materials are improved versions of CRGO.
- Saturation flux density has remained more or less constant around 2.0 Tesla for CRGO; but there is a continuous improvement in watts/kg and volt-amperes/kg characteristics in the rolling direction.
- The core building technology has improved from the non-mitred to mitred and then to the step-lap construction
- The better grades of core steel not only reduce the core loss but they also help in reducing the noise level by few decibels
- Use of amorphous steel for transformer cores results in substantial core loss reduction (loss is about one-third that of CRGO silicon steel). Since the manufacturing technology of handling this brittle material is difficult, its use in transformers is not widespread
- In the early days of transformer manufacturing, inferior grades of laminated steel (as per today's standards) were used with inherent high losses and magnetizing volt-amperes. Later on it was found that the addition of silicon content of about 4 to 5% improves the performance characteristics significantly, due to a marked reduction in eddy losses (on account of the increase in material resistivity) and increase in permeability. Hysteresis loss is also lower due to a narrower hysteresis loop. The addition of silicon also helps to reduce the aging effects.
- Although silicon makes the material brittle, it is well within limits and does not pose problems during the process of core building.
- The cold rolled manufacturing technology in which the grains are oriented in the direction of rolling gave a new direction to material development for many decades, and even today newer materials are centered around the basic grain orientation process.
- Important stages of core material development are: non-oriented, hot rolled grain oriented (HRGO), cold rolled grain oriented (CRGO), high permeability cold rolled grain oriented (Hi-B), laser scribed and mechanically scribed.
- Laminations with lower thickness are manufactured and used to take advantage of lower eddy losses. Currently the lowest thickness available is 0.23 mm, and the popular thickness range is 0.23 mm to 0.35 mm for power transformers.
- Maximum thickness of lamination used in small transformers can be as high as 0.50 mm.
- Inorganic coating (generally glass film and phosphate layer) having thickness of 0.002 to 0.003 mm is provided on both the surfaces of laminations, which is sufficient to withstand eddy voltages (of the order of a few volts).
- Since the core is in the vicinity of high voltage windings, it is grounded to drain out the statically induced voltages. While designing the grounding system, due care must be taken to avoid multiple grounding, which otherwise results into circulating currents and subsequent failure of transformers.

4) Transformer Core:

a) Core Type Construction: (Mostly Used):

- Generally in India, Core type of construction with Two/Three/Five limbed cores is used. Generally five limbed cores are used where the dimensions of the Transformer is to be limited due to Transportation difficulties. In three limbed core the cross section of the Limb and the Yoke are the same where as in five Limbed core, the cross section of the Yoke and the Flux return path Limbs are very less (58% and 45% of the principal Limb).
- **Limb:** which is surrounded by windings, is called a limb or leg?
- **Yoke:** Remaining part of the core, which is not surrounded by windings, but is essential for completing the path of flux, is called as yoke.
- **Advantage:**
- Construction is simpler, cooling is better and repair is easy.
- The yoke and end limb area should be only 50% of the main limb area for the same operating flux density.
- Zero-sequence impedance is equal to positive-sequence impedance for this construction (in a bank of single-phase transformers).
- Sometimes in a single-phase transformer windings are split into two parts and placed around two limbs as shown in figure (b). This construction is sometimes adopted for very large ratings. Magnitude of short-circuit forces are lower because of the fact that ampere-turns/height are reduced. The area of limbs and yokes is the same. Similar to the single-phase three-limb transformer.
- The most commonly used construction, for small and medium rating transformers, is three-phase three-limb construction as shown in figure (d). For each phase, the limb flux returns through yokes and other two limbs (the same amount of peak flux flows in limbs and yokes).
- Limbs and yokes usually have the same area. Sometimes the yokes are provided with a 5% additional area as compared to the limbs for reducing no-load losses.

- It is to be noted that the increase in yoke area of 5% reduces flux density in the yoke by 5%, reduces watts/kg by more than 5% (due to non-linear characteristics) but the yoke weight increases by 5%. Also, there may be additional loss due to cross-fluxing since there may not be perfect matching between lamination steps of limb and yoke at the joint. Hence, the reduction in losses may not be very significant.
- In large power transformers, in order to reduce the height for transportability, three-phase five-limb construction depicted in figure (e) is used. The magnetic length represented by the end yoke and end limb has a higher reluctance as compared to that represented by the main yoke. Hence, as the flux starts rising, it first takes the path of low reluctance of the main yoke. Since the main yoke is not large enough to carry all the flux from the limb, it saturates and forces the remaining flux into the end limb. Since the spilling over of flux to the end limb occurs near the flux peak and also due to the fact that the ratio of reluctances of these two paths varies due to non-linear properties of the core.
- Fluxes in both main yoke and end yoke/end limb paths are non-sinusoidal even though the main limb flux is varying sinusoidal [2, 4]. Extra losses occur in the yokes and end limbs due to the flux harmonics. In order to compensate these extra losses, it is a normal practice to keep the main yoke area 60% and end yoke/end limb area 50% of the main limb area.
- The zero-sequence impedance is much higher for the three-phase five-limb core than the three-limb core due to low reluctance path (of yokes and end limbs) available to the in-phase zero-sequence fluxes, and its value is close to but less than the positive-sequence impedance value.

b) Shell-type construction:

- Cross section of windings in the plane of core is surrounded by limbs and yokes, is also used.
- Shell type of construction of the core is widely used in USA.
- **Advantage:**
- One can use sandwich construction of LV and HV windings to get very low impedance, if desired, which is not easily possible in the core-type construction.
- **Analysis of overlapping joints and building factor:**
- While building a core, the laminations are placed in such a way that the gaps between the laminations at the joint of Limb and yoke are overlapped by the laminations in the next layer.
- This is done so that there is no continuous gap at the joint when the laminations are stacked one above the other (figure). The overlap distance is kept around 15 to 20 mm.
- There are two types of joints most widely used in transformers: non-mitred and mitred joints.
- **Non-mitred joints:**
- In which the overlap angle is 90° , are quite simple from the manufacturing point of view, but the loss in the corner joints is more since the flux in the joint region is not along the direction of grain orientation. Hence, the on-mitred joints are used for smaller rating transformers. These joints were commonly adopted in earlier days when non-oriented material was used
- **Mitred joints:**
- The joint where these laminations meet could be Butt or Mitred. In CRGO, the Mitred Joint is preferred as it reduces the Reluctance of the Flux path and reduces the No Load Losses and the No Load current (by about 12% & 25% respectively).
- The Limb and the Yoke are made of a number of Laminations in Steps. Each step comprises of some number of laminations of equal width. The width of the central strip is Maximum and that at the circumference is Minimum. The cross section of the Yoke and the Limb are nearly Circular. Mitred joint could be at 35/45/55 degrees but the 45 one reduces wastage.
- The angle of overlap (α) is of the order of 30° to 60° , the most commonly used angle is 45° . The flux crosses from limb to yoke along the grain orientation in mitred joints minimizing losses in them. For airgaps of equal length, the excitation requirement of cores with mitred joints is $\sin \alpha$ times that with non-mitred joints.
- **Building Factor:**
- Better grades of core material (Hi-B, scribed, etc.) having specific loss (watts/kg) 15 to 20% lower than conventional CRGO material (termed hereafter as CGO grade, e.g., M4) are regularly used. However, it has been observed that the use of these better materials may not give the expected loss reduction if a proper value of building factor is not used in loss calculations
- The building factor generally increases as grade of the material improves from CGO to Hi-B to scribed (domain refined). This is a logical fact because at the corner joints the flux is not along the grain orientation, and the increase in watts/kg due to deviation from direction of grain orientation is higher for a better grade material.
- The factor is also a function of operating flux density; it deteriorates more for better grade materials with the increase in operating flux density. Hence, cores built with better grade material may not give the expected benefit in line with Epstein measurements done on individual lamination. Therefore, appropriate building factors should be taken for better grade materials using experimental/test data.

- Also the loss contribution due to the corner weight is higher in case of 90° joints as compared to 45° joints since there is over-crowding of flux at the inner edge and flux is not along the grain orientation while passing from limb to yoke in the former case. Smaller the overlapping length better is the core performance; but the improvement may not be noticeable.
- The gap at the core joint has significant impact on the no-load loss and current. As compared to 0 mm gap, the increase in loss is 1 to 2% for 1.5 mm gap, 3 to 4% for 2.0 mm gap and 8 to 12% for 3 mm gap. These figures highlight the need for maintaining minimum gap at the core joints.
- Lesser the laminations per lay, lower is the core loss. The experience shows that from 4 laminations per lay to 2 laminations per lay, there is an advantage in loss of about 3 to 4%. There is further advantage of 2 to 3% in 1 lamination per lay. As the number of laminations per lay reduces, the manufacturing time for core building increases and hence most of the manufacturers have standardized the core building with 2 laminations per lay.
- Joints of limbs and yokes contribute significantly to the core loss due to cross-fluxing and crowding of flux lines in them. Hence, the higher the corner area and weight, the higher is the core loss.
- The corner area in single-phase three-limb cores, single-phase four-limb cores and three-phase five-limb cores is less due to smaller core diameter at the corners, reducing the loss contribution due to the corners. However, this reduction is more than compensated by increase in loss because of higher overall weight (due to additional end limbs and yokes).
- Building factor is usually in the range of 1.1 to 1.25 for three-phase three-limb cores with mitred joints. Higher the ratio of window height to window width, lower is the contribution of corners to the loss and hence the building factor is lower.
- **Step-lap joint :**
- It is used by many manufacturers due to its excellent performance figures. It consists of a group of laminations (commonly 5 to 7) stacked with a staggered joint as shown in figure.
- Its superior performance as compared to the conventional mitred construction.
- It is shown that, for a operating flux density of 1.7 T, the flux density in the mitred joint in the core sheet area shunting the air gap rises to 2.7 T (heavy saturation), while in the gap the flux density is about 0.7 T. Contrary to this, in the step-lap joint of 6 steps, the flux totally avoids the gap with flux density of just 0.04 T, and gets redistributed almost equally in laminations of other five steps with a flux density close to 2.0 T. This explains why the no-load performance figures (current, loss and noise) show a marked improvement for the step-lap joints.
- **Yoke Studs:**
- The assembled core has to be clamped tightly not only to provide a rigid mechanical structure but also required magnetic characteristic. Top and Bottom Yokes are clamped by steel sections using Yoke Studs. These studs do not pass through the core but held between steel sections. Of late Fiber Glass Band tapes are wound round the Limbs tightly upto the desired tension and heat treated. These laminations, due to elongation and contraction lead to magnetostriction, generally called Humming which can be reduced by using higher silicon content in steel but this makes the laminations become very brittle.
- **Over Excited:**
- The choice of operating flux density of a core has a very significant impact on the overall size, material cost and performance of a transformer.
- For the currently available various grades of CRGO material, although losses and magnetizing volt-amperes are lower for better grades, viz. Hi-B material (M0H, M1H, M2H), laser scribed, mechanical scribed, etc., as compared to CGO material (M2, M3, M4, M5, M6, etc.), the saturation flux density has remained same (about 2.0 T). The peak operating flux density (B_{mp}) gets limited by the over-excitation conditions specified by users.
- The slope of B-H curve of CRGO material significantly worsens after about 1.9 T (for a small increase in flux density, relatively much higher magnetizing current is drawn). Hence, the point corresponding to 1.9 T can be termed as knee-point of the B-H curve.
- It has been seen in example 1.1 that the simultaneous over-voltage and under-frequency conditions increase the flux density in the core. Hence, for an over-excitation condition (over-voltage and under-frequency).
- When a transformer is subjected to an over-excitation, core contains an amount of flux sufficient to saturate it. The remaining flux spills out of the core. The over-excitation must be extreme and of a long duration to produce damaging effect in the core laminations
- The laminations can easily withstand temperatures in the region of 800°C (they are annealed at this temperature during their manufacture), but insulation in the vicinity of core laminations, viz. press-board insulation (class A: 105°C) and core bolt insulation (class B: 130°C) may get damaged. Since the flux flows in air (outside core) only during the part of a cycle when core gets saturated, the air flux and exciting current are in the form of pulses having high harmonic content which increases the eddy losses and temperature rise in windings and structural parts.

Winding Insulation in Transformer:

- In Transformers, the insulating oil provides an insulation medium as well as a heat transferring medium that carries away heat produced in the windings and iron core. Since the electric strength and the life of a Transformer depend chiefly upon the quality of the insulating oil.

Requirement of Insulating Oil	
400KVA to 1600KVA	1.0 Litter / KVA
1600KVA to 8000KVA	0.6 Litter / KVA
Above 8000KVA	0.5 Litter / KVA

- It is very important to use a high quality insulating oil to provide a high electric strength and Permit good transfer of heat.
- **Transformer have low specific gravity:** In oil of low specific gravity particles which have become suspended in the oil will settle down on the bottom of the tank more readily and at a faster rate, a property aiding the oil in retaining its homogeneity.
- **Transformers have a low viscosity:** Oil with low viscosity, i.e., having greater fluidity, will cool Transformers at a much better rate.
- **Transformers have low pour point:** Oil with low pour point will cease to flow only at low temperatures.
- **Transformers have high flash point:** The flash point characterizes its tendency to evaporate. The lower the flash point the greater the oil will tend to vaporize. When oil vaporizes, it loses in volume, its viscosity rises, and an explosive mixture may be formed with the air above the oil.

The Core Insulation Material:

- SRBP- Synthetic Resin Bonded Paper
- OIP – Oil Impregnated Paper
- RIP – Resin Impregnated Paper
- Resin Coated Paper/ Kraft Paper/ Crepe Kraft Paper is used for making core for the above. It is Hermetically Sealed.
- Pre-compressed pressboard is used in windings as opposed to the softer materials used in earlier days. The major insulation (between windings, between winding and yoke, etc.)
- Mineral oil has traditionally been the most commonly used electrical insulating medium and coolant in transformers. Studies have proved that oil-barrier insulation system can be used at the rated voltages greater than 1000 KV. A high dielectric strength of oil-impregnated paper and pressboard is the main reason for using oil as the most important constituent of the transformer insulation system.
- Manufacturers have used silicon-based liquid for insulation and cooling. Due to non-toxic dielectric and self-extinguishing properties. High cost of silicon is an inhibiting factor for its widespread use.
- Super-biodegradable vegetable seed based oils are also available for use in environmentally sensitive locations.
- SF₆ gas has excellent dielectric strength and is non-flammable. Hence, SF₆ transformers find their application in the areas where fire-hazard prevention is of paramount importance.
- Due to lower specific gravity of SF₆ gas, the gas insulated transformer is usually lighter than the oil insulated transformer. The dielectric strength of SF₆ gas is a function of the operating pressure; the higher the pressure, the higher the dielectric strength.
- However, the heat capacity and thermal time constant of SF₆ gas are smaller than that of oil, resulting in reduced overload capacity of SF₆ transformers as compared to oil-immersed transformers. Environmental concerns, sealing problems, lower cooling capability and present high cost of manufacture are the challenges.
- Dry-type resin cast and resin impregnated transformers use class F or C insulation. High cost of resins and lower heat dissipation capability limit the use of these transformers to small ratings.
- The dry-type transformers are primarily used for the indoor application in order to minimize fire hazards. Nomex paper insulation, which has temperature withstand capacity of 220°C, is widely used for dry-type transformers. The initial cost of a dry-type transformer may be 60 to 70% higher than that of an oil-cooled transformer at current prices, but its overall cost at the present level of energy rate can be very much comparable to that of the oil-cooled transformer.

Transformer Noise: