भारत सरकार GOVERNMENT OF INDIA
रेल मंत्रालय MINISTRY OF RAILWAYS

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सामान्य सेवाओं हेतु विद्युत पावर केबल की लघु पुस्तिका

Handbook on Electrical Power Cables for General Services

TARGET GROUP – TECHNICIANS & SUPERVISORS OF ELECTRICAL GENERAL SERVICES

CAMTECH/E/2006/ CABLES / 1.0
केमटेक / ई / 2006 / केबल / 1.0

March 2006

Centre for Advanced Maintenance TECHnology

Excellence in Maintenance

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FOREWORD

Power cables are commonly used for transmission and distribution of electrical power. Knowledge of selection of proper size and type of cables, their laying, jointing and termination is important for economical, safe and reliable power supply system.

CAMTECH has prepared this handbook with the objective of improving the reliability of power cables used in Railways. The book covers different types of cables, their constructional features and applications etc. It also covers selection, laying, installation, jointing, testing and maintenance of cables.

I am sure the handbook will prove to be very useful to our field supervisors and technicians in their day-to-day work.

CAMTECH, Gwalior ***Kulbhushan***
Date:23.03.2006 ***Executive Director***

PREFACE

Power cables are used for transmission and distribution of electrical power in thickly populated areas, in sub-stations, in industries and in workshops etc. General awareness about the power cables is essential for the electrical general service staff to keep the power supply system in safe and reliable condition.

This handbook has been prepared by CAMTECH with the objective of making our field staff aware of different power cables, their selection, proper procedure of laying, installation, testing and maintenance to be adopted in their day to day work.

It is clarified that this handbook does not supersede any existing provisions laid down by RDSO or Railway Board. The handbook is for guidance only and it is not a statutory document.

I am sincerely thankful to Director (PS & EMU) RDSO/LKO for his valuable comments. I am also thankful to all field personnel who helped us in preparing this handbook.

Technology upgradation and learning is a continuous process. Hence feel free to write to us for any addition or modification in this handbook. We shall highly appreciate your contribution in this direction.

CAMTECH, Gwalior — ***Randhawa Suhag***
Date: 23.03.2006 — ***Director/Elect.***

CONTENTS

ISSUE OF CORRECTION SLIP

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/E/2006/CABLES/1.0/ C.S. # XX date---

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

Sr. No.	Date of issue	Page no. and Item no. modified	Remarks

CHAPTER 1

GENERAL

1.1 INTRODUCTION

Cables are used for transmission of electrical power. They are mostly used for low voltage distribution in thickly populated area, in substations from transformers to main distribution panels and from main distribution panels to different distribution panels. Low voltage cables are also used in industries, workshops and maintenance shops/ sheds. Medium & high voltage transmission cables are also used for crossing the roads, railway lines and in densely populated areas in big cities.

Cables as compared to overhead lines have the following advantages.

i. The cable transmission and distribution are not subjected to supply interruptions caused by lightening or thunderstorms, birds and other severe weather conditions.

ii. It reduces accidents caused by the breaking of the conductors.

iii. Its use does not spoil the beauty of place, cities.

But if a fault occurs due to any reason, it is not easily located.

1.2 MAIN PARTS OF CABLES

Conductor, insulation and protection are the main three parts of the cables.

1.2.1 Conductor

Conductor is a material that provides low resistance to the flow of electrical current. Electrical grade high conductivity annealed copper or annealed aluminium conductors are used in cables. Generally all power cables have aluminium as the conductor material.

Aluminium of high purity, (99.5% pure electrical grade) which is highly anticorrosive and highly conductive is used as conductor in cables. Annealing softens the aluminium, reduces tensile strength and increase conductivity.

1.2.2 Insulation

Insulation material means a material having good dielectric properties, which is used to separate or isolate the conducting electrical parts. Insulation to be used for cables must have following properties.

- It should have a high specific resistance and dielectric strength.
- It should be tough and flexible.
- It should not be hygroscopic i.e. it should not absorb moisture from air or surroundings.
- It should be capable of standing high temperatures without much deterioration.

- It should be non-inflammable, fire retardant.
- It should not be attacked by acids or alkalies.
- It should be capable of withstanding high rupturing voltages.

The following are the main types of insulation group, which are used.

i. Butyle rubber. (BR)

ii. Polyethylene (PE)

iii. Polyvinyl chloride (PVC)

iv. Fiberous material suc as paper, jute etc.

v. Ethylene propylene rubber (EPR)

vi. Cross linked polyethylene (XLPE)

vii. Polychloroprene (PCP)

viii. Oil impregnated paper insulation.

1.2.3 Protection

Following protecting layers are provided for protection of the cable.

a. Inner Sheath

For protection from moisture and aggressive elements, sheath is provided over the insulation. For oil impregnated paper insulated cables, lead sheath or impregnated jute tapes with layers of bitumen compound are used.

For polymeric material insulated cables, extruded PVC sheath or wrapping of plastic tapes are used.

b. Armouring

Armouring is provided to avoid mechanical injury to the cable. Depending upon the application, the cable may be armoured or unarmoured. The armouring is applied over the core insulation or inner sheath for single core cables and over the inner sheath for the multicore cables.

Armour is a metallic wrapping over the cable insulation. For single core cables, non magnetic materials are used as armour, for example, flat aluminium wire. In multicore cables, common armour is provided for all the laid up cores and the armour material may be galvanized round steel wire or flat steel strip.

c. Outer Sheath

Single core and multicore cables are provided with an extruded PVC outer sheath. The colour of the outer sheath is generally black.

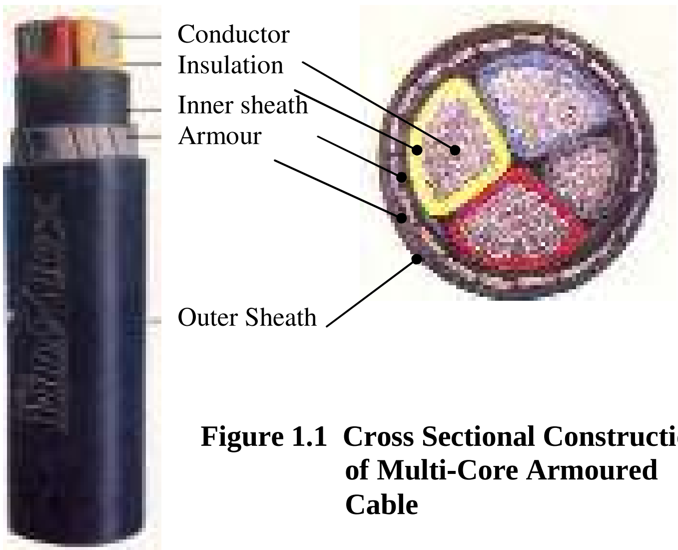

Figure 1.1 Cross Sectional Construction of Multi-Core Armoured Cable

1.3 CLASSIFICATION OF ELECTRICAL CABLES

Electrical cables may be classified according to their application as follows:

i. Wiring cables

These cables are used for internal wiring of the buildings and other protected installations and have two components viz. conductor and insulation. PVC as insulation material and annealed copper (solid or stranded) as conductor are commonly used for wiring cables. Voltage grade of these cables is upto 1100 Volts.

ii. Control cables

These are designed for control purposes or measuring circuits for carrying signals of direct current upto 220 Volts and alternating currents up to 440 volts. These cables are available with armour and without armour. In these cables PVC, XLPE, EPR, Neoprene etc. are used as insulation. Control cables are available in 0.5/0.75/1.00/ 1.5/2.5 mm^2 size copper conductor (solid/stranded) from 2 cores to 61 cores.

iii. Power Cables

Electrical power cables are used for distribution and transmission of electrical energy. These cables either single core or multicore are particularly useful in power stations, substations, house service connections, street lighting, etc. They can be installed indoors or outdoors, in air, in cable ducts or under ground.

iv. *Special Application Cables*

Cables are also classified based on special applications such as –

i. Fire performance and heat resistant cables.
ii. Pilot cables.
iii. Instrumentation cables.
iv. Submarine cables & ship board cables.
v. Airport lighting cables.
vi. Mining cables.
vii. Cables for lifts and hoisting gears.
viii. Welding cables.
ix. Cables for hazardous areas such as petro-chemical industries etc.

1.4 CLASSIFICATION OF POWER CABLES

Electrical power cables are generally classified according to their designed (rated) voltages or the type of insulation used.

1.4.1 Classification as Per Designed Voltage

Electrical power cables are generally classified according to their designed (rated) voltages as given below:

i. Low voltage cables – up to and including 1100 volts.

ii. Medium voltage cables –from 3.3 kV up to and including 33 kV.

iii. High voltage cables – above 33 kV and up to and including 132 kV

iv. Extra high voltage cables – above 132 kV and up to and including 700 kV.

Medium voltage electrical power cables are usually available in following voltage ratings

Rated voltage of cables

U_O (kV)	U (kV)	U_M (kV)
0.65	1.1	1.21
1.9	3.3	3.63
3.3	3.3	3.63
3.8	6.6	7.26
6.6	6.6	7.26
6.35	11	12.1
11	11	12.1
12.7	22	24.2
19	33	36.3

Where,

U_O = Rated power frequency voltage between conductor and earth or metallic screen.

U = Rated power frequency voltage between phase conductors.

U_M= Maximum permissible continuous 3 phase system voltage.

1.4.2 Classification as Per Type of Insulation Used

Electrical power cables are generally classified according to the type of insulation used as given below:

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i. PILC (Paper insulated lead sheath covered) cables.
ii. PVC (Poly Vinyl Chloride) cables.
iii. XLPE (Cross Linked Poly Ethylene) cables.

1.4.2.1 PILC Cables

For many years, the superior insulation material for power cables from low voltage to high voltages was oil-impregnated paper. Oil impregnated paper has excellent electrical properties and a high degree of thermal overload capacity without excessive deterioration. However PILC cables have the following disadvantages.

- Prone to moisture and damage.
- Low current carrying capacities.
- Low operating temperatures.
- Heavier weight and difficult to handle during installation.
- Migration of impregnating compound which do not permit laying cables vertically or on steep slopes.

Due to above disadvantages, the use of PILC cables is limited.

1.4.2.2 PVC Cables

PVC is a general purpose thermoplastic used for wires and cables insulation and is a suitable alternative to paper insulation. PVC is applied as continuous seam free extrusion as insulation and sheath.

PVC cables has following properties and advantages:

- Insulation resistance and breakdown strength are practically unaffected by moisture.

- There is no impregnating compound in these cables, hence these cables can be laid vertically and on steep slopes.

- These cables can withstand a high transient conductor temperature with out any deformation of insulation.

- These cables are practically resistant to all chemicals encountered in practice.

- These cables are flame retardant since PVC ignites with great difficulty and that too when directly exposed to a flame.

- These cables are easy to install and handle due to their lighter weight.

- Small bending radii permit the termination of these cables in limited space. This eases the termination of PVC cables in switch boards and control panels etc.

- PVC cables have a smooth outer surface resulting in a neat appearance when installed. PVC outer sheath is tough and abrasion proof.

The main disadvantage of PVC is that it becomes brittle due to high temperature variations.

Generally there are two types of PVC, general purpose and fire retardant (FR-PVC). PVC insulation is suitable for voltages up to 11 kV.

1.4.2.3 XLPE Cables

Polyethylene has a linear molecular structure. Molecules of polyethylene, not chemically bonded, are easily deformed at high temperatures. This linear structure is changed into cross-linked structure by special processes. This thermo setting XLPE insulation material provide extra-ordinary electrical, thermal and mechanical properties to the cables, like low dielectric loss, excellent dielectric strength, higher continuous current rating, high resistance to thermal ageing etc.

Following are the main advantages of XLPE cables over PVC cables:

i. Excellent electrical & physical properties

High resistance to thermal deformation and the ageing property of XLPE cables provides greater continuous and short circuit current capacity ensuring higher degree of reliability over wide range of temperature variation as compared to PVC cables.

Permissible maximum conductor temperature

	XLPE cables	PVC cables
Continuous duty	90°C	70°C
Short circuit	250°C	160°C

ii. Higher current carrying capacity

Current carrying capacity of XLPE cables of the same size is approximately 20 to 30% higher than that of PVC due to higher operating temperature.

iii. Resistant to heat

With cross-linked molecules structure, XLPE cables are excellently ozone resistant and provide outstanding stability and are resistant to heat.

iv. XLPE cables have lower dielectric loss, lower permitivity as compared to PVC cables.

v. Due to lower specific gravity, XLPE cables are comparatively lighter in weight than PVC cables, therefore, ease in handling, laying and installation. The cable requires less supporting due to low weight.

vi. XLPE cable has higher mechanical properties and more robust as compared to PVC cables due to thermosetting process.

*****

CHAPTER 2

PVC AND XLPE POWER CABLES

2.1 PVC INSULATED (HEAVY DUTY) ELECTRIC CABLES

These cables are generally used upto & including 11 kV installations. Insulation material used is polyvinyl chloride (PVC) and conductors are made from electrical purity aluminium or copper. To give flexibility the conductors of cables are stranded.

These cables are used where combination of ambient temperature and temperature rise due to load results in conductor temperature not exceeding 70°C under normal operation and 160°C under short circuit conditions.

2.1.1 Core Identification

Different cores in a cable are identified by colours of PVC insulation. Accepted colour codes for PVC insulated cables are as under.

a. Single core : Red, yellow, blue or black.

b. Twin core : Red and black

c. Three core : Red, yellow and blue.

d. Four core : Red, yellow, blue and black.

e. Five core : red, yellow, blue, black and light grey.

In 3.5 core cables, the three main cores are red, yellow, blue for phases and reduced core is black for neutral.

Red, yellow, blue colours represent phase ‘R’, ‘Y’, ‘B’ and black colour represents neutral ‘N’.

For cables of voltage grade upto and including 6.6 kV, method of core identification shall be as under:

i. Different colouring of the PVC insulation or

ii. Coloured strips applied on the cores or

iii. By numerals (1,2,3), either applying numbered strips or by printing on the cores.

For cables of voltage grade of 6.35/11 kV method of core identification shall be as under:

i. Coloured strips applied on the cores or

ii. By numerals (1,2,3), either by applying numbered strips or by printing on the cores.

2.1.2 Constructional Features

i. ***Conductor*** : The conductor is made of electrical grade aluminium or copper. Generally all power cables have aluminium as the conductor. The conductor shall be of stranded construction size 2.5 sq mm. and above.

ii. ***Conductor Screening*** : Cables rated for 6.35/11 kV are provided with conductor screening over the conductor by applying non-metallic semi-conducting tape or by extrusion of semi-conducting compound or a combination of the both.

iii. ***Insulation*** : PVC compound is applied to the conductors by the extrusion process. It is so applied that it can be removed without damaging the conductor.

iv. ***Insulation screening*** : Cables rated for 6.35/11 kV are provided with insulation screening. It consists of two parts, namely non-metallic (semi-conducting) and metallic.

v. Inner sheath (for multi core cables)

The laid up cores are surrounded by an inner sheath of any of the following types.

a. Extruded PVC compound (for armoured cables)

b. Wrapping of PVC/plastic tapes. (for unarmoured cables).

Inner sheath is also known as bedding in case of armoured cables.

vi. Armouring

Depending upon the application these cables can be armoured or unarmoured.

For single core cables flat aluminium wire armour is used, since aluminium being a non magnetic material, will not induce stray current.

For multi core cables, galvanized round or flat steel wire armour or double steel tape armour is used.

The armouring is applied over the core insulation or inner sheath in case of single core cables and over the inner sheath in case of multicore cables.

vii. Outer sheath

Outer sheaths are made of black polyvinyl chloride (PVC) compound, which protect the armour material from corrosion. This PVC compound is applied by extrusion method.

Outer sheath is applied over the non-magnetic metallic tape covering the insulation or over the non-magnetic metallic part of insulation screening in case of unarmoured single core cables and over the armouring in case of armoured cables.

2.1.3 Ratings and Applications

PVC insulated power cables are generally designed and manufactured from rated voltage 650/1100 volts up to and including 6.35/11 kV and no. of cores are 1, 2, 3, 3.5,4 or 5 cores.

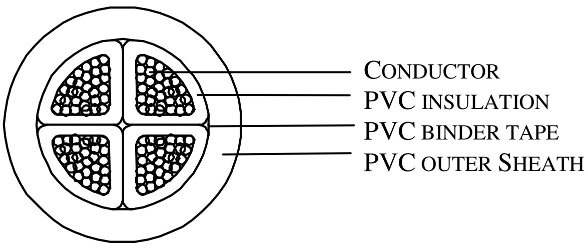
Nominal area of aluminium conductor ranges from 1.5 to 1000 sq. mm for single core cables and from 2.5 to 630 sq. mm for multicores cables.

PVC unarmoured single core and multicore cables are particularly useful in power stations, sub stations, house service connections, street lighting, building wiring etc. They can be installed indoors or outdoors, in air or in cable ducts.

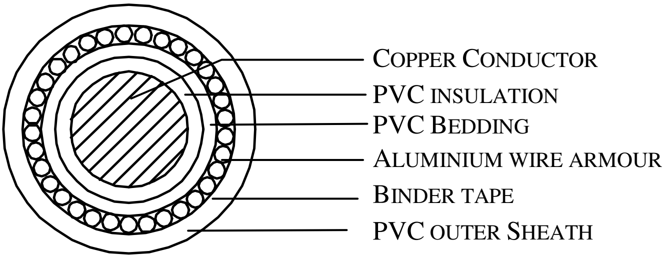
PVC armoured single core and multicore cables are useful in generating stations, substations, distribution systems, street lighting, industrial installations etc. On account of the armouring the cables can withstand rough installation, operation conditions and tensile stresses. They can be laid in water or buried direct in the ground even on steep slopes.

Cross sectional view of some of the PVC insulated cables are given below:

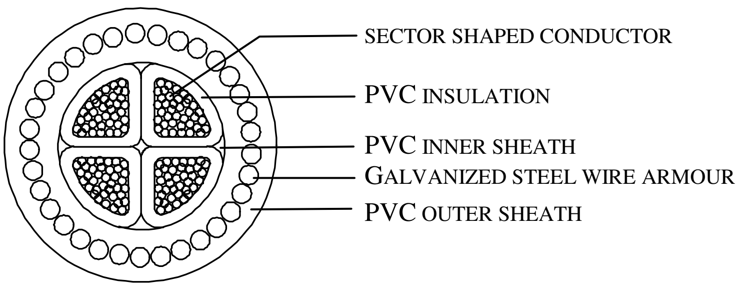
i. PVC insulated, PVC sheathed, unarmoured low voltage multi-core cable:



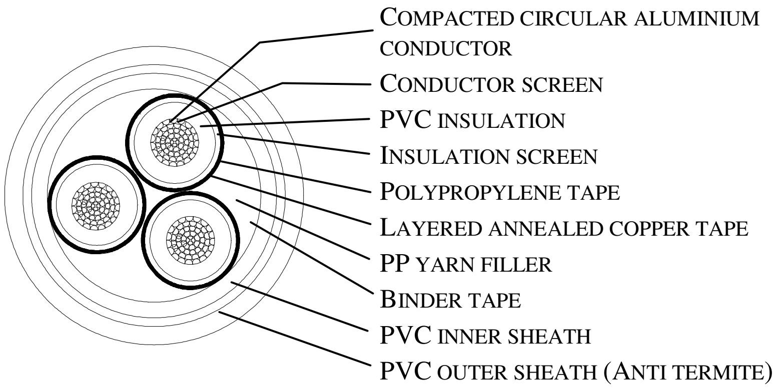
ii. PVC insulated, armoured, PVC sheathed single core low voltage cable:



iii. PVC insulated, armoured, PVC sheathed low voltage multi-core cable:



iv. PVC insulated, PVC sheathed medium voltage three core cable



2.2 XLPE Cables

Cross linked polyethylene (XLPE) insulated single core and multicore cables are manufactured with colours of cores red, yellow, blue to represent phase R, Y, B respectively and black colour to represent neutral N.

Construction of XLPE insulated cables are similar to that of PVC cables. Therefore they have all the advantages of PVC cables in terms of cleanliness., ease of handling and simple jointing and terminations.

The basic physical difference is that XLPE cables are more robust thus allowing the thickness to be reduced which in turn allows a corresponding reduction in the over all size of the cables.

These cables are suitable for use where combination of ambient temperature and temperature rise due to load results in conductor temperature not exceeding 90°C under normal operation and 250° C under short circuit condition.

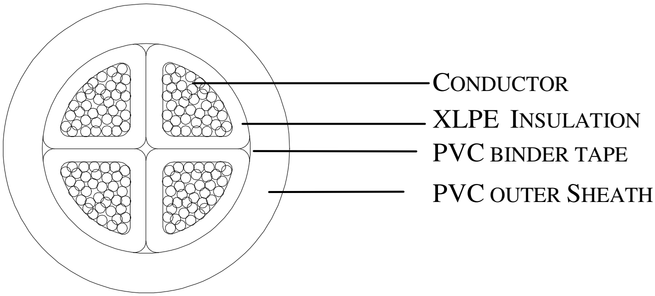
2.2.1 Low Voltage XLPE Cables

These cables are suitable for use on ac single phase or three phase (earthed or unearthed) systems for rated voltages up to and including 1100 V. These cables may be used on dc systems also for rated voltage up to and including 1500V to earth. These cables are generally available in following configurations.

2.2.1.1 Low Voltage XLPE Insulated, Unarmoured, PVC Sheathed Cables.

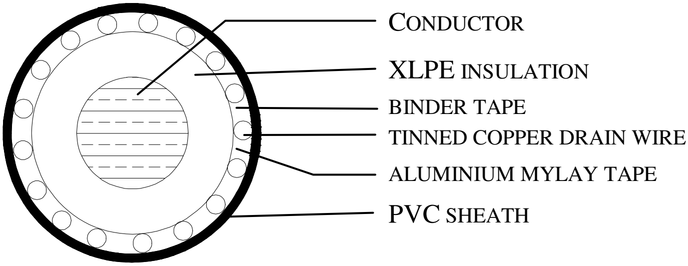
These cables are designed for general purpose indoor power distribution application. Plain circular or sector shaped stranded annealed aluminium or copper conductors are used and insulation of core consists cross linked polyethylene.

For multicore cables, cores are laid up together and filled with non-hygroscopic material (plastic fillers) compatible with the insulation. Outer sheath consists of black colour PVC type ST2.



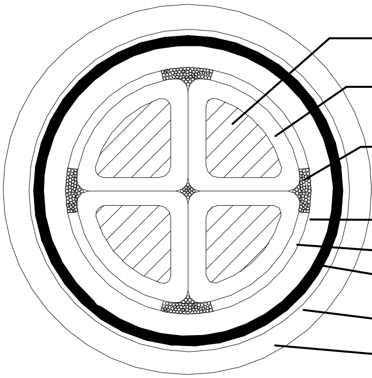
2.2.1.2 Low voltage XLPE Insulated, Screened, PVC Sheathed Cables

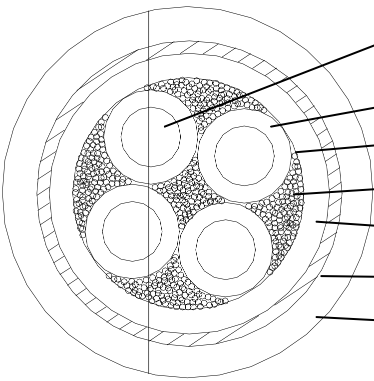
Design of the these cables are same as described in 2.2.1.1 except that aluminium mylar tape or annealed copper wire or tinned copper braid is used as screen material over XLPE insulation. Screening prevents external electro magnetic influences to the cable.



2.2.1.3 Low voltage XLPE insulated armoured PVC sheathed cables

Constructional features of single core aluminium armoured cables and multicore steel wire armoured cables are similar to PVC insulated cables mentioned earlier in 2.1.2. These cables are most suitable for under ground power distribution application, where there is a risk of mechanical damages.





2.2.2 Medium Voltage XLPE Cables.

Cross linked polyethylene insulated and PVC sheathed medium voltage power cables are suitable for voltages from 3.3 kV and up to and including 33kV.

Following categories of armoured screened or unscreened single core and three core XLPE insulated and PVC sheathed cables are available for electricity supply purposes.

a. Earthed system (Uo/U) – 1.9/3.3kV, 3.8/6.6kV, 6.35/11kV, 12.7/22kV and 19/33kV.

b. Unearthed system – 3.3/3.3kV, 6.6/6.6kV and 11/11kV.

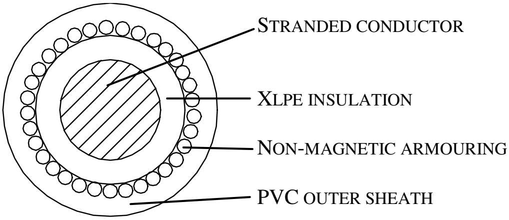
In these cables conductors are compacted stranded aluminium of smooth profile, free from sharp juts that could damage the insulation due to high local electric stresses.

XLPE insulation is processed using the triple layer dry curing extrusion method. These cables are supplied with extruded cross linked semi conducting screens to protect the main solid XLPE insulation. The conductor screen fills the interstices between wires and provides a smooth circular envelope around the conductor. This diminishes the concentration of flux lines around the individual wires and hence the electrical stress around the conductor.

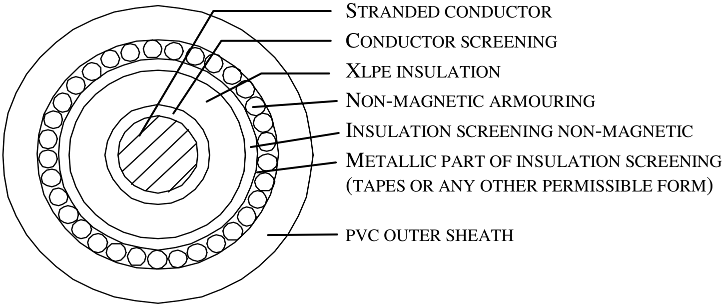
Semi conductive insulation screen either strippable or bonded is applied over the core insulation. A layer of annealed un coated copper tapes or copper wires is provided over the extruded insulation screen. This metallic screen provides an earthed envelope. This metallic shield provides protection from external fields, reduced stress concentration and uniform radical field lines from conductor and does not cause induced current.

XLPE insulated medium voltage cables are generally available in the following categories.

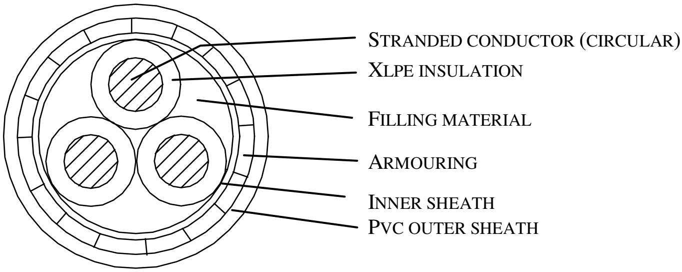
i. Armoured single core unscreened cable.

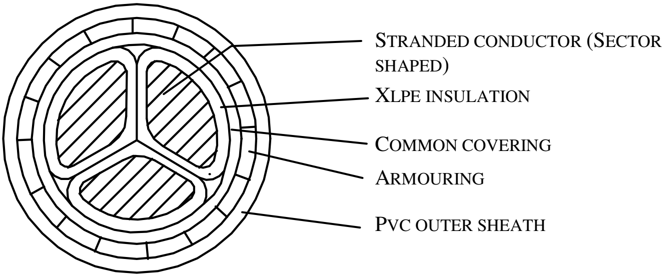


ii. Armoured single core screened cable.

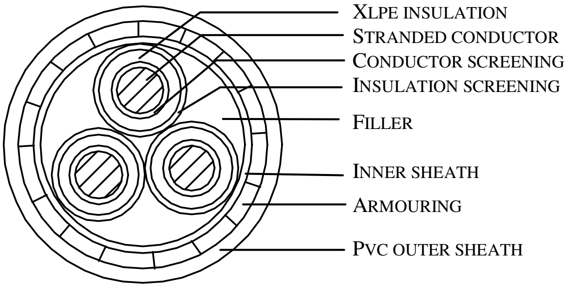


iii. Armoured 3 core unscreened cable.

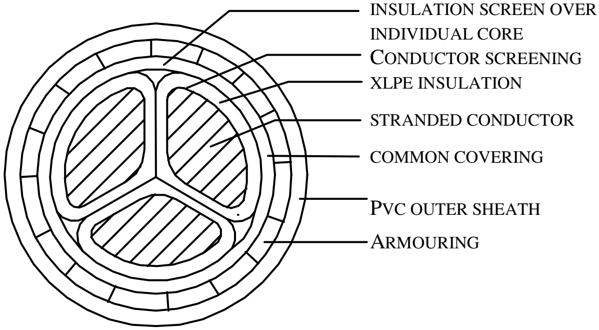




iv. Armoured 3 core screened cable.



Circular Conductor



Sector Shaped Conductor

CHAPTER 3

SELECTION, LAYING AND INSTALLATION OF CABLES

3.1 SELECTION OF SIZE AND TYPE OF CABLE

Selecting the proper type and size of cable for the desired application is very important. Selecting the correct type and size of cable not only ensures the trouble free performance but also optimises the cost of material, installation and the operation as well.

While selecting the correct type and size of the cable, following factors to be kept in mind.

i. System voltage

Important factors to be considered are rated voltage, maximum operating voltage whether dc or ac, number of phases and frequency. The permissible operating voltages are given in following table.

Rated voltage of cable		Max. permissible continuous 3-Phase system voltage	Max. permissible continuous 1-Phase system voltage		Maximum permissible dc voltage
Uo	U	Um	Both cores insulated	One core earthed	
kV	kV	kV	kV	kV	kV
0.65	1.1	1.21	1.4	0.7	1.8
1.9	3.3	3.63	4.2	2.1	--
3.3	3.3	3.63	4.2	4.2	--
3.8	6.6	7.26	8.1	4.0	--

Rated voltage of cable		Max. permissible continuous 3-Phase system voltage	Max. permissible continuous 1-Phase system voltage		Maximum permissible dc voltage
Uo	U	Um	Both cores insulated	One core earthed	
kV	kV	kV	kV	kV	kV
6.6	6.6	7.26	8.1	8.1	--
6.35	11	12.1	14	7	--
11	11	12.1	14	14	--
12.7	22	24.2	28	14	--
19	33	36.3	42	21	--

ii. Load conditions

Actual load conditions helps in choosing correct cross section of conductors for the cable. Following are the basic load conditions.

a. ***Normal continuous load*** – It means that the given load current will be flowing continuously through cable. Annexures may be referred for current ratings for PVC cables which are based on the normal conditions of installation. If the actual conditions are not the same as the normal conditions, the values for the normal current ratings should be multiplied by the relevant rating factors given in the IS-3961.

b. ***Intermittent load*** – If the cable is switched on and off periodically, so that the time between switching ‘off’ and then ‘on’ is not sufficient to cool the conductor to the ambient temperature during the rest period, then such load is called intermittent load. A proper cross-section of cable conductors for such load conditions may be decided in consultation with the cable manufacturers.

c. ***Short time load*** – Under these load conditions, the conductor is allowed to cool down to ambient temperature after the load period. Here again, the conductor cross-section may be decided in consultation with the cable manufacturers.

d. ***Cyclic load*** – If the load is cycle, the maximum permissible current may be increased by an amount depending on the shape of the load curve, type of cable, its heat capacity and method of installation.

iii. Earthing conditions

In 3 phase systems, it is necessary to know whether the neutral points is effectively earthed or earthed through resistance, inductance or earthing transformer or if system is totally unearthed.

iv. Permissible voltage drop

This factor also decides the minimum conductor size, particularly in long feeders so as to maintain voltage drop with statutory limits. Guidance about voltage drop in volts per kilometer per ampere, at the operating temperatures of the cables, may be taken from IS: 1255-1983.

In case of very high volt drop, it is necessary to choose a bigger conductor size.

In addition to above factors, following information should also be kept in mind while selecting proper type of the cable.

i. Soil conditions such as nature of soil, chemical action, electrolytic corrosions.

ii. Installation conditions.

iii. Economic considerations.

iv. Future expansions.

3.2 SELECTION OF THE CABLE ROUTE

Prior to start excavation of cable trench, conduct a preliminary survey of the cable route and prepare a plan drawing and obtain approval from all concerned authorities if necessary. Following points may be considered while selecting cable route.

a. Select the shortest but the easiest route to reduce the overall cast.

b. Due consideration shall be given for access/transportation of cable drums. Check the road conditions, turns and width.

c. As far as possible avoid paved roads and follow the footpaths.

d. The route should be as far as possible, away from parallel running gas, water pipes and telephone/ telecommunication cables.

e. Suitable locations for cable joints and terminations should be selected as required.

f. Take due consideration of future expansion or upgrading the system.

3.3 MINIMUM PERMISSIBLE BENDING RADII

The cable should not be bent to a sharp radius. Minimum permissible bending radii for cables as given in IS: 1255 – 1983 are given below:

Voltage rating(kV)	PILC cables		PVC and XLPE cables	
	Single core	Multi core	Single core	Multi core
Up to 1.1	20 D	15 D	15 D	12 D
Above 1.1 to 11	20 D	15 D	15 D	15 D
Above 11	25 D	20 D	20 D	15 D

Note : D is outer diameter of cable.

At joints and terminations bending radius for the individual cores should be above 12 times the diameter over the insulation.

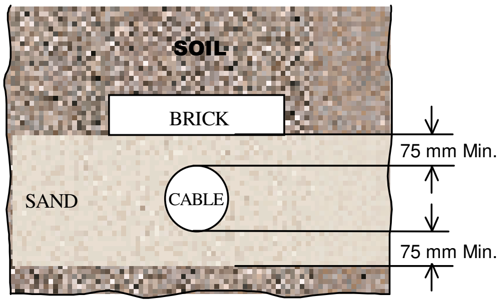
3.4 METHODS OF CABLE LAYING & INSTALLATION

The conventional methods of cable laying and installation are:

- Laying direct in ground.
- Drawing in ducts.
- Laying on racks in air.
- Laying on racks inside a cable tunnel.
- Laying along buildings or structures.

3.4.1 Laying Direct in Ground

This method involves digging a trench in the ground and laying cables on a bedding of minimum 75mm riddled soil or sand at the bottom of the trench, and covering it with additional riddled soil or sand of minimum 75mm and protecting it by means of bricks, tiles or slabs.



Cable Trench Layout

3.4.1.1 Depth

The desired minimum depth of laying from ground surface to the top of the cable should be as following :

- Cables, 3.3 KV to 11 kV Voltage rating : 0.9m
- Cables, 22 kV, 33 kV Voltage rating : 1.05 m
- Low voltage and control cables = 0.75 m
- Cables at road crossings : 1.00 m
- Cables at railway level crossings : 1.00 m

(Measured from bottom of sleepers to the top of pipe)

3.4.1.2 Clearances

The desired minimum clearances are as following.

- Power cable to power cable – Clearance not necessary. However larger the clearance, better would be current carrying capacity.
- Power cable to control cables : 0.2m
- Power cable to communication cable : 0.3m
- Power cable to gas/ water main : 0.3m

3.4.1.3 Cable Laid Across Roads, Railway Tracks and Water Pipe Lines.

- Hume pipe/ 'B' grade GI pipe of suitable size shall be used where cable cross roads, railway tracks. Spare ducts for future extensions shall also be provided.

- The duct/ pipe joints shall be covered by collars to prevent settlement in between pipes.

- The diameter of the cable conduit or pipe/duct shall be at least 1.5 times the outer diameter of cable. The ducts/pipes shall be mechanically strong to withstand forces due to heavy traffic when they are laid across the road/ railway tracks.

- The cable entry and exit shall be through bell mouth or padding.

- The bending radii of steel or plastics ducts shall not be less then 1.5m.

- Single core cables shall not be laid individually in steel ducts but instead, all three cables of the same system shall be laid in one duct.

3.4.1.4 Cable Over Bridges

On bridges, the cables are generally supported on steel cable hooks or clamped on steel supports at regular intervals. It is advisable that cables laid in bridges are provided with sun shields to protect the cable from direct heating by sun's rays.

3.4.1.5 Trenching

Following are the known methods of trenching.

i. Manual excavation
ii. Excavation with mechanical force.
iii. Thrust bore
iv. Trench ploughing

Manual excavation method is generally in practice. Trenches shall be excavated according to the line and level shown on the cable route plan. It possible the cable trench shall be of straight lines. All curves must be smooth and suitable for laying the cable. The excavated trench sides and trench floor should be trimmed to remove the sharp projections, if any, which might damage cables.

During excavation take adequate measures to protect all existing structures and existing services such as electrical cables, telecom cables, gas line, water pipe etc.

3.4.1.6 Cable Laying (By hand)

Before laying the cable, it should be examined for any exterior damage. Mount the cable drum on a cable jack with a strong spindle. Drum is to be jacked high enough to fit in braking plank. Weak shaft should not be used otherwise drum would revolve unevenly.

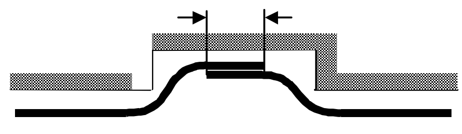
The drum should never be kept flat on its side on the ground and the cable taken away from the same. This invariably leads to kinking and bird caging.

The pay in rollers, corner rollers and properly aligned and smooth running cable rollers should be placed every 3 to 4 m in the cable trench. At least three solid plates for guiding the cable around the bend should be used for maintaining minimum bending radius.

Raise the drum slowly equally from both the ends by using both the jacks. Now the cable is to be paid out from the top of the drum by rolling the drum in the direction of arrow marked on the drum. A cable grip may be provided at the end of the cable or men may also directly grip the cable, positioning themselves near the cable rollers and pull after a sufficient length about 50m has been pulled.

The gangman (Mucadam) should stand in a commanding position and make evenly timed calls. This enables the men positioned at each roller to pull the cable evenly, simultaneously and without jerks. The number of man required for pulling largely depends on the size and weight of the cable being laid. The men at rollers should also apply graphite grease in the course of pulling, as and when required. When pulling round a bend, corner rollers should be used so as to minimise abrasion.

During the preliminary stages of laying the cable, consideration should be given to proper location of the joint position so that when the cable is actually laid the joints are made in most suitable places.



CABLE JOINT PIT AND OVERLAPPING OF CABLE ENDS

There should be sufficient overlap of cables to allow for the removal of cable ends which may have been damaged. This point is extremely important as otherwise it may result in a short piece of the cable having to be included. The joint should not be near pipe end or at the bend.

3.4.1.7 Reinstatement

- After laying the cable it should be checked again for ensuring that the all cable ends are undamaged and sealed.

- If trench is partially filled with water, cable ends should kept clear off water as far as possible.

- If cable has to be cut, reseal both the cable ends immediately. Lead cap for paper cable and plastic cap for PVC/XLPE cable should be used. As a temporary measure, end can be sealed by inserting them in an empty tin which is filled with hot bitumen based compound.

- Each cable length should be aligned immediately after it is laid starting from one end. When aligning the cable, it should be ensured that there is no external damage.

- If the joints are not to be made immediately after laying the cable, the cable ends should be covered. The position of cable joint should be marked with markers.

- The trench at the duct mouth at road or railway crossing should be deepened to prevent the stone or the gravel from being drawn into duct and clogging it.

- Before the trench is filled in, all joints and cable positions should be carefully plotted.

- The requisite protective covering should then be provided, the excavated soil replaced after removing large stones and well rammed in successive layers of not more than 0.3m in depth. Where necessary, the trenches should be watered to improve consolidation.

- It is advisable to leave a crown of earth not less than 50mm in the center and tapering towards the sides of the trench to allow for settlement.

- After the subsidence has ceased, the trench may be permanently reinstated and the surface restored to its original conditions.

- Cable route markers are to be installed on either sides of the cable trench at every 100m interval on straight runs, and turning points. Joint markers should be installed at all the four corners of the joint pit.

3.5 CABLE JOINTING

Cable joint is a device used to join two or more cables together for extension of lengths or to branch. These joints are made to perform at the same voltage class and ratings of the intended cables and are able to withstand the normal and emergency loading conditions. Selection of proper cable accessories, proper jointing techniques, skill and workmanship is important. The quality of joint should be such that it does not add any resistance to the circuit. All underground cable joints must be mechanically and electrically sound and it is protected against moisture and mechanical damage. The joint should further be resistant to corrosion and chemical effects.

3.5.1 Basic Types of Joints

The basic types of cable joints are

i. Straight through joints

This type of joint is used to connect two cables lengths together. This joint is further divided in two categories.

a. Simple straight through joints.

For jointing same type of cables such as PVC to PVC, XLPE to XLPE.

b. Transition straight through joints.

For jointing two different type cables such as XLPE to PILC.

ii. Tee/branch joint

These joints are normally used for jointing a service cable to the main distribution cable in distribution network.

These joints should be restricted to 1.1kV grade cables. Tee joints on HT cables upto and including 11kV may be done only in exceptional cases.

These joints are made either using cast resin kits or C.I. boxes with or without sleeves for PILC cables and cast resin kits for PVC and XLPE cables.

iii. Termination or sealing end

This is generally used to connect a cable to switch gear terminal in switch boards, distribution pillars, transformer box, motor terminal box and to overhead lines.

3.5.2 Types of Cable Jointing Accessories

Following types of jointing accessories are mainly used for jointing all types of low voltage & medium voltage power cables. Every jointing kit is provided with an instruction manual supplied by the manufacturer. Joints shall be made according to the guidelines given in instruction manual.

i. Heat shrinkable jointing kit. (Preferred)

ii. Cold shrinkable jointing kit.

iii. Tapex tape type jointing kit.

iv. Push on type jointing kit.

v. Cast resin jointing kit.

3.5.3 Measurement of Insulation Resistance

Before jointing is commenced, it is advisable that the insulation resistance of both sections of the cable to be jointed, be checked by insulation resistance testing instruments like megger.

3.5.4 One example is given below for making straight joint for better understanding (M-seal tapex type joint for 12 kV to 36 kV XLPE cables)

Cable jointing is basically a technique of rebuilding the cable construction in the same formation as the original cables to be jointed. Jointing of XLPE power cables is based on following components.

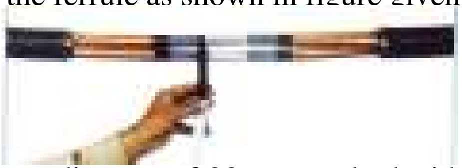
i. Crimping type jointing ferrule.
ii. Self amalgamating insulating tapes.
iii. Self amalgamating semiconducting tapes.
iv. Non-linear stress grading pads.
v. Earthing connector and clamps.
vi. Plastic mould and jointing compound etc.

The important steps in the cable jointing of medium voltage XLPE insulated screened armoured cable is given below.

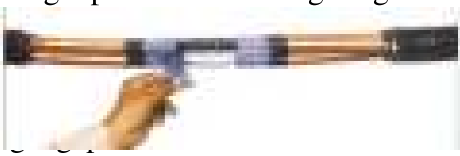
a. Strip the jointing ends of both the cables to be done i.e. stripping of outer sheath, armour, inner sheath, insulation screen, core insulation and conductor screen.

b. Joint all the conductor cores shall be joint with the help of jointing ferrule and its crimping by suitable crimping tool.

c. Fill up the space between the ferrule and the core insulation and the crimped portion in ferrule with semi conducting tape, so that it forms a smooth and round profile with 2 mm. Overlap on the insulation on each side of the ferrule as shown in figure given below.



d. Measure a distance of 20 mm on both sides of the semi-conducting tape. Apply stress grading pad of 30mm width over the core covering 10mm of the semi conducting tape as shown in figure given below.



e. Keepi ucting layer of core, wrap the self alamgamating insulating tape so that the required insulation thickness is built up. Ensure a tapered profile of the tape towards the semi conducting layer of the insulation, the self amalgamating tape should be stretched to 2/3 rds of its original width while applying as shown in figure given below.

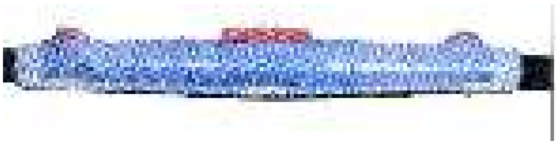
f. Fill up the gap 5mm between self amalgamating insulating tape and semi conducting layer of core by stress grading pad of 30mm width as shown in figure given below

g. Apply semi conducting tape one layer half over lapped about 10mm on one side of metallic shielding to the other end in the same manner as shown in figure given below.

h. Wrap 2 layers of self amalgamating insulating tape, each half overlapped to cover the semi conducting tape. Stretch the tape 2/3rds of width while applying as shown in figure given below.

i. Wrap one layer of copper wire mesh on the core to connect the copper tape from end to another over the tapes as shown in figure given below.

j. After earthing place the mould & fill it with cable jointing compound as shown in figure given below.



3.6 CABLE END TERMINATIONS

Termination kits are designed for terminating cable ends at an indoor type equipment with an indoor termination kit or on pole tops/ outdoor transformer with an out door type termination. Both type of terminations are designed to operate at optimum level during normal loading and emergency condition of the cables.

Following types of termination kits are mainly used for terminating all types of PVC/XLPE power cables upto medium voltage.

i. Heat shrink termination kit.

ii. Cold shrink termination kit.

iii. Premoulded push on termination kit.

iv. Cast resin termination kit.

v. Brass glands (for low voltage indoor terminations in dry and non corrosive atmosphere.)

Every terminating kit is provided with an instruction manual supplied by the manufacturer. Terminations shall be made according to the guidelines given in instruction manual.

3.6.1 One example is given below for making end termination for better understanding (M-seal push-on type pre moulded terminations for XLPE/ EPR/ PVC cables upto 36 kV)

M-seal push on type termination kit comprises of intricately engineered and moulded EPDM (Ethylene Propylene Diene Monomer) rubber components and these are available up to 1000 sq. mm for cables from 3.3 kV to 22 kV and up to 630sq. mm for cables of 33kV grade.

This type of kit comprises

i. Stress cone which consists of highly track resistant insulating section vulcanised to a semi-conducting section.

ii. A semi conducting pad which is used to make the connection between screen and cone. The pad material has cold flow properties. When it is taped into position, the active pressure of the tape induces the cold flow property of the material so that it fills in all the cavities at the screen edge and in the folds of the material itself.

    This push on method suit all type of core screen including extruded or taped. This can be used on both type of conductors i.e. circular compacted or sector shaped.

iii. The number of rain sheds to be provided is determined by the operating voltage and the location of the termination. The same termination can be used on 3.3 kV to 33kV by only increasing or reducing the number of rain sheds. Rain sheds are generally provided for outdoor terminations. However rain sheds can also be used on indoor terminations to increase creepage path in very highly polluted atmosphere or to match limited space availability. M-seal push on has an approx. creepage of 4cm/kV.

iv. A lug seal (for out door terminations is also provided to prevent any ingress of moisture.

Important steps to be followed while carrying out M-seal push-on termination are given as under:

- Strip the end of the cable to be terminated i.e. stripping of outer sheath, armour, inner sheath, insulation screen, core insulation etc.
- Push on the stress cone on the prepared cable core as shown in figure no. 1.
- Connect the stress cone and cable outer screen with semiconducting cold flow material as shown in figure no. 2.
- Wind the self bonding insulating tape over the semiconducting cold flow material with active pressure. This active pressure ensures that voids are eliminated between the termination and the cable insulation as shown in figure no. 3.

Figure 1

Figure 2

Figure 3

- Now if the termination is to be used for indoor use, provide the cable lug and crimp it using suitable crimping tool. This completed termination is ready for indoor use as shown in figure no. 4.

- For out door termination, provide rain sheds and top cap. Number of rain sheds vary with voltage rating of the cables as shown in figure no. 5.

- Crimp the cable lug by using suitable crimping tool and provide lug seal. This completed termination is ready for outdoor use as shown in figure no. 6.

Figure 4

Figure 5

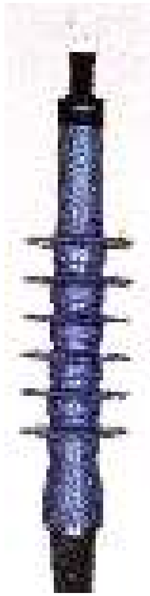


Figure 6

3.7 Earthing and Bonding of Cables

- The metal sheath, metal screen (if any) and armour of any cable should be efficiently earthed at both ends.

- In case of single-core cables of larger sizes, the armour, lead sheath and metal screen, if any, is bonded at times only at one point. Attention is drawn in this case to the presence of standing voltages along armour or lead sheath and to the considerable increase in such voltages when cables carry fault currents. These voltages must be taken into account when considering safety and outer sheath insulation requirement.

- All metal pipes or conduits in which the cables have been installed should be efficiently bonded and earthed.

- Where cables not having metallic sheath are used, embedding additional earth electrodes and connecting the same with steel armour of cable becomes necessary.

- Earthing and bonding should be done in accordance with IS: 3043-1987.

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CHAPTER 4

TESTING OF CABLES

4.1 TESTING OF CABLE INSTALLATION

4.1.1 Insulation Resistance Test on Newly Installed Cables Before Jointing.

All new cables should be tested for insulation resistance before jointing. After satisfactory results are obtained cable jointing and termination work should commence. It should be noted here that insulation resistance test gives only approximate insulation resistance and the test is meant to reveal gross insulation faults.

A fairly low insulation resistance reading compared to the values obtained at factory testing should not be a cause of worry since the insulation resistance varies greatly with parameters such as length and temperature. This is particularly more pronounced in the case of PVC cables. The voltage rating of the insulation resistance tester for cables of different voltage grades should be chosen from the following table.

Voltage Grade of Cable	Voltage Rating of IR Tester
1.1kV	500V
3.3kV	1000V
6.6kV	1000V
11kV	1000V
22kV	2.5kV
33kV	2.5kV

Note : For long feeders, motorized insulation resistance tester should be used.

4.1.2 Tests on Completed Cable Installation

The test of completed installation may be measured and entered into record book for comparison purposes during service life of cable installation and during fault location.

4.1.2.1 Insulation Resistance

Insulation resistance is measured by a suitable bridge. In non-screened cables, the insulation resistance of each core is measured against all the other cores and armour/metal sheath connected to earth. With screened construction the insulation resistance of each core is measured against all the other core and the metal screen connected to earth.

4.1.2.2 Conductor Resistance (dc)

(a) The resistance of conductor is measured by a suitable bridge. For this purpose conductors at other end are looped together with connecting bond of at least same effective electrical cross-section as conductor. The contact resistance is kept to a minimum by proper clamped or bolted connections. With properly installed and jointed cables, values thus measured and corrected to 20°C, are in general agreement with values given in test certificates.

(b) The measured loop resistance is converted to ohms per km per conductor as:

$$R_t = R / 2L$$

Where

R = measured loop resistance in ohms at temperature, t°c;

R_t = measured resistance per conductor at t°C in ohms per km.

L = length of cable (not the loop) in km.

The ambient temperature at the time of measurement to be recorded and the conductor resistance to be corrected to 20°C by the following formula:

$$R_{20} = \frac{R_t}{(1+\alpha)(t-20)} \quad \text{ohm/km at } 20°C.$$

Where

R_{20} = conductor dc resistance at 20°C in ohm/km,

t = ambient temperature during measurement in °C, and

α = temperature coefficient of resistance (3.93×10^{-3} ohms/°C for aluminium).

4.1.2.3 Capacitance

For unscreened cables, capacitance is measured for one conductor against others and metal sheath/armour connected to earth. In case of screened cable it is measured between conductor and screen. Capacitance bridge is used for this purpose. This measurement may be carried in case of cables above 11kV; alternatively values given in test certificate are considered sufficient.

4.1.2.4 High voltage test

Cables after jointing and terminating are subjected to dc high voltage test. The recommended values of test voltages are given in table.

The leakage current shall also be measured and recorded for future reference.

Rated voltage of cable	Test voltage between		Duration
Uo/U	Any conductor and metallic sheath/ screen/ armour	Conductor to conductor (For Unscreened cables)	
kV	kV	kV	Minutes
0.65/1.1	3	3	5
1.9/3.3	5	9	
3.3/3.3	9	9	
3.8/6.6	10.5	18	
6.6/6.6	18	18	
6.35/11	18	30	
11/11	30	30	
12.7/22	37.5	--	
19/33	60	--	

- Generally dc test should be preferred as test equipment required is compact, easily portable and power requirements are low.

- The cable cores must be discharged on completion of dc high voltage test and cable should be kept earthed until it is put into service.

- DC test voltage for old cables is 1.5 times rated voltage or less depending on the age of cables, repair work or nature of jointing work carried out etc. In any case, the test voltage should not be less than the rated voltage. Test voltage in these cases should be determined by the engineer-in-charge of the work.

- It may be noted that frequent high voltage tests on cable installations should not be carried out. This test should be carried only when essential. During the high voltage test, all other electrical equipment related to the cable installation, such as switches, instrument transformers, bus bars, etc. must be earthed and adequate clearance should be maintained from the other equipment and framework to prevent flashovers.

- In each test, the metallic sheath/screen/armour should be connected to earth.

4.2 CABLE INSTALLATION PLAN

On completion of laying, terminating and jointing of the cables, a plan should be prepared, which should contain the following details of the installation.

a. Type of cables, cross-section area, rated voltage. Details of construction, cable number and drum number.

b. Year and month of laying.

c. Actual length between joint-to-joint or end.

d. Location of cables and joints in relation to certain fixed reference points, for example, buildings, hydrant, boundary stones, etc.

e. Name of the jointer who carried the jointing work.

f. Date of making joint.

g. Results of original electrical measurements and testing on cable installation.

All subsequent changes in the cable plan should also be entered.

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CHAPTER 5

MAINTENANCE

5.1 GENERAL

The maintenance of cable installation includes inspection, routine checking of current loading, maintenance and care of all cables and end terminations.

5.2 INSPECTION

- When ever the cables or joints are accessible as in manholes, ducts, distribution pillars etc., periodical inspection should be made so that timely repairs can be made before the cables or joints actually cause interruption to service. The frequency of inspection should be determined by individual from its own experience. Important heavily loaded lines will require more frequent attention than less important lines.

- Cables laid direct in the ground are not accessible for routine inspection, but such cables are often exposed when the ground is ex-cavated by other public utilities for installing or repairing their own properties. Preventive maintenance in the form of regular inspection of all digging operations by other utilities or persons, carried out in areas they are electric cables exists is of utmost importance.

  In a city where the roads are congested with services of other utilities, the likelihood of damaged two electric cables is very high. Cable inspectors should patrol the various sections of the city and where it is found that cables are exposed, these should be examined thoroughly for any signs of damaged; such as deformation or dents in the cable or damage to earthenware troughs or ducts.

5.3 CHECKING OF CURRENT LOADING

The life of paper insulated cables is considerably reduced through overloading. It is, therefore, essential to check the loads as frequently as possible to ensure that the cables are not loaded beyond the safe current carrying capacities. The derating factors due to grouping of several cables, higher ambient ground temperature and higher thermal resistivity of soil, should not be neglected.

In the case of HV feeder cables emanating from generating station, receiving station, or sub-station, panel-mounted ammeters which are usually provided, should be read daily. In the case of medium voltage distribution cables emanating from distribution pillars, the loads are conveniently checked by ‘clip-on’ type portable ammeters. Distributor loads should be checked at intervals not exceeding three months.

5.4 MAINTENANCE OF CABLES

Repairs of cables generally involve replacement of a section of the defective cable by a length of new cable and insertion of two straight joints. All repairs and new joint in connection with repairs should be made in the same manner as joints on new cables.

In some cases where the insulation has not been damaged severely, or where moisture has not obtained ingress into the insulation, it may only be necessary to install a joint at the point of cable failure.

5.5 MAINTENANCE OF END TERMINATIONS

- Visual inspection of all the cable end termination should be carried out regularly for any over heating flashing mark, insulation damage etc.

- Cable end terminations should be checked for tightness with a suitable torque wrinch/spanner periodically.

- Check the cable support clamps, glands for proper position and intactness.

5.6 RECOMMENDATIONS FOR STORAGE AND TRANSPORTATION OF CABLES

- No drums should be stored one above the other.
- Drums should be stored preferably on a plain ground without having any projected hard stones above the ground surface.
- The drums should be stored preferably in the shed.
- Drums should be kept in a such a way that bottom cable end does not get damaged.
- Both the ends of the cable should be sealed with plastic caps.
- The cable drums or coils must not be dropped or thrown from railway wagons or trucks during unloading operations. A ramp or crane may be used for unloading cable drums. If neither of these is available, a temporary ramp with inclination 1:3 to 1:4 approximately should be constructed. The cable drum should then be rolled over the ramp by means of ropes and winches. Additionally a sand bed at the foot of the ramp may be made to brake the rolling of cable drum.

- The arrows painted on the flange of the drum indicate the direction in which the drum should be rolled. The cable will unwind and become loose if the drum is rolled in the opposite direction.
- The site chosen for storage of cable drums should be well-drained and should preferably have a concrete surface/firm surface which will not cause the drums to sink and thus lead to flange rot and extreme difficulty in moving the drums.
- All drums should be stored in such a manner as to leave sufficient space between them for air circulation. It is desirable for the drums to stand on battens placed directly under the flanges. During storage, the drum should be rolled to an angle of 90° once every three months.
- In no case should the drums be stored on the flat; that is, with flange horizontal.
- Overhead covering is not essential unless the storage is for a very long period. The cable should, however be protected from direct rays of the sun by leaving the battens on or by providing some form of sun shielding.
- When for any reason, it is necessary to rewind a cable on to another drum, the barrel of the drum should have a diameter not less than that of the original drum.

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CURRENT RATINGS (ac) AS PER IS 3961 (Pt.-II)-1967 FOR TWO SINGLE CORE 650/1100 VOLTS UNARMOURED OR NON-MAGNETIC ARMOURED PVC INSULATED (HEAVY DUTY) CABLES

NOMINAL AREA OF CONDUCTOR	LAID DIRECT IN THE GROUND		IN DUCTS		IN AIR	
	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM
mm^2	A	A	A	A	A	A
1.5	25	21	23	19	24	18
2.5	35	28	31	25	32	25
4	46	36	42	33	43	32
6	57	44	54	42	54	41
10	75	59	72	56	72	56
16	94	75	92	71	92	72
25	125	97	120	93	125	99
35	150	120	140	110	155	120
50	180	145	165	130	190	150
70	220	170	200	155	235	185
95	265	205	230	180	275	215
120	300	230	255	200	310	240
150	340	265	280	220	345	270
185	380	300	305	240	390	305
240	420	335	340	270	445	350
300	465	370	370	295	500	395
400	500	410	405	335	570	455
500	540	435	430	355	610	490
625	590	485	465	395	680	560

ANNEXURE II

CURRENT RATINGS (ac) AS PER IS 3961 (Pt.-II)-1967 FOR THREE SINGLE CORE 650/1 100 VOLTS UNARMOURED OR NON-MAGNETIC ARMOURED PVC INSULATED (HEAVY DUTY) CABLES.

NOMINAL AREA OF CONDUCTOR	LAID DIRECT IN THE GROUND		IN DUCTS		IN AIR	
	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM
mm^2	A	A	A	A	A	A
1.5	22	17	21	17	20	15
2.5	30	24	29	24	27	21
4	39	31	38	30	35	27
6	49	39	48	37	44	35
10	65	51	64	51	60	47
16	85	66	83	65	82	64
25	110	86	110	84	110	84
35	130	100	125	100	130	105
50	155	120	150	115	165	130
70	190	140	175	135	205	155
95	220	175	200	155	245	190
120	250	195	220	170	280	220
150	280	220	245	190	320	250
185	305	240	260	210	370	290
240	345	270	285	225	425	335
300	375	295	310	245	475	380
400	400	325	335	275	550	435
500	425	345	355	295	590	480
625	470	390	375	320	660	550

ANNEXURE III

CURRENT RATINGS (ac) AS PER IS 3961 (Pt.-II)-1967 FOR TWIN 650/1 100 VOLTS ARMOURED OR UNARMOURED PVC INSULATED (HEAVY DUTY) CABLES.

NOMINAL AREA OF CONDUCTOR	LAID DIRECT IN THE GROUND		IN DUCTS		IN AIR	
	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM
mm^2	A	A	A	A	A	A
1.5	23	18	20	16	20	16
2.5	32	25	27	21	27	21
4	41	32	35	27	35	27
6	50	40	44	34	45	35
10	70	55	53	45	60	47
16	90	70	75	58	78	59
25	115	90	97	76	105	78
35	140	110	120	92	125	99
50	165	135	145	115	155	125
70	205	160	180	140	195	150
95	240	190	215	170	230	185
120	275	210	235	190	265	210
150	310	240	270	210	305	240
185	350	275	300	240	350	275
240	405	320	345	275	410	325
300	450	355	385	305	465	365
400	490	385	425	345	530	420

Note : The current ratings apply to cables with sectors shaped conductor of sizes above 25 mm2 for round conductors lower ratings shall be taken.

ANNEXURE IV

CURRENT RATINGS (ac) AS PER IS 3961 (Pt.-II)-1967 FOR THREE, FOUR & FIVE CORE 650/1 100 VOLTS ARMOURED OR UNARMOURED PVC INSULATED (HEAVY DUTY) CABLES.

NOMINAL AREA OF CONDUCTOR	LAID DIRECT IN THE GROUND		IN DUCTS		IN AIR	
	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM
mm^2	A	A	A	A	A	A
1.5	21	16	17	14	17	13
2.5	27	21	24	18	24	18
4	36	28	30	23	30	23
6	45	35	38	30	39	30
10	60	46	50	39	52	40
16	77	60	64	50	66	51
25	99	76	81	63	90	70
35	120	92	99	77	110	86
50	145	110	125	95	135	105
70	175	135	150	115	165	130
95	210	165	175	140	200	155
120	240	185	195	155	230	180
150	270	210	225	175	265	205
185	300	235	255	200	305	240
240	345	275	295	235	355	280
300	385	305	335	260	400	315
400	425	335	360	290	455	375

Note : 1. The current ratings apply to cables with sectors shaped conductors of sizes above 25 mm2 for round lower conductors ratings shall be taken.

2. In case of four and five core cables only three cores are carrying full load current.

CURRENT RATINGS (dc) AS PER IS 3961 (Pt.-II)-1967 FOR 650/1 100 VOLTS ARMOURED OR UNARMOURED PVC INSULATED (HEAVY DUTY) CABLES.

NOMINAL AREA OF CONDUCTOR	LAID DIRECT IN THE GROUND				IN DUCTS				IN AIR			
	TWO SINGALS		ONE TWIN		TWO SINGALS		ONE TWIN		TWO SINGALS		ONE TWIN	
	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM	COPPER	ALUMINIUM
mm^2	A	A	A	A	A	A	A	A	A	A	A	A
70	225	175	205	160	215	165	180	140	240	190	195	150
95	270	210	245	195	250	195	215	170	285	225	230	180
120	310	240	285	220	285	225	240	190	335	260	265	210
150	350	270	320	250	325	255	275	215	390	300	310	240
185	390	305	360	285	370	285	310	245	445	345	360	280
240	455	355	425	330	425	330	360	280	520	405	425	335
300	510	400	480	370	475	375	410	320	590	470	490	380
400	590	460	550	425	560	435	495	385	710	560	580	450
500	650	510	--	--	630	490	--	--	800	630	--	--
625	760	600	--	--	730	570	--	--	960	750	--	--

Note : 1. For conductor size smaller than 70 mm2 the dc rating is the same as the ac rating. (See annexure 1 & 2).

REFERENCE

1. IS 1554 (Part-I) – 1988 Specification for PVC Insulated (Heavy duty) Electrical cables for working voltages upto and including 1100 V.

2. IS 1554 (Part-II) – 1988 Specification for PVC Insulated (Heavy duty) Electrical cables for working voltages from 3.3kV upto and including 11kV.

3. IS 7098 (Part-I) – 1988 Specification for Cross Linked Polyethylene Insulated PVC Sheathed Cables for working voltages upto and including 1100 V.

4. IS 7098 (Part-II) – 1988 Specification for Cross Linked Polyethylene Insulated PVC Sheathed Cables for working voltages from 3.3kV upto and including 33kV.

5. IS 3961 (Part-II) – 1967 Recommended current rating for PVC Insulated and PVC sheathed heavy duty cables.

6. IS 1255 – 1983 Code of practice for Installation and Maintenance of Power cables upto and including 33 kV rating.

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OUR OBJECTIVE

To upgrade maintenance technologies and methodologies and achieve improvement in productivity, performance of all Railway assets and manpower which inter-alia would cover reliability, availability, utilisation and efficiency.

If you have any suggestions and specific comments please write to us.

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