

## ► 4 GENERALITIES

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### 4.1 CHOICE OF VOLTAGE

The rated voltage is specified as  $U_o / U$  where :

$U_o$  is the rated voltage between conductor and screen or outer metallic protection.

$U$  the rated voltage between any two conductors.

In three phase systems  $U_o$  is  $U / \sqrt{3}$

The voltage of the cable must be chosen according to the maximum voltage  $U_m$  in normal working conditions, which must not exceed the rated voltage by more than 20%.

The following table gives the maximum permissible operating voltage relative to each rated voltage ( $U_o / U$ ).

| Rated voltage<br>$U_o / U$ (Kv) | Max. voltage<br>$U_m$ (Kv) |
|---------------------------------|----------------------------|
| 1.8 / 3                         | 3.6                        |
| 3.6 / 6                         | 7.2                        |
| 6 / 10                          | 12                         |
| 8.7 / 15                        | 18                         |
| 12 / 20                         | 24                         |
| 18 / 30                         | 36                         |

### 4.2 DETERMINATION OF THE CROSS SECTIONAL AREA

The determination of the cross sectional area depends on the :

- Current carrying capacities in continuous loading,
- Permissible short-circuit current,
- Conditions of installation (temperature, spacing, ...).

### 4.3 CURRENT CARRYING CAPACITIES

The heat produced by the cable under the set conditions must be able to dissipate to the ambient environment at any point of the cable installation; therefore the loading of the cable must be limited accordingly. The current carrying capacities shown in the electrical characteristics tables are calculated according to the internationally adopted method of the IEC publication 60287 for a maximum core temperature of 90°C, at the following installation conditions :

#### **4.3.1. BURIED CABLES**

The stated values are for cables or ducts placed in the ground at a depth of 800 mm of average thermal resistivity of 100°C.cm/w and spaced so that the temperature rise in each duct has no effect on the other ducts ( space being greater than 1 meter ), for a soil temperature of 20°C.

Where the thermal resistivity is different (not 100° Ccm/w) the current rating should be multiplied by the correction factors shown in the following table.

**Correction factor for different soil thermal resistivity**

| Nature of the soil | Soil thermal resistivity<br>°C.cm/w | Correction factor |
|--------------------|-------------------------------------|-------------------|
| Very wet soil      | 40                                  | 1.25              |
|                    | 50                                  | 1.21              |
|                    | 70                                  | 1.13              |
| Normal soil        | 85                                  | 1.05              |
|                    | 100                                 | 1.00              |
| Dry soil           | 120                                 | 0.94              |
|                    | 150                                 | 0.86              |
| Very dry soil      | 200                                 | 0.76              |
|                    | 250                                 | 0.70              |
|                    | 300                                 | 0.65              |

Where the temperature of the soil is different (not 20°C) the current rating should be multiplied by the following correction factors.

**Correction factor for different soil temperature**

| Soil<br>temperature<br>(°C) | Carrying core temperature (°C) |      |      |      |      |      |      |      |      |
|-----------------------------|--------------------------------|------|------|------|------|------|------|------|------|
|                             | 65                             | 70   | 75   | 80   | 85   | 90   | 95   | 100  | 105  |
| 0                           | 1.20                           | 1.18 | 1.17 | 1.15 | 1.14 | 1.13 | 1.13 | 1.12 | 1.11 |
| 5                           | 1.15                           | 1.14 | 1.13 | 1.12 | 1.11 | 1.10 | 1.10 | 1.09 | 1.08 |
| 10                          | 1.11                           | 1.10 | 1.09 | 1.08 | 1.07 | 1.07 | 1.06 | 1.06 | 1.06 |
| 15                          | 1.05                           | 1.05 | 1.04 | 1.04 | 1.04 | 1.04 | 1.03 | 1.03 | 1.03 |
| 20                          | 1                              | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |
| 25                          | 0.94                           | 0.95 | 0.95 | 0.96 | 0.96 | 0.96 | 0.97 | 0.97 | 0.97 |
| 30                          | 0.88                           | 0.89 | 0.90 | 0.91 | 0.92 | 0.93 | 0.93 | 0.94 | 0.94 |
| 35                          | 0.82                           | 0.84 | 0.85 | 0.87 | 0.88 | 0.89 | 0.89 | 0.90 | 0.91 |
| 40                          | 0.75                           | 0.77 | 0.80 | 0.82 | 0.83 | 0.85 | 0.86 | 0.87 | 0.87 |
| 45                          | 0.67                           | 0.71 | 0.74 | 0.76 | 0.78 | 0.80 | 0.82 | 0.83 | 0.84 |
| 50                          | 0.58                           | 0.63 | 0.67 | 0.71 | 0.73 | 0.76 | 0.77 | 0.79 | 0.80 |

When several cables or ducts are laid underground with less than one meter spacing the current rating values should be multiplied by the following correction factors :

#### **Correction factor of proximity effect for underground cables**

| Single or multicore cables |                 |                                       |             |            |            |
|----------------------------|-----------------|---------------------------------------|-------------|------------|------------|
| Number of circuits         | Touching cables | One diameter spaced cables<br>$a = D$ | $a = 0.25m$ | $a = 0.5m$ | $a = 1.0m$ |
| 2                          | 0.76            | 0.79                                  | 0.84        | 0.88       | 0.92       |
| 3                          | 0.64            | 0.67                                  | 0.74        | 0.79       | 0.85       |
| 4                          | 0.57            | 0.61                                  | 0.69        | 0.75       | 0.82       |
| 5                          | 0.52            | 0.56                                  | 0.65        | 0.71       | 0.80       |
| 6                          | 0.49            | 0.53                                  | 0.60        | 0.69       | 0.78       |

D = overall outer sheath diameter      a = Space between cables

#### **4.3. 2. CABLES LAID “ IN AIR ” :**

The stated values are for cables or ducts laid “ in air ” with an ambient temperature of 30°C and out of direct sunlight, spaced so that the temperature rise of individual cables has no influence on others. The spacing between adjacent cables is at least twice the cable or duct diameter.

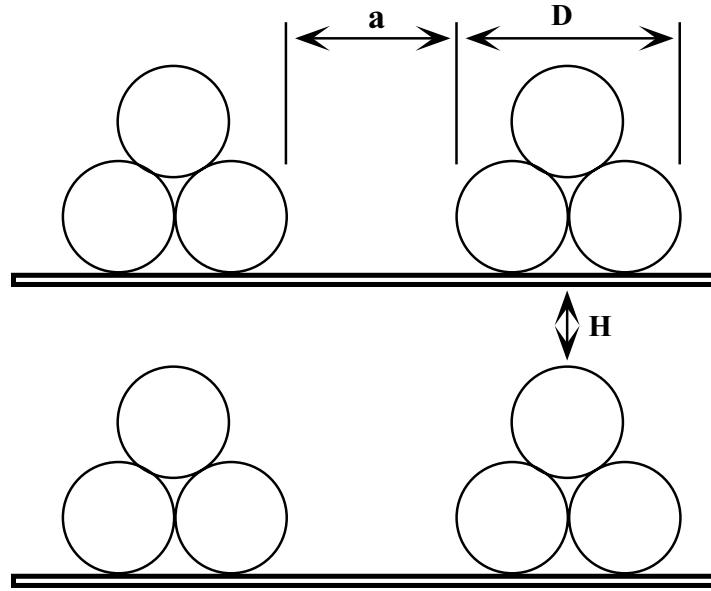
When the ambient temperature is different ( not 30°C ) the current rating values should be multiplied by the following correction factors :

#### **Correction factor for different ambient temperature**

| Ambient temperature (°C) | Carrying core temperature (°C) |      |      |      |      |      |      |      |      |
|--------------------------|--------------------------------|------|------|------|------|------|------|------|------|
|                          | 65                             | 70   | 75   | 80   | 85   | 90   | 95   | 100  | 105  |
| 0                        | 1.36                           | 1.32 | 1.29 | 1.26 | 1.24 | 1.22 | 1.21 | 1.20 | 1.18 |
| 5                        | 1.31                           | 1.27 | 1.25 | 1.22 | 1.21 | 1.19 | 1.18 | 1.16 | 1.15 |
| 10                       | 1.25                           | 1.22 | 1.20 | 1.18 | 1.17 | 1.15 | 1.14 | 1.13 | 1.13 |
| 15                       | 1.20                           | 1.17 | 1.15 | 1.14 | 1.13 | 1.12 | 1.11 | 1.10 | 1.10 |
| 20                       | 1.13                           | 1.12 | 1.11 | 1.10 | 1.09 | 1.08 | 1.07 | 1.07 | 1.06 |
| 25                       | 1.07                           | 1.06 | 1.05 | 1.05 | 1.04 | 1.04 | 1.04 | 1.04 | 1.03 |
| 30                       | 1                              | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |
| 35                       | 0.93                           | 0.94 | 0.94 | 0.95 | 0.95 | 0.96 | 0.96 | 0.96 | 0.97 |
| 40                       | 0.85                           | 0.87 | 0.88 | 0.89 | 0.90 | 0.91 | 0.92 | 0.93 | 0.93 |
| 45                       | 0.76                           | 0.79 | 0.82 | 0.84 | 0.85 | 0.87 | 0.88 | 0.89 | 0.89 |
| 50                       | 0.65                           | 0.71 | 0.75 | 0.77 | 0.80 | 0.82 | 0.83 | 0.85 | 0.86 |
| 55                       | 0.53                           | 0.61 | 0.67 | 0.71 | 0.74 | 0.76 | 0.78 | 0.80 | 0.82 |
| 60                       | 0.38                           | 0.50 | 0.58 | 0.63 | 0.67 | 0.71 | 0.73 | 0.76 | 0.77 |
| 65                       |                                | 0.35 | 0.47 | 0.55 | 0.60 | 0.65 | 0.68 | 0.71 | 0.73 |
| 70                       |                                |      | 0.33 | 0.45 | 0.52 | 0.58 | 0.62 | 0.65 | 0.68 |
| 75                       |                                |      |      | 0.32 | 0.43 | 0.50 | 0.55 | 0.60 | 0.63 |
| 80                       |                                |      |      |      | 0.30 | 0.41 | 0.48 | 0.53 | 0.58 |
| 85                       |                                |      |      |      |      | 0.29 | 0.39 | 0.46 | 0.52 |
| 90                       |                                |      |      |      |      |      | 0.28 | 0.38 | 0.45 |
| 95                       |                                |      |      |      |      |      |      | 0.27 | 0.37 |
| 100                      |                                |      |      |      |      |      |      |      | 0.26 |



When several cables or ducts are grouped, the current ratings values should be corrected as follows :



### SINGLE CORE CABLES

| Method<br>of laying                   | Number of layers | Number of ducts | 1    | 2    | 3    |                                  |
|---------------------------------------|------------------|-----------------|------|------|------|----------------------------------|
|                                       |                  |                 | 0.97 | 0.89 | 0.87 |                                  |
| Touching                              | 1                |                 | 0.97 | 0.89 | 0.87 | 3 cables in horizontal layer     |
|                                       | 2                |                 | 0.94 | 0.85 | 0.81 |                                  |
|                                       | 3                |                 | 0.93 | 0.84 | 0.79 |                                  |
| One diameter spaced cables<br>$a = D$ | 1                |                 | 1.0  | 0.98 | 0.96 | 3 cables in triangular formation |
|                                       | 2                |                 | 0.97 | 0.93 | 0.89 |                                  |
|                                       | 3                |                 | 0.96 | 0.92 | 0.86 |                                  |

### MULTICORE CABLES

| Method<br>of laying                   | Number of layers | Number of ducts | 1   | 2    | 3    | 4    | 6    |
|---------------------------------------|------------------|-----------------|-----|------|------|------|------|
|                                       |                  |                 | 1.0 | 0.88 | 0.82 | 0.78 | 0.76 |
| Touching                              | 1                |                 | 1.0 | 0.87 | 0.80 | 0.76 | 0.73 |
|                                       | 2                |                 | 1.0 | 0.86 | 0.79 | 0.75 | 0.71 |
|                                       | 3                |                 | 1.0 | 0.98 | 0.86 | 0.92 | 0.87 |
| One diameter spaced cables<br>$a = D$ | 1                |                 | 1.0 | 1.0  | 0.98 | 0.95 | 0.91 |
|                                       | 2                |                 | 1.0 | 0.98 | 0.86 | 0.92 | 0.87 |
|                                       | 3                |                 | 1.0 | 0.98 | 0.95 | 0.91 | 0.85 |

Note : the space H between layers must not be less than 30cm

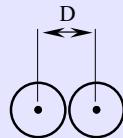
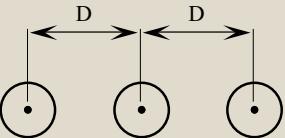
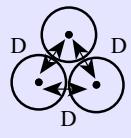
#### 4.4 Inductance

The Inductance L depends on the geometrical characteristics of the cable as well as the disposition of conductors

$$\text{for unarmoured cables : } L = 0.05 + 0.46 \log_{10} \frac{D_m}{r} \quad (\text{mH / Km})$$

where :  $r$  = Conductor Radius

$D$  = Distance between Conductors

| Single phase system  | Three phase system flat formation   | Three phase system trefoil formation   |
|--|---|--|
| <br>$D_m = D$ | <br>$D_m = 1.26 D$ | <br>$D_m = D$ |

For armoured Cables increase the inductance of about 10%

#### 4.5 Capacitance

$$C = \frac{2.3}{18 \ln \frac{D}{d}}$$

$d$  = Diameter of conductor ( including the eventual semi-conductive layer )

$D$  = Diameter of insulated Conductor

#### 4.6 Conductors short - circuit current :

Current densities given in the table below are in ( $\text{A} / \text{mm}^2$ ), for a maximum condutor temperature of  $250^\circ\text{C}$  at the end of the short - circuit.

| Temperature of conductor before overload<br>$T$ ( $^\circ\text{C}$ ) | Current density ( $\text{A} / \text{mm}^2$ ) |     |     |     |    |           |     |     |    |    |
|--|--|-----|-----|-----|----|-----------|-----|-----|----|----|
|  | Conductor metal                              |     |     |     |    |           |     |     |    |    |
|  | Copper                                       |     |     |     |    | Aluminium |     |     |    |    |
|  | overload time in secs                        |     |     |     |    |           |     |     |    |    |
|  | 0.1  | 0.5 | 1   | 2   | 5  | 0.1       | 0.5 | 1   | 2  | 5  |
| 20   | 556  | 249 | 176 | 124 | 78 | 366       | 164 | 116 | 82 | 51 |
| 30   | 537  | 241 | 170 | 120 | 76 | 354       | 159 | 112 | 79 | 50 |
| 70   | 464  | 207 | 147 | 103 | 65 | 325       | 145 | 103 | 72 | 46 |
| 90   | 439  | 196 | 139 | 98  | 62 | 287       | 128 | 91  | 64 | 40 |

For an overload duration ( $t$ ) different than those figured in the above table, the correspondant current density is given by the following formula :

$$\text{Current density for a duration } (t) = \frac{\text{Current density for 1 sec}}{\sqrt{t}}$$

#### 4.7 Screen short-circuit current

Following short-circuit current in Ampere, are approximative, calculated for copper tape screen of 0.1mm thickness applied helically with about 10% overlapping.

| Nominal Conductor cross section<br>in mm <sup>2</sup> | 0.5 second            |           |           | 1 second   |           |           | 2 seconds  |           |           |
|---|-----------------------|-----------|-----------|------------|-----------|-----------|------------|-----------|-----------|
|   | Specified Voltage, KV |           |           |            |           |           |            |           |           |
|   | 8.7/15(18)            | 12/20(24) | 18/30(36) | 8.7/15(18) | 12/20(24) | 18/30(36) | 8.7/15(18) | 12/20(24) | 18/30(36) |
| 16  | 1500                  | 1800      |           | 1150       | 1350      |           | 900        | 1050      |           |
| 25  | 1550                  | 1800      |           | 1200       | 1350      |           | 920        | 1050      |           |
| 35  | 1650                  | 1800      |           | 1250       | 1350      |           | 970        | 1050      |           |
| 50  | 1750                  | 2000      | 2550      | 1300       | 1500      | 1950      | 1000       | 1200      | 1500      |
| 70  | 1950                  | 2150      | 2600      | 1500       | 1650      | 2000      | 1150       | 1300      | 1550      |
| 95  | 2100                  | 2300      | 2950      | 1600       | 1750      | 2250      | 1250       | 1350      | 1800      |
| 120   | 2250                  | 2400      | 3050      | 1700       | 1850      | 2350      | 1350       | 1450      | 1850      |
| 150   | 2350                  | 2550      | 3200      | 1800       | 1950      | 2400      | 1400       | 1500      | 1920      |
| 185   | 2550                  | 2900      | 3500      | 1950       | 2250      | 2700      | 1500       | 1800      | 2150      |
| 240   | 2950                  | 3150      | 3750      | 2250       | 2450      | 2900      | 1800       | 1950      | 2300      |
| 300   | 3150                  | 3500      | 3950      | 2450       | 2750      | 3050      | 1900       | 2200      | 2450      |

#### 4.8 Minimum Bending Radius :

Listed values represent the permanent bending radius the cables withstand in fixed installation and on dispatching reels. Other constraints may impose greater bending radius.

|                                   | Cable on drum | Cable during installation | Installed Cable |
|-----------------------------------|---------------|---------------------------|-----------------|
| <b>Armoured single core</b>       | 8 D           | 16 D                      | 8 D             |
| <b>Unarmoured single core</b>     | 10 D          | 20 D                      | 10 D            |
| <b>Armoured multi core</b>        | 7 D           | 16 D                      | 7 D             |
| <b>Unarmoured multi core</b>      | 8 D           | 16 D                      | 8 D             |
| <b>D = Overall diameter in mm</b> |               |                           |                 |