Cables Facts and Figures

ABERDARE CABLES

Driven by Powertech

Revised 012008

Aberdare Power Cables

"with Compliments from Aberdare Cables"

Driven by Powertech

Preview

This booklet has been revised several times to meet the demands of an ever-changing market, as well as specification changes as the result of improving technology. It is not a treatise on electrical technology, but it is published to give supplementary information to engineers, technicians and electricians involved in cable selection and installation.

Aberdare hopes that users find it useful and invites any constructive (or corrective) criticism.










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Contents

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1.0	**How to Select a Cable**	**1**
1.1	Load to be supplied	1
1.2	Permissible Voltage Drop	1
1.3	Prospective Fault Current	5
1.4	Environmental Conditions of Installation	7
1.4.1	Cables Laid Direct in the Ground	8
1.4.2	Cables Installed in Air	9
1.4.3	Cables installed in Ducts	10
1.4.4	Composite Cable Routes	10
1.4.5	Intermittent Operation	10
1.4.6	Solar Heating	11
2.0	**Useful Electrical Formulae**	**12**
2.1	Volt Drop	12
2.2	Charging Current	13
2.3	Per Unit System	13
2.4	Load Growth	13
2.5	Load Factor	13
2.6	Capacitor Voltage Rise	13
2.7	Load Sharing	14
2.8	Conductor Resistance	14
2.9	Lead Resistance	15
2.10	Wire Armour Resistance	15
3.0	**Transport, Handling and Installation of Electric Cables**	**16**
3.1	Cables on Wooden Drums	16
3.2	Cable Transportation	17
3.3	Cable Storage	18
3.4	Mechanical Forces on Cables during Installation	18
3.5	Pulling Cables through Pipes or Ducts	19
3.6	Preparation for Cable Laying	20
3.7	Backfilling and Reinstatement	26
3.8	Repairs to PVC Oversheaths	26

Contents

Continuation ...

4.0 Paper Insulated and Lead Covered 6.35/11 kV Cables **27**

- 4.1 Notes on impregnating compound 27
- 4.2 Moisture in Paper cables 27
- 4.3 Derating factors for non-standard conditions 29
- 4.4 Short circuit ratings for PILC cables 30
- 4.5 Earth fault ratings 31

5.0 Medium Voltage XLPE Insulated, PVC Bedded, SWA, PVC sheathed 6.35/11 kV Cables **32**

- 5.1 Notes on XLPE insulation 32
- 5.2 Derating factors for non-standard conditions 34
- 5.3 Short circuit ratings for XLPE insulated 6.35/11 kV cables 35
- 5.4 Earth fault current 36

6.0 Low Voltage PVC and XLPE insulated 600/1000 V Power Cables **37**

- 6.1 Notes on PVC and XLPE insulation 37
- 6.2 Cable cross section 37
- 6.3 Derating factors for non-standard conditions 44
- 6.4 Short circuit ratings for PVC and XLPE insulated 600/1000 V cables 46

7.0 Elastomeric Trailing Cables **46**

8.0 Overhead Aluminium Conductors **50**

9.0 Innovative products - INTERDAC 3 **52**

1.0 How to Select a Cable

When selecting a cable for your specific application, a number of variables require attention. These are:

(a) Size and type of load to be supplied
(b) Permissible voltage drop
(c) Prospective fault current
(d) Circuit protection
(e) Environmental conditions of installation

1.1 Load to be supplied

In order to select the appropriate cable, it is necessary to know the voltage and the load current in amps. This information will be available either directly in amps or as kW or kVA.

The following formulae apply:

$$I_{FL} = \frac{kW \times 1000}{\sqrt{3} \times V \times \text{Cos}\phi}$$ Amps if we know kW, voltage, as well as power factor

$$I_{FL} = \frac{kVA \times 1000}{\sqrt{3} \times V}$$ Amps if we know the kVA rating as well as the voltage

Use this value of current to determine the cable size by reference to the relevant tables given in Section 4 (Paper insulated), Section 5 (XLPE insulated medium voltage) or Section 6 (PVC and XLPE insulated low voltage) for Copper or Aluminium conductors.

A slightly larger conductor size may be chosen for safety aspects, and to provide for the higher than usual current which may be experienced during starting of electric motors.

Example of Cable Selection for Low Voltage

Suppose it is required to supply a 3 phase, 400 volt, 100 kW motor connected in star/delta, over a distance of 50m buried direct in ground. The motor load is known to have a power factor of 0,9 lagging. The full load line current, IFL can be calculated as follows:

$$I_{FL} = \frac{100 \times 1000}{\sqrt{3} \times 400 \times 0{,}9}$$

$$= 161 \text{ Amps}$$

We now refer to table 6.2 on pg 38 and note that the smallest copper conductor, PVC insulated cable, that can supply a current of 161 amps in the ground, is a 50 mm² rated area cable. This cable can carry 169 amps continuously if installed under standard conditions.

1.2 Permissible Voltage Drop

Calculate the highest current drawn by the load, by multiplying the current as calculated in 1.1 by an appropriate factor. If a Star/Delta motor starter is used on a motor, this factor is 3. If the motor is started direct on line, then use a factor of 6. Where the load is resistive heating, lighting or a transformer, it is not necessary to increase the current as calculated in 1.1.

Calculate the volt drop which will be experienced at the load terminals by reference to table 6.2 or 6.3 on pg 38 or pg 39. The maximum volt drop allowed by SANS 10142-1 during full load running condition. There is no hard and fast rule as to the allowable volt drop under starting conditions. Depending on the type of load to be started, there is the possibility that the torque may be compromised during starting, if the motor is subjected to difficult starting conditions. A reasonable volt drop should be chosen in these cases

The volt drop may be calculated in two different ways:

(a) Multiplying the current by the impedance of the length of cable. Calculate the percentage volt drop by reference to the phase to earth voltage.

(b) Multiply the current by the length of cable, and then multiply the result by the volt drop per amp per metre figure as given in table 6.2 or 6.3 on page 38 or page 39, depending on the type of conductor.

Previous example using method (a)

Starting Current = 3 x Running Current
= 3 x 161 Amps
= 483 Amps

Impedance of 50m of $50mm^2$ Cable (Table 6.2) pg 38

$$= \frac{0,4718}{1000} \times 50$$

= 0,02359 ohms

Volt Drop = 483 x 0,02359

$$= \frac{11,394}{230} \times \frac{100}{1}$$

= 4,95% (Acceptable)

Using Method (b)

Starting Current = 3 x 161 Amps
= 483 Amps

Volt Drop per amp per metre = 0,817 mV/A/m (Table 6.2) pg 38

Volt Drop = $0,817 \times 10^{-3} \times 483 \times 50$
= 19,73 volts

Percentage Volt Drop

$$= \frac{19,73}{400} \times \frac{100}{1}$$

= 4,93% (Acceptable)

Note: It often happens on long runs of electric cable that a larger conductor than that calculated in 1.1 is required for volt drop reasons.

Example of Cable Selection for Medium Voltage (11 kV)
We wish to supply a 2 MVA 11 kV transformer from an Eskom supply point which is 3km away. We are to use an underground paper insulated, copper conductor cable. The depth of burial of the cable is 1,25 m. Ground thermal resistivity is 2K.m/W. The ground temperature is 25°C and there are no other cables in the trench.

Short circuit level may be assumed to be 250 MVA, and the earth fault level 100 MVA, and it may be assumed that a fault will be cleared in half a second.

Using the previous formulae:

$$I_{FL} = \frac{2\,000\,000}{\sqrt{3} \times 11\,000}$$

= 105 Amps before derating for non standard conditions

Derating factor for Depth of Burial at 1,25 m is 0,96.
Derating factor for Soil Thermal Resistivity at 2 K.m/W is 0,84.
Derating factor for Ground Temperature of 25°C is 1,00.

Total Derating = 0,96 x 0,84 x 1,00

= 0,8064

$$\text{Standard} = \frac{105}{0{,}8064}$$

= 130 Amps

Table 4.2 on pg 28 shows that a 35 mm² Copper conductor cable would be capable of carrying this load (130 A). This is confirmed by reference to the Paper Insulated Cable brochure (Page 13).

The cable size required is thus 35 mm² Copper conductor, 3 Core General purpose belted cable. (Table 17 SANS 97).

Checking for volt drop:

$$\text{Volt Drop} = \frac{Z \times \sqrt{3} \times I \times \text{distance}}{1000}$$

$$= \frac{0{,}6371 \times 1{,}73 \times 105 \times 3000}{1000}$$

= 347,6 volts (3,2% of 11 kV)

Volt drop is seldom a problem at Medium Voltage, even for long runs of small conductor size as shown above.

Checking for fault current
Prospective Symmetrical (Short Circuit) Current

$$= \frac{250\,000\,000}{\sqrt{3} \times 11\,000}$$

$$= 13{,}122 \text{ kA}$$

Cable short circuit current with stand is

$$I_{sc} = \frac{\text{Cross Section} \times K}{\sqrt{t}}$$

K is 115 A/mm² for copper conductors, paper insulated.

The half second rating is thus:

$$\frac{35 \times 115}{\sqrt{0{,}5}} = 5{,}692 \text{ kA}$$

This cable will not survive the prospective short circuit current.

Conductor size required is thus:

$$\frac{x \times 115}{\sqrt{0{,}5}} = 13{,}122 \text{ kA}$$

$$\therefore x = 80 \text{ mm}^2$$

Nearest standard size is a 95 mm² Copper conductor.
This has a current rating of 235 Amps under standard conditions.

Earth fault current for half a second:
Lead area for a 95 mm² x 3 Core PILC cable is approximately 200 mm²

Cable earth fault current withstand is:

$$= \frac{200 \times 0{,}024}{\sqrt{0{,}5}}$$

$$= 6{,}8 \text{ kA for half a second}$$

Required earth fault current:

$$I_{EF} = \frac{100\,000\,000}{\sqrt{3} \times 11\,000}$$

$$= 5{,}25 \text{ kA for half a second}$$

In many cases, the cable conductor size is larger than dictated by the full load current, and is chosen in order to survive the prospective short circuit current. The use of large conductors can be avoided by improving the speed of protection, (fuses for example) and in the case of earth fault current, by the use of sensitive earth fault protection.

1.3 Prospective Fault Current

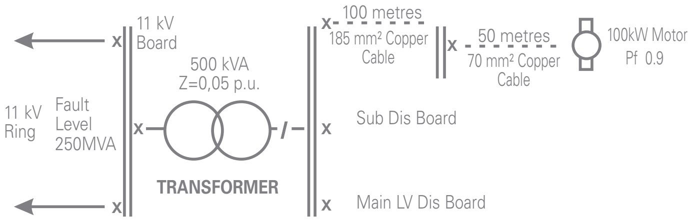
Electric cables are designed to operate below a certain maximum temperature, this being dependent on the conductor material and the type and the thickness of the insulation.

Cable selection for a particular installation must therefore be made on the basis of not exceeding these temperature limits.

Suppose the 400 volt distribution board from which a cable is fed has a fault level of 5 MVA. This translates to a fault current of 7,22 kA, and the cable must be capable of passing this current without damage until the fault is cleared.

The smallest cable that can safely handle this fault current for a 1 second fault, is a 70 mm² copper conductor cable, or a 95 mm² aluminium conductor cable. Suppose now that the fault clearance time (including any mechanical delays on the tripping mechanism) is closer to 2 seconds, then the smallest cable would be a 95 mm² copper conductor($10{,}925 \div \sqrt{2} = 7{,}725$ kA for 2 seconds) or a 150 mm² aluminium conductor ($11{,}400 \div \sqrt{2} = 8{,}061$ kA for 2 seconds). Likewise, a fault duration less than 1 second will allow the use of smaller conductors than were calculated for the 1 second rating.

Another Example:
Consider the following diagram:
Diagrammatically, the system is:-



We are required to calculate the fault current at the sub dist board.

P.U. SYSTEM

p.u. source impedance $= \dfrac{\text{Base MVA}}{\text{Fault Level MVA}}$ **(1)**

p.u. transformer impedance $= \dfrac{\text{Base MVA x Transformers \% Impedance}}{\text{Transformer MVA}}$ **(2)**

p.u. cable impedance $= \dfrac{\text{Z (ohms) x Base MVA}}{V^2 \text{ (kV)}}$ **(3)**

(1) + (2) + (3) = p.u. impedance

$$\text{Fault Level} = \frac{\text{Base MVA}}{\text{p.u. impedance}} \quad \text{MVA}$$

$$\text{Fault Current} = \frac{\text{Fault Level (MVA)} \times 1\,000\,000}{\sqrt{3} \times \text{Voltage (V)}}$$

Example 1: Using a base of 100 MVA and the per unit method, the impedance of the system at the sub-dist board can be determined:

Source $\frac{100}{250} = 0{,}4$ p.u.

Transformer $\frac{100}{0{,}5} \times 0{,}05 = 10$ p.u.

From Table 6.2 on pg 38 the impedance of 185 mm² cable = 0,1445 Ω/km
Thus the impedance of 100 m = 0,01445 Ω

$$\text{Z.p.u.} = \frac{\text{Z (ohms) c MVA}}{\text{V2 (kV)}} = \frac{0{,}01445 \times 100}{(0{,}400)2} = 9{,}03 \text{ p.u.}$$

The fault level at the sub-dist board is then found by dividing the base MVA by the total per unit impedance:

$$\text{Fault Level at Sub Board} = \frac{100}{0{,}4 + 10 + 9{,}03} = 5{,}147 \text{ MVA}$$

$$\text{Fault Current at Sub-Dist Board} = \frac{5{,}147 \times 1\,000\,000}{3 \times 400} = 7{,}429 \text{ kA}$$

Example 2: Using a Base of 250 MVA, the same result is obtained:

Source $\frac{250}{250} = 1$ p.u.

Transformer $\frac{250}{0{,}5} \times 0{,}05 = 25$ p.u.

Cable $\frac{0{,}01445 \times 250}{(0{,}400)2} = 22{,}578$ p.u.

Total Impedance $= 48{,}578$

$$\text{Fault Level} = \frac{250}{48{,}578} = 5{,}146 \text{ MVA}$$

$$\text{Fault Current} = \frac{5{,}146 \times 1\,000\,000}{\sqrt{3} \times 400}$$
$$= 7{,}428 \text{ kA}$$

From the above illustration, it is clear that whatever may be the value of Base MVA, short circuit current is the same. However, in the interest of simplicity a numerical convenient value of the Base MVA should be chosen.

Where k = 115 A/mm² for PVC / Copper cables, shows that a 70 mm² copper cable can withstand a short circuit current of 8.05 kA for 1 second. This is above the potential fault level of the system. Moreover, the duration of the fault or the time taken by the protective device to operate has to be considered. The circuit supplying the motor would very likely be protected by a 200 amp fuse or a circuit breaker. Both these devices would operate well within 1 second, the actual time being read from the curves showing short circuit current / tripping time relationships supplied by the protective equipment manufacturer. Suppose the fault is cleared after 0,2 seconds. We need to determine what short circuit current the cable can withstand for this time

This can be found from the expression $I_{sc} = \frac{A \times K}{\sqrt{t}}$

where *K = 115 for PVC / Copper cables (70°C - 160°C)*
K = 143 for XLPE / Copper cables (90°C - 250°C)
K =76 for PVC / Aluminum (solid or stranded) cables (70°C - 160°C)
K = 92 for XLPE / Aluminum (solid or stranded) cables (90°C - 250°C)
K = 115 for PILC / Copper cables (70°C - 160°C)
K = 76 for PILC / Aluminum (stranded) cables (70°C - 160°C)

and where A is the conductor cross sectional area in mm² and t the duration of the fault in seconds

So in our example $I_{sc} = \frac{70 \times 115}{\sqrt{0,2}} = 18\text{ kA}$

This is well in excess of the system potential fault level and so it can be concluded that a 70 mm² cable is suitable for this example. During the period of short circuits, the forces acting upon individual cores of a 3 phase system are enormous. These are forces of repulsion and attraction, and hence cause the cores to move if inadequately restrained. In the case of 3 core armoured cables, the fact that the cores are laid up, and the restraining effect of the armour wires is such as to limit the core movement. Bursting strengths are, however, still important in the case of PILC cables where the effect of the resultant voids left in the insulation (even after small movement) may be detrimental to the long term life of the cable so affected.

1.4 Environmental Conditions of Installation

The data used for determining the current ratings given in this publication are based on calculations according to IEC 287. Ratings for multicore cables are given for a single cable run. Where groups of cables run in a common route the appropriate derating factors are given in the tables on pages 29 ; 34 and 44 depending on the type of cable being used.

Similarly when the installation conditions differ from standard, the derating factors in the appropriate sections must be used.

A qualitative assessment of the conditions immediately surrounding the cable should be made. Factors such as the need for a fire retardant sheath, additional mechanical protection, safeguards against chemical attack and corrosion should be considered in this category. These influences affect mainly the external finish of the cable, the armouring and serving.

Cables are sometimes specified with a termite repellent sheath. It is worth mentioning that no sheath will repel insects since sheath material has to be ingested by the termite to be fatal. Thus, the statement 'cable with a termite repellant sheath' is somewhat erroneous.

In the case of paper lead cables there are several alternative sheath metals available, pure lead is prone to fatigue when subjected to vibration. Alloy E sheath can be supplied which will resist deterioration through fatigue.

The foregoing notes are by no means an exhaustive treatment of the points to consider when choosing a cable for a particular application but are rather guidelines to the salient points which need consideration.

1.4.1 Cables Laid Direct in the Ground

The ratings given are based on a ground thermal resistivity (g) of 1,2 K.m/W. The factor (g), varies considerably with differing ground conditions and has a pronounced effect on a cable's current carrying capacity. The only sure way to determine (g) is to measure it along the cable route. This practice is normally reserved for supertension cables, but there could be other applications where soil thermal resistivity is critical.

Suitability of soils for bedding and backfill

Clay: Clay is a dense, compact material, greasy to the touch when wet and which has a low Thermal Resistivity even in the fully dried-out condition. Most clays however, shrink when drying and can thus not be used as a bedding for the cable. They can be used as backfill and should be consolidated by rolling rather than tamping.

Sand: Sand is a crumbly material with particle grains easily distinguished and gritty to the touch even when wet. Particle sizes larger than 2 mm are known as gravel. Sea sand or sand obtained from a river bed usually consists of spherical particles and has a very high Thermal Resistivity when dry. Some quarried sands and man-made sands as used for making concrete, have irregularly shaped particles of varying size and can be compacted to a high density. These can be used as a bedding material especially when 5-10% clay is added and will have a satisfactorily low Thermal Resistivity in the dried-out state. Sand/gravel mixes should be used with care as sharp particles can damage the cable serving.

Sand clay: Sand clay is, as its name implies, a mixture of sand and clay. It is an ideal material for use as bedding and backfill and is best compacted by rolling. It rarely dries out to lower than 6% moisture content.

Loam: Loam can vary in colour from reddish brown to dark brown and may contain quantities of organic matter. It crumbles well, even when dry, and can be well compacted to achieve satisfactory values of Thermal Resistivity. It is very suitable as a bedding material.

Chalk: Chalk is a soft white or grey porous material having a lower Thermal Resistivity when wet, but drying out to very high values and is unsuitable for use as bedding or backfill in any area where drying out is likely.

Ouklip: Ouklip is decomposed rocky material, varying in particle size and having very low Thermal Resistivity in the undisturbed state. It can be used as a backfill material when mixed with loam or clay but should not be used as a cable bedding.

Peat: Peat or humus is composed mainly of organic material and is black or dark brown in colour. It should not be used as bedding or backfill as dried-out Thermal Resistivity values of over 4 K.m/W are usually obtained. It should be removed and alternative material used for both bedding the cables and backfilling the trench.

Make-up soil: This is a general term for the soil in any area, the level of which has been raised artificially using imported fill which may consist of bricks, concrete, cinders, ash, slag, stones, other refuse or any of the material considered above. If any doubt exists as to suitability, it is best removed completely and a suitable material imported.

Mine sand: Mine sand is thermally very satisfactory, but is highly corrosive and should therefore not be used.

Table 1.1

Material	Thermal Resistivity (g) K.m/W
Sandy Soil	1,20
Clay	1,60
Chalky Soil	1,80
Concrete	0,90
Water logged ground	0,50
Gravel	1,00

The thermal resistivity of a substance is greatly influenced by the moisture content at a given time. The higher the quantity of retained moisture the lower will be the thermal resistivity. A heavily loaded cable will dry out the soil around the cable and cause an increase in (g). This process is cumulative and damage could be done to the cable insulation through over-heating.

Impurities such as slag, ash and the like increase the value of (g), as does intense vegetation on the cable route, by drawing moisture from the ground.

1.4.2 Cables Installed in Air

Multicore cables should be installed with a space of $\geq$ 0,3 x overall diameter and single core cables with a space of $\geq$ 0,5 x overall diameter between themselves and the vertical wall or surface supporting them as per IEC 287 If they are installed in direct contact with the wall then the current rating given should be reduced by 5% as a rough guide line provided there is a space of 150 mm or six times the overall diameter of the cable whichever is the greater between adjacent cables or cable groups in the case of single core cables. If the installation fails to comply with this requirement then the derating factors in the relevant sections should be applied.

Where the ambient temperature along a route varies, the highest value should be taken to select the cable size.

1.4.3 Cables Installed in Ducts

The air within a pipe or duct will increase the thermal resistance of the heat dissipation path. Consequently the current rating or a cable run in a duct (pipe) is lower than that for an equivalent cable in the ground or in free air. The ratings given can be applied to cables laid in concrete, asbestos,

pitch fibre, PVC, earthenware or cast iron pipes which are the more common materials encountered. It should be noted that single core cables forming a part of an a.c. system should not be individually installed in cast iron pipes due to the heavy losses incurred by eddy current induction.

Generally the size of the duct (pipe) chosen should depend upon the ease of pulling in, or out, the cable. It should be borne in mind that a larger cable may be required in the future to cater for increased load growth. Common pipe sizes used in South Africa are 100 mm and 150 mm internal diameters. When groups of cables are run in pipes along the same route, they should be derated according to the factors given in the relevant tables.

1.4.4 Composite Cable Routes

It frequently happens that a cable run is made partly in air, partly direct in the ground and partly in ducts. The latter conditions lead to the lowest rating and it is here that attention must be focused. Very little heat travels longitudinally along the cable, the main dissipation being vertically through the duct wall and surrounding ground. Any rating where the route is part ground, part duct must therefore be treated with care.

Where the length of ducting does not exceed 5 metres per 100 m of route length, the cable rating may be assumed to be that for direct burial in the ground.

1.4.5 Intermittent Operation

Certain types of loads have an intermittent characteristic where the load is switched on and off before the cable has time to cool completely. Depending upon the load cycle it may be possible to select a smaller cable for intermittent operation than would be the case if the load were continuously applied. When a current in excess of the normal rated current is applied, the heating of the cable will be a correspondingly quicker operation than the cooling.

Generally I = *Equivalent RMS current*
I_n = *Current flowing during $_n$th period (Including periods of zero current).*
t_n = *Duration of $_n$th period*
N = *Number of periods, (includes periods of zero current)*

Thus

$$I = \sqrt{\frac{\sum_{n=1}^{n=N} \left[(I_n)^2 t_n\right]}{\sum_{n=1}^{n=N} (t_n)}}$$

Example
Suppose a process cycle is as follow:

- 150 Amps for 1 minute
- 100 Amps for 3 minutes
- 50 Amps for 2 minutes
- 0 Amps for 4 minutes

Then applying the expression for RMS current.

$$I = \sqrt{\frac{\sum_{n=1}^{n=N} \left[(I_n)^2 t_n\right]}{\sum_{n=1}^{n=N} (t_n)}}$$

$$= \sqrt{\frac{57\ 500}{10}}$$

$$= 75{,}83 \text{ Amps}$$

Thus a continuous current of 76 amps flowing over the 10 minute cycle time would produce the same heating effect as the individual cyclic currents, and the size of cable could be selected based on 76 amps.

1.4.6 Solar Heating

When cables are installed in direct sunlight, an appreciable heating due to solar absorption takes place. This results in a significant reduction in the cables current carrying capacity and for this reason it is strongly recommended that cables be protected from direct sunlight. The maximum intensity of solar radiation measured in South Africa varies between 1000 and 1250 Ω/m^2 depending upon location.

2.0 Useful Electrical Formulae

2.1 Volt Drop

The voltage drop in a single phase circuit is given by:

Volt Drop = $2\,X\,I \times (R\cos\phi \pm x\sin\phi)$

where

I = *Line current amps*

R = *Circuit resistance ohms/phase*

X = *Circuit reactance ohms/phase*

ϕ = *Angle of lead or lag between current and voltage*

Induction Reactance $X_L = 2\pi fL$ ohms

Capacitive Reactance $X_C = \dfrac{1}{2\pi fC}$

where

f = *supply frequency Hertz*

L = *circuit inductance Henrys*

C = *circuit capacitance Farads*

Impedance $Z = \sqrt{R^2 + (\omega L)^2}$ ohms

Where $\omega = 2\pi f$

Power Factor cos $\phi = \dfrac{R}{Z}$

Admittance Y = G-jB ohms

Where

G = *conductance (Siemens)*

B = *susceptance (Siemens)*

Capacitive Susceptance $B = 2\pi fC$ (Siemens)

For a 3 Core Screened Underground Cable or Overhead Line:

$$L = 0{,}0516 + 0{,}46 \log \frac{GMD}{r} \text{ mH/km/phase}$$

and

$$C = \frac{0{,}024\, l\in r}{\log \dfrac{GMD}{r}} \ \mu\text{F/km/phase}$$

where

GMD = *Geometric mean diameter mm*

r = *Conductor radius mm*

$\in r$ = *Relative permittivity of dielectric*

$$GMD = \sqrt[3]{abc}$$

Where a, b and c are the distance in mm between the centres of the three phases conductors.

2.2 Charging Current

Charging current $= \dfrac{2\pi f C E}{\sqrt{3} \times 10^6}$ amps/km

where C = *Capacitance per phase μF*

E = *Line to line voltage*

In the case of an underground cable with shaped conductors, C is increased by 8%.

2.3 Per Unit System

Per unit impedance Z $= \dfrac{I}{E} \times Z$ (ohms)

Per unit impedance referred to a given base MVA

$= \text{Actual } Z \text{ p.u.} \times \dfrac{\text{Base MVA}}{\text{Full Load MVA}}$

Z p.u. on given MVA base

$= \dfrac{\text{MVA Base}}{E^2} \times Z$ (ohms)

2.4 Load Growth

Load growth L in n^{th} year at (g) % per annum

$Ln = Lo\left(1 + \dfrac{g}{100}\right)^n$ MW

where Lo = Load in first year in MW.

2.5 Load Factor

Monthly Load Factor $= \dfrac{\text{kWh Sold per Month}}{\text{Number of Hours per Month x M.D. kW}}$

Monthly Diversity Factor $= \dfrac{\sum \text{Individual Consumers M.D.'s}}{\text{Simultaneous M.D. Recorded during the Month}}$

2.6 Capacitor Voltage Rise

Per unit voltage rise in a circuit due to capacitors V p.u. =

$\dfrac{\text{3 Phase Capacitor kVAR}}{\text{3 Phase Fault Level kVA}}$

2.7 Load Sharing

Natural load sharing between 2 parallel feeders

$$I_1 = \frac{Z_2\angle\theta_2}{Z_1\angle\theta_1 + Z_2\angle\theta_2} \quad I\angle\phi \text{ Amps}$$

$$I_2 = \frac{Z_1\angle\theta_1}{Z_1\angle\theta_1 + Z_2\angle\theta_2} \quad I\angle\phi \text{ Amps}$$

where I = $I_1 + I_2$
ϕ = *Angle of load current*
θ_1 = *Angle of transmission line 1*
θ_2 = *Angle of transmission line 2*

2.8 Conductor Resistance

Change of conductor resistance with temperature

$$R_t = R_o\left[(1 + \alpha(T_t - T_o)\right] \quad \text{ohms}$$

where R_t = *d.c. resistance at temperature* T_t *°C*
R_o = *Initial d.c. resistance at temperature* T_t *°C*
α = *Temperature co-efficient of resistance of conductor material*

The a.c. resistance of a conductor is given by:

$$R_a = R_d\ (1+y+y_1)$$

where R_d = *d.c. resistance*
y = *skin effect factor*
y_1 = *proximity effect factor*

Table 2.1 : Values of $(1 + y + y_1)$ for 1000 volt cables

Conductor Area	$(1 + y + y_1)$	
mm²	3 Core	Single Core
Up to 185	1,027	1,019
240	1,041	1,027
300	1,068	1,048
400	1,115	1,087
500	1,175	1,136
630	-	1,208
800	-	1,315
1000	-	1,516

2.9 Lead Resistance

$$\text{Resistance} = \frac{238{,}1}{\text{area of Pipe Wall}} \quad \text{ohms/km}$$

2.10 Wire Armour Resistance

$$\text{Resistance} = \frac{185{,}03}{d^2N} \quad \text{ohms/km}$$

where d = *wire diameter*
N = *Number of wires*

Table 2.2 : Characteristics of Copper and Aluminium conductors

Property	Copper Annealed	Aluminium Annealed
Volume Resistivity ohm/mm²/km	17,2414	28,03
Specific Gravity	8,89	2,703
Temperature co-efficient of Resistance per °C	$3{,}93 \times 10^{-3}$	$4{,}03 \times 10^{-3}$
Co-efficient of linear Expansion per °C	17×10^{-6}	23×10^{-6}
Specific Heat cals/g	0,093	0,24
Melting Point °C	1065	659

It can be shown that aluminium has 78% of the current carrying capacity of an equivalent size copper conductor. The current rating of a cable depends upon the thermal dissipation of the conductor I^2R losses. Using the suffixes ‘c’ for copper and ‘a’ for aluminium, equal conductor losses are satisfied by:

$$I_c^2 \times R_c = I_a^2 \times R_a$$

$$I_a^2 = \frac{R_c}{R_a} \times I_c^2$$

$$= \frac{17{,}2414}{28{,}03} \times I_c^2$$

$$= 0{,}61 \times I_c^2$$

$$I_a = \sqrt{0{,}61} \times I_c$$

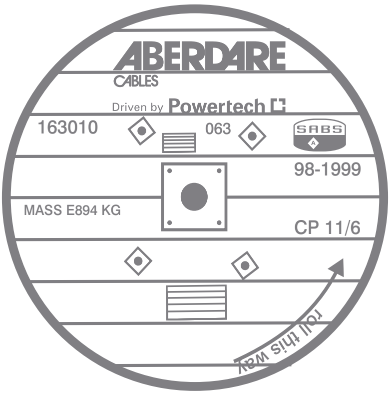
$$= 0{,}78\ I_c$$

3.0 Transport, Handling and Installation of Electric Cables

3.1 Cables on Wooden Drums

(a) The cable drum is manufactured from carefully selected locally grown wood with a low moisture content (typical not more than 15%) (Fig. 1) if they are required to be treated it shall be done in accordance with SANS 05 with a Class C preservative or with chromate copper arsenate. Saligna, which is a hardwood, does not require treatment.

Figure 1



(b) Marking on drum flanges should be clear, stencilled or burned into the wood and should include the following information:

- (i) Manufacturer's name or trade mark.
- (ii) Rated voltage, rated area, number of cores and specification.
- (iii) Length of the cable in metres.
- (iv) Year of manufacture.
- (v) Gross mass in kilograms.
- (vi) The instruction "NOT TO BE LAID FLAT".
- (vii) Serial number or other identification.
- (viii) On each flange an arrow with the words "ROLL THIS WAY".
- (ix) SABS Mark (if applicable).

(c) Both ends of the cables on the drum should be sealed and the inner end fixed to the flange of the cable drum to prevent loose coiling. The outer end is fixed to the flange as well, for the same reason.

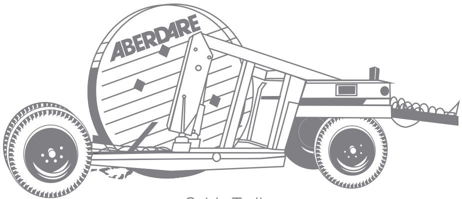
(d) Cable drums should stand on firm, well-drained surfaces.

(e) In the past, it was common practice to rotate stored cable drums through 180° to re-distribute the rosin impregnation oil through the dielectric. The use of MIND cables has obviated this reason for rotating drums. However, it is still recommended that wooden cable drums that are stored in the open, irrespective of the type of cable contained, should be periodically rotated to avoid the drum timber rotting through rising damp.

3.2 Cable Transportation

(a) **Preparation**
- (i) The truck must match the drum size.
- (ii) Do not overload the trucks.
- (iii) Cable ends must be sealed, secured and protected
- (iv) Use special cable trailers for depot to site transportation if possible (See fig. 2).

Figure 2



Cable Trailer

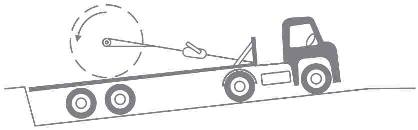
(b) **Loading**
- (i) Check drums for correct cable and size, serial number, mass and possible damage.
- (ii) Select correct forklift/crane.
- (iii) Select correct slings and spindle and check sling condition.
- (iv) If a crane is to be used, ensure that a spreader is incorporated to prevent damage to drum flanges.
- (v) If the drum is to be rolled, observe correct rolling direction by referring to arrows on flanges.
- (vi) Ensure that the drum bolts are tight.
- (vii) Ensure that truck surface is clear of obstructions, nails etc.
- (viii) Do not drop drums onto truck loading bed.

(c) **Securing**
- (i) Secure drums to the truck bed to prevent sliding and rolling, using adequate steel chains and chocks.
- (ii) Always try to pack drums flange-to-flange.
- (iii) Do not lay drums flat.
- (iv) Stop the vehicle during transportation and check that the load is secure.

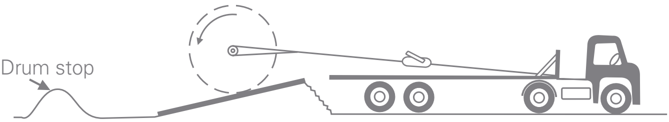
(d) **Off loading**
- (i) Check for damage to cable drums.
- (ii) Select correct spindle slings for the drum size and mass and ensure that same are in good order, ensure that a spreader is used.
- (iii) Do not drop drums but lower gently onto firm and relatively level surfaces.
- (iv) Off load drums in such a way that they are easily accessible.
- (v) If using a fork-truck, ensure that it is of adequate size relative to the task at hand.
- (vi) Ensure that the fork-truck tyres lateral spacing is correct.
- (vii) Take care that the protruding tyres do not damage other equipment or drums.
- (viii) There are two methods of rolling drums from loading beds if cranes are not available (See fig.3)

Figure 3

Method 1: Hole excavated maximum slope 1 in 10 to receive



Method 2: Ramp constructed maximum slope 1 in 4



3.3 Cable storage

(a) **Indoors**

- (i) Stack flange-to-flange and preferably not one on top of the other.
- (ii) Stack so that drums are easily accessible.
- (iii) Observe fire prevention rules.
- (iv) Cable ends must be sealed at all times.
- (v) Despatch on "first in - first out" basis.
- (vi) Rotate Paper insulated cable drums one complete revolution per annum.

(b) **Outdoors**

- (i) Drums should stored on a hard surface at a slight angle and the area should have a drainage system.
- (ii) Drums should be released on a "first in - first out" basis.
- (iii) Cable ends should be sealed at all times.
- (iv) Stack flange-to-flange but if this is not possible limit vertical stacking practice to smaller drums only.
- (v) Stack in such a way that drums are easily accessible.
- (vi) Observe fire protection rules.
- (vii) Cable racks are ideal for storage but take care not to overload.
- (viii) Cables must be identifiable at all times.
- (ix) If drums are expected to be stored for a long time they must be specially treated or made of hard wood.
- (x) Rotate Paper insulated cable drums one complete revolution per annum.

3.4 Mechanical Forces on Cables during Installation

Any cable has a maximum pulling force which should not be exceeded during installation. The cable construction imposes the limitation on the pulling-in force. When a cable stocking is used the maximum force can be related to overall cable diameter in mm as follows:

Steel Wire Armoured Cables	F	=	$0.94\ d^4 \times 10^{-6}$ kN
Steel Tape Armoured or Unarmoured Cable	F	=	$0.39\ d^4 \times 10^{-6}$ kN
Control and Communication Cables	F	=	$0.26\ d^4 \times 10^{-6}$ kN

Attempts should be made to limit the pulling force required to a minimum to avoid stretching the outer layers of the cable. This is particularly relevant where control and communication cables are concerned since instances are known where the cores have finished 2-3 metres inside the sheath and insufficient overlap at straight joint positions has necessitated re-laying some lengths.

An increase in the pulling force is permissible when the cable is laid by means of a pulling eye attached to the conductors. As a rule of thumb, the following forces may be applied to a conductor:-

Copper	4.9×10^{-2} kN/mm²
Aluminium	2.94×10^{-2} kN/mm²

Then, for example the maximum force that should be applied via a pulling eye to a 70mm² 3 core copper cable is:-

$70 \times 3 \times 4.9 \times 10^{-2} = 10.29$ kN

Generally when cables are installed using well-oiled rollers and jacks, the following forces can be expected:-

straight route15 - 20% of cable weight
2 - 90° bends 20 - 40% of cable weight

Cables laid in open trenches should be left slightly "snaked" so that any longitudinal expansion or contraction can be accommodated. Similarly when cables are installed in cleats or on hangers a slight sag between fixing points is recommended.

3.5 Pulling cables through Pipes or Ducts

When a cable is pulled through a pipe, friction between the cable serving and the pipe material increases the longitudinal force requirements. Representative values for the co-efficient of friction (μ) between the more common cable servings and pipe materials are given below:-

Table 3.1

Serving Material	Pipe Material	μ
PVC	Asbestos	0,65
PVC	Metal (Steel)	0,48
PVC	Pitch Fibre	0,55
PVC	PVC	0,35
Bitumenized	Asbestos	0,97
Hessian	Metal (Steel)	0,76
or Jute	Pitch Fibre	0,86
	PVC	0,55

This information can readily be used to determine the maximum length of cable that can be pulled through a given pipe without exceeding the maximum permissible pulling force. Take for example the 70 mm² x 3 core cable previously quoted, if this is a low voltage cable with a PVC sheath and it is desired to know the maximum length of PVC pipe it can be pulled through then:-

Maximum force = 10.29 kN (by pulling eye)

for PVC to PVC = 0.35

But force = μ x Reactive force

= μ x Cable weight

= $\mu \times \frac{\text{Cable mass}}{102}$

mass of cable = $\frac{10.29}{0,35} \times 102 = 2\,998$ kg

(1 kN = 102 kg)

From the table the mass of 70 mm² x 3 Core copper cable is 3,6 kg/m.

Thus the maximum length of cable that can be pulled through a PVC pipe is:

$$\frac{2\,998}{3,6} = 832 \text{ metres}$$

If there are any bends in the route then these will create additional loading and reduce the theoretical length of cable that can be installed.

In certain instances when long runs in pipes or ducts are encountered it may be beneficial to grease the cable with petroleum jelly or some other non aggressive compound to facilitate the pulling-in.

Considerable damage can be done to cable serving at the mouth of a pipe and precautions should be exercised at such points. This point is achieving more importance with the present day trend towards impermeable anti corrosive sheaths which have to withstand periodic pressure tests. Included among the protective measures that can be adopted are the fitting of a rubber grommet to the mouth of the pipe and inserting a reasonable thickness of rag.

When unarmoured cables are pulled into pipes it will be beneficial to ensure that there is no foreign matter present which could cause damage to the sheath before pulling. Pushing a draw rod through the pipe will usually clear any obstruction.

3.6 Preparation for Cable Laying

(a) **Planning**

When planning a cable route there are several factors to be considered, among the most important of these are:

(i) GroundThermal resistivity (TR) tests.

(ii) Position of joint bays.

(iii) Provision to indicate on the 'as laid' drawings, the serial or drum number of the cable installed.

(iv) The use of mass or pre-impregnated non-draining Paper insulated cables, XLPE and PVC dielectrics has all but eliminated the need for special precautions when laying cables on steep slopes in shafts.

(b) **Drum Handling**

(i) Always use the best hoisting equipment available.

(ii) Do not drop drums of cable onto the ground as this not only damages the drum but will damage the cable as well (especially Paper insulated cable).

(iii) It is most important that a minimum of rolling of the drums on the ground be allowed and then only in the direction of the arrows painted on the flanges.

(iv) When rolling a drum of cable, to change direction use 2 steel plates with grease between them, and by standing one flange on these plates the cable drum may then be swivelled in the desired direction.

(v) Position the drum prior to cable-pulling so that the cable is pulled from the top of the drum.

(vi) Note that a drum of power cable can weigh up to 10 tons so make sure that adequate cable drum jacks are used, that the spindle is strong enough to hold the drum and that the jacks stand on firm ground and that they hold the spindle horizontal.

(vii) Site the drum at the most convenient place for cable-pulling, usually at the start of a reasonably straight section near the commencement of the trench work.

(viii) Allow for drum braking.

(c) **GroundThermal Resistivity**

(i) This often governs the rating of a power cable buried directly, as does the temperature of the soil. Losses for cables running at the maximum temperature at which the dielectric system can faithfully operate for a maximum life of say, 25 years, are considerable, ranging from 15 W/m for normal distribution cables. Cable conductor temperature and the soil surrounding the cable must be able to dissipate this heat effectively or thermal instability (runaway)will result. For example an XLPE insulated 11 kV cable with conductors running at 90°C could end up with a surface temperature of about 80°C resulting in drying-out of the soil. Depth of burial plays an important factor here and has been set at 800 mm. Most MV Cable current ratings are calculated with ground temperatures at 25°C at depths of burial of 800 mm.

LV cables are normally buried at 500 mm. Soil thermal resistivity (the ability of the soil to conduct or dissipate heat) is standard at 1.2 K.m/W.

(ii) The actual soil thermal resistivity along the proposed route should be measured either by means of an ERA needle probe or the SABS needle probe, but these are outside the scope of this paper, suffice it to say that different soil compositions along the route will have different rates of heat dissipation and could result in "hot spots".

(iii) To overcome this, bedding and backfill soils may have to be "imported".

(d) **Positioning of Joint Bays**

Ensure that there is sufficient working space, consider passing traffic and other obstructions. If it is not possible to position the joint bays at standard cable length distances, remember that the cable can be ordered in specific lengths. Consider drainage for large bays and try to construct the bays prior to cable pulling to prevent any damage to the cable at a later stage.

(e) **Recording Cable Drum Serial Numbers on "As Laid" Drawings**
In the unlikely event of a cable failure in the future, quoting the cable drum serial number will assist the cable manufacturer in his quality control, as this serial number is related to the manufacturing and raw material management in the factory.

(f) **Preparing for Cable Laying**

The following "VITALACTIONS" must be observed prior to a cable pull.

(i) Cable rollers must be placed between 2 and 3 m apart in the trench(depending on size of cable) (See fig. 4a on page 23).

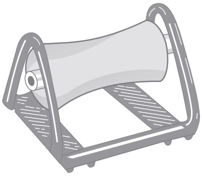
(ii) Ensure that graphite lubricants have been applied where necessary.

(iii) Check that skid plates are secure and in position, corner rollers are a good alternative (See fig. 4b on page 23).

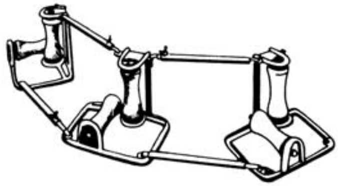
(iv) Ensure that each member of the pulling gang knows exactly what he is to do and that communication signals between members are clear.

(v) The trench floor must be clear of stones and other obstructions and the cable bedding correctly dispersed.

Figure 4



(a) Cable Roller



(b) Corner Roller

(c) Cable Stocking

(d) Pulling Eye

Ensure that:

(vi) Cable covers are available at convenient points.

(vii) Any objects that may fall into the trench and damage the cable during the pull and prior to backfilling have been removed.

(viii) If the ambient temperature is below 10°C or has been so for the past 24 hours, the cable on the drum will have to be covered with a tarpaulin and heated with suitable lamps or heaters for at least 24 hours under close supervision. Ensure that sufficient ventilation exists, and pay the cable off the drum slowly and carefully. The drum should be lagged with only a few of the bottom lags removed during the heating process.

(ix) Place the drum at a convenient point prior to the pull on strong jacks and on sound footing (as mentioned earlier) with the arrow on the drum flanges POINTING IN THE OPPOSITE DIRECTION to the rotation when the cable is being pulled.

(x) Before pulling, cut the inner end of the cable free.

(xi) Remove the drum battens carefully and from the bottom.

(xii) Inspect the cable ends for any sign of leakage (especially Paper insulated cables). If a leak is suspected, it can be proved by heating the cap until just too hot to touch and insulating oil will exude out, the cap should then be removed and the extent of the damage assessed, by means of the dielectric test (See Section 4.2). Cables with extruded dielectrics should be sealed and free from moisture.

(xiii) The cable must be payed off from the top of the drum but take care not to bend it too sharply.

(xiv) Cable pulling stockings should be examined and placed over the nose of the cable with care (see fig. 4c & d on pg 23). The pulling rope or wire must be attached to the stocking in such a way that the cable cap will not be damaged during the pull. The use of swivels is recommended to prevent twisting of the stocking. The use of stockings is preferable to tying a rope directly to the cable for pulling-in.

(xv) For permissible mechanical forces see Section 3.4.

(xvi) Bending radius of cables as recommended by the manufacturer should not be exceeded. They are:

Table 3.2 : Recommended Bending radii

Cable Type	Bending Radius up to & including 11kV	22 kV & 33 kV
Paper Insulated Cables		
• Single Core	20 x d	25 x d
• Multicore	12 x d	15 x d
PVC Insulated Cables 1000 Volt		
• Multi and Single Core 16-50 sq mm	8 x d	-
• Armoured Multi & Single Core 70 sq mm and greater	10 x d	-
XLPE Insulated Cables		
• Single Core	17 x d	17 x d
• Multicore	15 x d	15 x d

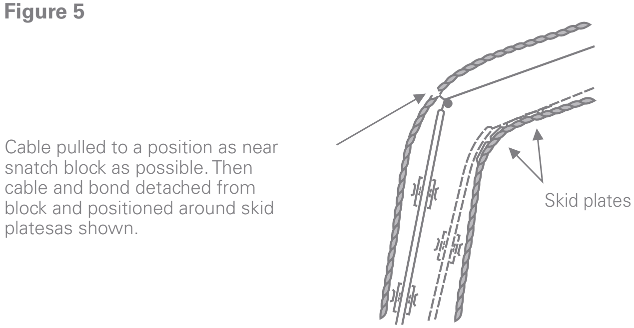
Where d *is the diameter over the outer sheath.*

(xvii) One man should remain at the drum and "brake" the drum in order to maintain the correct tension on the cable during the pull.

(xviii) Cables should be pulled to their final position in a continuous manner.

(xix) If a winch is being used to pull the cable and unavoidable sharp bends are encountered, a snatch block could be used to assist the pulling tension at bend (See fig. 5).

Figure 5



(xx) Heavy lead-sheathed Paper insulated cables in long lengths may need very large gangs of men if no winch is used; lighter XLPE insulated cables require fewer men.

(g) **Sealing of Cable Ends**
Once the cable pull is completed, the nose-end of the cable is carefully lifted off the rollers and placed on the bottom of the trench, leaving enough slack to terminate the cable and observing the minimum bending radius. Immediately after cutting, the cable should be suitably sealed on both ends of the cut to prevent the ingress of moisture. Examine the nose cap and make good any damage that may have occurred during pulling.

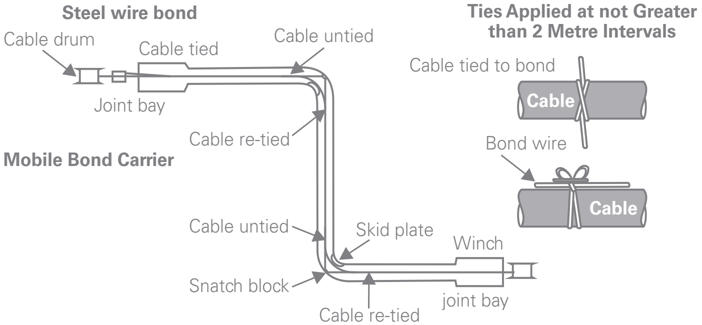
(h) **Bond Pulling**
These techniques are applied when heavy cables are to be laid or the trench undergoes many changes of direction or very long lengths of cable have to be laid, or a combination of these.

As in the previously mentioned methods of cable pulling, the trench would have been prepared with cable rollers, corner rollers and skid plates. Snatch blocks would have been anchored to the sides of the trench at bends and a winch placed at the far end of the section. At the near end a mobile bond carrier is placed conveniently adjacent to the cable drum, ensuring that its braking system is adequate and that it has rewinding facilities. A steel rope, more than twice the length of the cable to be pulled, is wound onto the bond carrier drum and its end fed over the rollers and through the snatch blocks and then secured to the drum of the winch.

The cable end is manhandled onto the first rollers and tied to the steel rope (See fig. 6) at intervals of about 2 metres. Start the winch and as the nose of the cable arrives at the snatch block untie it from the steel cable, take it around the corner roller and retie on the straight.

Once the nose has reached the winch end, and allowing the necessary slack, the cable can be untied, the steel rope rewound onto the bond carrier. Further preparation for backfilling may then be commenced.

Figure 6 : Bond Pulling



3.7 Backfilling and Reinstatement

Once the cables have been laid, and before commencing with backfilling carry out a visual inspection of the installation to ensure that:

(a) The cables are properly bedded.
(b) Correct spacing between cables if there is more than one in the trench.
(c) Cable entrances at ducts are suitably protected against the possibility of vermin gaining entrance.
(d) Laying and pulling equipment has been removed.
(e) That there is no obvious damage to cable sheaths. Up to 90% of the service failures experienced in any cable system can be avoided if appropriate action is taken at this stage.

3.8 Repairs to PVC oversheaths

As mentioned above PVC sheaths damaged 'during pulling' should be repaired taking every care to do a workmanlike job.

(a) **Superficial Damage**
Generally the local area damaged should be removed, the remaining sheath chamfered for 25 mm at the edges. A EPR self-amalgamating tape is then applied after cleaning the affected area thoroughly with a suitable solvent (i.e. Genklene). The PVC tape should be approximately 30 mm wide and is applied under tension with a 50% overlap continuing up the chamfer until the top is reached plus 4 layers extending 75 mm beyond the chamfer.

(b) **Holes or Slits in the PVC Sheath**
Chamfer the edges of the damaged area for a distance of 30 mm and abrade the area with Carborundum strip for a further 20 mm.

Clean the area with a solvent and apply a filling putty (B sealing tape) followed by a layer of EPR self-amalgamating tape applied at high tension extending 50 mm from the patch, followed by 3 layers of PVC tape extending 100 mm from the edges of the EPR tape.

(c) **Removal of a complete section of oversheath**
Upon removal of the damaged ring, chamfer the remaining edges for a distance of 30 mm, clean with the solvent and apply 4 layers of EPR tape at high tension to 50 mm beyond the chamfer. Apply PVC self-adhesive tape at one third overlap to a level corresponding to the original over sheath diameter. Five layers of PVC self-adhesive tape are then applied, each one extending 5 mm further along the cable.

The repair is then completed with a resin poultice reinforcement consisting of 6 layers of ribbon gauge or bandage, impregnated and painted with an approved grade of freshly mixed epoxy resin. Allow 12 hours to cure.

4.0 Paper Insulated And Lead-covered 6.35/11 kV Cables

The following chapter generally covers 6.35/11 kV PILC cables. For higher voltages or single core applications please consult our application engineers for specialised technical or installation information. The cables described in this section are manufactured according to SANS 97. (For greater details see brochure covering this product).

4.1 Notes on impregnating compound

Present day paper insulated cable are mass impregnated with non-draining compound (MIND). This Poly-Iso-Butylene compound remains in a solid state at normal operating temperatures and melts at approximately 100°C.

Compound migration, as was experienced in earlier rosin-oil impregnated cables installed vertically or on inclines, has thus been eliminated by the use of this non-draining compound.

4.2 Moisture in Paper cables

If cable is damaged and the lead sheath or end cap is punctured, moisture almost invariably penetrates into the insulation and, if not detected immediately and removed, may cause trouble at a later date. In every such case, therefore, a moisture test should be carried out and the cable cut back until all traces of dampness are removed. The following simple, but reliable test is recommended:

Moisture Test
Heat about 1 litre of oil compound (or melted paraffin wax)in a saucepan to a temperature of 150°C (check by thermometer). Remove individual paper tapes from the cable under test and immerse them in the hot compound. If any moisture is present, it will boil out of the paper and form bubbles or froth, which will rise to the surface of the liquid. If no moisture is present, the hot compound will be undisturbed.

When carrying out the above test do not handle the portion of the paper tapes to be immersed in the compound, as moisture from the hands may give rise to false conclusions. As moisture is most likely to travel along the cable under the lead sheath or along the conductors, the papers next to the sheath and conductors are those most likely to contain moisture.

To minimise the penetration of moisture into the cable from the atmosphere or other sources, the cores should be moisture-blocked at each end, by sweating them solid or using solid centre ferrules.

Table 4.1 : Current Rating Parameters

Maximum sustained conductor temperature	70°C
Ground Temperature	25°C
Ambient air temperature (free air-shaded)	30°C
Ground Thermal Resistivity	1,2 K.m/W
Depth of laying to top of cable or duct	800 mm

Table 4.2

Electrical and Physical Properties of 3 core Paper insulated and lead covered double steel tape armoured Jute Served 6.35/11 kV cables to SANS 97 Table 17 (General purpose belted)

Cable Size	COPPER CONDUCTORS					STRANDED ALUMINIUM CONDUCTORS				
	Electrical Properties			Physical Properties		Electrical Properties			Physical Properties	
	Current rating (Ground)	Impe-dance	1 second short circuit rating	Diameter over lead	Approx. Cable Mass	Current rating (Ground)	Impe-dance	1 second short circuit rating	Diameter over lead	Approx. Cable Mass
(mm²)	(A)	(Ω/km)	(kA)	(mm)	(kg/km)	(A)	(Ω/km)	(kA)	(mm)	(kg/km)
25	105	0,8779	2,875	31,38	4890	80	1,4421	1,900	31,38	4415
35	130	0,6371	4,025	33,64	5710	100	1,0492	2,660	33,64	5055
50	160	0,4751	5,750	33,49	6020	125	0,7777	3,800	33,49	5195
70	195	0,3365	8,050	36,50	7080	155	0,5423	5,320	36,50	5790
95	235	0,2499	10,925	39,33	8260	185	0,3972	7,220	39,33	6505
120	265	0,2053	13,800	41,73	9440	210	0,3183	9,120	41,73	7225
150	295	0,1739	17,250	44,36	10770	235	0,2640	11,400	44,36	7980
185	335	0,1481	21,275	47,42	12290	265	0,2166	14,060	47,42	8870
240	380	0,1245	27,600	52,14	14480	305	0,1734	18,240	52,14	10050
300	425	0,1106	34,500	56,15	16940	340	0,1472	22,800	56,15	11415

(Short circuit ratings based on temperature rise of 70°C to 160°C)

4.3 Derating factors for non-standard conditions

Table 4.3.1 : Depth of laying - multicore PILC cables (up to 300 mm²)

Depth of Laying (mm)	Direct in Ground	In Single Way Ducts
800	1,00	1,00
1000	0,98	0,99
1250	0,96	0,97
1500	0,95	0,96
2000	0,92	0,94

Table 4.3.2 : Ground Thermal Resistivity (Multicore PILC cables)

Thermal Resistivity (K.m/W)	Direct in Ground	In Single Way Ducts
1,0	1,07	1,03
1,2	1,00	1,00
1,5	0,92	0,95
2,0	0,84	0,88
2,5	0,75	0,82

Table 4.3.3 : Grouping of PILC cables in Horizontal Formation at standard soil conditions (multicore cables)

No of Cables in Group	Direct in Ground					In Single Way Ducts			
	Axial Spacing (mm)					Axial Spacing (mm)			
	Touching	150	300	450	600	Touching	300	450	600
2	0,80	0,85	0,89	0,90	0,92	0,88	0,91	0,93	0,94
3	0,69	0,75	0,80	0,84	0,86	0,80	0,84	0,87	0,89
4	0,63	0,70	0,77	0,80	0,84	0,75	0,81	0,84	0,87
5	0,57	0,66	0,73	0,78	0,81	0,71	0,77	0,82	0,85
6	0,55	0,63	0,71	0,76	0,80	0,69	0,75	0,80	0,84

Table 4.3.4 : Ground Temperature derating factors

Maximum Conductor Temperature (70°C)	Groung Temperatures (°C)				
	25	30	35	40	45
	1,00	0,95	0,90	0,85	0,80

Table 4.3.5 : Air Temperature derating factors

Maximum Conductor Temperature (70°C)	Air Temperatures (°C)				
	25	30	35	40	45
	1,10	1,00	0,94	0,87	0,79

Note: PILC Cables may be grouped in air without derating providing that the cables are installed on cable ladders, and that for:

(a) **Horizontal formation**
The clearance between cables is not less than 2 x the overall diameter of the largest cable (or 150 mm) whichever is least.

(b) **Vertical formation**
(i) The clearance from a supporting wall is greater than 20 mm, and
(ii) The vertical clearance between cables is greater than 150 mm.

Note: If the number of cables > 4, they are to be installed in a horizontal plane.

Table 4.3.6 : Correction factors for direct solar radiation

Cross-Sectional Area of Conductor	Correction Factors Solar Radiation	
mm²	1000 W/m² (Coastal)	1250 W/m² (Highveld)
1,5 - 10	0,70	0,62
16 - 35	0,68	0,57
50 - 95	0,65	0,53
120 - 185	0,62	0,49
240 - 400	0,59	0,44

4.4 Short circuit ratings for PILC cables

Short circuit ratings do not lend themselves to rigid treatment due to unknown variables, and wherever possible conservative values should be applied.

With the continued growth of power system fault capacity, attention must be given, when selecting a cable, to its short circuit capacity as well as to the continuous current rating.

Other limiting effects in avoiding damage during subsequent short circuit conditions are as follows:-

(a) Weakening of joints due to softening of solder at conductor temperatures above 160°C.

(b) If crimped or welded ferrules and lugs are used (see A - 1.2 of annex A SANS 97) temperatures of 250°C can be tolerated.

(c) Bursting effects are only of concern with unarmoured screened cables larger than 150 mm². Multicore wire armoured cables are only likely to burst at currents in excess of 33 kA for cable sizes below 70mm², in excess of 39 kA for cables below 150 mm² and in excess of 22 kA for cables below 300 mm².

Cable short circuit ratings are based on the adiabatic performance of the conductors and may thus be regarded as "internal ratings" which are not affected by external factors as in the case of current ratings. Therefore, no derating factors are needed.

Ratings are derived from temperature limits as follows:-

$$I = \frac{K \times A}{\sqrt{t}} \quad \text{Amps}$$

where *I = short circuit rating in Amps*
K = constant combining temperature limits and conductor material properties
A = area of conductor
t = duration of short circuit in seconds

The values of K for copper and aluminium conductors of 6.35/11 kV PILC cables are 115 & 76 amps/mm² respectively, for a conductor temperature rising from 70°C to 160°C.

Table 4.2 on pg 28 provides 1 second short circuit ratings.

4.5 Earth Fault Ratings

Some systems make provision for reducing earth fault currents by the inclusion of a neutral earthing resistor (NER) at the star point of the distribution transformer.

Where this is not the case, the resultant high earth fault current under a fault condition will be carried by the lead sheath and by the galvanised steel wire armour. The bitumised steel tape armour is expected to rust in time and should not be included in any calculation to carry fault current.

The value of K for lead sheaths and galvanised steel wire armour is 24 & 44 amps/mm² respectively. The following formula must be applied:

$$I = \frac{K \times A}{\sqrt{t}} \quad \text{Amps}$$

The area of the lead sheath and the armour wires of the cable must be obtained.

Reference to SANS 97 will provide the necessary information.

5.0 Medium Voltage XLPE Insulated, PVC Bedded, SWA, PVC sheathed cables

The following chapter generally covers 6.35/11 kV XLPE cables. For higher voltages or single core applications please consult our application engineers for specialised technical or installation information. The cables described in this section are manufactured according to SANS 1339. (For greater details see brochure covering this product).

Quality Assurance

MV XLPE cable manufactured by Aberdare Cables is required to undergo a partial discharge test at our Standford Road Port Elizabeth factory. The partial discharge measurement technique involves scanning of every metre of every drum of cable using the only such scanner installed in the Southern Hemisphere. The technique has been in use since the introduction of XLPE by Aberdare Cables and has given superb performance over the past 20 years.

The advantage of the scanning technique is that non-complying XLPE cores can be re-insulated before they are further processed (application of copper tape screen, laying up of 3 cores, application of PVC bedding, application of Steel Wire Armour and extrusion of outer sheath). Although this is a expensive operation, it is dramatically cheaper than rectification of faults at final test or after installation on the customer premises. In factories where partial discharge detection is carried out only as a final test, and assuming a non-complying partial discharge is detected, the decision to scrap the cable or alternatively to strip and replace an XLPE core will be very costly.

The advantage to the customer of the above testing is that he is assured of quality cable with an acceptable level of partial discharge.

Aberdare's unrivalled quality record in experiencing only one field failure of XLPE cable during its twenty years of manufacture of this product is adequate proof of the superiority of this testing method.

5.1 Notes on XLPE Insulation

For XLPE insulated conductors, continuous conductor temperatures of 90°C are permissible with overload excursions up to 130°C for a maximum of 8 hours continuous per event, with a maximum total of 125 hours per annum. In the case of short circuits the insulation can withstand conductor temperatures of up to 250°C for 1 second.

Table 5.1 : Current ratings are based on these parameters

Maximum sustained conductor temperature	90°C
Ground Temperature	25°C
Ambient air temperature (free air-shaded)	30°C
Ground Thermal Resistivity	1,2 K.m/W
Depth of laying to top of cable or duct	800 mm

Table 5.2

Electrical and Physical Properties of 3 core XLPE insulated PVC bedded, steel wire armoured, PVC sheathed 6.35/11 kV cables to SANS 1339 Type A (Individually screened)

Cable Size	COPPER CONDUCTORS					STRANDED ALUMINIUM CONDUCTORS				
	Electrical Properties			Physical Properties		Electrical Properties			Physical Properties	
	Current rating (Ground)	Impe-dance	1 second short circuit rating	Diameter over lead	Approx. Cable Mass	Current rating (Ground)	Impe-dance	1 second short circuit rating	Diameter over lead	Approx. Cable Mass
(mm^2)	(A)	(Ω/km)	(kA)	(mm)	(kg/km)	(A)	(Ω/km)	(kA)	(mm)	(kg/km)
25	140	0,9353	3,575	47,3	4655					
35	170	0,6783	5,005	49,7	5215					
50	200	0,5067	7,150	52,6	5895	155	8284	4600	526	5015
70	240	0,3581	10,010	56,3	6995	190	5767	6440	563	5635
95	290	0,2665	13,585	60,5	8170	225	4213	8740	605	6340
120	325	0,2187	17,160	64,2	9370	255	3375	11040	642	7045
150	360	0,1847	21,450	68,8	11240	285	2795	13800	688	8350
185	410	0,1571	26,455	72,8	12775	320	2285	17020	728	9245
240	470	0,1317	34,320	79,1	14955	370	1821	22080	791	10580
300	520	0,1160	42,900	85,6	17865	420	1535	27600	856	12070

5.2 Derating factors for non-standard conditions

Table 5.2.1 : Depth of laying - multicore XLPE cables (up to 300 mm²)

Depth of Laying (mm)	Direct in Ground	In Single Way Ducts
500 - 800	1,00	1,00
850 - 1000	0,97	0,96
1050 - 1200	0,95	0,95
1250 - 1400	0,93	0,95
1450 - 1600	0,92	0,94

Table 5.2.2 : Ground thermal resistivity - multicore XLPE cables (up to 300 mm²)

Thermal Resistivity (K.m/W)	Direct in Ground	In Single Way Ducts
0,7	1,23	1,28
1,0	1,08	1,12
1,2	1,00	1,00
1,5	0,90	0,93
2,0	0,80	0,85
2,5	0,72	0,80
3,0	0,66	0,74

Table 5.2.3 : Group of XLPE cables in horizontal formation at standard depths of laying and in standard soil conditions (multicore cables)

No of Cables in Group	Direct in Ground			In Single Way Ducts		
	Axial Spacing (mm)			Axial Spacing (mm)		
	Touching	250	700	Touching	250	700
2	0,79	0,85	0,87	0,87	0,91	0,93
3	0,69	0,75	0,79	0,80	0,86	0,91
4	0,63	0,68	0,75	0,75	0,80	0,87
5	0,58	0,64	0,72	0,72	0,78	0,86
6	0,55	0,60	0,69	0,69	0,74	0,83

Table 5.2.4 : Ground Temperature derating factors

Maximum Conductor Temperature (90°C)	Ground Temperatures (°C)				
	25	30	35	40	45
	1,0	0,96	0,92	0,88	0,84

Table 5.2.5 : Air Temperature derating factors

Maximum Conductor Temperature (90°C)	Air Temperatures (°C)				
	30	35	40	45	50
	1,0	0,95	0,89	0,84	0,78

Note: Cables may be grouped in air without derating provided that the cables installed on cable ladders, and that for:

(a) **Horizontal formation**
The clearance between cables is not less than 2 x the overall diameter of the largest cable (or 150 mm) whichever is least.

(b) **Vertical formation**
The clearance from a supporting wall is greater than 20 mm, and
The vertical clearance between cables is greater than 150 mm.

Note: If the number of cables > 4, they are to be installed in a horizontal plane.

Table 5.2.6 : Correction factors for direct solar radiation

Cross-Sectional Area of Conductor	Correction Factors Solar Radiation	
mm²	1000 Ω/m² (Coastal)	1250 Ω/m² (Highveld)
1,5 - 10	0,70	0,62
16 - 35	0,68	0,57
50 - 95	0,65	0,53
120 - 185	0,62	0,49
240 - 400	0,59	0,44

5.3 Short circuit ratings for XLPE insulated 6.35/11 kV cables

Short circuit ratings do not lend themselves readily to rigid treatment due to unknown variables. Wherever possible conservative values should be applied. As the growth of a power system increases so do the system fault levels. When selecting a cable attention must be given to it's short circuit capability, as well as to the continuous current ratings.

Other limiting effects in avoiding damage during short circuit conditions are as follows:-

(a) Weakening of joints due to softening of the solder at a conduct temperature of 160°C and above, although most conductor joining nowadays is done by compression fittings, particularly on XLPE insulated cables.

(b) Bucking of the conductors in joint boxes due to longitudinal expansion of cables laid direct in ground.

Cables short circuit ratings are based on the adiabatic performance of the conductors. This assumes no heat loss from the cable during the period of the fault. No derating factors are necessary with regard to soil temperature, depth of burial etc.

Ratings are derived from temperature limits as follows:-

$$I = \frac{K \times A}{\sqrt{t}} \quad \text{Amps}$$

Where I = *Short circuit rating in Amps*
K = *constant combining temperature limits and conductor material properties*
A = *area of Conductor*
t = *duration of short circuit in seconds*

The value of K for copper and aluminium conductors of 6.35/11 kV XLPE cables is 143 & 92 amps/mm² respectively, for a conductor temperature rising from 90°C to 250°C.

5.4 Earth Fault Current

Some systems provide for reducing earth fault currents by the inclusion of a neutral earthing resistor (NER) at the star point of the distribution transformer, to typically 300 A.

Where this is not the case, the resistance of the copper tapes and steel wire armour should be included in the calculation.

Typical 1 second Earth Fault ratings for XLPE insulated 6.35/11 kV Type A cables manufactured to SANS 1339 - 1991 are shown in table 5.3

Table 5.3 : Earth fault ratings

Cable Size	Earth Fault Rating
mm²	kA/s
25	10,4
35	12,2
50	13,1
70	17,6
95	18,7
120	19,7
150	20,8
185	25,0
240	26,8
300	28,6

6.0 Low Voltage PVC and XLPE Insulated 600/1000 V Power Cables to SANS 1507

6.1 Note on PVC insulation

For PVC insulation continuous conductor temperatures up to 70°C are permissible. Care must be exercised in matching the cable to the circuit protection. Under short circuit conditions, a maximum conductor temperature of 160°C is allowed for a maximum period of 1 second.

Note of XLPE insulation

For XLPE insulation, continuous conductor temperature up to 90°C are permissible with excursions of up to 130°C or a maximum of 8 hours continuous per event, with a maximum total of 125 hours per annum.

Table 6.1 : Current rating parameters

	PVC	XLPE
Maximum sustained conductor temperature	70°C	90°C
Ground temperature	25°C	25°C
Ambient air temperature (free air shaded)	30°C	30°C
Ground Thermal Resistivity	1,2 K.m/W	1,2 K.m/W
Depth of laying to top of cable or duct	500mm	500mm

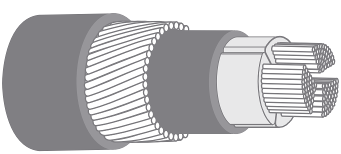
6.2 Physical dimensions of the cables are given in terms of the sketch below and these abbreviations are used in the tables.

C/S OF SINGLE CORE CABLE

D1 = diameter over bedding

d = diameter of armour wires

D2 = diameter over outer sheath



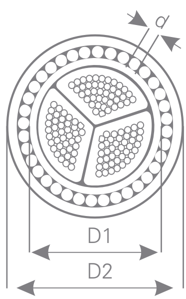


Table 6.2

Electrical and Physical Properties of 3 and 4 core PVC Insulated PVC bedded SWA PVC sheathed 600/1000 V cables manufactured to SANS 1507-3

COPPER CONDUCTORS

Cable Size	Electrical Properties						Physical Properties							
	Current Rating			Impe-dance	3φ Volt drop	1φ Volt drop	Nominal Diameters						Approx. Mass	
	Ground	Ducts	Air				D1		d		D2			
							3c	4c	3c	4c	3c	4c	3c	4c
(mm²)	(A)	(A)	(A)	(Ω/km)	(mV/A/m)	(mV/A/m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(kg/km)	(kg/km)
1,5	24	20	19	14,48	25,080	28,956	8,51	9,33	1,25	1,25	14,13	14,95	448	501
2,5	32	26	26	8,87	15,363	17,734	9,61	10,56	1,25	1,25	15,23	16,18	522	597
4	42	34	35	5,52	9,561	11,034	11,40	12,57	1,25	1,25	17,02	18,39	667	762
6	53	43	45	3,69	6,391	7,374	12,58	13,90	1,25	1,25	18,40	19,72	790	910
10	70	58	62	2,19	3,793	4,384	14,59	16,14	1,25	1,25	20,41	21,96	996	1169
16	91	75	83	1,38	2,390	2,759	16,55	19,18	1,25	1,60	22,37	25,92	1295	1768
25	119	96	110	0,8749	1,515	1,749	19,46	21,34	1,60	1,60	26,46	28,34	1838	2196
35	143	116	135	0,6335	1,097	1,267	20,89	23,97	1,60	1,60	27,89	31,17	2215	2732
50	169	138	163	0,4718	0,817	0,944	24,26	28,14	1,60	2,00	31,46	36,54	2871	3893
70	210	171	207	0,3325	0,576	0,665	27,07	31,29	2,00	2,00	35,47	40,09	3617	4837
95	251	205	251	0,2460	0,427	0,492	31,19	35,82	2,00	2,00	39,99	44,62	4901	6115
120	285	234	290	0,2012	0,348	0,402	33,38	38,10	2,00	2,00	42,18	47,40	5720	7269
150	320	263	332	0,1698	0,294	0,339	36,68	42,05	2,00	2,50	45,98	52,65	6908	9250
185	361	298	378	0,1445	0,250	0,289	40,82	46,75	2,50	2,50	51,12	57,45	8690	11039
240	416	344	445	0,1220	0,211	0,244	46,43	53,06	2,50	2,50	57,13	64,16	10767	13726
300	465	385	510	0,1090	0,189	0,218	51,10	58,53	2,50	2,50	62,20	70,13	12950	16544

Table 6.3

Electrical and Physical Properties of 3 and 4 core PVC Insulated PVC bedded SWA PVC sheathed 600/1000 V cables manufactured to SANS 1507-3

ALUMINIUM CONDUCTORS

Cable Size	Electrical Properties						Physical Properties							
	Current Rating			Impe-dance	3ϕ Volt drop	1ϕ Volt drop	Nominal Diameters						Approx. Mass	
	Ground	Ducts	Air				D1		d		D2			
							3c	4c	3c	4c	3c	4c	3c	4c
(mm^2)	(A)	(A)	(A)	(Ω/km)	(mV/A/m)	(mV/A/m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(kg/km)	(kg/km)
25	90	73	80	1,4446	2,502	2,889	17,76	20,65	1,60	1,60	24,76	27,65	1301	1554
35	108	87	99	1,0465	1,813	2,093	19,33	21,93	1,60	1,60	26,33	29,13	1477	1757
50	129	104	119	0,7749	1,342	1,549	21,87	25,05	1,60	1,60	29,07	32,25	1782	2150
70	158	130	151	0,5388	0,933	1,078	24,76	29,27	1,60	1,60	31,96	37,67	2132	2930
95	192	157	186	0,3934	0,681	0,787	28,68	33,73	2,00	2,00	37,08	42,53	2908	3647
120	219	179	216	0,3148	0,545	0,629	31,09	35,44	2,00	2,00	39,89	44,24	3328	4023
150	245	201	250	0,2607	0,452	0,521	33,99	39,39	2,00	2,50	42,79	49,69	3837	5276
185	278	229	287	0,2133	0,369	0,427	37,80	44,51	2,00	2,50	47,10	54,81	4557	6231
240	324	268	342	0,1708	0,296	0,342	42,60	50,04	2,50	2,50	52,9	61,14	5977	7550

Table 6.4
Electrical and Physical Properties of 3 and 4 core XLPE Insulated PVC bedded SWA PVC sheathed 600/1000 V cables manufactured to SANS 1507-4

COPPER CONDUCTORS

Cable Size	Electrical Properties									Physical Properties							
	Current Rating						Impe-dance	3ϕ Volt drop	1ϕ Volt drop	Nominal Diameters						Approx. Mass	
	Ground		Ducts		Air					D1		d		D2			
										3c	4c	3c	4c	3c	4c	3c	4c
(mm^2)	70°C	90°C	70°C	90°C	70°C	90°C	(Ω/km)	(mV/A/m)	(mV/A/m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(kg/km)	(kg/km)
1,5	26	30	21	25	16	22	15,43	26,726	30,861	8,08	8,85	1,25	1,25	13,70	14,47	416	453
2,5	34	40	28	32	21	30	9,45	16,368	18,900	9,18	10,08	1,25	1,25	14,80	15,70	487	521
4	45	52	36	42	28	39	5,88	10,184	11,761	10,06	11,07	1,25	1,25	15,68	16,69	566	650
6	55	64	44	52	35	49	3,93	6,807	7,862	11,25	12,40	1,25	1,25	16,87	18,02	683	778
10	75	87	60	70	48	68	2,33	4,053	4,663	13,25	14,64	1,25	1,25	19,07	20,46	890	1033
16	94	110	76	89	60	85	1,46	2,546	2,924	15,21	17,68	1,25	1,25	21,03	24,42	1191	1544
25	123	143	98	116	107	132	0,9313	1,613	1,863	18,13	19,86	1,60	1,60	25,13	26,86	1693	2018
35	148	172	119	139	132	163	0,6738	1,167	1,348	19,56	22,32	1,60	1,60	26,56	29,52	2025	2511
50	177	206	142	167	163	200	0,5009	0,868	1,002	22,49	25,76	1,60	1,60	29,69	32,96	2606	3242
70	216	252	175	205	206	253	0,3521	0,610	0,704	25,74	29,81	2,00	2,00	32,94	38,21	3323	4503
95	258	302	209	248	251	312	0,2589	0,448	0,518	28,76	33,1	2,00	2,00	37,16	41,90	4442	5650
120	293	344	238	282	291	362	0,2109	0,365	0,422	31,39	35,87	2,00	2,00	40,19	44,67	5335	6731
150	329	387	268	318	334	416	0,1775	0,307	0,355	34,69	40,12	2,50	2,50	43,49	50,42	6403	8708
185	371	435	302	359	383	478	0,1500	0,260	0,300	39,05	44,77	2,50	2,50	49,35	55,07	8184	10343
240	428	498	349	413	453	557	0,1247	0,216	0,249	44,22	50,58	2,50	2,50	54,52	61,68	10073	12932
300	482	558	401	471	520	634	0,1099	0,190	0,219	48,45	55,56	2,50	2,50	58,35	67,16	12076	15575

Table 6.5

Electrical and Physical Properties of 3 and 4 core XLPE Insulated PVC bedded SWA PVC sheathed 600/1000 V cables manufactured to SANS 1507-4

ALUMINIUM CONDUCTORS

Cable Size	Electrical Properties						Physical Properties							
	Current Rating			Impe-dance	3ϕ Volt drop	1ϕ Volt drop	Nominal Diameters						Approx. Mass	
	Ground	Ducts	Air				D1		d		D2			
							3c	4c	3c	4c	3c	4c	3c	4c
(mm²)	(A)	(A)	(A)	(Ω/km)	(mV/A/m)	(mV/A/m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(kg/km)	(kg/km)
25	115	92	108	1,5408	2,669	3,082	15,53	19,16	1,25	1,60	21,53	26,16	925	1377
35	138	111	131	1,1159	1,933	2,232	18,00	20,44	1,60	1,60	25,00	27,44	1307	1549
50	164	132	160	0,8258	1,430	1,652	20,09	23,06	1,60	1,60	27,09	30,26	1550	1872
70	199	161	200	0,5736	0,994	1,147	23,43	27,38	1,60	1,60	30,63	34,98	1911	2371
95	238	194	245	0,4178	0,724	0,836	25,85	30,99	1,60	2,00	33,05	39,39	2254	3158
120	272	221	285	0,3337	0,578	0,667	29,09	33,20	2,00	2,00	37,49	42,00	2929	3584
150	306	249	328	0,2756	0,477	0,551	32,15	36,75	2,00	2,00	40,95	46,05	3457	4274
185	344	283	378	0,2247	0,389	0,449	36,02	42,52	2,00	2,50	45,32	52,82	4132	5650
240	392	325	438	0,1785	0,309	0,357	40,39	50,40	2,50	2,50	50,69	61,50	5375	7024

Table 6.6

Electrical and Physical Propertied of Single core unarmoured PVC insulated PVC sheathed 600/1000 V cables manufactured to SANS 1507-3

STRANDED COPPER CONDUCTORS

Cable Size	Electrical Properties								Physical Properties		
	1 ϕ Cables AC or DC			3ϕ Cables in Trefoil Formation.				Impe-dance	Nominal Diameters		Nominal Mass
	Current Rating		Volt Drop per amp per mV	Current Rating			Volt drop per amp per mV				
	Ground	Air		Ground	Duct	Air			D1	D2	
(mm²)	(A)	(A)	mV	(A)	(A)	(A)	mV	(Ω/km)	(mm)	(mm)	(kg/km)
25	118	126	1,75	127	111	112	1,52	0,8767	5,95	11,91	366
35	156	156	1,27	153	132	141	1,10	0,6356	7,00	12,96	469
50	186	191	0,95	180	155	172	0,82	0,4745	8,15	15,15	632
70	232	246	0,67	221	190	223	0,58	0,3356	9,79	16,57	880
95	281	300	0,50	265	226	273	0,43	0,25	11,54	19,04	1160
120	324	349	0,41	301	256	318	0,36	0,2054	12,96	20,24	1413
150	370	404	0,35	338	287	369	0,30	0,1734	14,39	22,07	1734
185	424	463	0,30	381	323	424	0,26	0,1499	16,10	24,08	2145
240	498	549	0,25	442	372	504	0,22	0,1268	18,71	27,81	2725
300	566	635	0,23	499	419	584	0,20	0,1131	21,45	30,75	3375
400	651	742	0,21	565	472	679	0,18	0,1028	24,30	34,10	4395
500	740	835	0,19	634	532	778	0,17	0,0963	26,51	37,13	5299
630	836	953	0,18	718	603	892	0,15	0,089	33,15	43,62	6965
800	931	1086	0,17	792	689	1020	0,15	0,852	37,70	49,00	9118
1000	1041	1216	0,16	856	741	1149	0,14	0,0819	42,25	53,45	11050

Note: (1) D1 is the diameter over the conductor. (2) D2 is the diameter over the sheath.

Table 6.7

Electrical and Physical Propertied of Single core unarmoured XLPE insulated PVC sheathed 600/1000 V cables manufactured to SANS 1507-4

STRANDED COPPER CONDUCTORS

Cable Size	Electrical Properties								Physical Properties		
	1 ϕ Cables AC or DC			3ϕ Cables in Trefoil Formation.				Impe-dance	Nominal Diameters		Nominal Mass
	Current Rating		Volt Drop per amp per mV	Current Rating			Volt drop per amp per mV				
	Ground	Air		Ground	Duct	Air			D1	D2	
(mm²)	(A)	(A)	mV	(A)	(A)	(A)	mV	(Ω/km)	(mm)	(mm)	(kg/km)
25	169	174	1,866	151	137	137	1,616	0,9332	5,95	11,81	328
35	205	211	1,352	181	164	167	1,710	0,6760	7,00	12,86	426
50	245	257	1,007	213	192	203	0,872	5,3600	8,15	14,38	567
70	302	236	0,710	260	235	257	0,615	0,3552	9,79	16,22	824
95	366	404	0,526	312	281	318	0,456	0,2631	11,54	17,97	1071
120	422	475	0,431	355	319	372	0,373	0,2154	12,96	19,32	1304
150	480	542	0,363	397	356	426	0,315	0,1818	14,39	21,42	1628
185	554	629	0,309	449	402	494	0,268	0,1545	16,10	23,63	1995
240	656	753	0,259	522	466	594	0,224	0,1295	18,71	26,69	2461
300	766	881	0,229	589	524	692	0,199	0,1149	21,45	30,05	3182
400	902	1045	0,207	668	592	807	0,179	0,1035	24,30	33,30	4117
500	1040	1182	0,192	750	664	925	0,167	0,0963	26,51	36,33	5032
630	1229	1417	0,178	848	746	1094	0,154	0,8890	33,15	42,79	6641
800	1366	1603	0,171	942	823	1254	0,148	0,0856	37,70	48,84	8535
1000	1486	1790	0,166	1025	892	1400	0,144	0,0831	42,25	54,21	10676

Note: (1) D1 is the diameter over the conductor. (2) D2 is the diameter over the sheath.

6.3 Derating factors for non-standard conditions

Table 6.3.1 : Derating factors for depth of laying - multicore cables (up to 300 mm²)

Depth of laying (mm)	Direct in ground	In single way ducts
500	1,00	1,00
800	0,97	0,97
1000	0,95	0,96
1250	0,94	0,95
1500	0,93	0,94
2000	0,92	0,93

Table 6.3.2 : Derating factors for ground thermal resistivity (multicore cables)

Thermal Resistivity (K.m/W)	Direct in ground	In single way ducts
1,0	1,08	1,04
1,2	1,00	1,00
1,5	0,93	0,96
2,0	0,83	0,88
2,5	0,78	0,87

Table 6.3.3 : Derating factors for grouping of cables in horizontal formation, at standard depths of laying and in standard soil conditions. Multi-core cables (up to 300 mm²)

No of Cables in Group	Direct in Ground					In Single Way Ducts			
	Axial Spacing (mm)					Axial Spacing (mm)			
	Touching	150	300	450	600	Touching	300	450	600
2	0,81	0,87	0,91	0,93	0,94	0,90	0,93	0,95	0,96
3	0,70	0,78	0,84	0,87	0,90	0,82	0,87	0,90	0,93
4	0,63	0,74	0,81	0,86	0,89	0,78	0,85	0,89	0,91
5	0,59	0,70	0,78	0,83	0,87	0,75	0,82	0,87	0,90
6	0,55	0,67	0,76	0,82	0,86	0,72	0,81	0,86	0,90

Table 6.3.4 : Ground Temperature factors - multicore cables (up to 300 mm²)

Maximum Conductor Temperature (°C)	Ground Temperatures (°C)					
	25	30	35	40	45	50
70 (PVC)	1,00	0,95	0,90	0,85	0,80	0,70
90 (XLPE)	1,00	0,96	0,92	0,88	0,82	0,76

Table 6.3.5 : Air Temperature derating factors

Maximum Conductor Temperature (°C)	Air Temperatures (°C)			
	30	35	40	45
70 (PVC)	1,00	0,94	0,87	0,79
90 (XLPE)	1,00	0,95	0,89	0,84

Table 6.3.6 : Derating factors for grouping of multicore cable installed horizontally in air

No. of cables	1	2	3	6	9
Condition	Derating Factor				
Cable touching	1	0,9	0,84	0,80	0,75
Clearance D* between Cables	1	0,95	0,9	0,88	0,85

D is the overall diameter of one cable*

Note: Cables may be grouped in air without derating, provided that the cables are installed on ladders, and that for:-

(a) **Horizontal formation**
The clearance is greater than 2x the cable overall diameter (or 150 mm, whichever is the least).

(b) **Vertical formation**
(i) The clearance from a vertical wall is greater than 20 mm, and
(ii) The vertical clearance between cables is greater than 150 mm.

Note: If the number of cables > 4, they are installed in the horizontal plane.

Table 6.3.7 : Correction factors for direct solar radiation

Cross-Sectional Area of Conductor	Correction Factors Solar Radiation	
mm²	1000 Ω/m² (Coastal)	1250 Ω/m² (Highveld)
1,5 - 10	0,70	0,62
16 - 35	0,68	0,57
50 - 95	0,65	0,53
120 - 185	0,62	0,49
240 - 400	0,59	0,44

6.4 Short circuit ratings for PVC and for XLPE insulated 600/1000V cables to SANS 1507.

With PVC and with XLPE insulated cables, care must be taken to limit the conductor temperature for continuous operation and for short circuit conditions as indicated in Table 6.9.

Short circuit ratings are regarded as internal ratings. Their calculation is based on an adiabatic equation and is not affected by external consideration. Due to unknown variables, short-circuit ratings do not lend themselves readily to rigid treatment, so whenever possible conservative values should be applied.

Ratings are derived from temperature limits as follows:

$$I_{sc} = \frac{K \times A}{\sqrt{t}} \text{ Amps}$$

where I_{sc} = *Short circuit rating in amps*
K = *A constant combining temperature limits and properties of conductor materials*
A = *area of conductor*
t = *duration of short circuit in seconds*

Table 6.9 : Values of conductor/temperature constant K

Insulation material	Conductor material	Operating Temperature °C	Short Circuit Temperature °C	K factor
PVC	Copper	70	160	115
PVC	Aluminium	70	160	76
XLPE	Copper	90	250	143
XLPE	Aluminium	90	250	92

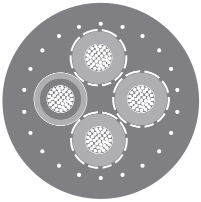
7.0 Elastomeric Trailing Cables

The following chapter generally covers Type 41 and 61 elastomeric trailing cables. For other elastomeric cables or different voltages please consult our application engineers for specialised technical or installation information. The cables described in this section are manufactured according to SANS 1520 part 2 (for greater details see brochure covering this product).

Features of Aberdare's trailing cables
Aberdare's mining trailing cables are manufactured according to SANS 1520 part 1 and 2 and bear the SANS mark up to 33 kV. The sheath is reinforced by means of an open-mesh braid in order to limit cut-spread. The elastomers used for the sheaths are carefully selected to ensure that the product will withstand even the highest levels of ultraviolet radiation found in South Africa.

Type 41 Trailing Cable

Conductors : Tinned soft copper
Insulation : Co-Extrusion of EPM/CSM
Screens : 3 Power cores individually screened with copper/textile braid. Pilot core unscreened.
Sheath : Extra-Heavy-Duty CR
Rated Voltage : 640/1100 V
Specification : SANS 1520 Part 1



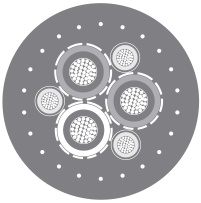
Applications

Self-propelled electrically driven machines, movable electric apparatus in hazardous areas (Minerals Act,1991), typically,

- Type 41; 4 mm² for small pumps, drills, fans etc.
- Type 41; 10 and 16 mm² for shuttle-cars.

Type 61A and 61B Trailing Cable

Conductors : Tinned soft copper
Insulation : Co-Extrusion of EPM/CSM
Screens : 3 Power cores individually screened with copper/textile braid. 3 Pilot cores unscreened..
Sheath : Extra-Heavy-Duty CR
Rated Voltage : 640/1100 V
Specification : SANS 1520 Part 1



Applications

Self-propelled electrically driven machines, portable electric apparatus and movable electric apparatus in hazardous areas (Minerals Act, 1991), typically,

- Type 61A 25 mm² for LHD's 70 mm² for Shearer and reeling applications.
- Type 61B 70 mm² for Continuous Miners and non-reeling applications where a lighter cable is required.

Table 7.1 640/1 100 V Trailing Cable Technical Data

Cable Size		Electrical Properties					Physical Properties				
Cable Size		Maximum conductor resistance (dc at 20°C)		Maximum combined screen resistance (dc at 20°C)	Impedance (Z)	Current rating (at 90°C) *	Overall diameter		Cable mass (approx)	Lay ratio	Bending radius (min)
Power	Pilot	Power	Pilot				min	max			
(mm²)		(Ω/km)		(Ω/km)	(Ω/km)	(A)	(mm)		(kg/km)	(xPCD)	(mm)
Type 41 Trailing cable (3xind.scr. Power plus 1 x Pilot cores)											
4	4	5,5	5,5	3,5	7,01	45	25	27	0,9	8	150
6	6	3,66	3,66	3,6	4,67	57	28	30	1,4	8	180
10	10	2,11	2,11	2,0	2,69	77	32	34	1,8	8	190
16	16	1,34	1,34	1,6	1,71	100	33	36	2,2	8	200
Type 61A Trailing cable (3xind.scr. Power plus 3 x Pilot cores)											
25	10	0,859	2,26	1,1	1,1	130	41	44	2,9	8	240
35	10	0,61	2,26	1,2	0,778	160	46	50	4,2	8	280
50	16	0,424	1,44	1,4	0,553	200	51	55	5,2	8	300
70	16	0,299	1,44	0,7	0,387	245	55	59	6,2	8	330
95	16	0,227	1,44	0,85	0,301	295	60	64	7,6	8	360
Type 61B Trailing cable (3xind.scr. Power plus 3 x Pilot cores)											
16	6	1,34	3,66	1,6	1,71	105	31	33	2,1	8	185
**35	6	0,61	3,66	1,2	0,783	160	38	41	3,3	12	315
**50	6	0,42	3,66	1,4	0,55	200	43	46	3,9	12	350
70	10	0,29	2,23	0,7	0,389	245	48	52	5,5	12	390
95	16	0,22	1,44	0,85	0,301	295	54	58	6,9	12	430
**120	16	0,17	1,44	0,8	0,243	315	58	60	7,7	12	470

Note: *[1] Low-Voltage Trailing Cables with lay ratios of more than 8 are Not suitable For Continuous Reeling*

* Current ratings in shade at ambient temperature of 30°C. .

** Not covered by SANS 1520 Part 1

Derating Factors for Ambient Temperatures (Mining Cables)					
Ambient Temperature (°C)	25	30	35	40	45
Factor	1,10	1,00	0,90	0,80	0,70

Derating Factors for Number of Layers on a Reeling Drum			
Number of layers	1	2	3
Factor	0,84	0,65	0,45

1 Second Short-circuit Ratings			
Cable Size	**Current**	**Cable Size**	**Current**
(mm²)	**(kA)**	**(mm²)**	**(kA)**
16	2,0	95	11,6
25	3,1	120	14,6
35	4,3	150	18,3
50	6,1	185	22,6
70	8,5	240	29,3

Based on an initial conductor temperature at 90°C and a final temperature of 200°C

Physical Properties of Sheathing Materials				
Property	**UNITS**	**GP**	**HD**	**EHD**
Tensile Strength (min.)	MPa	8	11	15
Elongation at Break (min.)	%	250	250	250
Tear Resistance (min.)	N/mm	5	7,5	10

Tested to SANS Test Methods statement 503, 504 and 506

8.0 Overhead Aluminium Conductors

Aluminium conductors have achieved wide acceptance all over the world for use in overhead transmission and distribution lines. Generally a steel core is used with the aluminium to give the conductor mechanical strength. This arrangement is termed Aluminium conductor steel reinforced or ACSR. Conductors comprised entirely of aluminium are known as All aluminium conductors or AAC. These conductors are extensively used for busbars in outdoor substations where spans are short. All aluminium alloy conductors or AAAC consist of an alloy of aluminium to give a tensile strength in excess of that of AAC, allowing longer spans. These conductors are recommended for coastal areas where severe corrosion is a problem.

Hard drawn aluminium in H9 temper is used in both ACSR and AAC. High strain steel wire is used in ACSR and this is sometimes protected from corrosion by an application of grease. Such measures are particularly adopted when the conductor is intended for use in aggressive environments as encountered in coastal regions.

Aberdare Cables manufacture a wide range of AAC, ACSR and AAAC to customers' requirements or national specifications. The information contained in table 8.2 relates to the more popular sizes and standards under the following conditions:

Table 8.1 : Current Rating parameters

Ambient Temperature	30°C
Maximum Conductor Temperature	75°C
Wind Speed	0.44 m/s
Normal Stringing Temperature	25°C
Solar Radiation	0,089 W/cm²
Solar Absorption Co-efficient	1

Sag and tension charts are available on request. The following information needs to be supplied:

- Span length
- Maximum design load (45% of UTS if not specified)
- Stringing temperature.

Table 8.2
Physical and Electrical Data for popular ACSR sizes

Code Name	Equival. Copper Area	Standing/ wire diam.	Overall Diameter	Mass (kg/km)			Ultimate tensile strength	DC resistance at 20°C	Current rating
	(mm²)	(mm)	(mm)	Aluminium	Steel	Total	(N)	(Ω/km)	(Amps)
Squirrel	12,90	6/1/2,11	6,33	57,70	27,50	85,20	8020	1,3677	130
Gopher	16,30	6/1/2,36	7,08	72,20	34,40	107	9610	1,0933	150
Fox	22,58	6/1/2,79	8,37	101	48,10	149	13100	0,7822	190
Ferret	25,81	6/1/3,00	9,00	117	55,60	173	15200	0,6766	210
Rabbit	32,26	6/1/3,35	10,05	145	69,40	214	18500	0,5426	240
Mink	38,71	6/1/3,66	10,98	174	82,80	257	21900	0,4546	260
Hare	64,52	6/1/4,72	14,16	289	138	427	36000	0,2733	360
Dog	64,52	6/4,72+7/1,57	14,15	289	100	389	34700	0,2733	360
Wolf	96,77	30/7/2,59	18,13	438	292	730	69200	0,1828	470
Panther	129,00	30/7/3,00	21,00	588	391	970	90800	0,1363	560
Bear	161,30	30/7/3,35	23,45	733	488	1220	112000	0,1093	650
Goat	193,50	30/7/3,71	25,97	899	598	1500	136000	0,0891	730

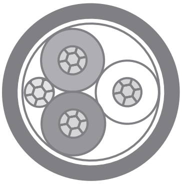
9.0 Innovatice Products (INTERDAC 3)

Intermediate voltage 3 phase 4 wire 1900/3300V underground supply cable

(a) Use of intermediate Voltage allows increased power transfer over long distances with smaller conductor sizes, eg for loads typically 25 kVA this represents a considerable saving when compared to conventional systems.
(b) Underground cable - with a specially adapted tractor, the cable can be buried with minimum labour, and thus least cost.
(c) Screened cable construction for ease of fault location.
(d) Buried cable results in a "clean" landscape - no poles or overhead lines to hinder farm vehicles.

Construction

3 Circular stranded plain soft copper conductors, XLPE insulated, layed up with one circular stranded tinned soft copper earthing conductor, collectively screened with an aluminium polyethylene laminate (APL) tape, polyethylene sheathed 1900/3300V underground supply cable.



Mechanical forces during installation

The maximum pulling force that should be applied to the conductor of INTERDAC 3 Cable during installation is 200 kg.

Table 9.1 : Electrical properties

Cable Size (mm²)		10	16	25
Phase Conductor Resistance*	(Ω/km)	1,83	1,15	0,73
Earth Conductor Resistance*	(Ω/km)	1,83	1,15	0,73
Impedance (Z)	(Ω/km)	2,34	1,47	0,93
Current Rating**	(A)	80	105	135
1 Second Short Circuit Rating	(kA)	0,82	2,29	3,57

* *DC at 20°C*
** *In ground. Soil temperature 25°C. Depth of lay 500 mm.*
Soil thermal resistivity 1,2 K.m/W. Operating temperature 90°C

Table 9.2 : Physical properties

Cable Size (mm²)		10	16	25
Phase Conductor Construction (no. x diam.)	(mm)	7 x 1,33	7 x 1,67	19 x 1,38
Earth Conductor Construction (no. x diam.)	(mm)	7 x 1,33	7 x 1,67	19 x 1,38
Insulation Thickness (nominal)	(mm)	2,1	2,2	2,2
Aluminum Screen Thickness	(mm)	0,15	0,15	0,15
Sheath Thickness (nominal)	(mm)	1,45	1,6	2,0
Cable Diameter (nominal)	(mm)	20,5	21,3	26,4
Approximate Cable Mass	(kg/km)	545	990	1100
Minimum Bending Radius	(mm)	205	210	260

Product Range

Our Services are Wide but Specialised

ABERDARE CABLES

Driven by Powertech

The Aberdare Group's product range and services are wide but specialised. Tried and tested and carrying South African Bureau of Standards (SABS) marks and complying with International Standards, we stand by our products.

Paper Insulated Cables up to 42 kV

- Screened or belted
- Fully impregnated, general purpose, heavy duty or drained
- Copper or Aluminium conductors up to 400 mm² (3 core) and 1000 mm² (single core)

XLPE Insulated Cables up to 66 kV

- Individually screened
- Copper or aluminium conductors up to 300 mm² (3 core) and 500 mm² (single core)

Elastomeric Insulated Cables

- Flexible Cable (Types HO5 RN-F,HO7 RN-F)
- Welding Cable
- Mining Trailing Cable (Up to 33 kV)

Overhead Aluminium Conductors

- AAC (All Aluminium Conductors)
- AAAC (All Aluminium Alloy Conductors)
- ACSR (Aluminium Conductor Steel Reinforced)
- PHDC (Plain Hard Drawn Copper)

General Wire Insulated & Bare Copper Wire

- Slipdac Single Core Cable
- Surfix Cable
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- Nitrile Trailing Cable
- Bare Copper
- Single Core PVC 1kV Cable
- Single Core XLPE PVC 3.3 kV Cable

Low Voltage Armoured Cables

- Bells and Mains Cable
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