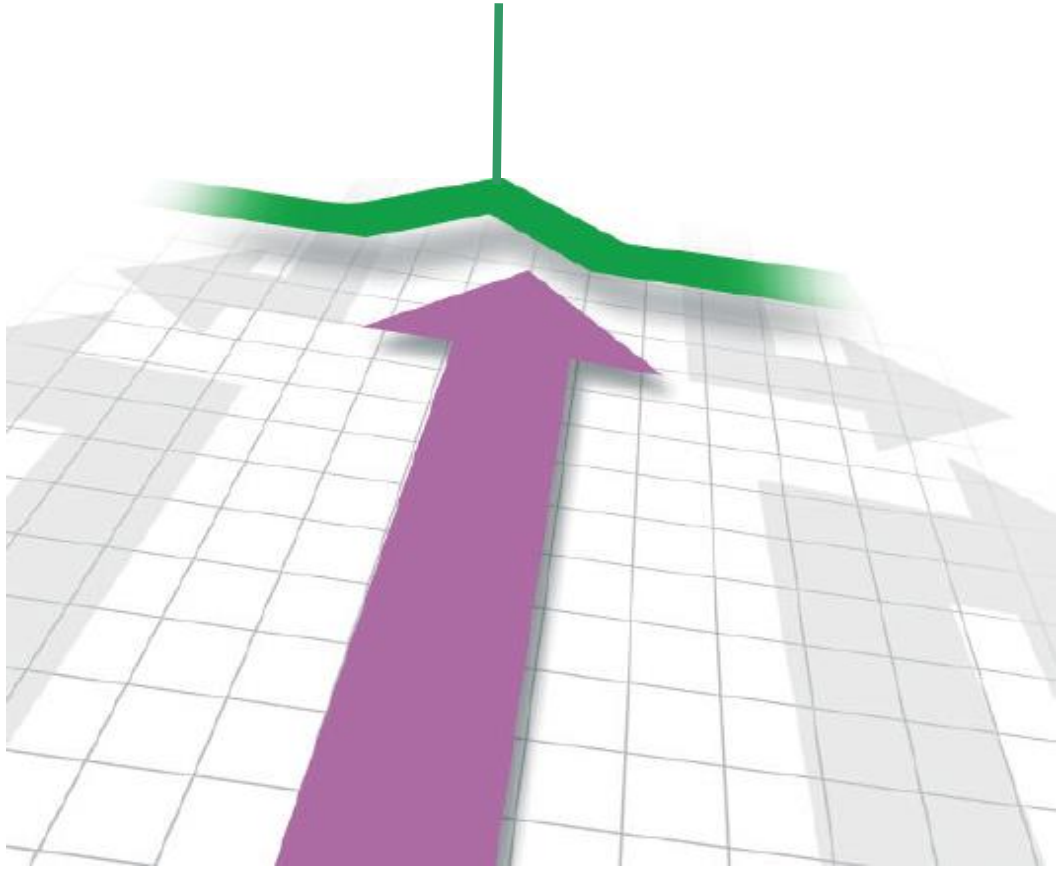
Cables & Power Network Calculations



By

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1	L.V Conventional Cables Construction
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3	Conventional Cables Classifications
4	General Hints about cables
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6	How to write Conventional cables on SLD
7	Fire Cables
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Schneider
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L.V Conventional Cables Construction

Low Voltage Cable Construction

1. Conductor

- AL
- CU

2. Insulation or Dielectric

- PVC (Polyvinyl Chloride) - “Thermoplastic”
- XLPE (Cross-linked polyethylene) - “Thermoset”

3. Filler or Assembly

- PVC or Polypropylene to fill spaces between cores to make the round form of cable.
- Polypropylene tape is used as a barrier tape over the laid up cores. Such tape(s) will bind the cores together and prevents them from opening out

4. Bedding or Inner jacket or Inner Sheath

- PVC bedding , Mandatory in case of armoured cables.
- Used under cable armouring to protect the laid up cores and as a separation sheath

5. Armouring

- Steel tape or wire tape , it is used for protection of cable against mechanical stresses.

6. Outer jacket or Outer Sheath

- PVC , it contains & protects all cable layers and its metallic parts from corrosion.

Self Study Question "Q1"

Self Study Question “Q1”

- ✓ **State M.V Cable construction**
- ✓ **Clarify the function of each layer in this construction.**

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Interactive Question !

When It’s Mandatory to use Bedding in cables?

Conventional Cables Classifications

Conventional Cables Classifications

1. **According to conductor type**
   - AL
   - CU
2. **According to Number of conductors**
   - Single Core
   - Multicores (2 or 3 or 4) Cores
3. **Neutral type “Regarding Multi Cores Cables”**
   - Full Neutral
   - Half Neutral
4. **According to Inner Insulation Types**
   - PVC
   - XLPE

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Interactive Question !

“Regarding Multi-Cores Cables”
When to use 2 cores , 3 cores , 4 cores cables respectively ?

5. According to Insulation Voltage Level

Voltage

The strandard rated voltage of a cable is denoted by Uo/U (Um),

where

Uo : is the rated power-frequency voltage between conductor and earth or metallic screen.

U : is the rated power-frequency voltage between conductors.

Um: is the maximum continuously permissible operating voltage of a cable at time or in any part of the network.

Uo/U (kV)	0.6/1	1.8/3	3.6/6	6/10	8.7/15	12/20	18/30	38/66	76/132	127/220
Um (kV)	1.2	3.6	7.2	12	17.5	24	36	72.5	145	245

6. According to Insulation Voltage Level

- PVC (Thermo-plastic)
  - ❖ Lower cost
  - ❖ Max. operating temp. = 70 or 85 °C
  - ❖ Max. short circuit temp. = 160 °C
  - ❖ Softens at high temperatures

- XLPE (Thermo-Setting)
  - ❖ Higher cost
  - ❖ Max. operating temp. = 90 ℃
  - ❖ Max. short circuit temp. = 250 ℃
  - ❖ Highly resistant against humidity
  - ❖ Rigid, doesn't Soften at high temperatures
  - ❖ Superior electrical properties (XLPE Cables provides higher current rating than PVC cables for same C.S.A
  - ❖ Superior Moisture resistance capability than PVC cables.
  - ❖ Longer service life compared to PVC Cables
  - ❖ XLPE Cable is environment friendly compared with PVC insulated Cable while burning

7. According to Armouring

- Armoured
  - ❖ STA (Steel Tape Armouring)
  - ❖ SWA (Steel Wire Armouring)
  - ❖ DST (Double Steel Tape Armouring)
  - ❖ ATA (Aluminum Tape Armouring)
  - ❖ AWA (Aluminum Wire Armouring)

- Non-Armoured

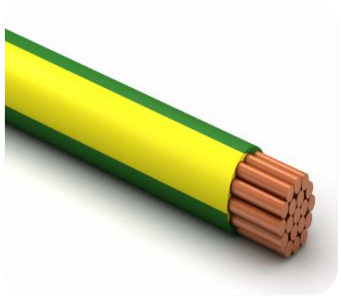
STA

SWA

General Hints about Cables

General Hints about cables

✓ Stranded conductors are preferable than solid conductors due to skin effect.



Stranded

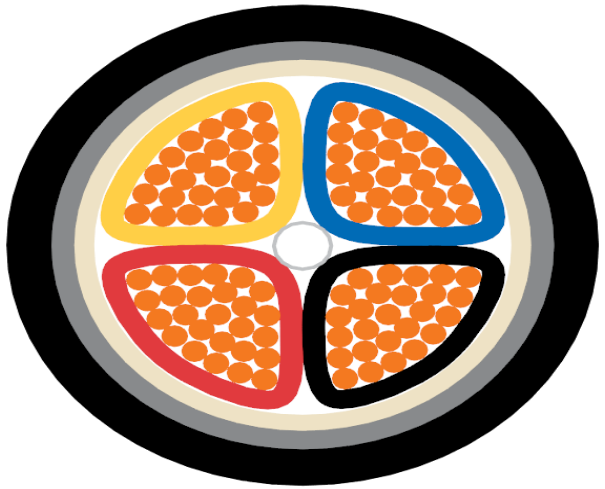
Solid

✓ Armouring enhances Cable's mechanical strength but reduces cable's flexibility.

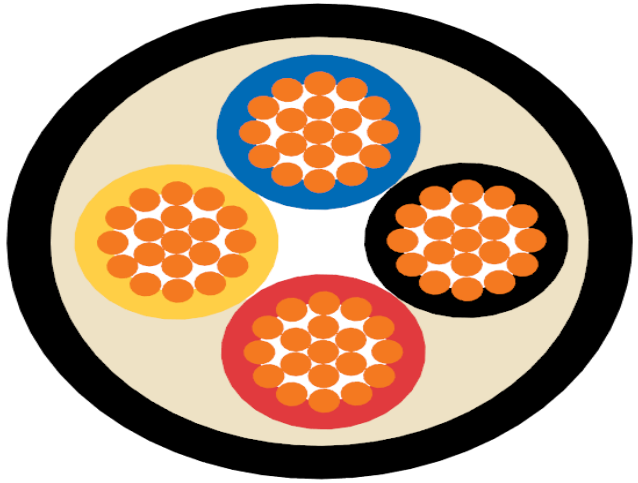
✓ In case of armoured single core cables , ATA or AWA shall be used in stead of STA or SWA.

✓Core shape types

Sectoral



Circular



Self Study Question "Q2"

Self Study Question “Q2”

- ✓ **State Difference between SWA & STA Armoured cables regarding below mentioned points:**
  - **Overall Cable Diameter.**
  - **Overall Cable Weight.**

- ✓ **State When to use Full Neutral Cables & Half Neutral Cables.**

How to write Conventional cables on SLD

Cables

- (4x240) CU/XLPE/PVC +(1x120) CU/PVC
- (3x240+1X120) CU/PVC/PVC +(1x120) CU/PVC
- 2//(4x240) CU/XLPE/PVC +(1x240) CU/PVC
- 4//(4x240) CU/XLPE/PVC +2//(1x240) CU/PVC

Wires

- 3X(1X6) CU/PVC

Fire Cables

INTRODUCTION

- In a fire accident some people die because of the fire, but the majority die because of the smoke.

- Halogen is added to the plastics used in conductor's insulation to give it the property of self-extinguish such as PVC which contain chlorine atom. Chlorine is one of halogens as Fluorine, Bromide and Iodine. But, in case of fire, halogens produce great amount of smoke which contains That hamper visibility required for escaping from a dangerous places or trying to find an exit out.

- (HCI, CO & CO2) which are produced while a conventional cable is burning out, dissolves in the fluids of the human body organs like lungs, nose and eye causing cell damage, shortage of oxygen and suffocation.

LS0H Cables

- **Why to use LSHF cables ?**
  - ✓ Doesn't contain halogen: hydrochloric acid isn't formed during the fire so there is no threat of suffocation.
  - ✓ Reduces smoke to the minimum: reducing the confusion , panic and suffocation ratio.

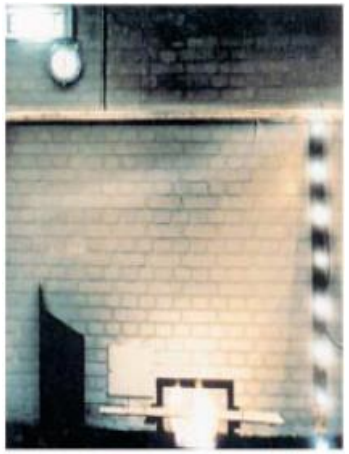
- **When to use LSHF cables ?**
  - ✓ In theaters , hotels , hospitals , under ground tunnels and all closed public places where we can't afford losing people by suffocation.

- **LSFH VS PVC**

PVC Cables: 30 sec

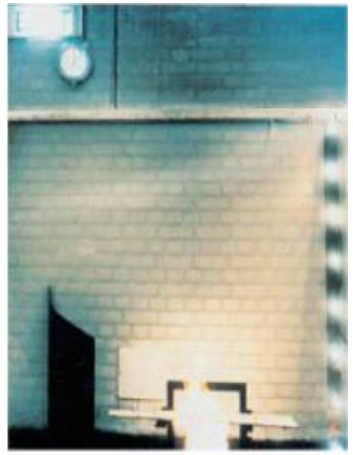
PVC Cables: 3 mins

PVC Cables: 6 mins

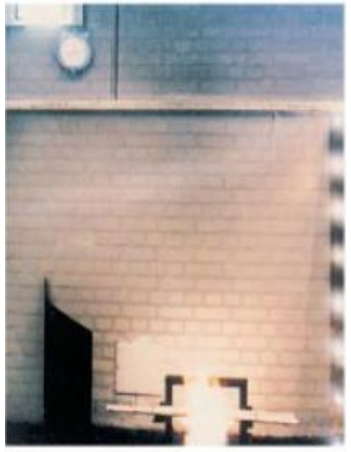


LSHF: 30 sec

LSHF: 3 mins



LSHF: 6 mins



LSHF:12 mins

How to Write LS0H on SLD?

- ✓ **For cables**: (4 x70) CU/XLPE/LSHF
- ✓ **For wires**:3X(1X6) CU/LS0H

- ✓ **Note**: LS0H cables have Flame Retardancy properties according to most of cables manufacturers.

What is meant be: fire retardant cable?

- Cables which doesn't spread fire rapidly according to test certificates IEC / BS.
- Cables which are self-extinguishing.

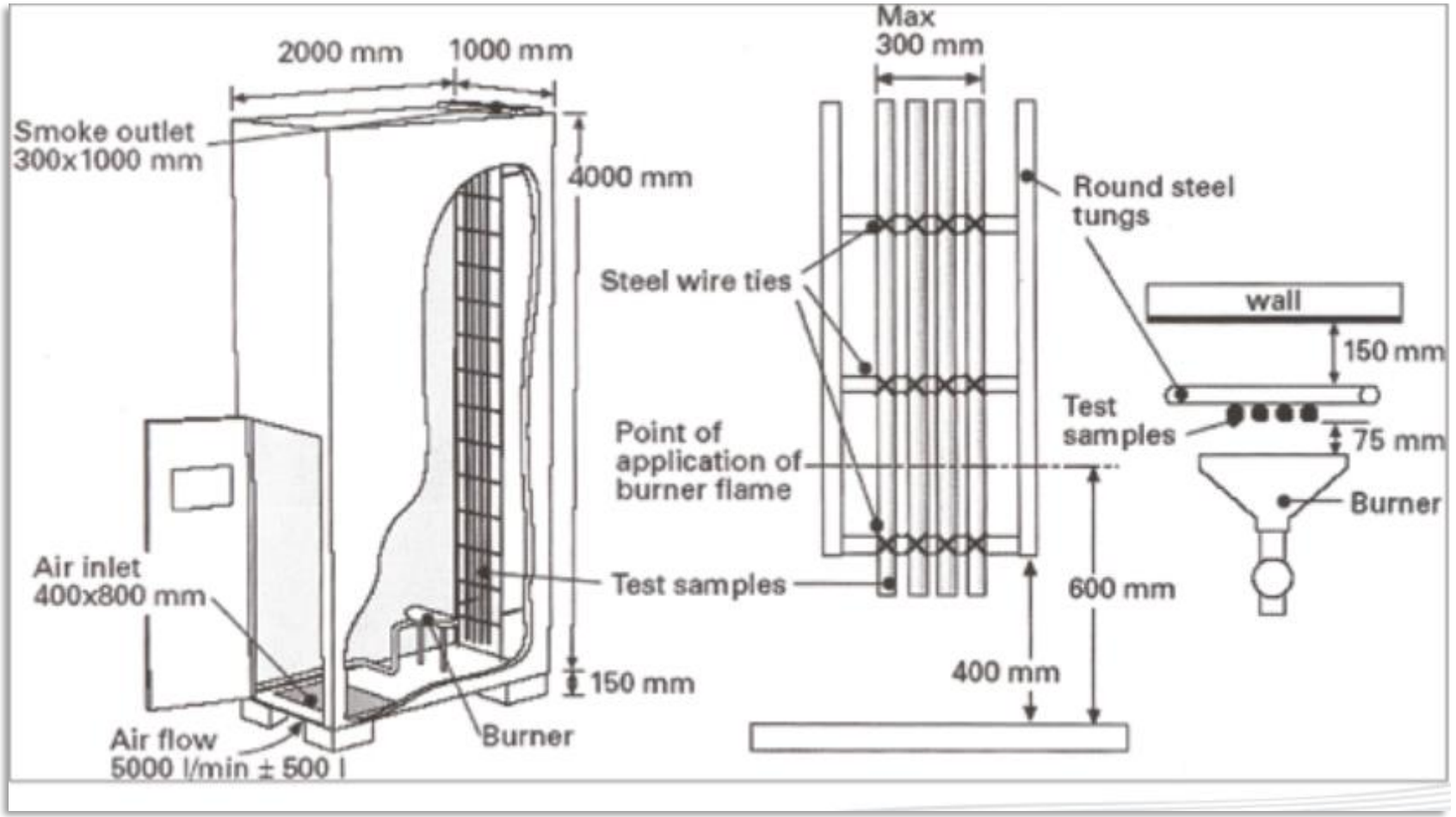
According to BS EN / IEC60332 There are 3 Categories of flame retardant cables A, B & C

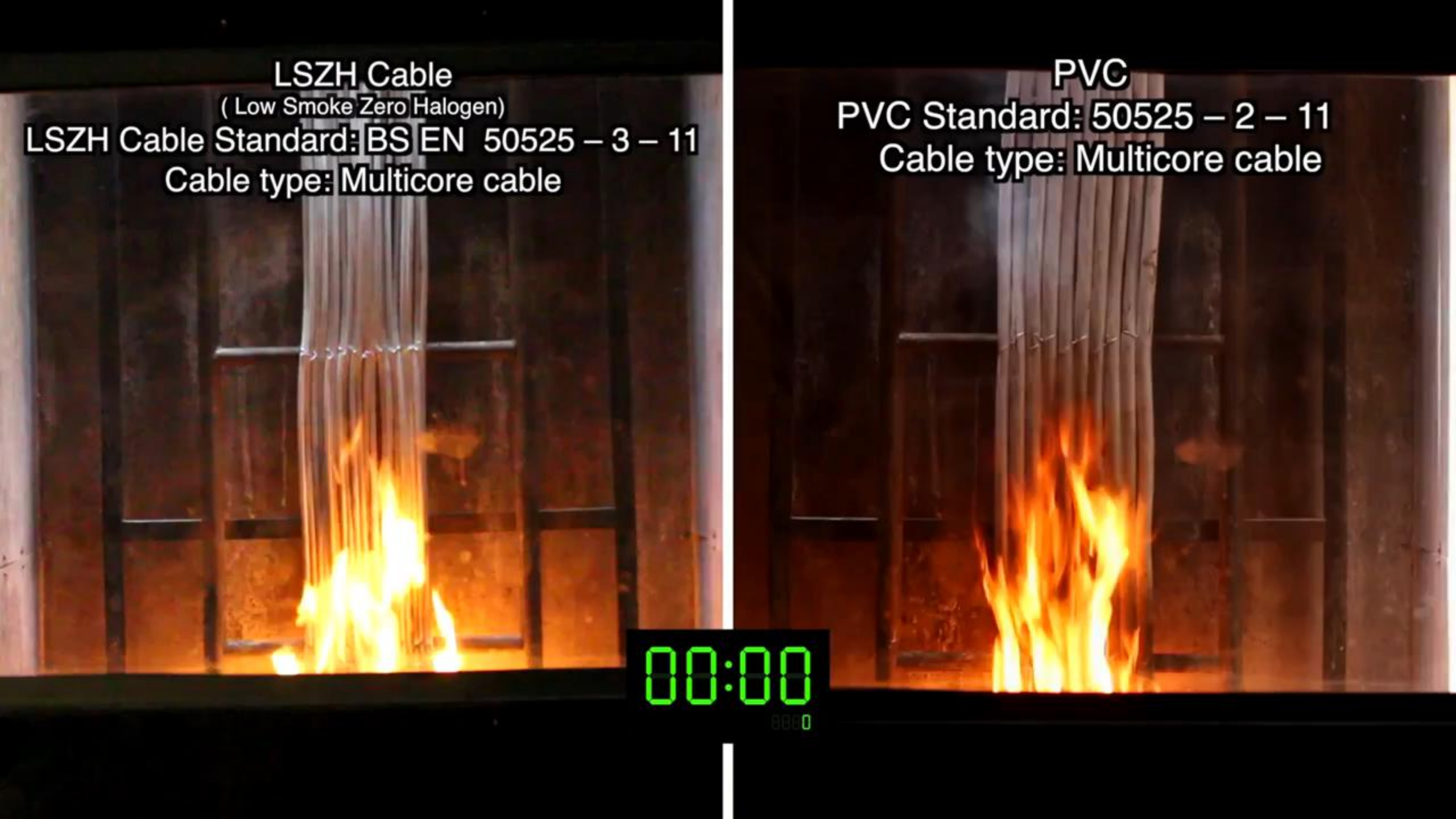
For Example:

BS EN / IEC 60332-3-22 (CAT A): is the most severe test:

sample of cables of length of 3.5m at least, fixed vertically on a ladder, then to be exposed to a flame of 70.000 Btu/h for a period of (40) minutes.

Length of the damage will be measured, the length of charred position on the test sample should not have reached a height exceeding 2.5 m above the bottom edge of the burner.


2000 mm
1000 mm
Smoke outlet
300x1000 mm
4000 mm
Air inlet
400x800 mm
150 mm
Air flow
5000 l/min ± 500 l
Burner
Max
300 mm
Round steel
tungs
Steel wire ties
wall
150 mm
Test
samples
75 mm
Point of
application of
burner flame
Test samples
Burner
600 mm
400 mm


LSZH Cable
(Low Smoke Zero Halogen)
LSZH Cable Standard: BS EN 50525 – 3 – 11
Cable type: Multicore cable
PVC
PVC Standard: 50525 – 2 – 11
Cable type: Multicore cable
00:00


EMERGENCY
EXIT
PVC
HALOGEN FREE

Flame Resistance Cables

- **Why to use Fire Resistant cables ?**

✓ Designed to maintain circuit integrity of those vital emergency services during the fire for certain time (fire safety loads).

✓ The individual conductors are wrapped with a layer of fire resisting mica/glass tape which prevents phase to phase and phase to earth contact even after the insulation has been burnt away.

- **Where to use Fire Resistant cables ?**

Feeding all fire safety loads at any type of buildings where the integrity of the circuit is required during the fire conditions , for example:

✓ Fire pumps.

✓ EMCCs feeding loads related to life safety like: smoke fans & pressurization fans ...etc.

IEC 60331 Fire Resistance Test:

✓ A sample is connected to an electrical supply at its rated voltage from one end with indicator lamps at the other end.
Fire is applied for a period of 90 minutes with temperature on the cable equals to 750°C

✓ The fire shall be extinguished but the cable sample shall remain energized for a further 15 min.
The cable sample must maintain its circuit integrity after the total period of test (105 minutes).

BS 6387 Fire Resistance Test (more stringent than IEC 60331-21):

1.Fire resistant test (Fire Alone):

Cables are tested by gas burner flame while a current is passing at its rate voltage Four categories are defined:

- **Category A:** Cables are subjected to fire at 650°C for 3 hours.
- **Category B:** Cables are subjected to fire at 750°C for 3 hours.
- **Category C:** Cables are subjected to fire at 950°C for 3 hours.
- **Category S:** Cables are subjected to fire at 950°C for 20 minutes.

2. Resistance to fire with water:

- **Category W:** Cables are subjected to fire at 650°C for 15 minutes, then at 650°C with water spray for a further 15 minutes.

3. Resistance to fire with water:

Resistance to fire with mechanical shock:

- **Category X:** Cables are subjected to fire at 650°C with mechanical shock each 30 seconds for 15 minutes.
- **Category Y:** Cables are subjected to fire at 750°C with mechanical shock each 30 seconds for 15 minutes.
- **Category Z:** Cables are subjected to fire at 950°C with mechanical shock each 30 seconds for 15 minutes.

The highest category for BS 6387 is **CWZ where the three tests are performed on** the three samples of the same cable.

Planning & Design aspects to use Fire Cables:

Planning an electrical safety system means finding answers to these questions:

- ✓Which electrical system has to be supplied for how long?
- ✓Which circuits are involved (safety circuits)?
- ✓Which is the best cable routing for these circuits?
- ✓Are there restrictions concerning fire load (like fire pump)?
- ✓How many hours required to evacuate the building acc. to evacuation plan

How to Write Fire Cables on SLD:

- Regarding LS0H Cables:
  - ✓ For cables: (3 x70 + 1 x 35) CU/XLPE/LSHF
  - ✓ For wires: 3X(1X6) CU/LS0H

- Regarding Fire Resistant Cables:
  - ✓ For cables: (3 x70 + 1 x 35) CU/Mica/XLPE/LSHF
  - ✓ For wires: 3X(1X6) CU/LS0H

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Interactive Question !

How to write: Multi-Cores Cable – Half Neutral – Steel Tap Armoured – Fire Resistant – C.S.A = 50 mm^2

Self Study Question "Q3"

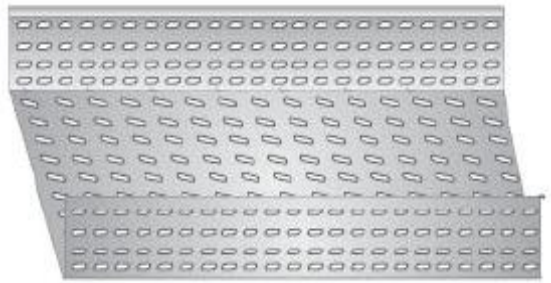
Self Study Question “Q3”

- ✓ **Provide a conclusion about below tests:**
  - For Low Smoke and Halogen free Cables
    - Smoke Emission Tests: (IEC 61034, BS EN 61034)
    - Acid Gas Emission Tests: (IEC 60754, BS EN 50267)
- ✓ **Provide a conclusion about below tests:**
  - For flame retardant cables
    - BS EN 60332, IEC 60332-3
- ✓ **Provide a conclusion about below tests:**
  - For flame resistant cables
    - BS BS 6387 , IEC 60331-21

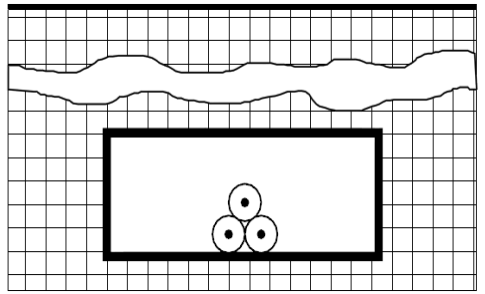
Cable Routing Types

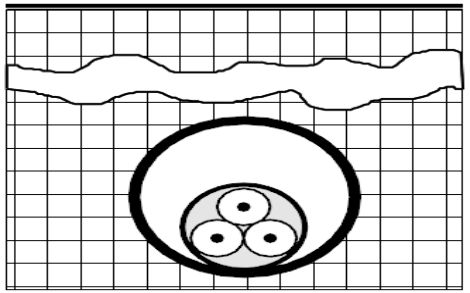
Cable Routing Types

- **Free in air**
  - ✓ Cables are installed on cable trays or cable ladders.

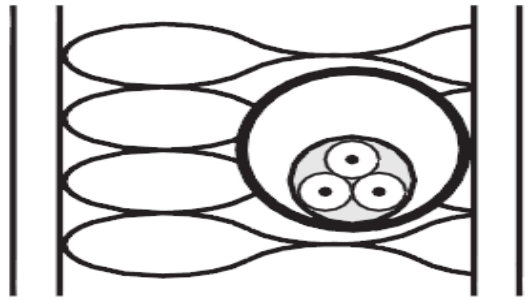


- **Laid in ground**
  - ✓ Directly buried in ground
  - ✓ Buried in ground inside conduit
  - ✓ Buried in ground inside duct bank “Concrete encasement”



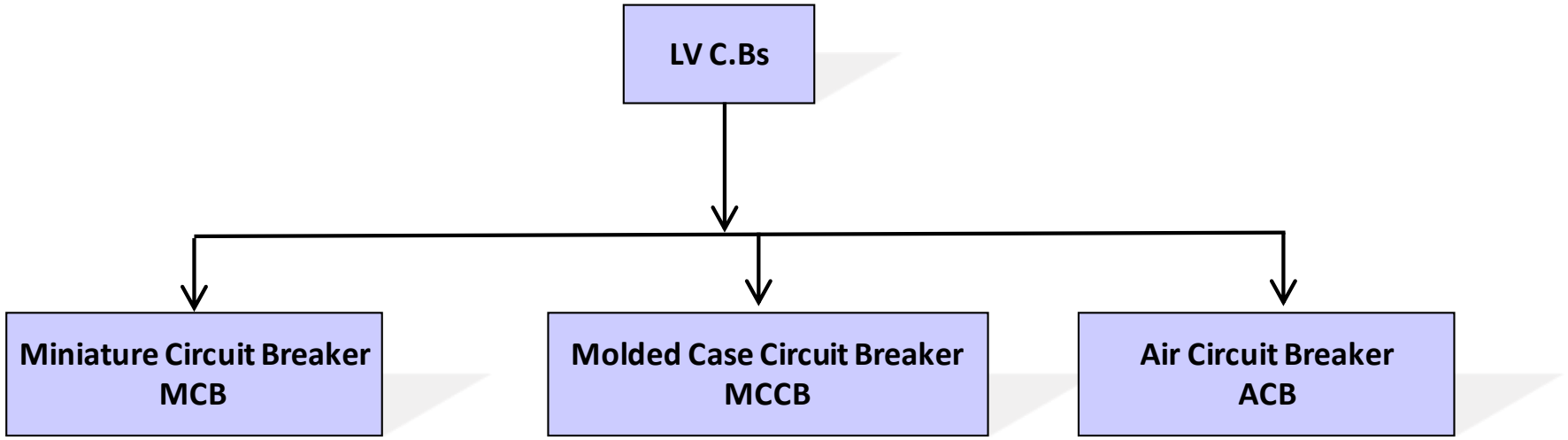


- **In conduits**
  - ✓ Inside wall



Cables Derating Factors Overview

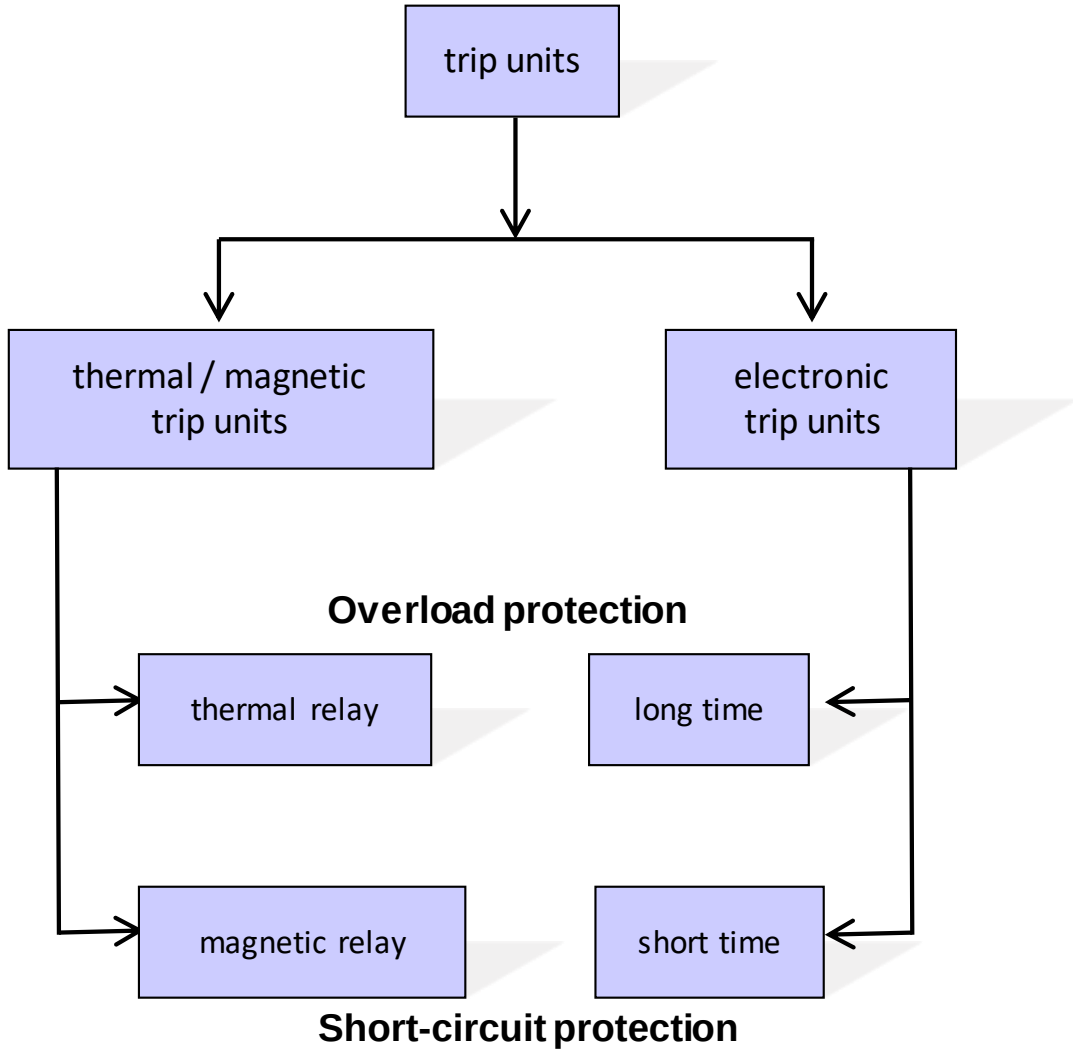
Type of Circuit Breakers



Type of trip units

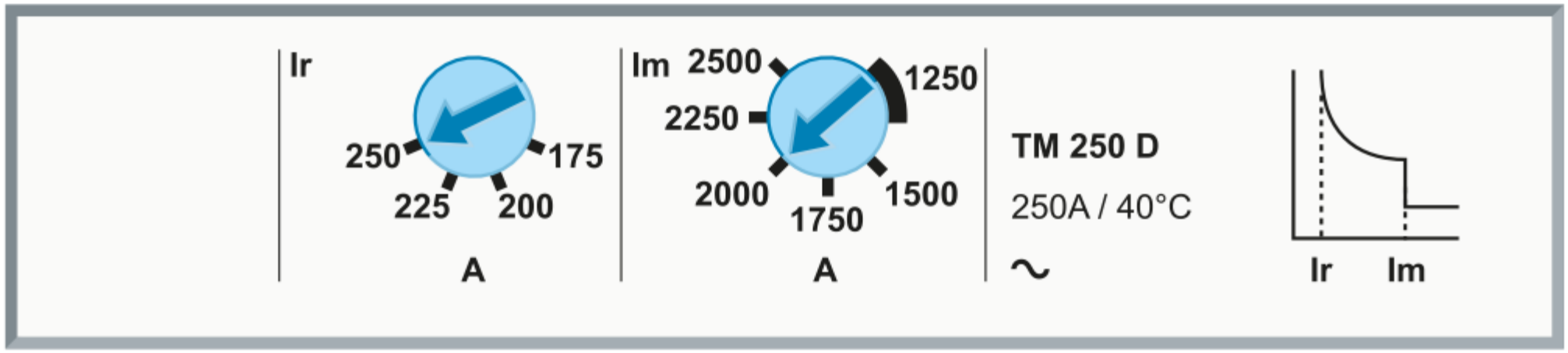
- ✓There are basically two types of units:
  - mechanical (commonly known as thermal / magnetic trip units)
  - electronic (Micro-logic) trip units (also known as solid state trip units)

- ✓Both trip units serve the same primary function:
  - to provide overcurrent protection,
  - to provide the disconnection of a circuit carrying an excess current.

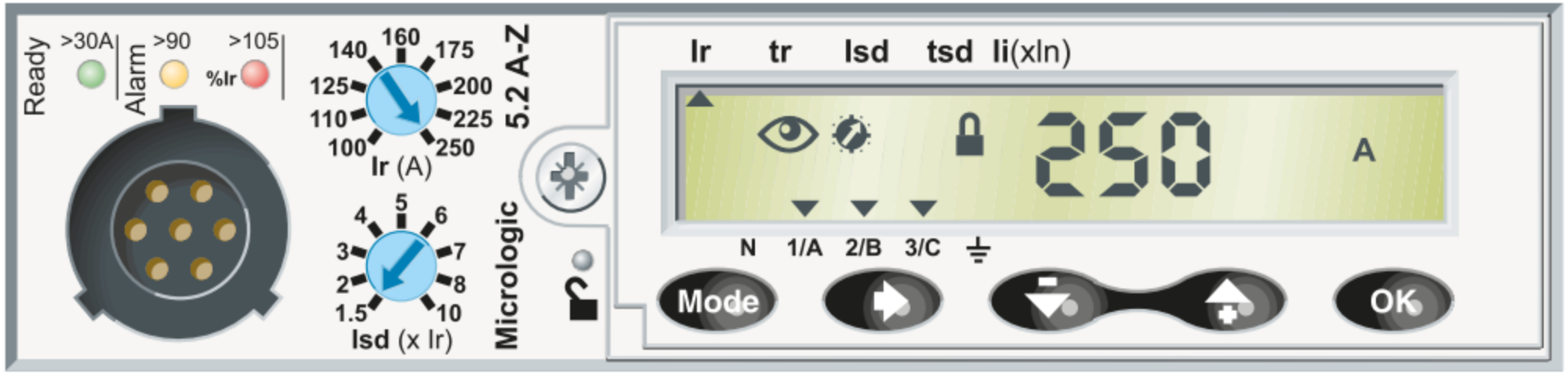


The difference between a thermal-magnetic and electronic curve

TM



M.L



Relation between (Protective device , Cable & Load)

$$I_b \leq I_n \leq I_z$$

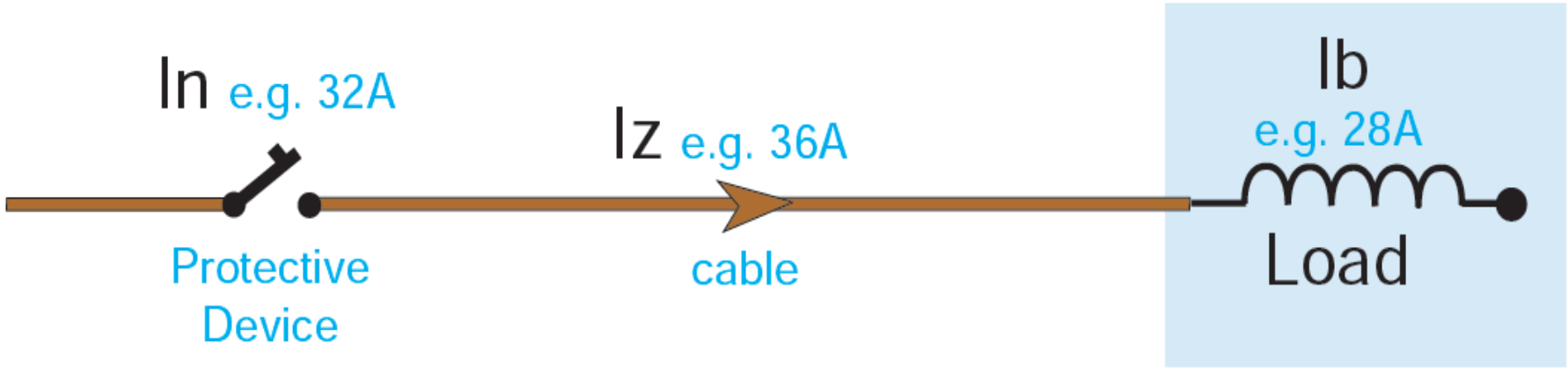
where

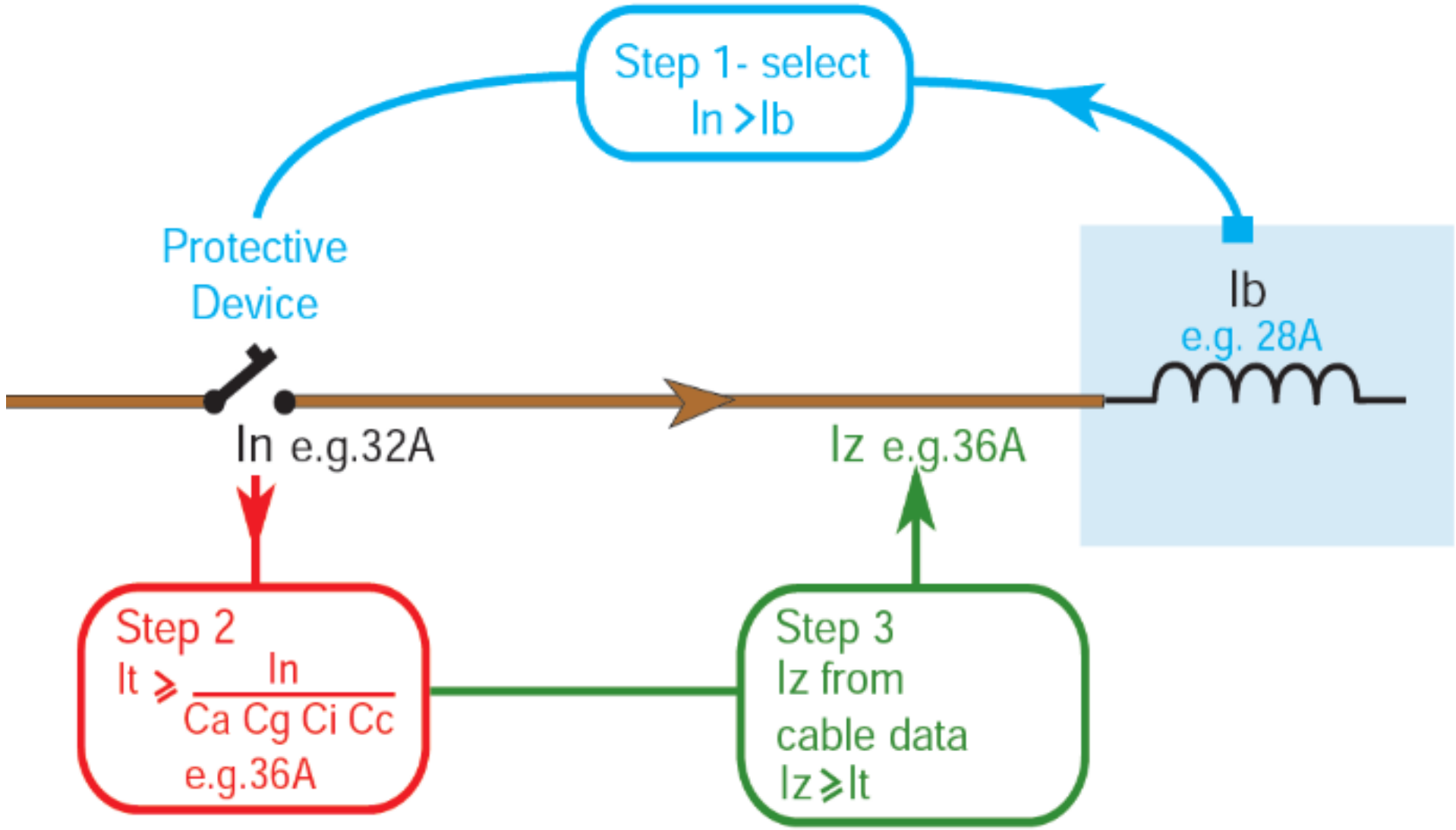
I_b is the design current of the circuit,

I_n is the nominal current or current setting of the protective device,

I_z is the current-carrying capacity of the conductor in the particular installation conditions.

Pictorially represented this requirement is as follows:




Step 1- select
In >Ib
Protective
Device
Ib
e.g. 28A
In e.g.32A
Iz e.g.36A
Step 2
It ⩾ In / Ca Cg Ci Cc
e.g.36A
Step 3
Iz from
cable data
Iz⩾It

$$I_B = \frac{p}{\sqrt{3}\ x\ V\ x\ P.F} \quad \textbf{or} \quad I_B = \frac{S}{\sqrt{3}\ x\ V}$$ For 3-phase load

$$I_n > I_B$$

$$I_t = \frac{In}{C.F\ (total)}$$

I_t is the target cable current carrying capacity / target cable Ampacity.

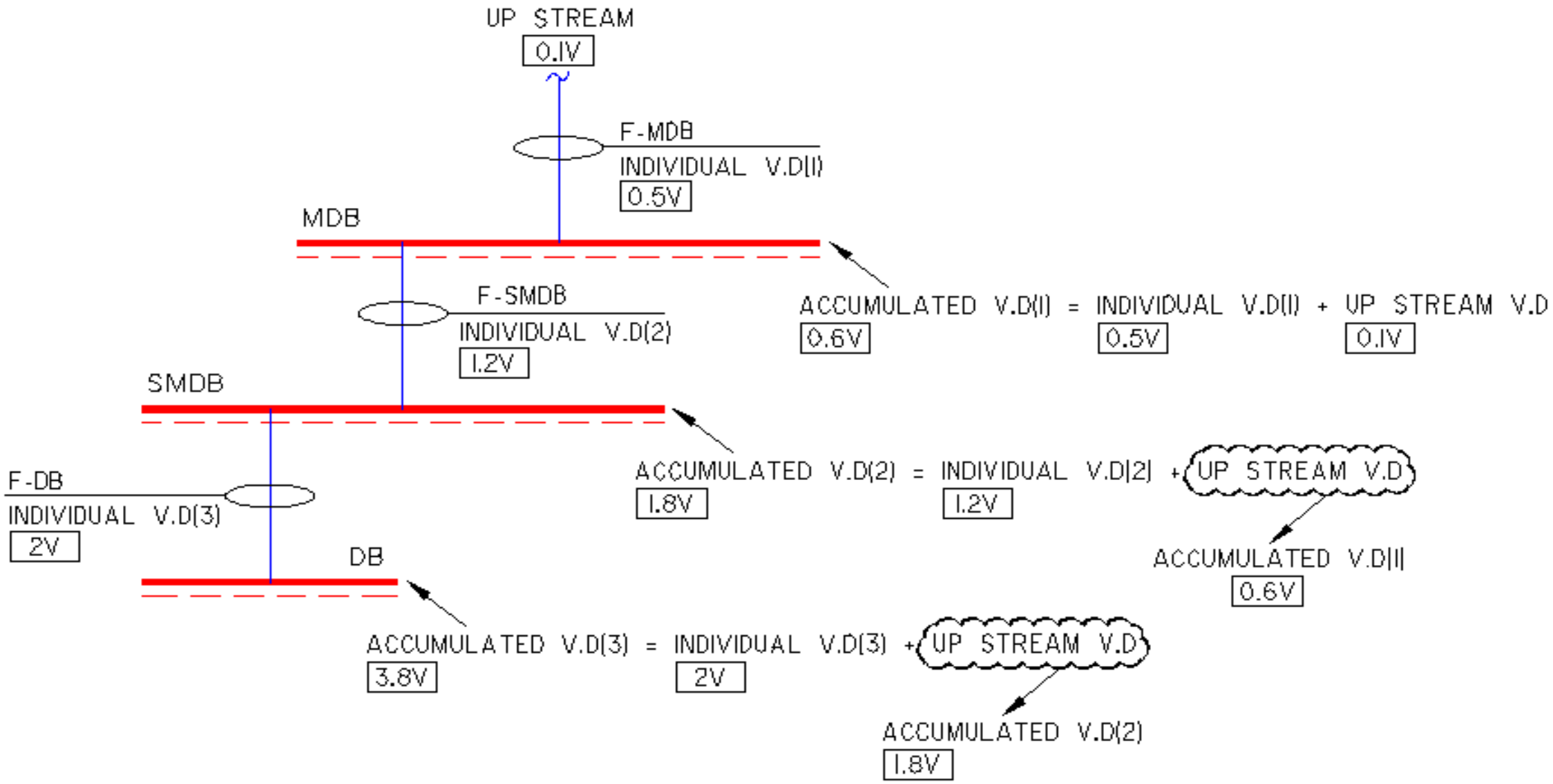
$\mathbf{C.F\ (total)}$ is the Resultant Correction factor or Resultant Derating factor according to cable installation surrounding conditions.

Finally the below condition should be applied:

$$I_Z \geq I_t > I_n > I_b$$

I_Z is the standard current carrying capacity or Cable Ampacity of cable mentioned in catalogues / codes.

Voltage Drop


UP STREAM
0.1V
F-MDB
INDIVIDUAL V.D(1)
0.5V
MDB
F-SMDB
INDIVIDUAL V.D(2)
1.2V
SMDB
F-DB
INDIVIDUAL V.D(3)
2V
DB
ACCUMULATED V.D(1) = INDIVIDUAL V.D(1) + UP STREAM V.D
0.6V
0.5V
0.1V
ACCUMULATED V.D(2) = INDIVIDUAL V.D(2) + UP STREAM V.D
1.8V
1.2V
ACCUMULATED V.D(1)
0.6V
ACCUMULATED V.D(3) = INDIVIDUAL V.D(3) + UP STREAM V.D
3.8V
2V
ACCUMULATED V.D(2)
1.8V

$$\textbf{V.D}\text{ind} = \frac{(\text{mv/A/m}) x\ I_b\ x\ L}{1000} = \ldots \text{(v)}$$

Where:
V.D = Voltage Drop (v)
(mv/A/m) = specific voltage drop
L = cable length (m)
I_b = Base current or load current (A)

Type of installations	Lighting circuits	Other uses (heating and power)
A low-voltage service connection from a LV public power distribution network	3%	5%
Consumers MV/LV substation supplied from a public distribution MV system	6%	8%

NOTE:
The previous lows are for individual V.D
Accumulated V.D = Individual V.D + Up stream voltage drop
Accumulated V.D % = 5 % according to NEC
Accumulated V.D % = 2.5 % according to EGY. CODE

$$\text{V.D\%} = \frac{V.D\ (accumulated)}{Source\ Voltage} \ldots (\%)$$

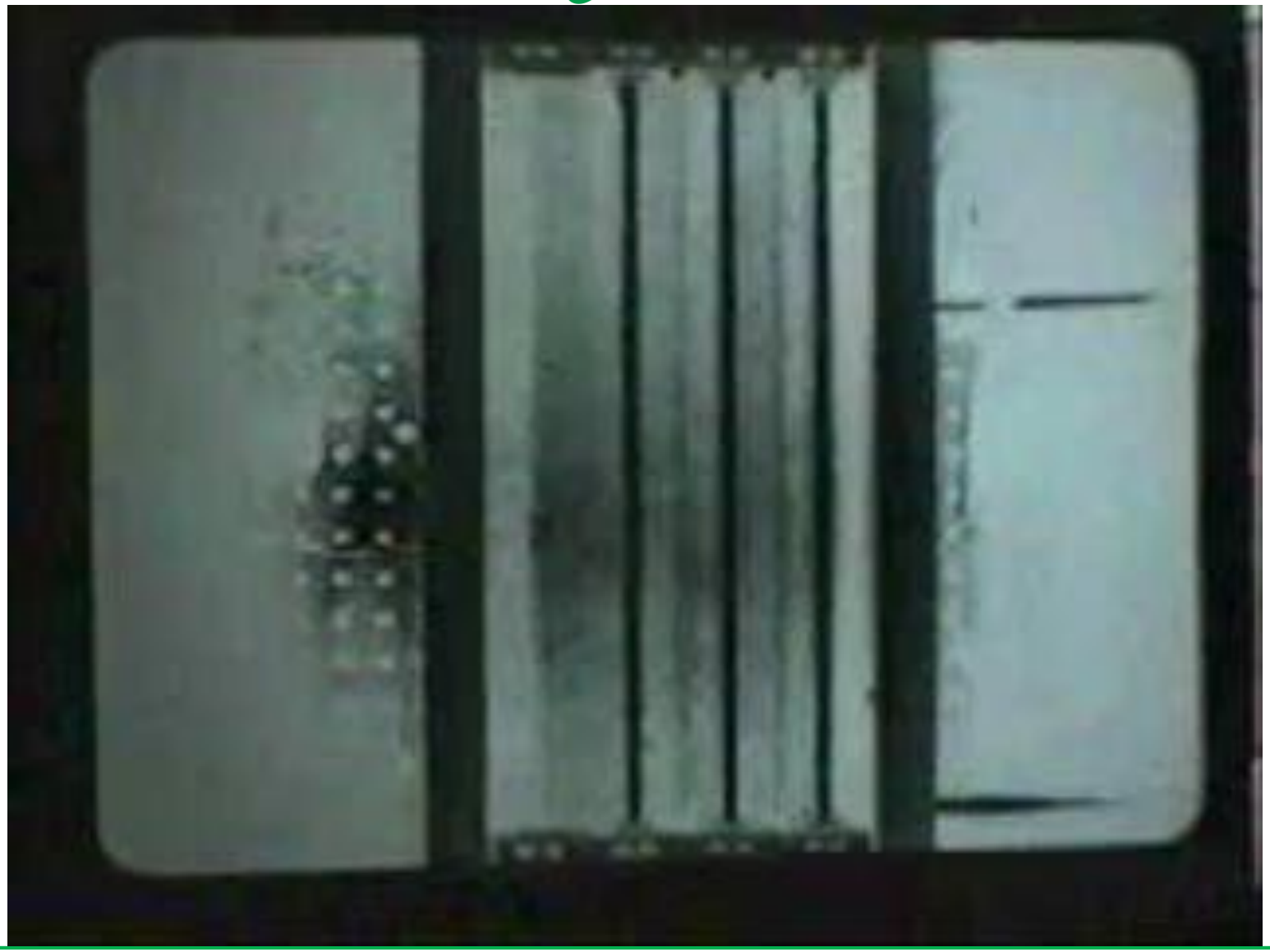
Short Circuit

The negative effects of short-circuits on installations:

Thermal effects
temperature rise in conductors.

Mechanical effects
High electrodynamic forces, High risk of electrical contacts or busbars being deformed or broken.

Electromagnetic effects
Disturbances for measuring devices located near electrical circuits.



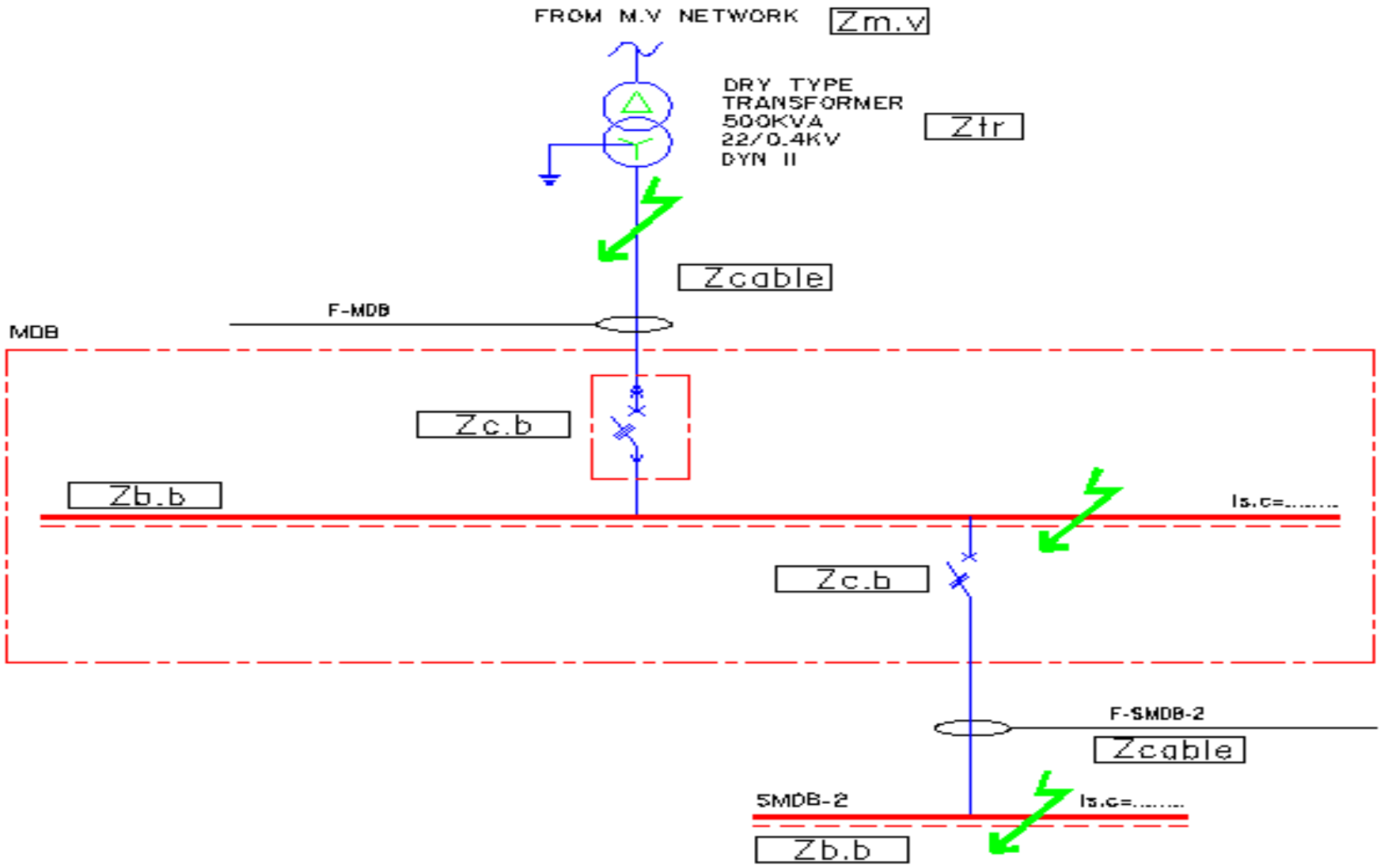
$$I_{s.c} = \frac{V_{n.l}}{Z_t}$$ = … short circuit current (KA)

Where:

$V_{n.L}$ = No load (L-N) secondary voltage of distribution transformer (V)

Z_t = Total impedance contributing in s.c level (m.Ω)

Z_t


FROM M.V NETWORK
Zm.v
DRY TYPE
TRANSFORMER
500KVA
22/0.4KV
DYN 11
Ztr
Zcable
F-MDB
MDB
Zc.b
Zb.b
Is.c=.....
Zc.b
F-SMDB-2
Zcable
SMDB-2
Is.c=.....
Zb.b

Transformer Impedance

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Rated	Oil-immersed				Cast-resin			
Power (kVA)	Usc (%)	Rtr (mΩ)	Xtr (mΩ)	Ztr (mΩ)	Usc (%)	Rtr (mΩ)	Xtr (mΩ)	Ztr (mΩ)
100	4	37.9	59.5	70.6	6	37.0	99.1	105.8
160	4	16.2	41.0	44.1	6	18.6	63.5	66.2
200	4	11.9	33.2	35.3	6	14.1	51.0	52.9
250	4	9.2	26.7	28.2	6	10.7	41.0	42.3
315	4	6.2	21.5	22.4	6	8.0	32.6	33.6
400	4	5.1	16.9	17.6	6	6.1	25.8	26.5
500	4	3.8	13.6	14.1	6	4.6	20.7	21.2
630	4	2.9	10.8	11.2	6	3.5	16.4	16.8
800	6	2.9	12.9	13.2	6	2.6	13.0	13.2
1,000	6	2.3	10.3	10.6	6	1.9	10.4	10.6
1,250	6	1.8	8.3	8.5	6	1.5	8.3	8.5
1,600	6	1.4	6.5	6.6	6	1.1	6.5	6.6
2,000	6	1.1	5.2	5.3	6	0.9	5.2	5.3

Transformer Impedance

جدول (٩/٦) قيم المقاومة . الممانعة والمعاوقة للمحولات

قدرة المحول KVA	هبوط الجهد Usc	المقاومة R_{Sc} m.ohm	الممانعة X_{Sc} m.ohm	المعاوقة Z_{Sc} m.ohm
٢٥	٪ ٤	١٧٩	١٨٣	٢٥٦
٥٠	٪ ٤	٧٠,٣	١٠٧	١٢٨
١٠٠	٪ ٤	٢٨	٥٧,٥	٦٤
١٦٠	٪ ٤	١٤,٧	٣٧,٥	٤٠
٢٠٠	٪ ٤	١١,٤	٢٩,٩	٣٢
٢٥٠	٪ ٤	٨,٣	٢٤,٢	٢٥,٦
٣١٥	٪ ٤	٦,٢٨	١٩,٣	٢٠,٣
٤٠٠	٪ ٤	٤,٦	١٥,٣	١٦
٥٠٠	٪ ٤	٣,٥٢	١٢,٣	١٢,٨
٦٣٠	٪ ٤	٢,٦٢	٩,٨٢	١٠,١٦
٨٠٠	٪ ٤,٥	٢,٥٥	٨,٦٣	٩
١٠٠٠	٪ ٥	١,٩٤	٧,٧٦	٨
١٢٥٠	٪ ٥	١,٥١	٦,٧٨	٧,٠٤
١٦٠٠	٪ ٦	١,١٣	٥,٨٩	٦
٢٠٠٠	٪ ٧	٠,٩	٥,٥٣	٥,٦

Cable Impedance

$$R_c = \rho \frac{L}{A}$$

Where:

- R_c = Cable resistance (Ω)
- ρ = Resistivity constant of conductor material (mΩ.mm²/M)
  - ρ_{cu} = 23.69 mΩ.mm²/M
  - ρ_{Al} = 37.65 mΩ.mm²/M
- L = Cable length (M)
- A = Cross sectional area (mm²)

Xc =

Cable reactance values can be obtained from the manufacturers. For c.s.a. of less than 50 mm² reactance may be ignored. In the absence of other information, a value of 0.08 mΩ/metre may be used (for 50 Hz systems) or 0.096 mΩ/metre (for 60 Hz systems). For busways (busbar trunking systems) and similar pre-wired ducting systems, the manufacturer should be consulted.

Motors Contribution in Short circuit Value

At the instant of short-circuit, a running motor will act (for a brief period) as a generator, and feed current into the fault.

In general, this fault-current contribution may be ignored. However, if the total power of motors running simultaneously is higher than 25 % of the total power of transformers, the influence of motors must be taken into account. Their total contribution can be estimated from the formula:

Iscm = 3.5 In from each motor i.e. 3.5*m*In for *m* similar motors operating concurrently.

The motors concerned will be the 3-phase motors only; single-phase-motor contribution being insignificant.

Short circuit Rating of M.V network acc. To Egy. Code:

تـــتحمل اللوحة سعة قطع لا تقل عن ٢٥ كيلو أمبير عند جهد ١١ كيلو فولت أو ٢٠ كيلو أمبير عند جهد ٢٢ كيلو فولت.

Solved Example