4 GENERALITIES

4.1 CONDUCTORS

The commonly used conductors materials are copper and aluminium meeting the requirements of IEC 60228.

Theoretical characteristics of copper and aluminium are as follows :

	Annealed Copper	Annealed Aluminium
Specific Gravity (kg/dm^3)	8.9	2.7
Resistivity at 20˚C ($Ohm.\ mm^2/m$)	17.241×10^{-3}	28.264×10^{-3}
Breaking Load (daN/mm^2)	23 to 25	12 to 15
Elongation at break (%)	20 to 40	1 to 4

Equivalent standardized cross sectional area at equal voltage drop

Copper (mm^2)	Aluminium (mm^2)
6	10
10	16
16	25
25	35
35	50
50	70
70	95
95	150
120	185
150	240
185	300

4.2 PROPERTIES OF INSULATING MATERIALS

MATERIAL	PVC	PE	XLPE
Specific gravity (kg/dm^3)	1.3 - 1.5	0.92 - 0.97	0.92 - 1.18
Dielectric constant	5 - 8	2.3	2.5
Breaking load (bars) min.	100 - 200	100	125 - 150
Elongation at break min.	150 %	350 %	200 %
Max. continuous operating temperature (˚C)	70 - 105	70	90
Max. short circuit temperature (˚C)	160	150	250
Moisture proof	Good	Very good	Very good
Flame proof	Very good	Poor	Poor
Flexibility	Good	Poor	Poor
Insulation resistance constant, Ki at 20˚C (Megohm x km)	5000	> 20.000	> 20.000

4.3 DETERMINATION OF THE CROSS SECTIONAL AREA

The determination of the cross sectional area depends on the :

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

4.4 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 70˚C for PVC insulated cables and 90˚C for XLPE insulated cables, at the following installation conditions :

4.4.1. BURIED CABLES

The stated values are for cables or ducts placed in the ground at a depth of 600 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˚ C.cm/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 ˚C.cm/w	Correction factor
Very wet soil	40 50 70	1.25 1.21 1.13
Normal soil	85 100	1.05 1.00
Dry soil	120 150	0.94 0.86
Very dry soil	200 250 300	0.76 0.70 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 temperatures

Soil temperature (˚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 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

4.4. 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.

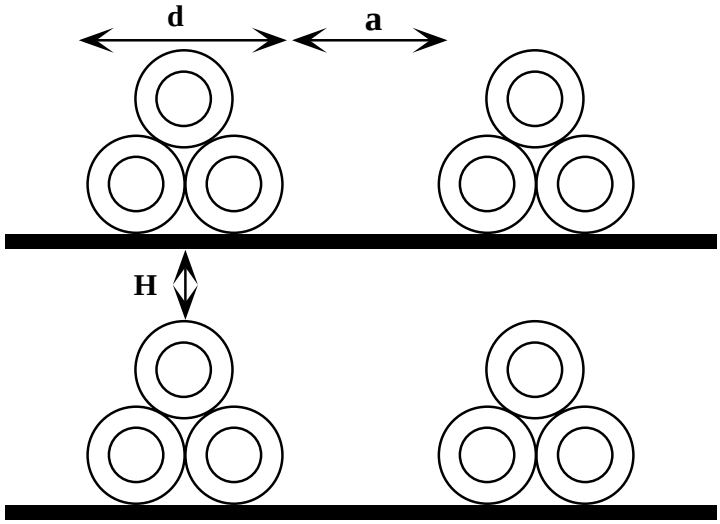
When the ambient temperature is different (not 30˚C) the current rating values should be multiplied by the following correction factors :

Correction factor for different ambient temperatures

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 are grouped, the current ratings values should be corrected as follows :

Correction of proximity effect for Cables in air



Distance	Number of layers	Number of cables					
a & H		1	2	3	4	5	6
≥ 2d	No proximity effect						
1/4d to 2d	1	1.00	0.94	0.91	0.88	0.87	0.86
	2	0.92	0.87	0.84	0.81	0.80	0.79
	3	0.85	0.81	0.78	0.76	0.75	0.74
	4	0.82	0.78	0.74	0.73	0.72	0.72
	5	0.80	0.76	0.72	0.71	0.70	0.70
	6	0.79	0.75	0.71	0.70	0.69	0.68
≤ 1/4d	1	1.00	0.80	0.70	0.65	0.60	0.57

4.5 VOLTAGE DROP

In addition to the current rating, the determination of the cross sectional area should ensure that the selected cable size is capable to carry the required current between sending and receiving ends of line with a maximum of 3 % in voltage drop for lighting purpose circuits and 5 % for others.

The voltage drop values shown in the electrical characteristics tables are in V/A x Km calculated for a maximum core temperature of 70˚C for PVC cables and 90˚C for XLPE cables.

The voltage drop between sending and receiving ends of line is :

$$DU = U_1 - U_2 \text{ in Volts}$$

$$DU = \frac{U_1 - U_2}{U_1} \times 100 \text{ in \%}$$

In D.C. : $DU = 2 \rho \frac{L}{S} I$

In Single phase : $DU = 2 \rho \frac{L}{S} I (R \cos \varphi + LW \sin \varphi)$

In three phase : $DU = \rho \frac{L}{S} I\sqrt{3} (R \cos \varphi + LW \sin \varphi)$

Where

DU = Voltage drop in volt
l = Cable length in km
I = Current rating in Amper
R = Conductor resistance at the maximum operating temperature in Ohm/km
L = Inductance in H/km
W = Pulsation = 2 πF = 314 for F = 50 Hz
cos φ = Power factor

4.6 CONDUCTORS SHORT - CIRCUIT CURRENT

Current densities given in the table below are in (A / mm²), for different insulation materials and different overload time.

material	Temperature of conductors		Current density (A / mm²)									
			Conductor metal									
	Initial °C	Final °C	Copper					Aluminium				
			overload in secs									
			0.1	0.2	0.5	1	2	0.1	0.2	0.5	1	2
PE	20	150	446	315	199	141	99	294	208	131	93	66
	30		424	300	189	134	95	278	197	125	88	63
	70		375	237	150	106	75	221	156	99	70	49
PVC	20	160	458	324	205	145	102	304	215	135	96	68
	30		436	309	195	138	98	284	210	127	90	64
	70		351	248	158	111	79	231	163	104	73	52
XLPE	20	250	557	394	249	176	124	367	260	164	116	82
	30		538	380	241	170	120	354	254	159	112	79
	90		439	311	196	139	98	288	203	129	91	65

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 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
Unarmoured single core cables	9 D	18 D	9 D
Unarmoured multi core cables	6 D	12 D	6 D
Armoured cables - steel tapes	8 D	16 D	8 D
- steel wires	10 D	20 D	10 D
	D = Overall diameter in mm		