SELECTION OF LOW VOLTAGE CABLES

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Different Types of Cables

- There are different types of cables in the Low Voltage Power supply. Those are categorized based on the *materials* used for the construction of the cables and the *voltage rating* of the cables.

- The different types of cables used nowadays based on the type of main conductive materials used for construction of cables are

  (a) Copper cables (b) Aluminum cables

- The different types of cables based on the type of insulation materials:

  (a) Rubber insulated cables
  (b) Paper insulated cables.
  (c) PVC insulated cables.
  (d) XLPE insulated cables.
  (e) Mineral insulated cables.

MAXIMUM OPERATING TEMPERATURE FOR DIFFERENT TYPES OF CABLE INSULATION

TABLE 52.1 – Maximum operating temperatures for types of cable insulation

Type of insulation	Temperature limit[a]
Thermoplastic	70 °C at the conductor
Thermosetting	90 °C at the conductor[b]
Mineral (Thermoplastic covered or bare exposed to touch)	70 °C at the sheath
Mineral (bare not exposed to touch and not in contact with combustible material)	105 °C at the sheath[b, c]

[a] The maximum permissible conductor temperatures given in Table 52.1 on which the tabulated current-carrying capacities given in Appendix 4 are based, have been taken from IEC 60502-1 and BS EN 60702-1 and are shown on these tables in Appendix 4.

[b] Where a conductor operates at a temperature exceeding 70 °C it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection.

[c] For mineral insulated cables, higher operating temperatures may be permissible dependent upon the temperature rating of the cable, its terminations, the environmental conditions and other external influences.

NOTE: For the temperature limits for other types of insulation, refer to cable specification or manufacturer.

Different Types of Cables

1. Notation of cables in common practice.

    (a) Cu/PVC – PVC insulated copper cable.
    (b) Cu/PVC/PVC – PVC sheathed, PVC insulated copper cable.
    (c) Cu/XLPE/PVC – PVC sheathed, XLPE insulated copper cable
    (d) Cu/XLPE/SWA/PVC – same as above but with "steel wire armour" for additional mechanical protection.

2. (a) Cu/PVC cables are used for earth cables in Sri Lanka. But it can be used for power cables also.

    (b) Cu/PVC/PVC cables are used for final circuits such as light point wiring, socket outlet wiring, etc.

    (c) Cu/XLPE/PVC cables are used as main or sub power feeders within the building.

    (d) Cu/XLPE/SWA/PVC are used as the main or sub power feeder especially.

Current Currying Capacity of Cables

- The current currying capacity of the cables depends on its ability to lose the heat produced in it by the current it carries.

- The heat dissipation of the cables depends on the followings:

(a) The way / method of cable installation.
(b) The number of cables / circuits grouped together.
(c) The ambient temperature.

Different Types of Cables

Different types of cables based on the voltage ratings:

(a) Cables with a voltage rating of 300/500 V.
(b) Cables with a voltage rating of 450/750 V.
(c) Cables with a voltage rating of 600/1000 V.

DETERMINATION OF THE SIZE OF CABLE TO BE USED

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STEPS INVOLVED IN CABLE SIZING

- Step-1: Determination of design current (I_b).
- Step-2: Determination of the rated current of the protective device (I_n). $I_n \geq I_b$
- Step-3: Determination of the tabulated current of the cable (I_t) using the following formula:

$$I_t \geq I_n / C_a C_c C_d C_f C_g C_i C_s$$

Where,

C_a – Correction factor for ambient temperature.
C_c – Correction factor for circuits buried in the ground.
C_d – Correction factor for depth of burial.
C_f – Correction factor for semi-enclosed fuse to BS3036.
C_g – Correction factor for grouping.
C_i – Correction factor for thermal insulation.
C_s – Correction factor for thermal resistivity of the soil.

For cables installed above ground, C_s=C_d=C_c=1.

STEPS INVOLVED IN CABLE SIZING

- For cables installed above ground, C_s=C_d=C_c=1.
- For cables protected by any protective devices except semi-enclosed fuse to BS3036, C_f = 1.
- For cables protected by semi-enclosed fuse to BS3036, C_f = 0.725.
- For cables installed “in a duct in the ground” or “buried direct”, C_c = 0.9.

Step-4: Determination of the tabulated current of the cable (I_t) using the following formula (if overload protection is not required):

$$I_t \geq I_b / C_a C_c C_d C_f C_g C_i C_s$$

Where overload protection is not required, C_c=1.

Example: Consider a three phase with a design load (fundamental current) of 58A is to be installed using a 4 core 90°C thermosetting insulated cable. The cable will be installed with three other circuits on a perforated cable tray (method E or F) in an expected maximum ambient temperature of 35°C. The cable will be protected at its origin using a circuit breaker to BS EN60898-1.

Solution:

Case-1: Load does not produce 3rd harmonic currents.

$I_b = 58A$

So, rated current of the circuit breaker selected, $I_n = 63A$

$I_t \geq I_n / C_a C_g$

$C_a = 0.96$ *from Table 4B1 and* $C_g = 0.77$ *from Table 4C1*

$I_t \geq 63 / (0.96 * 0.77)$

$I_t \geq 85.23A$

So, the selected cable is 4C x 16mm^2 *Cu/XLPE/SWA/PVC (from Table 4E4A)*

TABLE 4B1 – Rating factors (C_a) for ambient air temperatures other than 30 °C

Ambient temperature[a] °C	Insulation				
				Mineral[a]	
	60 °C thermosetting	70 °C thermoplastic	90 °C thermosetting	Thermoplastic covered or bare and exposed to touch 70 °C	Bare and not exposed to touch 105 °C
25	1.04	1.03	1.02	1.07	1.04
30	1.00	1.00	1.00	1.00	1.00
35	0.91	0.94	0.96	0.93	0.96
40	0.82	0.87	0.91	0.85	0.92
45	0.71	0.79	0.87	0.78	0.88
50	0.58	0.71	0.82	0.67	0.84
55	0.41	0.61	0.76	0.57	0.80
60	–	0.50	0.71	0.45	0.75
65	–	–	0.65	–	0.70
70	–	–	0.58	–	0.65
75	–	–	0.50	–	0.60
80	–	–	0.41	–	0.54
85	–	–	–	–	0.47
90	–	–	–	–	0.40
95	–	–	–	–	0.32

a For higher ambient temperatures, consult manufacturer.

TABLE 4C1 – Rating factors for one circuit or one multicore cable or for a group of circuits, or a group of multicore cables, to be used with current-carrying capacities of Tables 4D1A to 4J4A

Item	Arrangement (cables touching)	Number of circuits or multicore cables												To be used with current-carrying capacities, Reference Method
		1	2	3	4	5	6	7	8	9	12	16	20	
1.	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.60	0.57	0.54	0.52	0.50	0.45	0.41	0.38	A to F
2.	Single layer on wall or floor	1.00	0.85	0.79	0.75	0.73	0.72	0.72	0.71	0.70	0.70	0.70	0.70	C
3.	Single layer multicore on a perforated horizontal or vertical cable tray system	1.00	0.88	0.82	0.77	0.75	0.73	0.73	0.72	0.72	0.72	0.72	0.72	E
4.	Single layer multicore on cable ladder system or cleats etc.	1.00	0.87	0.82	0.80	0.80	0.79	0.79	0.78	0.78	0.78	0.78	0.78	

NOTE 1: These factors are applicable to uniform groups of cables, equally loaded.

TABLE 4E4A – Multicore armoured 90 °C thermosetting insulated cables (COPPER CONDUCTORS)

Air ambient temperature: 30 °C
Ground ambient temperature: 20 °C
Conductor operating temperature: 90 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method C (clipped direct)		Reference Method E (in free air or on a perforated cable tray etc, horizontal or vertical)		Reference Method D (direct in ground or in ducting in ground, in or around buildings)	
	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC	1 two-core cable, single-phase AC or DC	1 three- or 1 four-core cable, three-phase AC
1	2	3	4	5	6	7
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)
1.5	27	23	29	25	25	21
2.5	36	31	39	33	33	28
4	49	42	52	44	43	36
6	62	53	66	56	53	44
10	85	73	90	78	71	58
16	110	94	115	99	91	75
25	146	124	152	131	116	96
35	180	154	188	162	139	115
50	219	187	228	197	164	135
70	279	238	291	251	203	167
95	338	289	354	304	239	197
120	392	335	410	353	271	223
150	451	386	472	406	306	251
185	515	441	539	463	343	281
240	607	520	636	546	395	324
300	698	599	732	628	446	365
400	787	673	847	728	-	-

Case-2: Load produces an additional 3rd harmonic content (THD_i = 20%)

I_f = 58A…………………..(fundamental current)

Since the 3rd harmonic current is 15 – 33%, the cable sizing will be based on the line current as per Table 4Aa.

TABLE 4Aa – Rating factors for triple harmonic currents in four-core and five-core cables

Third harmonic content of line current* %	Rating factor	
	Size selection is based on line current	Size selection is based on neutral current
0 – 15	1.0	–
>15 – 33	0.86	–
>33 – 45	–	0.86
> 45	–	1.0

* **NOTE:** The third harmonic content expressed as total harmonic distortion.

*I_{bh} = 58*C_h ……(design current including the effect of 3rd harmonic current)*

*I_{bh} = 58*sqrt(1^2+0.2^2)*

I_{bh} = 59.1A

So, rated current of the circuit breaker selected, I_n = 63A

$$C_h = \sqrt{\frac{I_f^2 + \ldots + I_{hn}^2}{I_f^2}}$$

where: I_f = 50 Hz current

I_{hn} = n^{th} harmonic current

$I_t \geq I_n / C_a C_g * 0.86$

$C_a = 0.96$ *from Table 4B1 and* $C_g = 0.77$ *from Table 4C1*

$I_t \geq 63/(0.96*0.77*0.86)$

$I_t \geq 99.1A$

From Table 4E4A, a 16mm² cable has a tabulated current currying capacity of 99A, thus a rule-based system may select a 25mm² cable whereas a designer may exercise judgement and select a 16mm² cable.

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Case-3: Load produces an additional 3rd harmonic content (THD_i = 42%)

I_f = 58A…………………...(fundamental current)

Since the 3rd harmonic current is 33 –45%, the cable sizing will be based on the neutral current as per Table 4Aa.

TABLE 4Aa – Rating factors for triple harmonic currents in four-core and five-core cables

Third harmonic content of line current* %	Rating factor	
	Size selection is based on line current	Size selection is based on neutral current
0 – 15	1.0	–
>15 – 33	0.86	–
>33 – 45	–	0.86
> 45	–	1.0

*** NOTE:** The third harmonic content expressed as total harmonic distortion.

*I_{bn} = 3*0.42*58 ……(neutral current due to the 3rd harmonic current)*

I_{bn} = 73.08A

So, rated current of the circuit breaker selected, I_n = 100A

$I_t \geq I_n / C_a C_g * 0.86$

C_a = 0.96 from Table 4B1 and C_g = 0.77 from Table 4C1

$I_t \geq 100/(0.96*0.77*0.86)$

$I_t \geq 157.3A$

So, the selected cable is 4C x 35mm^2 Cu/XLPE/SWA/PVC (from Table 4E4A)

Example:

An immersion heater rated at 230V, 3kW is to be installed using *twin* with protective conductor PVC insulated and sheathed cable. The circuit will be running for much of its length in a roof space which is thermally insulated with glass fiber. The roof space temperature is expected to rise to *50^oC in summer*, and where it leaves the Consumer Unit and pass through a *50mm insulation* filled cavity, the cable will be *bunched with seven others*. Calculate the cross-sectional area of the required cable. Consider reference method A for the installation.

Solution:

$I_b = 3000/230 = 13.04A$

So, a 16A MCB of Type-B can be selected to provide the circuit protection.

So, $I_n = 16A$

So, $I_t = I_n/(C_a*C_g*C_i)$

$C_a = 0.71$ (from Table 4B1)

$C_g = 0.52$ (from Table 4C1)

$C_i = 0.88$ (from Table 52.2)

So, $I_t = 16/(0.71*0.52*0.88)$

So, $I_t = 49.24\ A$

TABLE 52.2 – Cable surrounded by thermal insulation

Length in insulation (mm)	Derating factor
50	0.88
100	0.78
200	0.63
400	0.51

So, the selected cable is $16mm^2$ twin cable (Table 4D5)

COPPER CONDUCTORS

TABLE 4D5 – 70 °C thermoplastic insulated and sheathed flat cable with protective conductor (COPPER CONDUCTORS)

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes) and VOLTAGE DROP (per ampere per metre):

Conductor cross-sectional area	Method 100# (above a plasterboard ceiling covered by thermal insulation not exceeding 100 mm in thickness)	Method 101# (above a plasterboard ceiling covered by thermal insulation exceeding 100 mm in thickness)	Method 102# (in a stud wall with thermal insulation with cable touching the inner wall surface)	Method 103# (in a stud wall with thermal insulation with cable not touching the inner wall surface)	Reference Method C* (clipped direct)	Reference Method A* (enclosed in conduit in an insulated wall)	Voltage drop (per ampere per metre)
1	2	3	4	5	6	7	8
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(mV/A/m)
1	13	10.5	13	8	16	11.5	44
1.5	16	13	16	10	20	14.5	29
2.5	21	17	21	13.5	27	20	18
4	27	22	27	18.5	37	26	11
6	34	27	35	23.5	47	32	7.3
10	45	36	47	32	64	44	4.4
16	57	46	63	42.5	85	57	2.8

Example:

An immersion heater rated at 230V, 3kW is to be installed using *single core* conductor PVC insulated and PVC sheathed cable. The circuit will be running in PVC conduit embedded in a wall. The ambient temperature is expected to rise to *40^oC in summer*, the conduit is pass through a *50mm insulation* filled cavity also, and the cable will be *bunched with two others*. Calculate the cross-sectional area of the required cable.

Solution:

I_b = 3000/230 = 13.04A
So, a 16A MCB of Type-B can be selected to provide the circuit protection.

So, I_n = 16A

So, $I_t = I_n/(C_a*C_g*C_i)$

C_a = 0.87 (from Table 4B1)

C_g = 0.70 (from Table 4C1)

C_i = 0.88 (from Table 52.2)

*So, I_t = 16/(0.87*0.70*0.88)*

So, I_t = 29.85 A

TABLE 52.2 – Cable surrounded by thermal insulation

Length in insulation (mm)	Derating factor
50	0.88
100	0.78
200	0.63
400	0.51

So, the selected cable is 2 x 1C x 4mm^2 cable (Table 4D1A)

COPPER CONDUCTORS

TABLE 4D1A – Single-core 70 °C thermoplastic insulated cables, non-armoured, with or without sheath (COPPER CONDUCTORS)

Ambient temperature: 30 °C
Conductor operating temperature: 70 °C

CURRENT-CARRYING CAPACITY (amperes):

Conductor cross-sectional area	Reference Method A (enclosed in conduit in thermally insulating wall etc.)		Reference Method B (enclosed in conduit on a wall or in trunking etc.)		Reference Method C (clipped direct)		Reference Method F (in free air or on a perforated cable tray horizontal or vertical)				
							Touching			Spaced by one diameter	
	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC	3 or 4 cables, three-phase AC	2 cables, single-phase AC or DC flat and touching	3 or 4 cables, three-phase AC flat and touching or trefoil	2 cables, single-phase AC or DC flat	3 cables, three-phase AC flat	3 cables, three-phase AC trefoil	2 cables, single-phase AC or DC or 3 cables three-phase AC flat	
										Horizontal	Vertical
1	2	3	4	5	6	7	8	9	10	11	12
(mm^2)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)	(A)
1	11	10.5	13.5	12	15.5	14	-	-	-	-	-
1.5	14.5	13.5	17.5	15.5	20	18	-	-	-	-	-
2.5	20	18	24	21	27	25	-	-	-	-	-
4	26	24	32	28	37	33	-	-	-	-	-
6	34	31	41	36	47	43	-	-	-	-	-
10	46	42	57	50	65	59	-	-	-	-	-
16	61	56	76	68	87	79	-	-	-	-	-
25	80	73	101	89	114	104	131	114	110	146	130
35	99	89	125	110	141	129	162	143	137	181	162
50	119	108	151	134	182	167	196	174	167	219	197
70	151	136	192	171	234	214	251	225	216	281	254
95	182	164	232	207	284	261	304	275	264	341	311
120	210	188	269	239	330	303	352	321	308	396	362
150	240	216	300	262	381	349	406	372	356	456	419
185	273	245	341	296	436	400	463	427	409	521	480
240	321	286	400	346	515	472	546	507	485	615	569
300	367	328	458	394	594	545	629	587	561	709	659
400	-	-	546	467	694	634	754	689	656	852	795
500	-	-	626	533	792	723	868	789	749	982	920
630	-	-	720	611	904	826	1005	905	855	1138	1070
800	-	-	-	-	1030	943	1086	1020	971	1265	1188
1000	-	-	-	-	1154	1058	1216	1149	1079	1420	1337

NOTE:

For cables having flexible conductors, see section 2.4 of this Appendix for adjustment factors for current-carrying capacity and voltage drop.

Example:

An immersion heater rated at 230V, 3kW is to be installed using *single core* conductor PVC insulated and PVC sheathed cable. The circuit will be running in PVC conduit embedded in a wall. The ambient temperature is expected to rise to *35^oC in summer*, and the cable *will not be bunched with others*. Calculate the cross-sectional area of the required cable.

Solution:

I_b = 3000/230 = 13.04A

So, a 16A MCB of Type-B can be selected to provide the circuit protection.

So, I_n = 16A

So, $I_t = I_n/(C_a*C_g*C_i)$

C_a = 0.94 (from Table 4B1)

C_g = Not applicable

C_i = Not applicable

So, I_t = 16/0.94

So, I_t = 17.02 A

TABLE 52.2 – Cable surrounded by thermal insulation

Length in insulation (mm)	Derating factor
50	0.88
100	0.78
200	0.63
400	0.51

So, the selected cable is 2 x 1C x 1.5mm² cable (Table 4D1A, single core cables)

The selected cable will be 1 x 2C x 2.5mm² cable (Table 4D2A, multi core cables)

The selected cable will be 1 x 2C x 2.5mm² Twin cable (Table 4D5, flat cables)

VOLTAGE DROP IN CABLES

- The (mV/A/m) value is given in the cable catalogues. These values correspond to the maximum permitted normal operating temperature of the cables.

- The voltage drop is calculated by the following formula:

$$V_d = [(mV/A/m)*I_b*L]/1000 \text{ V}$$

Were,

V_d = Voltage drop in Volts.
I_b = Design current in Ampere.
L = Length of the cable in meter.

- For cable having 16mm^2 or less cross-sectional area, their inductances can be ignored and $(mV/A/m)_r$ values are only tabulated.

- For cable having conductors greater than 16mm^2 cross-sectional area, the impedance values are given as $(mV/A/m)_z$ together with their resistive component $(mV/A/m)_r$ and reactive component $(mV/A/m)_x$.

VOLTAGE DROP IN CABLES

TABLE 4D1B

VOLTAGE DROP (per ampere per metre): Conductor operating temperature: 70 °C

Conductor cross-sectional area	2 cables, DC	2 cables, single-phase AC									3 or 4 cables, three-phase AC											
		Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (clipped direct, on tray or in free air)						Reference Methods A & B (enclosed in conduit or trunking)			Reference Methods C & F (clipped direct, on tray or in free air)								
					Cables touching			Cables spaced*						Cables touching, Trefoil			Cables touching, Flat			Cables spaced*, Flat		
1	2	3			4			5			6			7			8			9		
(mm^2)	(mV/A/m)	(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)			(mV/A/m)		
1	44	44			44			44			38			38			38			38		
1.5	29	29			29			29			25			25			25			25		
2.5	18	18			18			18			15			15			15			15		
4	11	11			11			11			9.5			9.5			9.5			9.5		
6	7.3	7.3			7.3			7.3			6.4			6.4			6.4			6.4		
10	4.4	4.4			4.4			4.4			3.8			3.8			3.8			3.8		
16	2.8	2.8			2.8			2.8			2.4			2.4			2.4			2.4		
		r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z	r	x	z
25	1.75	1.80	0.33	1.80	1.75	0.20	1.75	1.75	0.29	1.80	1.50	0.29	1.55	1.50	0.175	1.50	1.50	0.25	1.55	1.50	0.32	1.55
35	1.25	1.30	0.31	1.30	1.25	0.195	1.25	1.25	0.28	1.30	1.10	0.27	1.10	1.10	0.170	1.10	1.10	0.24	1.10	1.10	0.32	1.15
50	0.93	0.95	0.30	1.00	0.93	0.190	0.95	0.93	0.28	0.97	0.81	0.26	0.85	0.80	0.165	0.82	0.80	0.24	0.84	0.80	0.32	0.86
70	0.63	0.65	0.29	0.72	0.63	0.185	0.66	0.63	0.27	0.69	0.56	0.25	0.61	0.55	0.160	0.57	0.55	0.24	0.60	0.55	0.31	0.63
95	0.46	0.49	0.28	0.56	0.47	0.180	0.50	0.47	0.27	0.54	0.42	0.24	0.48	0.41	0.155	0.43	0.41	0.23	0.47	0.40	0.31	0.51

VOLTAGE DROP IN CABLES

- The tabulated voltage drop values (mV/A/m) can be corrected for temperature and power factor.
  - The correction for power factor can be done as follows:
    - For cable having conductors of cross-sectional area $16mm^2$ or less,

$$\boxed{\text{Corrected mV/A/m} = \text{PF}*(\text{Tabulated (mV/A/m)})}$$

    - For cable having conductors of cross-sectional area greater than$16mm^2$,

$$\boxed{\text{Corrected mV/A/m} = \text{Cos}\Phi*(\text{Tabulated (mV/A/m)}_r) + \text{Sin}\Phi*(\text{Tabulated(mV/A/m)}_x)}$$

VOLTAGE DROP IN CABLES

- The tabulated voltage drop values (mV/A/m) can be corrected for temperature and power factor.
  - The correction for temperature can be done as follows:
    - For cable having conductors of cross-sectional area $16mm^2$ or less,

$$\boxed{\text{Corrected mV/A/m} = C_t{*}(\text{Tabulated (mV/A/m)})}$$

    - For cable having conductors of cross-sectional area greater than$16mm^2$,

$$\boxed{\text{Corrected mV/A/m} = Ct{*}(\text{Tabulated }(\text{mV/A/m})_r) + (\text{Tabulated}(\text{mV/A/m})_x)}$$

    - C_t can be calculated using the following formula:

$$C_t = \frac{230 + t_p - \left(C_a{}^2 C_g{}^2 C_s{}^2 C_d{}^2 - \frac{I_b{}^2}{I_t{}^2}\right)(t_p - 30)}{230 + t_p}$$

where t_p is the maximum permitted normal operating temperature (°C).

VOLTAGE DROP IN CUSTOMER'S INSTALLATION

6.4 Voltage drop in consumers' installations

The voltage drop between the origin of an installation and any load point should not be greater than the values in the table below expressed with respect to the value of the nominal voltage of the installation.

The calculated voltage drop should include any effects due to harmonic currents.

TABLE 4Ab – Voltage drop

	Lighting	Other uses
(i) Low voltage installations supplied directly from a public low voltage distribution system	3 %	5 %
(ii) Low voltage installation supplied from private LV supply (*)	6 %	8 %

(*) The voltage drop within each final circuit should not exceed the values given in (i).

Where the wiring systems of the installation are longer than 100 m, the voltage drops indicated above may be increased by 0.005 % per metre of the wiring system beyond 100 m, without this increase being greater than 0.5 %.

The voltage drop is determined from the demand of the current-using equipment, applying diversity factors where applicable, or from the value of the design current of the circuit.

VOLTAGE DROP IN CUSTOMER'S INSTALLATION

Example: Consider a three phase with a design load (fundamental current) of 58A is to be installed using a 4 core 90°C thermosetting insulated cable. The cable will be installed with three other circuits on a perforated cable tray (method E or F) in an expected maximum ambient temperature of 35°C. The cable will be protected at its origin using a circuit breaker to BS EN60898-1 and the route length of the cables is 160m. Calculate the voltage drop.

Solution: ***(Case-1: Load does not produce 3rd harmonic currents)***

I_b = 58A

The selected cable is 4C x 16mm^2 Cu/XLPE/SWA/PVC.

So, $(mV/A/m)_r$ = 2.5 mV/A/m (from Table 4E4B)

L= 160 m.

Use the formula of $V_d = [(mV/A/m)*I_b*L] / 1000$ V

$V_d = (2.5*58*160) / 1000$ V

$V_d = 23.2$ V

$V_d = (23.2*100) / 400$ %

$V_d = 5.8\%$ *(> 5% and thus, not acceptable as per Table 4Ab (i))*

So, 4C x 16mm^2 Cu/XLPE/SWA/PVC cable is not suitable and hence we have to try with the next higher size.

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VOLTAGE DROP IN CUSTOMER'S INSTALLATION

Solution: ***(Case-1: Load does not produce 3rd harmonic currents)***

I_b = 58A

The proposed cable is 4C x 25mm^2 Cu/XLPE/SWA/PVC.

So, $(mV/A/m)_z$ = 1.65 mV/A/m (from Table 4E4B)

L= 160 m.

Use the formula of $V_d = [(mV/A/m)*I_b*L] / 1000$ V

$V_d = (1.65*58*160) / 1000$ V

$V_d = 15.31$ V

$V_d = (15.31*100) / 400$ %

$V_d = 3.83\%$ (< 5% and thus, acceptable as per Table 4Ab (i))

So, 4C x 25mm^2 Cu/XLPE/SWA/PVC cable is the selected cable for this application.

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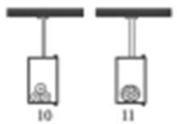
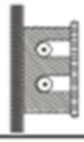
METHOD OF INSTALLATION

Installation Method			Reference Method to be used to determine current-carrying capacity
Number	**Examples**	**Description**	
1		Non-sheathed cables in conduit in a thermally insulated wall with an inner skin having a thermal conductance of not less than $10\ W/m^2K$ [c]	A
2		Multicore cable in conduit in a thermally insulated wall with an inner skin having a thermal conductance of not less than $10\ W/m^2K$ [c]	A
3		Multicore cable direct in a thermally insulated wall with an inner skin having a thermal conductance of not less than $10\ W/m^2K$ [c]	A
4		Non-sheathed cables in conduit on a wooden or masonry wall or spaced less than 0.3 × conduit diameter from it [c]	B
5		Multicore cable in conduit on a wooden or masonry wall or spaced less than 0.3 × conduit diameter from it [c]	B
6 7		Non-sheathed cables in cable trunking on a wooden or masonry wall 6 - run horizontally [b] 7 - run vertically [b, c]	B
8 9		Multicore cable in cable trunking on a wooden or masonry wall 8 - run horizontally [b] 9 - run vertically [b, c]	B[a]
10 11		Non-sheathed cables in suspended cable trunking [b]	B
		Multicore cable in suspended cable trunking [b]	B
12		Non-sheathed cables run in mouldings [c, e]	A

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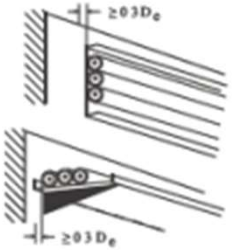
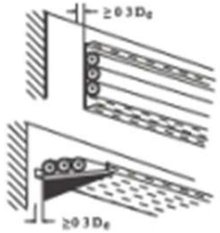
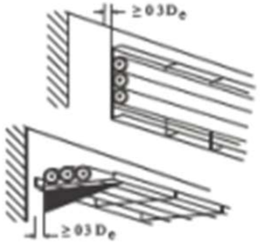
METHOD OF INSTALLATION

30		Single-core or multicore cables: - on unperforated tray run horizontally or vertically [c, h]	C with item 2 of Table 4C1
31		Single-core or multicore cables: - on perforated tray run horizontally or vertically [c, h]	**E or F**
32		Single-core or multicore cables: - on brackets or on a wire mesh tray run horizontally or vertically [c, h]	**E or F**

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SIZING OF PROTECTIVE CONDUCTOR

- The cross-sectional area of every protective conductor, other than a protective bonding conductor, shall be
    - calculated in accordance with Regulation 543.1.3 or
    - selected in accordance with Regulation 543.1.4

- If the protective conductor
    - Is not an integral part of a cable, or
    - Is not formed by conduit, ducting or trunking, or
    - Is not contained in an enclosure formed by a wiring system,

The cross-sectional area shall be not less than $2.5mm^2$ copper equivalent if protection against mechanical is provided, and $4mm^2$ copper equivalent if protection against mechanical is not provided.

SIZING OF PROTECTIVE CONDUCTOR

- Calculation of the cross-sectional area of the protective conductor in accordance with Regulation 543.1.3:

$$S = \frac{\sqrt{I^2 t}}{k}$$

NOTE: This equation is an adiabatic equation and is applicable for disconnection times not exceeding 5s.

where:

- S is the nominal cross-sectional area of the conductor in mm^2
- I is the value in amperes (rms for AC) of fault current for a fault of negligible impedance, which can flow through the associated protective device, due account being taken of the current limiting effect of the circuit impedances and the limiting capability (I^2t) of that protective device
- t is the operating time of the protective device in seconds corresponding to the fault current I amperes
- k is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

SIZING OF PROTECTIVE CONDUCTOR

Example:

The fault current is 6kA and the disconnection time of the protective device is 0.2 sec. Calculate the size of the protective conductor made of copper which is not integrated or bunched together with the power cable.

Solution:

I_f = 10 kA
t = 0.2 s
k = 143

$$S = \frac{\text{sqrt}\ (6000^2 * 0.2)}{143}$$

S = 18.76 mm^2

TABLE 54.2 –
Values of k for insulated protective conductor not incorporated in a cable and not bunched with cables, or for seperate bare protective conductor in contact with cable covering but not bunched with cables, where the assumed initial temperature is 30 °C

Material of conductor	Insulation of protective conductor or cable covering		
	70 °C thermoplastic	90 °C thermoplastic	90 °C thermosetting
Copper	143/133*	143/133*	176
Aluminium	95/88*	95/88*	116
Steel	52	52	64
Assumed initial temperature	30 °C	30 °C	30 °C
Final temperature	160 °C/140 °C*	160 °C/140 °C*	250 °C

* Above 300 mm^2

So, the selected Protective Conductor is 1C x 25mm^2 Cu/PVC.

SIZING OF PROTECTIVE CONDUCTOR

- Selection of the cross-sectional area of the protective conductor in accordance with Regulation 543.1.4:

543.1.4 Where it is desired not to calculate the minimum cross-sectional area of a protective conductor in accordance with Regulation 543.1.3, the cross-sectional area may be determined in accordance with Table 54.7.

Where the application of Table 54.7 produces a non-standard size, a conductor having a larger standard cross-sectional area shall be used.

TABLE 54.7 –
Minimum cross-sectional area of protective conductor in relation to the cross-sectional area of associated line conductor

Cross-sectional area of line conductor S	Minimum cross-sectional area of the corresponding protective conductor	
	If the protective conductor is of the same material as the line conductor	If the protective conductor is not of the same material as the line conductor
(mm^2)	(mm^2)	(mm^2)
$S \leq 16$	S	$\frac{k_1}{k_2} \times S$
$16 < S \leq 35$	16	$\frac{k_1}{k_2} \times 16$
$S > 35$	$\frac{S}{2}$	$\frac{k_1}{k_2} \times \frac{S}{2}$

where:

k_1 is the value of k for the line conductor, selected from Table 43.1 in Chapter 43 according to the materials of both conductor and insulation.

k_2 is the value of k for the protective conductor, selected from Tables 54.2 to 54.6, as applicable.

TYPES OF PROTECTIVE CONDUCTOR

- A protective conductor may consist of one or more of the following:
  - ✓ A single core cable.
  - ✓ A conductor in a cable.
  - ✓ An insulated or bare conductor in a common enclosure with insulated live conductors.
  - ✓ A fixed bare or insulated conductor.
  - ✓ A metal covering, for example, the sheath, screen or amouring of a cable.
  - ✓ A metal conduit, metallic cable management system or other enclosure or electrically continuous support system for conductors.
  - ✓ An extraneous-conductive-parts complying with Regulation 543.2.6.

THE MINIMUM CROSS-SECTIONAL AREA OF A BURIED EARTHING CONDUCTOR

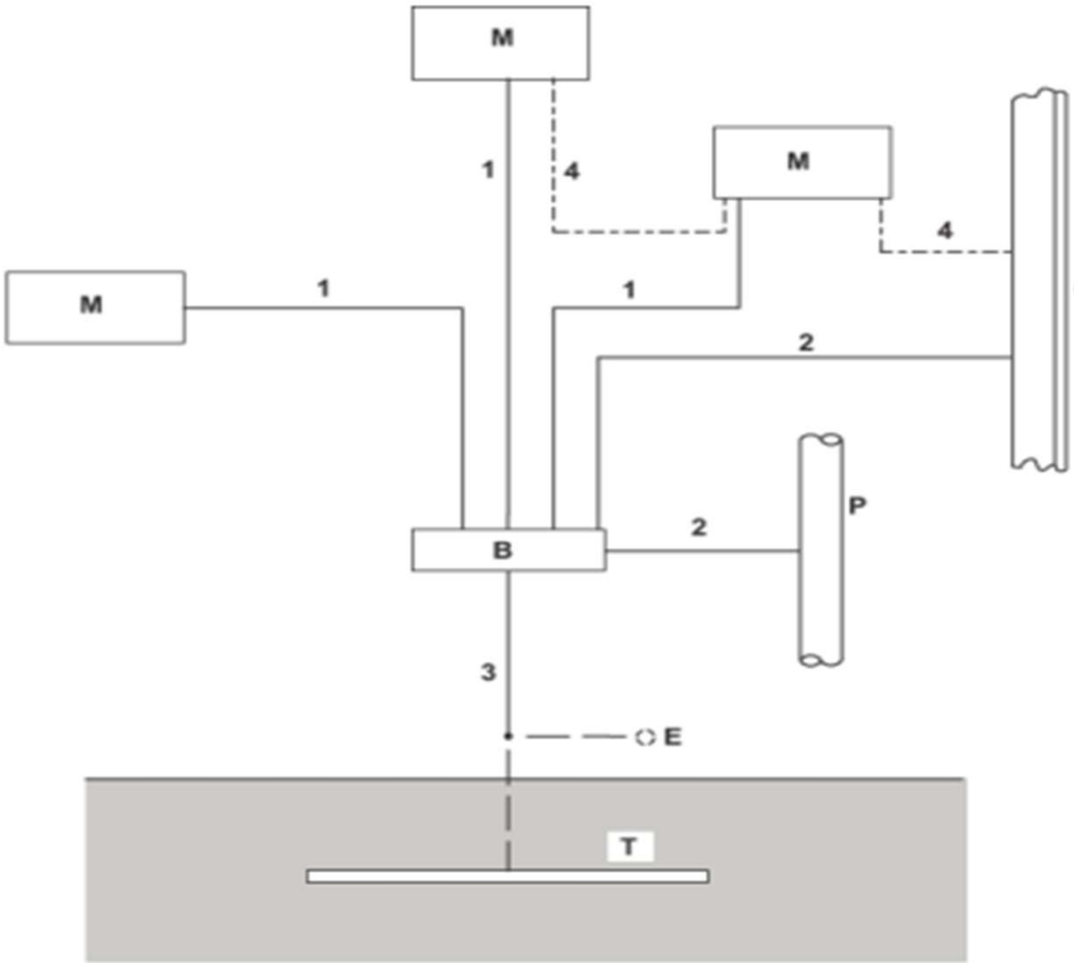
TABLE 54.1 –
Minimum cross-sectional area of a buried earthing conductor

	Protected against mechanical damage	Not protected against mechanical damage
Protected against corrosion by a sheath	2.5 mm^2 copper 10 mm^2 steel	16 mm^2 copper 16 mm^2 coated steel
Not protected against corrosion	25 mm^2 copper 50 mm^2 steel	

542.3.2 The connection of an earthing conductor to an earth electrode or other means of earthing shall be soundly made and be electrically and mechanically satisfactory, and labelled in accordance with Regulation 514.13.1(i). It shall be suitably protected against corrosion.

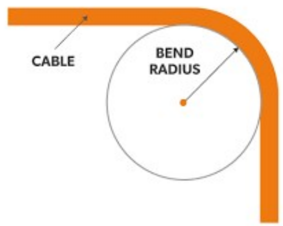
TYPICAL EARTHING ARRANGEMENT

Fig 2.1 – Illustration of earthing and protective conductor terms (see Chapter 54)



1,2,3,4	=	protective conductors
1	=	circuit protective conductor
2	=	main protective bonding conductor
3	=	earthing conductor
4	=	supplementary protective bonding conductors (where required)
B	=	main earthing terminal
M	=	exposed-conductive-part
C	=	extraneous-conductive-part
P	=	main metallic water pipe (extraneous-conductive-part)
T	=	earth electrode (TT and IT systems)
E	=	other means of earthing (TN systems)

CABLE BENDING



- Cables can’t be bended as we want.
- There is something called minimum bending radius applicable for cables.
- This minimum bending radius may vary depends on cable size, cable construction, conductor type, sheathing & insulation types, etc.
- The manufacturer’s recommendation must be followed for the minimum bending radius for various types of cables.
- Generally, the minimum bending radius is given as 8 times the overall cable diameter for non-armoured cables and 12 times the overall cable diameter for armoured cables.
- It is highly recommended to maintain the minimum bending radius suggested by the cable manufacturer in order to avoid any property damages to the materials used for sheathing, insulation as well as conductor.