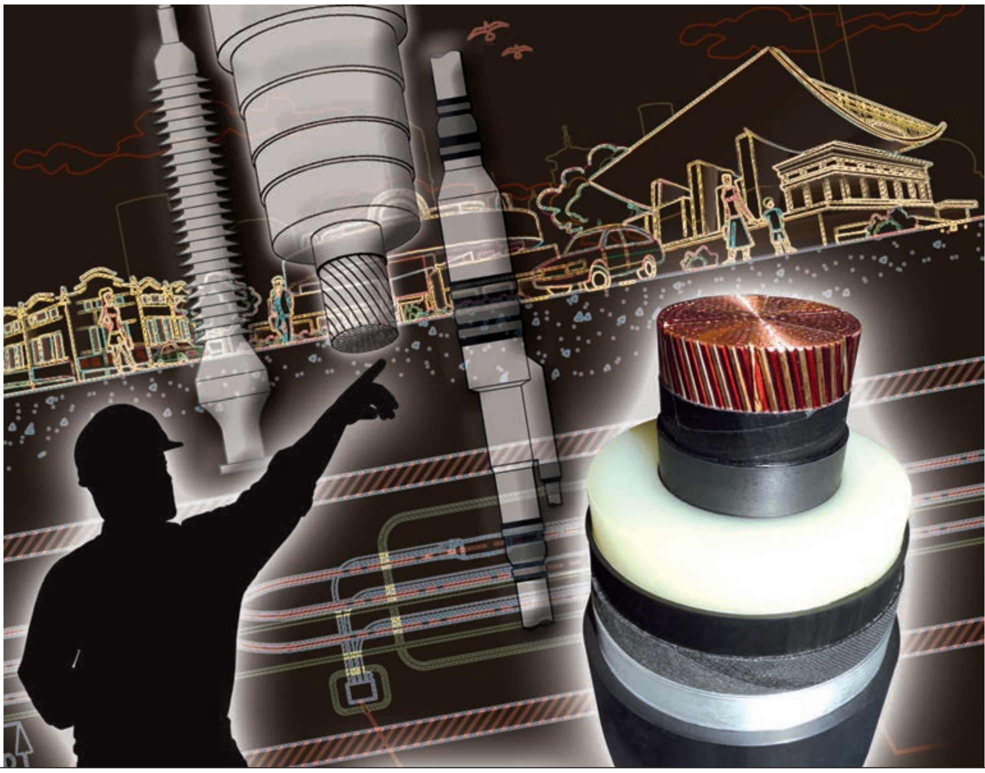
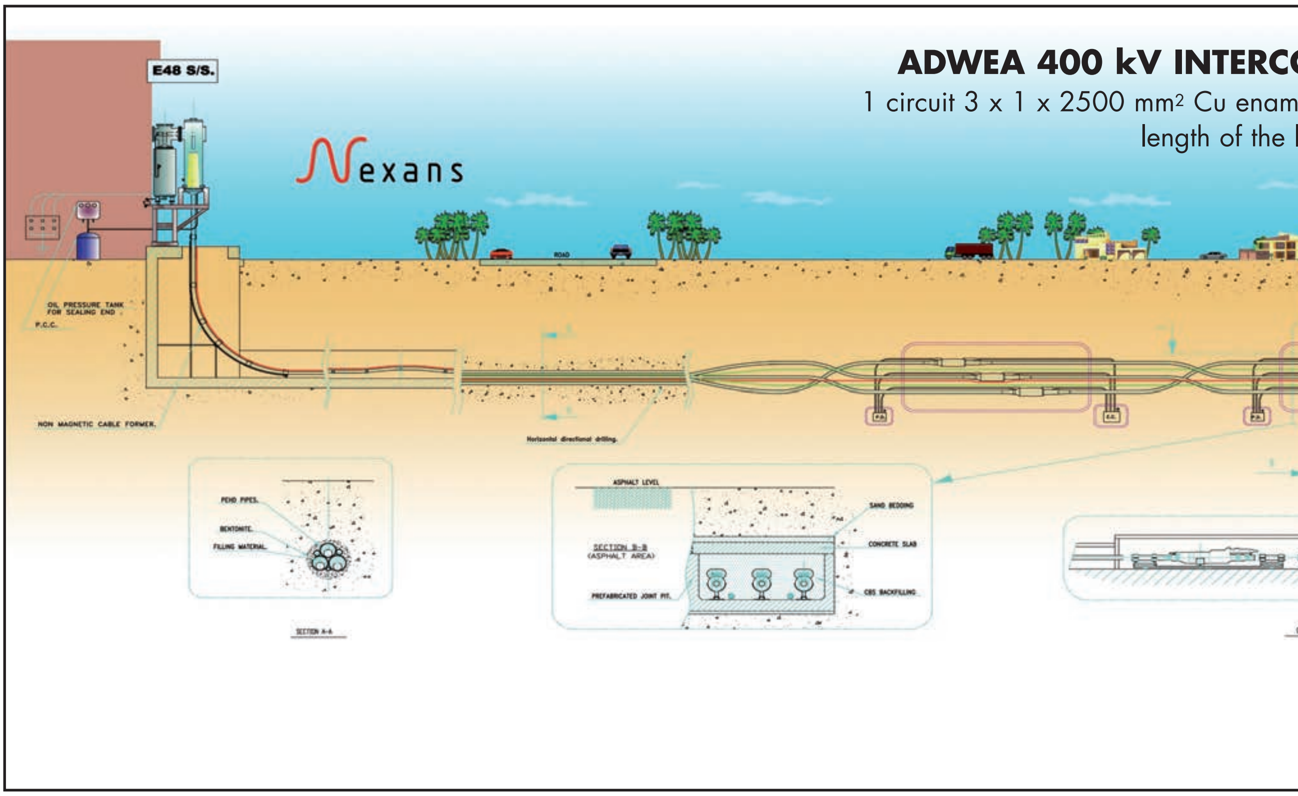
60-500 kV High Voltage Underground Power Cables

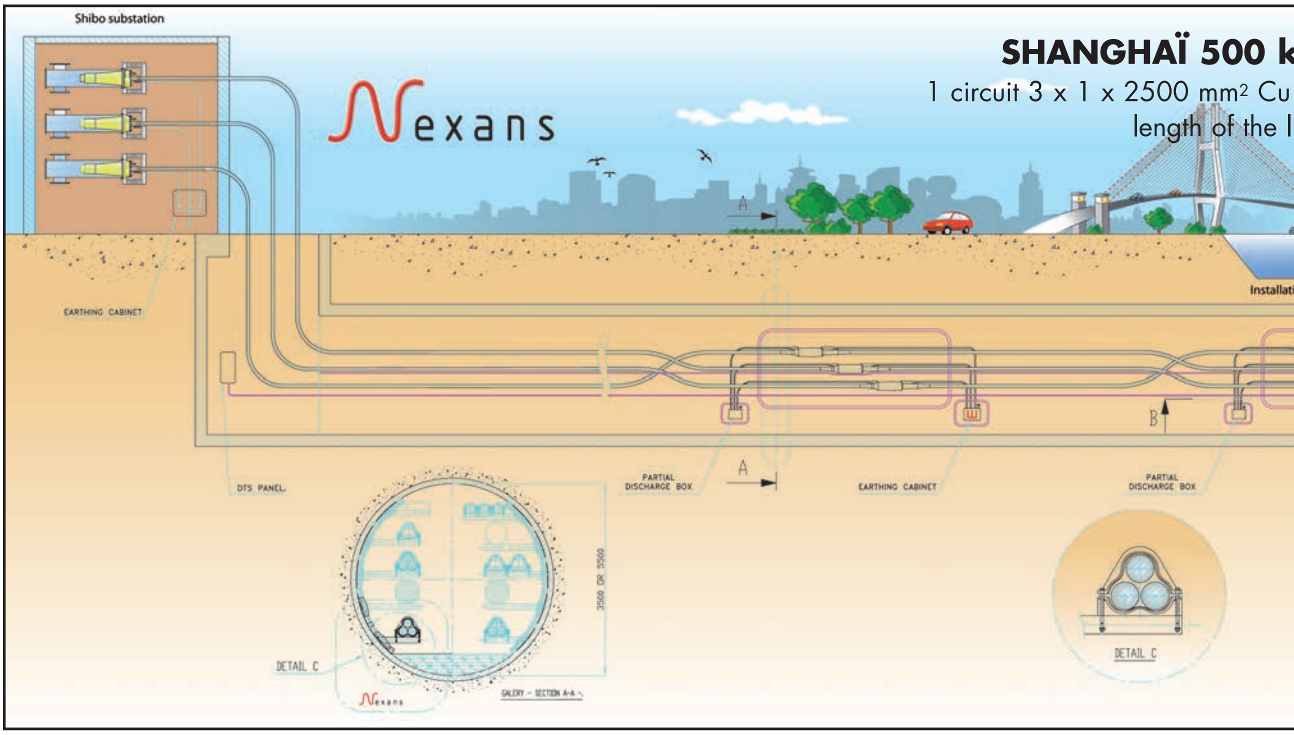
XLPE insulated cables

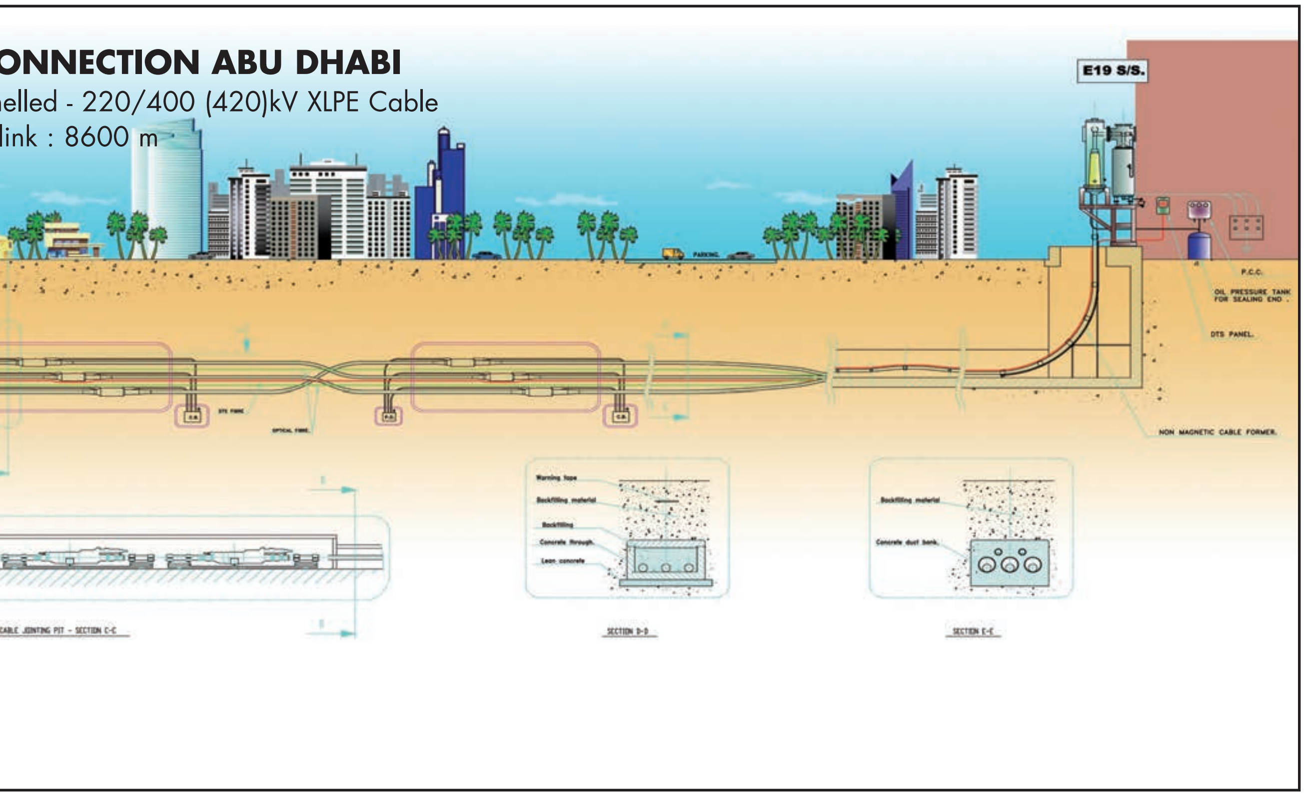


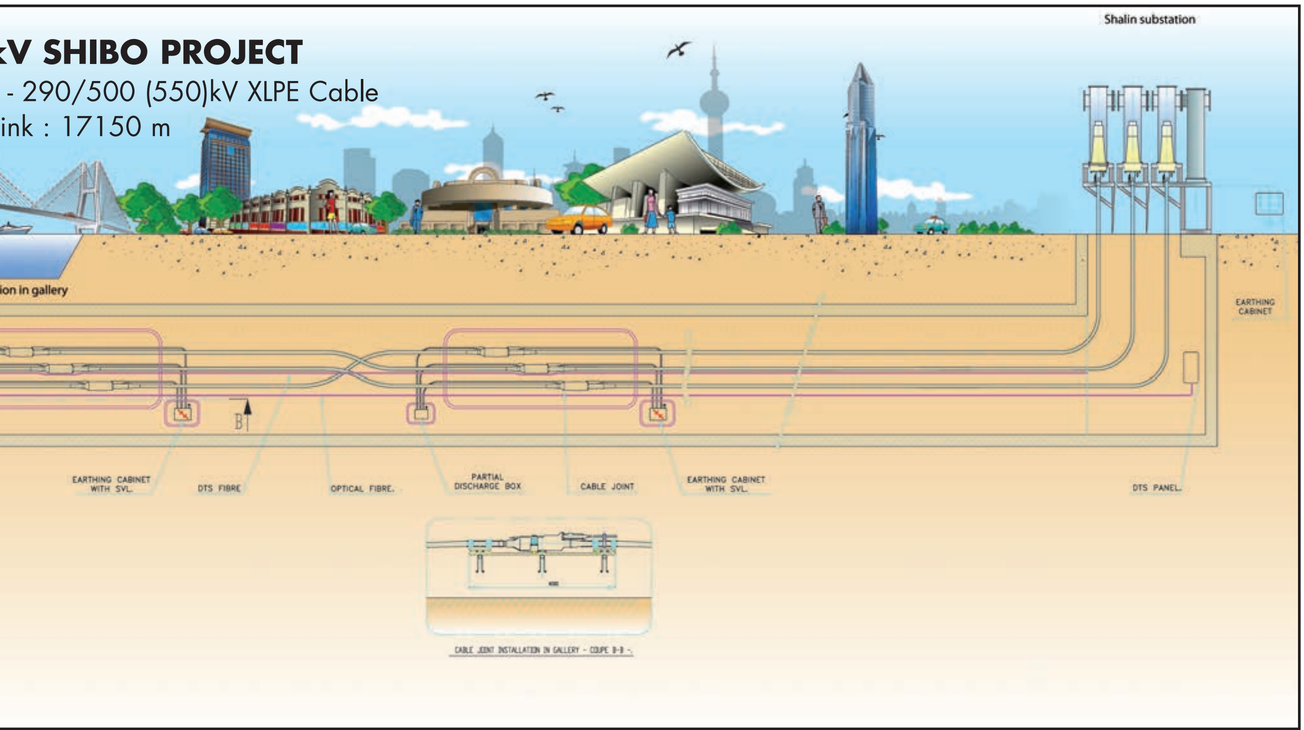
Nexans

Underground Power Cables






ONNECTION ABU DHABI
nelled - 220/400 (420)kV XLPE Cable
link : 8600 m
E19 S/S.
PARKING
P.C.C.
OIL PRESSURE TANK FOR SEALING END
DTS PANEL.
NON MAGNETIC CABLE FORMER.
Warning tape
Backfilling material
Backfilling
Concrete through.
Lean concrete
Concrete duct bank.
SECTION D-D
SECTION E-E


kV SHIBO PROJECT
- 290/500 (550)kV XLPE Cable
ink : 17150 m
Shalin substation
ion in gallery
EARTHING CABINET
EARTHING CABINET WITH SVL.
DTS FIBRE
OPTICAL FIBRE.
PARTIAL DISCHARGE BOX
CABLE JOINT
EARTHING CABINET WITH SVL.
DTS PANEL.

Contents

General power circuit design

This brochure deals with underground power circuits featuring three-phase AC voltage insulated cable with a rated voltage between 60 and 500 kV. These lines are mainly used in the transmission lines between two units of an electricity distribution grid, a generator unit and a distribution unit or inside a station or sub-station. These insulated cable circuits may also be used in conjunction with overhead lines.

The voltage of a circuit is designated in accordance with the following principles:

Example:

Uo/U (Um) : 130/225 (245)

Uo	=	130 kV phase-to-ground voltage,
U	=	225 kV rated phase-to-phase voltage,
Um	=	245 kV highest permissible voltage of the grid

Phase-to-ground voltage, designated Uo, is the effective value of the voltage between the conductor and the ground or the metallic screen. Rated voltage, designated U, is the effective phase-to-phase voltage. Maximum voltage, designated Um, is the permissible highest voltage for which the equipment is specified (see also standard IEC 38).

A high voltage insulated cable circuit consists of three single-core cables or one three-core cable with High Voltage sealing ends at each end. These sealing ends are also called "terminations" or terminals. When the length of the circuit exceeds the capacity of a cable reel, joints are used to connect the unit lengths. The circuit installation also includes grounding boxes, screen earthing connection boxes and the related earthing and bonding cables.

The structure of high voltage cable with synthetic cross-linked polyethylene insulation will always involve the following items:

Conductor core

The aluminium or copper conductor carries the electrical current.

The conductor behaviour is characterized by two particularly noteworthy phenomena: **the skin effect and the proximity effect.**

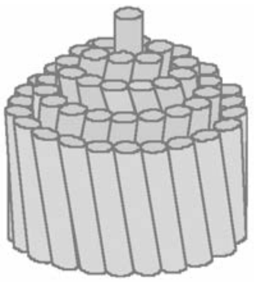
The skin effect is the concentration of electric current flow around the periphery of the conductors.
It increases in proportion to the cross-section of conductor used.
The short distance separating the phases in the same circuit generates **the proximity effect**.
When the conductor diameter is relatively large in relation to the distance separating the three phases, the electric current tends to concentrate on the surfaces facing the conductors. The wires of the facing surfaces indeed have a lower inductance than wires that are further away (the inductance of a circuit increases in proportion to the surface carried by the circuit).
The current tends to circulate in the wires with the lowest inductance.
In practice, the proximity effect is weaker than the skin effect and rapidly diminishes when the cables are moved away from each other.

The proximity effect is negligible when the distance between two cables in the same circuit or in two adjacent circuits is at least 8 times the outside diameter of the cable conductor.

There are two designs of conductor, **compact round stranded** and **segmental "Milliken" stranded.**

1. Compact round conductors, composed of several layers of concentric spiral-wound wires.

In round stranded compact conductors, due to the low resistance electrical contacts between the wires, the skin and proximity effects are virtually identical to those of solid plain conductor.

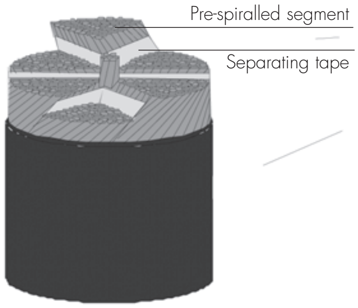


2. **Segmental conductors, also known as "Milliken" conductors are composed of several segment-shaped conductors assembled together to form a cylindrical core.**

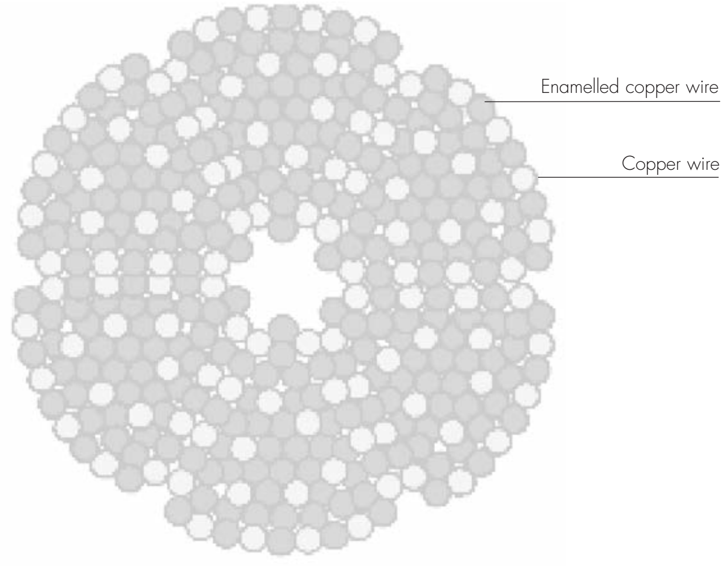
The large cross-section conductor is divided into several segment-shaped conductors. There are from 4 to 7 of these conductors, which are known as segments or sectors. They are insulated from each other by means of semi-conductive or insulating tape.

The spiral assembly of the segments prevents the same conductor wires from constantly being opposite the other conductors in the circuit, thus reducing the proximity effect.

This structure is reserved for large cross-sections greater than 1200 mm^2 for aluminium and at least 1000 mm^2 for copper.
The Milliken type structure reduces the highly unfavourable skin effect and proximity effect.



Milliken conductor construction



Typical diagram of an enamelled wire conductor

Enamelled copper wire
For copper conductors with a cross-section greater than 1600 mm^2, enamelled wires (around two thirds of the wires) are included in the structure of the Milliken type segmental conductor.

The proximity effect is almost completely **eliminated**, as each conducting wire follows a path alternating between areas that are far away from and areas close to the other phases conductors.

The skin effect is reduced owing to the small cross-section of the wires used, each insulated from the others. In practice, a **structure containing enamelled wires adds roughly a whole conductor cross-section.**
For example, a 2000 mm^2 enamelled copper cable is equivalent to a 2500 mm^2 non-enamelled copper cable.
The connection of enamelled copper conductors requires a different technology, which Nexans has recently developed.

Reduction of the skin effect

AC_{90} resistance / DC_{90} resistance	Conductor structure		
Cross-section (mm2)	Compact round stranded	Milliken segmental stranded	Milliken enamelled stranded
1600	1.33	1.24	1.03
2000	1.46	1.35	1.04
2500	1.62	≈ 1.56	1.05
3000	1.78	≈ 1.73	1.06

The cable

Semi-conductor screen on conductor.

To prevent electric field concentration, there is an interface of ultra-smooth semi-conductor XLPE between the conductor and the insulation.

XLPE insulation.

As its name suggests, the insulation insulates the conductor when working at high voltage from the screen working at earthing potential. The insulation must be able to withstand the electric field under rated and transient operating conditions.

Semi-conductor screen on insulation.

This layer has the same function as the conductor screen:
Progressive transition from an insulating medium, where the electric field is non- null, to a conductive medium (here the metal cable screen) in which the electric field is null.

Metallic screen.

When the voltage reaches tens or even hundreds of kV, a metallic screen is necessary.

Its main **function** is to **nullify the electric field outside the cable**.
It acts as the second electrode of the capacitor formed by the cable.

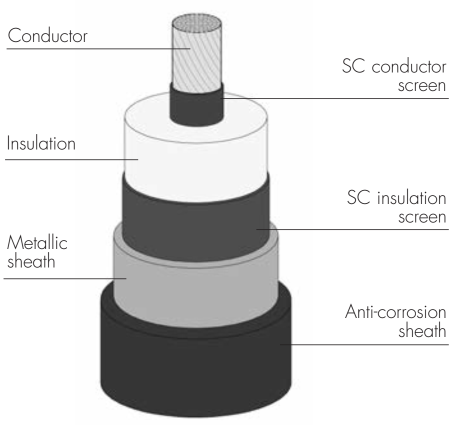
Use of a metallic screen implies:

- The need to connect it to earth at least at one point along the route.
- Draining the capacitive current that passes through the insulation.
- Draining the **zero-sequence short-circuit currents**, or part of them. This function is used to determine the size of the metallic screen.
- **The circulation of the currents induced by the magnetic fields from other cables in the vicinity.** These circulating currents cause further energy loss in the cables and have to be taken into account when assessing the transmission capacity of a cable system.
- **The need to electrically insulate the metallic screen from earth** over the greater part of the length of cable installed.
- **The need to protect the metallic screen** from chemical or electrochemical corrosion.

The second **function** of the metallic screen is to form a **radial barrier to prevent humidity** from penetrating the cable, particularly its insulation system.

The synthetic insulation system should not be exposed to humidity. When humidity and a strong electric field are present together, the insulation deteriorates by what is called watertreeing, which can eventually cause the insulation to fail.

Note:
In the case of an overhead line, the insulation is formed by the air between the bare conductor and the ground.
Several metres between the powered conductors and the ground are required to ensure adequate electrical insulation and to prevent arcing between the high voltage conductors and objects or living beings on the ground.



Cable components

Different types of metallic screen

Extruded lead alloy sheath

Advantages:

- Waterproofing guaranteed by the manufacturing process,
- High electrical resistance, therefore minimum energy loss in continuous earthing links,
- Excellent corrosion resistance.

Drawbacks:

- Heavy and expensive,
- Lead is a toxic metal whose use is being restricted to a minimum following European directives,
- Limited capacity to expel zero-sequence short-circuit currents.

Concentric copper wire screen with aluminium tape bonded to a polyethylene or PVC jacket

Advantages:

- Lightweight and cost effective design,
- High short-circuit capacity.

Drawbacks:

- Low resistance necessitating special screen connections (earthing at one point or cross-bonding) in order to limit circulating current losses.

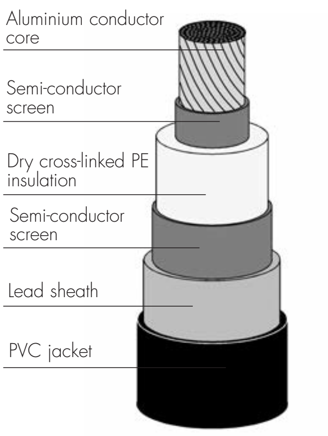
Aluminium screen welded longitudinally and bonded to a polyethylene jacket

Advantages:

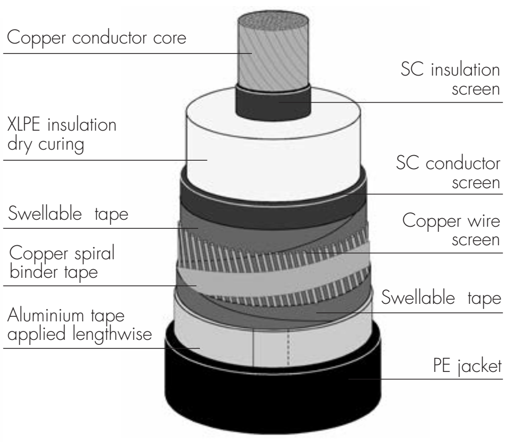
- Lightweight structure
- High short-circuit capacity,
- Impervious to moisture, guaranteed by the manufacturing process.

Drawbacks:

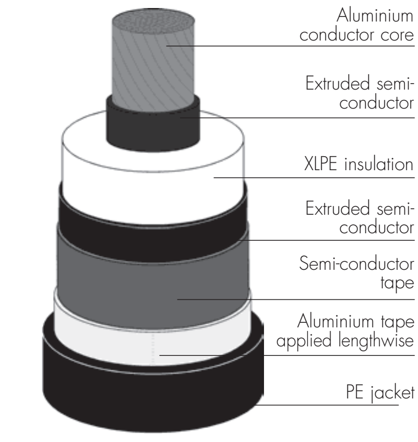
- Low resistance necessitating special screen connections (earthing at one point or cross-bonding) in order to limit circulating current losses.
- Higher Eddy Current losses than with the previous screen types.



Lead screen



Copper wire/alu sheath



Smooth aluminium sheath

Copper wire screen with extruded lead sheath

This is a combination of the above designs. It combines the advantages of the lead sheath and concentric copper wire screen.

Its main drawbacks lie in its cost and the lead content.

The copper wire screen is placed under the lead sheath thus enabling it to share the anti-corrosion properties of the latter.

Anti-corrosion protective jacket

The jacket has a dual function:

- **It insulates the metallic screen from ground** (particularly for lines with special screen connections)
- **It protects the metal components of the screen from humidity and corrosion.**

The outer jacket must also withstand the **mechanical stresses** encountered during installation and service, as well other risks such as termites, hydrocarbons, etc.

The most suitable material for this is polyethylene.

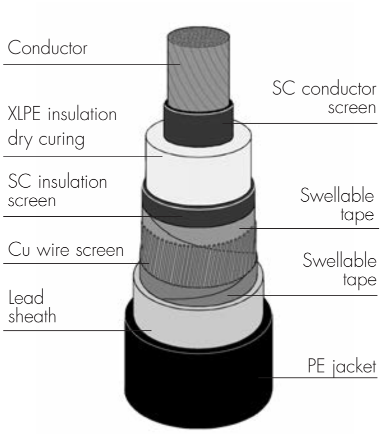
PVC is still used but increasingly less so. Indeed, one of the advantages of PVC is its fire-retardant properties, although the toxic and corrosive fumes released are prohibited by many users.

If **"fire-retardant"** is specified in accordance with IEC standards 332, **HFFR** (Halogen-Free Fire Retardant) materials will be used in preference to PVC.

These materials however have mechanical properties that are inferior to those of polyethylene and are more costly. They should be reserved for installations or parts of installations where fire protection is required.

To verify the integrity of the outer jacket, a semi-conducting layer is often applied to this jacket.

This layer is made of semi-conducting polymer co-extruded with the outer jacket.



Copper wire/lead sheath

Item	Function	Composition
Conductor	• to carry current - under normal operating conditions - under overload operating conditions - under short-circuit operating conditions • to withstand pulling stresses during cable laying.	**S≤1000mm^2 (copper) or ≤1200mm^2 (aluminium)** Compact round stranded cable with copper or aluminium wires **S≥1000mm^2 (copper)** segmental **S>1200mm^2 (aluminium)** segmental
Internal semi-conductor	• To prevent concentration of electric field at the interface between the insulation and the internal semi-conductor • To ensure close contact with the insulation. To smooth the electric field at the conductor.	**XLPE semi-conducting shield**
Insulation	• To withstand the various voltage field stresses during the cable service life: - rated voltage - lightning overvoltage - switching overvoltage	**XLPE insulation** The internal and external semi-conducting layers and the insulation are co-extruded within the same head.
External semi-conductor	To ensure close contact between the insulation and the screen. To prevent concentration of electric field at the interface between the insulation and the external semi-conductor.	**XLPE semi-conducting shield**
Metallic screen	To provide: • An electric screen (no electric field outside the cable) • Radial waterproofing (to avoid contact between the insulation and water) • An active conductor for the capacitive and zero-sequence short-circuit current • A contribution to mechanical protection.	• **Extruded lead alloy, or** • **Copper wire screen with aluminium bonded to a PE jacket** • **Welded aluminium screen bonded to a PE jacket** • **Combination of copper wires and lead sheath**
Outer protective sheath	• To insulate the metallic screen from the surrounding medium • To protect the metallic screen from corrosion • To contribute to mechanical protection • To reduce the contribution of cables to fire propagation.	**Insulating sheath** • Possibility of semi-conducting layer for dieletric tests • Polyethylene jacket • HFFR jacket

Metallic screens earthing

When an alternating current runs through the conductor of a cable, voltage that is proportional to the induction current, to the distance between phases and to the length of the line will be generated on the metallic screen.

The end that is not earthed is subjected to an induced voltage that needs to be controlled.

Under normal operating conditions, this voltage may reach several tens of volts.
Risks of electrocution can be prevented using some simple methods. In the case of a short-circuit current (several kA), the induction voltage proportional to the current can reach several kV.
In practice however, this value remains lower than the voltage needed to perforate the outer protective jacket of the cable.

On the other hand, in the case of lightning overvoltage or switching overvoltage, the voltage between earth and the insulated end of the screen may attain several tens of kV.
There is therefore a risk of electric perforation of the anti-corrosion sheath insulating the metallic screen from the earth.

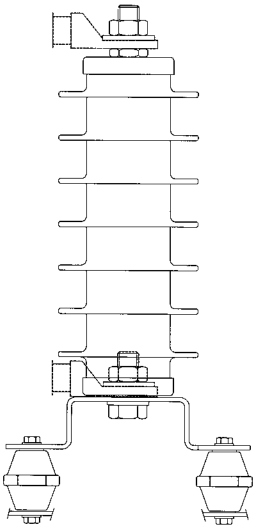
It is therefore necessary to limit the increase in potential of the screen by using a Sheath Voltage Limiters (SVL) between the metallic screen and the ground.

These sheath voltage limiters basically operate like non-linear electrical resistances.

At low voltage (in the case of normal operating conditions), the sheath voltage limiters are extremely resistant and can be considered as non-conducting.

In the event of lightning overvoltage or switching overvoltage, the sheath voltage limiters are subjected to extremely high voltage. They become conducting and thus limit the voltage applied to the protective jacket. This limitation voltage is sometimes called **protection voltage**.

Finally, it is important to ensure that, in the case of a short-circuit in the circuit, the **induction voltage in the screen is not higher than the rated voltage of the sheath voltage limiter.**
This final criteria determines the type of sheath voltage limiter to be used for a given power line.



Sheath voltage limiter

Short-Circuit Operating Conditions

Short-circuit currents in an electric network are a result of the accidental connecting of one or more phase conductors, either together, or with ground.
The neutral of the transformers is generally connected to ground in high voltage networks.
The impedance of this connection can vary in size, according to whether the neutral is directly connected to ground or via an impedant circuit.

There are two types of short-circuit current:

1. Symmetrical short-circuits
   (3 phase short-circuits) where the currents in the three phases form a balanced system. These currents therefore only circulate in the main conductors of the cables.
2. Zero-sequence short-circuits
   result from an asymmetrical, i.e. unbalanced current system. Zero-sequence currents return via the ground and/or by the conductors that are electrically parallel to ground. These conductors are mainly:
   - ground conductors,
   - metallic screens connected to ground at the line terminations
   - the ground itself

The metallic screens of the cables must therefore have a large enough cross-section to withstand these so-called zero-sequence short-circuits.

Different grounding methods

Grounding method	**Continuous, at 2 points:** The metallic screens are earthed at least at both ends of the line.	**At one point:** The metallic screen is earthed at one end and connected to a voltage limiter (SVL) at the other.	**Cross-bonding:** The metallic screens are earthed directly at each end. The cross-bonding of the screens cancels the total induced voltage generated in the screen of each phase. This is achieved by connecting the metallic screens using joints and screen separations.
Line characteristics	• Line length greater than 200m • Cable cross-section under or equal to 630 mm^2	• Circuit length under 1 km	• Long Circuits • High capacity, cross-section greater than 630 mm^2 Cu • Joints • Number of sections: multiples of 3 of almost equal lengths
Necessary equipment	• R2V cable or low voltage insulated cable	• Sheath voltage limiter • R2V cable or low voltage insulated cable	• Joints with screen separations • Coaxial cable • Sheath voltage limiter at the screen cross-bonding point
Advantages	• Easy to implement • No equipotential cable installed along the circuit	• Optimal use of transmission capacity • Earth-cable protection possible	• Optional equipotential cable along the circuit • No induced currents in the screens
Drawbacks	• Reduced transmission capacity • No ground cable protection possible	• Equipotential cable along the circuit • Use of sheath voltage limiters	• Maintenance • Cost

The cable

Earth cable protection

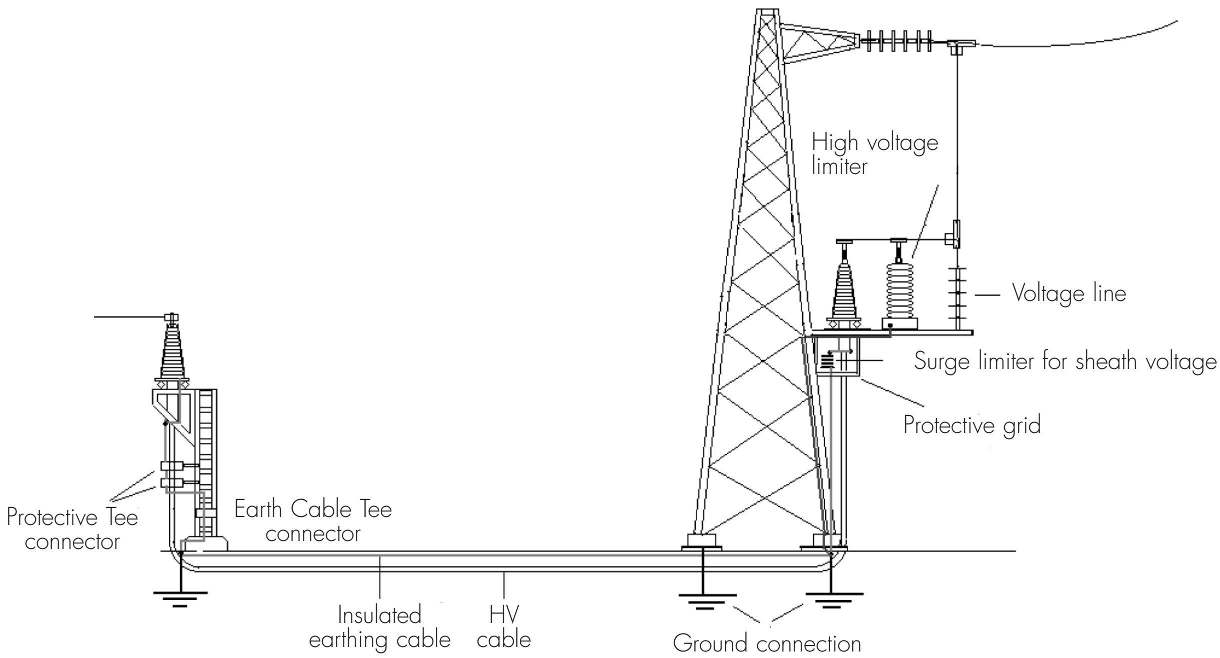
A ground cable protection is used for **overhead or underground lines that are grounded at one point.** This device allows any flaws in the cable to be detected. It prevents power from being restored to the defective cable by putting the line out of service.

Principle

A current transformer, CT, is installed on the earthing circuit of the screen.
If there is a flaw in the overhead line, the transformer, located on the earthing circuit of the cable screen, will not detect any current. The CT is connected to a relay that closes the contact. The contact reports the flaw and prevents the line from being automatically re-energised.

The advantage of the earth cable protection is to facilitate use of an overhead-underground line.
It prevents risks of fire in galleries.
Low in cost, it is especially used in hazardous locations such as power plants and galleries.

INSTALLATION OF AN OVERHEAD-UNDERGROUND LINE
with ground cable protection



Different Earthing Connection Types

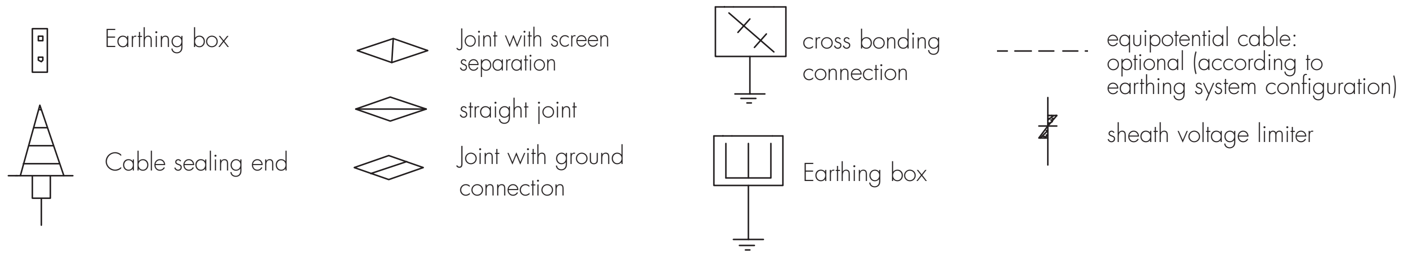
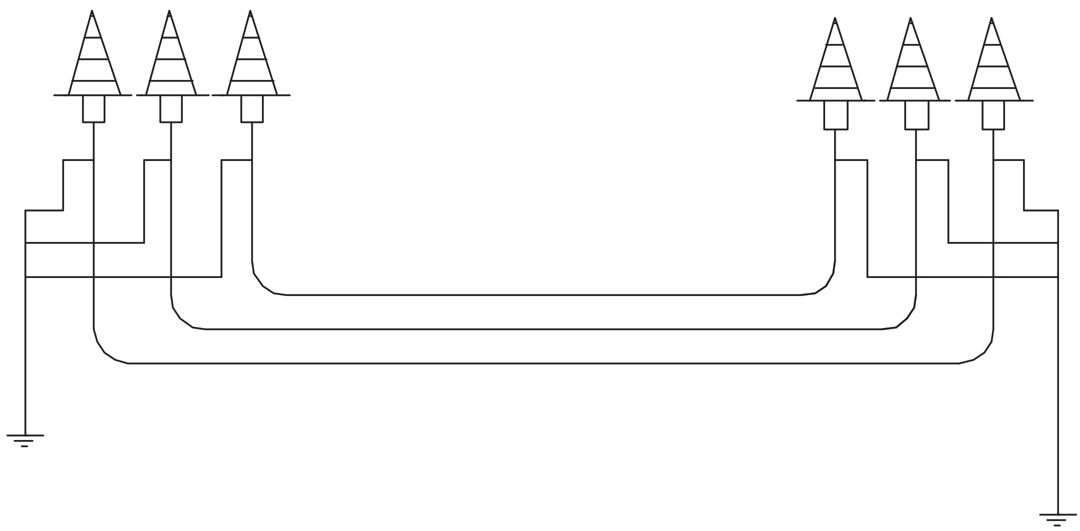


Diagram of earth connection at both ends



Cross-bonding system

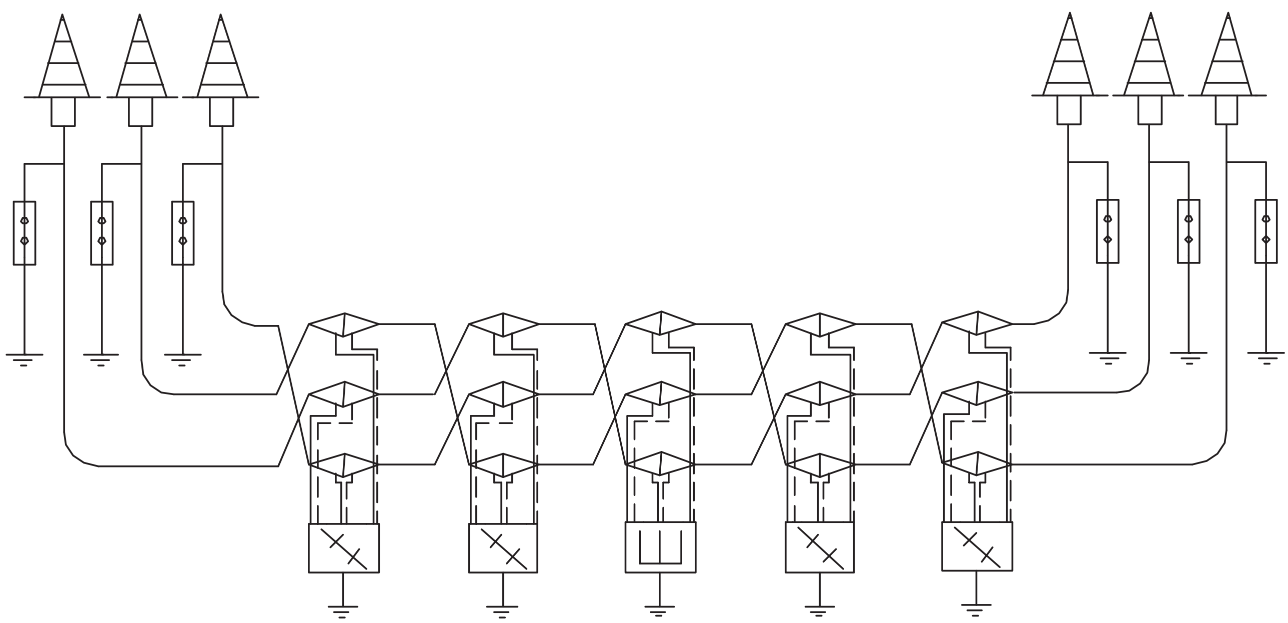
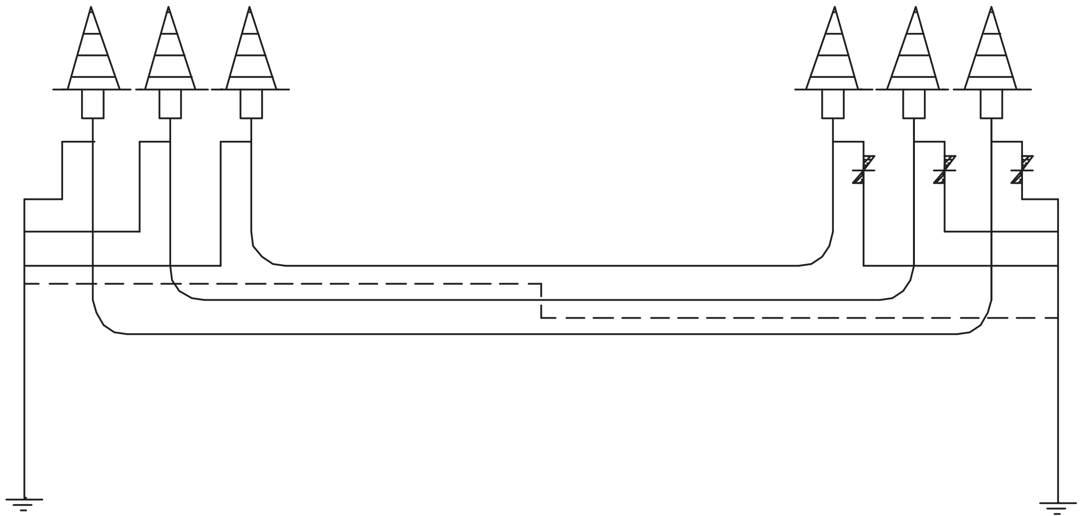
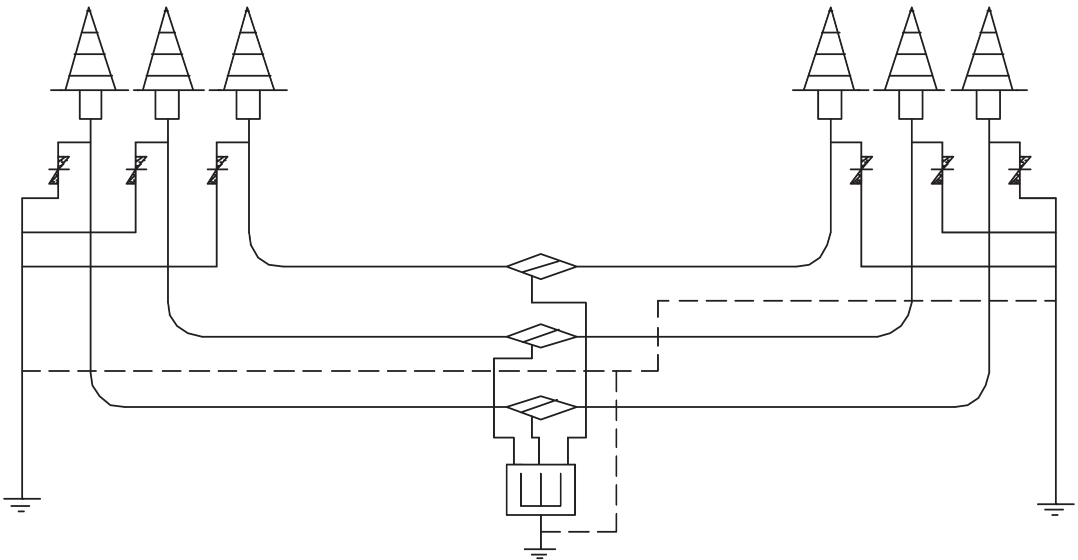


Diagram showing the principle of a power line with earthing at one point



Other variant:
Earthing at mid-point when there are 2 sections in one circuit or 1 joint in 1 section

Earthing system mid-point



Laying methods

Mechanical considerations

Apart from the electrical and thermal aspects of the cable design, it is necessary to consider the mechanical and thermomechanical stresses to which the cable system will be subjected during installation and service.

Stresses due to winding and bending

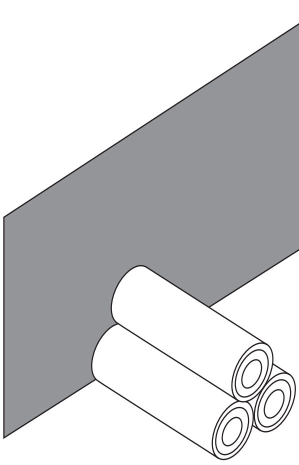
An elementary comparison can be made between a cable and a beam.
When the cable is bent, the neutral fibre becomes the cable axis and the stretched fibre is elongated according to the following formula:

$$\varepsilon = \frac{D_e}{D_p}$$

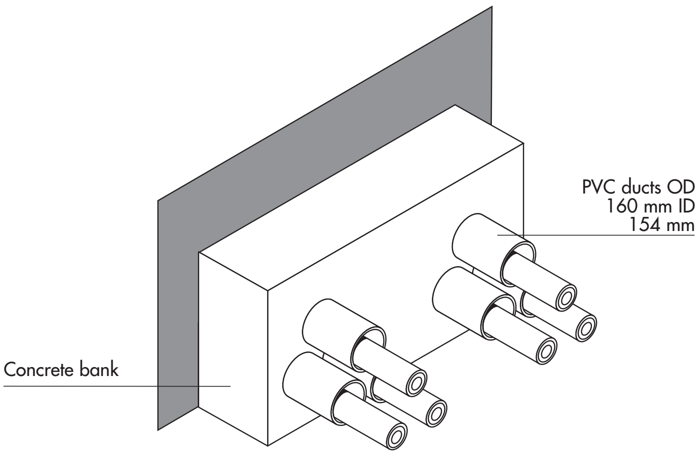
ε : elongation
where D_e is the outside diameter of the cable and D_p is the bending diameter.

The compressed wire is subjected to the same deformation but with the opposite sign.
It is customary to express the cable deformation limit by a minimum ratio between the bending or winding diameter and the outside diameter of the cable. This ratio is reciprocal to the maximum permitted deformation Emax.

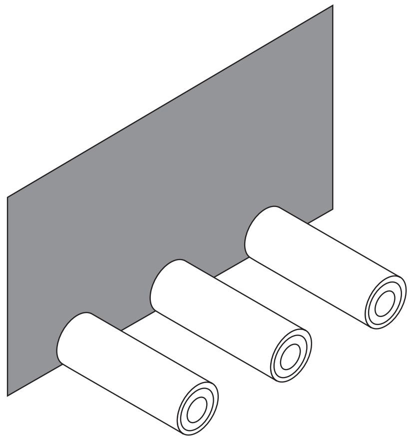
Cables buried directly in trefoil formation



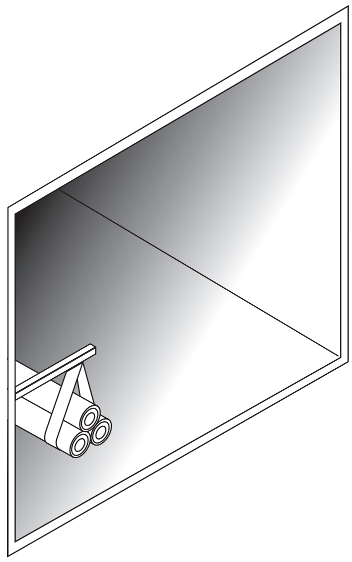
Cables buried inside ducts in trefoil formation



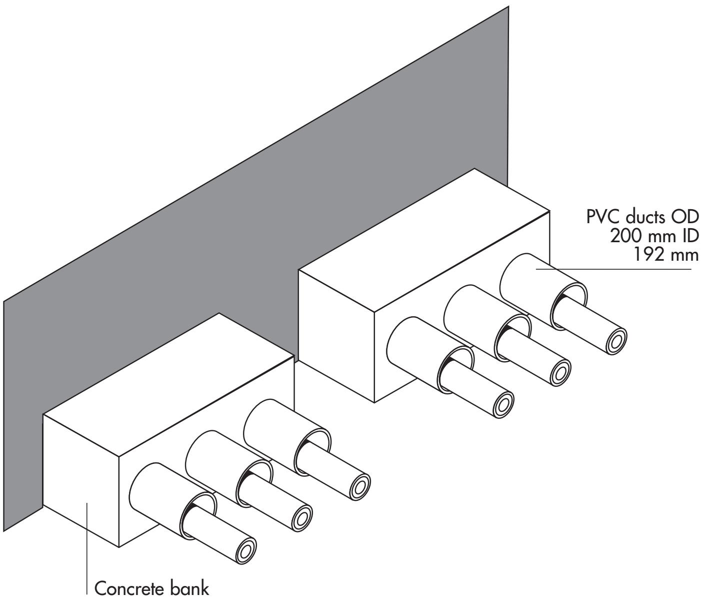
Cables directly buried in flat formation



Cables in the air inside a gallery in touching trefoil formation



Cables buried flat in ducts



Cables laid flat in the air inside a gallery

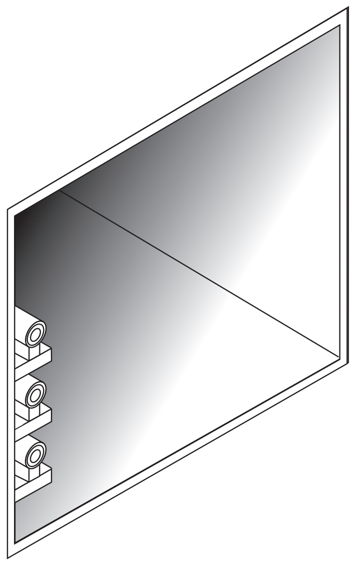
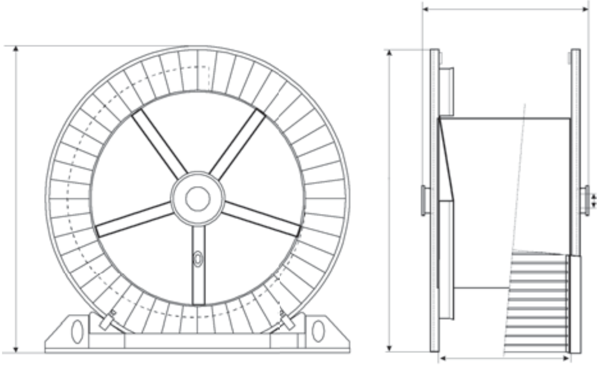


Diagram of a metal reel with bearing plate for handling and stowing purposes



maximum dimensions:
flange diameter: 4,5m; width: 2,5m; load: 40t

Cable reels

The following rules are used to determine the barrel diameter of storage reels:

Choice of storage reel

Type of screen	Minimum barrel diameter expressed as a multiple of the cable diameter
Lead screen with PVC jacket	20
Welded aluminium screen with PE jacket	20
Bonded aluminium screen	21
Lead screen with co-extruded PE jacket	18

For installation, it is not the bending diameter that is used but the minimum bending radius or curve radius.

Curve radius of cable

Condition	Minimum curve radius expressed as a multiple of the cable diameter
When pulling cable over rolls	30
When pulling through ducts	35
After installation without a cable former	20
After installation with a cable former (cable clamps mounted along an uniform curve)	15

These are general rules that can be reassessed according to the particularities of a project.

Tensile stress and sidewall pressure

When pulling a cable by applying a traction force at one end, most of the load is taken by the cable core. This supposes that the pull head is securely anchored to the cable core.

Use of a " Chinese finger " must be restricted to cases where the tensile load is below 500 daN.

Standard pull heads have a rated strength of 4000 daN.

The maximum tensile load on the conductor is given by the following formula:

Max load on conductor = KxS (daN)

S: cross-section of conductor (mm^2)

K: max stress (daN/mm^2)

K = 5 daN/mm^2 for aluminium conductor cables

K = 6 daN/mm^2 for copper conductor cables

Type of metallic screen	Permitted sidewall pressure in daN/m
Copper wire + aluminium-PE	1000
Copper wire + lead sheath	1000
Welded plain aluminium sheath + bonded PE jacket	2500
Lead sheath alone + PE jacket	1500
Lead sheath alone + PVC jacket	1000

Fastening systems

Thermomechanical stresses

When a cable heats up, it expands both radially and axially.

Radial expansion causes problems for the clamps used to fasten the cables, while axial expansion has to be controlled either:

- By clamping the cable with clamps that are sufficiently close together to prevent the cable from buckling (rigid method), or
- By fastening the cable using clamps that are sufficiently well spaced to allow the cable to bend within the allowed bend radius, and without risk of fatigue of the metallic screen due to these repetitive deformations.

Electrodynamic stress due to a short-circuit event

In the event of a short-circuit, intense currents can run through the cables. This results in high electrodynamic loads between the conductors.

These loads have to be taken into account in the cable fastening system design, the accessory fastening devices and in the spacing of the cables.

Cable system Tests

These cable system tests can be grouped into three main categories:

1. Individual tests or **"routine tests"**. These non-destructive tests are performed on the complete delivery at the final production stage.

2. **Special tests,** sometimes called "sample tests" by some standards. These tests, which can be destructive, are performed on part of the production at the final stage and at the frequency defined by the standards.

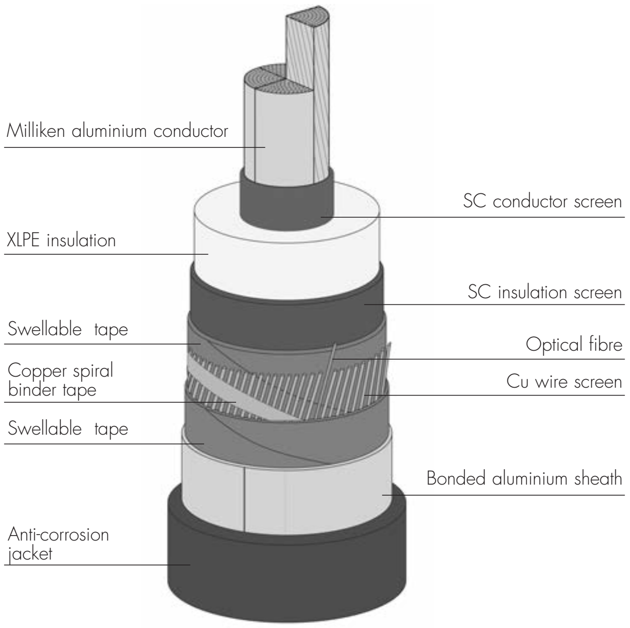
3. **Type tests.** These tests validate the cable system design, that is all the materials that make up a high voltage electrical power line. They are generally performed on a loop including a cable and all the accessories to deliver. The standards define the criteria for judging the relevance of a type test for different cable systems, such as cable with a different conductor cross-section but of the same voltage range and with identical accessories. The type tests also serve to qualify the materials used to manufacture the cable.

The cables manufactured by Nexans are usually tested in accordance with international standards CEI 60 840 for voltages Um $\leq$ 170 kV and with IEC 62 067 for higher voltages. Test programs in accordance with national standards or client particular technical specifications may also be performed.

Current development work and technological changes

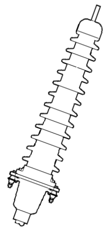
Our Research & Development Department is currently developing the next products, both cables and accessories:

- **Cable with insulated wire conductor**, with low skin and proximity effects, for less energy loss and increasingly higher unitary carrying capacity.
- Cable with **welded aluminium screen bonded or not bonded** to the outer synthetic jacket
- 150 kV cable **with integrated optical fibre** (which serves to control the temperature along the whole cable length offering better grid efficiency). A Nexans mainly development for the Benelux countries (Belgium, Netherlands and Luxemburg).
- **Joint with integrated mechanical**, electrical and anti-corrosion (HOP type) protection for minimum volume, robust design and restricted number of on site manual operations.
- **Sealing ends with explosion-proof device** for increased sub-station safety.
- **Fully synthetic sealing ends**, for minimum maintenance.
- **Composite sealing ends**, for greater safety and shorter procurement times.
- **Joint and sealing end** with **integrated partial sensors** for early PD detection.
- **Dry GIS sealing end** oil maintenance free.
- **Dry outdoor sealing end**, fluid (gas or oil) maintenance free.
- **Step up joint** between two different sizes and two different metals conductors.



1 x 2000 mm² (150) kV + optical fiber

Accessories, sealing ends



Accessories are used to join cables together by means of a joint or to joint a cable to the network by means of a sealing end.
Each accessory is defined in detail according to its physical and electrical environment.

SEALING ENDS

Their function is to connect the power cable to the network via the substations or overhead and underground connections. They control the leakage path from the cable insulation to the insulating medium of the station (air in the case of an air-insulated substation or SF6 in the case of a gas-insulated substation). There are "outdoor" sealing ends with porcelain or synthetic insulators. The cables connected to gas-insulated substations have sealing ends with epoxy insulators.These mould themselves directly onto the substation pipes.

OUTDOOR SEALING ENDS

These are defined by:

• the type of insulator and its leakage path. The leakage path is directly in contact with the surrounding air.

• whether or not a dielectric fluid is used.

Leakage path

The leakage path is the insulation distance measured along the surface separating the voltage point and the earthed screens. It avoids direct conduction by diverting the voltage into the surrounding fluid (air, gas or oil).

The leakage path is a concept applicable to both indoor and outdoor type sealing ends.Indoors, the leakage path is unaffected by environmental factors. But outdoors, the level of voltage diverted through the air is a function of the electrical insulation resistance between the voltage point and the earthed point. This electrical resistance depends on environmental factors, such as relative humidity, salinity and atmospheric pollution. Thus outdoors, the leakage path has to be designed in line with environmental conditions.

The leakage path of a termination is determined by multiplying the pollution factor expressed in mm/kV and the maximum grid voltage.

Pollution factor
in mm/kV x maximum voltage
= leakage path of the termination (mm).

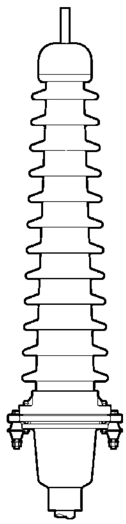
TYPES OF INSULATOR WITH OR WITHOUT FLUID

(SF6 gas or silicon oil).

INSULATORS
FILLED WITH INSULATING FLUID

GLAZED PORCELAIN INSULATORS

The insulator is made of brown or grey glazed porcelain and is closed by two aluminium flanges. There are several advantages to a porcelain sealing end: it is self supporting and does not require any top fastening system. Its surface is self-cleaning which makes it the best choice for the usage in severely polluted environments or highly saline atmospheres.



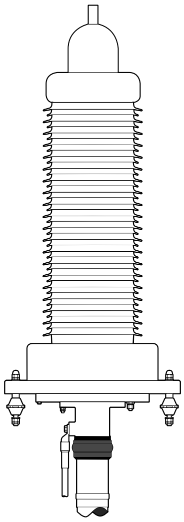
Porcelain sealing end

SYNTHETIC INSULATOR

Known as a composite or rigid synthetic sealing end in which the insulator is made of an epoxy resin glass-fibre reinforced tube, covered

Accessories, sealing ends

with silicon sheds and closed with two aluminium flanges. Composite sealing ends are particularly suited for the usage in industrial sites where the risks of explosion must be limited.



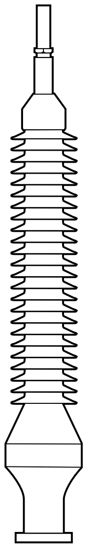
Composite sealing end

INSULATORS
WITHOUT INSULATING FLUID

The sealing ends are said to be "dry" as they do not contain any dielectric fluid.
They can be rigid (self-supporting) or flexible.

FLEXIBLE TYPE ENDS

The insulator is fabricated of a stack of "skirts" made of silicon or a derived product. Due to their light weight, they are especially suited to being installed on pylons. Due to their lack of fluid they are environment-friendly and are often installed in industrial environments. These insulators are not self-supporting and therefore require a fastening system in order to suspend them.



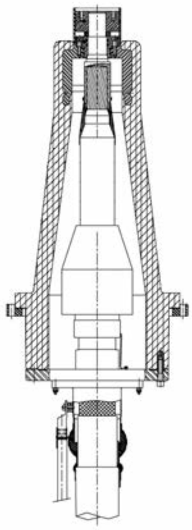
Flexible type dry sealing end

RIGID TYPE SEALING END

The insulator is solid and the cable is connected directly by means of a deflector cone.
Their design is similar to that of the sealing ends used in gas-insulated substations.

GIS OR CIRCUIT-BREAKER SEALING ENDS

These are used to connect the cable to the insulated set of bars. It is necessary to check that the sealing end of the cable is compatible with the type of connection at the substation.
The standard interfaces between a GIS substation and the cable sealing end are defined in standard CEI62271-209. It can be filled with fluid or be dry.
The epoxy insulator represents the limit of liability between the manufacturers of the GIS and the cable system. This is not necessary, if there is only one supplier for both

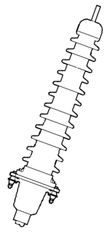


Circuit-breaker sealing end

the GIS and the cable, as it is the case with the French power grid.

When there is no separating insulator, the filling fluid is the same as the GIS fluid. This is generally SF6 gas.

When there is a separating insulator, it may be filled with SF6 or silicon oil. In the latter case, and if the sealing end is not vertical, the use of a compensation tank may be necessary according to the temperature of the oil.



Sealing ends

New designs of GIS sealing ends have appeared on the market. These are dry type sealing ends without fluid. There are two types: **inner cone** and **outer cone.**

TRANSFORMER SEALING END

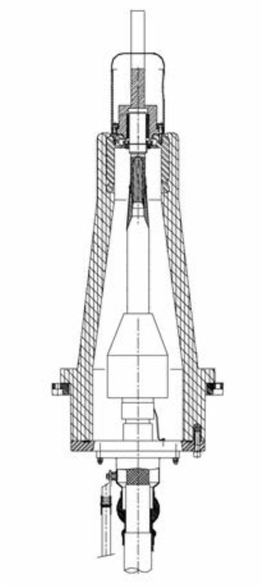
As their name indicates, this type of sealing end is used to connect the cable directly to a transformer. The interface between the cable and the transformer is governed by European standard EN 50299. As there are a great many models of transformers, they are not all compliant to this standard. It is therefore essential to know the transformer design in order to define the most suitable sealing end. In new plants, the sealing ends tend to be the GIS type.

The information required to define the accessory is:

- The position of the sealing end and of the cable
- The type of fluid in which the sealing end is immersed (oil, gas or air).
- The operating temperature
- The standard or particular requirements.

Transformer sealing ends that use an epoxy resin insulator are, totally immersed in the dielectric filling fluid (oil or gas) of the transformer.

If it is installed inclined or with the connection upside down, an expansion compensation tank will be necessary for oil-filled insulators. The electric field is controlled by means of a premoulded elastomer stress cone located on the cable insulation.



Transformer sealing end

ENVIRONMENT-FRIENDLY

The filling fluids are a potential source of pollution. SF6, which is a greenhouse gas, is one of the six gases that need to be closely monitored according to the Kyoto agreement. Silicon oil also has to be monitored, nevertheless to a lesser extent, as it could leak or ignite if the end should become damaged. For these reasons, dry sealing ends without filling fluid are being increasingly developed. This technology is used both for outdoor sealing ends and GIS or transformer sealing ends. Apart from the fact that they have less impact on the environment, dry sealing ends greatly reduce the risk of explosion with projectiles as well as the risk of fire. They also have the advantage of not requiring a system to control the pressure of the fluid.

DIFFERENT MODELS OF SEALING END

Porcelain sealing end **with oil** ➜ From 60 to 500 kV ➜ Utilization: Poles/structures ➜ Polluted environments ➜ Most commonly used	Sealing end in indoor chambers of GIS substations **with oil** ➜ From 60 to 500 kV	Indoor "Transformer" sealing end **with oil** ➜ 500 kV
Outdoor composite sealing end **with oil or SF6 gas** ➜ From 60 to 500 kV ➜ Utilization: Risk of earthquakes and risks of explosion ➜ Installed on pylons		
Outdoor, **flexible, dry sealing end** ➜ From 60 to 145 kV ➜ Utilization: Restricted space ➜ Explosion and fire risks ➜ Restricted installation positions ➜ Installed on pylons ➜ Industrial use	Sealing end in Indoor chambers for **dry** GIS substations ➜ From 60 to 400 kV	Indoor **dry** "Transformer" sealing end ➜ From 60 to 145 kV

Accessories, joints

JOINTS

These accessories are used to join two sections of a cable together in order to allow the power lines to stretch over many kilometers.

There are many different solutions for joining cables. They may differ with regard to the core, materials or thicknesses of the cables. It is nevertheless essential to know the types of cables to be joined.

The joints are named according to their technology as well as the available connections for earthing the screens.

The most commonly used technology for all voltages is the **PREMOULDED** joint.

The taped joint is the technique that has been around the longest and is still used when there are low electrical stresses in the cable insulation.

A **transition** joint is used to join cables with different types of insulation. When the only difference is in the dimensions or type of core (same type of insulation) the joint is called an **adapter** joint.

THE TECHNOLOGY

PREMOULDED JOINT

This consists of a premoulded elastomer body. It is pretested in the factory to ensure its reliability.

The properties of the synthetic material of the premoulded joint ensures that sufficient pressure is maintained at the interface between the cable and the joint throughout the cable's service life.

The dielectric properties of the material offer good electrical esistance under alternating current as well as to lightning and switching overvoltages.

They are mounted either by expanding the premoulded joint or by slipping it onto the cable.

Although the design of the premoulded joint is based on an assembly of prefabricated items, the preparation of the interfaces requires the skills of well-trained technicians.

TAPED JOINTS

The cable insulation is made of synthetic tapes with good dielectric properties and self-bonding abilities. Its use is limited to maximum voltages of 110 kV. As this joint is made manually, its efficiency is directly related to the skill of the electrician.

TRANSITION JOINT

This is used to join cables based on different technologies, such as a paper-insulated cable with a synthetic cable.

It consists of the same components as those used in the to be joined cables and ensures their physical and electrical continuity.

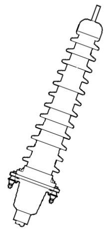
ADAPTER JOINT

This is used when the cables which are to be joined, have the same type of insulation but are of different dimensions.

There are several different methods, some of which are patented, for making these joints.
Among these are:

- A bi-metal joint to join an aluminium core to a copper core.
- A tapered electrode to join two insulated cables of slightly different diameters using a standard premoulded joint.
- A dissymmetrical premoulded joint to join cables with very different dimensions.

Transition joints and adapter joints always require specific design studies.

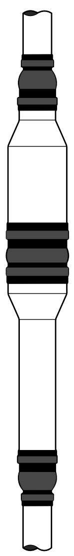


MODELS OF JOINTS ACCORDING TO THE EARTHING OF THE SCREENS

STRAIGHT JOINT

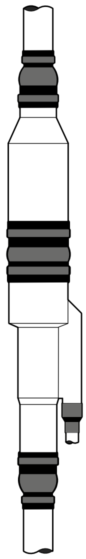
Not earthed: This joint offers electrical continuity of the metal screens of the two cables to be joined. It is used in the case where earthing is at two points, or as an intermediate joint in other earthing systems.

Earthed: this joint ensures the continuity of the metal screens. There is also a connection which allows the screens to be connected to a local earthing point.
This type of joint can be found in mid-point earthing systems and in screen switching systems.



Straight joint

JOINT WITH SCREEN SEPARATION



Joint with screen separation

This joint separates the screen of the right hand cable from that of the left hand cable.

It is used in the case of earthing with cross-bonding

Cross-bonding involves creating interruptions in the screen circuits and making connections between the circuits of different phases in order to cancel out the induced voltages between two earthing points.
Joints with screen separation have two earth connections using two single pole cables or a coaxial cable.

Miscelleanous equipment

The metal screen of a high voltage power line must be earthed.
This requires special components such as earthing boxes and sheath lightning conductors.

MISCELLANEOUS EQUIPMENT

Protective equipment

In high voltage cable installations, the screens are grounded via direct connections or by means of internal or external voltage limiters.

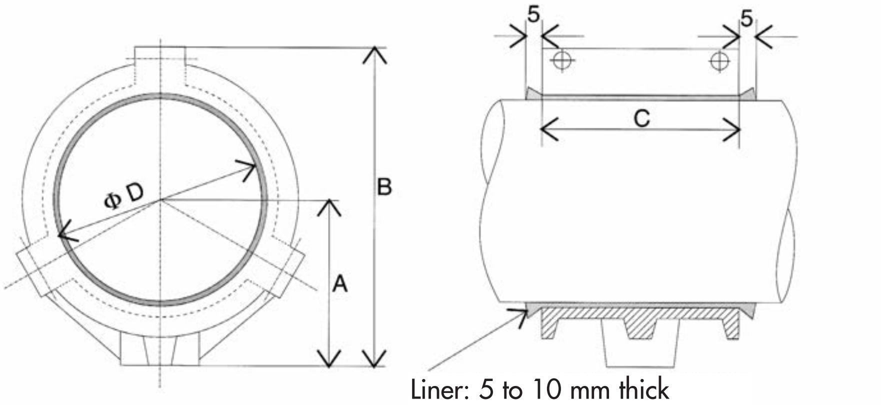
The characteristics of the voltage limiters are as follows:

- service voltage under continuous operation
- allowed short-circuit voltage
- energy dissipation power

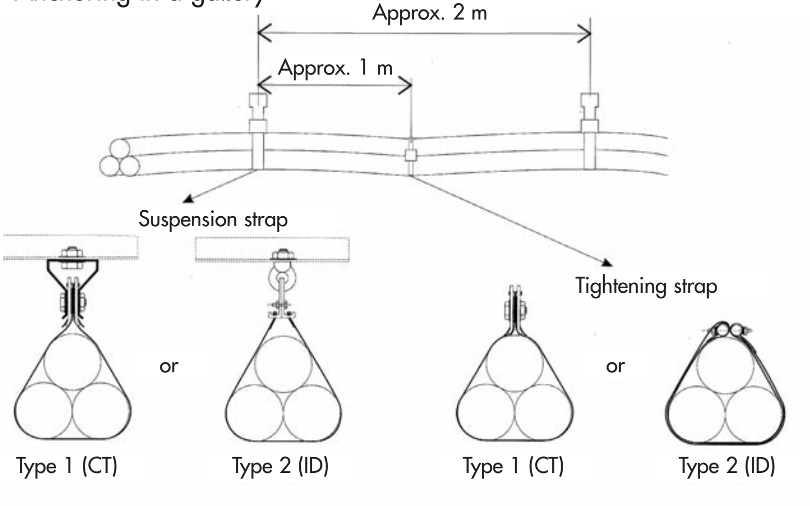
Anchoring devices

Clamps are used to fasten the cables laid along posts or pylons. Straps are used for cables laid in galleries.

These clamps are fastened to rods and fixed or pivot mounts.



Anchoring in a gallery



ERECTING SEALING ENDS

When preparing the cable, it is necessary to prevent direct contact between the outer jacket of the cable and rough protrusions in the concrete. The cable is therefore laid inside a flexible plastic duct (such as the ringed type). This duct is a few centimetres above ground level at the outlet from the concrete (it is then closed with plaster).

Protective grid

Where the metallic screens are insulated from ground using voltage limiters, it is necessary to protect the cable layers from any power surges from the screens (up to 400 V under continuous operation and 20 kV under transient operating conditions) by means of an amagnetic grid. If the lower metal parts of the box (mount) are located at a height of over 3 m (for 400 kV in particular) this protective grid is not necessary.

Cable clamps

Where the cable is laid vertically, 2 or more clamps are used to fasten the cable to the structure.

SEALING ENDS INSTALLED ON TOWERS

Platform

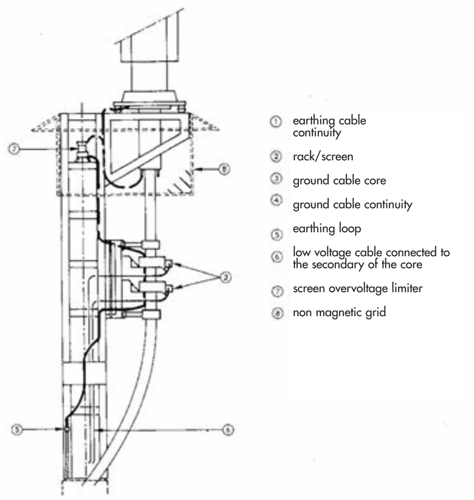
The connection with the overhead lines is via a retention chain. The cable sealing ends are installed on a horizontal platform at a minimum height of 6 m, surrounded by a protective safety fence (made of removable panels) in order to prevent unauthorized access to the tower structures (after locking out the work area).

Screen overvoltage limiter

In the case of special sheath connections, the overvoltage limiters are installed on the screens at the tower end to prevent retransmission of the "cable earthing protection", as mentioned above, with an amagnetic grid or other system to protect the personnel (the CT is installed at the relay side).

Cables

Rising cables, clamped in place between the ground and the sealing ends are protected by a metal structure at least 2 m high, surrounding the three phases.



Erecting sealing end

In-service experience has shown that the reliability of underground links is dependent on the careful transportation, reel handling and the quality of the cable installation on the site.

CABLE LAYING

Protection of the cable

External aggression

To ensure long service life of the installation, the cable protection is dependent on the cable laying conditions. In general, cables should be installed in such a way as to avoid any mechanical aggression, both on laying and during its service life.

Mechanical Aggressions

These may occur during transport, handling, pulling or installation of accessories.

Corrosion

Corrosion may be of chemical or electrochemical origin, or from sulphate reducing bacteria. In direct current supply areas (electric traction, trams, static or mobile industrial plant such as electrolyte refining plant, welding machines, etc.) the presence of stray-currents can give rise to extremely violent and rapid corrosion.

Environmental constraints

Some structures such as pipe lines and ducts require particular precautions when installed near to a high voltage line. The terrain (coastal area, water table, mining area, for example) and such natural obstacles as tree roots may also present further constraints.

Installation of cable circuits - choice of route

The following criteria apply:

- Width of the available land,
- Sub-soil conditions,
- Particular features (drains, bridges, etc.),
- Proximity of heat sources (other cables, district heating systems).

In addition, the location of the joint chambers must take into consideration:

- The maximum production lengths of cable,
- The maximum pulling lengths,
- The grounding technique used (cross-bonding).

Proximity of telecommunications cables (other than those included in the cable installation, whose protection is integrated) and hydrocarbon pipes must be avoided owing to the problems caused by induction.

The distances to be observed must comply with existing standards.

Type of installation

Buried cables

In most cases, insulated cable lines are laid inside underground ducts whose main characteristics are described below.

Direct burial

This cable laying technique is widely used in most countries. Its speed and relatively low cost are its main advantages. Use of light mortar or thermal filler instead of fine sand considerably improves the transmission performance of the circuit.

Excavation depth

These depths are necessary to ensure that the cables are protected from mechanical aggressions (vehicles, digging tools, etc …) and to ensure the safety of property and people in the event of an electric fault.

- public land:
  1.30 m/1.50 m
- electricity stations:
  1.00 m

The electrodynamic effects of a fault are more severe with this laying method than when the cables are laid in a duct, as the duct acts as a decompression chamber.

Excavation width

The width depends on the laying method used and the spacing recommended by the cable-layer according to the currents to be transmitted. The width occupied by the cables is further increased to allow for:

- the filling sand or mortar,
- operations such as cable pulling on the excavation floor,
- lacing:
  for safety reasons, lacing is compulsory for depths of over 1.30 m

Excavation floor

The cables must be layed on a bed of sand at least 15 cm thick or on a smooth surface.

Smooth bed:

A smooth bed of 100 kg mortar 5 to 10 cm thick is made at the bottom of the excavation.

Distance between two lines:

This distance depends on the thermal assumptions used for calculating the transmission capacity of each line.
In practice, a minimum distance of 70 cm is recommended.

Backfilling

According to the laying method used, this is made in successive compacted layers.

Warning device

According to the laying system used, this can be a cement slab, a warning grid or warning tape.

Earthing cable

The insulated earthing cable, if used (for earthing of "special sheath connections" and/or installing a special drainage system to prevent stray-current corrosion) is placed near to the cables.

Mechanical laying with light mortar

This laying method, still quite uncommon, is only applicable for HV < 150 kV and more commonly for medium voltages, outside urban or suburban areas containing a dense utilities network (water, gas, electricity, telecommunications, district heating, etc.).

Excavation width

The minimum width is approximately 0.25m.
This width (occupied by the cables) should be increased as indicated above.

Excavation floor

Cable pulling directly on the excavation floor is strictly prohibited. A clean bed of 100 kg mortar 5 to 10 cm thick must be made on the excavation floor.
The clean bed and distance between lines are the same as in the conventional laying method..

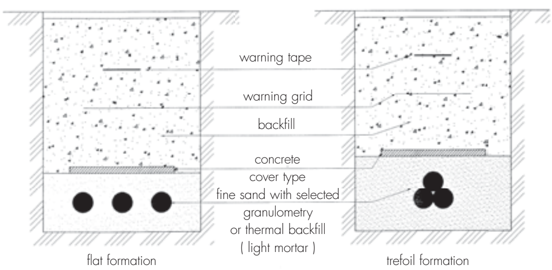
Warning device

A warning device is placed around 10 cm above the top surface of the mortar on each line (grid, slab or steel plate, for example).

Thermal backfill

Experience has shown that the thermal characteristics of controlled backfill on public land can not be maintained over time (other works nearby, soil decompression or reduced earth resistivity).
Thermal backfill should even be avoided in electricity stations wherever possible.
In some exceptional cases, however, installation in soil that is unsuitable for compacting or manifestly hostile (rock, clinker, plastics, clay, chalk, pumice stone, basalt, vegetable matter), it will be necessary to use thermal backfill.

Simple trench



LAYING IN CONDUIT

Buried conduits

Close trefoil formation

This cable laying method is generally used in urban areas as it offers good mechanical protection of the cables.

Excavation depth

The dynamic effects of a short-circuit necessitate particular precautions at shallow depths (in the particular case of reinforced concrete with cables laid in ducts). On public land, the minimum depth is 1.4 m at the excavation floor and 0.80 m inside electricity stations. It is essential to compact the filling material, tamping it after each 20 cm layer, in order to ensure that the ground is firmly reconstituted.

Excavation width

- Trenches
  The minimum excavation width must take into account the space needed for the workmen, the lacing if used, and when two lines are installed together, a minimum distance of 0.70 m between the two conduits. When lacing is used, an extra 4 cm must be allowed on either side of the excavation.
- Between circuits
  This distance depends on the thermal assumptions used for calculating the transmission capacities of each line. In practice, a minimum distance of 0.70 m is recommended.

Warning device

A warning device is placed above the conduit (at a depth of approximately 20 cm); this may be a grid, some bricks or a steel plate.

Earthing cable

In the case of special screen connections, the earthing cable will be placed in the conduit above the cable trefoil, as near as possible to the cables, in order to reduce induced voltage on the cables.
The earthing cable will be transposed if the cables are not.
In certain cases of areas with stray currents, an auxiliary earthing cable may be laid in the same way.

Telecommunication cables

Telecommunication cables, known as "pilot cables" will always be laid inside concrete encased ducts, which offers excellent mechanical protection and facilitates access for repairs.

Particular precautions
Lacing is compulsory at depths over 1.3 m.

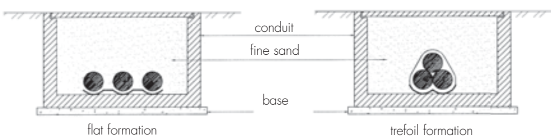
Ground level conduits

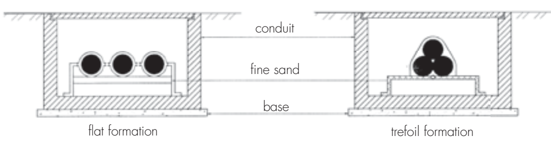
These are mainly located inside electricity stations.

Cable laying in air on a support

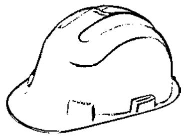
To take lengthwise expansion of the cables into account, these are laid in a "snaking" fashion along the conduit.
To maintain the cables when subjected to the electrodynamic loads resulting from a short-circuit, they must be clamped together at regular intervals, the distance of which depends on the quality of the clamping system and the forces developed.

Laying in conduits





Laying in buried conduits



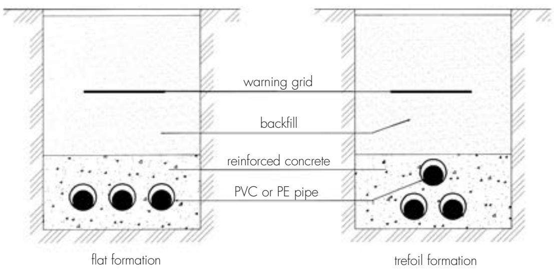
LAYING IN DUCTS

Cable-laying in ducts has a major advantage over conventional burial in that the civil engineering work can be done before laying the cables, thus avoiding the problems of leaving the trenches open for a prolonged period in urban areas.

Note that the use of ducts meets the following requirements:
- Limited duration of the installation works,
- Efficient mechanical protection wherever the ground is subjected to particularly heavy loads and where there is considerable vibration (risk of lead crystallization),
- Avoids having to reopen a trench for the same route.

Laying in non-touching trefoil formation inside concrete encased PVC or PE ducts:
This is the most common formation.
Laying flat and non-touching in concrete encased PVC or PE ducts:
This formation is generally reserved for particular cases (protected cables: 225 and 400 kV auxiliaries, road crossings, etc.).

Typical road crossing



Non-touching trefoil formation

Excavation depth

The excavation floor depths are as follows:
- on public land: 1.50 m
- in electricity stations: 0.90 m

A minimum thickness of 10 cm of concrete around the ducts is recommended. It is essential to compact the filling material to ensure that the ground is firmly reconstituted.

Excavation width

This depends mainly on the outside diameter of the duct used for the cable as well as on the necessary space for:
- installing the ducts: 4 cm is allowed between the ducts for filling with concrete
- lacing:
  an extra width of 4 cm on either side of the trench must be allowed for installing the lacing. There should be 10 cm between the lacing and the ducts to be filled with concrete.
- space between two lines:
  This distance depends on the thermal assumptions used for calculating the transmission capacity of each power line. In practice, a minimum distance of 70 cm is recommended.

Duct installation

- The bend radius of the ducts must be 20 times their outside diameter.
- The ducts are assembled together according to the pulling direction
  - A gauge of the appropriate diameter must be passed through the ducts (0.8 times the inside diameter of the duct). The ducts must be gauged and closed.
  - It is recommended to use tube supports to ensure the correct distance between the ducts (the distance between the "teeth" of the tube support is 10 times the outside diameter of the duct).

Warning device

In the case of cables laid in concrete encased ducts, a warning device is placed around 10 cm above the top of the concrete (grid, steel plate, slab, etc.).

Earthing cable

The insulated earthing cable, if any, is placed inside a PVC duct of OD 75 mm embedded in the concrete alongside the cable trefoil between two phases (as near as possible to the cables to reduce the induced voltages on the screens). For the same reason, the earthing cable must be transposed if the power cables are not.

Thermal backfill

As concrete has good thermal characteristics, there is no need to use thermal backfill.

Shallow Laying (in reinforced concrete)

In public areas, where the excavation depth is limited by certain obstacles, it is recommended to use reinforced concrete, while the cables cannot be laid at a depth of less than 0.60 m.

Flat, in spaced ducts

This laying technique is used in exceptional cases only. The laying technique is identical to that described above, while the distance between the ducts is calculated according to a thermal study.

Installation

LAYING IN GALLERIES

Where there are several power links running along the same route, it may be decided to construct a gallery to house the cables.

ADVANTAGES

- Several cables can be installed in a limited space, without reducing the transmission capacity of each line due to thermal proximity, providing that the gallery is well aired or evenly ventilated,
- Cables can be laid at different times by reopening the gallery,
- Repair and maintenance work can be conducted inside the galleries.

DRAWBACKS

- The main drawback is the high construction cost (water tightness, floor work, equipment)
- The necessary fire prevention measures must be taken.

TYPES OF GALLERY

The gallery design must comply with the following minimum values:

- Minimum height 2 m (under ceiling), regardless of the width,
- Free passage 0.90 m wide (in the centre for cables installed on both sides or at one side).

  This minimum passage is used for installing and mounting cables, repairs, maintenance, gallery maintenance, etc.

Maintenance Shaft

Safety

There must be at least two entrances to the gallery, regardless of its length, with a maximal distance of 100 m between two shafts to ensure the safety of workers in the event of an accident and to allow them to escape. Minimum cross-section of the shaft 0.9 m x 0.9 m (1.5 m x 1 m at the entrance).

Ventilation Shaft

When defining the cables to be installed in a gallery, the ambient temperature inside the gallery is assumed to be 20°C in winter and 30°C in summer.

For a conventional HV or EHV line installation in a conduit, the energy loss per line is around 50 to 200 W/m, dissipated by conduction into the ground through the walls of the chase. This energy loss is also dissipated by the air in the gallery, the temperature of which should be maintained within the above temperatures.

Gallery fittings

The cables are generally suspended from fittings attached to the wall or in cable tray (BA or metal racks, etc.).

In all cases, the metal fittings contained inside the gallery will be grounded (equipotential bonding lead).

Cable fittings in galleries, tunnels or ground level conduits

XLPE cables have the particularity of having a high expansion coefficient, both radially and longitudinally.

To compensate for radial expansion, an elastomer (Hypalon or EPDM type) lining must be inserted between the clamp and the cable. For reasons of longitudinal expansion, and when the cables are installed in the air over long distances, they must be laid in a "snaking" fashion.

The amplitude, sag and pitch of the snaking pattern will vary according to the electrical characteristics of the circuit. As a rule, a pitch of 25 times the cable diameter between two static supports and a sag amplitude equal to the cable diameter are used.

There are different laying methods

Flat Vertical

Installation

- The cables are fastened to supports at regular intervals
- The cables snake vertically
- The cables can be clamped together between supports
- The cables may be unwound directly onto the support

Flat Horizontal

Installation

- The cables are fastened to supports at regular intervals or run along cable trays
- The cables snake vertically or horizontally
- The cables may be clamped together

Touching Trefoil Formation

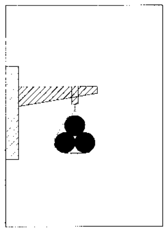
Installation

- The cables are suspended on supports at regular intervals
- The cables can be strapped together between the supports
- The cables snake vertically

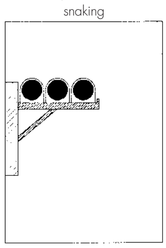
Trefoil Formation on Rack

As above

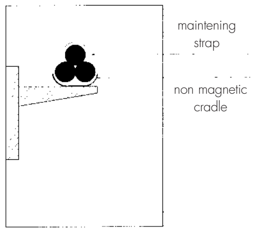
trefoil formation vertical snaking configuration



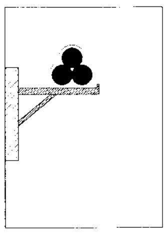
flat formation on rack, with horizontal snaking

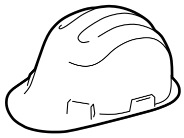


trefoil formation on supports, vertical snaking



trefoil formation on rack, horizontal snaking





An underground circuit may be composed of several sections jointed together inside what are called "jointing chambers" or joint pits, or joint vaults.

CONNECTION

IN JOINTING CHAMBERS

Before the joint boxes are installed, the jointing chambers are composed of a clean bed and water sump.

Cable layout

The cables are laid flat inside the splicing chamber to allow the joint boxes to be installed.

Joint layout

The layout will depend on the space available.
We may cite the following types of layout:

- offset joints: the most common layout
- side-by-side joints, if the jointing chamber is wide and not very long
- staggered joints: rarely used.

Whatever the layout, the long side of the joint is always offset from the chamber axis in order to allow for expansion and contraction (expansion bend).

Telecommunication cables

Telecommunication cables (carrier or fibre optic cables) which are always laid in duct banks, are installed in the above chambers or in a special chamber.

BACKFILLING AND COMPACTING

Ensure the following functions:

- Safety in the event of a short-circuit,
- Heat exchange with the ground (cable transmission capacity),
- Mechanical strength of the ground (traffic, etc.),
- Protect the cable against external impact.

All excavations are filled in successive layers, well tampered between each layer.

THERMAL BACKFILL

Backfill with controlled thermal characteristics is used to compensate for thermal insufficiency at certain points along the cable route which limits the transmission capacity of the line.
Natural sand can be used for this.

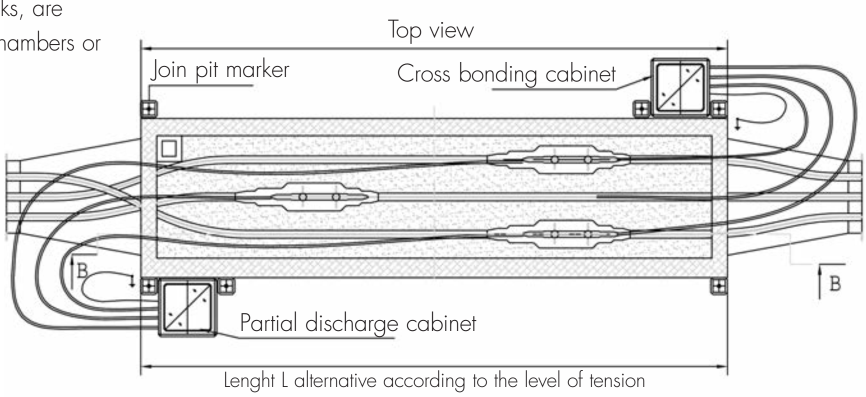
Cable Temperature Control
Thermocouples can be installed at particular points along the cable route, such as:

- entrance to duct-banks,
- galleries,
- splice boxes,
- cable crossings,
- near heat sources.

MARKING OF UNDERGROUND CABLES

Self-extinguishing, self-tightening PVC labels are affixed at particular points along the cable route, such as:
at the sealing end,
at the jointing chambers: on either side of splices,
in the galleries: upstream and downstream,
in the duct banks and connection box: at the input and output of the bank and in elements belonging to other utilities, with a danger sign.
Earthing cables, telecommunications cables and wiring boxes are marked in the same way.

Type of joint pit



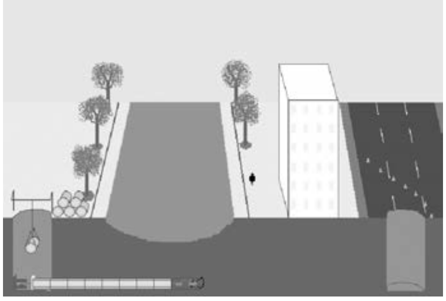
SPECIAL CIVIL ENGINNERING WORKS

The techniques used for sinking shafts and boring galleries have specific advantages when tackling particular problems such as road, motorway, railway, canal, river or bank crossings.

SHAFT SINKING TECHNIQUE

This process is specially designed for installing prefabricated, reinforced concrete, large diameter (>1000 to <3,200mm) pipe sections with the same cross-section as the gallery to be made, which is either horizontal or on a slight slope, without affecting the obstacle to be crossed (road, etc.).

Two microtunneling techniques exist, depending on project specifics:
- Pilot Soil Displacement System
- Slurry Spoil Removal System

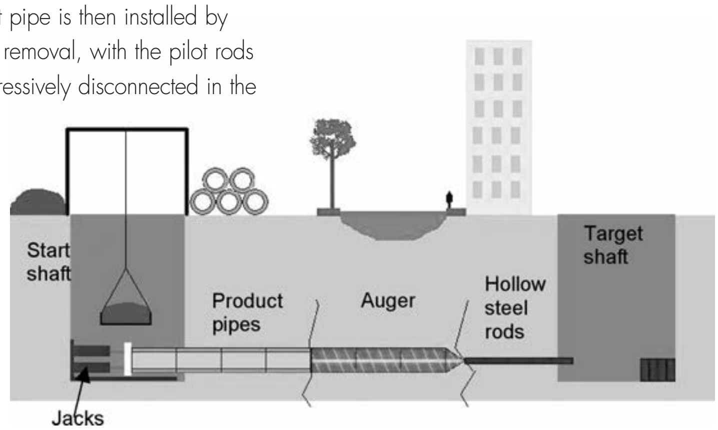


PILOT SOIL DISPLACEMENT SYSTEM

Hollow steel pilot rods are first jacked from the start shaft, steered by a laser beam.

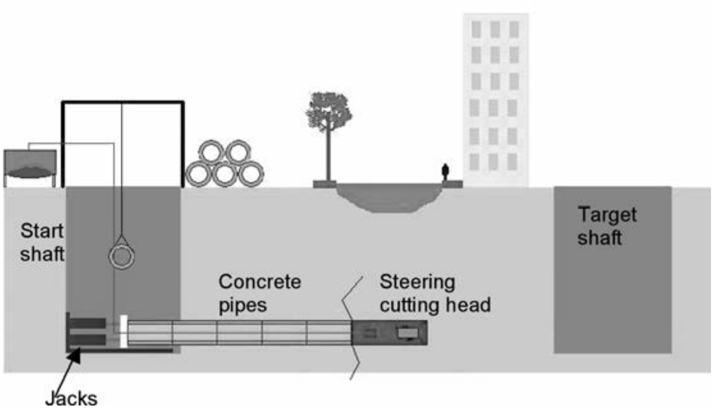
When the tip of the first pilot rod has arrived in the target shaft, an auger system is then connected to the last pilot rod that has been inserted.

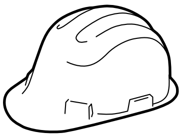
The product pipe is then installed by auger spoil removal, with the pilot rods being progressively disconnected in the target shaft.



SLURRY SPOIL REMOVAL SYSTEM

The cutting head is steered by a laser beam.
The microtunneling machine steering head advances and pipes are successively pushed forward by hydraulics jacks.
A slurry spoil system excavated earth.





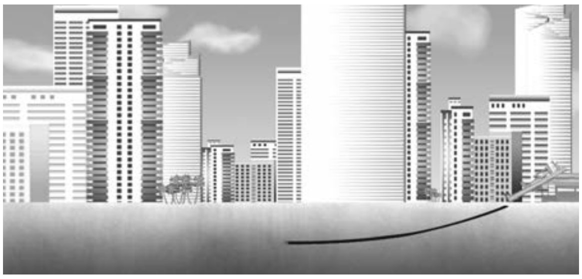
Horizontal Directional Drilling

This method (HDD) is particularly useful for water crossings (rivers or canals).

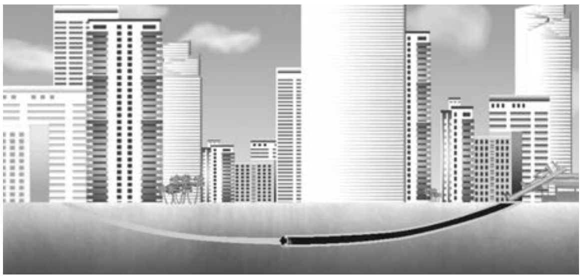
The diagrams opposite gives an example of the horizontal directional drilling process, showing some of the equipment used.

Drilling methods

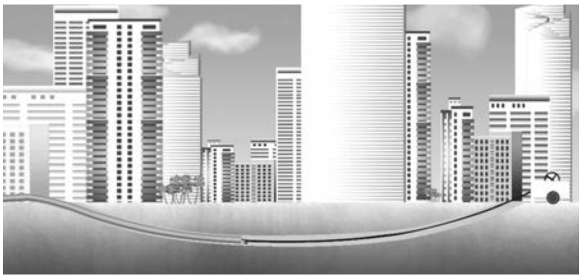
Pilote hole



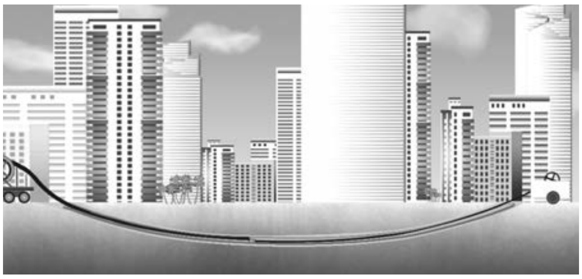
Tubing



Boring



Pulling



Necessary information for designing a HV power line

- Grid voltage
- Length of power line
- Current to be transmitted
- Laying method
- Maximum laying depth
- Short-circuit current value and duration
- Ground and air temperature
- Proximity of heat sources (cable, hot water pipes for example)
- Thermal resistivity of the ground

and for determining the necessary accessories for a high voltage line

- Position of the line in the grid,
- Atmospheric environment,
- Type of transformer, if applicable,
- Accessory installation height
- Temperatures (min and max)

Laying method	Transmission capacity Phase-to-phase voltage Current Circuit Length	120 MVA 132 kV 523 A 300 m	400 MVA 220 kV 1050 A 1000 m
Direct burial - 1 circuit	Conductor cross-section and type	400 mm^2 aluminium	800 mm^2 cuivre
Thermal resistivity of ground = 1 K.m/W	Metallic screen earthing system	At 2 points	At 1 point
Ground température = 20°C	Laying method	Touching trefoil formation	flat
Laying depth L = 800 mm	Laying diagram	T1	N1 : s = 180 mm
Direct burial – 1 circuit	Conductor cross-section and type	630 mm^2 aluminium	1600 mm^2 copper (segmental - enamelled wire)
Thermal resistivity of ground = 2 K.m/W	Metallic screen earthing system	At 2 points	At 1 point
Ground temperature = 35°C	Laying method	Touching trefoil formation	flat
Laying depth L = 2000 mm	Laying diagram	T1	N1 : s = 450 mm
In cable gallery	Conductor cross-section and type	300 mm^2 aluminium	630 mm^2 copper
Air temperature = 40°C	Metallic screen earthing system	At 2 points	At 1 point
	Laying method	Touching trefoil formation	flat
	Laying diagram	T2	N2 : s = 180 mm
Cable in concrete-embedded ducts - 2 circuits	Conductor cross-section and type	800 mm^2 aluminium	2000 mm^2 copper (segmental - enamelled wire)
Thermal resistivity of ground = 2 K.m/W	Metallic screen earthing system	At 2 points	At 1 point
Ground temperature = 35°C	Laying method	Touching trefoil formation	flat
Laying depth L = 800 mm	Laying diagram	T3 : s = 200 mm x 700	N3 : s = 400 mm x 2500 mm

IMPACT OF LAYING METHOD ON THE ALLOWED CURRENT

We can seen in the above table that different cross-sections are required for the same current transmission, depending on the cable laying conditions which affect the electrical efficiency of the cable.
This is why it is necessary to know these parameters before calculating the cross-section.

Tables of current ratings for copper and aluminium conductors

The metallic screens are designed to withstand short-circuit current as per the table below.

Phase-to-Phase Voltage kV	Short-circuit current
63 ≤ U < 220	20 kA – 1 sec
220≤ U ≤ 345	31,5 kA – 1 sec
345< U ≤ 500	63 kA – 0,5 sec

load factor: 100%

The figures given in the following tables allow **an initial estimation** to be made of the necessary cable cross-section.

They can not replace the calculation made by Nexans' High Voltage Technical Department that integrates all the necessary parameters.

Conductor cross-section and calculation of current rating

The conductor cross-section is determined by the transmission capacity or the current transmitted by each phase according to the following formula

$$I = \frac{S}{\sqrt{3} x U} \text{ in amperes}$$

I: current rating
S: apparent power of the line in kVA
U: rated phase-to-phase voltage.

The conductor cross-section must be such that the heating of the cable insulation due to the resistance losses and dielectric losses generated in the cable is compatible to its resistance to heat.

These rated temperatures are as follows for XLPE insulation:

- Temperature under rated operating conditions	90 °C
- Temperature under emergency operating conditions	105 °C
- Temperature in the event of a short-circuit (< 5 sec)	250 °C

The current ratings in amps given in the following tables need to be corrected according to the different parameters.

These parameters are:

- the laying conditions, buried or in air
- the thermal resistivity of the ground,
- the temperature of the ground,
- the temperature of the air,
- the proximity effect from 2, 3 or 4 circuits

Correction factors

Laying depth in meters	1,0	1,2	1,3	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0
Correction factor	1,03	1,01	1,00	0,98	0,95	0,93	0,91	0,89	0,88	0,87	0,86

Thermal resistivity of the ground	0,8	1,0	1,2	1,5	2,0	2,5
Correction factor	1,09	1,00	0,93	0,85	0,74	0,67

Ground temperature in °C	10	15	20	25	30	35	40
Correction factor	1,07	1,04	1,00	0,96	0,92	0,88	0,84

Air temperature in °C	10	20	30	40	50	60
Correction factor	1,17	1,09	1,00	0,90	0,80	0,68

Proximity effects distance between 2 circuits (mm)	400	600	800	1000
1 circuit	1,00	1,00	1,00	1,00
2 circuits	0,79	0,83	0,87	0,89
3 circuits	0,70	0,75	0,78	0,81
4 circuits	0,64	0,70	0,74	0,78

Tables of rated currents

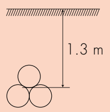
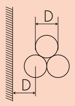
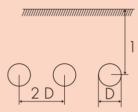
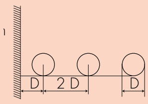
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
185 R	16.2	10.9	0.1640	0.18	190	55	3	95	60	7	105	56	3	250	64	3	810	63	12
240 R	18.4	10.5	0.1250	0.20	200	56	3	95	62	8	105	58	4	260	65	3	810	64	12
300 R	20.5	10.5	0.1000	0.22	190	59	3	95	64	8	100	60	4	270	67	4	810	66	12
400 R	23.3	10.7	0.0778	0.23	180	62	4	90	67	9	100	64	4	310	72	4	820	69	13
500 R	26.4	10.9	0.0605	0.25	180	65	4	85	71	9	100	67	5	330	76	5	810	72	13
630 R	30.3	11.1	0.0469	0.27	190	70	5	85	76	10	95	72	5	350	80	6	800	76	14
800 R	34.7	11.4	0.0367	0.29	190	75	6	80	81	11	90	77	6	400	87	7	800	80	15
1000 R	38.2	11.5	0.0291	0.31	170	79	7	75	85	13	90	81	7	420	91	7	790	84	15
1200 R	41.4	11.6	0.0247	0.33	180	82	7	65	88	14	85	84	8	470	95	8	810	87	16
1600 S	48.9	11.9	0.0186	0.37	210	92	9	55	98	17	80	94	10	560	106	11	800	96	18

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions induced current in the metallic screen	Direct burial  ρ_T en K.m/W		In air, in gallery 		Earthing conditions induced current in the metallic screen	Direct burial  ρ_T en K.m/W		In air, in gallery 		
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
185 R	With circulating currents	350	305	435	345	Without circulating current	375	325	505	405	185 R
240 R		405	350	510	405		435	375	595	475	240 R
300 R		455	390	580	460		490	420	680	545	300 R
400 R		515	445	670	530		560	485	795	635	400 R
500 R		580	500	770	610		645	555	925	735	500 R
630 R	Without circulating current	695	595	930	740		735	635	1 080	860	630 R
800 R		785	675	1 070	850		835	720	1 250	1 000	800 R
1000 R		870	745	1 210	960		940	805	1 425	1 135	1000 R
1200 R		930	800	1 310	1 040		1 015	870	1 560	1 245	1200 R
1600 S		1 130	970	1 640	1 300		1 230	1 055	1 940	1 550	1600 S

Voltage 36/63 to 40/69 (72,5)kV Copper Conductor

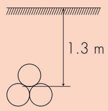
Constructional data (nominal)

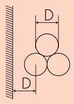
Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
185 R	15.9	11.0	0.0991	0.18	190	55	4	95	60	8	105	56	5	250	64	4	820	63	13
240 R	18.4	10.5	0.0754	0.20	200	56	5	95	62	9	105	58	5	260	65	5	810	64	14
300 R	20.5	10.5	0.0601	0.22	190	59	5	95	64	10	100	60	6	270	67	6	810	66	14
400 R	23.2	10.7	0.0470	0.23	180	62	6	95	67	11	100	63	7	310	72	7	820	69	15
500 R	26.7	10.9	0.0366	0.25	180	66	7	85	71	12	100	68	8	330	76	8	810	72	16
630 R	30.3	11.1	0.0283	0.27	190	70	9	85	76	14	95	72	9	350	80	9	800	76	18
800 R	34.7	11.4	0.0221	0.29	190	75	11	80	81	17	90	77	11	400	87	12	800	80	20
1000 R	38.8	11.5	0.0176	0.31	180	79	13	75	85	19	90	81	14	430	91	14	800	84	22
1000 S	40.0	11.6	0.0176	0.33	180	82	14	65	88	20	85	84	14	470	95	15	810	87	23
1200 S	42.5	11.7	0.0151	0.34	190	85	15	65	91	22	85	87	16	490	98	16	810	90	24
1600 S	48.9	12.6	0.0113	0.36	170	93	20	50	100	29	80	96	21	570	108	22	780	98	29
1 600 S En	48.9	12.6	0.0113	0.36	170	93	20	50	100	29	80	96	21	570	108	22	780	98	29

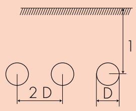
*Indicative value

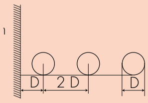
R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)









Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial (ρ_T en K.m/W)		In air, in gallery		Earthing conditions	Direct burial (ρ_T en K.m/W)		In air, in gallery		
mm²	induced current in the metallic screen	ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	induced current in the metallic screen	ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
185 R	With circulating currents	445	385	555	440	Without circulating current	480	415	645	515	185 R
240 R		510	440	645	510		555	480	765	610	240 R
300 R		570	490	730	580		630	540	875	700	300 R
400 R		635	550	835	660		715	615	1 010	810	400 R
500 R		710	610	955	755		815	700	1 175	940	500 R
630 R	Without circulating current	860	740	1 155	915		925	795	1 360	1 085	630 R
800 R		955	820	1 310	1 040		1 040	895	1 560	1 245	800 R
1000 R		1 045	895	1 455	1 155		1 150	985	1 755	1 400	1000 R
1000 S		1 130	970	1 590	1 260		1 225	1 050	1 870	1 495	1000 S
1200 S		1 210	1 035	1 715	1 360		1 320	1 130	2 040	1 625	1200 S
1600 S		1 285	1 100	1 860	1 475		1 405	1 205	2 215	1 770	1600 S
1600 S En		1 385	1 190	2 015	1 600		1 535	1 315	2 420	1 930	1600 S En

Voltage 52/90 (100)kV Aluminium Conductor

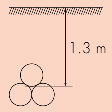
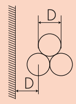
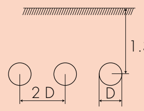
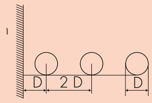
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
240 R	18.4	12.4	0.1250	0.18	190	59	3	95	65	8	100	61	4	280	68	4	820	67	12
300 R	20.5	11.4	0.1000	0.20	190	60	3	95	65	8	100	61	4	300	70	4	810	67	12
400 R	23.3	10.1	0.0778	0.24	190	60	4	95	65	8	100	62	4	300	70	4	810	67	13
500 R	26.4	11.3	0.0605	0.24	180	65	4	85	71	9	100	67	5	330	76	5	810	72	13
630 R	30.3	10.4	0.0469	0.28	180	68	5	85	73	10	95	70	5	340	78	5	820	74	14
800 R	34.7	12.4	0.0367	0.27	190	76	6	80	82	12	90	78	6	410	88	7	810	82	15
1000 R	38.2	10.8	0.0291	0.32	190	76	6	75	83	12	90	79	7	410	88	7	820	82	15
1200 S	41.4	11.4	0.0247	0.33	180	81	7	75	87	14	90	83	8	460	94	8	790	86	16
1600 S	48.9	11.2	0.0186	0.39	200	90	9	60	96	17	85	93	10	520	104	10	810	95	18

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
240 R	With circulating currents	405	350	510	405	Without circulating current	435	375	590	470	240 R
300 R		455	390	580	460		490	420	675	540	300 R
400 R		515	440	670	530		560	485	795	635	400 R
500 R		580	500	770	610		640	550	920	735	500 R
630 R	Without circulating current	695	595	930	735		735	630	1085	865	630 R
800 R		780	670	1070	845		835	715	1245	995	800 R
1000 R		865	740	1205	955		935	800	1430	1140	1000 R
1200 S		930	795	1310	1035		1010	865	1565	1245	1200 S
1600 S		1130	965	1645	1300		1230	1050	1950	1555	1600 S

Voltage 52/90 (100)kV Copper Conductor

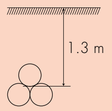
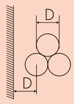
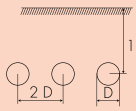
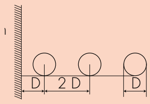
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectiona area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	μF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
240 R	18.4	12.4	0.0754	0.18	190	59	5	95	65	9	100	61	5	280	68	5	820	67	14
300 R	20.5	11.4	0.0601	0.20	190	60	5	95	65	10	100	61	6	300	70	6	810	67	14
400 R	23.2	10.1	0.0470	0.24	190	60	6	95	65	11	100	62	7	300	70	6	810	67	15
500 R	26.7	11.2	0.0366	0.24	180	65	7	85	71	12	100	67	8	330	76	8	810	72	16
630 R	30.3	10.4	0.0283	0.28	180	68	9	85	73	14	95	70	9	340	78	9	820	74	18
800 R	34.7	12.4	0.0221	0.27	190	76	11	80	82	17	90	78	12	410	88	12	810	82	20
1000 R	38.8	10.5	0.0176	0.33	190	77	13	75	83	19	90	79	13	410	88	13	790	82	22
1000 S	40.0	12.0	0.0176	0.31	180	81	13	75	87	20	90	83	14	460	94	14	790	86	22
1200 S	42.5	12.0	0.0151	0.33	190	85	15	65	91	22	85	88	16	490	98	16	790	90	24
1600 S	48.9	11.2	0.0113	0.39	200	90	20	60	96	28	85	93	21	520	104	21	810	95	29
1600 S En	48.9	11.2	0.0113	0.39	200	90	20	60	96	28	85	93	21	520	104	21	810	95	29

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
240 R	With circulating currents	510	440	645	515	Without circulating current	555	480	755	605	240 R
300 R		565	490	730	580		630	540	870	695	300 R
400 R		635	545	830	660		715	615	1015	810	400 R
500 R		715	610	955	755		815	700	1175	935	500 R
630 R	Without circulating current	860	740	1155	915		925	795	1365	1090	630 R
800 R		955	820	1310	1040		1040	890	1550	1240	800 R
1000 R		1035	890	1450	1150		1145	980	1765	1405	1000 R
1000 S		1130	970	1590	1260		1225	1050	1875	1495	1000 S
1200 S		1205	1035	1715	1360		1315	1130	2035	1625	1200 S
1600 S		1265	1080	1850	1465		1400	1195	2225	1775	1600 S
1600 S En		1365	1170	2000	1585		1520	1305	2430	1935	1600 S En

Voltage 64/110 (123)kV Aluminium Conductor

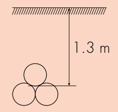
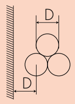
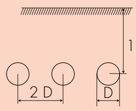
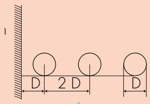
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen: Sectional area*	Aluminium screen: Outside diameter of cable*	Aluminium screen: Weight of cable*	Copper wire/lead sheath: Sectional area* copper screen	Copper wire/lead sheath: Outside diameter of cable*	Copper wire/lead sheath: Weight of cable*	Copper wire/alu sheath: Sectional area* copper screen	Copper wire/alu sheath: Outside diameter of cable*	Copper wire/alu sheath: Weight of cable*	Corrugated Alu sheath: Sectional area*	Corrugated Alu sheath: Outside diameter of cable*	Corrugated Alu sheath: Weight of cable*	Lead sheath: Sectional area*	Lead sheath: Outside diameter of cable*	Lead sheath: Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
240 R	18.4	15.4	0.1250	0.16	180	66	4	85	72	9	100	68	5	330	77	4	800	73	13
300 R	20.5	14.7	0.1000	0.17	180	67	4	85	73	9	100	69	5	340	77	5	810	73	13
400 R	23.3	14.0	0.0778	0.19	190	69	4	85	74	10	95	71	5	340	79	5	810	75	13
500 R	26.4	13.4	0.0605	0.21	190	71	5	80	76	10	95	72	5	380	82	5	810	76	14
630 R	30.3	12.9	0.0469	0.24	180	73	5	80	79	11	90	76	6	390	85	6	800	79	14
800 R	34.7	12.9	0.0367	0.27	170	78	6	75	84	12	90	80	7	420	90	7	810	83	15
1000 R	38.2	13.1	0.0291	0.28	180	82	7	70	88	14	85	84	8	470	95	8	800	87	16
1200 R	41.4	13.3	0.0247	0.29	190	86	8	65	92	15	85	88	8	490	99	9	790	90	16
1600 S	48.9	13.6	0.0186	0.33	170	95	10	50	102	18	80	98	10	580	110	11	800	100	19

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen					induced current in the metallic screen					
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
240 R	With circulating currents	405	350	510	405	Without circulating current	430	375	580	465	240 R
300 R		455	390	580	460		485	420	665	535	300 R
400 R		515	445	670	530		560	480	780	625	400 R
500 R		580	500	770	610		640	550	910	725	500 R
630 R	Without circulating current	695	595	925	735		735	630	1 065	850	630 R
800 R		785	670	1 070	845		835	715	1 240	990	800 R
1000 R		870	745	1 205	955		935	800	1 410	1 125	1000 R
1200 R		930	795	1 305	1 035		1 010	865	1 545	1 230	1200 R
1600 S		1 135	975	1 645	1 305		1 230	1 055	1 925	1 535	1600 S

Voltage 64/110 (123)kV Copper Conductor

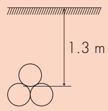
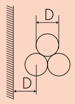
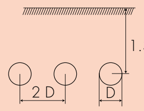
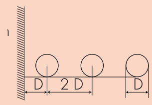
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
240 R	18.4	15,4	0.0754	0.16	180	66	5	85	72	11	100	68	6	330	77	6	800	73	14
300 R	20.5	14,7	0.0601	0.17	180	67	6	85	73	11	100	69	7	340	77	6	810	73	15
400 R	23.2	14,0	0.0470	0.19	190	68	7	85	74	12	95	70	7	340	79	7	810	75	16
500 R	26.7	13,4	0.0366	0.22	190	71	8	80	77	13	95	73	8	380	82	9	820	77	17
630 R	30.3	12,9	0.0283	0.24	180	73	9	80	79	15	90	76	10	390	85	10	800	79	18
800 R	34.7	12,9	0.0221	0.27	170	78	11	75	84	17	90	80	12	420	90	12	810	83	20
1000 R	38.8	13,2	0.0176	0.28	180	83	13	65	89	20	85	85	14	470	96	14	810	88	23
1000 S	40.0	13,3	0.0176	0.29	190	86	14	65	92	21	85	88	15	490	99	15	790	90	23
1200 S	42.5	13,4	0.0151	0.31	200	89	16	60	95	23	85	91	16	510	101	17	790	93	24
1600 S	48.9	14,4	0.0113	0.32	170	97	21	50	104	29	80	100	22	650	112	23	790	101	30
1600 S En	48.9	14,4	0.0113	0.32	170	97	21	50	104	29	80	100	22	650	112	23	790	101	30

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
240 R	With circulating currents	510	440	645	515	Without circulating current	555	480	745	595	240 R
300 R		570	490	730	580		625	540	855	685	300 R
400 R		635	550	835	665		715	615	995	795	400 R
500 R		710	610	950	755		810	700	1 160	925	500 R
630 R	Without circulating current	860	740	1 155	915		925	795	1 345	1 075	630 R
800 R		960	820	1 310	1 040		1 040	890	1 545	1 235	800 R
1000 R		1 040	895	1 455	1 155		1 145	985	1 735	1 385	1000 R
1000 S		1 125	965	1 580	1 255		1 220	1 045	1 850	1 480	1000 S
1200 S		1 205	1 030	1 710	1 355		1 315	1 125	2 015	1 610	1200 S
1600 S		1 280	1 095	1 850	1 470		1 400	1 200	2 190	1 750	1600 S
1600 S En		1 380	1 185	2 005	1 590		1 525	1 310	2 390	1 910	1600 S En

Voltage 76/132 (145)kV Aluminium Conductor

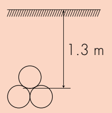
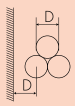
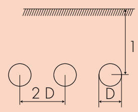
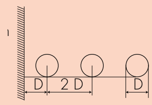
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	μF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
300 R	20.5	18.1	0.1000	0.15	180	74	5	80	80	10	90	76	5	400	86	6	810	80	14
400 R	23.3	17.1	0.0778	0.17	190	75	5	80	81	11	90	77	6	400	87	6	800	80	14
500 R	26.4	16.3	0.0605	0.19	190	76	5	75	83	11	90	79	6	410	88	6	810	82	14
630 R	30.3	15.5	0.0469	0.21	170	79	6	75	85	12	90	81	6	420	91	7	790	84	15
800 R	34.7	14.8	0.0367	0.24	180	82	7	70	88	13	85	84	7	470	95	8	800	87	16
1000 R	38.2	14.7	0.0291	0.26	190	85	7	65	91	14	85	88	8	490	98	8	790	90	16
1200 R	41.4	14.9	0.0247	0.27	200	89	8	60	95	16	85	91	9	510	102	9	800	93	17
1600 S	48.9	15.3	0.0186	0.30	180	99	10	45	106	19	80	102	11	660	114	12	800	103	19
2000 S	54.0	15.5	0.0149	0.32	190	105	12	35	112	22	75	108	12	760	120	14	790	109	21

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
300R	With circulating currents	455	390	575	460	Without circulating current	485	420	655	525	300R
400 R		515	445	665	530		560	480	765	615	400 R
500 R		580	500	770	610		640	550	895	715	500 R
630 R	Without circulating current	695	595	925	735		735	630	1050	840	630 R
800 R		780	670	1065	845		835	715	1225	980	800 R
1000 R		865	745	1 200	950		935	800	1395	1115	1000 R
1200 R		930	795	1 300	1 035		1010	865	1525	1220	1200 R
1600 S		1 135	970	1 635	1 295		1225	1055	1900	1520	1600 S
2000 S		1 255	1 075	1 845	1 465		1375	1180	2170	1735	2000 S

Voltage 76/132 (145)kV Copper Conductor

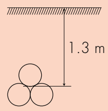
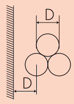
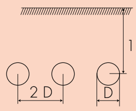
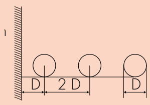
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
300 R	20.5	18.1	0.0601	0.15	180	74	7	80	80	12	90	76	7	400	86	7	810	80	16
400 R	23.2	17.1	0.0470	0.17	190	75	7	80	81	13	90	77	8	400	87	8	800	80	16
500 R	26.7	16.2	0.0366	0.19	190	77	9	75	83	15	90	79	9	410	88	9	790	82	17
630 R	30.3	15.5	0.0283	0.21	170	79	10	75	85	16	90	81	10	420	91	11	790	84	19
800 R	34.7	14.8	0.0221	0.24	180	82	12	70	88	18	85	84	12	470	95	13	800	87	21
1000 R	38.8	14.8	0.0176	0.26	190	86	14	65	92	21	85	88	14	490	99	15	790	91	23
1000 S	40.0	14.9	0.0176	0.27	200	89	14	60	95	22	85	91	15	510	102	15	800	93	23
1200 S	42.5	15.0	0.0150	0.28	160	92	16	55	98	24	80	94	16	560	106	17	790	96	25
1600 S	48.9	16.4	0.0113	0.29	180	101	22	40	108	31	80	104	22	740	117	23	790	105	30
1600 S En	48.9	16.4	0.0113	0.29	180	101	22	40	108	31	80	104	22	740	117	23	790	105	30
2000 S	57.2	16.4	0.0090	0.32	160	110	25	25	117	35	75	113	25	870	126	27	830	114	34
2000 S En	57.2	16.4	0.0090	0.32	160	110	25	25	117	35	75	113	25	870	126	27	830	114	34

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions induced current in the metallic screen	Direct burial  1.3 m ρ_T en K.m/W		In air, in gallery  D		Earthing conditions induced current in the metallic screen	Direct burial  1.3 m, 2 D, D ρ_T en K.m/W		In air, in gallery  D, 2 D, D		
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
300 R	With circulating currents	570	490	730	585	Without circulating current	625	540	840	675	300 R
400 R		640	550	835	665		710	615	980	785	400 R
500 R		710	610	955	760		810	700	1 140	915	500 R
630 R		860	740	1 150	915		920	795	1 325	1 060	630 R
800 R	Without circulating current	780	670	1065	845		835	715	1225	980	800 R
1000 R		1 040	895	1 450	1 150		1145	980	1 720	1 375	1 000 R
1000 S		1 125	965	1 575	1 250		1215	1 045	1 830	1 465	1 000 S
1200 S		1 215	1 040	1 715	1 360		1315	1 130	2 000	1 600	1 200 S
1600 S		1 275	1 095	1 840	1 460		1400	1 200	2 160	1 730	1 600 S
1600 S En		1 375	1 180	1 995	1 585		1525	1 305	2 360	1 890	1 600 S En
2000 S		1 385	1 185	2 050	1 630		1535	1 315	2 435	1 945	2 000 S
2000 S En		1 540	1 315	2 290	1 815		1730	1 480	2 755	2 200	2 000 S En

Voltage 87/150 (170)kV Aluminium Conductor

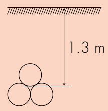
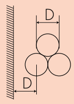
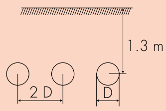
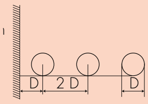
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
400 R	23.3	20.7	0.0778	0.15	180	82	6	65	88	13	85	85	6	470	95	7	810	87	15
500 R	26.4	19.6	0.0605	0.16	190	83	6	65	89	13	85	85	7	480	96	7	790	88	15
630 R	30.3	18.5	0.0469	0.19	190	85	7	65	91	13	85	87	7	490	98	8	810	90	16
800 R	34.7	17.6	0.0367	0.21	200	88	7	60	94	15	85	90	8	500	101	8	810	92	16
1000 R	38.2	17.0	0.0291	0.23	200	90	8	60	96	15	85	92	9	520	103	9	810	94	17
1200 R	41.4	16.6	0.0247	0.25	160	92	9	55	99	17	80	95	9	560	107	10	800	97	18
1600 S	48.9	15.8	0.0186	0.30	180	100	10	45	107	19	80	103	11	670	115	12	780	104	19
2000 S	54.0	15.5	0.0149	0.32	190	105	12	35	112	22	75	108	12	760	120	14	790	109	21

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
400 R	With circulating currents	515	445	665	530	Without circulating current	555	480	755	605	400 R
500 R	With circulating currents	580	500	765	610	Without circulating current	635	550	880	705	500 R
630 R	With circulating currents	690	595	920	730	Without circulating current	730	630	1 035	830	630 R
800 R	With circulating currents	780	670	1065	845	Without circulating current	835	715	1225	980	800 R
1000 R	Without circulating current	865	745	1 195	950	Without circulating current	930	800	1 375	1 100	1000 R
1200 R	Without circulating current	935	800	1 300	1 035	Without circulating current	1 010	865	1 515	1 210	1200 S
1600 S	Without circulating current	1 130	970	1 630	1 295	Without circulating current	1 225	1 050	1 895	1 515	1600 S
2000 S	Without circulating current	1 255	1 075	1 845	1 460	Without circulating current	1 375	1 175	2 170	1 735	2000 S

Voltage 87/150 (170)kV Copper Conductor

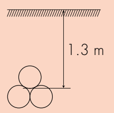
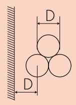
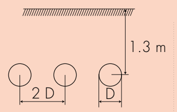
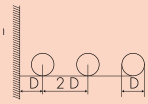
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
400 R	23.2	20.8	0.0470	0.15	180	82	8	65	88	15	85	85	9	470	95	9	810	87	17
500 R	26.7	19.5	0.0366	0.17	190	83	9	65	89	16	85	86	10	480	96	10	790	88	18
630 R	30.3	18.5	0.0283	0.19	190	85	11	65	91	17	85	87	11	490	98	12	810	90	20
800 R	34.7	17.6	0.0221	0.21	200	88	12	60	94	20	85	90	13	500	101	13	810	92	21
1000 R	38.8	17.0	0.0176	0.23	200	91	15	55	97	22	85	93	15	550	105	16	780	95	23
1000 S	40.0	16.7	0.0176	0.25	170	92	15	55	99	23	80	95	15	560	107	16	800	97	24
1200 S	42.5	16.7	0.0151	0.26	170	95	16	50	102	25	80	98	17	580	110	18	800	100	25
1600 S	48.9	16.4	0.0113	0.29	180	101	22	40	108	31	80	104	22	740	117	23	790	105	30
1600 S En	48.9	16.4	0.0113	0.29	180	101	22	40	108	31	80	104	22	740	117	23	790	105	30
2000 S	57.2	16.4	0.0090	0.32	160	110	25	25	117	35	75	113	25	870	126	27	830	114	34
2000 S En	57.2	16.4	0.0090	0.32	160	110	25	25	117	35	75	113	25	870	126	27	830	114	34

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
400 R	With circulating currents	640	550	835	665	Without circulating current	710	615	960	775	400 R
500 R		715	615	955	760		810	700	1 125	900	500 R
630 R		860	740	1 145	910		920	795	1 305	1 045	630 R
800 R		780	670	1065	845		835	715	1225	980	800 R
1000 R	Without circulating current	1 040	895	1 445	1 150		1 140	980	1 700	1 360	1000 R
1000 S		1 130	970	1 575	1 250		1 220	1 045	1 815	1 455	1000 S
1200 S		1 210	1 040	1 705	1 355		1 315	1 130	1 980	1 585	1200 S
1600 S		1 275	1 090	1 840	1 460		1 395	1 200	2 160	1 730	1600 S
1600 S En		1 375	1 180	1 990	1 580		1 520	1 305	2 360	1 885	1600 S En
2000 S		1 385	1 185	2 050	1 625		1 530	1 310	2 435	1 945	2000 S
2000 S En		1 535	1 315	2 290	1 815		1 725	1 480	2 750	2 200	2000 S En

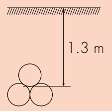
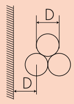
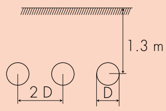
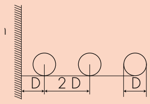
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
400 R	23.3	21.6	0.0778	0.14	310	85	6	145	91	14	165	87	8	480	97	7	1290	93	21
500 R	26.4	22.2	0.0605	0.15	300	90	7	135	96	15	160	92	8	510	102	8	1280	97	21
630 R	30.3	20.4	0.0469	0.17	300	90	7	135	96	15	160	92	8	510	102	8	1290	97	22
800 R	34.7	18.4	0.0367	0.20	300	90	8	135	97	16	160	93	9	510	102	9	1290	98	22
1000 R	38.2	18.4	0.0291	0.21	290	94	9	130	100	17	155	96	10	560	107	10	1290	101	23
1200 R	41.4	18.7	0.0247	0.22	300	98N	10	120	105	19	155	100	11	650	112	11	1280	105	24
1600 S	48.9	18.5	0.0186	0.25	300	107	12	110	114	22	150	109	13	770	121	13	1270	113	26
2000 S	54.0	20.1	0.0149	0.25	290	115	14	95	123	25	145	118	15	940	130	16	1280	121	28
2500 S	63.5	19.2	0.0119	0.30	280	123	16	80	131	29	140	126	17	1 080	139	18	1260	128	30

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
400 R	Without circulating current	525	455	675	540	Without circulating current	555	480	750	600	400 R
500 R		600	520	780	625		630	545	870	700	500 R
630 R		680	585	910	725		725	625	1 025	820	630 R
800 R		765	660	1 045	830		820	705	1 200	960	800 R
1000 R		850	730	1 180	935		920	790	1 360	1 090	1000 R
1200 R		910	780	1 280	1 015		995	855	1 490	1 190	1200 R
1600 S		1 095	935	1 590	1 260		1 200	1 030	1 850	1 480	1600 S
2000 S		1 210	1 035	1 785	1 420		1 345	1 155	2 100	1 680	2000 S
2500 S		1 345	1 145	2 050	1 625		1 520	1 300	2 455	1 960	2500 S

Voltage 130/225 (245)kV Copper Conductor

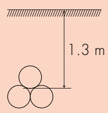
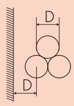
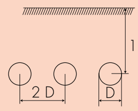
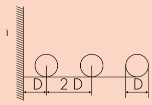
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
400 R	23.2	21.6	0.0470	0.14	310	85	9	145	91	16	165	87	10	480	97	10	1290	93	23
500 R	26.7	22.1	0.0366	0.15	300	90	10	135	96	18	160	92	11	510	102	11	1280	97	24
630 R	30.3	20.4	0.0283	0.17	300	90	11	135	96	19	160	92	12	510	102	12	1290	97	26
800 R	34.7	18.4	0.0221	0.20	300	90	13	135	97	21	160	93	14	510	102	14	1290	98	27
1000 R	38.8	18.1	0.0176	0.21	290	94	15	130	100	24	155	96	16	560	107	16	1290	101	29
1000 S	40.0	18.5	0.0176	0.22	300	97	16	120	104	25	155	100	17	640	111	17	1280	104	30
1200 S	42.5	19.5	0.0151	0.22	290	102	18	115	109	27	150	104	19	740	116	19	1280	109	32
1600 S	48.9	18.5	0.0113	0.25	300	107	23	110	114	33	150	109	24	770	121	24	1270	113	37
1600 S En	48.9	18.5	0.0113	0.25	300	107	23	110	114	33	150	109	24	770	121	24	1270	113	37
2000 S	57.2	18.5	0.0090	0.28	290	115	26	95	123	38	145	118	27	940	130	28	1280	121	40
2000 S En	57,2	18.5	0.0090	0.28	290	115	26	95	123	38	145	118	27	940	130	28	1280	121	40
2500 S En	63.5	19.2	0.0072	0.30	280	123	32	80	131	45	140	126	33	1080	139	35	1260	128	46

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
400 R	Without circulating current	665	575	855	685	Without circulating current	705	610	955	770	400 R
500 R		750	650	985	785		800	690	1 110	890	500 R
630 R		845	725	1 130	900		910	785	1 290	1 035	630 R
800 R		935	800	1 285	1 020		1 020	875	1 495	1 195	800 R
1000 R		1 020	875	1 425	1 130		1 125	965	1 680	1 345	1000 R
1000 S		1 090	935	1 535	1 220		1 195	1 025	1 785	1 425	1000 S
1200 S		1 170	1 000	1 660	1 320		1 285	1 105	1 935	1 550	1200 S
1600 S		1 225	1 045	1 785	1 415		1 365	1 170	2 115	1 690	1600 S
1600 S En		1 315	1 125	1 930	1 530		1 480	1 270	2 305	1 840	1600 S En
2000 S		1 315	1 125	1 975	1 565		1 490	1 275	2 370	1 895	2000 S
2000 S En		1 450	1 235	2 195	1 740		1 665	1 425	2 675	2 135	2000 S En
2500 S En		1 585	1 350	2 445	1 940		1 860	1 585	3 035	2 425	2500 S En

Voltage 160/275 (300)kV Aluminium Conductor

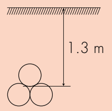
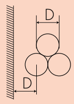
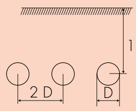
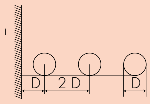
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
500 R	26.4	23.8	0.0605	0.14	290	93	8	130	100	16	160	95	9	560	106	9	1270	100	22
630 R	30.3	22.0	0.0469	0.16	290	93	8	130	100	16	155	96	9	560	107	9	1280	100	22
800 R	34.7	21.8	0.0367	0.17	300	97	9	125	104	18	155	100	10	640	111	10	1280	104	23
1000 R	38.2	20.2	0.0291	0.19	300	97	9	120	105	18	155	100	10	650	111	10	1280	104	23
1200 R	41.4	20.7	0.0247	0.20	290	102	10	115	109	20	150	104	11	740	116	12	1280	108	24
1600 S	48.9	22.4	0.0186	0.22	290	115	13	95	122	25	145	117	14	940	130	15	1270	120	27
2000 S	54.0	23.5	0.0149	0.23	280	122	15	80	130	28	140	125	16	1040	138	17	1250	127	29
2500 S	63.5	22.7	0.0119	0.26	300	130	17	60	138	31	135	133	18	1190	147	20	1260	135	31

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
500 R	Without circulating current	595	515	775	620	Without circulating current	630	545	865	690	500 R
630 R		680	585	905	720		720	620	1 015	810	630 R
800 R		765	655	1 040	825		815	700	1 175	940	800 R
1000 R		845	725	1 170	930		915	785	1 345	1 075	1000 R
1200 R		905	775	1 275	1 010		990	845	1 470	1 175	1200 R
1600 S		1 090	930	1 575	1 250		1 195	1 025	1 810	1 450	1600 S
2000 S		1 210	1 035	1 775	1 410		1 340	1 145	2 060	1 650	2000 S
2500 S		1 330	1 135	2 025	1 605		1 505	1 285	2 400	1 920	2500 S

Voltage 160/275 (300)kV Copper Conductor

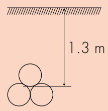
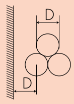
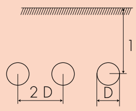
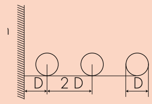
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen: Sectional area*	Aluminium screen: Outside diameter of cable*	Aluminium screen: Weight of cable*	Copper wire/lead sheath: Sectional area* copper screen	Copper wire/lead sheath: Outside diameter of cable*	Copper wire/lead sheath: Weight of cable*	Copper wire/alu sheath: Sectional area* copper screen	Copper wire/alu sheath: Outside diameter of cable*	Copper wire/alu sheath: Weight of cable*	Corrugated Alu sheath: Sectional area*	Corrugated Alu sheath: Outside diameter of cable*	Corrugated Alu sheath: Weight of cable*	Lead sheath: Sectional area*	Lead sheath: Outside diameter of cable*	Lead sheath: Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
500 R	26.7	23.7	0.0366	0.14	290	93	11	130	100	19	160	95	12	560	106	12	1270	100	25
630 R	30.3	22.0	0.0283	0.16	290	93	12	130	100	20	155	96	13	560	107	13	1280	100	26
800 R	34.7	21.8	0.0221	0.17	300	97	14	125	104	23	155	100	15	640	111	15	1280	104	28
1000 R	38.8	21.9	0.0176	0.19	290	101	16	115	108	26	150	104	17	740	116	18	1270	108	30
1000 S	40.0	20.4	0.0176	0.20	290	101	16	115	108	26	150	104	17	670	115	18	1270	108	30
1200 S	42.5	21.4	0.0151	0.20	300	106	18	110	113	28	150	108	19	770	121	20	1270	112	32
1600 S	48.9	22.4	0.0113	0.22	290	115	24	95	122	36	145	117	25	940	130	26	1270	120	38
1600 S En	48.9	22.4	0.0113	0.22	290	115	24	95	122	36	145	117	25	940	130	26	1270	120	38
2000 S	57.2	21.9	0.0090	0.25	280	122	27	80	130	40	140	125	28	1040	138	29	1250	127	41
2000 S En	57.2	21.9	0.0090	0.25	280	122	27	80	130	40	140	125	28	1040	138	29	1250	127	41
2500 S En	63.5	21.8	0.0072	0.27	290	129	33	65	136	47	135	131	34	1170	145	36	1270	134	47

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
500 R	Without circulating current	750	645	980	780	Without circulating current	795	690	1 100	880	500 R
630 R		840	725	1 125	895		905	780	1 280	1 025	630 R
800 R		930	800	1 275	1 015		1 015	870	1 465	1 175	800 R
1000 R		1 015	870	1 415	1 125		1 120	960	1 645	1 320	1000 R
1000 S		1 085	930	1 530	1 215		1 185	1 015	1 765	1 410	1000 S
1200 S		1 155	990	1 645	1 305		1 275	1 095	1 910	1 530	1200 S
1600 S		1 220	1 045	1 775	1 405		1 355	1 160	2 070	1 655	1600 S
1600 S En		1 310	1 120	1 915	1 520		1 475	1 260	2 260	1 805	1600 S En
2000 S		1 315	1 120	1 965	1 560		1 480	1 265	2 330	1 860	2000 S
2000 S En		1 450	1 235	2 185	1 735		1 660	1 420	2 630	2 100	2000 S En
2500 S En		1 565	1 330	2 425	1 920		1 840	1 570	2 990	2 385	2500 S En

Voltage 200/345 (362)kV Aluminium Conductor

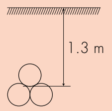
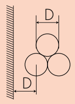
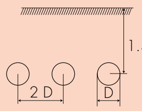
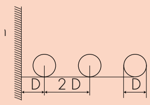
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
500 R	26.4	25.7	0.0605	0.13	300	97	8	125	104	17	155	99	9	640	111	9	1270	104	22
630 R	30.3	23.9	0.0469	0.15	300	97	8	125	104	17	155	100	9	640	111	10	1270	104	23
800 R	34.7	21.8	0.0367	0.17	300	97	9	125	104	18	155	100	10	640	111	10	1280	104	23
1000 R	38.2	22.1	0.0291	0.18	290	101	10	115	108	19	150	104	11	740	116	11	1270	108	24
1200 R	41.4	22.6	0.0247	0.19	300	106	11	110	113	21	150	108	12	770	120	12	1270	112	25
1600 S	48.9	22.4	0.0186	0.22	290	115	13	95	122	25	145	117	14	940	130	15	1270	120	27
2000 S	54.0	23.5	0.0149	0.23	280	122	15	80	130	28	140	125	16	1040	138	17	1250	127	29
2500 S	63.5	22.7	0.0119	0.26	300	130	17	60	138	31	135	133	18	1190	147	20	1250	135	31

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions induced current in the metallic screen	Direct burial  ρ_T en K.m/W		In air, in gallery 		Earthing conditions induced current in the metallic screen	Direct burial  ρ_T en K.m/W		In air, in gallery 		
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
500 R	Without circulating current	595	510	770	615	Without circulating current	625	540	855	685	500 R
630 R		675	580	900	715		715	615	1 005	805	630 R
800 R		755	650	1 035	820		810	695	1 175	935	800 R
1000 R		840	720	1 165	925		910	780	1 330	1 065	1000 R
1200 R		900	770	1 265	1 000		980	840	1 455	1 160	1200 R
1600 S		1 080	920	1 565	1 240		1 185	1 010	1 805	1 445	1600 S
2000 S		1 200	1 020	1 770	1 400		1 330	1 135	2 055	1 640	2000 S
2500 S		1 315	1 115	2 015	1 595		1 490	1 270	2 395	1 910	2500 S

Voltage 200/345 (362)kV Copper Conductor

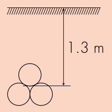
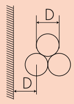
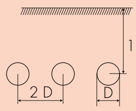
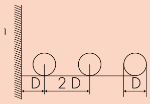
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
500 R	26.7	25.5	0.0366	0.13	300	97	11	125	104	20	155	99	12	640	111	12	1270	104	25
630 R	30.3	23.9	0.0283	0.15	300	97	12	125	104	21	155	100	13	640	111	14	1270	104	26
800 R	34.7	21.8	0.0221	0.17	300	97	14	125	104	23	155	100	15	640	111	15	1280	104	28
1000 R	38.8	21.9	0.0177	0.19	290	101	16	115	108	26	150	104	17	740	116	18	1270	108	30
1000 S	40.0	22.6	0.0176	0.19	300	106	17	110	113	27	150	108	18	770	120	19	1260	112	31
1200 S	42.5	21.4	0.0151	0.20	300	106	18	110	113	28	150	108	19	770	121	20	1270	112	32
1600 S	48.9	22.4	0.0113	0.22	290	115	24	95	122	36	145	117	25	940	130	26	1270	120	38
1600 S En	48.9	22.4	0.0113	0.22	290	115	24	95	122	36	145	117	25	940	130	26	1270	120	38
2000 S	57.2	22.0	0.0090	0.25	280	122	27	80	130	40	140	125	28	1080	138	30	1250	128	41
2000 S En	57.2	22.0	0.0090	0.25	280	122	27	80	130	40	140	125	28	1080	138	30	1250	128	41
2500 S En	63.5	22.7	0.0072	0.26	300	130	34	60	138	48	135	133	35	1190	147	36	1250	135	48

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen					induced current in the metallic screen					
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
500 R	Without circulating current	745	640	975	775	Without circulating current	790	685	1 090	870	500 R
630 R		835	715	1 120	890		900	770	1 265	1 010	630 R
800 R		925	790	1 270	1 005		1 005	865	1 460	1 170	800 R
1000 R		1 010	860	1 410	1 120		1 110	950	1 645	1 310	1000 R
1000 S		1 075	920	1 515	1 200		1 175	1 010	1 740	1 390	1000 S
1200 S		1 145	980	1 640	1 300		1 265	1 080	1 905	1 520	1200 S
1600 S		1 210	1 030	1 765	1 400		1 345	1 150	2 065	1 650	1600 S
1600 S En		1 300	1 105	1 910	1 510		1 460	1 250	2 250	1 800	1600 S En
2000 S		1 305	1 105	1 960	1 550		1 470	1 250	2 320	1 850	2000 S
2000 S En		1 435	1 220	2 180	1 720		1 645	1 400	2 620	2 090	2000 S En
2500 S En		1 550	1 315	2 410	1 905		1 820	1 550	2 965	2 365	2500 S En

Voltage 230/400 (420)kV Aluminium Conductor

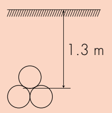
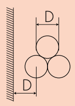
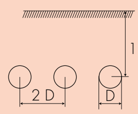
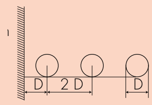
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm^2	mm	mm	Ω/km	μF/km	mm^2	mm	kg/m	mm^2	mm	kg/m	mm^2	mm	kg/m	mm^2	mm	kg/m	mm^2	mm	kg/m
500 R	26.4	31.6	0.0605	0.12	400	110	10	195	117	22	240	112	12	860	124	12	1840	119	31
630 R	30.3	29.8	0.0469	0.13	400	110	11	195	117	22	240	113	12	860	124	12	1850	119	31
800 R	34.7	27.7	0.0367	0.15	400	110	11	195	118	22	240	113	13	860	125	12	1850	119	31
1000 R	38.2	26.1	0.0291	0.16	410	110	11	195	118	23	240	113	13	860	125	13	1850	119	32
1200 R	41.4	24.6	0.0247	0.18	410	111	12	195	118	23	240	113	13	870	125	13	1860	120	32
1600 S	48.9	25.8	0.0186	0.20	420	122	15	170	131	28	230	125	16	1030	137	16	1840	130	35
2000 S	54.0	24.7	0.0149	0.22	430	125	16	165	134	30	230	128	17	1100	141	18	1840	133	36
2500 S	63.5	25.8	0.0119	0.24	430	138	19	140	146	35	220	140	20	1290	154	21	1860	144	39
3000 S	70.0	26.1	0.0099	0.25	420	145	21	120	154	39	220	148	23	1450	162	24	1830	152	41

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial		In air, in gallery		Earthing conditions	Direct burial		In air, in gallery		
	induced current in the metallic screen	 ρ_T en K.m/W				induced current in the metallic screen	 ρ_T en K.m/W				
mm^2		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm^2
500 R	Without circulating current	585	505	760	605	Without circulating current	620	535	835	670	500 R
630 R		665	570	885	705		710	610	980	785	630 R
800 R		750	640	1 015	810		805	690	1 140	910	800 R
1000 R		825	705	1 145	910		900	770	1 305	1 040	1000 R
1200 R		880	750	1 245	985		970	825	1 435	1 145	1200 R
1600 S		1 050	895	1 530	1 210		1 165	995	1 765	1 410	1600 S
2000 S		1 150	975	1 720	1 360		1 295	1 105	2 020	1 610	2000 S
2500 S		1 265	1 070	1 955	1 545		1 455	1 235	2 335	1 860	2500 S
3000 S		1 360	1 150	2 150	1 695		1 590	1 350	2 605	2 075	3000 S

Voltage 230/400 (420)kV Copper Conductor

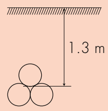
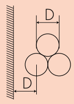
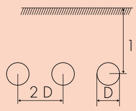
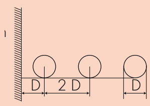
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen: Sectional area*	Aluminium screen: Outside diameter of cable*	Aluminium screen: Weight of cable*	Copper wire/lead sheath: Sectional area* copper screen	Copper wire/lead sheath: Outside diameter of cable*	Copper wire/lead sheath: Weight of cable*	Copper wire/alu sheath: Sectional area* copper screen	Copper wire/alu sheath: Outside diameter of cable*	Copper wire/alu sheath: Weight of cable*	Corrugated Alu sheath: Sectional area*	Corrugated Alu sheath: Outside diameter of cable*	Corrugated Alu sheath: Weight of cable*	Lead sheath: Sectional area*	Lead sheath: Outside diameter of cable*	Lead sheath: Weight of cable*
mm²	mm	mm	Ω/km	μF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
500 R	26.7	31.5	0.0366	0.12	400	110	13	195	117	25	240	113	15	860	124	15	1840	119	34
630 R	30.3	29.8	0.0283	0.13	400	110	15	195	117	26	240	113	16	860	124	16	1850	119	35
800 R	34.7	27.7	0.0221	0.15	400	110	16	195	118	28	240	113	18	860	125	18	1850	119	36
1000 R	38.8	25.8	0.0176	0.17	410	111	18	195	118	29	240	113	19	860	125	19	1860	119	38
1000 S	40.0	24.6	0.0176	0.18	410	111	18	195	118	30	240	113	20	860	125	19	1860	119	38
1200 S	42.5	25.3	0.0151	0.18	420	115	20	185	123	32	240	118	21	930	129	21	1860	123	40
1600 S	48.9	25.8	0.0113	0.20	420	122	26	170	131	39	230	125	27	1030	137	27	1840	130	46
1600 S En	48.9	25.8	0.0113	0.20	420	122	26	170	131	39	230	125	27	1030	137	27	1840	130	46
2000 S	57.2	25.5	0.0090	0.22	450	131	29	155	139	44	230	133	30	1180	146	31	1840	138	49
2000 S En	57.2	25.5	0.0090	0.22	450	131	29	155	139	44	230	133	30	1180	146	31	1840	138	49
2500 S En	63.5	25.8	0.0072	0.24	430	138	35	140	146	51	220	140	37	1290	154	38	1860	144	56
3000 S En	70.0	26.1	0.0060	0.25	420	145	39	120	154	57	220	148	40	1450	162	42	1830	152	59

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Trefoil formation: Earthing conditions	Trefoil: Direct burial  ρ_T en K.m/W		Trefoil: In air, in gallery 		Flat formation: Earthing conditions	Flat: Direct burial  ρ_T en K.m/W		Flat: In air, in gallery 		Nominal section area
mm²	induced current in the metallic screen	ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	induced current in the metallic screen	ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
500 R	Without circulating current	735	630	960	765	Without circulating current	785	680	1 065	850	500 R
630 R		825	705	1 100	875		890	765	1 235	990	630 R
800 R		910	780	1 250	990		995	855	1 420	1 135	800 R
1000 R		985	840	1 385	1 100		1 095	935	1 605	1 285	1000 R
1000 S		1 050	895	1 490	1 180		1 160	990	1 715	1 370	1000 S
1200 S		1 115	950	1 600	1 270		1 245	1 060	1 860	1 485	1200 S
1600 S		1 170	995	1 720	1 360		1 320	1 125	2 015	1 610	1600 S
1600 S En		1 255	1 065	1 855	1 470		1 430	1 220	2 195	1 755	1600 S En
2000 S		1 245	1 055	1 890	1 495		1 430	1 215	2 255	1 800	2000 S
2000 S En		1 360	1 150	2 090	1 650		1 590	1 355	2 540	2 025	2000 S En
2500 S En		1 470	1 245	2 325	1 835		1 765	1 495	2 880	2 295	2500 S En
3000 S En		1 510	1 275	2 425	1 915		1 825	1 545	3 025	2 410	3000 S En

Voltage 290/500 (550)kV Aluminium Conductor

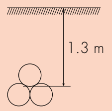
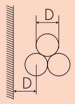
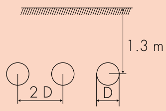
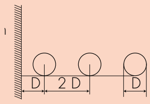
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
1000 R	38.2	37.0	0.0291	0.13	420	133	15	150	141	31	225	136	17	1210	149	18	1840	140	36
1200 R	41.4	35.5	0.0247	0.14	420	133	16	150	141	31	225	136	17	1210	149	18	1840	140	36
1600 S	48.9	31.3	0.0186	0.17	420	134	17	150	142	32	225	137	18	1260	150	19	1850	141	37
2000 S	54.0	30.1	0.0149	0.19	430	137	18	140	145	34	225	140	20	1280	153	21	1850	144	38
2500 S	63.5	30.9	0.0119	0.21	420	148	21	110	157	39	215	151	23	1480	165	24	1830	155	41
3000 S	70.0	30.9	0.0099	0.22	450	155	23	95	164	42	210	158	25	1650	173	27	1820	161	43

*Indicative value

R : round stranded
S : segmental stranded

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions induced current in the metallic screen	Direct burial  ρ_T en K.m/W		In air, in gallery 		Earthing conditions induced current in the metallic screen	Direct burial  ρ_T en K.m/W		In air, in gallery 		
mm²		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C		ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
1000 R	Without circulating current	820	700	1 120	890	Without circulating current	890	765	1 245	1 000	1000 R
1200 R		880	750	1 220	970		960	820	1 370	1 095	1200 R
1600 S		1 035	880	1 505	1 190		1 150	980	1 720	1 370	1600 S
2000 S		1 135	960	1 695	1 340		1 280	1 085	1 965	1 565	2000 S
2500 S		1 250	1 055	1 930	1 520		1 435	1 215	2 275	1 810	2500 S
3000 S		1 335	1 120	2 115	1 665		1 560	1 320	2 535	2 015	3000 S

Voltage 290/500 (550)kV Copper Conductor

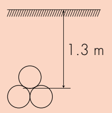
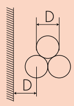
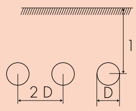
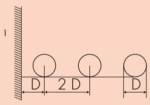
Constructional data (nominal)

Nominal section area	Conductor diameter	Thickness of insulation	DC conductor resistance at 20°C	Electrostatic capacitance	Aluminium screen			Copper wire/lead sheath			Copper wire/alu sheath			Corrugated Alu sheath			Lead sheath		
					Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area* copper screen	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*	Sectional area*	Outside diameter of cable*	Weight of cable*
mm²	mm	mm	Ω/km	µF/km	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m	mm²	mm	kg/m
1000 R	38.8	36.7	0.0176	0.13	420	133	22	150	141	37	225	136	23	1210	149	24	1840	140	42
1000 S	40.0	35.4	0.0176	0.14	420	133	22	150	141	37	225	136	24	1210	149	24	1840	140	42
1200 S	42.5	34.2	0.0151	0.15	420	133	23	150	141	38	225	136	25	1210	149	26	1840	140	43
1600 S	48.9	31.3	0.0113	0.17	420	134	28	150	142	43	225	137	29	1260	150	30	1850	141	48
1600 S En	48.9	31.3	0.0113	0.17	420	134	28	150	142	43	225	137	29	1260	150	30	1850	141	48
2000 S	57.2	32.0	0.0090	0.19	410	144	31	125	153	49	220	147	33	1440	161	35	1860	151	52
2000 S En	57.2	32.0	0.0090	0.19	410	144	31	125	153	49	220	147	33	1440	161	35	1860	151	52
2500 S En	63.5	30.9	0.0072	0.21	420	148	37	110	157	55	215	151	39	1480	165	41	1830	155	58
3000 S En	70.0	30.9	0.0060	0.22	450	155	41	95	164	60	210	158	43	1650	173	45	1820	161	61

*Indicative value

R : round stranded
S : segmental stranded
S En : segmental stranded enamelled

Continuous current ratings (Amperes)

Nominal section area	Laying conditions : Trefoil formation					Laying conditions : Flat formation					Nominal section area
	Earthing conditions	Direct burial  ρ_T en K.m/W		In air, in gallery 		Earthing conditions	Direct burial  ρ_T en K.m/W		In air, in gallery 		
mm²	induced current in the metallic screen	ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	induced current in the metallic screen	ρ_T = 1,0 T = 20°C	ρ_T = 1,2 T = 30°C	T = 30°C	T = 50°C	mm²
1000 R	Without circulating current	985	840	1 365	1 080	Without circulating current	1 085	930	1 540	1 230	1000 R
1000 S		1 040	885	1 455	1 155		1 145	980	1 640	1 315	1000 S
1200 S		1 105	940	1 575	1 250		1 230	1 055	1 790	1 430	1200 S
1600 S		1 155	980	1 700	1 340		1 305	1 110	1 965	1 565	1600 S
1600 S En		1 240	1 050	1 835	1 450		1 410	1 200	2 140	1 705	1600 S En
2000 S		1 240	1 050	1 875	1 480		1 415	1 205	2 195	1 750	2000 S
2000 S En		1 360	1 150	2 080	1 640		1 585	1 345	2 470	1 970	2000 S En
2500 S En		1 460	1 230	2 305	1 815		1 745	1 475	2 815	2 240	2500 S En
3000 S En		1 535	1 285	2 490	1 960		1 875	1 580	3 105	2 470	3000 S En

Notes

Notes

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