Ravin

EHV Cables,
Accessories & Services

POWERING THE NATION

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Front Cover inside page

RAVIN.

ELECTRICITY FOR A BRIGHTER TOMORROW.

A specialist across power and electricity sector, Ravin Group, with an experience of over 7 decades, has carved a niche for itself in the domestic and global markets, as the Electricity Expert. With a view to stay ahead of the curve, Ravin has managed to make its mark and light up lives with its comprehensive solutions and futuristic approach wherever they go and will continue to do so for years to come.

At Ravin, the focus is on providing world class, safe and cutting-edge products and services to satisfy the ever-increasing electricity needs. The products and services, across the electricity spectrum, are laced with technologically advanced solutions that allow us to actively build a safe and strong future for the electrified world.

Ravin Group has a diversified portfolio across the electricity value chain, with its prowess in the manufacturing of **Electric Cables, EHV Cables & EPC Services, Power Equipments, Moisture Management Systems and Solar Energy Solutions.**

OUR VALUES DEFINE US

Our strongly imbibed core values of Safety, Dependability and Sustainability comes across as our strength and the basis of our growth and development across the decades of our operation.

SAFETY to the users, the public in general, our employees and the environment is our priority. Safety coincides with production and quality and is an integral part of our business. A series of pioneering safety innovations has made Ravin a leader in safety over the past few years.

DEPENDABILITY is living up to our word and fulfilling our promises. Our customers and communities deserve our respect, honesty, and expert abilities. When a project is completed, our goal is to be remembered as a trusted partner that delivered the promised results. And to berelied on again.

SUSTAINABILITY for us is an approach that integrates people, planet and profit, resulting in a greener and safer tomorrow. Our aim is to promote a responsible culture and implement robust corporate systems to meet our sustainability goals.

ACHIEVEMENTS

- **Best Infrastructure Brand Award**, 2016 by The Economic Times
- **Export Excellence Awarded** by EEPC since 2001
- Group CMD, **Mr. Vijay P Karia** awarded with **Inspiring Entrepreneurs of India**
- Group CMD, **Mr. Vijay P Karia** awarded with **Asia's Most Promising Business Leaders**

UNMATCHED ENGINEERING FINESSE

In providing a unique approach to process design, construction and project management, Ravin's engineering expertise, production and process knowledge can provide a range of services to meet requirements like:

- Feasibility Study
- Design
- Customised Manufacturing
- Equipment Supply
- Installation
- Commissioning

Through our process, engineering prowess and reputation, we can deliver a diverse range of process solutions to both domestic and overseas markets.

Our customer base extends to major national and international companies, worldwide private and public sector clients, all of whom have benefited from our ability to adapt technologies and tailor our services to meet the specific requirements of a project.

BUSINESS OFFERINGS

Electric Cables

India's first integrated provider of electricity distribution cables, Ravin group has become a powerhouse supplier of world class electric cables and equipments to the power generation and distribution sector. With manufacturing facilities in India and UAE and a presence in more than 50 countries, Ravin group are expert manufacturers of a wide range of electric cables of various capacities ranging from 1.1 kV to 220 kV and specialties including variable frequency drive, fire survival, low smoke zero halogen, solar and wind cables, among many more.

Electric Cables up to 220 kV

Large scale Termination and Jointing Projects

Ehv Projects And EPC Services

Ravin Group provides a wide range of solutions including designing, manufacturing, cable laying, installation, jointing, termination and maintenance of Extra High Voltage Cables for power transmission directly from power plant sites to primary distribution networks. With its stellar expertise, Ravin Group installs pre-moulded joints and terminations for all voltages from 11 kV onwards to 400kV in India with the support of a fully trained and certified jointing team and an extensive experience of thousands of joints and terminations.

Power Equipment

Ravin Group also offers a high end Molecular Moisture Management System. It includes an on-line molecular sieve that is designed to lower the ppm level of water in the oil to maintain the natural hydrostatic equilibrium, and hence, significantly reduce the water content within the solid insulation. This on-line process not only reduces insulation ageing, but also improves the dielectric strength of the oil and health of the transfomers.

Moister Management Systems

Solar Energy Solutions

Ravin's global approach and research in technology is aimed towards delivering sustainable and efficient solar solutions across the globe. Ravin has introduced an innovative and path-breaking tracking system which is a device that orients various solar energy generating components towards the direction of the sun. The revolutionary tracking systems help maximize the energy yield by 15% to 35%, thus increasing the ROI.

#Stealmorefromthesun

The tracking systems include the following design solutions, suited for various applications:

- Single Axis and Dual Axis Tracking System
- Unipolar Tracking Systems
- Rooftop and Ground Mounted Tracking Systems
- Mobile Solar Power Generation Station with a Tractor Trolley

Single/ Dual Axis Trackers

Unipolar Trackers

Ground Mounted Trackers

SMS 5.4 Mobile Solar Power Generator

Solar Water Pump being used for irrigation

Solar Water Pumping Solutions

Ravin also offers an advanced Solar Water Pumping System with **built in automatic tracking mechanism** to maximize the system output. Some of its features include:

- Non-polluted, clean and efficient energy
- Fully Unattended Automated Operation
- No electricity or fuel costs
- Easy installation on roof or ground
- Long life of over 20 years; Low maintenance
- Solutions for upto 200 meters water head
- Pump Capacity from 0.74 Hp to 24 Hp

INTRODUCTION

The energy market has changed dramatically over the last few years as a consequence of deregulation, privatisation and unbundling of generation and transmission. The new network owners mainly focus on the cost-effectiveness of their assets. This applies to new network investments but, certainly, also includes the optimisation of usage of the existing underground network. The design of a High Voltage underground system is extremely important and requires an in-depth knowledge of cables, accessories, methods of installation, the fault current of the system and impact on the electrical network. Ravin specialises in providing total management of major projects and offers to its customers a complete turnkey approach, from system planning to final testing and post-sales services. Installation design and methods, co-ordination and scheduling of installation activities, are as crucial as the manufacture of cables and accessories to achieve a reliable and satisfactory connection. Ravin operates to the highest accreditation and safety standards to meet the demands of the most complex project environments. Turnkey approach, worldwide experience, top class customer references and strong focus on innovation represent the winning recipe that makes Ravin a world leader in HV systems. The effective management of the existing networks require different knowledge and experience, as they are often of hybrid nature (fluid filled, gas insulated and XLPE extruded cables).

As India marches forward power becomes an essential ingredient for infrastructural development. With rapid urbanisation around the corner to sustain the industrial growth, the necessity of transmitting large blocks of power to load centres assume significance. Over the years, there has been a marked increase in the voltage level for transmission of bulk power, due to the distinct advantages offered by the use of high voltage.

Necessity for EHV Transmission: With increase in transmission voltage, for the same amount of power to be transmitted, the current in the line decreases which reduces I2R losses. This leads to increase in transmission efficiency. With decrease in transmission current, size of conductor required reduces which decreases the size of conductor. The transmission capacity is proportional to square of operating voltages. Thus the transmission capacity of line increases with increase in voltage. With increase in level of transmission voltage, the installation cost of the transmission per km decreases. It is economical with EHV transmission to interconnect the power systems on a large scale. The number of circuits and the land requirement for transmission decreases with the use of higher transmission voltages. Over the years, there has been a marked increase in the voltage level for transmission of bulk power, due to the distinct advantages offered by the use of high voltage. This had ushered in the generation of Extra High Voltage (EHV) power transmission systems with voltage grades of 66 kV and above.

Underground EHV cables are also used for evacuating bulk power generated in pumped storage hydroelectric power generating stations, situated at a lower altitude, at outdoor switchyard located at a higher altitude. Similarly, underground cable systems are the appropriate means of power transmission over short distances where erection of overhead tower lines would be infeasible considering the space constraints.

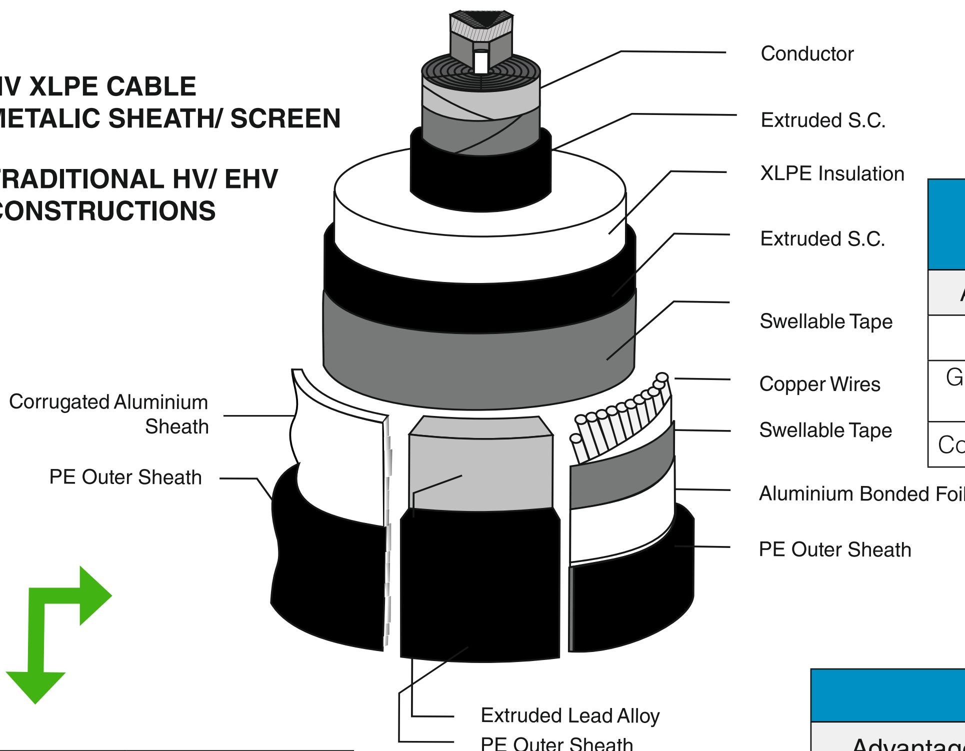
It is in this context that Cross-linked Polyethylene (XLPE) insulated cables offer significant advantages. As an insulating material, XLPE combines the advantages of improved mechanical and thermal properties with excellent electrical characteristics of high dielectric strength, low relative permittivity and low dielectric losses. These advantages have rendered what XLPE cables can achieve today - carrying large currents at voltages up to 500 kV, with an inherent higher short circuit withstand capacity of 250°C. Additional benefits that occur are simple construction, easy installation and trouble-free operation.

EHV cables come in different combinations as per the features mentioned in chart below:

Conductor	Metallic Sheath	Outer Sheath	Optional DTS System
Aluminium/Copper	Aluminium Laminated Foil	PVC/HDPE	Fibre Optic Cable embedded in main cable/ FOC laid separately
	Copper Laminated Foil		
	Corrugated Aluminium		
	Lead Sheath		
	Lead Sheath + Copper Wire + Aluminium Wire		

HV XLPE CABLE METALIC SHEATH/ SCREEN

TRADITIONAL HV/ EHV CONSTRUCTIONS



Copper Wires + Aluminium Foil	
Advantages	Disadvantages
Weight	Not Fully Protected Against Water Penetration
Good Thermal Behaviour	
Compact Cable	

Extruded Lead	
Advantages	Disadvantages
Well Known Solutions	Very Heavy Weight ↓ Short Lengths on Drum, More Joints more Costly Cables.
Thermal Behaviour	

Extruded Corrugated Aluminium	
Advantages	Disadvantages
Less Weight	Gap Between S.C. and Alu. Tube
Good Mechanical Strength of the Screen.	Current Carrying Capacity Lesser by 5%
Cost Effective Solutions	

Weight Comparison for a 220 kV 2500 mm² Copper Cable 63 kA - 1s		
Ex Corr	Ext Lead	Al-Foil
41,6 kg/ m	65,6 kg/ m	40,4 kg/ m

EHV Cable Design

The 3 fundamental components of an EHV cable:
(1) Conductor
(2) Insulation System (Conductor screen, Insulation and Insulation screen)
(3) Metallic Screen/Sheath requirements

(1) DESIGN OF THE CONDUCTOR
The 2 basic Design drivers for designing the conductor are:
(a) Current Rating (continuous operation and short circuit)
(b) Mechanical Behaviour (flexibility, pulling strength)

(a) Current Rating depends on:
- DC resistance: choice of metal and cross section area (CSA)
  CSA = depends on maximum DC resistance (IEC 60228) or minimum weight (US standards)
- AC resistance: depends on choice of construction (stranded/segmented) and wire surface treatment (bare/oxidised/enamelled)

Additional features:
• Longitudinal water blocking system • Semi-conducting binder

(2) DESIGN OF THE INSULATION SYSTEM
The 2 basic Design drivers for designing the insulation system are:
(a) Electrical Gradients (b) Thermo-Mechanical & Thermo-Electrical Properties

(a) Electrical Gradients depend on:
- Intrinsic reliability Life curve and reliability derivation
- Qualification coverage Type test and pre qualification coverage (IEC 60840, IEC 62067, Cigré Technical Brochure 303)

(b) Thermo-Mechanical & Thermo-Electrical Properties:
- Dissipative Power Factor (tg δ)
  - Dielectrical losses = f (U^2)
  - Relative permittivity (ε)
    Reactive power (power flows); charging current
    (off load current, setting of protections)
  - Temperature withstand
    In continuous operation, in overload and short circuit

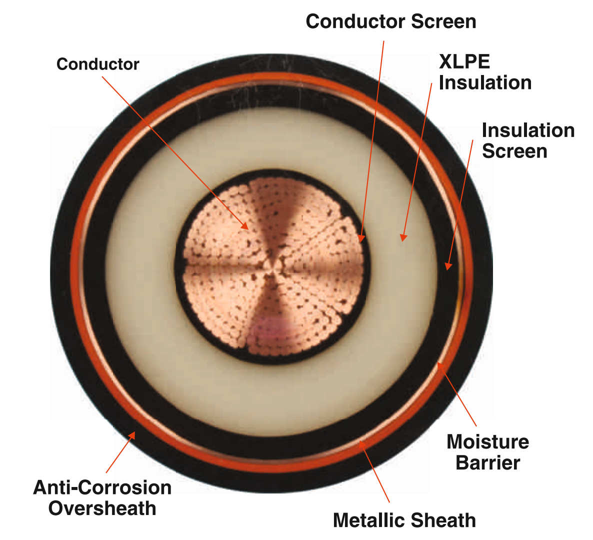
(3) DESIGN OF SCREEN / SHEATH REQUIREMENTS
The 2 basic Design drivers are:
(a) Mechanical Properties (b) Thermo-Electrical Properties

(a) Mechanical Properties:
- Bending capability (laying behaviour)
- Core protection (shocks, punctures, radial water tightness)
- Fatigue (thermal cyclic loading)

(b) Thermo-Electrical Properties:
- Short circuit capability (IEC 60949, IEC 61443, Cigré TB 272)
- Screen losses (generated in AC systems)

Additional features

- Longitudinal water blocking system
- Outersheath
  - Anti-corrosion protection
  - Safety of personnel (induced voltages)
  - Mechanical strength (abrasion during laying, deformation in cleats)
  - **Special properties:**
    - •Flameretardancy&LSOH
    - •Anti-termite/anti-rodentproperties
    - •UVprotection
    - •Resistancetohydrocarbonsandsolvents



Anatomy of an EHV Cable

Normally, high voltage cables are characterised by the presence of the following components:

- Conductor
- Semi-conductingconductorscreen
- Insulation(alsocalled“dielectric”)
- Semi-conductinginsulationscreen
- Metallicsheathorscreen
- Protectiveoutercovering

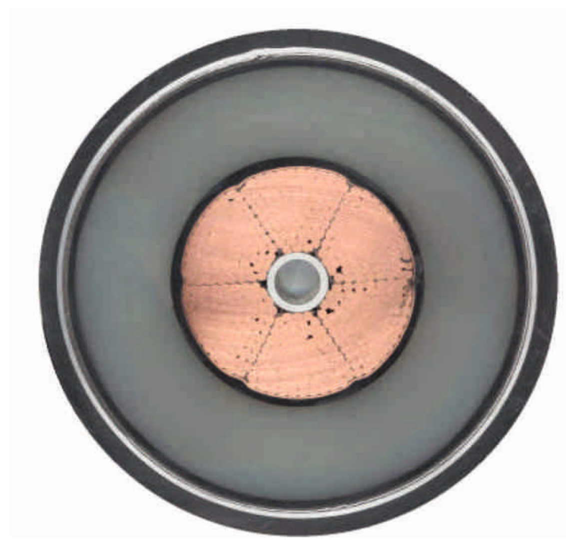
Each of these components is described in the following paragraphs:

Cable Components

CONDUCTORS

Conductors are made from copper or aluminium, using wires or segments. Copper conductors are mainly used when a high current carrying requirement is needed (typically >1000 A) in addition to higher fault current. In case of lower requirements, aluminium conductors are frequently preferred due to the lower cost impact. Another important parameter that has to be taken into account is the resistance with alternating current. Because of the skin effect, the 'A.C. resistance' of a conductor tends to be more significant as the cross section increases. The skin effect forces the current to flow along the peripheral areas, so the central section of the conductor becomes less efficient. For this reason, a special conductor construction, called 'segmental Milliken', is used with big cross sections (from 1000 up to 2500 mm^2). The conductor is typically divided in 5 or 6 segments that are slightly insulated from each other, so the current is “constrained” to flow inside the segments.

Moreover, in order to obtain a further reduction of the skin effect, it’s possible to oxidise or enamel a certain percentage of the wires inside the segments. The 400 kV cable shown in Figure has a Milliken Conductor.



A 400 kV cable
with a Milliken Conductor

Water blocking of the conductor is generally recommended in order to limit the water propagation along the conductor in case of damage to the cable.

Insulation and semi-conducting screens

The main materials used for high voltage extruded cables are detailed below:

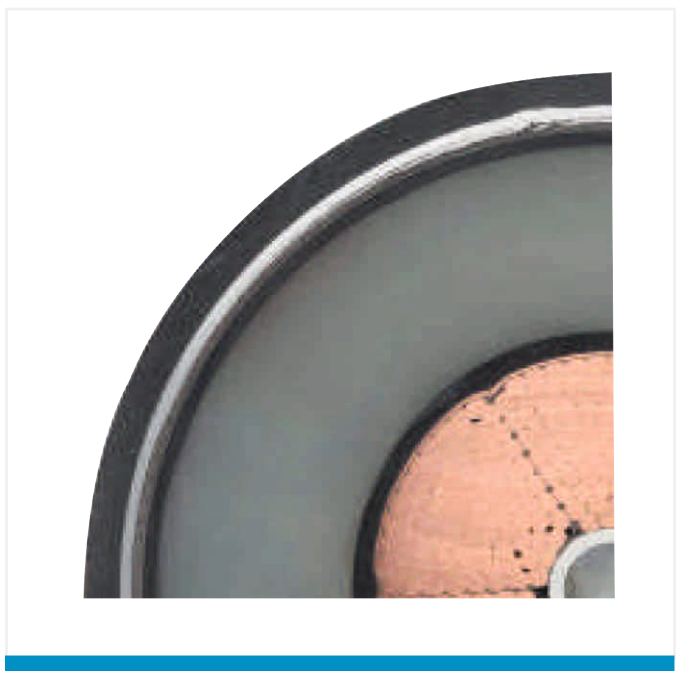
a) High Density Polyethylene (HDPE) is a thermoplastic material that was used for a limited period. Due to its limitations with regard to its working and short circuit temperatures (respectively 80°C and 150°C), HDPE insulation has been replaced by other extruded materials. HDPE has also been observed to have some difficulties in handling the cables at low temperatures.

b) Ethylene Propylene Rubber (EPR) is a thermosetting compound and it is made from a blend of components, which formulation can be modified in order to obtain specific characteristics. It is manufactured and offers good performance in terms of "water treeing" resistance, as well as good elasticity characteristics. EPR has high dielectric losses compared to XLPE and this has limited its use to the maximum voltage level of 150 kV. EPR hasaratedmaximumconductortemperatureof90°C,anemergencyratingofapprox130°Candaconductor short-circuit rating of 250°C.

c) Cross Linked Polyethylene (XLPE) is a thermosetting material. It offers a degree of purity higher than that offered by the EPR and this makes this insulation a suitable material for applications up to 500 kV. Contrary to EPR insulation, XLPE is very sensitive to moisture which would lead to its degradation. For this reason, it's necessary to prevent water penetration into the insulated core. This is achieved by applying a radial water barrier. XLPE cableshaveratedmaximumconductortemperatureof90°Candanemergencyratingofuptoapprox105°C (depending on emergency time). The conductor shortcircuit rating is 250°C.

Figure shows a close-up of an XLPE cable and the black semi-conducting screens can be seen on each side of the XLPE insulation. Semi-conducting screens are used on all high voltage cables from 6.6 kV onwards to ensure a smooth electrical interface between conducting and insulating regions. The stranded profile of the conductor would initiate localised field concentration (i.e. high stress areas) if interfaced directly with the insulation and a consequent risk of ionisation and ultimately electrical breakdown. Hence, provision of semi-conducting screens removes these high stress areas and provides uniform stressing at the interface with the insulation.

To ensure a good interface, all three layers (i.e. conductor screen, insulation and insulation screen) are extruded in one process (triple extrusion). The electrical properties for the various extruded type insulations are detailed below:



A close-up of an extruded XLPE cable

	Tan Delta	Electrical Permittivity
Pe	0.001	2.3
EPR	0.005	3
XLPE	0.001	2.5

Metallic Sheath

While EPR cables up to 150 kV may be used without any metallic barrier, it is recommended that all XLPE cables with rated voltages higher than 60 kV are provided with a radial moisture barrier comprising one of the following metallic sheaths:

- Extrudedleadsheath
- Extrudedcorrugatedaluminiumsheath(CAS)
- Smoothlongitudinallyweldedaluminiumsheath(WAS)
- Aluminiumorcopperlaminatedandgluedfoil

The main functions of the metallic sheaths are:

- Protectionagainsttheingressofmoisture
- To givemechanicalprotection,thuspreventingdamageagainst external actions
- Towithstandthesingle-phasefaultcurrent
- Tocarrythechargingcurrent
- To providetheearthornear-earthpotentialreferenceforthe cable insulation

Sometimes the above designs may be used in combination with copper wires or aluminium wires in order to increase the short circuit carrying capability. All the above sheathing methods have advantages and disadvantages when compared towards the following topics:

- Thermalperformance
- Electricalperformance
- Corrosionresistance
- Waterresistance
- Mechanicalfatigue
- Weight
- Environmentalimpact

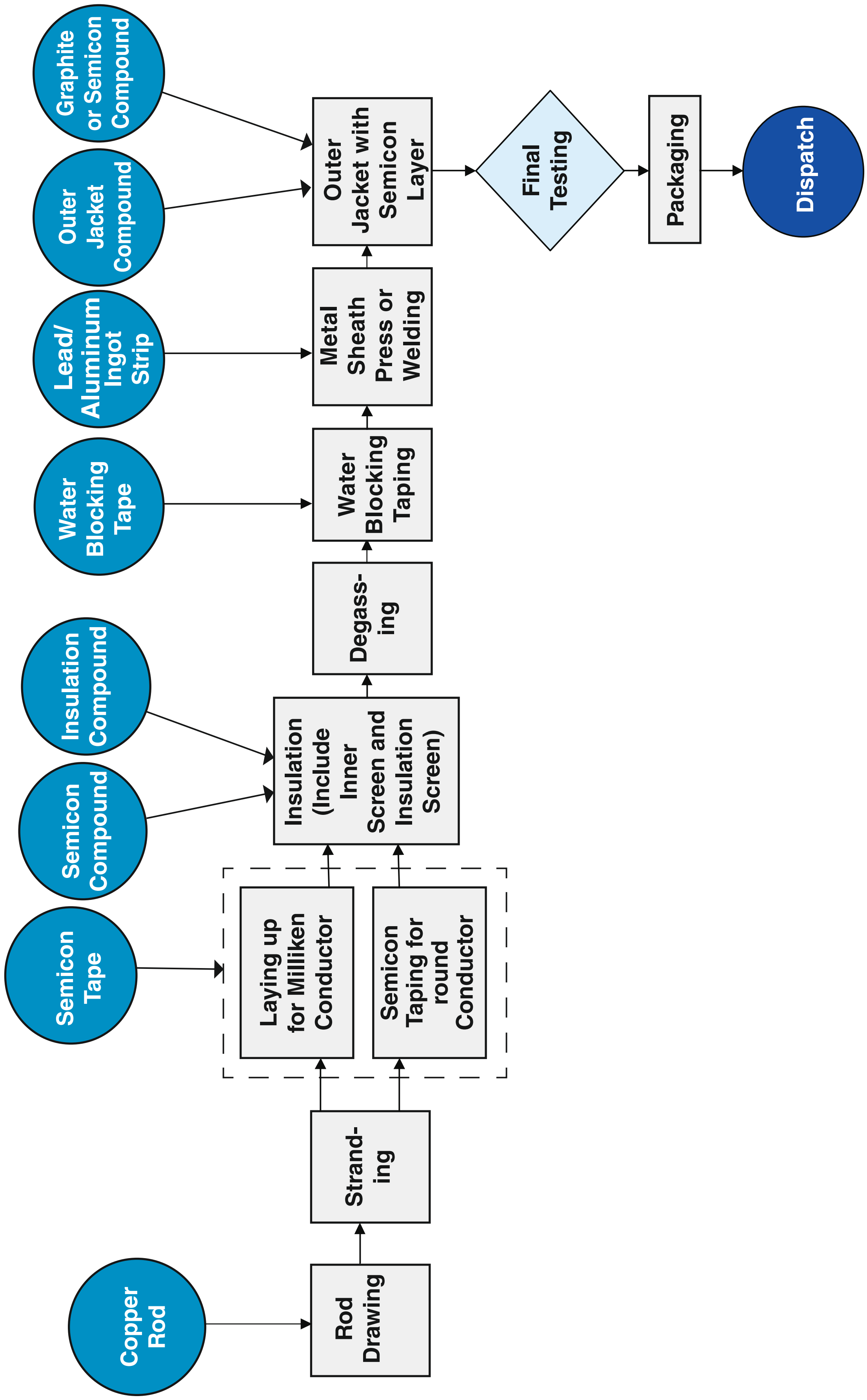
A lead sheathed XLPE cable

Consideration of the optimum sheathing system will usually depend on the specific application and maybe also any specific country requirements.

Outer Sheath

Generally PE (Polyethylene) is used as the sheathing material for buried cables. This is normally Medium-Density Polyethylene (MDPE) or alternatively High Density Polyethylene (HDPE), both of which provide good mechanical protection, good corrosion protection and good resistance to abrasion. PVC (Polyvinyl Chloride) may also be used for buried cables. Cables laid in air (gallery, shaft, tunnel, etc.) normally have either a flame retardant PE or a PVC sheath. Both systems are widely used.

HV & EHV PROCESS FLOW CHART



MANUFACTURING PROCES
OF HV XLPE CABLE

There are 3 types of EXTRUSION TECHNOLOGIES

CCV line (Catenary)

VCV line (Vertical)

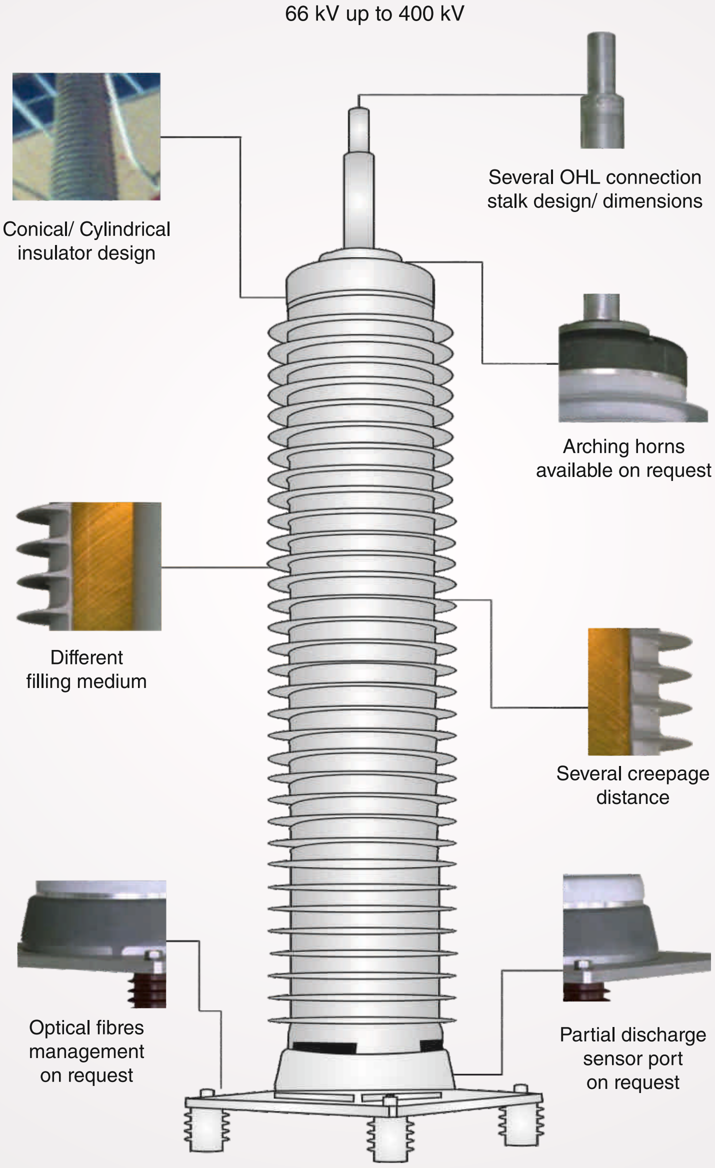
MDCV line (Horizontal)

EHV Cable Accessories

ACCESSORIES FOR HIGH VOLTAGE POLYMERIC CABLES

OUTDOOR POLYMERIC TERMINATIONS

66 kV up to 400 kV



R&D EXPERTISE ACCESSORIES FOR HIGH VOLTAGE POLYMERIC CABLES

Silicone/ EPR one-piece pre-moulded joints available

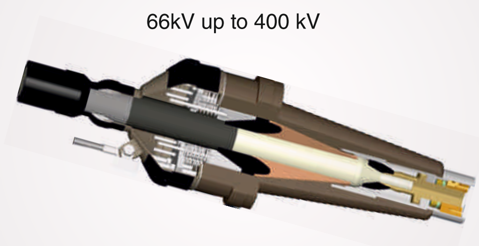
66 kV up to 400 kV

Transformer Terminations

66kV up to 400 kV

GIS Terminations

66kV up to 400 kV



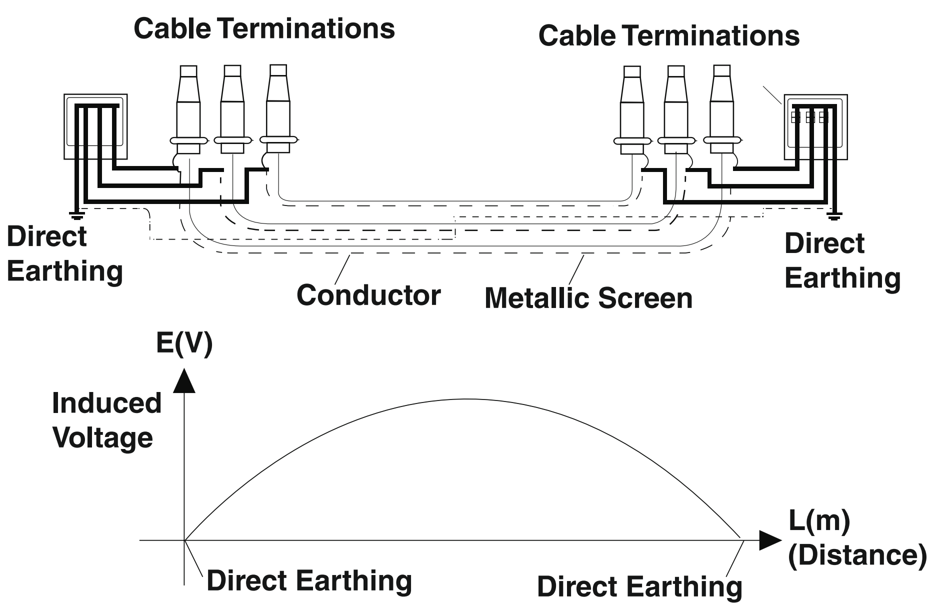
Bonding Systems

Where cable sheaths are bonded and earthed at both ends of a system, there is necessarily an induced circulating current flowing through the sheaths and ground. This constitutes a power loss in the sheaths and therefore a de-rating of the system current carrying capability. These solidly bonded systems are commonly used at High Voltage level (up to 170 kV system). However, for the bulk power transmission requirements of most Extra High Voltage systems (above 170 kV, up to 550 kV), and for some HV systems, it is essential to use a special bonded system in order to realise the full rating capability of cables with large conductors.

Solidly Bonded System

The simplest and most common sheath bonding arrangement is termed “solid bonding”. Cable sheaths are bonded and earthed at each end of the route, and possibly also at one or more intermediate joints for long route lengths. Under normal (50/60Hz) loading conditions, a circulating current is induced in the sheath-earth loop generating a power loss. This “sheath loss” therefore causes a reduction of the cable current carrying capability. The effect is kept to a minimum by reducing mutual inductance between phase cables, i.e. cables are installed in touching trefoil formation. Whilst cable proximity is thermally undesirable, it is more beneficial from the cable rating aspect to minimise mutual induction and to accept greater mutual heating than for spaced cables.

For through-faults in the system, the return fault current to earth is shared by the three cable sheaths in parallel, since the sheaths are bonded together at each end of the cable route. In case of an internal cable fault, the relevant short circuit current flows along one cable sheath in the faulty cable length only and then sub-divides into three currents at the first adjacent joint bay provided that the three sheaths are bonded together at this position.



Solidly Bonded System

Specially Bonded System

The basic principle of specially bonded systems is that of connecting the cable metallic sheaths in such a way that circulating currents in the sheaths are either prevented or reduced to a minimum. The advantages of special bonding over solid bonding are:

- Sheathlossesarereducedandthereforecableheatingduetosheathlossesisreduced
- Smaller conductorsizemaybeusedoralternativelyahighercurrentcanbecarriedbyagivenconductorsize
- Cables canbelaidatrelativelywidespacingthusimprovingheatdissipationandhenceallowinganincrease in current rating or a further reduction in conductor size
- Reducedconductorsizeresultsinsmallerchargingcurrent

The disadvantages of special bonding are:

- There isastandingvoltageonthecablesheathandonthemajorityofjoints.Thisvoltagemustbelimitedtoan agreed value by a suitable correlation between conductor current, phase spacing and cable section length
- Transient phenomena(e.g.switchingoperations,faultconditionsandlightninginducedsurges)cancausehigh voltages to appear across the sectionalising insulation and across the cable over sheath, and special steps must be taken where necessary to limit these to acceptable levels
- Smallerconductorsizeresultsinincreasedconductorlosses
- Insingle-pointbondedsystems,itisusuallynecessarytoinstalaparallelearthcontinuityconductor
- Maintenance testsarerecommendedonsheathvoltagelimitersboxcomprisingofsupportinsulators,lightning arrestors etc in addition to the ingress protection test

Sheath Standing Voltage Limits

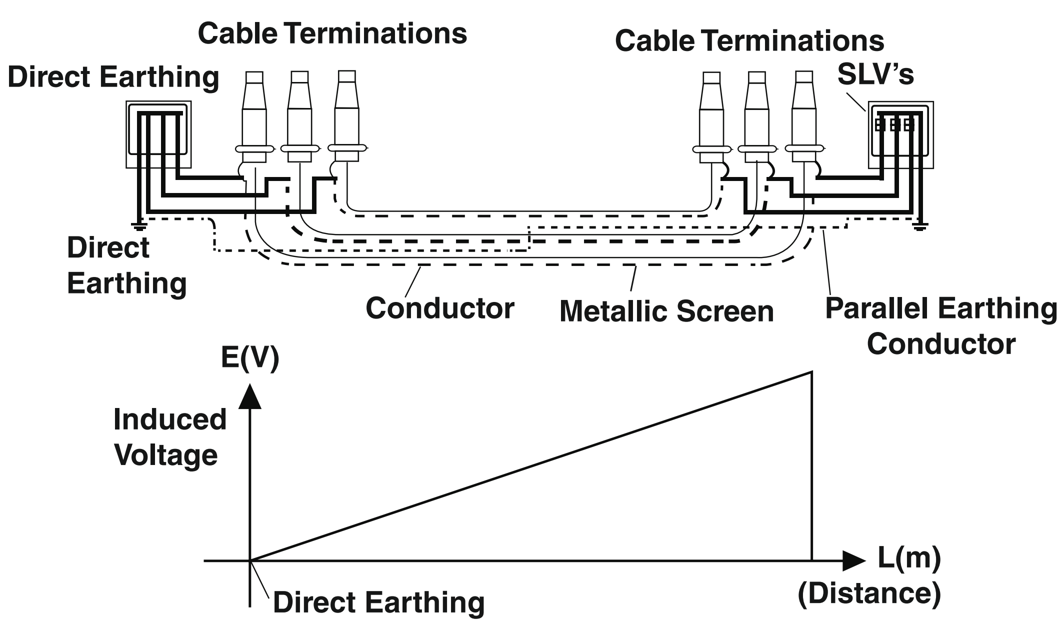
There isn't any international standard on limits of sheath standing voltage under normal maximum loading conditions. Some countries are rather conservative (e.g. 65V for HV systems and 150V for EHV systems are widely used), others are allowing up to 400V, others have no limits providing that the part under voltage is not accessible.

At accessible positions (e.g. at terminations) components on which the induced voltage may rise to greater than 10V are commonly fitted with shrouds to prevent any accidental contact generated.

Single Point Bonded Systems

On relatively short cable routes which would normally require no joint or perhaps just one joint, the most practical special bonding method is single point bonding. The cable sheaths in any one minor section are bonded and earthed at one position only, usually (but not always) at one end of the cable route. Sheath circulating currents are thus eliminated by leaving one end of the system unearthed or 'floating'. Under conditions of current loading, the unearthed end of the cable sheath rises in voltage via induction and it is necessary to control this voltage level under normal system operating conditions, during short circuits, and during transient overvoltages (switching and lightning).

Where the overall route length causes an excessive standing voltage level, a single point bonding system may be 'repeated'. This arrangement is commonly used when there are two sections (for three sections Cross Bonding System is used, ref. Clause 3.4). In such case, a 'Mid Point Bonding System' is used. Cable sheaths may be bonded and earthed at the midpoint of the route only, with the sheaths rising in voltage at the terminations. Alternatively, cable sheaths may be bonded and earthed at terminations, whilst at an intermediate point along the route the sheath continuity is interrupted by an insulating barrier.



Single Point Bonded System

Normal System Loading

Under normal system loading conditions, the level of induced sheath voltage (standing voltage) is usually measured in tens of volts and is determined by conductor current, cable dimensions, phase spacing, section length, and earth conductor size and position. The voltage level is not harmful to the sheath insulation but is maintained within limits set by utilities for the purpose of personnel safety.

Fault Conditions

Under through-fault conditions, the induced voltage level is determined by short circuit current. Maximum acceptable levels of induced voltage are determined not by the sheath and joint insulation capabilities but by the rated maximum power frequency voltage of sheath voltage limiters (SVLs) connecting the unearthed end of each sheath to ground (refer to section 5.0 for SVL data). Under transient overvoltage conditions of lightning and switching impulse, it is essential to limit the voltage level to which the cable sheath may be permitted to rise up to. Specific concerns are **(a)** to protect the cable anti-corrosion covering, and **(b)** to limit the potential difference across sectionalising insulation at the unearthed positions. For these reasons, non-linear resistors known as SVLs (sheath voltage limiters) are connected between cable sheaths and earth at the floating ends of single point bonded systems.

SVL units are not expected to withstand internal fault conditions (i.e. cable faults).

Earth Continuity Conductor

Since there exists no continuous sheath path to carry return fault current to earth, the standard practice in single point bonded systems is to install a parallel earth continuity conductor (ECC) at a specified proximity to the power cables. Also by transposing the ECC about the power cables at the midpoint of the section, voltage induction from the power cables can be balanced, thus avoiding a permanent circulating loss in the ECC.

Cross Bonded Systems

On long cable systems beyond the scope of one or two single point bonded systems, cross bonding is normally used to eliminate sheath circulating currents. An example of a cross bonded system is shown in Figure. This is based on the principle that the induced voltages in the three phase cable sheaths are displaced vectorally by 120° (as per the conductor currents). It therefore follows that by cross connecting three sheaths of different phase in series along the route, the vector sum of the induced voltages will be zero. If this is achieved, then circulating current through cable sheaths will also be zero and sheath losses are reduced to eddy effects only.

The approach described pre-supposes that:

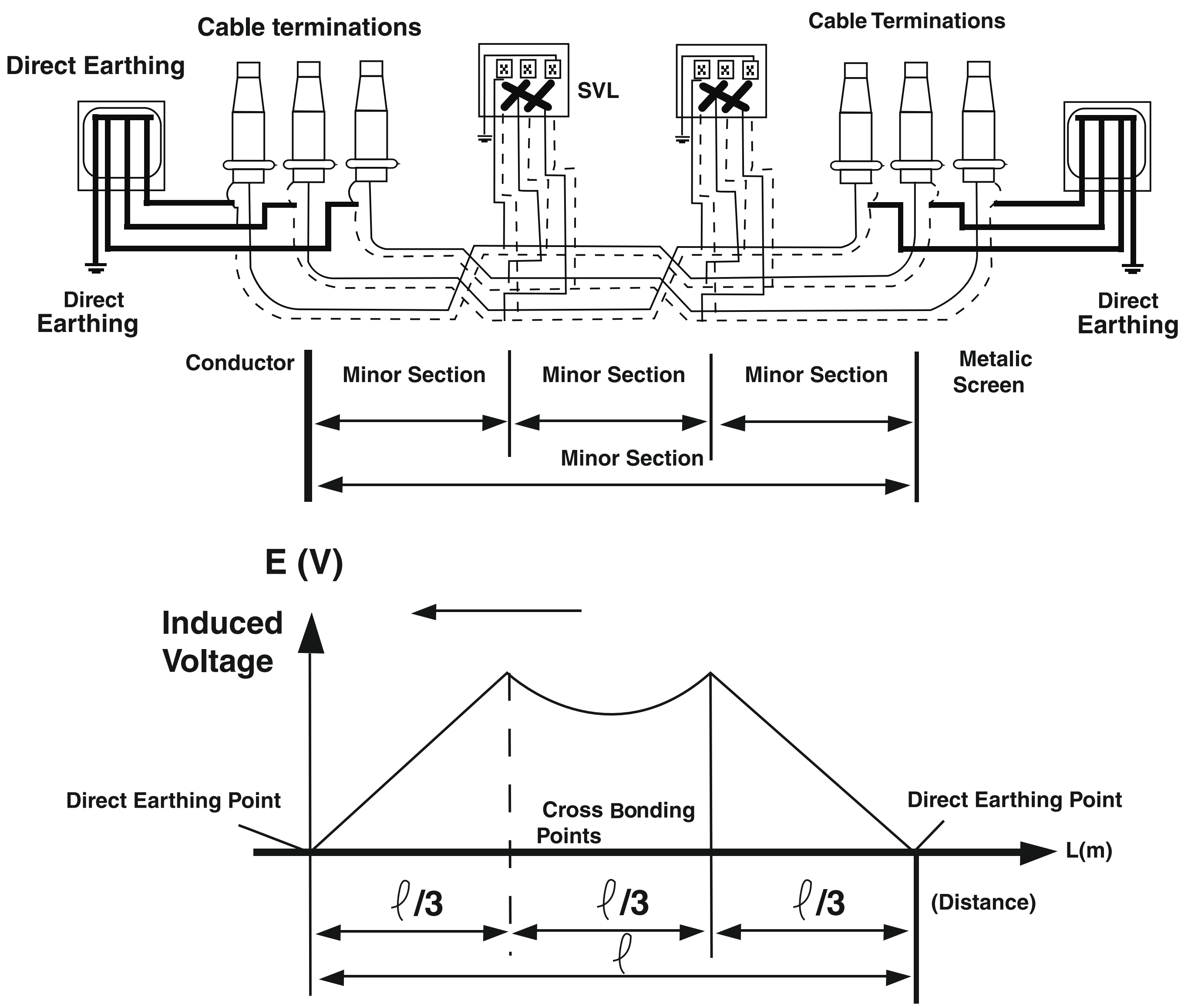
- Thatthecableroutecomprisesthreesections(oramultipleofthree)
- Equalminorsectionlengths
- Abalancedtrefoilarrangement

In practice, specially bonded systems are not often installed in trefoil formation since the rating benefits available through spacing the cables apart to reduce mutual heating are usually also taken advantage of. In a cable section installed in flat spaced formation, the voltage induced on the middle cable sheath is slightly less than in the outer cable sheaths. This difference is eliminated by transposing each cable, conveniently at the joint positions. At the terminations and at the ends of each major section, sheaths are usually solidly bonded and earthed. Calculation methods are established in IEC 60287 to assess the effects of any imbalance caused by unequal minor section lengths.

Except at the solid bond positions, the cable sheaths in a cross bonded system will rise in potential, the level being determined by cable dimensions, conductor current magnitude, phase spacing, section length and position of interest.

Systems are designed to limit sheath standing voltages within limits acceptable to customers (see section 3.2). The distribution of sheath voltage along each section in a cross bonded system is relatively complex and is shown in Figure below.

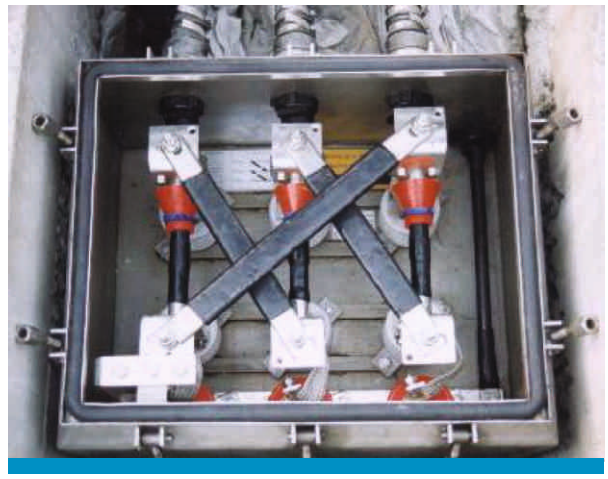
- Solidlybondedpositions
- Crossbondedpositions
- Minorsection
- Magnitudeofinducedvoltageoncablesheath



Induced Voltage Distribution in Cross Bonded System

Fault Conditions

For through-fault conditions, the induced voltage level is determined by short circuit current, cable dimensions, phase spacing and section length, the voltage being a maximum at the cross bond positions in a system of balanced minor sections. Maximum levels of induced voltage are determined by the ratings of SVLs connected between cable sheaths and earth at cross bond positions. Cross bonding arrangements at minor sectionalising positions are shown in Figure.



Lockable link box with sheath voltage limiters

Sheath Voltage Limiter Characteristics

In specially bonded systems, the induced voltages generated across the cable oversheath are of course also experienced by the sheath voltage limiter (SVL) units. The purpose of the SVL is to resist conduction under conditions of normal service sheath standing voltage and also during temporary overvoltages caused by system through faults (power frequency short circuit conditions). Conversely under transient overvoltage conditions of switching and lightning, the SVLs are required to conduct to earth and thus to limit sheath voltages to within levels safe for both the cable oversheath and the joint sectionalising insulation. SVL units as used on the earth side of cable systems (screen/sheath) should not be confused with higher energy surge arresters more typically connected to the high voltage side of power transmission plant.

The following parameters are typically considered for the selection of an SVL:

The **rated voltage** is the maximum design RMS power frequency voltage which can be applied across the terminals of an SVL for a period of not less than one second, without causing damage. SVL units are type tested to withstand two applications of rated voltage with a time interval between applications of between 10 and 15 seconds.

- The **reference residual voltage** is the voltage measured between the SVL terminals when an 8/20μs (8μs wave front, 20μs duration) 10kA current impulse is applied.
- The **reference voltage** is the mean voltage as measured between the terminals when the SVL conducts +10mA and -10mA (D.C.) at ambient temperature. SVL units appropriate for a particular system application are selected during the evaluation of maximum induced sheath voltage during short circuit conditions. Sheath Voltage Limiters as described above are usually enclosed in disconnecting Link Boxes. For particular applications, an SVL unit having a low residual voltage rating is used. For cable terminations into separately earthed gas-immersed switchgear, for example, it is essential to ensure that the sheath sectionalising insulation at the cable termination is suitably protected against risk of flashover during switching operations. The sectionalising ring in this case is usually bridged over with small-size SVLs, providing an open circuit during normal system operation and a conduction path for transient overvoltages.

Fault Types

Two-phase to earth faults can give rise to higher voltages across the SVL than single-phase to earth faults, where the terminal resistance is high. However, on the assumption that terminal earth resistance does not exceed 0.5 Ohms, the voltages are not greater than for the single-phase to earth fault. Three-phase to earth faults are not the limiting condition for the SVL and need not be considered, except where the star point is unearthed. Phase to phase faults free of earth are less onerous than the above and can be disregarded. As regards internal cable faults, only single-phase to earth faults need be considered as two-phase to earth faults are highly unlikely with single core cable systems.

Installation of EHV Cables and Accessories

Ravin Group supplies and installs high voltage cables and systems on turnkey packages. We provide our customers with a comprehensive cable service package which encompasses system design, design and selection of cables and compatible accessories, supply of quality materials, installation, testing, commissioning and finally ensuring full safety and reliability of the installation.

Our installation team consists of a highly qualified and experienced team of engineers, who work with clients and manufacturers to identify the quickest and most cost effective power solutions. Our team has been trained and experienced in various countries around the world, and they carry with them over 250 years of cumulative experience in specialty jobs. We have an experience of installation of more than 150 km of EHV cables and 300 joints and terminations at voltages greater than or equal to 220 kV.

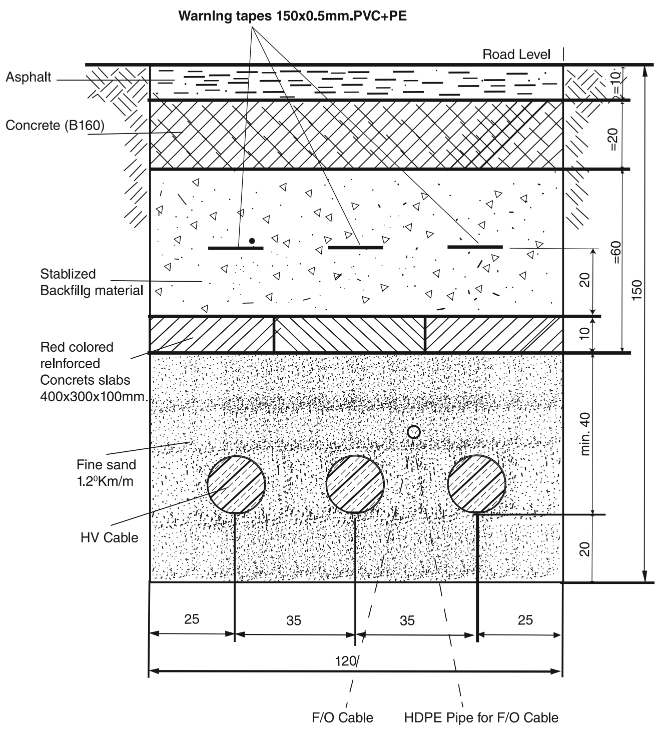
We provide our customers with a comprehensive cable service package which encompasses system design including design and selection of cables and compatible accessories, supply of quality materials, installation, testing, commissioning and finally ensuring full safety and reliability of the installation.

Laying of EHV Cables

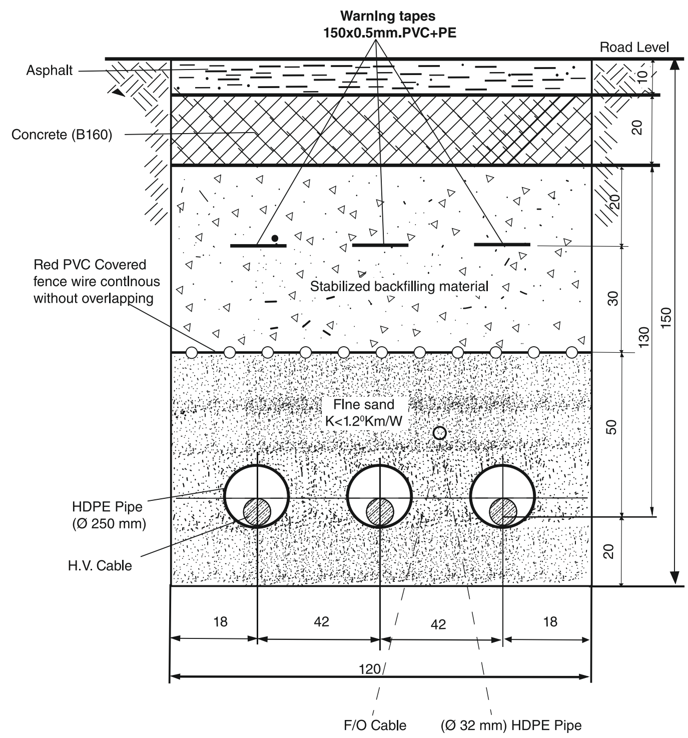
Direct Burial

Cable route shall be selected to avoid excess bending portions and to keep them as few as possible. It is recommended that the bending radius at corners should be maintained at least a few times the minimum bending radius, preferably more than 5 metres, as larger radius provides lower side wall pressure. Enough space shall be maintained inside the cable trench. Furthermore, it shall be confirmed from available records of existing services and utilities as well as with sufficient number of trial holes along the trench route, especially at joint bay locations, that the trench route has no obstructions. It shall also be confirmed that no chemical agents, that could be harmful to the cables, are present in the surrounding soil and water along the route. Always use a cable pulling winch. When pulling cable mechanically by the pulling winch, the cabling winch rope is coupled to the cable by means of the pulling eye. The pulling tension is thus transferred to the conductor. Pulling tension should not exceed the maximum permissible pulling tension recommended by Ravin in their technical data.

Cable Trench - Direct Burial



Cable Trench - With Pipe



Cable Duct System

Larger bending radius is generally required in duct systems as compared to direct buried cable. Since coefficient of friction of ducts is larger than that of cable rollers used in direct burial installation, resulting in higher pulling tensions, consequently the maximum section lengths between joint bays is relatively shorter than that for direct burial.

Therefore, each section length should be determined after careful calculation of the pulling tension and the sidewall pressure of the corresponding section. Cable expansion from duct due to thermal expansion should also be considered when dimensions of joint bays are determined. Offset arrangements should be envisaged to absorb the thermal b ehaviour of the cable during its service life. For a single cable in a duct, the inner diameter of the duct should be greater than at least two times the outer diameter of the cable being pulled. Internal surface of the duct including the surface at joints shall be smooth and free from any defects such as protrusions, projections, cracks, scratches, sharp edges etc., which may cause damage to cable outer sheath during pulling. Any sharp edges at both ends of the duct should be rounded off and pipe collars provided at ends. The PVC pipe collar should be installed at both ends of the ducts so as to prevent the duct edges from damage. Immediately prior to the installation of the cable, the ducts shall be thoroughly cleaned using conduit cleaning devices to ensure that any small pebbles, sand or other foreign material is removed before cable is installed. Use mandrels with a diameter 6 mm less than the duct size to check for breaks or sharp edges in the duct that would damage the cable. On completion of inspection, put the guide rope by blowing in to the pipe and connect to the winch pulling rope.

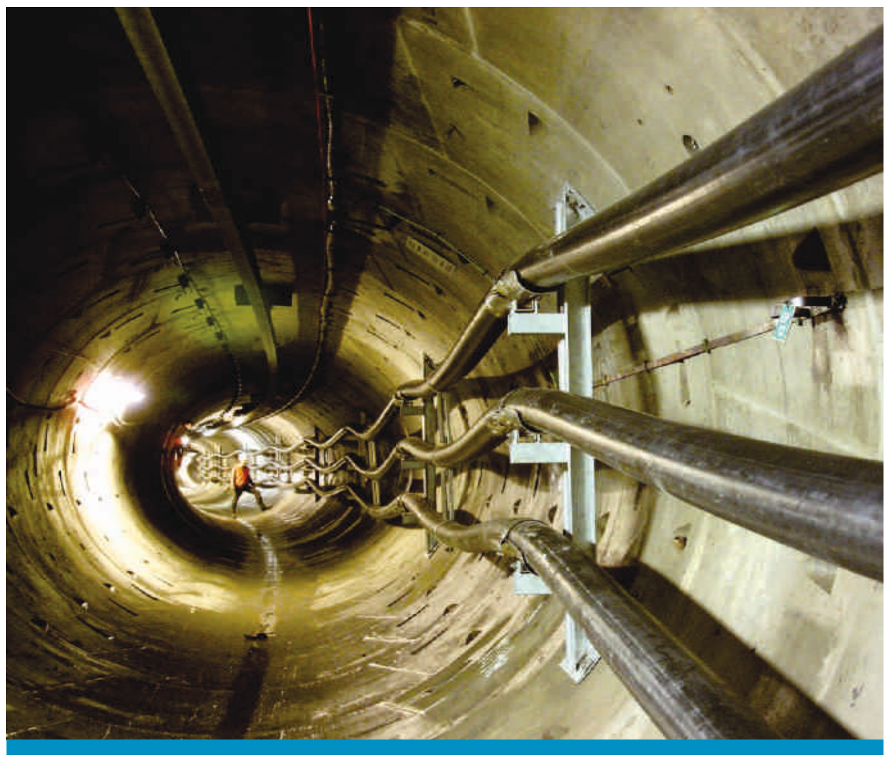
Each duct should be provided with a draw wire and both ends of the duct should be plugged in a proper manner to prevent ingress of any foreign material like soil, sand, concrete, water etc. Only winch pulling shall be applied for cable duct installation. The cabling winch rope is coupled to the cable by means of pulling eye. The pulling tension is thus transferred to the conductor. The pulling tension should not exceed the maximum permissible pulling tension recommended by Ravin in their technical data.

Lubrications of Cable

The use of cable lubricants, as the cables are pulled into ducts lessens the cable tensions and prevents any scratching of cable jackets due to irregularities in ducts. A liberal use of lubricant is recommended for all pulling operations. Only lubricants that are compatible with the outer sheath material (PVC, HDPE, and/or MDPE) shall be used. Petroleum-based lubricant shall never be used for any formation with polyethylene jackets. The lubricant is usually applied to the cable as the cable enters the duct or the feeding tube.

Cable Tunnel

Cable tunnel dimensions shall be so designed as to secure enough space both for settling of cables on supporting structures and for installation and jointing works. The bending corners of the cable tunnel should also be designed to provide the permissible bending radius to the cable with enough margins. When cables are laid on cable racks or cable supports, they shall then be fixed with cable cleats or clamps at adequate intervals to absorb the thermal expansion and contraction with their lateral or vertical movement within the length between adjacent cleats. If cables are laid without any binding, they may move according to the thermal behaviour and may drop from the rack or supports. Further, the metal sheath of the cable may be subjected to excessive strain at bent portions where the thermal movement of the cable is partially concentrated. In order to avoid this movement, snake installation i.e. laying the cable in uniform waveform, is usually applied along the route on racks or supports, to encourage the absorption of the cable movement smoothly. At the end of the cable route, the cable ends should be set straight and fixed with cable clamps before rising to the sealing ends.



Special Construction

There may be many types of special constructions along the cable routes, such as river crossings, road crossings, cable tunnel and cable bridges. Special care must be taken to lay cables at such locations. It is not possible to list all countermeasures to cope with and cover every special construction; however, following are generally recognised as the basic key points that should be taken into account:

a) The thermal environment must be satisfactory

b) Any thermo-mechanical forces that could be experienced must be adequately constrained or dissipated

c) Where cables are exposed to air, care must be duly taken of risks due to fire, vandalism, accidental damage by third party. Cables must also be provided adequate protection against direct solar radiation

d) Exposure to vibration

e) Specified bending radius must be observed

Cable Laying

Most adequate method should be adopted to pull the cable considering site conditions, so as to avoid any damage to the cable due to excessive mechanical forces experienced during cable installation and to ensure an efficient installation. It must be ensured that the cable to be installed can be pulled without any damage or defect in terms of cable pulling design according to route drawings and site conditions. Preliminary study shall be made to determine proper cable laying method, direction of cable pull, arrangement of tools/equipment, communication equipment, manpower and other necessary factors in order to achieve satisfactory cable installation. The most effective method of pulling a high voltage cable is by nose pulling with a cable pulling eye fixed to the conductor.

Cable Pulling Design

In order not to damage the cable during pulling, it is recommended to pull the cable keeping both the pulling tension and the sidewall pressure lesser than the permissible figures.

Data Of Cable Required

Following data on the cable is required for cable pulling:

a) Overall cable diameter (mm)

b) Cross sectional area of conductor (mm^2)

c) Unit weight of cable (kg/m)

d) Material of conductor (copper / aluminium)

Permissible Values

Permissible maximum value of pulling tension, which depends on the method of pulling, is decided by the criteria as detailed under or that as recommended by Ravin:

Fmax = A. dmax

A = Conductor cross sectional are (mm^2)

dmax = Maximum permissible stress (N/mm^2)

= 50 N/mm^2 for single core Copper Conductor

= 30 N/mm^2 for single core Aluminium Conductor

Maximum Cable Pulling Tensions will be followed as per below table:

MAX. CABLE PULLING TENSIONS FOR HV CABLES

Cross Section & Construction	Max. Pulling Tension for Copper	Max. Pulling Tension for Aluminium
630 mm^2 XLPE	3150 kg	1850 kg
800 mm^2 XLPE	4000 kg	2100 kg
1000 mm^2 XLPE	5000 kg	3000 kg
1200 mm^2 XLPE	6000 kg	3600 kg
1600 mm^2 XLPE	8000 kg	4800 kg
2000 mm^2 XLPE	10000 kg	6000 kg
2500 mm^2 XLPE	12000 kg	7500 kg

Coefficient of friction

Following are the coefficient of friction between the cable outer sheathing and the rubbing surface during laying process.

- Pullingcablesoverrollers:μ=0.15-0.3
- Pullingcablesthroughconcreteducts:μ=0.4-0.6
- Pullingcablesthroughconcreteducts:
  - Grease Lubrication: μ = 0.15 - 0.25
  - Water Lubrication: μ = 0.15 - 0.25
  - Grease and Water Lubrication: μ = 0.10 - 0.20

If cables are to be pulled through long plastic pipes, it is essential that a lubricant be used. Otherwise, the heating produced as a result of friction between the cable and the plastic surface could cause the thermoplastic sheathing to stick to pipe walls.

Minimum Temperatures for Cable Laying

High Voltage Cable should not be laid at temperatures below -2°C.

In case, the cable must be laid at temperatures below -2°C, the cable must then be heated in special insulated tents at 30°C - 40°C for 24 hours and then must be laid rapidly.

Cable Pulling Force Calculations

a) Horizontal/Flat Cable Pulling

The pulling force (F) at the end of the cable path is given by:

F = W.I.μ

Where: W = Cable weight (kg/m)

I = Length of cable route / path (m)

μ = Coefficient of friction

b) Sloping Cable Path Pulling

The pulling force (F) will be increased when laying sloping up/uphill and decreased when laying sloping down/downhill and is given by:

F = WI (μ cos b ± sin b)

Where: b = angle of slope)

\+ is used for uphill laying

\- is used for downhill laying

On slopes up to approximately 20 deg. (36%), the pulling force may be calculated by:

F = (W.I.μ) ± (W.h)

Where:

h = difference in level (mm)

c) Curved Cable Path

When the cable is pulled around a curve, the pulling force is increased by a factor (f), which is dependent on the coefficient of friction (μ) and the angle of the bend (μ)

Fo = Fi x $e^{\mu\alpha}$

Fo = Force at exit of bend

Fi = Force at entry of bend

μ= Coefficient of friction

α = Bend angle in radians

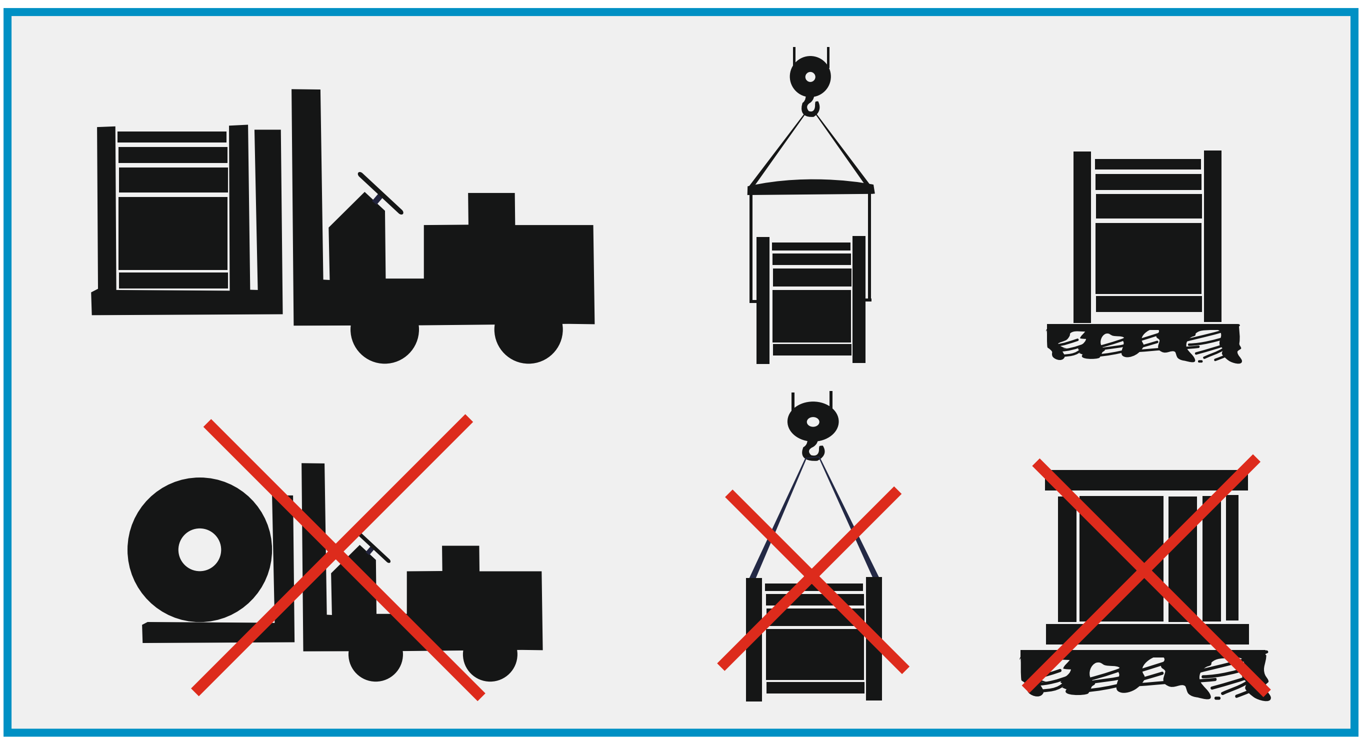
Cable Laying Work

General Instructions:

This section describes general instructions to be observed during cable pulling work.

a) Handling of Cable

At the time of acceptance and prior to installation, the cable reel should be thoroughly examined for any outside physical damage or damage to cable end caps. This examination should also include lagging, reel flanges and reel marking, tags and labels. While handling cables, necessary precaution should be taken to prevent damage to the cables.



Cable reels that are to be transported on trucks must be securely blocked or anchored to prevent rolling. If a reel of cable is to be rolled for any appreciable distance, it shall be rolled in the direction indicated by the arrow on the reel flange or with the outside end of cable trailing, if not marked, so as not to loosen the turns of cable on the reel. When rolling reels on the ground, they shall be carefully eased over any rough surfaces. Care shall be taken to avoid damaging reel lagging in order that outer layer of cable remains protected. In removing lagging from cable reels, care shall be taken not to damage the cable. Remove all nails, staples or bolts from inside flange before unreeling cable. Care is to be taken to prevent cable from dragging.

Before Cable Pulling

- It shallbeconfirmedthattrenchfloororotherplaceswherethecableistobeinstalledarefreefromanyforeign materials such as stones, nails and pieces of concrete, asphalt, brick pieces, glass pieces, sharp-edged objects etc., which may damage the cable. Such materials should be removed at least 30 cm away from the trench. Any water inside the trench should be pumped out completely. The trench wall must be secured appropriately in accordance with specification prescribed by the client. The cable trench curves must be checked thoroughly, to ensure that the minimum bending radius of the cable is attained. Sweet sand (or backfill soil as required by project specifications) shall be evenly distributed on the trench floor with minimum thickness of 150 mm or to a thickness prescribed in the project specifications.
- Prior tostartofcablepulling,RavinrecommendstoconducttheDCsheathtestonthereelinordertoensure that no damage has taken place during transporting and handling of the cable. Upon completion of the test heat shrinkable end caps, to protect against ingress of water or foreign particles, must immediately seal the exposed area. Whenever a cable is cut, the exposed end shall be sealed to protect from rain, mist or dripping or splashed water by heat shrinkable caps. The drum should be mounted on transport and laying trailer. For cable pulling, the cable drum shall be set at the opposite direction to the arrow painted on the drum that indicates the direction of rolling during transportation. Care should be taken not to damage the cable by battens when removing them from the cable drum. The direction of pulling should be so chosen so as to require the least pulling strength at the end of the cable path.
- Reliable communicationbetweenthedrum,theheadofcable,oncurves,entrancetoduct,intermediatepost and the winch has to be established to effectively coordinate the work process. The equipment to be used should be of proven reliability and should be thoroughly tested before cable installation begins. Ensure that the winch has a pulling recorder and a tension meter, to continuously monitor the cable pulling force. It should not exceed the maximum pulling force of the cable recommended by Ravin.
- Essential wordsorsignalsforcablepulling,atleastSTARTandSTOP,arefixedandunderstoodbyallthe associated staffs.

  The meeting prior to cable pulling is recommended to decide position of watchmen with communicative equipment to guide cable pulling works. Watchmen shall be positioned every 50 metres and at every corner.
- It shallbeconfirmedthatcabledrum,drumbrake,winch,rollers,wirerope,drumforwireropeandanyother necessary tools/equipment have been set properly. Swivel shall be installed between wire rope and pulling eye to prevent the cable from twisting. At the entrance to the cable trench, a cable guiding and bearer stand is positioned, over which the cable taken off the cable drum is pulled into the trench. The rollers that are inclined towards the centre ensure that the cable is fed centrally into the trench. The rule for curves in the trench is that under no circumstances should they fall below the minimum prescribed bending radius of the cable (15 x ØD of cable). The cable rollers in straight portions shall be set at approximately 2 metre intervals to avoid the slack of the cable pulling. Whereas the cable rollers in bend portions shall be set as close as possible, so as not to be subjected to the sidewall pressures partially. Sufficient numbers of corner cable rollers are positioned on the curves in the trench, to prevent cable sliding off. In-field practice anchor pins have proved ideal for anchoring the corner rollers.
- Final checkoftrenchshallbecarriedoutsoastoeliminatetherisksthatmaydamagethecable.Anditshall be confirmed that trench will not collapse at any portion along the cable route. Timbering/Shuttering shall be provided securely prior to cable pulling at positions where trench mayor is liable to collapse.
- When thecableispulledintoshaftorinclinedtunnel,sufficientcapacityofbrakefacilitiesshallbeappliedso that the cable may not slip down due to its weight.

During Cable Pulling

- Maximum pullingspeedshallbe7m/min.Thepullingspeedshall be reduced at corners, inlets of duct, etc. where the smooth pulling may be blocked. After confirming that no damage has occurred at these portions, the pulling tension may be increased. Necessary action should be taken to eliminate the cause of damages, in case of its occurrence.
- Watch thecableonthecablerollers,especiallyatbendportions and maintain sufficient clearance between existing services and the cable along the whole cable route all the time during cable pulling..

- The pullingtensionandthesidewallpressureshouldneverexceedthepermissiblevalues.Itisessentialtobe able to control the speed of pulling by monitoring pulling force speed and the length.

  These parameters should be recorded continuously on a recorder, which is an indication and proof of the correct laying. When pulling force exceeds the maximum permissible setting, the pulling should stop.
- The outlookofthecableshallbecheckedanditshallbeconfirmedthatthecablehasnotbeendamaged during cable pulling. The cable pulling should be stopped immediately on finding any damage and should not be resumed until the causes are removed. The damage portion of cable shall be repaired as required.
- When theinnerendofthecableonthecabledrumisloosenedduringcablepulling,itshallbetightenedagain to the cable drum.

After Cable Pulling

- The outlookofthecableshallbecheckedwhether the cable has been damaged or not. Any damage shall be repaired in a proper manner after careful examination.
- Integrity ofanti-corrosivesheathshallbeconfirmed by carrying out DC high voltage test on it before and after backfilling.

  Immediately after the first phase of backfilling and prior to final backfilling, DC sheath test at 10 kV for 1 minute should be conducted to ensure that no damage has occurred to the cable sheath during cable pulling. Upon completion of the test heat shrinkable end caps to protect against ingress of water or any foreign particles, must immediately seal the exposed area.
- Necessary protection to the cable shall be provided against mechanical damage, vandalism and any other possibility to damage the cable. It is recommended to backfill the trench as soon as possible and not to leave the cable exposed.
- The cable end shall be raised up higher than the maximum water level expected. The integrity of sealing at the cable ends shall be confirmed to prevent water or any moisture entering the cable. Repair work shall be carried out if necessary.
- Power cablesandauxiliarycablesshallbearranged so as to keep the specified distance between them, in order to maintain the current rating capacity and to limit sheath current/sheath induced voltage of the cable and induced voltage on auxiliary cables as per designed values.

We have an impressive client list pan-India. Some of the jobs which we have undertaken are as follows:

Completed Jobs

Client	Voltage	Year of Execution	Type of Job
Reliance Power - Samalkot	400 kV	2012	Installation of terminations
NTPC - SAIL - L & T	220 kV	2006-07	Supply of Cable, and accessoriesLaying of cable and Installation of accessories (18 terminations and 4 kms cable)
Reliance Infrastructure Ltd.	220 kV	2007-08	Supply of Cable, and accessoriesLaying of cable and Installation of accessories (54 nos terminations, cable 4 kms)
Uttam Galwa Wardha factory	220 kV	2009	Supply of accessoriesJointing and termination services
Siemens	220 kV	2010	Supply of accessoriesJointing and termination services
Reliance Infrastructure Ltd.	220 kV	2010-12	Supply of Cable, and accessoriesLaying of cable and Installation of accessories (54 km cable and 210 joints and terminations)
Vardhman Group	220 kV	2012 - 13	Supply of Cable, and accessoriesLaying of cable and Installation of accessories (30 nos joints and terminations, cable 4.8 kms)
Dhaka Electric	132 kV	2008	Jointing in Oil filled cable for Dhaka Electric
Mahagenco, Vaitarna	132 kV	2009	Supply of accessoriesLaying of cable (3kms) and installation of accessories
Mahatransco, Vasai	110 kV	2009	Supply and installation of accessories, Shifting of existing cable and installation of accessories
Crompton Greaves	66 kV	2008	Installation of GIS terminations for Torrent Power in Surat
Iljin Electric	66 kV	2008	Installation of outdoor terminations for MRVCL
Universal Cables	66 kV	2008	Installation of outdoor terminations for MRVCL
Reliance	66 kV	2005 onwards	Call centre operations for jointing services

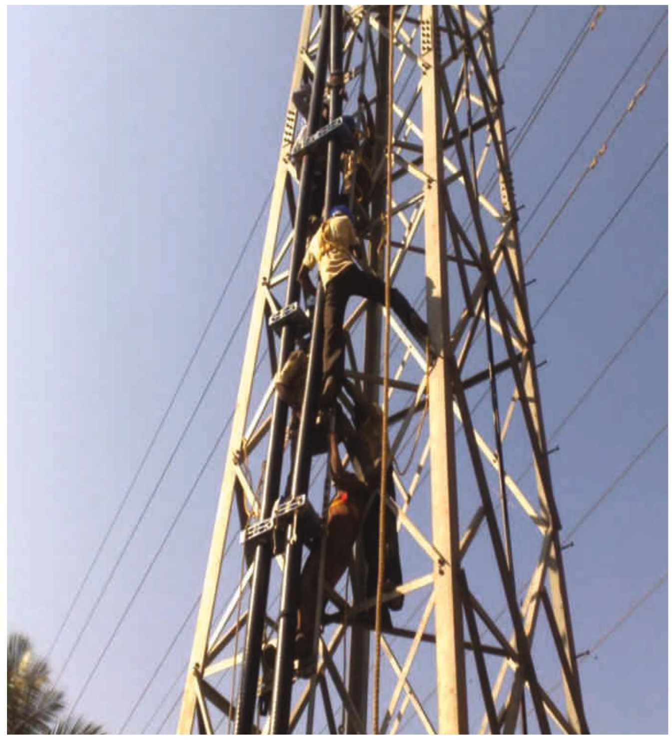
Pictures of some key and difficult locations

Gorai Towers of Reliance Infrastructure:

Before Project Start

After Project Completion

Goregaon Towers of Reliance Infrastructure:



Cable Installation on Ladders

After Project Completion

After Project Completion

Table No.1: Reference Test Voltages for EHV Cables

Rated Voltage of Cables (Uo/U)	Highest Voltage for equipment Between Conductors (Um)	30 min Voltage test (2.5Uo)	Partial Discharge test(1.5Uo)	Tan delta measurement (Uo)	Heating Cycle test (2Uo)	Impulse Withstand test	15 min Power Frequency Voltage test after impulse test(2.5Uo)
kV	kV	kV	kV	kV	kV	kV	kV
38/66	72.5	90	57	38	76	325	90
64/110	123	160	96	64	128	550	160
76/132	145	190	114	76	152	650	190
127/220	245	315	190	122	254	1050	315

*TestVoltagesaregenerallyinlinewithIEC60840/IS:7098Part3

Table No. 2: Conductor Resistance

Cross-Sectional Area of Conductor (sq.mm.)	Max DC resistance of Conductor at 20°C		App. AC resistance of Conductor at 90°C	
	Aluminium conductor (Ohm/km)	Copper conductor (Ohm/km)	Aluminium conductor (Ohm/km)	Copper conductor (Ohm/km)
95	0.3200	0.1930	0.4110	0.2460
120	0.2530	0.1530	0.3250	0.1960
150	0.2060	0.1240	0.2640	0.1590
185	0.1640	0.0991	0.2110	0.1270
240	0.1250	0.0754	0.1610	0.0972
300	0.1000	0.0601	0.1290	0.0780
400	0.0778	0.0470	0.1010	0.0618
500	0.0605	0.0366	0.0791	0.0491
630	0.0469	0.0283	0.0622	0.0393
800	0.0367	0.0221	0.0497	0.0322
1000	0.0291	0.0176	0.0380	0.0236
1200	0.0247	0.0151	0.0326	0.0207
1600	0.0186	0.0113	0.0251	0.0163
2000	0.0149	0.0090	0.0207	0.0138

Ravin

Table No. 3: Conductor Short Circuit Rating

Cross Sectional area ofConductor(Sq.mm.)	ShortCircuitRatingfor1Sec.30min	Voltagetest(2.5Uo)
	AlkA (rms)	CukA (rms)
95	8.93	13.58
120	11.30	17.16
150	14.10	21.45
185	17.40	26.45
240	22.60	34.32
300	28.20	42.90
400	37.60	57.20
500	47.00	71.50
630	59.20	90.10
800	75.20	114.40
1000	94.00	143.00
1200	112.80	171.60
1600	150.40	228.80
2000	188.00	286.00

Table No. 4: Minimum Conductor Cross-sections and Insulation Thickness

VoltageGrade(kV)	Smallest Nominal Conductor cross-section	Nominal Thickness of Insulation
	(Sq.mm.)	(mm)
38/66	95	11.0
64/110	150	16.0
76/132	185	18.0
127/220	400	27.0

Note: Above values are as per IS:7098(Part3)

Table No. 5: Capacitance of Cable (μf/Km)

Cross-Sectional Area of Conductor(Sq.mm.)	Voltage grade of Cable			
	38/66 kV	64/110 kV	76/132 kV	127/220 kV
95	0.150			
120	0.160			
150	0.170	0.135		
185	0.180	0.140	0.130	
240	0.195	0.150	0.140	
300	0.210	0.165	0.150	
400	0.230	0.175	0.165	0.125
500	0.250	0.190	0.175	0.135
630	0.275	0.205	0.190	0.145
800	0.300	0.225	0.205	0.155
1000	0.325	0.245	0.225	0.170
1200	0.360	0.270	0.245	0.185
1600	0.400	0.295	0.270	0.200
2000	0.445	0.325	0.300	0.220

Table No. 6A: Current Rating of EHV Single Core 66kV Cable

Cross-Sectional Area of Conductor (Sq.mm.)	Single Point Bonding/Cross Bonding							
	Trefoil Formation				Flat Formation			
	In Ground		In Air		In Ground		In Air	
	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)
95	194	250	271	349	202	261	295	380
120	221	383	312	401	230	296	341	438
150	246	316	352	452	257	331	385	496
185	277	354	402	515	290	372	440	566
240	319	407	471	602	335	429	519	666
300	358	455	537	685	377	483	594	762
400	408	513	624	789	431	548	692	882
500	462	576	722	904	491	620	806	10021
630	523	644	835	1033	560	701	938	11179
800	585	708	953	1161	632	781	1080	1341
1000	686	816	11111	1372	723	905	1264	1592
1200	722	871	12 235	1503	790	977	1416	1763
1600	815	965	1434	17716	907	11108	1669	2055
2000	892	1038	1613	18897	1008	12 216	1904	2317

Note: The above current ratings correspond to a metallic sheath/screen short circuit current capability of 31.5 kA. For one second duration. For any variation from this value of short circuit current and duration, kindly refer to us.

Table No. 6B: Current Rating of EHV Single Core 66 kV Cable

Cross-Sectional Area of Conductor (Sq.mm.)	Both End Bonding							
	Trefoil Formation				Flat Formation			
	In Ground		In Air		In Ground		In Air	
	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)
95	191	242	267	341	189	234	284	357
120	215	272	307	390	211	258	324	404
150	239	301	345	437	231	281	362	449
185	267	334	391	494	255	305	408	501
240	305	378	456	571	284	335	469	570
300	339	417	516	642	309	359	524	629
400	380	461	593	728	337	384	591	697
500	424	507	678	821	365	407	662	767
630	471	554	772	920	391	429	737	837
800	516	595	866	1013	415	447	806	900
1000	554	631	961	1115	437	465	884	976
1200	587	660	1048	1198	453	477	946	1032
1600	639	704	1176	1317	474	493	1030	1105
2000	678	736	1285	1415	490	505	1101	1166

Table No. 7A: Current Rating of EHV Single Core 110/132 kV Cable

Cross-Sectional Area of Conductor (Sq.mm.)	Single Point Bonding/Cross Bonding							
	Trefoil Formation				Flat Formation			
	In Ground		In Air		In Ground		In Air	
	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)
185	277	354	398	510	289	371	429	551
240	319	407	467	598	335	429	505	649
300	358	456	533	680	377	483	578	742
400	408	514	618	783	431	548	673	859
500	463	577	715	898	491	620	783	992
630	523	646	826	1027	560	701	910	1145
800	586	712	943	1155	632	782	1046	1302
1000	666	817	1098	362	723	905	223	1544
1200	721	873	1219	492	789	977	368	1708
1600	816	969	1417	707	906	1108	1612	1992
2000	893	1043	1595	890	1007	1217	1838	2247

Note: The above current ratings correspond to a metallic sheath/screen short circuit current capability of 31.5 kA. For one second duration. For any variation from this value of short circuit current and duration, kindly refer to us.

Table No. 7B: Current Rating of EHV Single Core 110/132 kV Cable

Cross-Sectional Area of Conductor (Sq.mm.)	Both End Bonding							
	Trefoil Formation				Flat Formation			
	In Ground		In Air		In Ground		In Air	
	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)
185	268	336	390	494	256	308	403	499
240	306	381	455	574	286	338	465	570
300	341	421	516	646	312	363	521	632
400	383	466	593	735	341	389	591	705
500	428	513	679	830	369	414	664	778
630	475	561	775	933	396	436	741	853
800	522	605	871	1030	420	454	815	920
1000	559	639	970	1138	443	473	897	1003
1200	593	668	1057	1222	459	485	961	1060
1600	645	713	1190	1347	480	500	1050	1137
2000	685	746	1303	1449	496	512	1123	1200

Table No. 8A: Current Rating of EHV - Single Core 220 kV Cable

Cross-Sectional Area of Conductor (Sq.mm.)	Single Point Bonding/Cross Bonding							
	Trefoil Formation				Flat Formation			
	In Ground		In Air		In Ground		In Air	
	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)
400	406	513	608	771	430	546	651	831
500	461	576	703	885	490	619	756	960
630	522	645	811	1212	558	699	878	1106
800	585	712	927	1141	630	780	1009	1258
1000	664	815	1077	1342	720	902	1178	1490
1200	718	870	1195	1470	785	973	1316	1647
1600	809	961	1386	1678	899	1101	1546	1916
2000	869	1010	1544	1833	990	1191	1756	2147

Note: The above current ratings correspond to a metallic sheath/screen short circuit current capability of 31.5 kA. For one second duration. For any variation from this value of short circuit current and duration, kindly refer to us.

Table No. 8B: Current Rating of EHV - Single Core 220 kV Cable

Cross-Sectional Area of Conductor (Sq.mm.)	Both End Bonding							
	Trefoil Formation				Flat Formation			
	In Ground		In Air		In Ground		In Air	
	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)	Aluminium (Amp)	Copper (Amp)
400	384	469	589	734	344	394	585	706
500	429	518	674	831	373	419	660	784
630	478	566	770	935	400	442	740	862
800	525	612	869	1038	425	461	818	935
1000	562	646	971	1152	448	480	904	1024
1200	595	674	1059	1237	465	493	971	1085
1600	643	713	1188	1358	493	516	1071	1174
2000	670	728	1286	1440	537	561	1186	1288

Note: The above current ratings correspond to a metallic sheath/screen short circuit current capability of 31.5 kA. For one second duration. For any variation from this value of short circuit current and duration, kindly refer to us.

Table No. 9: Rating factors for variation in ambient air temperature

Air temperature (°C)	15	20	25	30	35	40	45	50	55	60
Conductor Temp90°C Rating Factors	1.25	1.2	1.16	1.11	1.05	1	0.94	0.88	0.82	0.76

Table No. 10: Rating factors for variation in ground temperature

Air temperature (°C)	15	20	25	30	35	40	45	50
Conductor Temp90°C Rating Factors	1.12	1.08	1.04	1	0.96	0.91	0.87	0.82

Table No.11: Rating factors for grouping of single core cable laid directing round in horizontal formation

Distance between centres of circuits	Number of circuits in group								
mm	1	2	3	4	5	6	7	8	9
100	1	0.76	0.67	0.59	0.55	0.51	0.49	0.47	0.46
200	1	0.81	0.71	0.65	0.61	0.58	0.56	0.53	0.52
400	1	0.85	0.77	0.72	0.69	0.66	0.64	0.63	0.62
600	1	0.88	0.81	0.77	0.74	0.72	0.71	0.7	0.69
800	1	0.9	0.84	0.81	0.79	0.77	0.76	0.75	0.75
2000	1	0.96	0.93	0.92	0.91	0.91	0.91	0.9	0.9

Table No.12: Rating factor for thermal resistivity of soil

Soil thermal resistivity (Deg. C cm/Watt)	70	100	120	150	200	250	300
Rating factor	1.36	1.19	1.11	1	0.88	0.78	0.73

Table No.13: Rating factor for depth of laying

Depth of laying (cm)	90	100	120	150	160	170	180	190	200
Rating factor	1.06	1.05	1.03	1	0.99	0.99	0.98	0.98	0.97

Table No.14: Rating factor for phase spacing in flat formation

Phase Spacing (S) (Cm)	D	D+70	D+200	D+250	D+300	D+350	D+400
Rating factor	0.93	1	1.03	1.05	1.07	1.08	1.1

Note: D is the overall diameter of cable.

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