LV Power (PVC and XLPE) Cable, Wire and Cords

Low Voltage 0.6kV/1kV

The below References are used:

1- Switchgear manual by A. Hoppner.
2- Practical Fundamental of electrical construction by Ahmed Abd Al-Mtal.
3- Mechanisms and modes for ignition of low voltage PVC cables, wires and cords by Vytenis Babrauskas, Ph.D.

Low Voltage (0.6kV /1kV) power cables

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Abbreviation:

A	Ampere
AC	Alternating current
Al	Aluminum
CF	Conversion factor
CF1	Conversion factor 1
CF2	Conversion factor 2
Cu	Copper
DC	Direct Current
HV	High Voltage
kV	Kilo Volt
L	Distance between the load and the power supply
LV	Low voltage
PE	Polyethylene
PVC	Polyvinyl chloride
R	Resistance
Vd	Voltage drop
XLPE	Cross Linked Polyethylene
XL	Inductance

Index

1 Abstract

The purposes of this document are:

1- Providing some topics on the insulation types of the LV power cables, and their type as well

2- How the engineer can select the proper cable in work environment in term of metal of cable, cross section, current-carrying capacity, Low voltage drop and etc. ?

3- How the selected cable can be protected?

Thus, it is so important while any projects that may be included the electrical affairs especially the cabling or wiring part have to be planned and designed in proper way.

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2 Introduction

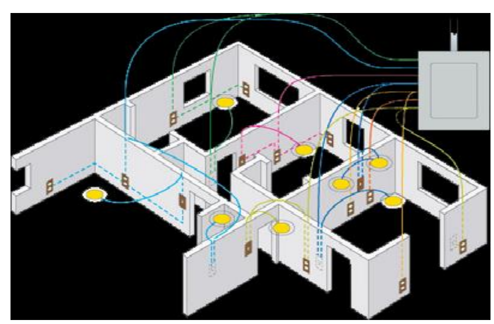
Low voltage power cables, wire and cords (0.6/1kV) are used in most of electrical project like low voltage side of distribution transformer, buildings, low voltage network, control board of motors, control boards in Diesel generators, Telecommunication (DC and AC) power system and etc..

The selection of LV cables, wire and cords for any types of above mentioned projects has to be in proper or an engineering way, otherwise a set of risks will be come up and the cost will be impacted and some time some disaster may be happened.

So, below are two different types of work that LV power cables and wires are used as an example:

1- Distribution transformer
   Regarding the low voltage side of low
   Voltage Transformer, normally the single
   Core cable are used.

2- Wiring of building:
   Building, workshop, establishment building
   Have also needed the engineering plan and
   Design.



3 LV power cable structure

There are two types of Low voltage (0.6/1kV) power cables that are being used in different fields which are:

1- Single core.
2- Multi-core.

In both types, different metals and different types of insulations cab be used, in (figure 1) generally the structure or the construction of the low voltage (0.6/1kV) power cable are as below:

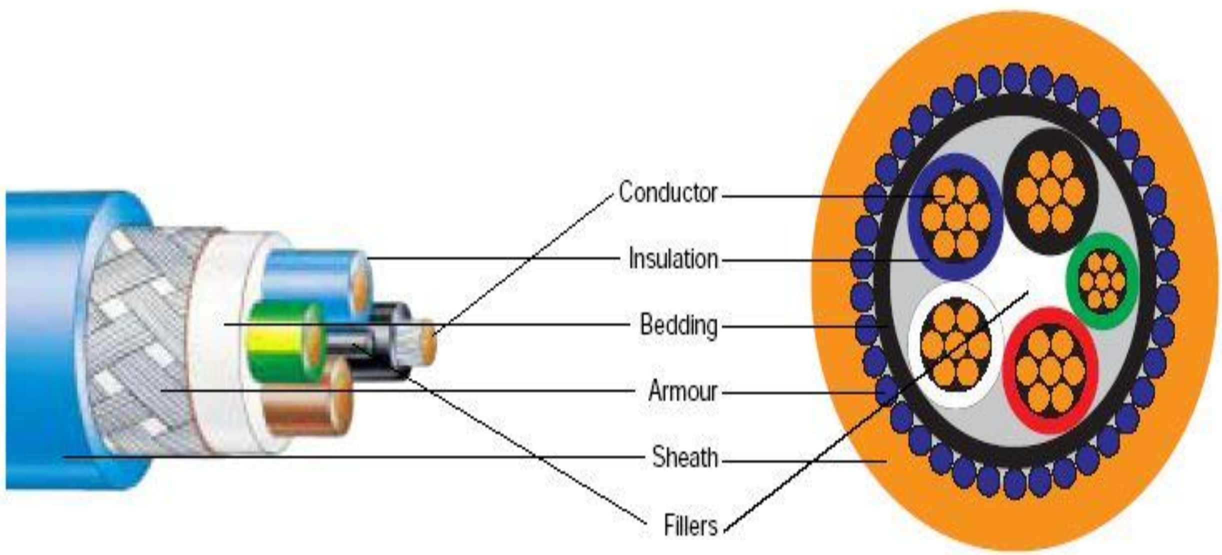


Figure 1 General overview of LV power cable structure

- Metal core:
  This part of the LV power cable is responsible for carrying the electrical amperes, it can be either solid or stranded wire and normally the metal is Aluminum or copper.

- Insulation:
  This part is responsible for insulating the metal core from the surrounded area, and there are different types of insulations:

  1- PVC (Polyvinyl chloride)
  2- XLPE (Cross Linked Polyethylene)
  3- PE (Polyethylene)

- Bedding, separating sheath, type of armour and outer sheath: These parts of cable are giving the cable the circular shape, providing the shielding layer of the cable for availability of mechanical protection of the cable, providing the protection of the voltage that are bigger than 1Kv and carrying the error current that may be happened during the error that may generated due to earthing system..

4 Metal Core

Previously as it is mentioned the most popular metal that are used in the manufacturing of the LV (0.6/1kV) power cable, wire and cords are copper and aluminum, because these two metals own the high conductivity.

4.1 Copper Core

Copper metal can be used as a solid metal till the cross-section area $16mm^2$, in this case the used copper will be Fermented type so as it will be soft.

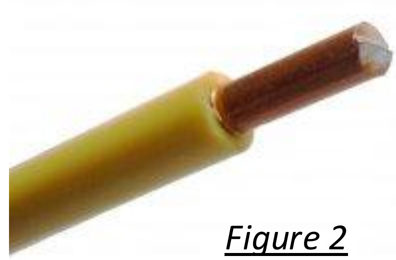


Figure 2

If more than $16mm^2$ cross section is required, it will be stranded wire over each other and this will be made some layers and this construction will provide a soft to the copper conductor and Increasing in the diameter of this structure will give a Benefit of skin effect of Alternating current.

Figure 3

Moreover at ambient temperature 20 C^o the resistivity of solid copper metal is $1.777*10^{-8}$ Ω.m and the resistivity of the stranded wire copper metal is $1.724*10^{-8}$ Ω.m.

4.2 Aluminum Core

Alumiua conductor is cheaper and light weight if it is compared with copper conducter but there is a shortcoming in Aluminum conductor which is high resistiveity for exampe if the ambient tempreture is 20 C^o it is $2.803*10^{-8}$ Ω.m, thus it will make the diameter of aluminum conductor become bigger comparing with copper for the same current-carrying capacity.

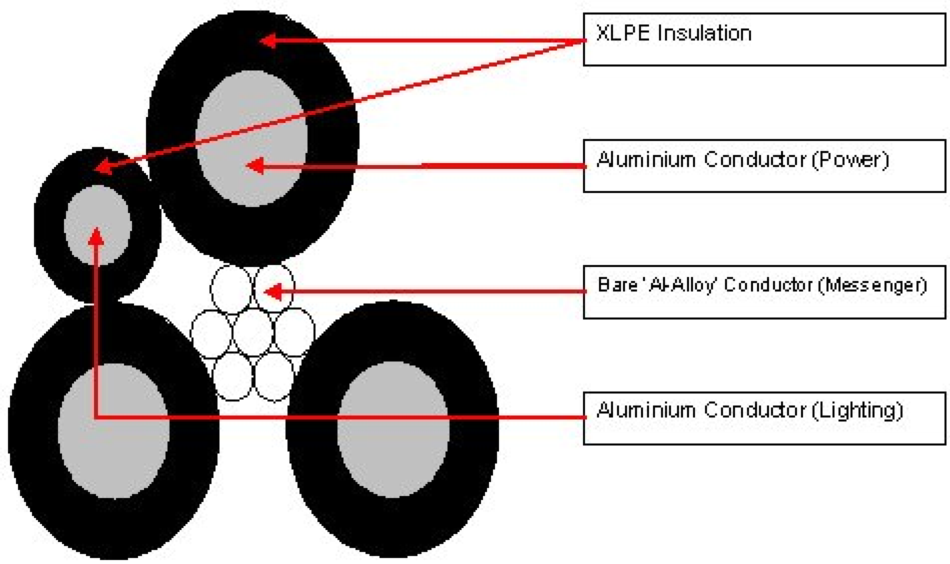


Figure 4 LV power cable with Aluminum conductor

In add to that due to high resistance of Aluminum, this give a benefit to this type which is decreasing the erosion inside the stranded and in parallel with that there will be some Oxidation due to weather effect, yes it is right that this oxidation will protect the conductor from the erosion but the impact will be on the conductivity.

5 Type of Insulation of LV power cables

In LV (0.6/1Kv) power cables structure there is one layer which is called insulation layer, within this layer couple types of insulation can be used like (PVC, XELP and PE), in the structure of these insulation types, the polymer material are being used.

Polymer material is divided in two types:

- Thermoplastic.
- Thermo sets.

5.1 Thermoplastic

This type of insulation will be impacted by the temperature, heat will make it soften and cold will make it harden.

The most important types of Thermoplastic insulator that is used in cable manufacturing are:

- PVC:
  This type is more commonly used and it is In the form of white powder (Figure 3), and this material is Non-flammable and it becomes soft at temperature 80C^{o} , the increasing the temperature to 70C^{o} has to be avoided.
- PE:
  In electrical specification point of view it is lower than PVC. And it is being used in a narrow range in industry it will be used for protection layer of the cable, it is divided in to two types, low density it can support till the temperature 70C^{o} and high density it can support till the temperature 115C^{o}.

5.2 Thermosets

This type is not effected by the heat , and the most important types that are used in cable manfacturing are as below:

- Rubber:
  There is two types of Rubber, Natural rubber which is used in narrow range due to the its working temprature 60C^{o} and industrial rubber which is called Butyl, this one can stand against Oils and greases, so that it is used in cablieng and wiring in ships.
- XLPE:
  This type is the famous one within the Thermosets insulation kind and the famous one as well in that is being used in insulation of cables, it can stand the tempretute till 90C^{o} and in add to that due to the short circuit it can stand the tempreture till 250C^{o} for short period.

  The usage of this insulation is not for only the LV power cable some time it can be used for HV, the disadvange of this type is,it is hard material and there will be some diffculities during the manfacturing process.

Figure 5 CU/XLPE/PVC

6 Cable external protection layer

Commonly PVC is used for the external layer of the cable, PVC is characterized by chemical specification and its resistance toward Organic materials that are available in the soil, but there are some other external materials that may be destroyed this layer which is Hydrocarbon component so that extending or drawing the PVC cable will be avoided in that areas that has like this material.

For that if it is mandatory that there has to be the need of cable in the areas that may contain Hydrocarbon component so HPDE will be used.

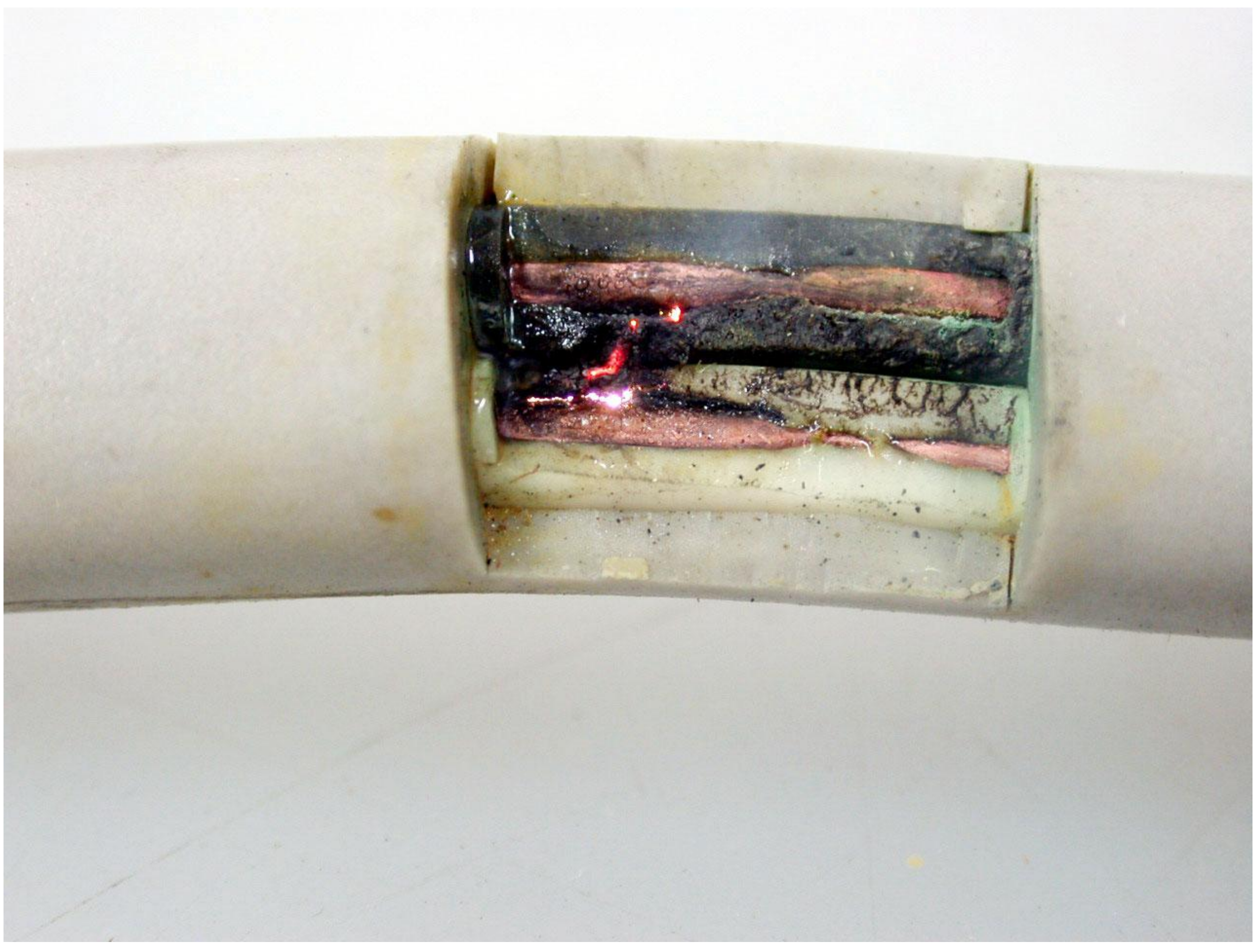


Figure 6 Showing the damaging of PVC cable

7 Cable Cross section selection

In Previous sections, some ideas are gotten in the type of insulation, metal core and etc.., currently is a time of how we can select which cross-section are needed of the LV (0.6/1Kv) power cable?

Reference to Appendix A there a full list of the cross-section types of copper cable*, thus the load study of the location that is needed the electricity via LV(0.6/1Kv) power cable/wire are strongly required if you see the Appendix A the first column is the type of the cross-section of copper cable, the other columns are the current-carrying capacity of the type of copper cable so the below data collection has to be taked in to the consideration:

1- Load study of the location to calculate the required current by supposing the voltage is low voltage, there is some other study are needed in term of the calculation which is the diversity factor has to be applied properly, otherwise the huge amount of amperes will be required.
2- How many numbers of systems are needed? Single, double, triple and etc..
3- Is the cable laying in the ground or in the conduits or on the wall or in air or etc..
4- Proper connector either Cu terminal or Bi-metallic terminal have to be selected.

Moreover, the selection or the mentioning name of the LV cable has to be according to the standard like below:

*planning and design in this document is just for copper LV (0.6/1kV) power cables and wire.

1- 0.6/1kV PVC cable laid in air: the standard name is N(A)YY or N(A)YCWY.

2-0.6/1kV XLPE laid in air: the standard name is N(A)2XY.

3-0.6/1kV PVC cable laid in ground: the standard name is N(A)YY:N(A)YCWY.

4-0.6/1kV XLPE laid in ground: the standard name is N(A)2XY.

Thus according to that the cable will be selected in term of the insulation, core conductor and etc.. then the current-carrying calculation and other calculation should be started.

As an example, if the cable is three phase cable it will be:

3*25+16mm^2 , Cu PVC N(A)YCWY or in some other resource it is Cu PVC N(A)YCWY 3*25+16 mm^2 both case are correct.

8 Current-Carrying Capacity Calculation

In section 7 by supposing the load study is done for a building which is a certain house, for interconnecting it to the low voltage network the assumption is as follows:

1- The required electrical current is 45A.
2- The engineer selected a pair core system (CU PVC 2*Xmm^2).

X is the cross-section of cu cable that has to be calculated for that the below equation can be used:

A=current rating in Y * conversion factor for air temperature CF * conversion factor for laying method CF1*margin ration (85%)

Y: Appendix A

CF: Appendix B

CF1: Appendix C

The current ratings that are mentioned in Appendix A can be applied for ambient temperature 25C^o so that the conversion factor is so important with this regard.

The result will be:

The engineer has to make an assumption, first the engineer select one cable size for example 2*10mm^2 so,

A= 66*0.71*1*0.85

A=39.83 A

So from appendix A 2*10 PVC cable cannot carry the required load so that 2*16mm^2 is the suitable one.

Some time in some environment a single core can be used and as an example laid on the floor so the below formula must be applied:

Exact current rating= current rating in Y * conversion factor for air temperature CF * conversion factor for laying method CF1*margin ration (85%)* conversion factor for grouping in case it is three phase or more that one core CF2

Y: Appendix A

CF: Appendix B

CF1: Appendix C

CF2: Appendix D

Reference to the above formulas the exact current-capacity will be achieved.

9 Call Drop Calculation

In previous sections the suitable cross-section (Cu PVC N(A)YY 2*16mm^2

Was selected then the exact current –carrying capacity was calculated as well, a very important thing does not have forgotten which is the voltage drop, it means once the cable type and the current-carrying capacity were selected it is not meaning that this the end of story and it has to be implemented.

The distance from the source of the electricity to the destination has to be measured then the below formula has to be applied for calculating the amount of voltage that may be dropped within this distance.

$Vd=\sqrt{3} * I * L * (RL\cos\Phi + XL\sin\Phi)$

$Vd=\sqrt{3}$ * I*Distance between the source and the destination*resistance per unit length Rm

Then :

Vd percentage = vd/line voltage or phase voltage

Rm Appendix E

For example:

The distance between the source and destination is 100m

The maximum load is 39A

The resistance per unit length for PF 0.8 is 1.14

$Vd=\sqrt{3}$ *39*0.1*1.14= 7.7Volte Vd percentage= 7.7/240=3.2% it means the terminated voltage is 232v

10 LV Power Cable protection

Once the LV (0.6/1Kv) power cable is designed, there must be some protection provisioning to be there like the circuit breaker in case it is high current and miniature circuit breaker if it is for house hold usage.

In this document the main topics are on LV power cables and wires within the operating voltage from 0.6/1kV.

But the current and the voltage rating of the circuit breaker and the miniature circuit breaker have to be within the current-carrying capacity of the LV cables even lower so as it will not be reached to disaster situation.

11 Appendixes

11.1 Appendix A

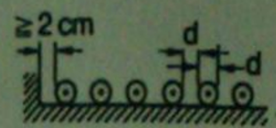
Arrangement	⊙ [4]	⊗	⊕ ⊕ [6]	⁂	○○○	⊙ [4]	⊕ ⊕ [6]	⁂	○○○
Nom. cross-section Copper conductor mm²									
1.5	26	20	18.5	20	25	32	24	25	32
2.5	35	27	25	27	34	43	32	34	42
4	46	37	34	37	45	57	42	44	56
6	58	48	43	48	57	72	53	57	71
10	79	66	60	66	78	99	73	77	96
16	105	89	80	89	103	131	96	102	128
25	140	118	106	118	137	177	130	139	173
35	174	145	131	145	169	218	160	170	212
50	212	176	159	176	206	266	195	208	258
70	269	224	202	224	261	338	247	265	328
95	331	271	244	271	321	416	305	326	404
120	386	314	282	314	374	487	355	381	471
150	442	361	324	361	428	559	407	438	541
185	511	412	371	412	494	648	469	507	626
240	612	484	436	484	590	779	551	606	749
300	707	–	481	549	678	902	638	697	864
400	859	–	560	657	817	1 070	746	816	1 018
500	1 000	–	–	749	940	1 246	–	933	1 173
Nom. cross-section Aluminium conductor mm²									
25	128	91	83	–	–	137	100	–	–
35	145	113	102	113	131	168	122	131	163
50	176	138	124	138	160	206	147	161	200
70	224	174	158	174	202	262	189	205	254
95	271	210	190	210	249	323	232	253	313
120	314	274	220	244	291	377	270	296	366
150	361	281	252	281	333	433	308	341	420
185	412	320	289	320	384	502	357	395	486
240	484	378	339	378	460	605	435	475	585
300	548	–	377	433	530	699	501	548	675
400	666	–	444	523	642	830	592	647	798
500	776	–	–	603	744	966	–	749	926

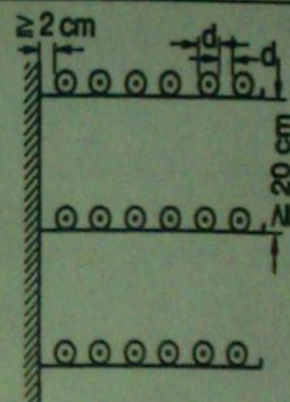
11.2 Appendix B

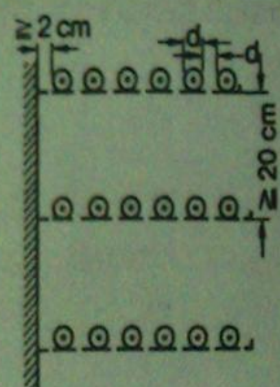
	2	3	4	5	6	7	8	9	10	11	12
able type	Max. operating tempe-rature	Max. tempera-ture in-crease	Conversion factors for air temperature in °C 10	15	20	25	30	35	40	45	50
	°C	K	—	—	—	—	—	—	—	—	—
PE cable	90	—	1.15	1.12	1.08	1.04	1.0	0.96	0.91	0.87	0.82
/C cable	70	—	1.22	1.17	1.12	1.07	1.0	0.94	0.87	0.79	0.71
ass-impregnated cable lted cable /1 to /6 kV	80	55	1.05	1.05	1.05	1.05	1.0	0.95	0.89	0.84	0.77
0 kV	65	35	1.0	1.0	1.0	1.0	1.0	0.93	0.85	0.76	0.65
gle-core, and able											

11.3 Appendix C

	Number of systems next to each other	1	2	3
Lying on floor		0.92	0.89	0.88
	Number of trays			
Lying on cable trays (restricted air circulation)	1	0.92	0.89	0.88
	2	0.87	0.84	0.83
	3	0.84	0.82	0.81
	6	0.82	0.80	0.79
	Number of racks			
Lying on cable racks (unrestricted air circulation)	1	1.00	0.97	0.96
	2	0.97	0.94	0.93
	3	0.96	0.93	0.92
	6	0.94	0.91	0.90

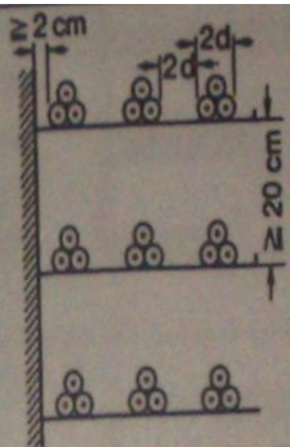




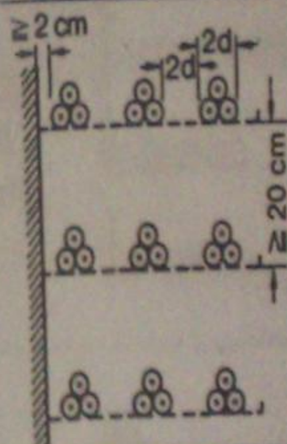


11.4 Appendix D

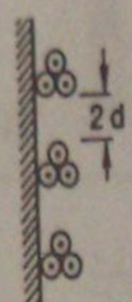
	Number of trays			
Lying on cable trays (restricted air circulation)	1	0.95	0.90	0.88
	2	0.90	0.85	0.83
	3	0.88	0.83	0.81
	6	0.86	0.81	0.79



	Number of racks			
Lying on cable racks (unrestricted air circulation)	1	1.00	0.98	0.96
	2	1.00	0.95	0.93
	3	1.00	0.94	0.92
	6	1.00	0.93	0.90



	Number of cables under each other	1	2	3
On supports or against wall		0.89	0.86	0.84



11.6 Appendix E

Number of conductors and cross-section	D. C. resistance at 70 °C	Ohmic resistance at 70 °C	Inductive reactance	Effective resistance per unit length $R'_L \cdot \cos\varphi + X'_L \cdot \sin\varphi$ at $\cos\varphi$				
	R'_L	R'_L	X'_L	0.95	0.9	0.8	0.7	0.6
mm²	Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	Ω/km	Ω/km
4 x 1.5	14.47	14.47	0.115	13.8	13.1	11.65	10.2	8.77
4 x 2.5	8.71	8.71	0.110	8.31	7.89	7.03	6.18	5.31
4 x 4	5.45	5.45	0.107	5.21	4.95	4.42	3.89	3.36
4 x 6	3.62	3.62	0.100	3.47	3.30	2.96	2.61	2.25
4 x 10	2.16	2.16	0.094	2.08	1.99	1.78	1.58	1.37
4 x 16	1.36	1.36	0.090	1.32	1.26	1.14	1.02	0.888
4 x 25	0.863	0.863	0.086	0.847	0.814	0.742	0.666	0.587
4 x 35	0.627	0.627	0.083	0.622	0.60	0.55	0.498	0.443
4 x 50	0.463	0.463	0.083	0.466	0.453	0.42	0.38	0.344
4 x 70	0.321	0.321	0.082	0.331	0.326	0.306	0.283	0.258
4 x 95	0.231	0.232	0.082	0.246	0.245	0.235	0.221	0.205
4 x 120	0.183	0.184	0.080	0.2	0.2	0.195	0.186	0.174
4 x 150	0.149	0.150	0.080	0.168	0.17	0.168	0.162	0.154
4 x 185	0.118	0.1202	0.080	0.139	0.143	0.144	0.141	0.136
4 x 240	0.0901	0.0922	0.079	0.112	0.117	0.121	0.121	0.119
4 x 300	0.0718	0.0745	0.079	0.0954	0.101	0.107	0.109	0.108