ORLEN Unipetrol RPA, s.r.o. LDS section	LAYING OF LV, HV AND 110 KV CABLES	N 11 025

Content

Replaces:	**Standards Administrator:** Maintenance Support Section	**Valid from:** 1.9.2021

LIST OF PICTURES

1 In general

1.1 Purpose

Company standard N 11 025 applies to the design and laying of new or reconstructed LV, HV, EHV power electrical cables, including optical cables in distribution networks, new and reconstructed, into the ground and in the air, at the outlet to the terminal power stations and follows ČSN 33 2000 -5-52. The standard does not apply to suspension cables and insulated overhead line conductors and self-supporting dielectric optical cables.

Voltage levels for the following distribution systems:

- LV cables up to 1 kV
- HV cables above 1 kV up to 35 kV
- EHV cables above 35 kV up to 110 kV

With regard to different conditions during laying and installation of EHV cables and LV and HV cables, only LV and HV cables are solved in part 2 and only EHV cables in part 3. All other parts of the standard are common to all, LV and HV cables and EHV cables.

Optical cables are designed for installation in outdoor environments, in the ground, in pipeline and energy bridges, for indoor environments and in cable conduits. Optical cables are usually installed (blown, pulled or pressed) into pre-prepared plastic optotubes and microtubes. They are used for functions connected with the operation of the power system, for example for connecting electrical stations, distribution and customer transformer stations to the optical network, for a remote reading of electricity meters or for other possible uses.

1.2 Scale of validity

The standard is binding for all departments of the company and external organizations that perform activities with LV, HV, EHV cables in the Záluží complex, operated by ORLEN Unipetrol RPA. The departments are obliged to acquaint all external organizations that perform work related to the laying, maintenance and repair of cables with the standard and for which the standard is also binding. Does not apply to the Litvínov and Kralupy refinery unit.

1.3 Terminology

Basic terminology related to electrical cables is given in ČSN IEC 60050-461, ČSN IEC 60050-442, ČSN IEC 60050-826, ČSN EN 50368, ČSN EN 45510-2-9, ČSN EN 61537, ČSN IEC 50 (461) + A1, ČSN P 73 7505.ČSN IEC 60050-461, ČSN IEC 60050-442, ČSN IEC 60050-826, ČSN EN 50368, ČSN EN 45510-2-9, ČSN EN 61537, ČSN IEC 50(461) +A1, ČSN P 73 7505.

For the purposes of this standard, the following terms and definitions are introduced:

Cable route section

A section that is equally equipped along its entire length.

(Underground) conduit system

Mechanical protection of cable conduit is a plastic pipe (multi-compartment, single-compartment), laid in the ground in an outdoor environment used for laying cables and conductors.

NOTE 1 - *The surface cable conduit system has an overlayer depth of less than 600 mm, it consists of the body of the cable conduit and surface cable chambers (cable shaft). The deep cable conduit system has an over-layer depth of 600 mm and more, and consists of the body of the cable conduit and deep cable chambers.*

NOTE 2 - The term multichannel is sometimes used for cable conduit systems made of plastic multi-chamber fittings.

Cable chamber

Enclosed underground space intended for balancing different depths of cable conduit systems, for changing the direction of the cable conduit systems, for branching cables, for pulling cables and for laying cable couplings.

NOTE 1 - The chamber is made at the transition between cables laid in the ground or in the cable conduit system, collector or between cable conduit systems.

NOTE 2 - The surface cable chamber, also called cable shaft (cable pit), does not have a tightly closed upper side, it is equipped with a cover inserted into the frame along the entire cross-section of the shaft (single-leaf or double-leaf cover with a removable middle bar).

NOTE 3 - The deep cable chamber is firmly (structurally) closed on all sides and is provided with an inlet opening with a cover on the upper side.

Cable protective casing

Protective device used for the safe laying and protection of cable (s) and optotubes (or microtubes) against mechanical damage in a given place.

NOTE 1 - These are places with an increased risk of mechanical damage, which is caused by the operation of technical equipment or other activities during operation and maintenance of the equipment (e.g., a location of crossing or concurrence with other lines or roads, a place without the ability to achieve the minimum overlayer, passage through a building structure).

NOTE 2 - For the underground cable route, the cable protective casing turns directly into the terrain, termination of chambers is exceptional.

Cable trench

Regulated excavation for laying of underground cable lines and its components.

Common cable trench

Regulated excavation for laying several underground cable lines and their components.

Cable space

Constructionally delimited space intended for the laying of cable lines and allowing the entry of people.

Cable channel

Constructionally delimited space of a linear character, horizontal or inclined, which is intended for laying of electrical cables and insulated conductors.

Sifted soil
Soil class 1 - 3 with pebbles up to 16 mm in diameter, except clay.

Optical cable

A structure formed by one or more optical fibres or bundles of fibres inside a common sheath which protects them against mechanical stress and against external influences while maintaining the transmission quality of the fibres. An optical fibre is a glass or plastic fibre that transmits signals via light in the direction of its longitudinal axis. The optical cable is used to transmit information.

Optotube

Plastic protective tube designed for the installation of optical cable and microtubes. The optical cable is gently blown into the optotube by laminar air flow without the use of draft force. Optotube is made of various materials, most often HDPE (High Density PolyEthylene) for installation in the ground (cable trenches) and HFFR (Halogen Free Flame Retardant - halogen-free with reduced flammability) for installation in cable channels, tunnels and buildings. The outer side of the optotube is smooth, the inner side can be made with various modifications to reduce friction during blowing, for example grooved or with permanent lubrication.

Coupling for optotube
It is used to connect optotubes without welding. Disconnections and connections can be used repeatedly. The couplings are resistant to internal and external pressure, tension and are watertight. The coupling is designed for a minimum nominal overpressure of 16 bar.

End cap for optotube

It is used to terminate and close optotubes without welding and it allows reassembly. The end caps are resistant to internal and external pressure and are watertight.

The end cap can be equipped with a valve for pressurizing the optotubes. The end cap is designed for a minimum nominal overpressure of 16 bar.

Microtube

Plastic protective tube fulfilling the same function as an optotube, but with a smaller diameter than the optotube. Depending on its construction and the materials used, the microtube is intended for direct laying in the ground, cable channels and tunnels as well as for blowing into optotubes. The microtube can also be a part of LV and HV power cables. The microtubes are connected and terminated similarly to optotubes. The required minimum nominal overpressure of microtubes and other components is 10 bar.

1.4 Basic requirements

1.4.1 Accessibility, possibility of testing

The cable heads must be laid in such a way that they can be electrically tested after completion and so that access to them is provided for the purpose of performing line maintenance (inspections, tightening of screw connections, etc.).

1.4.2 Safety in relation to the environment

The cables, by their laying, choice of construction, type or installation material, etc., must not cause danger to persons and animals or objects. They must be located so as not to interfere with normal use of the space. If they are exposed to a risk of mechanical damage, the cables must be laid with regard to such an environment or protected.

1.4.3 Clarity

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Lines should be laid and arranged clearly so that they are as short as possible and so that they cross as little as possible. The lines should be laid in a straight line and considering the situation in the cable route.

1.5 External influences and environment

1.5.1 Ambient temperature

Cables must be dimensioned in such a way that the maximum permissible temperature of the individual cable components during normal operation and the maximum permissible short-circuit temperature are not exceeded due to the highest ambient temperature. The influence of the external environment is assessed according to ČSN 33 2000-5-51.

1.5.2 External sources of warming

Heat from external sources can have the influence via conduction, convection or radiation. The heat source can be, in particular, hot water systems or other cable systems in parallel or crossing or also solar radiation. The cables can be heated directly or indirectly from the vicinity of the heat sources by materials or media which conduct heat.

For protection against external heat, either a sufficient distance from the heat source or thermal shielding or a local increase in thermal insulation shall be used.

To prevent the effects of heat from external heat sources, one or more of the following methods or another method having the same effect must be used to protect the cable conduit system:

- provision of heat shielding,
- positioning at a sufficient distance from the heat source,
- choice of cable system considering possible temperature increase,

- local reinforcement of insulation (for example, using heat-resistant insulating sleeves) or replacement of insulation material,
- ventilation of the room with the cable systems,
- cooling of the cable systems.

NOTE - Heat can be supplied by radiation (conduction), conductive connection (conduction) or convection from the following external sources:

- from hot water systems,
- operating appliances and lighting,
- from production processes,
- from materials that conduct heat,
- from the influence of sunlight or from the surrounding environment on the cabling system.

The cable laying methods must be selected considering the highest or lowest possible ambient temperature and must ensure that the maximum permissible operating temperature is not exceeded.

It must also be ensured that the maximum permissible core temperature of the conductors and cables is not exceeded during normal operation.

The components of the cabling system, including conductors and cables and their accessories, must be laid at the temperatures specified in chap. 2.6.2 of this standard and so that the cable manufacturer's instructions are followed.

If cables for different nominal temperatures are installed in the same enclosure, the nominal temperature of the cable system is given by the lowest nominal temperature of the cable.

1.5.3 Water or high moisture

For transitions from areas with adverse external influences, such as atmospheric influences, the classification of the environment must be determined (see ČSN 33 2000-5-51). In the event of significant water exposure, seals and cable line systems must be protected against water penetration along the cable line system or against its accumulation around the seal, unless the material used for the seal is completely moisture-resistant after installation. The cable line must be selected and laid in such a way that it cannot be damaged by condensation or water penetration.

NOTE - The intact insulation of cable sheaths for fixed installations can be generally considered to be resistant to the penetration of moisture. Special requirements apply to cables that are frequently exposed to water splashing, water immersion or permanent water immersion.

If water can accumulate or condense in the cable systems, measures must be taken to drain it.

1.5.4 Foreign particles or dustiness

The selection and construction of cable line systems must be carried out in such a way as to minimize the danger which could be caused by the penetration of foreign solid parts.

In heavily dusty places, additional measures must be taken against the accumulation of dust or other particles in quantities which could adversely affect the heat dissipation from the cable system.

NOTE - A cable system that facilitates dust removal may be required (AE1 to AE6 ČSN 33 2000-5-51).

1.5.5 Corrosion and pollution protection

Cables must be protected against substances (including water or moisture) that cause contamination or corrosion. Protection can be done with tapes or coatings; the suitability of the measure must be consulted with the cable manufacturer.

Unless special precautions are taken to prevent electrolytic effects, the cable must not be in contact with the metals that cause it.

Materials which may cause mutual or individual deterioration or dangerous deterioration of properties must not touch each other.

1.5.6 Protection against mechanical damage

If the cable line system is exposed to the risk of mechanical damage, it must be protected by position, cover, reduction of load, etc., or it is necessary to choose a cable of suitable construction according to the relevant ČSN subject standards.

In fixed installations where moderate (AG2) or strong shocks (AG3) may occur, protection must be provided as follows:

- by corresponding mechanical characteristics of the cable system,
- by choice of positioning
- by implementation of additional local or general mechanical protection,
- by any combination of the above methods.

1.5.7 Protection against vibration

The cable line system, which is supported by a structure or fixed to a structure of a device, which is exposed to medium or strong vibrations (AH1 to AH3 ČSN 33 2000-5-51), must be adapted for such conditions, especially with regard to cables and cable connectors.

NOTE - Special attention must be paid to the connections to the vibrating device. For example, flexible connection systems must be used in certain areas.

1.5.8 Occurrence of animals

NOTE – See also Annex A of ČSN 33 2000-5-51, designations AL1 to AL2.

If field-proven or expected conditions are likely to cause danger to the cable systems induced by animals, an appropriate cabling system must be selected or special protective measures must be taken, such as:

- corresponding mechanical characteristics of the cable system,
- choice of positioning,
- providing additional local or general mechanical protection,
- any combination of the above measures.

1.5.9 Solar radiation

NOTE - See also Annex A of ČSN 33 2000-5-51, designations AN1 to AN3.

If medium solar radiation is detected or expected at a given location, a cable system that meets the given conditions or suitable shading must be selected and implemented.

1.5.10 Structure of buildings

NOTE - See also Annex A of ČSN 33 2000-5-51, ref. CB1 to CB4.

I. Where there is a risk of shifting buildings, the cable supports and the protection system used must allow relative movement which must not cause excessive mechanical stress on the conductors and cables.

II. For flexible and unstable constructions, a flexible cable system must be used.

1.6 Protection against injury caused by electric shock

Protection of non-living parts (metal pipes, metal packaging, metal laid structures, etc.) against electric shock and dangerous contact voltage is performed according to ČSN 33 2000-4-41.

1.7 Connecting and joining of conductors

The conductors (bare conductors and cores of insulated conductors) are connected, joined and branched by soldering, welding, screwing, crimping or by other equivalent means. Joints must be made so that their transient reluctance is permanently as low as possible.

NOTE – Detailed instructions on the mechanical connection of aluminium conductors are given in TNI 37 0606.

Substances that cause corrosion of conductors must not be used for soldering and welding.

For conductor connections in environments where there is a risk of corrosion, either of the following measures must be applied:

- Choose metals in such a combination that corrosion does not occur during the installation of conductors,
  or
- prevent access of corrosive agents (sealing, durable encapsulation, etc.).

Connections between conductors and other equipment must ensure a permanent electrical connection and suitable mechanical strength and protection.

All connections must be accessible for inspection, testing and maintenance, except in the following cases:

- connections laid in the ground,
- connections encapsulated with potting mixes and encapsulated connections.

Conductors must never be connected in pipes and similar storage materials.

The connections of the line conductors on the insulators must be secured so that they cannot be damaged or loosened.

Conductor connections of other types of cable lines must be relieved of tension. This also applies to the connection of conductors to clips.

1.8 Cable sets

Cable sets are used to terminate and connect cables and conductors.

1.7.1 LV and HV cable sets

ČSN 34 7006, ČSN 34 7007 and ČSN IEC 60840 apply to testing cable fittings.

1.7.2 HV cable sets

The type of sets, cable heads and components used (especially the deflector for electric field control) of the couplings must be tested and approved by the cable manufacturer according to ČSN IEC 60840 for the respective cable type.

1.7.2.1 **Cable heads for EHV**

<u>Outdoor cable heads</u>

Outdoor cable heads are used for the transition to outdoor cable lines, the insulating body is made of composite materials or porcelain, they are filled with insulating oil or they are dry.

Cable heads for the transition to outdoor cable lines (composite and porcelain) are designed and tested according to ČSN IEC 60840.

The contracting authority for the supply of the cable heads shall determine, according to the local degree of air pollution, the requirement for the minimum specific surface path of the cable head insulation according to ČSN 33 0405.

<u>Indoor cable heads</u>

Indoor cable heads are used to terminate cables in gas-insulated (SF6) switchboards (GIS) or in transformers, the insulating body is made of composite materials or porcelain, filled with insulating oil or they are dry.

It is recommended to use dry plug-in cable heads with the possibility of quick disconnection of cables.

GIS cable heads are designed and tested according to ČSN IEC 62271-209 and ČSN IEC 60840.

Cable heads for transformers are designed and tested according to ČSN IEC 60840.

1.7.2.2 **Cable couplings for EHV**

Cable couplings are used for connecting cable sections (production lengths), or for cable shielding for grounding or transposition.

In addition to the basic function of the cable coupling, the couplings must also fulfil the function of protection against penetration of water and mechanical protection of the entire coupling. In the interior, it must also fulfil the function of protection against the spread of flame. This protection must have the same or better parameters as the cable protection.

Couplings must also allow safe shielding if required. Couplings are manufactured as wound and prefabricated. It is recommended to use prefabricated couplings, with components tested by the manufacturer.

The contracting authority may determine the type of mechanical protection of the couplings according to the local conditions of the route:

- shrink jacket,
- HDPE box,
- copper tube with shrink sleeve,
- steel pipe with HDPE box.

Types of couplings:

- continuous couplings with interconnected shielding,
- couplings for shield earthing, shield connected and lead out from the coupling,
- connectors for transposition (cross-bonding) with separate shields led by cables from the coupling.

The main part of the prefabricated coupling is a silicone insulating part, which also contains electrodes for controlling the electric field. The great advantage of these couplings is that they can be tested in a production plant. The assembly of a prefabricated coupling is much simpler and not so prone to assembly errors. In addition to the cable coupling function, the cable couplings also have the function of protection against the penetration of water. Furthermore, the couplings must allow safe come out of the shielding both for its earthing and for transposition, with the exception of direct couplings (without lead-out earthing).

1.7.2.3 **Other equipment**

<u>Earthing boxes</u>

Earthing boxes are used to ground the metal shielding of EHV cable sheaths.

The selection is made according to the method of grounding the cable shield and the type of cable heads.

In principle, these are with and without surge protectors, they are single-pole and three-pole.

The selection of the single-pole / three-pole earth box is made with regard to the distance of the cable heads of the individual phases from each other. The general rule is to use single-pole for outdoor terminals and three-pole for GIS / TRF cable heads.

Earthing boxes for outdoor cable heads

1) Single-pole without surge protectors - for direct grounding of the cable shield at the external terminal, Fig.B.-2.
2) Single-pole with surge protector - for connecting the cable shield to ground via an integrated surge protector.

Earthing boxes for GIS and transformers

1) Three-pole without surge protectors - for direct earthing of cable shields for GIS / TRF cable heads.
2) Three-pole with surge protectors - for connecting cable shields to ground via integrated surge protectors.

Earthing boxes for couplings

1) Three-pole without surge protectors - for direct earthing of cable shields.
2) Box for "cross-bonding" - for transposition of cable shields between individual cable sections and their grounding via integrated surge protectors Fig.B.2-3.

1.7.3 Connection box for EHV cable

The connection box for EHV cables is used to protect the couplings.
The connection box must be designed to allow the couplings to be mounted while ensuring safe mechanical protection of the couplings during cable operation. A flat concrete slab reinforced with a

net will be built for the connection box. The couplings can be mounted one after another or next to each other according to local conditions. The connection box is protected on the sides by an external protective wall made of a suitable material for installation in the ground. After the mounting of the couplings, the connection box is sandblasted and covered with two layers of covering concrete slabs and a protective foil. In the case of a cross-bonding coupling, it is possible to place the box on the CB in the corner above the connection box. The sample of the connection box is shown in Fig.B.2-4 and B.2-5.

2 LV, HV cables including optical cables

2.1 Electrical requirements

2.1.1 Voltage

Cables must not be used at a voltage higher than their maximum (highest) voltage specified by the cable manufacturer and ČSN standards for the given cable type.

2.1.2 Current circuits

Separate current circuits for the distribution system.
Electrical distribution systems should be divided into separate circuits. The number of circuits is chosen according to the importance of individual sections of the distribution. A current circuit is a part of the electrical distribution with a separate fuse. Current circuits can be alternating, single-phase or three-phase, namely, three-wire (HV), four-wire (LV), or multi-wire. Separate current circuits must have the full number of conductors required for the function of the connected equipment and for protection against electric shock (dangerous contact) during normal operation, even in the event of a fault (living and non-living parts).

2.1.3 Use of metal sheaths

Metal sheaths, metal shields or armour cables must not be used to conduct current. This does not apply to LV cables of special construction, where the sheath (considered) is made as a PEN core (cable with a concentric core).

The shield of the HV cables is grounded at both ends. If it is necessary to limit the induced current in the shield, it is proceeded according to ČSN EN 61936-1.

2.1.4 Current return line

Metal pipes and metal pipe sheaths as well as earth must not be used for current return. Only a conductor that is or can be earthed must be used for the return line.

2.1.5 PEN conductor

The PEN conductor must always be laid in a common lining with the phase conductors or in their immediate vicinity.

2.1.6 Types of cables and insulation

2.1.6.1 New cable lines

Only cables with plastic (synthetic) insulation are used for newly built cable lines of all voltages. The technical parameters of LV cables, which are listed in the Enterprise Energy Standards PNE 34 7659-3 and PNE 34 7659-5 and for HV cables in PNE 34 7625, can be used within this N 11 025.

2.1.6.2 Repairs of HV cable lines after failures

For repairs of HV cable lines, cables with plastic insulation are used when replacing the defective section, even if cables with impregnated paper insulation are repaired. The only difference is in the coupling used.

For cables with XLPE, VPE, HFFR, etc. insulation, these are replaced by cables of the same type.

After the repair, it is necessary to perform an operational test according to the company standard N 11 018 - Operational tests of HV cable lines up to 35 kV.

2.1.6.3 Colour marking of LV cables

The color marking of LV cable cores must comply with ČSN 33 2000-5-51.

2.2 Laying cables and optotubes in the ground

The type of cable must be selected with regard to the environment and the method of installation, loading, electromagnetic compatibility and the dangerous effects of other lines. Instructions for use and laying, concerning the temperature during laying, adjustment of cable ends and bends, are given in the standard for the given cable (see e.g. ČSN EN 50565-1, ČSN EN 50565-2).

If the cable passes through various environments or rooms without interruption, the type of cable is chosen according to the most unfavourable place, or the cable is suitably protected in such a place. Cables can be laid on a level surface, cable trays, gratings, walls, structures, under plaster, in cable channels, collectors, pipes, ground, etc. Care must be taken to ensure that the environment in which they are laid does not adversely affect the cable.

2.2.1 Depths of overlayer

The cables must be laid in the ground at depths at least according to Fig. 2-1a Tab. A-1 (see Annex A). The method of laying is determined by the operator.

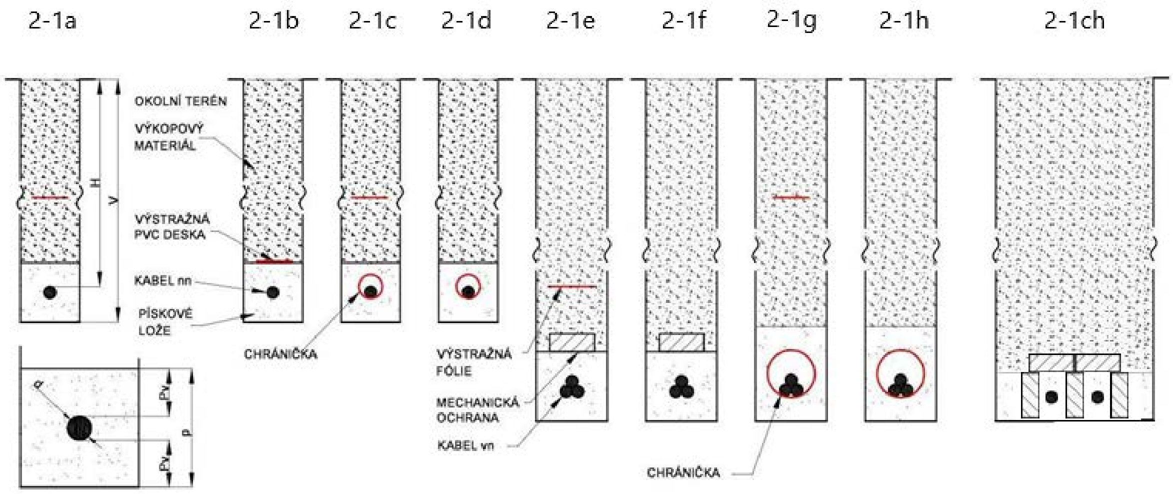


Fig. 2-1 – Cable trench cross-sections

H = depth of laying

V = trench digging depth = H + d + Pv

Pv = sand layer 80 mm up to and including 35 kV

p = sabd bed = d + 2 Pv

d = outer diameter of the cable or optotube

NOTE –

The depth of laying the cable in the ground (H) means the vertical distance of the upper part of the outer perimeter of the cable from the terrain surface of the cable route, e.g. sidewalk, path, other road.

Communication cables and cables for control and special circuits are usually laid in the same route (trench) as the power cables.

Where depths according to Table A-1 cannot be reached, see Annex A, and in places where there is an increased risk of mechanical damage, the cables must be provided with mechanical protection (pipes, troughs, etc.). Such cases occur, for example, when cables enter buildings, when bypassing or crossing structures in the ground, when crossing roads, etc.

The cables are laid in the trench either with a warning foil or without a warning foil.

- *The type of laying with the warning foil is shown in sections 2-1a, 2-1c, 2-1e, 2-1g.*
- *The type of laying without the warning foil is shown in sections 2-1b, 2-1d, 2-1f, 2-1h, 2.1-ch*

The type of storage with a warning foil or without a warning foil is determined by the cable route administrator / customer according to local customs.

2.2.2 Cable beds and cable arrangements

2.2.2.1 **Cables in trenches**

The cables are laid in a trench on a layer of fine-grained sand at least 80 mm thick. After laying, the cables are covered with a sand layer of the same thickness. This thickness is measured from the circumference (surface) of the cable.

LV cables in routes, where they cannot be mechanically damaged (e.g. by driving heavier vehicles over 6t, etc.), can be laid in the ground without mechanical protection only using the foil according to Figure 2-1a, or without using the foil according to Figure 2-1b, where a red plastic plate is placed on the sand bed, serving both as mechanical protection and as a warning.

LV cables in places with increased mechanical load are laid according to Figures 2-1c and 2-1d. When laying according to Figure 2-1c, the cable protective casing performs the function of increased protection and the foil the function of warning. When laying according to Figure 2-1d, the cable protective casing performs the function of increased protection and the foil performs function of warning. Only variants 2-1d can be used in places of passages under roads.

LV cables of the LDS operator of the ORLEN Unipetrol RPA company are laid only according to Fig. 2.1-h and 2.1-ch.

The HV cables must be covered with bricks as shown in Figure 2-1ch. The bricks must overlap the cable, or more cables laid side by side, by at least 40 mm from the end conductor. The same protection applies to the laying of communication cables for dispatch control, which coincide with these cable routes.

Increased mechanical protection of HV cables is performed according to Figures 2-1g or 2-1h. When laying according to Figure 2-1g, the cable protective casing performs the function of increased protection and the foil the function of warning. When laying according to Figure 2-1h, the cable protective casing fulfils the function of increased protection and warning. In the places where passages under the roads are made by extrusion only variant 2-1h can be used.

Cables must not be laid in soils containing salts and acids, in soils with rotting substances and in some sandy or stony soils. In such cases, it is recommended to lay the cables in channels, tunnels, pipes, or otherwise suitably protect them from mechanical and chemical action, or to use cables resistant to the effects of this environment. The trench must not be covered with ash or similar material.

NOTE –the method of laying and protection of cables in the cable trench is determined by the cable route administrator / customer according to local customs.

2.2.2.2 **Distances of cables from buildings and other parallel lines**

The distance of the first (outer) cable from the building should be at least 600 mm. In routes along buildings that have floors below ground level (sidewalk), the distance of the first cable to a voltage of 10 kV may be smaller, but at least 300 mm - (narrow sidewalk, narrowing of the route, etc.).

2.2.2.3 **Warning foil**

The warning foil has only a warning character, it does not provide mechanical protection of underground cable routes. For a cable route that does not require mechanical protection (determined by the cable route administrator), a warning foil is mandatory. The possibility of using the foil as an additional protection even if this route is mechanically protected will be determined by the relevant cable route administrator. When adding new cables to an existing cable route (cable route extension), the requirement is that the cables shall be mechanically protected in the same way as the existing route.

This means that for cable routes managed by LDS, the warning foil can only be used as additional protection to the mechanical cover.

The design and method of laying the foil in the route is determined by ČSN 73 6006. The mechanical properties and resistance of the warning foil should comply with the conditions of ČSN EN 12613.

The width of the warning foil should overlap the outer conductor on both sides by at least 40 mm.

The warning foil shall be laid at least 200 mm above the protected line of the technical equipment. The smallest depth of laying the warning foil under the terrain surface is 200 mm and in the case of shallow laying of LV cables in the sidewalk only 150 mm.

2.2.2.4 **Warning plastic plate**

The warning plastic plate serves as mechanical protection and warning of low voltage cables. It is laid directly on the cable bed, The width of the warning plastic plate should overlap the outer conductor on both sides by at least 40 mm, the plates are connected to each other, for example by pressed-in quick couplings.

The plates are made of PVC-U or PVC material. The plate thickness is 2 mm minimum, colour red, test requirements are based on standard ČSN EN 744.

The possibility of using the plastic plate will be determined by the relevant cable route administrator / customer.

2.2.2.5 **Marking of cables in the cable route**

The existing cables are marked with plastic or lead strips according to the laying time.

Newly laid LV, HV, EHV cables will be provided with plastic labels, where the cable number is indicated.

The cable number corresponds to the numerical series for the individual voltage levels.

In the case of cables for communication, control, management and special circuits, the number, type and direction of the cable (type, switchboard, construction) are also marked on the labels.

Marking of cables in above-ground cable routes and collectors is performed every 25 m.

Marking of cables in ground cable routes is performed every 5 m.

Marking of cables is also performed:

- at the entrance and exit of the building structure of buildings,
- at the entrance and exit of the cable protective casing,
- on both sides of the cable coupling,
- when crossing cable routes.

If the environment requires it, the cables must be marked with stainless steel labels, which will be attached with stainless steel strips or plastic labels with a milled label or laser label.
Cable protective casing for optical cables placed on bridges must be marked with stainless steel labels and fastened with resistant tapes against UV radiation and corrosion (stainless steel tapes). Additional markings can be used directly on the cable protective casing, which can be made during the production of the cable protective casing.
The marking of the cables is based on the company standard N 11 012.

2.2.3 Concurrence and crossing of cables in the ground

If there are several power cables next to each other in the same trench (route), there must be a gap between them in all directions according to Tab. A-1 - Cable distances in the ground according to ČSN 73 6005.

ČSN 73 6005 applies to cables in built-up areas.

Cables in concurrence are laid side by side along the entire route and it is prohibited to lay them in layers on top of each other. This does not apply in places with cable protective casings and cable underpasses.

Distances - gaps (usual) between parallel HV cables according to Tab. A-2 can be reduced, if necessary, if the vertical partition inserted between the cables is sufficiently mechanically strong and adequate in terms of the effect of the electric arc. A minimum gap of 40 mm is recommended. In the ground cable route for HV cables, the cables are separated by a brick partition in the entire length of the parallel and for LV cables, the partitions are placed every 5 m.

The brick partition separates cables with different voltage levels along the entire length of the concurrency and also delimits the edges of the cable route. The cable route consists of brick walls, which are bricked from above.

In the place of the cable marking, the brick on the upper coverage is placed horizontally.

If it is necessary to lay LV cables next to each other without gaps, the current load is determined by the appropriate factor according to ČSN 33 2000-5-52.

This laying must be approved by the relevant cable route administrator.

When crossing, the principle applies that the higher voltage cables are at the bottom, the lower ones at the top.

When crossing, the cables must be separated by a partition in terms of the effect of the electric arc. For cable crossings, the same provisions apply for the smallest gaps as for concurrency.

LV cables can be crossed without gaps, this variant must be approved by the relevant cable route administrator.

When crossing with a lightning conductor ground line, the cable must be laid above this line and at a distance of at least 500 mm from it at the crossing point. For further details see set of standards ČSN EN 62305.

2.2.4 Protection against mechanical damage

The type of cable is selected according to the category, nature and degree of external influence and especially according to the nature and degree of danger of mechanical stress. The mechanical stress applied on the structure in which the cable is stored must not be transferred to the cable. In case of increased mechanical stress, the cables must be protected by placing them in cable protective casings (plastic pipes) with or without concreting, trays, concrete trays, or by laying in cable channels, bypassing, etc.

The outlet from the cable protective casings (pipes, trays) must be made in such a way that the cable is not damaged, especially not pinched. Cable protective casings are only laid in straight sections without bends.

The loose cable protective casings are fitted with a cable wire and closed with a stopper or sealed. After placing the cable into the cable protective casing, the ends of the cable protective casing are sealed.

Cable lines leading along a wall of a building or supporting pole shall be protected from mechanical damage (detachable plastic cable trays, wire systems, steel trays, covers, etc.) up to the height of 3 m above the ground.

2.2.4.1 **Fire resistance requirements**

Steel and concrete protective structures meet the condition for non-flammability. According to ČSN EN 13501-1 + A1, plastic protective structures must meet the condition for inclusion in the reaction to fire class according to the given environment. In the event of an accident, such as a fire, the plastic protection structures must not emit toxic substances or gases at volumes that are harmful to health. Fire resistance is not considered when protecting cables laid in the ground.

2.2.4.2 **Single and multi-chamber protective structures, (underground) conduit system**

Overview of possible protective structures:

- concrete trays,
- plastic trays,
- rigid plastic protective tubes,
- flexible protective tubes,
- multi-chamber protective structures

Single and multi-chamber protective structures shall be considered in cases of expected increased mechanical stress in the cable route. The installation depth according to 2.2.2 can be reduced, if necessary, after considering the situation.

To lay the cables, it is possible to use cable conduit systems assembled from individual protective elements (concrete, plastic, etc.) in sections, the length of which guarantees safe cable routing without damage. In the case of very long cable lengths, cable (access) chambers can be installed in the cable conduit systems, which allow the cables to be pulled in their full lengths, without the need to connect shorter cable lengths.

When laying LV and HV cables in cable conduits systems, it is necessary to observe the principle that each element of the protective structure can be used only for one voltage level of these cables.

Only one separate current circuit is stored in one chamber (hole) of the protective structure.

Outer diameter D mm	**Inner diameter d** mm	**d_k= d / 1,5** mm	**$d_ž$= d_k / 2,15** mm
40	32	21.3	9.9
50	40	26.7	12.4
63	51	34.0	15.8

75	61	40.7	18.9
90	75	50.0	23.3
110	94	62.7	29.2
125	107	71.3	33.2
140	120	80.0	37.2
160	137	91.3	42.5
200	173	115.3	53.6
232	200	133.3	62.0
250	220	146.7	68.2

Tab. 2-1a – Cable protective casings

Fig. 2-2 - Figure for Table 2-1a.

Column **d / 1.5**, indicates the maximum outer diameter of the cable **dk**, or the equivalent diameter of several cables, or optotubes, that can be stored inside the cable protective casing.
Another option is a combined power cable with an integrated microtube.
During route crossings, the mechanical strength of the plastic cable protective casing can be increased by concreting.

Cables, optotubes	The length of the cable protective casing in the ground		Extrusion length	
	up to 15m	above 15m	up to 15m	above 15m
LV (AYKY 3x240+120) (even with integrated microtube) (NAYY 4x240)	110	160	110	160
HV up to240 mm^2, without integrated microtube	160	200	160	200
HV up to 240 mm^2, with integrated microtube	200	200	200	225
HV up to 240 mm^2, with optotube	160	200	160	200
metallic communication cables	110	160	110	160
optotubes up to 40mm	110	160	110	160

Tab. 2-1b Recommended selected diameters of cable protective casing in mm

NOTE – related to tab. 2-1b:

- *The diameters of the cable protective casings listed in the column "above 15 m" apply to the excavation of roads.*
- *A diameter of 160 mm of extrusion is used for cables up to 10 kV positioned under the roads and optotubes even at a length of less than 15 m.*

- *The diameter of the cable protective casings 110 and 160 mm can be increased to 160 or 200 mm in justified cases (use of cable protective casings in bends, complex orifices into the building, etc.)*
- *The distributor decides in his territory how to store the HDV cable between the connection or disconnection box towards the electricity meters. If he/she decides to use a plastic cable protective casing, its recommended inner diameter is 1.5 d of the outer diameter of the cable.*

Trench width

The width of the trench should not be greater than required by an adequate and safe working space so that there is enough space in the excavation for installation.

Trench depth

The depth of the trench will vary depending on the voltage level, type of cable line, type of protective structure (cable protective casing, cable tray, cable conduit system) and corresponds to Annex A, table Tab. A - 1 Laying depth.

Preparation of the bottom of the trench before laying

Protective structures must be installed on a level, firm and stable base. Any unevenness at the bottom of the trench must be levelled with loose granular material and subsequent reinforcement.

To ensure even load distribution, the levelling layer must contain 50 to 80 mm of non-compact flexible fillings made of granular material of different grain sizes.

This layer must be free of stones and other solid particles larger than 20 mm in order to avoid possible point loading.

To ensure the required quality of the excavation base, the final manual alignment of its bottom is suitable.

Installation in stable granular soil

After digging the trench to the prescribed depth, the bottom of the trench is manually adjusted by removing any unevenness, stones and other solid particles.

Installation in unstable and loose soil

To ensure the required quality of the trench base, the final manual alignment of its bottom is suitable. The most commonly used procedure for stabilizing the foundations of protective structures is to remove unstable soil to a suitable depth and replace it with processed material (stony) in a layer that guarantees the necessary strength and stabilization of foundations and compliance with the required depth of the trench.

2.2.5 Contact of cables with other underground cable lines

When concurrence and crossing of cables with other networks occur, it is necessary to respect the standard ČSN 73 6005. If it is unavoidable, it is necessary to take such measures (e.g., choice of distance, thermal insulation partition, etc.) so that the average soil temperature at the position of the cables is not greater than 20 ° C. Otherwise, the load on the cables must be reduced adequately according to ČSN 33 2000-5-52.

2.2.6 Cable junctions with roads, tracks

2.2.6.1 Cable junctions with roads and railways

The crossing is preferably performed perpendicular to the axis of the road or track by ground cables placed in cable protective casings or cable channels with sufficient strength to ensure operational safety and stability of the road body, railway body and to avoid disruption of the road or the rail body during maintenance, repairs or cable line replacement.

Cable protective casings or cable channels must extend beyond the space of the road, or railway body, or their components and accessories by at least 600 mm (i.e. 600 mm behind the outer edge of the rounded foot of the embankment, or behind the outer edge of the ditch, or behind the outer edge of the rounded upper edge of the section).

The cables must be laid at least 1 m below the road surface. If they are stored in cable protective casings, tubes or channels protected from mechanical damage or sufficiently mechanically strong, they can be stored at a smaller depth. However, the upper edge of the protective lining or channel must be at least 100 mm below the road structure, i.e. below the ground plane. (see ČSN 73 6005).

Underpasses in cable protective casings or tubes are basically terminated directly into the terrain with sealing of openings on both sides, for example with mounting PU foam. Termination with shafts is done only exceptionally.

When crossing or paralleling with other engineering networks, the cables are stored in cable protective casings according to ČSN 73 6005.

The laying of cables in a road or railway body must be discussed and specific conditions from the statement of road and railway administrators must be observed.

2.2.7 Cable arrangement

To laying of single-core cables, either an arrangement of three single-core cables in a triangle without gaps (arrangement I. - see Fig. 2-4) is selected, or side by side arrangement in one plane without gaps (arrangement II. See Fig. 2-4).

For longer and permanently fully loaded cable lines made of single-core cables, arrangement I. is recommended so that the energy losses caused by currents in the shield and in any sheath with conductive foil are as small as possible. The arrangement I. is also recommended in the vicinity of the communication cable line (when placed in a common trench).

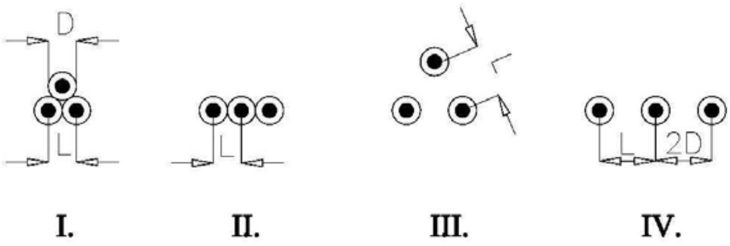


Fig. 2-4 - Cable arrangement

If the single-core cables are laid in the ground in the prescribed manner (i.e., covered with a layer of sand and protected by blocks or bricks) and the soil has been properly compacted after backfilling, no further measures are required to secure the cables against short-circuit currents. In arrangements I. and II., the cable shields and any cable sheaths with conductive foil are to be earthed at both ends.

When laying parallel lines from single core cables (i.e., lines connected to common busbars), it is recommended to alternate the phase sequence (L1L2L3, L3L2L1, L1L3L2, etc.) so that the cables of the same phase have approximately the same inductance in all parallel systems.
Laying single-core cables in blocks is not recommended due to the relatively large axial distance of cables of one system.

2.3 Laying cables in the air

2.3.1 Laying cables in buildings directly on the foundation

The cables are fastened (on walls, ceilings, boards, supporting ropes, etc.) with suitable metal or insulating clips, which are also suitable for the respective environment and do not have a harmful effect on the conductor in the given environment; they can also be placed freely on a non-flammable surface.

Distant spacers must be used in rooms with significant exposure to water, corrosive substances, etc. It is recommended to seal the fixing screws, if they are countersunk.

The single-core cables of a three-phase system must be fastened to each other against the dynamic effects of short-circuit currents.

Cables which must not be laid directly on a flammable foundation must be separated from the flammable foundation by a sufficiently thermally insulating pad. ČSN 33 2312 applies to low voltage cables.

When laying cables with a bare metal sheath directly on a metal foundation, appropriate measures must be taken, if necessary, to prevent electrolytic corrosion in the environment.

NOTE - Information on how to lay and fasten the cable is provided by the manufacturer.

2.3.2 Distance between clips or supports

The distance between the clips and supports should be 1000 mm, unless a different value is determined by calculation (e.g. according to ČSN EN 61914), or the requirement for a different distance between the clips is not specified in the technical documentation of the laid cable.

2.3.3 Laying cables in buildings

Single-core cables laid in buildings must be reliably secured against the effects of short-circuit currents. It is recommended to lay the cables on metal footbridges (metal grids).

In order to reduce the dynamic effects in the event of a short circuit, it is recommended to lay single-core cables on footbridges with gaps in arrangements III and IV (see Fig. 2-4), especially in networks with higher short-circuit power.

Cables in arrangement I. and II. are fastened with sleeves around all 3 cables.

To fasten the cables in arrangements III. and IV. (see Fig. 2-44) it is necessary to use clips made of non-magnetic material

The width of the clips should be at least equal to the diameter of the cable. There should be an insert made of flexible material (e.g., PVC, rubber band) between the clip and the cable.

When placing single-core cable systems on one grid next to each other, arrangement I. is recommended (see Fig. 2-4); when placing the systems on top of each other, arrangement II. is recommended. The width of the gaps between systems placed next to each other should be at least equal to the diameter of the cable (D) in arrangement I. or II., or rather say twice the diameter (2D) in arrangement III. or IV. (see Fig. 2-4).

2.3.4 Concurrence and crossing of cables in the air

Laying cables in the air is laying cables on the surface of building structures by laying (not stretching), on a pre-prepared supporting structure (cable footbridge, metal grid, etc.).

It is not about placing cables in a building cavity, in a pipe (stored in the ground, water, building structure), in an impenetrable cable channel, etc.

Cables must be laid in such a way that undesirable phenomena caused by inductive, capacitive and galvanic influences do not occur in adjacent lines. ČSN 33 2000-4-444 and ČSN 33 2160 deal with the issue of laying cables and lines from the point of view of protection against electromagnetic interference.

If cables of different voltages or different current systems are laid side by side, it is recommended to place them in separate groups, separated by larger gaps for clarity, especially if the groups are not otherwise distinguished.

If the cables are next to each other on the structure, the LV cables are laid separately from the HV cables. If the cables are on top of each other, the LV cables are usually laid under the HV cables. HV power cables should be placed above the control (or communication and special) cables. If HV power cables are laid in the opposite direction, they must be separated from LV cables or control, communication and special cables by a partition resistant to the thermal effects of an electric arc and preventing the cable behind the partition from exceeding the permissible short-circuit temperature (see ČSN 33 2000-4-43). See also National Annex ČSN 33 2000-5-52.

When laying cables of the same voltage in one row (layer) next to each other or on top of each other, cables up to 10 kV are usually laid with gaps equal to the outer diameter of the cable. Cables above 10 kV are then laid with gaps equal to at least twice the outer diameter, but at least 100 mm, unless separated by a partition. With different cable diameters, the larger diameter is determinative.

For these purposes, it is considered that the surface temperature of the cable behind the partition must not be higher than the permissible temperature of the cable core in the event of a short circuit. Smaller gaps without the use of partitions, or tight placement of cables in layers next to each other, above (below) each other is allowed only for low voltage cables and their load capacity is then reduced according to ČSN 33 2000-5-52. Single-core cables forming one current circuit are laid together and are considered as one cable when assessing distances to other cables.

There must be a gap of at least 250 mm between the HV and LV cables, unless they are separated by a partition according to the previous part of this article. The same applies to the gap between the HV power cables and the control, communication or special cables. The distance between the LV power cables and the control, communication or special cables is worked out as with the power cables between each other. However, the possible effect of induction must also be considered.

When LV cables run together with LV cables in pipes, the distance between them must be at least 30 mm; when in conjunction with communication lines it is necessary to comply with the requirements of ČSN EN 50174-2 and when in parallel with the cable lines of security devices (e.g. fire alarms, emergency lighting lines, equipment for evacuation elevators) on which the safety of persons or objects depends, it is necessary to maintain distance at least 60 mm in parallel for the length of up to 5 m and distance of 200 mm at a parallel of more than 5 m long, unless the standards for individual types of electrical distribution provide otherwise.

If the HV voltage cables are laid in parallel with another LV voltage line in the protective lining (e.g., lines in pipes on the wall, etc.), the distance between them must be at least 250 mm, unless the cables are separated by a partition.

NOTE - The distances (gaps) mentioned here always mean the actual gaps between the cables, not the axial distances.

2.4 Laying cables in cable channels (especially in substations and between buildings)

No pipes other than air ducts may be placed in the cable channels; when crossing channels occur, these pipes must be structurally separated.

When concurrence or crossing of the cable channel with the heat pipe occur, it should be ensured that the air temperature in the cable channel does not exceed 30 ° C, otherwise the load on the cables must be reduced accordingly, see ČSN 33 2000-5-52.

Where groundwater occurrence is possible, the cable channel must be carefully secured before its penetration. Drainage of the channel must be carried out in such a way as to prevent the penetration of return water. The bottom of the cable channel should always have a slight incline so that any water that has penetrated is drained into sewers or sumps, etc.

Cables are laid in cable channels either directly on the bottom of the channel or usually on special structures. Cables can be laid at the bottom of the channel if it is dry, and only outside the passage areas; if there is a possibility of water presence in the cable channel, the cables must not be laid directly on the bottom.

NOTE - For laying cables in cable distribution areas intended for storage of power and communication conductors and cables, directly related to electrical stations of the distribution and transmission system of license holders for transmission and distribution of electricity according to Act No. 458/2000 Coll. the company Energy standard PNE 38 2157 can be used.

2.4.1 Laying cables in cable protective casings

Tubes can be used to store cables, which guarantees safe cable routing without damage. A hole diameter of approximately 1.5 d is recommended, where "d" is the outer diameter of the cable.
One cable is pulled into each hole. LV and HV cables can be stored directly in plastic cable protective casings according to tables 2-1a and 2-1b.
Single-core cables forming one current circuit are considered as one cable from the point of view of pulling into the cable protective casing.
It is recommended to store individual sections of the cable protective casing line directly.

2.4.2 Placing lines close to other distributions

2.4.2.1 Location near power lines

Circuits with voltage bands I and II ***) must not be placed in the same cable systems unless each cable is insulated with regard to the highest voltage present or unless one of the following solutions is adopted:

- each conductor of a multicore cable is insulated to the highest voltage present in the cable,

or

- the cables are insulated to the voltage of their system and installed in separate sections of pulled-through wiring channels or laid wiring channels,

or

- a system of separate electrical installation pipes is used.

NOTE - Special conditions for electrostatic and electromagnetic interference may apply to telecommunication circuits, data transmission circuits and those like.

****) See ČSN IEC 449 Voltage bands for electrical installations in buildings.*

2.4.2.2 Laying of power lines with regard to metallic communication devices in the internal distribution

The power line must be laid in such a way that it does not affect the communication line or its operation. The power and communication lines can be in the same protective lining under the conditions according to Tab. 2-2.

Concurrence of an isolated power line with: an isolated communication line	Cable line distance for length of concurrence	
	up to 5 m	above 5 m[1)]
for telephone or radio	30 mm	100 mm[1)]
for bell, signal and others	as with power lines	
[1)] *NOTE: The values are determined with regard to dangerous, threatening and disturbing influences.*		

Tab. 2-2 - Concurrence with the metallic communication line

In addition to these basic provisions, the requirements of ČSN 34 2300 and other regulations for the distribution of communication equipment must be complied with.

2.4.2.3 **Laying power lines with respect to lightning conductor lines**

The set of standards ČSN EN 62305 applies to the distances of the power line from the lines and equipment of the lightning conductor.

2.4.2.4 **Placing cable lines close to non-electrical distribution systems**

Electrical distribution systems must not be located in the vicinity of those distribution systems that produce heat, smoke or fumes and may have harmful effects on the electrical distribution systems unless they are protected against such effects by a cover which does not affect the dissipation of heat from the cable line.

If the electrical distribution system is placed under distribution systems that may cause condensation (e.g., water, steam or gas supplies), measures must be taken to protect the electrical distribution system from the harmful effects of these distribution systems.

If the electrical distribution systems must be installed close to the non-electrical distribution systems, the installation must be carried out in such a way that any anticipated activity carried out on the non-electrical distribution systems does not cause damage to the electrical distribution systems and vice versa.

NOTE: This can be achieved as follows:

- *appropriate distance of both distribution systems*

  or

- *using mechanical or thermal covers.*

If the electrical distribution system is located in close proximity to non-electrical distribution system, both of the following conditions must be met:

- the cable lines must be adequately protected against the dangers which may arise from the presence of another distribution system during normal operation,

  and

- protection against contact with non-living parts must be ensured according to ČSN 33 2000-4-41, ČSN 33200-5-54, ČSN33 2000-6, ČSN EN 50522 and non-electrical metal distributions must be taken into account as foreign conductive parts.

2.4.3 Selection and methods of laying cable lines with regard to maintenance, including cleaning

When choosing the method of laying the cable lines, the knowledge and experience of persons, especially those qualified to perform its maintenance, must be taken into account. If any protective equipment needs to be removed during maintenance, measures must be taken to maintain the degree of protection originally required.
For maintenance purposes, measures must be taken to ensure safe and adequate access to all parts of the distribution system required for maintenance.

2.5 Protection against the spread of fire

Cable lines must be designed to prevent the spread of any fire along the cable line.

Cables that are designed to power technological equipment are grouped into sets according to the needs of that powered technological device. If the technological equipment requires the supply of electricity of the 1st degree (according to ČSN 34 1610), it is necessary to create as many sets of cables as there are systems of power supply provision required. Cables laid inside one set form a set of system cables (hereinafter also referred to as a set). Cables laid in the air can be laid either together with other equipment of the building in a common fire section, or a separate fire section can be created for them (e.g., a pass-through cable channel).

The sets of system cables must be fire-separated from each other so that a possible fire of one set for the duration of the fire in minutes (marked t according to ČSN 73 0810) does not affect the functionality of the cables stored in the other sets.

This can be done in particular by one of the following options:

a) by storing different sets of system cables in different fire compartments,

b) by storing various sets of system cables in a common fire compartment, provided that the conditions are met that the sets must be separated from each other by a space without fire risk according to Article 8.3 of the ČSN 73 0804 standard,

c) by storing different sets of system cables in a common fire compartment, but the cables inside each set must be functional in fire conditions and the temperature inside the fire-free set of system cables must not exceed 750 ° C due to fire of other sets of system cables (this can be achieved for example by heat dissipation, water sprinkling, thermal insulation).

Within the system cable sets, the cables are grouped according to the rated voltage and form a cable voltage group. The voltage groups of cables must be separated from each other by the prescribed distance or longitudinal partition corresponding to Article 2.3.5 Concurrency and crossing of cables in air.

The distances between the individual cable voltage groups are determined by the type of cables and the way they are laid. These distances are specified in the subject cables standards or are specified by the manufacturer.

Where, for reasons of space, the distance between the voltage groups of cables cannot be maintained, a longitudinal partition shall be used between these groups. The longitudinal partition must withstand the thermal effects of the electric arc.

The distance between the cables stored inside the voltage group of cables is given by the recommendations for laying and installation of cables specified in the relevant ČSN on these cables.

For unmanned HV / LV distribution stations at transformer stations:

- in buildings (built-in or free-standing - brick kiosks or tower),
- block transformer substations.

Single-sheathed HV cables with PE sheath may be used provided that the following conditions are met:

- the cables are stored in cable channels (space, etc.), which are sufficiently covered (steel plates, self-extinguishing boards, etc.) so that the operator is not endangered
- the cables do not cross another cable line or measures are taken during crossing (coverage by a non - flammable partition, etc.)
- when connected to another cable line, the distance is observed (according to ČSN) or separated by a non-flammable partition

For unmanned HV / LV distribution stations, with external service, where the length of the cable between its input and termination in the switchboard is less than 2 (3) m, it is possible to use a single-sheathed HV cable with PE sheath.

However, the following must be observed:

- the cable will not cross and will not be in concurrence with other lines.

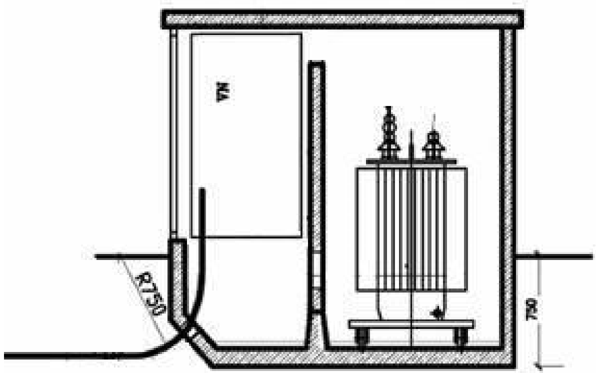


Fig. 2-5 – Example of passing to TS

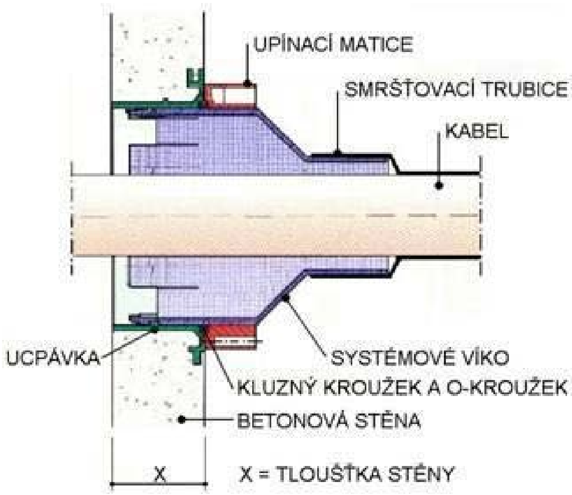


Fig. 2-6 – Example of a method of sealing with a lid with a shrink tube

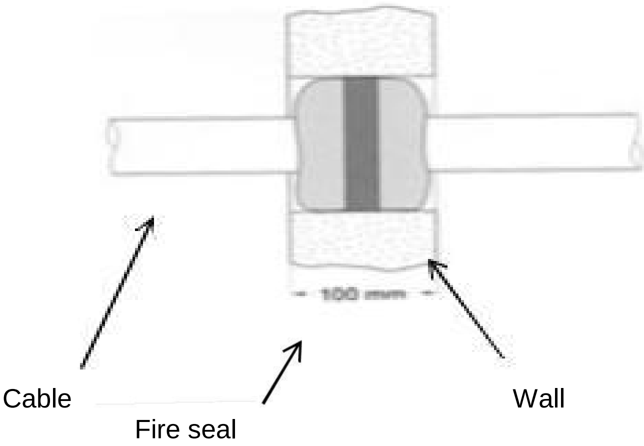


Fig. 2-7 – Example of cable passage through a wall with a fire seal

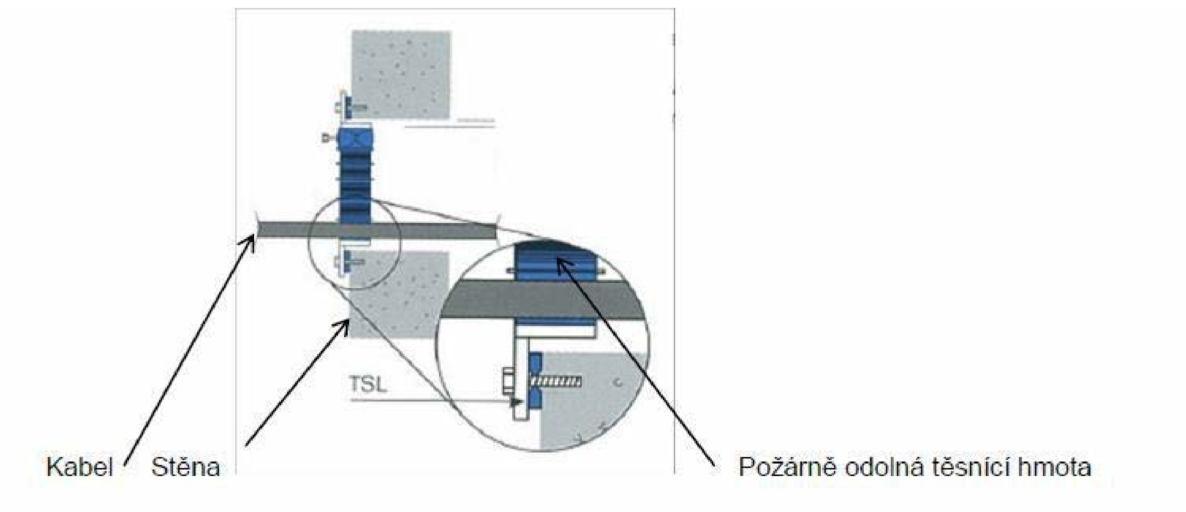


Fig. 2-8 – Example of passage for multiple cables through a wall with a fire seal

2.5.1 Fire protection - penetration seal

No distribution system shall penetrate the load-bearing element of the building structure, except in the case where its original load-bearing capacity can be ensured after creating an opening.

. All sealing modifications must meet the following requirements in terms of division of fire sections and technical requirements in construction Decree No. 268/2009 Coll.

Temporary sealing requirements may arise during the cable line laying.

Sealing should be done as soon as possible during adaptation work.

Sealing modifications must be subjected to an initial inspection at an appropriate time during the construction, which will confirm their compliance with the requirements of the Decree on Technical Requirements for Constructions No. 268/2009 Coll.

Protection of HV cables against the spread of fire, if they are laid in buildings, is governed by the basic ČSN 73 0804, Fire safety of buildings - Production facilities.

Cable penetrations through fire dividing structures and fire partitions are performed according to ČSN 73 0810 Art. 6.2.1 and 6.2.2. Fire closures of penetrations must comply with the classification according to ČSN EN 13501-2 and ČSN EN 1366-3.

NOTE: *Newly installed HV cables must comply with the resistance to flame propagation and the requirements of ČSN EN 60332-3-22. The basic requirement for cable sheaths is at least "Resistance to flame propagation" corresponding to ČSN EN 60332-1-1 and ČSN EN 60332-1-2.*

Depending on the nature of the space in which the HV line is laid, the length of fire sections is determined. These are divided as necessary by fire partitions (PP) or longitudinal fire partitions (PPP). For these purposes, the Enterprise Energy Standard PNE 38 2157 can be used.

2.6 Installation of cables and optotubes

2.6.1 Organization of installation and laying of cables

The organization of installation and laying of cables is performed according to the installation procedure and the manufacturer's recommendations.

The contractor of cable couplings and cable heads must prove his/her professional competence for this activity with a valid document of training - a certificate from the manufacturer.

2.6.1.1 Laying of low voltage cables

Cables can be laid on a level surface, cable footbridges, metal grids, structures, into cable channels, collectors, pipes, earth, etc. Care must be taken to ensure that the environment in which they are laid does not adversely affect the cable.

In case of increased mechanical stress, the cables must be protected by laying them in concrete or plastic cable protective casings. The output from them must be done in such a way that the cable is not damaged, especially is not pinched. In the ground, the cables are protected so that they are not damaged during excavations or landslides. The cable heads must be closed with shrink caps during storage, transport, cable laying and assembly of the sets. The cable head can only be left open for the time necessary to assemble the set.

2.6.1.2 Laying of HV cables

Unless otherwise specified by the cable manufacturer for a particular cable construction, the cables shall be laid in such a way that the maximum pulling force of the pulling head is $P = S. \sigma$, where the cross section of the core S is in mm^2 and the allowable tensile stress is: $\sigma = 50 \ N / mm^2$ for cables with copper cores and $\sigma = 30 \ N / mm^2$ for cables with aluminium cores. These tensile stresses guarantee that the permissible elongation of the cores by 0.2% is not exceeded. The maximum permissible pulling force (P is in units N) is calculated on the basis of the total sum of the individual cross-sections.

When pulling with a pull stocking, the same load as for the pulling head can be applied, as long as it is ensured that the force is reliably transmitted to the cable by friction.

<u>Principles for laying the cable:</u>

- the cables can be pulled by the sheath with a pull stocking,
- a device for limiting the maximum pull must be used,
- laying pulleys and rollers must be used when pulling,
- the minimum permissible bending radius must be observed when pulling.

The following exceptions apply to the triangular arrangement of XLPE cables:

- cable bundling is performed after every 1.5 m
- Cables with plastic sheaths are not endangered and do not require anti-corrosion measures against stray currents.

2.6.1.3 **Laying of optotubes**

Laying of optotubes is preferably done by hand laying. The condition must be met that during the laying of the optotube it is not pulled on the ground, it is not rubbed against the edge of the excavation, steel structure, concrete cable protective casing, etc. In places where these cases could occur, it is necessary to use suitably placed cable pulleys, etc. When laying, it is necessary to observe the prescribed bending radius, especially when pulling through openings into transformer stations, etc. During storage, laying and installation, it must be ensured that no dirt and water penetrates into the optotubes. Optotubes must be placed in a sand bed. The bottom layer of the bed should be at least 50 mm thick; it levels the bottom for laying the optotubes. Cover and side filling should be at least 80 mm thick. Optotubes laid freely outdoors must be UV stable or protected from solar UV radiation.

The connection of individual optotubes in the route is performed by designated couplings. The ends of the optotube for the purpose of the tightness test (pressure test) are closed at least at one end with fittings with a valve. The optotubes will be laid according to Appendix B Fig. B1-7.

Tests after laying optotubes

After the installation of the optotube, the following is always performed:

- throughput test (calibration) followed by
- tightness test (pressurization).

The tests are also carried out after each optotube repair.

The test results are supported by a protocol. The tests should reveal possible leaks and problems with throughput, which could subsequently prevent the optical cable from blowing. These tests are also performed before the actual blowing of the optical cable on routes that were previously carried out without the blowing of optical cable. The tests are performed even after a repair of an optotube.

Optotube throughput tests

The throughput test must be confirmed by a protocol demonstrating the throughput of a gauge 150 mm ± 5 mm long and 85% in diameter of the inside diameter of the optotube.

Optotube sections shorter than 10 meters do not need to be calibrated. The throughput test can be verified simply by passing an optical (or other) cable with a diameter of about 85% of the inner diameter of the optotube. Care must be taken not to damage the inside of the optotube.

Throughput tests of microtubes integrated in a power cable

A calibre consisting of an optical cable with an outer diameter of at least 80% of the inner diameter of the microtube and a length of approx. 400 mm terminated on one side with a brass tip with an outer diameter of approx. 85% of the inner diameter of the microtube and a length of at least 15 mm is used for the calibration test. It is prohibited to calibrate microtubes on construction sites with a steel ball.

Microtube sections shorter than 10 meters do not need to be calibrated. The throughput test can be verified simply by passing an optical (or other) cable with a diameter of about 85% of the inner diameter of the microtube. Care must be taken not to damage the inside of the microtubes.

Tightness tests of optotubes

The following requirements must be met for the tightness test of the optotube:

- The optotubes are pressurized with air to a pressure of 3 bar and are closed with an end fitting at one end and with a valve fitting at the other end. The initial pressure value is not read until 10 minutes after the end of the pressurization, in order to avoid the effect of different ambient temperatures, and to allow time for equalization of pressures along the entire length of the route.
- One hour after reading the initial pressure, another value is read and the pressure drop is evaluated. The difference in initial and final pressure must not be greater than 1%. The stated

conditions apply to sections up to 5 km long. Tests are not required for sections up to 100 m if there is no coupling in the route.

Tightness tests of microtubes integrated in the power cable

- The microtubes are pressurized with air to a pressure of 10 bar. The difference in initial and final pressure must not be greater than 1%. The pressurization time is at least 10 minutes.
- It is not recommended to leave the microtubes pressurized after the pressurization is completed. The end piece with the valve shall be dismantled and the tested microtube should be fitted with a termination end piece at both ends.
- When working on the microtube in the low-voltage connection / disconnection box in the power part, which is under voltage, the live parts in the box shall be covered with a cover shield or electrical insulating blanket, intended for the given type of box.
- Calibration and pressurization of the microtube integrated in the HV cable at new, transferred, or extended sections shall be performed when the HV cable is switched off, secured and short-circuited. Sections of microtubes shorter than 10 meters do not need to be pressurized.

Cable line marking

The optotube is marked with the appropriate colour or colour with longitudinal stripes, according to the requirements of the relevant operator. According to the purpose of using the optical fibres, the colour of optotubes is designed, which is determined according to the company standard N 11 012.

In order to ensure quick orientation in the laid optotubes in the ground, marking with identification labels is performed in justified cases. In transformer stations, the ends of the optotubes shall be marked with a label describing the direction. Additional markings may be defined by the relevant operator.

Termination in buildings (transformer stations, substations, etc.)

The entries of cables, optotubes and microtubes must be secured against the water penetration into buildings. The entries must be adjusted to prevent mechanical damage.

The optotube shall be terminated in the transformer station with a sufficient reserve at a suitable place, outside the zone of approach to the live parts of LV and HV. After the installation of the optical cable, a cable reserve holder is placed on the inner wall of the transformer stations at a suitable place, especially in the case of internal operation. The optical cable shall be reeled on the holder with sufficient reserve for possible mounting of the coupling.

Mechanical protection

In cases of increased mechanical stress (entrances, roads, car parks), the optotubes must be protected by placing them in plastic cable protective casings (flexible corrugated, straight corrugated or straight smooth), plastic or concrete trenches. The dimensions of the cable protective casings are according to the tab. 2-1a and tab. 2-1b. In case of crossing or concurrence with a heat pipe or steam pipe, protection against the action of an external heat source must be provided, either via a sufficient distance from the heat source or in another way with the same effect, e.g., shading.

Optotubes leading along a wall of a building or a supporting pole are protected from mechanical damage (by UV-resistant plastic cable trenches, pipes, etc.) up to the height of 2.5 m above the ground. The transition between the optotube and the mechanical protection in the outdoor environment (e.g., via UV-resistant protection tube) must be sealed, e.g., with a suitable thick-walled shrink tube.

2.6.2 Permissible temperatures of LV and HV cables

Operating temperature for cables with:

- PVC isolation, it is – 25 °C up to + 70 °C.
- XLPE isolation, it is – 25 °C up to + 90 °C.

The maximum permissible core temperature in the event of a short circuit with a switch-off time not exceeding 30 s is:

- + 160 °C for PVC isolation
- + 250 °C for XLPE isolation.

The lowest permissible cable temperature for cable laying is + 4 ° C.

The temperature for handling drums and rings is in the range of - 25 to + 40 ° C. **The minimum ambient temperature for cable storage is** -35 ° C.

Permissible ambient temperature when installing cables: the agreed lowest ambient temperature is + 4 ° C.

2.6.3 Bending radius of low voltage cables

The minimum permissible bending radius must be:

- 12d for cables with a diameter of "d" from 20 to 40 mm
- 15d for cables with a diameter "d" over 40 mm

When pulling the cables into the LV cable boxes, the permissible bending radius can be halved if necessary, during a one-time bending,

2.6.4 Bending radii of HV cables with XLPE insulation

- when pulling
  - 20 d
- after laying
  - 15 d for cables with PE, PVC or double sheath 20 d for cables with Al laminated PE sheath

where **d**… .is the diameter of the cable.

2.6.5 Minimum bending radii of optotubes and microtubes

Bending radii are given by individual types and sizes of optotubes and microtubes. The manufacturer's installation instructions must be observed. The throughput and tightness tests are used to verify correct assembly.

2.6.6 Pulling forces

The forces during machine pulling are determined by the manufacturer of the cable or optotube for a specific type, otherwise according to the relationship in 2.6.1.2.

2.6.7 Modification of cable heads

The cable heads must be suitably protected against external influences (atmospheric influences, water effects, effects of corrosive substances, etc.) before making the cable heads or couplings.

2.6.8 Cable connection, branching and termination

The cables are terminated, connected and branched in cable sets (couplings, branching boxes, boxes, etc.) which are, if possible, accessible and where the set and method of use are specified by the manufacturer for the given cable. Connecting cables and therefore using cable couplings is only recommended in cases where the production lengths of the cables are shorter than the length of the route, or when replacing a defective part of the cable. In these cases, the couplings shall be located in places of low fire load or separated from other cables by a partition according to paragraph 2.3.5 Concurrence and crossing of cables in air.

NOTE - In some situations, there may be a requirement to equip the distribution system with permanent means of access, such as ladders, alleys, etc.

2.6.9 Attachment of a foreign subject

Network routes of technical equipment of all administrators must respect the protection zones of individual networks according to the relevant laws. For example, Act 458/2000 Coll. (Energy Act) is the relevant law for the routing of energy cables, gas pipelines and heat distribution, Act 127/2002 Coll. (Act on Electronic Communications) applies to communication cables, Act 274/2001 / Coll. (Water Supply and Sewerage Act) applies to water supply and sewerage networks

Furthermore, the routes of technical equipment must respect the zones of interest and the minimum distances between the networks of technical equipment defined in the standard ČSN 73 6005.

In principle, it is not possible to place the networks of another administrator of technical equipment (foreign entity) in the energy protection zone given by the Energy Act. If, for technical reasons, it is necessary to place the network of a foreign entity in the protection zone (crossing, concurrence in a narrow sidewalk, etc.), the following rules must be observed:

- the distribution system operator may grant an exemption from the protection zone to a foreign entity and the foreign entity must also grant an exemption from the protection zone for the distribution system operator,
- the order of zones of interest according to the ČSN 73 6005 standard must be observed,
- the minimum permissible distances of individual networks of technical equipment defined by the ČSN 73 6005 standard must be observed, while it is necessary to pay attention to the possibility of expanding energy networks in the future (for example to cover increased demand for electricity in general),
- when allowing the foreign entity to place its network in the energy protection zone, it is necessary to take special care so that the networks do not interfere with each other (for example, causing reduction in the transmission capacity of energy cables) or such interaction must be reduced as much as possible,
- furthermore, it is necessary to eliminate the negative consequences of failures on both networks as much as possible, and that is not only regarding the direct mutual influence of damage by the failure itself, but also in the case of elimination of possible damage caused by troubleshooting a foreign network failure.

3 EHV Cables

3.1 Electrical requirements

3.1.1 Voltage

Cables must not be used at a voltage higher than their rated voltage.

Rated phase voltage of cable and accessories Uo = 64 kV

Rated system voltage In = 110 kV

The highest voltage for a device Um = 123 kV

Withstand voltage of normalized atmospheric pulse (peak value) 550 kV.

3.1.2 Current circuits

Three-phase current system 3x110kV, TT with directly grounded node, frequency 50 Hz.

3.1.3 Current return

Only earthed conductors must always be used for the return line.

3.1.4 Cable construction

Only single core cables are used.
Example of cable construction Fig. 3-1.

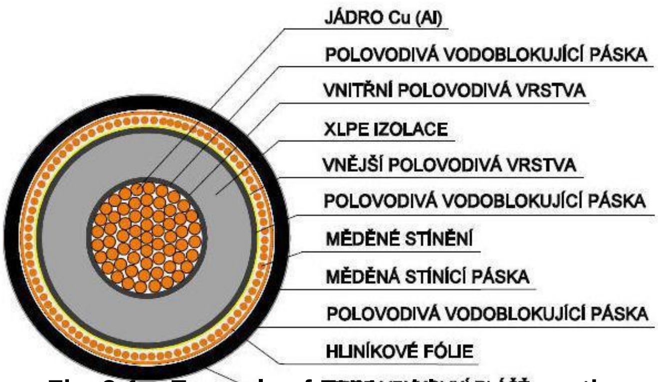


Fig. 3-1 – Example of EHV cable cross-section

3.1.4.1 Conductive cable core

Cu or Al conductor cores are used, their cross-section must be dimensioned according to ČSN IEC 60287-1-1 + A1, so that it meets the required load and short-circuit load capacity according to ČSN IEC 949 and IEC 61443 so as to correspond to the required short-circuit currents.

The possible types of conductive cable core are:

- rope, densified, circular
- compressed circular,
- segmental circular,
- cores of higher cross-sections can be segmented, circular, hollow.

3.1.4.2 **Cable insulation**

In particular, cables with XLPE (crosslinked polyethylene) insulation with an inner and outer semiconducting layer extruded in one operation simultaneously with the insulation are used.

The nominal insulation thickness must correspond to the permanent electrical stress (gradient) for the life span of the cable and at the same time must meet the requirements for electrical tests according to ČSN IEC 60840.

3.1.4.3 **Metal shielding or metal cable sheaths**

Metal shielding or metal sheaths are used to conduct leading capacitive currents, in the case of single-phase short-circuit currents it delimits the electric field of the cable and creates protection against dangerous contact.

The used types of shielding are:

- copper wire with anti-spiral,
- lead sheaths (100% protection against water penetration).

The cable manufacturer will design the cross-section according to the magnitude of short-circuit currents and the permitted heating of individual cable components according to IEC 61443, ČSN IEC 949.

For the calculation, the initial shielding temperature 80 ° C before short-circuit is considered, the final short-circuit temperature determined by the materials used according to IEC 61443 paragraph 4 is considered.

3.1.4.4 **Watertightness**

The decision on watertightness is given by the type of environment where the cable is laid. To lay a cable in water, it is necessary to use a cable in a waterproof design.

- longitudinal (axial) protection.

To lay a cable in water, axial watertightness is recommended, ensured by a water-blocking layer in the cable construction (tape or powder).

- transverse (radial) protection.

Transverse protection is always used and is provided with laminated Al or Cu tape for shielding from Cu wires (for the calculation of permissible load or short-circuit current shielding is not considered), or with a metal sheath. For environments without the presence of water, cables without longitudinal watertightness can be used.

3.1.4.5 **Cable outer sheath**

Depending on the cable routing, two basic types of sheaths are used. The type of sheath shall be chosen according to whether the cable is stored in the ground or is located in areas with air access, such as cable tunnels and substations. If the cable is stored in spaces with air access, the cable sheath shall be made of flame retardant material that complies with the set of standards ČSN EN 60332 or other measures must be taken in accordance with ČSN EN 60332. If the cable is stored directly in the ground, there is no need to use a sheathed cable with flame retardant properties. The standard casing material with high-quality mechanical parameters is HDPE (high density polyethylene).

To store the cable in water, it is necessary to use a waterproof cable.

Each cable shall have an outer sheath provided with an outer semiconducting layer to perform sheath integrity tests after laying the cable.

The recommended value of the minimum thickness of the outer sheath of the cable is according to ČSN IEC 60502-1 and ČSN IEC 60502-2:

$t = 0{,}035 \times D+1$ (mm), where D is the diameter under the outer shell.

3.1.5 Configuration of single-core cables

Single-core cables are laid in a tight triangular bundle or next to each other with gaps (straight laying). An exception is laying in cable protective casings, where a triangular laying with gaps can also be used. Methods of laying in cable protective casings are described in section 3.3 Laying cables in the ground. The arrangement is selected according to the length of the cable line and the conditions in the cable line route (e.g., whether there is space for couplings).

3.1.5.1 **Properties of single-core cable configurations**

A more detailed comparison of configuration properties is given in Annex F - Comparison of HV cable configuration properties.

3.1.5.2 **Laying in a tight triangle**

Advantages: less space requirements, less shielding losses, better ratios when interfering with the operation of the cable on the communication line, lower intensity of the magnetic field above the cable.

Disadvantages: higher warming of adjacent cores, even when compensating losses in shielding lower load capacity than when placed side by side.

3.1.5.3 **Flat laying (side by side) with spaces**

Advantages: lower warming of adjacent cores, higher load-bearing capacity when compensating for losses in shielding than when placed in a tight triangular bundle.

Disadvantages: greater space requirements, greater shielding losses, worse conditions when interfering with the operation of the cable on the communication line, higher intensity of the magnetic field above the cable.

3.1.6 Grounding of metal shields or metal sheaths of cables

The basic connection of a metal shield or sheath in a three-core cable system is its grounding at both ends of the cable line. To increase the load capacity of cables by reducing shielding losses and limiting the induced voltage on the shield, special shield earthing systems can also be used: one-sided shield earthing and transposition - cross shield connection.

A more detailed comparison of the properties of individual methods of earthing metal shields is given in Annex J.

3.1.6.1 **Both-ends bonding systems**

Both-ends bonding of metal shields or metal sheaths of cables, (abbreviated designation BEB or BE from both-ends bonding, or SB from solid-bonding are used), Fig. 3-2.

Metal shields or metal sheaths of cables are directly grounded at both ends of the cable line; they are directly connected in the couplings. The transposition of cores can be performed in the connector boxes, thus increasing the load capacity and better ratios for the interference of communication cables in concurrence.

Advantages: there is no voltage against the ground at the ends of the cables, simple connection and coupling, good conditions in case of interference with the communication line.

Disadvantages: higher induced current in the metal shield or metal sheaths of the cables, as a result higher loss in the metal parts, thus reducing the load capacity of the cables, when placed side by side by up to 10 to 15%.

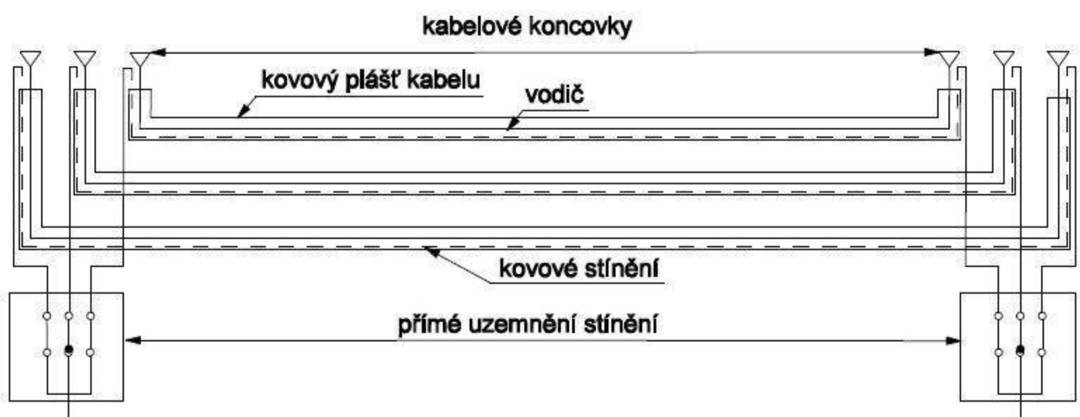


Fig. 3-2 - Both end bonding systems

3.1.6.2 **Specially bonded systems**

Cables and connectors must be designed as an insulated shielding system.

For specially bonded systems, the insulation condition of the outer sheath of the cable must be checked, so sheath tests must be performed regularly by connecting 10 kV DC for 1 minute between the metal shield or metal sheath of the cable and the outer semiconducting layer on the outer sheath of the cable. A possible violation of the insulating ability of the outer sheath would cause an undesired circulating current in the metal shield or metal sheath of the cable, which would cause additional heating of the cable, reducing the load capacity, which could lead to the destruction of the insulation. Calculations of the induced shield voltage in a 3-phase system with ungrounded shield ends are given in Annex D.

Single point bonding systems

Single point bonding systems of metal shields or metal sheaths of cables (abbreviated designation SPB is used) Fig. 0-3. Metal shields or metal sheaths of cables are grounded only at one end of the cable line; they are directly connected in the couplings.

Voltages at the ungrounded end of the metal shield or metal sheath of the cable can reach high dangerous values when a short-circuit current passes. The magnitude of these voltages is directly proportional to the cable length, so this earthing system can only be used for limited cable lengths, up to approx. 1 km. To limit surges caused by atmospheric phenomenon or transitional effects in the network, a surge protector must be used at the ungrounded end. To conduct currents in the event of a fault and to limit interference with the communication line, it is usually necessary to apply a parallel earth conductor with a cross-section corresponding to the 1-phase short-circuit current of the cable. The voltage at the ungrounded end must always be verified by calculation. See Annex J.

Advantages: The induced current does not flow in the metal shield or metal sheath of the cable, no losses occur, this allows a higher load capacity, simple coupling.

Disadvantages: consist in the need to ensure the above-mentioned measures.

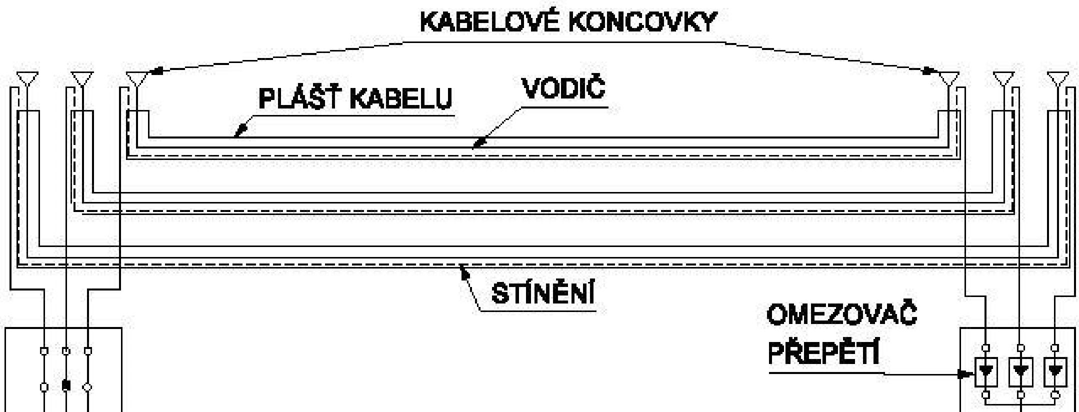


Fig. 3-3 - Single point bonding systems

Cross-bonding transposition

Cross-bonding transposition of metal shields or metal sheaths of cables and conductive cores of individual phases of single-core cables (abbreviated designation CB) Fig. 3-4.

The main CB section, which is grounded at both ends, always consists of 3 subsections where the couplings of metal shields and metal sheaths of cables are interrupted, separated, insulated and cross-connected, or to achieve a higher effect, individual cores are also transposed in the connector box.

The difference in the lengths of individual CB sub-sections should not exceed 10%.

The cable line can consist of one main CB section or several main CB sections. The use of CB is not economical if the number of cable lengths / drums per phase is less than 3.

There is a constant induced voltage on the metal shield and most of the couplings during operation. This voltage at full load must not exceed the values of permissible contact and step voltages of the relevant ČSN. The length of the individual CB sub-sections must be adjusted so that these values are not exceeded. Surge protectors must be used to limit possible overvoltage in the event of atmospheric or transient phenomena.

Earthing boxes (see paragraph 1.7.2.3 Other equipment of this standard) for connecting metal shields in couplings (for earthing or CB) shall be placed in pillars or shafts made of concrete or non-conductive plastic. Cabinets, pillars or shafts must be marked with appropriate warning signs and secured against intrusion by unauthorized persons.

Grounding, control of step and contact voltages and possible additional measures in the vicinity of cabinets (equipotential rings, insulation surfaces, etc.) must comply with the relevant provisions of the relevant ČSN, depending on whether the cabinets are located in remote or frequently visited places.

Advantages: elimination or significant reduction of circulating currents in the shield, low losses in the metal shield allow higher load capacity, the possibility of loading with gaps that reduces external thermal resistance, higher load capacity allows a reduction in cross section and thus a reduction in charging current.

Disadvantages: Cables and couplings must be designed as an insulated shielding system. Complex coupling with insulated metal shielding, implementation of the measures mentioned above.

For SPB and CB systems, it is recommended to install a separate parallel conductor together with the cable routing, which is laid between the endpoints of the cable system. The conductor is installed to one phase of the cable line with mounting tape and is earthed at both ends. In individual sections, it is transposed to the next phase in the middle of the section. Its function is important in terms of dangerous and threatening influences on communication and security equipment according to ČSN 33

2160 Electrotechnical regulations. Regulations for the protection of communication lines and equipment against the dangerous effects of three-phase HV, EHV and SHV lines. The conductor will be transposed in the middle of the length. The conductor will be dimensioned for the value of single-phase earth short-circuit current and its cross-section must comply with ČSN IEC 949.

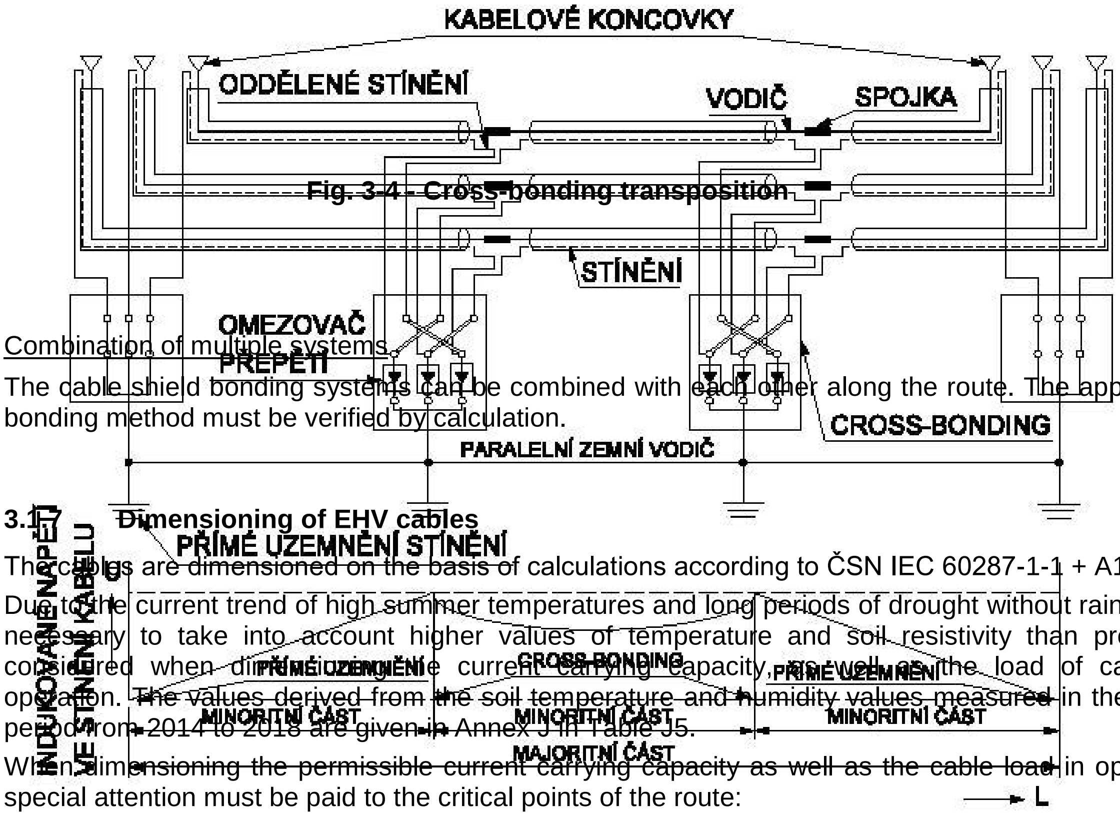


Fig. 3-4 - Cross-bonding transposition

Combination of multiple systems

The cable shield bonding systems can be combined with each other along the route. The appropriate bonding method must be verified by calculation.

3.1.7 Dimensioning of EHV cables

The cables are dimensioned on the basis of calculations according to ČSN IEC 60287-1-1 + A1.

Due to the current trend of high summer temperatures and long periods of drought without rainfall, it is necessary to take into account higher values of temperature and soil resistivity than previously considered when dimensioning the current carrying capacity, as well as the load of cables in operation. The values derived from the soil temperature and humidity values measured in the 5-year period from 2014 to 2018 are given in Annex J in Table J5.

When dimensioning the permissible current carrying capacity as well as the cable load in operation, special attention must be paid to the critical points of the route:

- concurrencies and crossings with local heat sources such as power cables of all voltages and heat or steam lines,
- extrusions or under-drills
- deeper placement of cables than with 1.3 m overlayer,
- laying cables in the area of tree root systems and tree lines (distance from the tree trunk less than the height of the tree).

Indicative maximum values of induced shield voltages in SPB CB earthing systems are given in Annex D.

Informative data on the induced voltages in the cable shield, the effects of the configuration, the bonding system of the load shielding capacity of the various cross-sections, the storage conditions and the effect of concurrence are given in Annex J in Table J1.

3.2 Cable fastening

Fasteners must ensure the stability of the cable system and must be designed to withstand operational influences.

Information on the methods of laying and fastening the cable, including the relevant calculations, is provided by the manufacturer with respect to local conditions.

Operating influences: the thermomechanical influence and electromagnetic influence acting mechanically on the cable line are listed in Annex G - Operating influences on EHV cables.

The provisions of ČSN EN 61914 Cable clamps for electrical installations can be used as appropriate for the terminology, properties and calculation of forces caused by short-circuit currents.

3.2.1 Basic division of elements for fastening single-core cables

- Bundling elements for loose laying (in the ground) Fig. 3-5.
- Bundling and fastening elements for fixed laying (on the fastening structure):

- elements with attachment to the fastening structure, Fig. 3-15a,
- intermediate bundling elements without attachment to the structure, Fig. 3-15b,
- suspension elements, Fig. 3-16.

3.2.2 Division of phase fastening

- Single-phase
- Three-phase

3.2.3 For loose storage in the ground (cables in a triangle, in a bundle)

See Figure 3-5 and Figure 3-6 are used

- Bundling tape
- Polyamide cord
- PE clips

3.2.4 For fixed storage in air

See fig. 3-15

Horizontal (cables in a triangle, bundle, or side by side individually)

- Strapping tape
- Polyamide cord
- PE clips
- Metal clamps
- Wooden clips
    - Suspended (cables in triangle)

See fig. 3-16

- Cable clips according to the manufacturer's catalogues
    - Vertical (cables in flat formation)

See fig. 3-17

- Single-phase and three-phase cable clips according to the manufacturer's catalogues.

NOTE - Single-phase bundling and fastening elements must not be made of uninterrupted magnetic material.

3.3 Laying cables in the ground

3.3.1 Laying in a sand bed with cement stabilization

The cables must be laid in the ground at depths at least according to Tab. A-1 and Fig. 3-5, Fig. 3-6. With regard to other routes of technical equipment networks, the laying of cables within the boundaries of cities and municipalities must comply with ČSN 73 6005.

Optotubes in concurrence with EHV cables are laid in a separate route above or next to EHV cables according to Fig. 3-5, 3-6. and according to the model cross-sections in Annex B. 2.

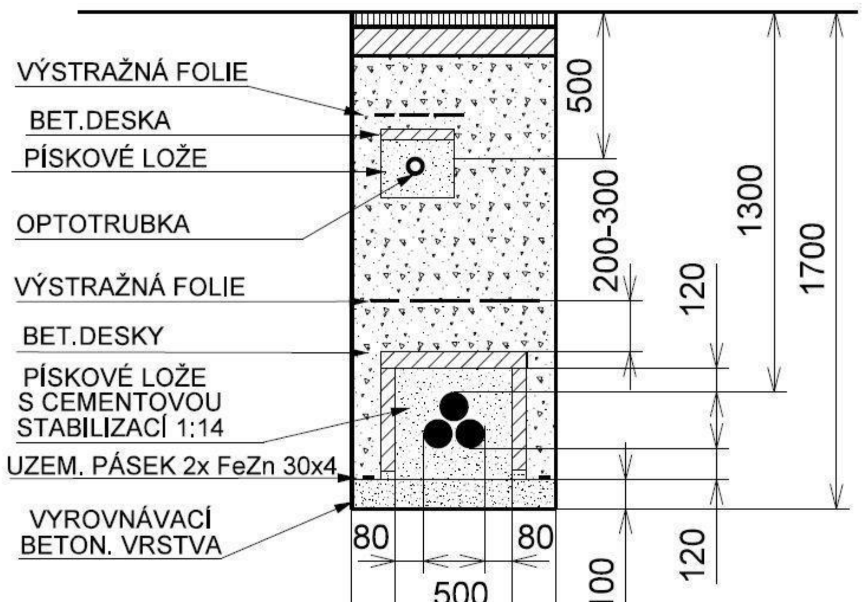


Fig. 3-5 - Laying the cable in the normal route in a triangular EHV formation

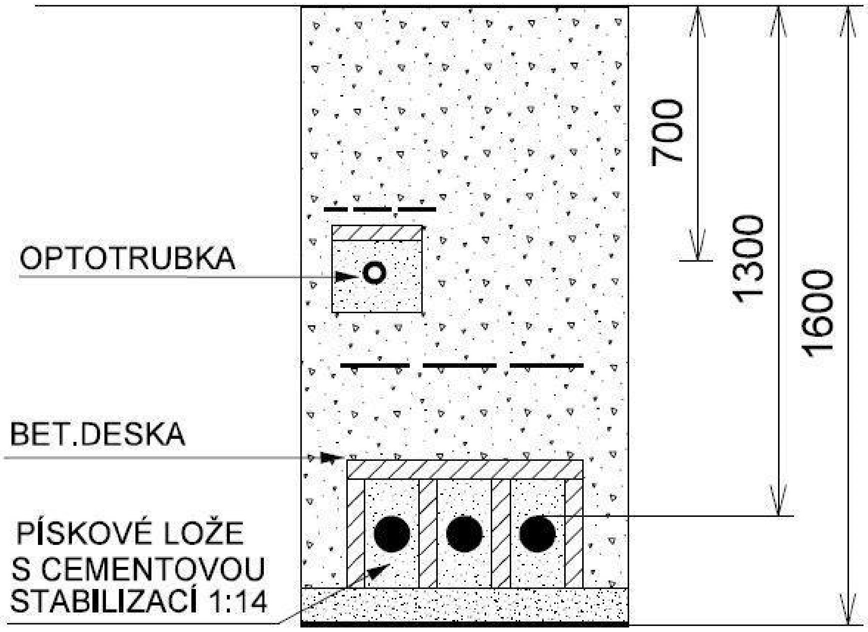


Fig. 3-6 - Laying of EHV cable in normal route in planar formation

Unless otherwise specified by the contracting authority, the maximum ambient temperatures at a depth of 1300 mm in winter and + 20 ° C in summer are considered.

NOTE – It is recommended to consider the calculated temperature in the ground at a depth of 1,300 mm at different times (winter, summer). The value significantly affects the permissible current load (A) of the cable.

The system of single-core EHV cables can be stored in a flat formation (next to each other) or a triangular formation. For reasons of space, it is more advantageous to store the system in a triangle. When laid in the triangle, the cables are bundled along the entire route after laying to maintain the shape of the formation. The distance between the bundles is 3 m. The cables are laid in the trench in a bed with a minimum thickness of 12 cm below and above the cable. The thickness is measured from the surface of the cable. The total thickness of the bed must not be less than 30 cm. The cable bed is made of thin concrete, i.e., a dry mixture of dug sand with a grain size of up to 3 mm and cement in a volume ratio of 14: 1, which stabilizes the thermal resistance of the cable bed to 1.2 Km / W. Separating concrete slabs must be placed on the side of both sides of the cable at a height of at least 25 cm with a thickness of at least 5 cm. A cover made of concrete slabs and a warning foil are placed above the cable bed.

If the depth or the way the cables are laid cannot be observed, for example when crossing other engineering networks, the depth of the cable can be increased or decreased to the necessary extent.

3.3.2 Storage in cable protective casings

In the case of crossings of roads, entrances, etc., the EHV cables are laid in cable protective casings. The individual phases of the cable line are stored in separate cable protective casings, it is recommended to establish a spare cable protective casing in the transition. The minimum inner diameter of the cable protective casing should be at least 1.5 Dk for direct pulling. Pulling via the cable protective casing in bending is not recommended. The recommended values of diameters of cable protective casings are in Annex E-1.

The recommended location of the cable protective casings for laying EHV cables is shown in Fig. 3-7 and Fig. 3-8. The outlet from the cable protective casing (pipes, trenches) must be made in such a way that the cable is not damaged, especially not pinched. Magnetic material (steel pipes) must not be used when installing cable protective casings for the individual phases of the cable line.

For the laying of EHV cable lines, it is not suitable to lay passages in sections that are not completely straight, horizontally nor vertically. In these cases, there is a danger that during laying, the rope will be tensioned during pulling by the towing device and thus the plastic cable protective casing will be deformed (cut) and subsequently the plastic cable protective casing will be completely deformed or torn out when the cable is pulled, thus blocking the passage. It is therefore necessary to establish passages for pulling only in straight sections of the route. Figure 2-13 shows an unrecommended method of establishing passages.

3.3.3 Laying in cable trenches

If it is not possible to apply a sand bed installation, according to Art. Laying in a sand bed with cement stabilization, or if the route is not straight, or if it is the case of protecting the existing line and at the same time the cable line must be sufficiently mechanically protected, the cable line is laid into cable trenches. The individual phases can be stored in separate cable trenches. Laying the cable line in one trench is possible if there is a gap of at least 10 mm between the cable and the cable trench on the sides, and at least 40 mm from the top.

3.3.4 Laying the cable in a drilled hole

In the case of crossing the road through a drilled hole underneath it, controlled drilling is the most suitable method. It is necessary to carry out a geological survey before the drilling itself. The extractability class of the soil has a direct influence on the choice of the magnitude of the compressive force and thus also on the wall thickness of the extruded pipe. The final technology of the drilled hole, the values of the compressive force and the wall thickness of the pipe used and the distance “A” in the case of planar formation are determined by the implementation project on the basis of the above-mentioned geological survey. Examples of cable laying in the drilled hole are shown in Fig. 3-7 and Fig. 3-8.

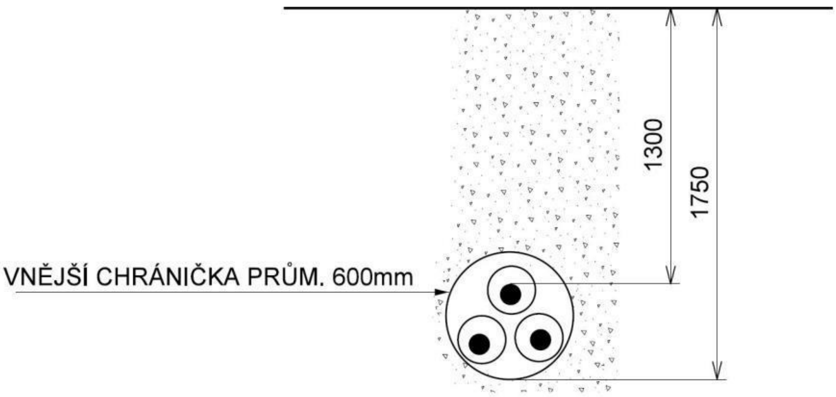


Fig. 3-7 - Laying the cable in a drilled hole with external cable protective casing

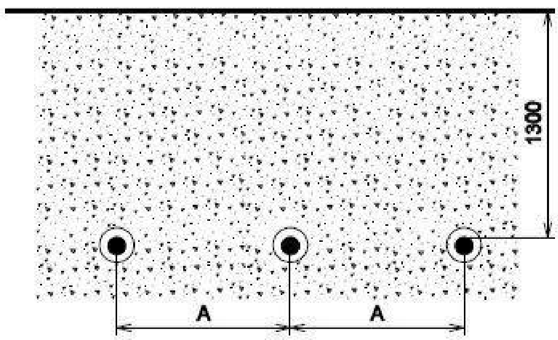


Fig. 3-8 - Laying the cable in a drilled hole with protection of individual phases

NOTE: Cable protective casings of individual phases in *fig.3-7 and fig.3-8 are from a non-magnetic material.*

3.3.5 Concurrence and crossing of cables in the ground

Due to their importance, EHV cables are usually not laid in parallel routes. The independent route is in terms of safety at a distance of 3 m.

The laying of EHV cables is limited in terms of mutual influence, especially in terms of thermal stress.

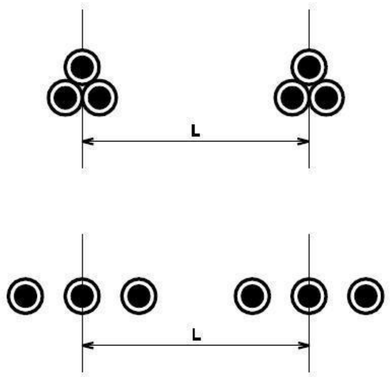
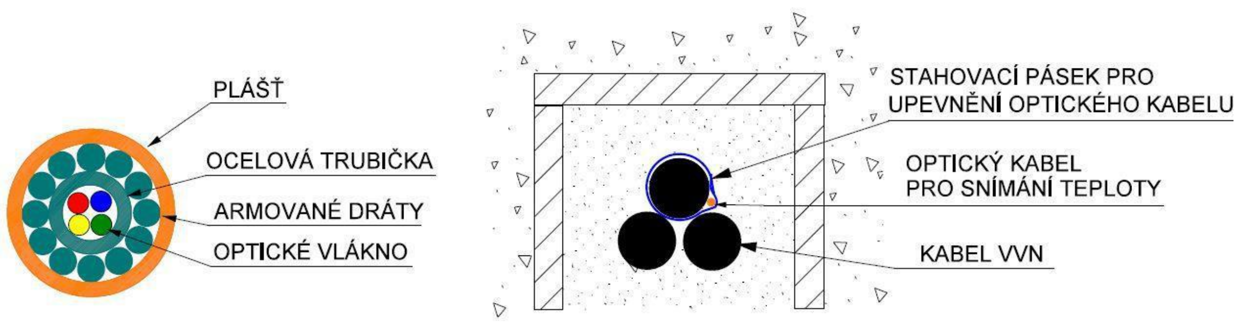


Fig. 3-9 - Method of laying EHV cables in a triangular and planar formation

3.3.6 Warming check-up

It is performed continuously with an optical fibre or at certain points by means of a temperature sensor. Measuring via optical fibre allows the cable temperature to be measured along its entire length online. It is used where there are frequent changes in the thermal conditions of the cable laying:

- The optical cable is additionally installed on the EHV cable sheath according to Fig. 3-10
- The optical fibre is integrated directly in the shield of the EHV cable Fig. 3-11



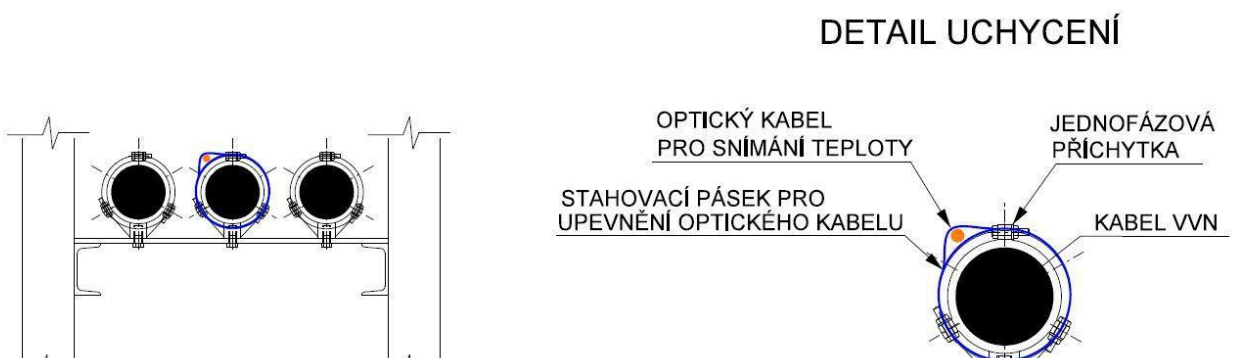


Fig. 3-10 - Location of the optical cable outside the sheath of the EHV power cable

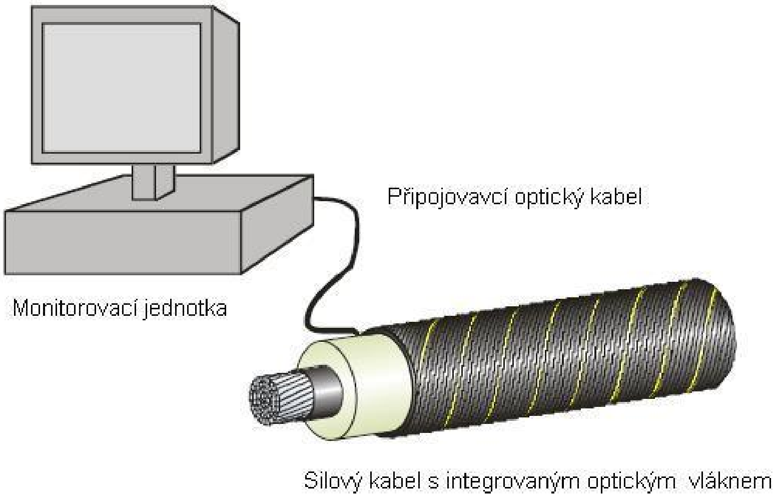


Fig. 3-11 - Example of DTS system connection

Another option is measuring temperature at certain critical points of the route (according to paragraph 3.1.7):

- Temperature measuring using a sensor - the measuring principle consists in changing the electrical resistance of the wire depending on the temperature, Fig. 3-12.

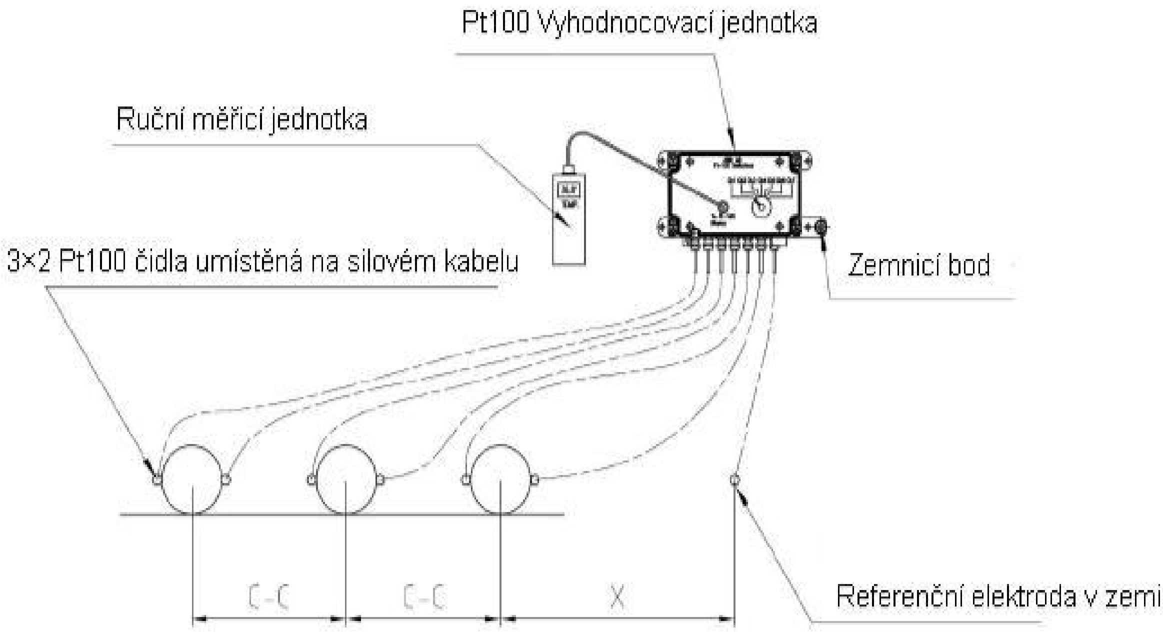


Fig. 3-12 – Measuring warming via sensor

3.3.7 Protection against mechanical damage

3.3.8.1 Warning foils

The warning foil is laid in accordance with ČSN 73 6006. The depth of laying the foil is 20-30 cm above the route of the EHV cable line, or above the cable protective casings or above the outer concrete slab. The foil will be in the entire width of the cable route. The colour of the foil is red.

3.3.8.2 Cover slabs

To cover the EHV cable route, concrete slabs with a minimum thickness of 50 mm are used in the normal cable route from above and on the sides of the cable bed.

3.3.8.3 Plastic cable protective casings

In places of intersection with other engineering networks, single-core EHV cables are stored in separate cable protective casings, it is recommended to establish a spare cable protective casing in the intersection. The minimum inner diameter of the cable protective casing should be at least 1.5 Dk for direct pulling. Pulling the cable protective casing in bending is not recommended. Recommended values of diameters of the cable protective casing are in Annex E-1.

Divided cable protective casing can be used for additional protection of existing cables or for additional protection of new EHV cables. The cable protective casing must be concreted with a layer of concrete at least 50 mm between each other and 100 mm around the cable protective casings. Concreting of pipes is necessary with regard to the mechanical effects of cable pulling.

3.3.8.4 Cable trenches

In places where the cable route intersects with other networks, where it is not possible to make a straight cable route and especially with additional protection of existing cables, it is possible to lay cables in cable trenches. In the event of a new installation, cable trenches must be laid on a level surface. The route will be under-concreted with a continuous layer of concrete at least 50 mm thick. In case the route is not straight, it is recommended to cover the places of bends between the individual trenches with another layer of concrete cover slabs. When protecting an existing cable route, it is possible to protect the cables by covering the cable trench from above. Instead of the cover slabs, the cable route will be under-concreted with sufficient overlap so that the rotated cable trench is seated on the bottom concrete layer.

3.3.9 Contact of cables with other underground lines

The installation of EHV cables at crossings with engineering networks is based on ČSN 73 6005 Tab. A1 and A2. Furthermore, it is necessary to respect the spatial possibilities at the crossing.

3.3.10 Cable junctions with roads, networks and tracks

3.3.10.1 Crossing with roads

The crossing of a cable route with roads is governed by ČSN 73 6005. The cable must be mechanically protected so that it is not damaged and at the same time its repair or replacement is possible. In the case of using an open excavation and establishing cable protective casings for individual phases, it is possible to lay cables in plastic cable protective casings in a triangular formation according to Annex B Fig. B 2-6 or in a planar formation according to Annex Fig. B 2-7. In these cases, it is recommended to establish a spare cable protective casing in the transition together with the other cable protective casings. The cable protective casings must be laid straight without arches. The coverage of the cable protective casings is at least 0.5 m behind the point of road crossing. When laying, it is necessary to connect the cable protective casings precisely and evenly to each other. The cable protective casings and their joints are concreted.

3.3.10.2 **Crossing with engineering networks**

Crossing the cable route with other networks is governed by ČSN 73 6005. In cases where the depth of cable laying cannot be observed, for example when crossing other engineering networks, it is possible to increase or decrease the depth of the cable line to the necessary extent. In this case, the cable lines must be additionally mechanically protected from each other by an arc-resistant partition. In addition, sufficient mechanical protection of the cable line in terms of external load must be ensured. Separation is done with a concrete slab or by placing the cable in a cable trench, or by placing it in a cable protective casing with external concreting. The method of cable routing and protection must be discussed with the network administrator. Examples of laying with selected networks are in Annex B in Fig. B 2-5, B 22-6, B 22-7, B 2-8.

3.3.10.3 **Crossing with railway tracks**

Crossing with the railway track is carried out in accordance with ČSN 73 6301 and ČSN 37 5711. It is necessary to fully respect the requirements of the railway administrator regarding the depth of the track underpass, the method of crossing and the material of cable protective casings, especially with regard to the requirement for non-magnetic materials. The cable protective casings under the railway tracks are set up an extrusion, if the situation allows.

The cover of the cable protective casings must be at least 1.5 m from the plain of the body of the railway undercarriage (or rather say 2 m from the upper storage area of the sleeper).

In the case of company railways, the placement of cable protective casings may take the form of an underpass with the consent of the railway manager.

The cable protective casing must be placed along the entire length of the crossing and, if possible, it should be laid perpendicular to the railway line. The ends of the cable protective casings must be at least 600 mm from the outer edge of the ditch, or 2 m from the foot of the embankment slope; at the same time, this distance shall not be less than 4 m from the track centreline. A prime example of crossings with railways is given in Annex B, Figure B 2-14. Cross-section A – cable protective casings made of non-magnetic material, cross-section B - common cable protective casing with protection of individual phases by PVC cable protective casings ø 232 mm.

3.3.11 Protection of cable lines against stray currents and external influences

3.3.11.1 **EHV cable protection**

The 110 kV cable is equipped with an outer sheath made of HDPE or PVC materials. This material is sufficiently resistant to the effects of stray currents.

3.3.11.2 **Effect of EHV lines on parallel lines**

EHV cable lines in TT networks in distribution systems can result in dangerous or threatening effects during single-phase short-circuits. It is therefore necessary to carry out a check by calculation according to the above-mentioned standards, where the geometric arrangement of phases in the cable system cannot be neglected. Laying side by side with its asymmetry can cause a permanent threat, resp. dangerous effect.

With regard to the magnitude of the effects, the size of the cable and especially the conductivity, or rather cross-section of a metal shield or metal shell, which directly determines the value of the so-called reduction factor determined by calculation or given by the manufacturer are also important.

From the point of view of influence, consistent earthing in terminals, couplings and crossings is important. It is not recommended to use passages and cable protective casings made of conductive materials, in case this cannot be avoided, their length should be reduced as much as possible.

3.3.11.3 **Protection of communication lines and equipment against dangerous effects of three-phase EHV lines**

The protection of communication lines and equipment against the dangerous effects of three-phase EHV lines is addressed in the standard ČSN 33 2160: Electrotechnical regulations. Regulations for the protection of communication lines and equipment against the dangerous effects of three-phase HV, EHV, SHV lines.

3.3.11.4 **Electromagnetic effects on the cable surroundings**

Electric field

Unlike the exterior lines, there is no electric field around the cables. The electric field is enclosed between the cable conductor and the earthed metal shield or metal sheath of the cable.

Magnetic field

The values specified in ČSN 33 2040 and Government Regulation 291/2015 apply to the highest permissible values of magnetic fields in the vicinity of the cable.

The magnitude of the magnetic field depends on the magnitude of the current in the cable, the magnitude of the circulating current in the metal shield of the cable, the configuration and axial distance of the cores, the depth of laying of the cable, the height of the detected field above the ground and the horizontal distance from the cable axis.

The triangular configuration carries a lower magnetic field, as the magnitude of the magnetic field increases with the axial distance of the cable cores. This applies in particular to coupling points. Couplings and any possible shield terminals must be placed close to each other if possible.

Approximate values of the magnetic field that can be assumed for EHV cable lines are given in the Annex K - Approximate values of the magnetic field above EHV cables.

3.4 Cable laying in the air

The cable line is fastened in the air by means of bundles and cable clips ensuring the stability of the cable system according to Fig. 3-15, Fig. 3-17 or by means of loose suspension in the bundle according to Fig. 3-16. At the same time, however, these elements must be designed to withstand operational influences.

3.5 Laying cables in cable channels and tunnels

For installation of EHV cables in cable channels, floors and shafts, the Company Energy Standards PNE 38 2157 can be used. Installation of EHV cables in collectors, technical corridors, channels and basements is in other cases governed by ČSN 73 7505.

3.5.1 Passages

Bushings for individual phases according to Fig. 3-13 are used for passages into cable channels. One passage for one bushing of all three phases is not recommended. The inner diameter of the Dv cable protective casing should be at least 1.5 times larger than the outer diameter of the DE cable. The passage into the cable space must allow sealing against moisture and gas. Follow-up routes before and after the passage must allow the laying of cables with permitted cable bending radii.

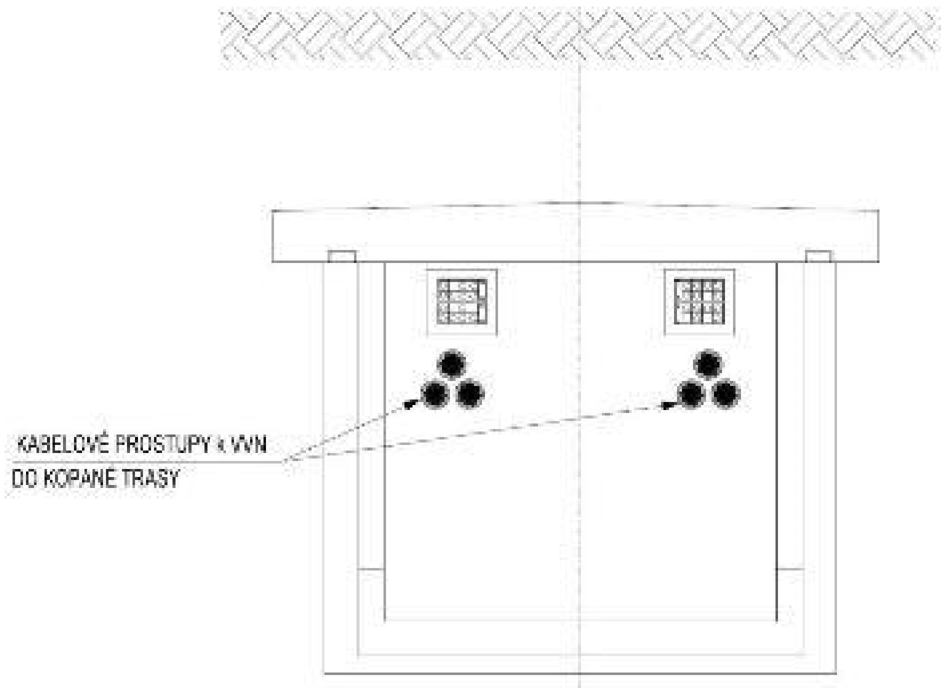


Fig. 3-13 - View of the passage to the EHV cable into the dug route

3.5.2 Horizontal laying

The EHV cables are stored horizontally on separate footbridges. Laying multiple cables on one footbridge is not recommended. If it is necessary to lay the cables on one footbridge, they must be separated by a fire barrier and there must be a sufficient distance between the booms for repair and maintenance of both cable lines. In the case of cable channels where couplings are not considered or in the case where the channels are designed with spaces with couplings (i.e., an extended channel space allowing the installation of couplings), the distance of adjacent footbridges above the EHV cable may be at least 400 mm according to Fig. 3-14.

NOTE: The Company Energy Standard PNE 38 2157 paragraph 4.1.4 can be used to determine the distance between the booms.

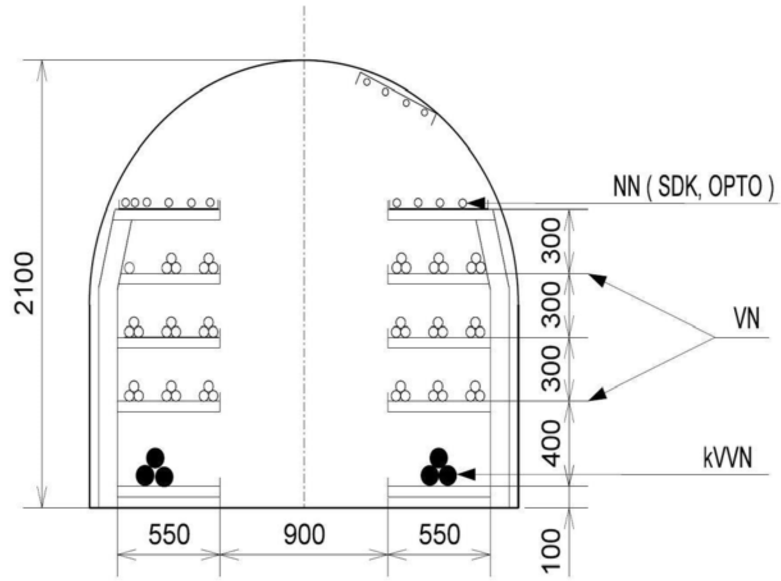
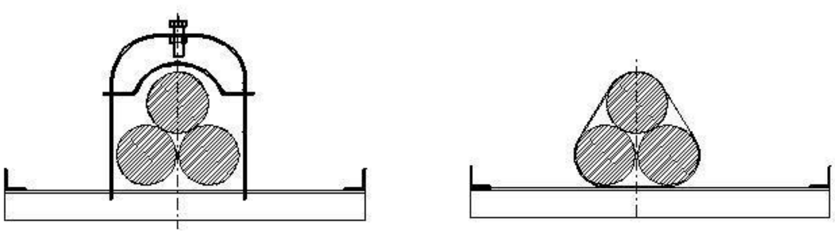


Fig. 3-14 – Cross-section through a cable tunnel with HV cable storage

The cables are laid firmly on the fastening structure using fixed and loose elements (intermediate) according to Fig. 3-15. or by means of suspension elements according to Fig. 3-16.

The fixed laying of cables is carried out in such a way that they maintain their position on footbridges or metal grids during heating during operation and are not damaged either by extension due to heating or by dynamic currents in the event of short circuits.

The cable fastening is proposed by the cable manufacturer (supplier).



a) fixing on construction b) intermediate fixing

Fig. 3-15 - Detail of fastening the bundle to the footbridge and bundling in a horizontal route

Loosely fastened cables allow extension in length as well as transverse corrugation in width in the case of cable heating by making the cable more corrugated between the individual fixed attachments on the structure. The cable fastening is proposed by the cable manufacturer (supplier).

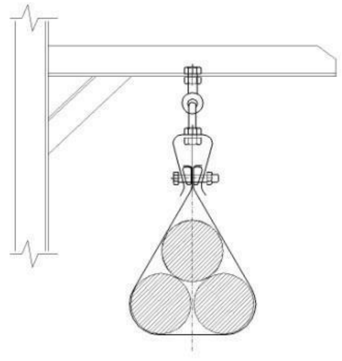


Fig. 3-16 - Detail of a loose cable fastening in a horizontal route

3.5.3 Vertical laying

For vertical laying of cables, flat mounting and fastening for EHV cables in separate phases is recommended. The Company Energy Standard PNE 38 2157 Art. 4.3 can be used to determine the distance of the clamps.

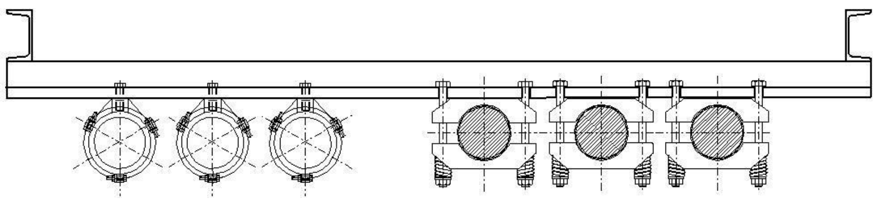


Fig. 3-17 - Example of vertical cable routing

The clamps must not reduce the fire resistance of the cable system.

3.6 Protection of EHV cable lines

- Protection against dangerous contact voltage is provided by earthing with a quick switch-off and bringing to the same potential.
- Surge protectors are used against atmospheric overvoltage.
- Distance protection and comparator protection is applied against overload and short circuit with.
- Surge protector is used against overload between the cable shield and the cable head.
- It is possible to place the lead-out ends of the shield in a separate switchboard with the corresponding IP protection according to the location of the switchboard or by direct mounting of a surge protector between the shield and earthing (outdoor environment).

3.7 Protection of cables against the spread of fire

The basic requirements for the protection of cable routes against the spread of fire are given in ČSN 73 0802 and ČSN 73 0804, while the classification of construction products and building structures related to electrical equipment and distribution are given in ČSN 73 0810.

The ČSN 73 0848 standard (Chapter 1 "Subject of the standard") applies to the fire safety design of EHV distribution systems, where the cables remain in operation even in the event of a fire.

ČSN 73 0848 does not apply to distribution systems licensed under Act No. 458/2000 Coll. as amended (Energy Act).

The protection of EHV cables against the spread of fire, if they are stored in buildings, is therefore governed by the basic ČSN 73 0804. Cable passages through fire dividing structures and fire partitions are carried out in accordance with ČSN 73 0810, Articles 6.2.1 and 6.2.2. and according to Article 12.4 of the ČSN 73 0804 standard. Fire closures of passages must correspond to the classification according to ČSN EN 13501-2 and must be tested from the point of view of fire resistance according to ČSN EN 1366-3.

NOTE: Within the LDS, the Company Energy Standard PNE 38 2157 can be used.

Newly installed EHV cables must comply with the resistance to flame propagation and the requirements of ČSN EN 60332-3-22 The basic requirement for cable sheaths is at least "Resistance to flame propagation" corresponding to ČSN EN 60332-1-1 and ČSN EN 60332-1-2. Depending on the nature of the space where the EHV line is laid, the lengths of the fire sections are determined, which are divided as necessary by main (HPP), partial (DPP) or longitudinal (PPP) fire partitions. The cables must be provided with fire protection partitions against the linear spread of fire in horizontal routes. These are carried out symmetrically for a maximum of 50 meters, each in the length of 3.0 m, along the entire circumference of each core, with a fire-resistant coating (or spraying). The material intended for this coating or spraying must attentively have retardation properties corresponding to the reaction to fire class A1. Routes in vertical sections (shafts, pits) are provided with fire-resistant paint along the entire length of the route, with overlaps to horizontal routes of 1.0 m.

Vertical routes are usually led by escape routes. The individual positions (footbridge routes), where EHV cables are installed in horizontal routes, must be separated from each other in their entire length by a horizontal continuous partition formed by slabs of properties of reaction to fire class A1 in accordance with ČSN EN 13 501-1. Vertical routes are solved in a similar way. The slabs in accordance with ČSN 33 2000-5-52 Art. 521.N11.10.4 to 521.N1.10.7 serve as a partition that protects the cable lines of adjacent positions against the thermal effects of the electric arc in the event of a fault.

Couplings are made exclusively on horizontal routes. When coupling, it is preferred to make the couplings in an excavation in the ground, rather than in the building. If coupling is carried out in the building, the couplings must be treated on both sides with an overlap of 0.5 m to a straight path, with a fire-resistant coating in fire reaction class A1, unless they already demonstrate this property by their construction. For each space where the laying of EHV cables is to be carried out, a report of fire safety solution, according to §41 par. 2 and 4 of Decree No. 246/2001 Coll., on the determination of fire safety conditions and the performance of state fire supervision (Decree on Fire Prevention) must be prepared in advance and (with Fire Brigade and the operator) unreservedly agreed on. On the basis of this report, the installation, operation and maintenance will be carried out.

NOTE -. For the fire protection of EHV cables laid in combined routes (collectors), the wording of ČSN 73 7505 (Chapter 10 "Fire safety"), as amended by the currently valid legislation, also applies.

Annex A Depth of laying cables and optotubes

Voltage kV	Depth H [mm]		
	Terrien	Pavement	Road, curbs of the road
Up to 1 (including) *	700	350	1000
above 1 to 10	700	500	1000
above 10 to 35	1000	1000	1000
above 35 to 110	1300	1300	1300
Optotube minimal	700	350	900
Communication manager and special circuits	usually at the same depth as the power cable		
*) The installation depth H = 700 is used in the field when laying cables without mechanical protection according to 2.2.1 in the manner shown in Figures 2 - 1a and when laying cables in arable land according to Figures 2-1a and 2-1b. The depth of placement in the pavement is minimal and the placement must correspond to local conditions (depth and composition of the base layers, statements of road managers, etc.)			

Tab. A - 1 – Depth of laying

Designation	Grouping of cables in the ground next to each other, above (below) each other	Minimum external distance of parallel cables mm (between surfaces)	
		optotube in a common route	optotube in contact with power cable
1.	Communication, optical, control, special power distribution circuits	50	0
2.	Communication, optical and power		
	up to 1 kV	150	0
	above 1 kV	200	0
3.	Power and power or power and control, special circuit		
	up to 1 kV	50	-
	up to 6 kV	100	-
	up to 10 kV	150	-
	up to 35 kV	200	-
	35kV up to 110kV	500	-

Tab. A - 2 - distance of cables in the ground side by side outside built-up areas

Annex B.1 Examples of cable laying

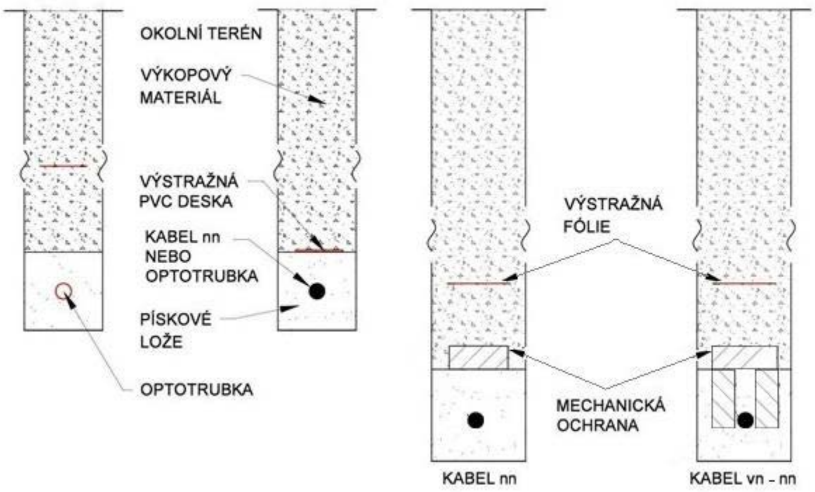


Fig. B 1-1 - Laying of optotubes, LV and HV cables in a sand bed

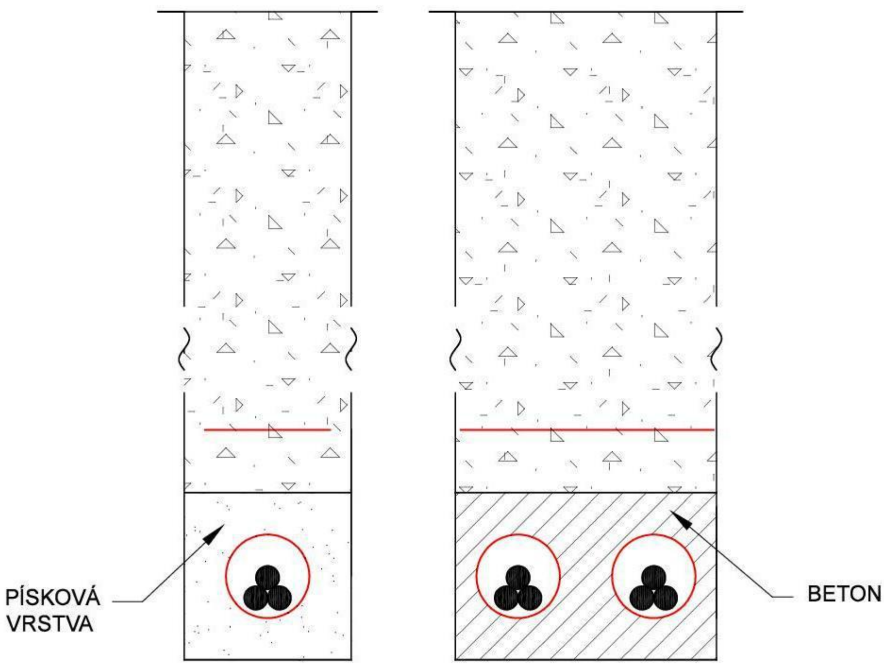


Fig. B 1-2 - Laying of the HV cable in a cable protective casing with backfill and concreting

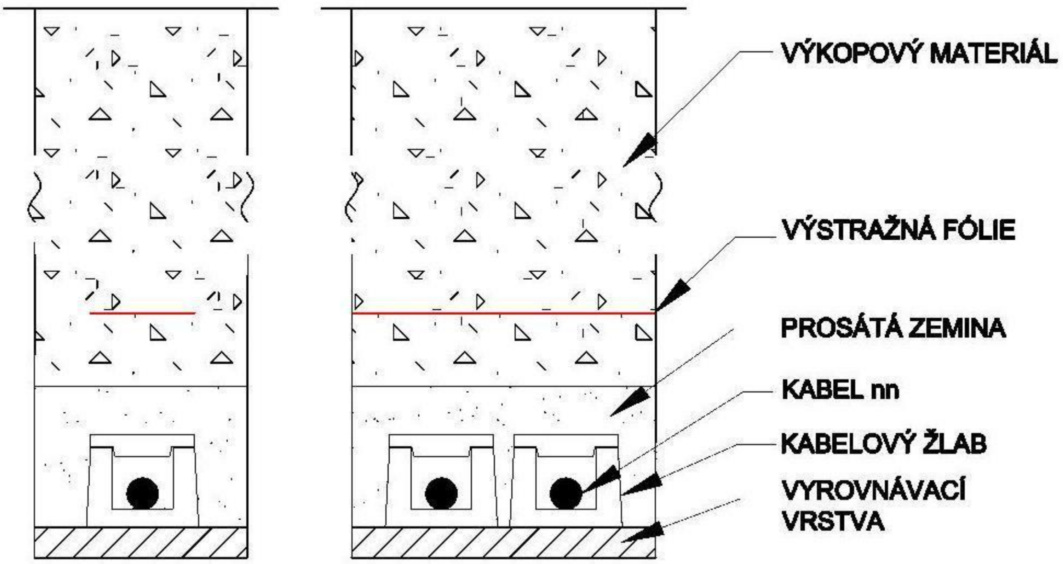


Fig. B 1-3 - Laying of LV cables in the cable trench

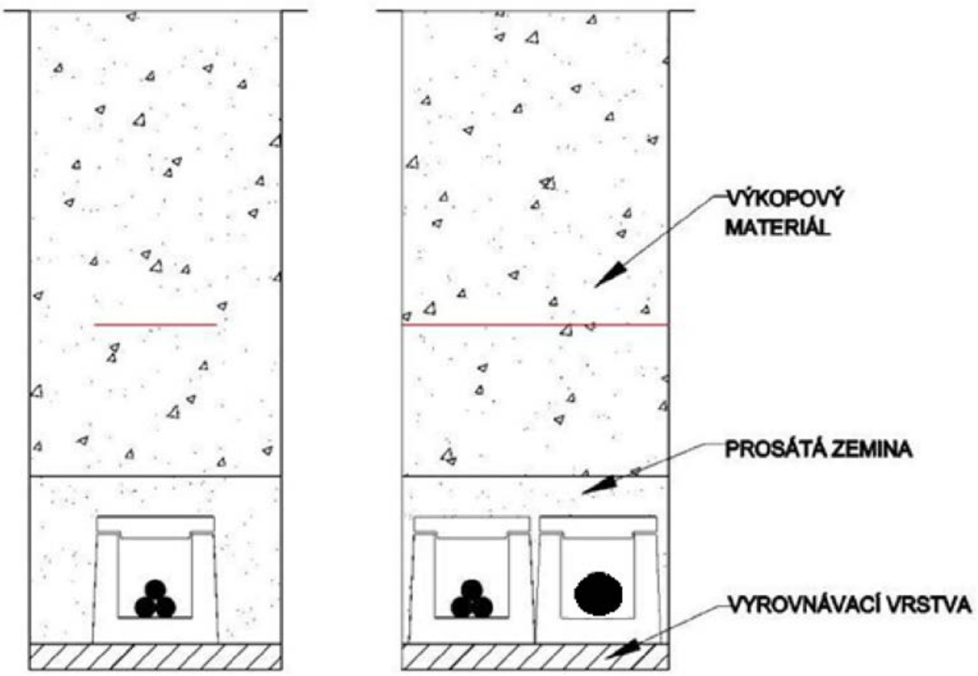


Fig. B 1-4 - Laying of HV cables in the cable trench

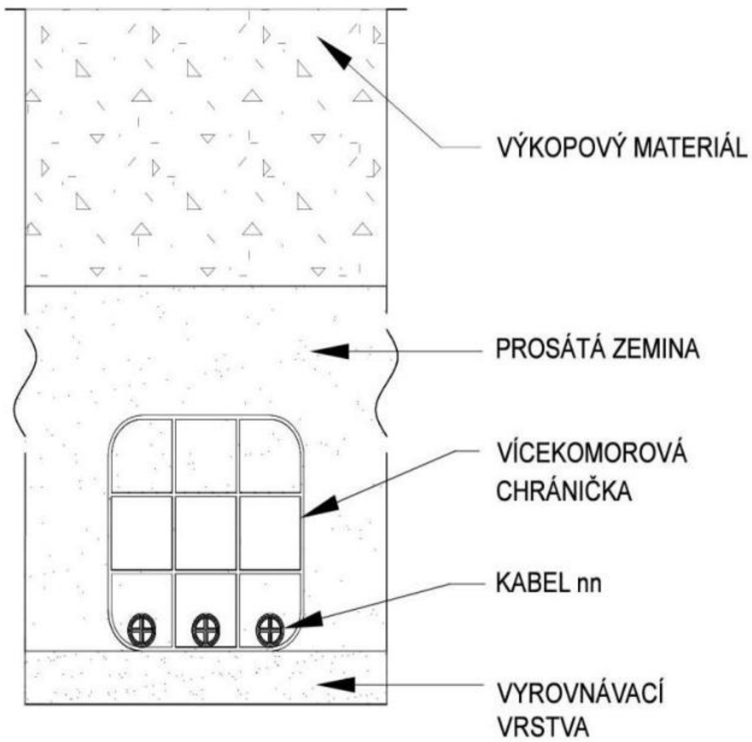


Fig. B 1-5 - Laying of LV cables in a multi-chamber cable protective casing

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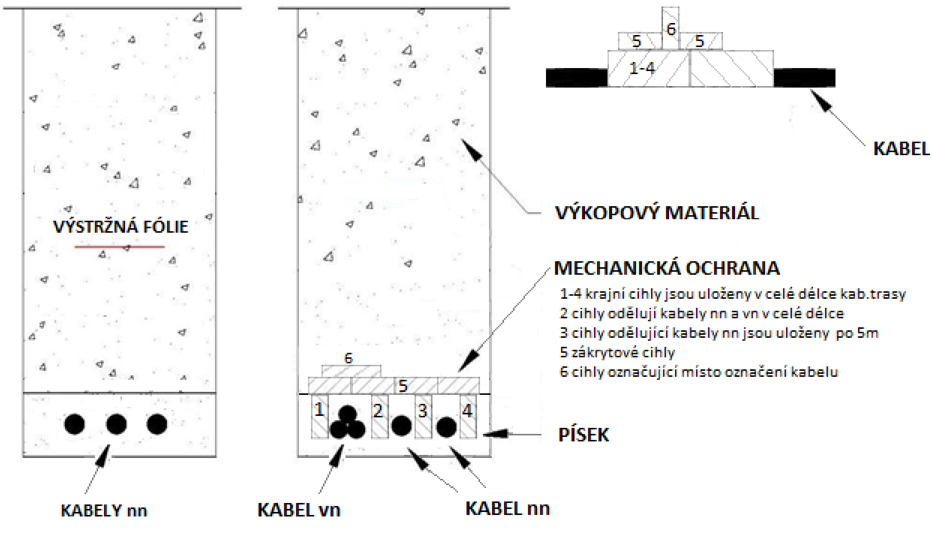


Fig. B 1-6 - Laying of cables in a sand bed - concurrence of HV and LV

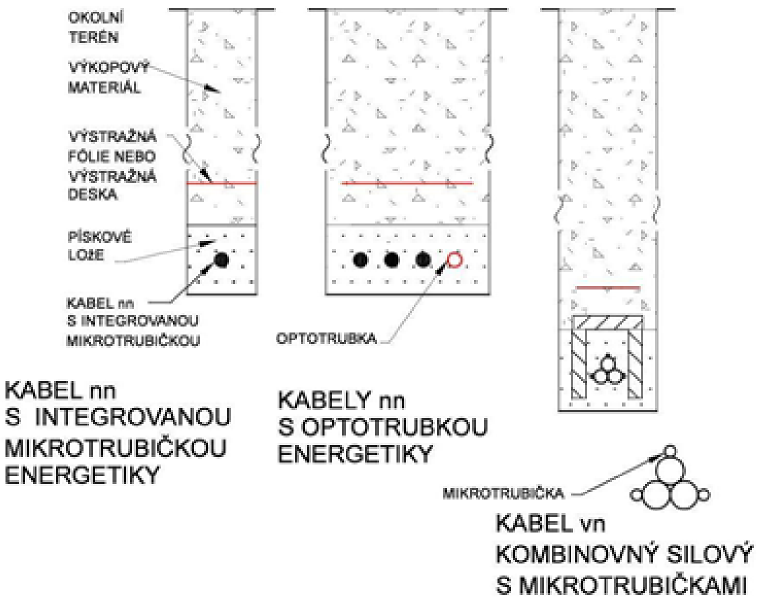


Fig. B 1-7 - Combination of LV, HV cables, communication cables, first part

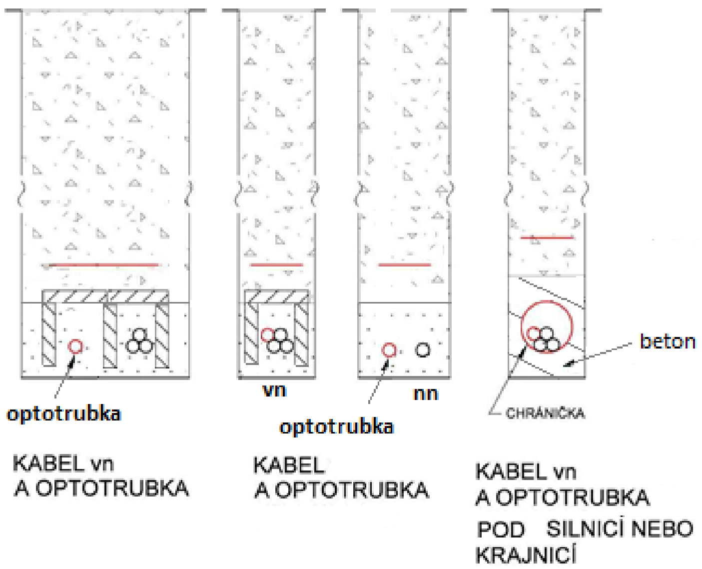


Fig. B 1-8 - Combination of LV, HV cables, communication cables, second part

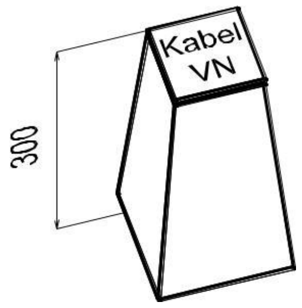


Fig. B 1-9 - Cable bollard for marking cable networks

Upper cast iron plate 100 x100 mm with text HV, LV cable, HV, LV coupling. Bottom base 150 x 150 mm

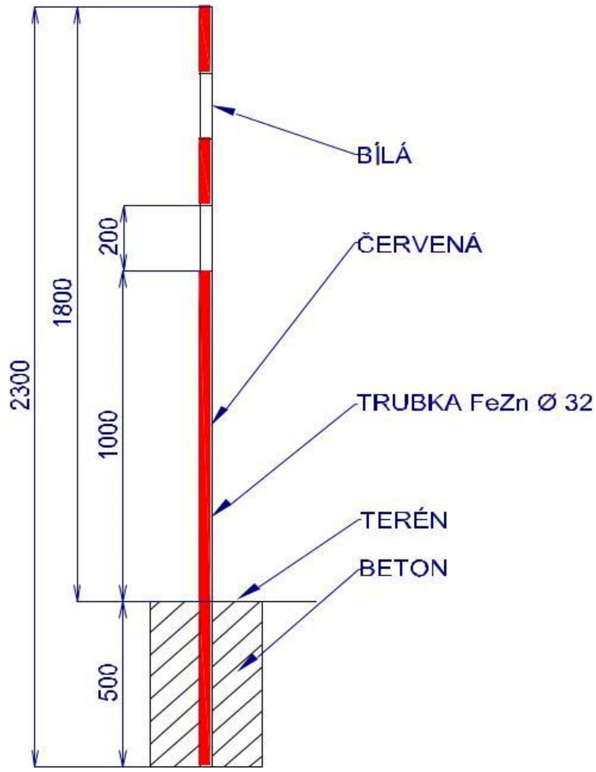


Fig. B 1-10 - Height marking of the breaking point of a railway crossing

Form A Protocol for measuring optotubes in the network

Optotube

Event name:						
Route section:	from	to	from	to	from	to
Section length (m)						
Diameter of the optotube						

Calibration test

Measurement date			
Measured by:			
Calibre diameter (mm) *			
Duration time (sec)			
Test result			

Pressure tightness test

Date of measuring			
Measured by:			
Measuring device:			
Initial pressure (bar) **			
Final pressure (bar)			
Duration time (hrs)***			
Test result (%)			
Performed by			

Name:	Stamp and signature:
Company:	
Date:	

Explanations:

* Outer diameter of calibre at least 85% of the inner diameter of the optotube **

** Optotubes will be tested at a pressure of 3 bar

*** The pressure tightness test of the optotube will be performed for at least 1 hour

Form B Protocol for measuring microtubes in the network

Combined HV power cable

Event name:						
Route section:	from	to	from	to	from	to
Core number (phase)	1		2		3	
Section length (m)						
Diameter of the optotube						

Calibration test

Measurement date			
Measured by:			
Calibre diameter (mm) *			
Duration time (sec)			
Test result			

Pressure tightness test

Date of measuring			
Measured by:			
Measuring device:			
Initial pressure (bar) **			
Final pressure (bar)			
Duration time (min)***			
Test result (%)			

Performed by

Name:	Stamp and signature:
Company:	
Date:	

Explanations:

*	Outer diameter of calibre at least 85% of the inner diameter of the microtube **
**	The microtubes will be tested at a pressure of 10 bar
***	The microtube pressure tightness test will be performed for at least ten minutes

Form C Protocol for measuring microtubes in the network

Combined low voltage power cable

Event name:				
Route section	from	to from		to
Section length (m)				
Diameter of the optotube				

Calibration test

Date of measurement:		
Measured by:		
Calibre diameter (mm)*		
Duration time (sec)		
Test result (pass/fail)		

Pressure tightness test

Date of measuring:		
Measured by:		
Measuring device:		
Initial pressure (bar)**		
Final pressure (bar)		
Duration time (min)***		
Test result (%)		

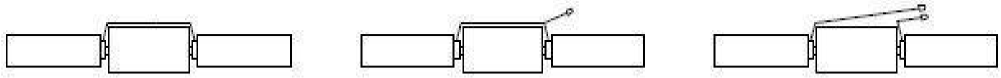
Performed by

Name:	Stamp and signature:
Company:	
Date:	

Explanations:

*	Outer diameter of calibre at least 85% of the inner diameter of the microtube **
**	The microtubes will be tested at a pressure of 10 bar
***	The microtube pressure tightness test will be performed for at least ten minutes

Annex B.2 Examples of laying EHV cables and optotubes



1 2 3

Fig. B 2-1 – Types of couplings

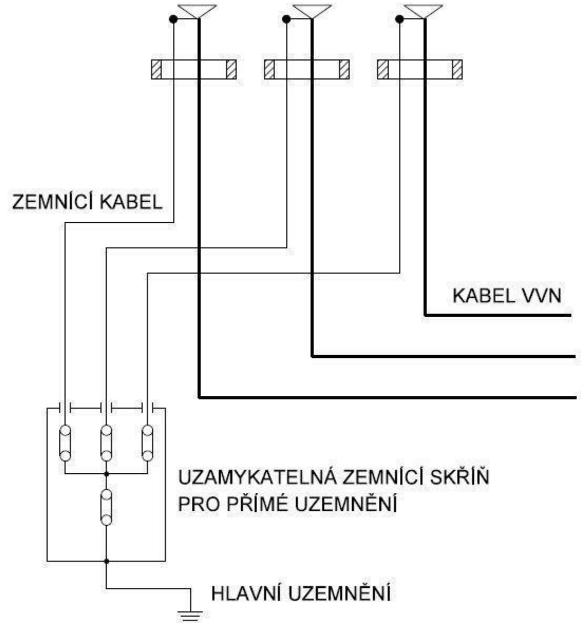


Fig. B 2-2 - Example of a terminal with direct earthing of the EHV shield

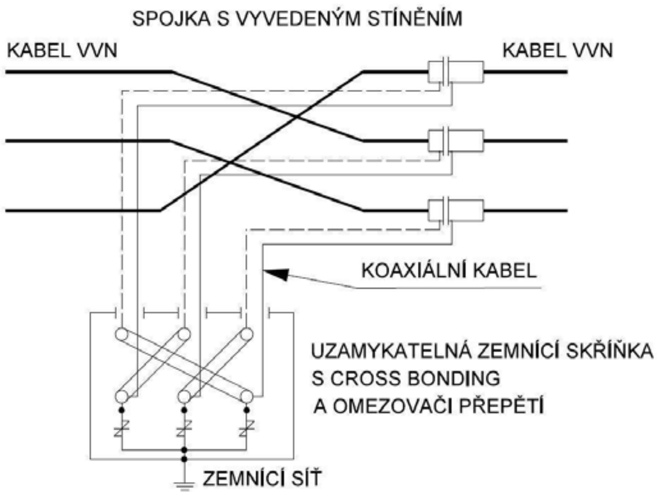


Fig. B 2-3 - Example of a coupling with cross-bonding and EHV surge protector

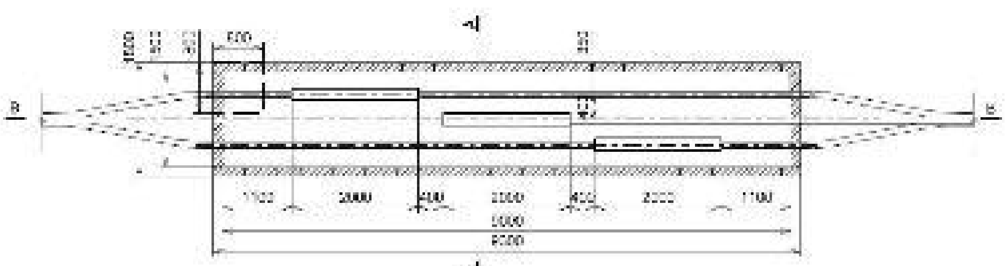


Fig. B 2-4 - Example of an optimal solution of a connection box for EHV cables + a coupling behind each other

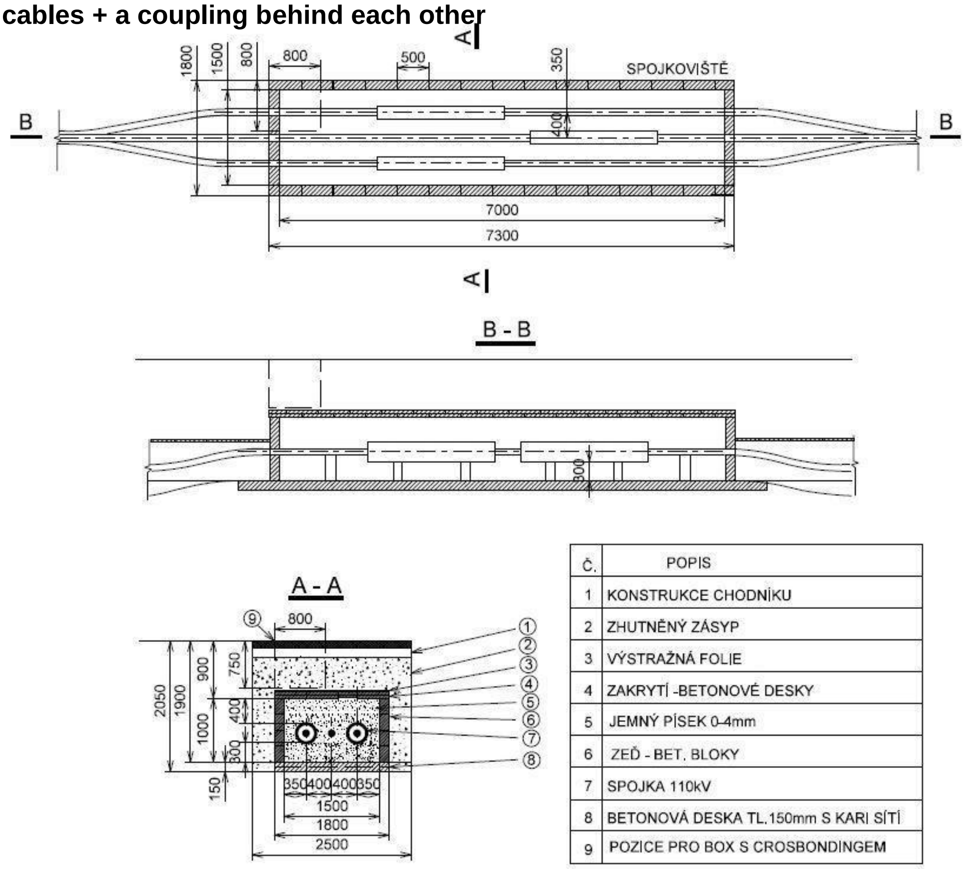


Fig. B 2-5 - Example of an optimal solution of a connection box for cables + a coupling next to each other

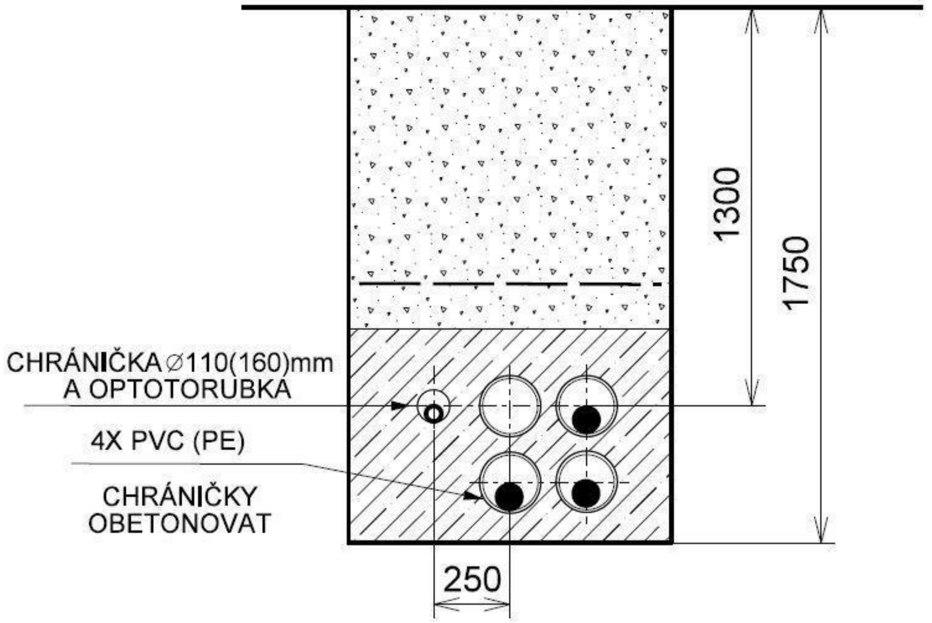


Fig. B 2-6 - Laying of the EHV cable in the communication transition in a triangular formation

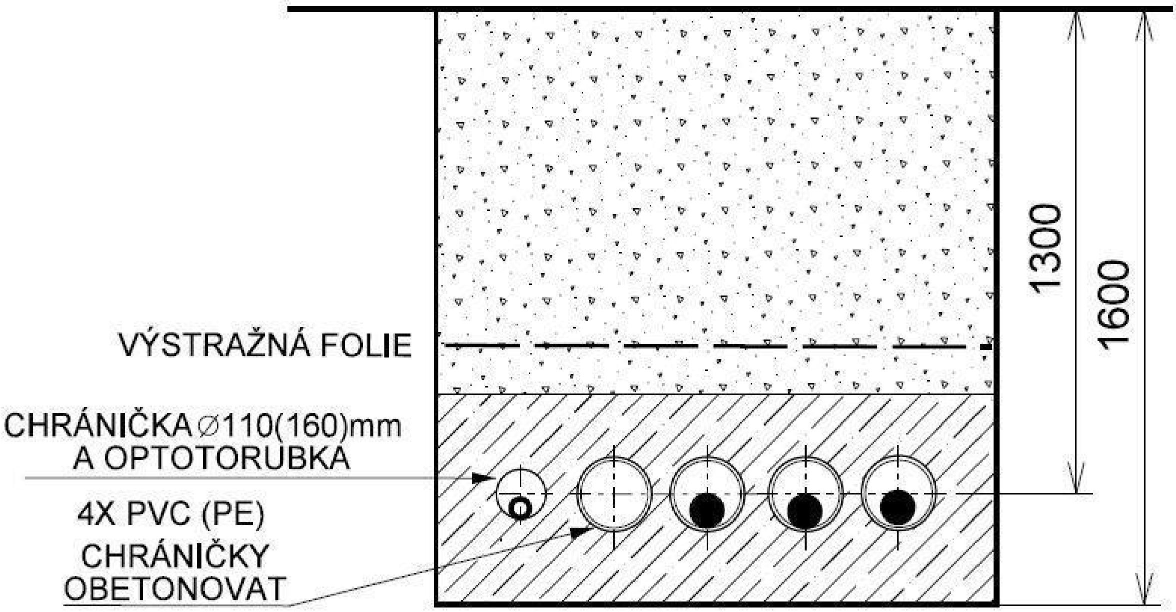


Fig. B 2-7 - Laying of the EHV cable in the communication transition in a planar formation

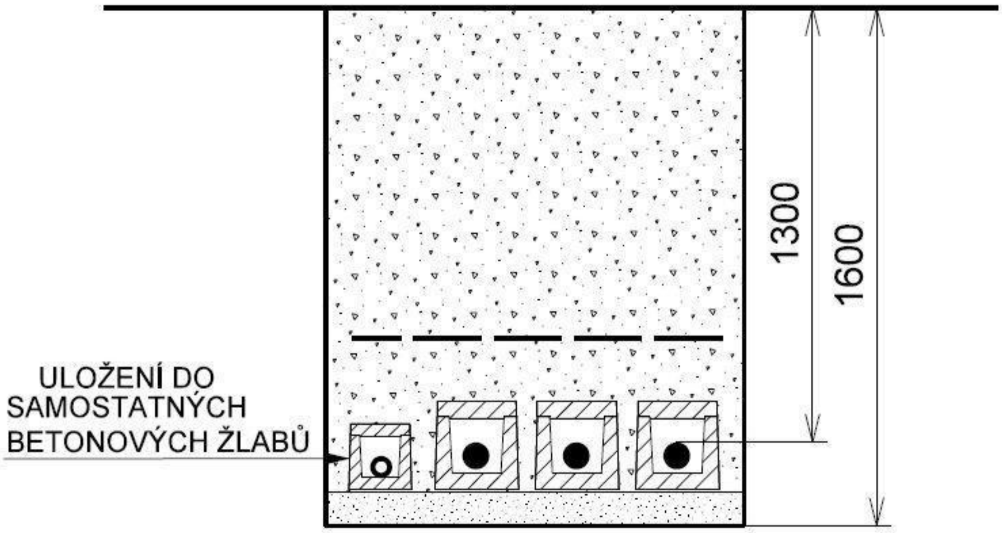


Fig. B 2-8 - Laying of EHV cable with protection in cable trench in planar formation

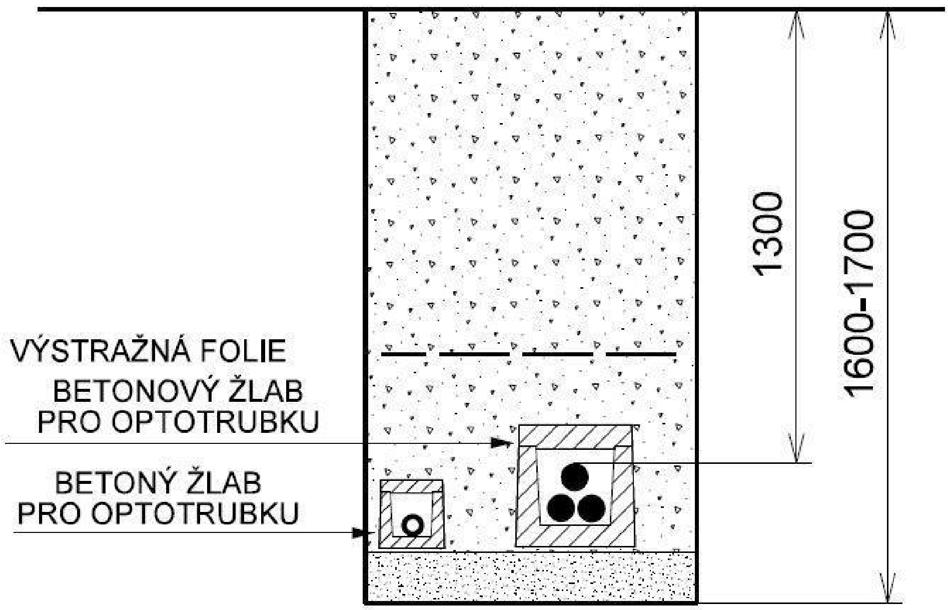
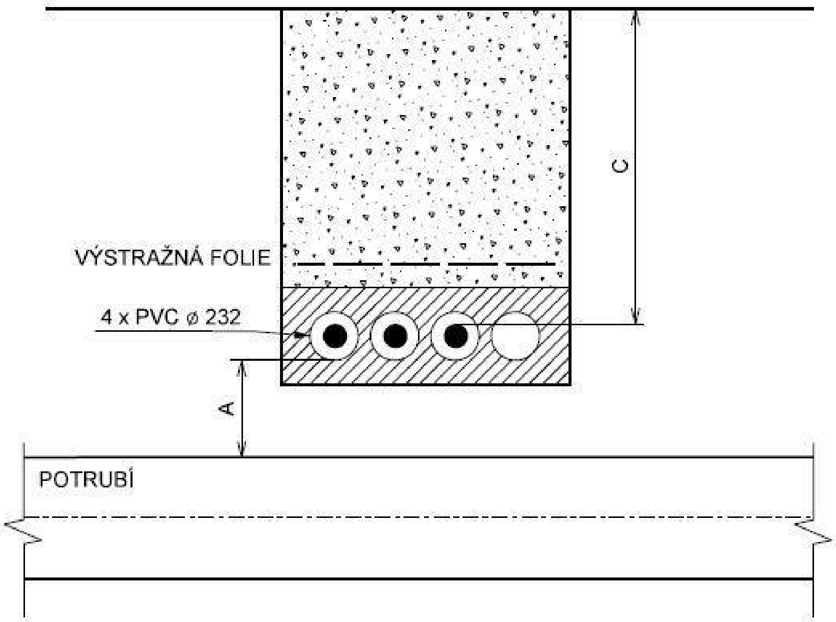


Fig. B 2-9 - Laying of EHV cable with protection in a common cable trench in a triangle

Examples of crossing HV cables with other networks



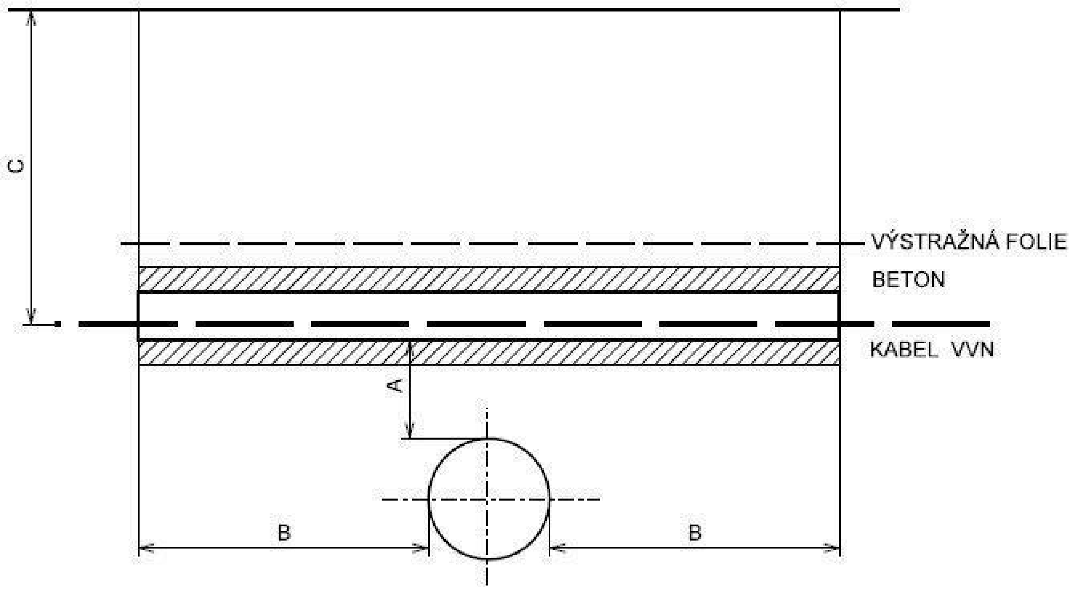


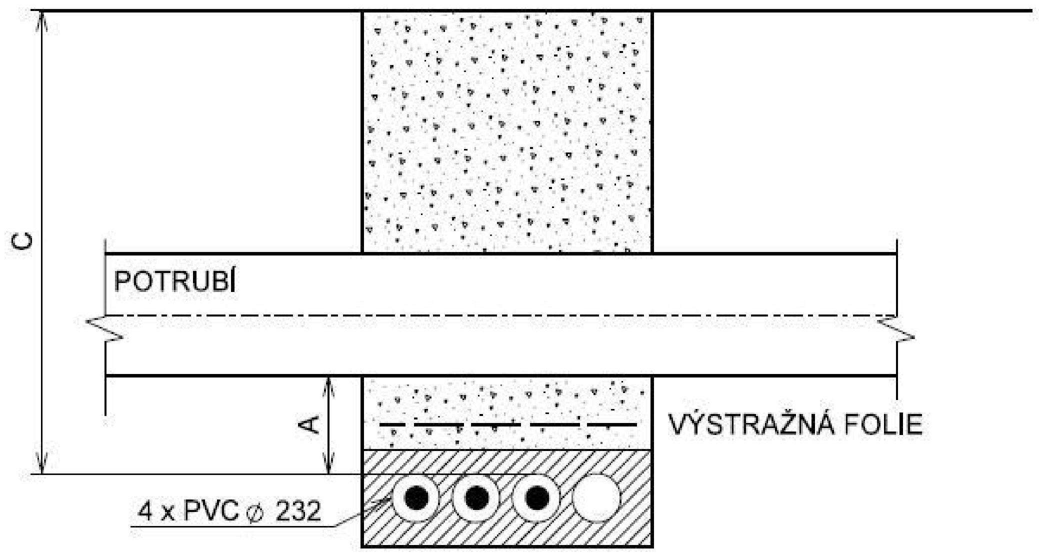
Fig. B 2-10 - Crossing of EHV cables under pipes (gas, water, sewage)

NOTE:

A – distance according to ČSN 73 6005 Tab. A2

B – protection zone of the crossed cable line

C – EHV cable line coverage –at least 1300 mm



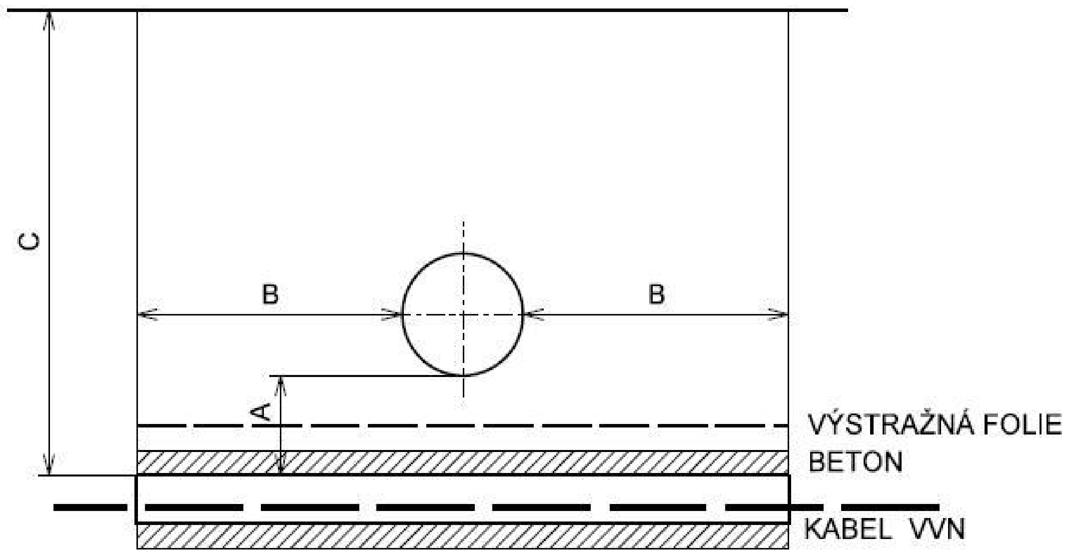


Fig. B 2-11 - Crossing of EHV cables under pipes (gas, water, sewage)

NOTE:

A – distance according to ČSN 73 6005 Tab. A2

B – protection zone of the crossed cable line

C – EHV cable line coverage

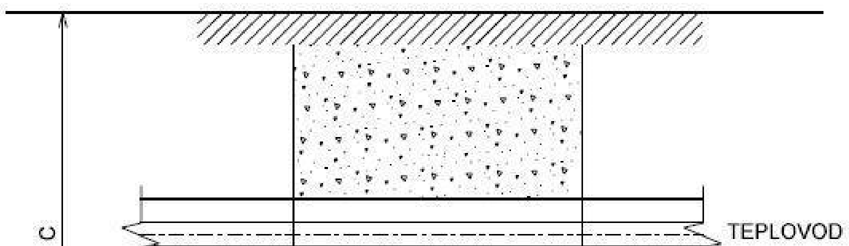


Fig. B 2-12 - Crossing of EHV cables with hot water pipes

NOTE:

A – distance according to ČSN 73 6005 Tab. A2

B – protection zone of the crossed cable line

C – EHV cable line coverage

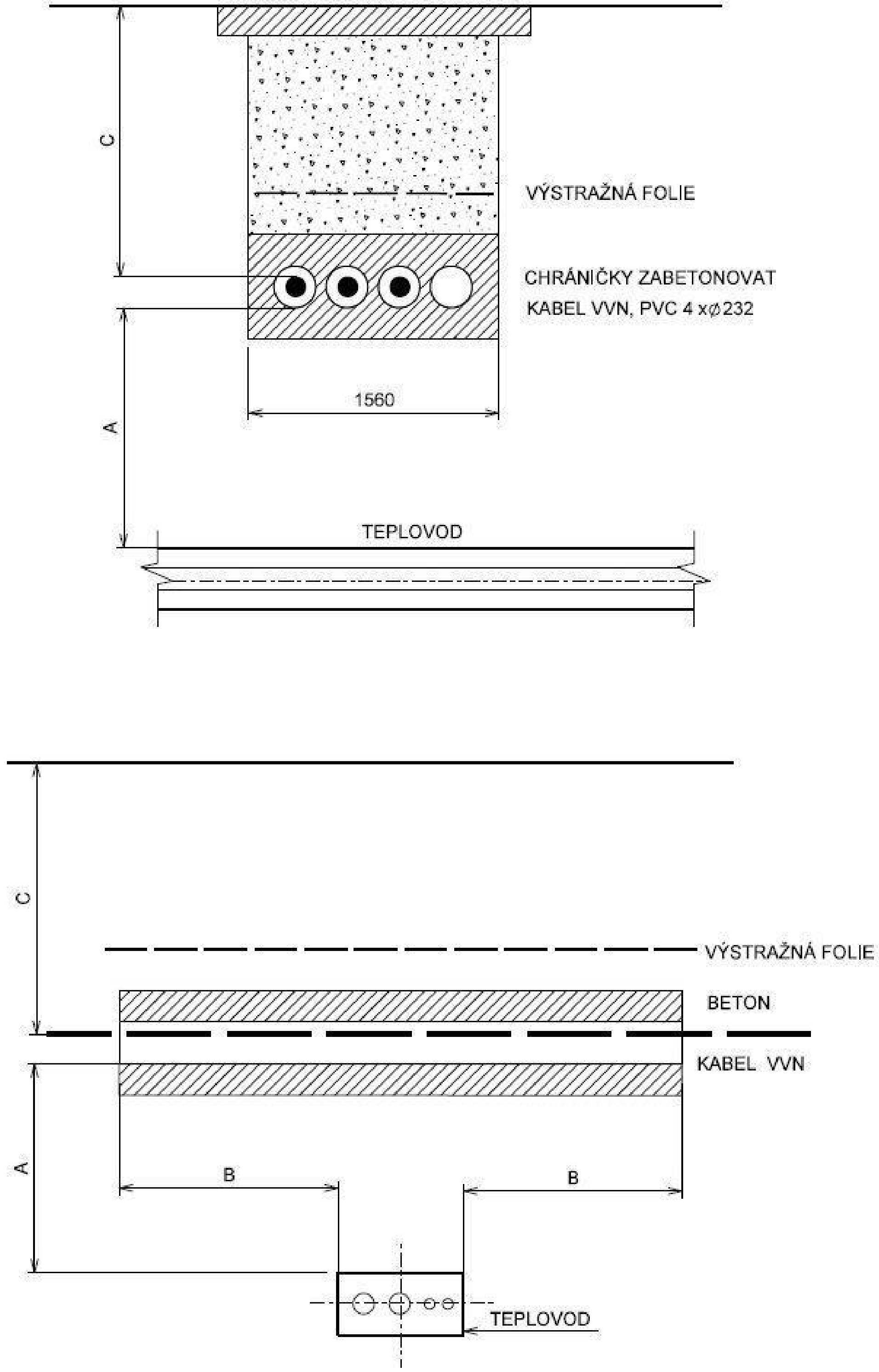


Fig. B 2-13 - Crossing of EHV cables with hot water pipes

NOTE:

A – distance according to ČSN 73 6005 Tab. A2

B – protection zone of the crossed cable line

C – EHV cable line coverage

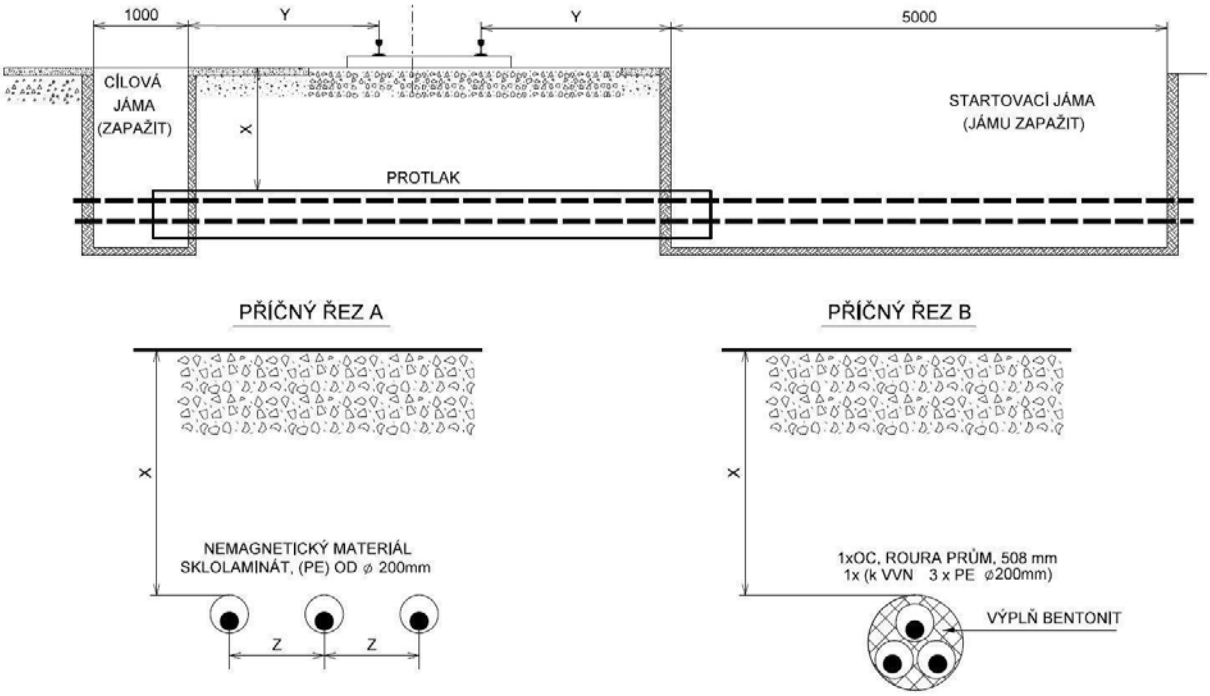


Fig. B 2-14 - Crossing of EHV cables with railway tracks by under-drilling

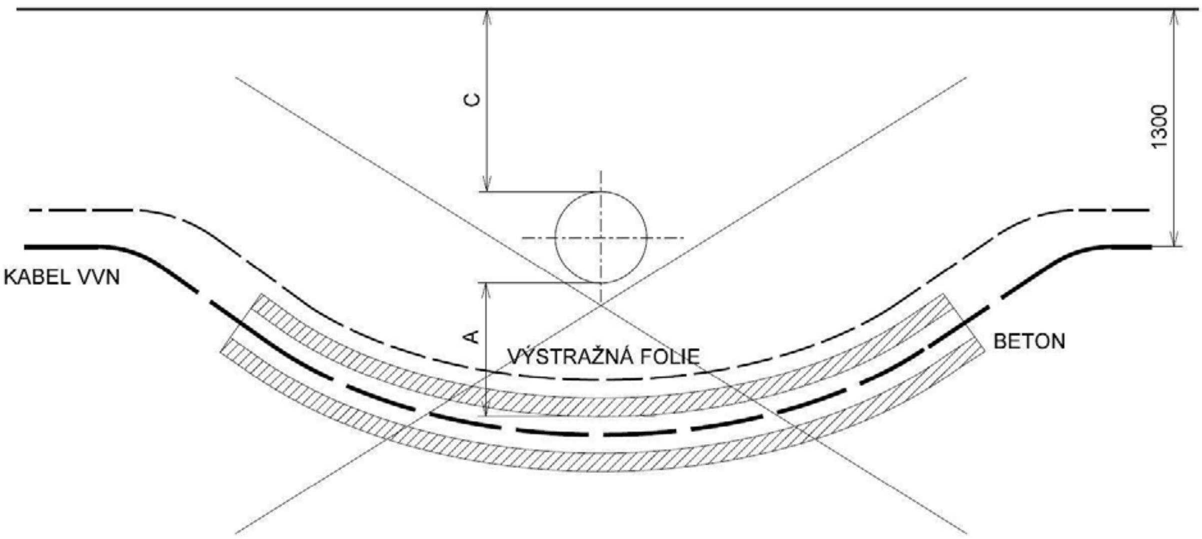


Fig. B 2-15 - Not recommended laying method for EHV cable lines

Annex C Requirements for laying EHV cable

C.1 Laying equipment

The contractor of construction and assembly work must be equipped with appropriate mechanisms for laying EHV cable lines. These are special machines and equipment enabling laying.

Cable lift with load capacity for EHV cable, and with the ability to load a drum. Drum dimensions and weights must be addressed individually for each case. From the cable manufacturer's point of view, the size and length of the cable are not limiting. These are the dimensional possibilities of transporting the cable drum and the dimensions of the cable chassis for laying cables. These limits must be set by the contracting authority during the tender.

For the excavation method of laying, the lift should be able to brake or drive the drum by means of pressure rubber rollers driven by an engine. It should also be able to load itself. It needs trained staff during laying. It is necessary for the operator to have the possibility of communication contact (transmitters) with all operators of other mechanisms on the route.

The towing machine must have sufficient force (3 to 5 t) and smooth running in the coil. Reverse idling to the winding of the rope and most importantly, it must have a recorder (digital) with the possibility of recording the immediate and continuous pull on the rope. It is also necessary for it to have a traction lock installed, which immediately shuts off the towing if the set maximum pulling force is exceeded.

Feeders – these are with hydraulic drive, where two silicone belts run in the lower part and the cable is pressed by four rubber pulleys. The hydraulics are driven either by a petrol engine or el. current 3x400 V.

They are used wherever the route is too complicated or long. They are usually installed in the route before the entrances to the boreholes at long cable protective casings or before difficult bends. They must always be installed in a straight section.

Rollers - straight or corner. They are placed after about each 3 - 5 meters in the route. The corner rollers, as the name implies, are placed in the bends of the route. They must be secured so that they do not come loose during towing. Pay attention to the size of the roller and its radius. Before towing, check the roller for burrs that could damage the cable sheath.

C.2 Organization of assembly and pulling of cables

The EHV cable line is made by so-called machine laying of cables. At one end of the route, there is a special chassis with a drum, which is braked separately. At the other end, there is a towing machine with a tow rope. The entire towing route is equipped with cable laying rollers before the start of the laying process. The rollers are distributed in sufficient numbers so that the cable does not rub against the bottom of the excavation or its sides.

A cable lift with a drum is placed at the pre-selected end of the section and a towing machine at the other end. Both mechanisms are well secured against shifting. A rope is stretched along the route and through all passages. The rope is clamped via a swivel coupling on a prepared cable with a welded eye on the cable core, or on a pull-on stocking.

The instruction is given and the rope is slowly tightened. At this stage, we can find out how prepared the route is, because the rope alternates with a towed cable.

If everything is in order, all operators of the mechanisms are instructed to lay the cable using the radio. At this point, a strict ban is issued on the movement of people in the route in front of the tip of the cable.

Workers can only move behind the tip of the cable to keep an eye on the cable movement.

Additional personnel must check the entire route for cable fall off the rollers.

In such cases, it is necessary to stop towing immediately and adjust the route.

The length of the pulling section is determined by the project and depends on the complexity of the route, the cross-section of the cable core, the weight of the cable and the number of couplings and CB. The maximum lengths for towing are around 1500 m depending on the capacity of the drum and the diameter of the cable. In practice, however, with regard to the number and complexity of the route, the length of one section is from 350-750 m. In tunnels, a towing length of 750 m can normally be achieved.

The pulling force (N) can be determined informatively from cable weight in % (kg / m) x 9.81:

- straight sections 15 to 20% of weight,
- 2 approx. 90^o bends 20 to 40 % of weight,
- approx. 90^o bends 40 to 60 % of weight,

After stretching, the cable is lowered from the rollers and laid in the future operating position. For this reason, the excavation must be wide enough to allow it to be laid on rollers and then placed in the final position next to the rollers.

Manual pulling can be used to lay shorter sections while maintaining work safety and not damaging the cable with a sufficient number of workers.

It is not allowed to drag the cable on the ground and lay it without rollers.

C.3 Qualifications

At least the managers must be trained by the cable manufacturer or the mechanism manufacturer (towing machine, towage) to lay EHV cables. Installers must be trained by the cable set manufacturer and hold certificates.

C.4 Supervision

The cable supplier shall ensure the supervision of the EHV cable manufacturer and the cable fitting manufacturer. Supervision is used where the manufacturer takes responsibility for the work performed.

C.5 Electrical tests after assembly

Test methods are specified in ČSN IEC 60840 Article 13.

If the cable is partially covered by a cable bed, a 10 kV sheath test shall be performed for 1 min. This test detects the integrity of the cable sheath. The test is performed also after the installation of cable heads and couplings in the entire length of the cable.

ČSN IEC 60840 according to 13.1.1 b) stipulates the test with alternating voltage. The test is performed with the normal operating voltage of the network applied for 24 h (1xUo without load).

Upon agreement between the supplier and the customer, it is possible to perform other tests, e.g.: 2xUo test for 1 hour. However, a special source is needed for this test.

An increased voltage test can be recommended in the case of a cable route where couplings are used. The test with increased voltage is not suitable in the case of relocation, repairs etc., where the tested cable includes a new cable and the original cable.

C.6 Permitted bends

The bend radius must be specified by the manufacturer for each cable type.

.

Approximate values of the minimum radius are given in the table. This applies to cables with Cu shielding. For cables with lead sheath, aluminium foil or integrated optical fibre, it is necessary to solve cases individually in agreement with the cable manufacturer.

Cable with Cu shielding during installation	20×D
Cable with Cu shielding after installation	18×D
Cu shielded cable after installation using a template	16×D

Tab. C-1 - Recommended permitted bends

C.7 Towing forces

The maximum pulling force depends on the material of the conductive core of the cable. Indicative values of towing that should not be exceeded are given in the table. It is necessary to check the maximum pulling force for each type of cable. The values are specified by the cable manufacturer.

Cables with aluminium conductive core	30 N/mm^2

Cables with copper conductive core	60 N/mm²

Tab. C-2 - Recommended pulling forces

The maximum permissible lateral force on the wall must also be checked to prevent the cable components from being deformed during bending. The values of this force are determined by the manufacturer for each type and cross-section of the cable. The manufacturer should also determine the distance between the rollers.

The lateral force on the wall FBS (N) for the given values is according to the equation:

FBS = (F x d)/RDO

(N) maximum pulling force,

(m) the distance between the rollers in bending, usually given as a multiple of the RDO / F ratio,

RDO (m) permissible bending radius.

If the compressive force on the wall FBS is given in (N / m) then the equation applies:

FBS = F /RDO

For orientation, the permissible value of the lateral force on the FBS wall (N / m) is usually half of the maximum allowable towing force.

C.8 Permissible ambient temperatures for cable installation

For cables with PE, HDPE or PVC sheath, the lowest ambient temperature during installation is recommended by the cable manufacturer. Cable heating is possible. In practice, it is recommended to place the cable in an environment with a higher ambient temperature for at least 24 hours and then install it. The laying time of the heated cable is limited by reducing its flexibility to the limit when it is no longer possible to install.

It is not recommended to lay the heated cable in windy weather, especially if the wind blows perpendicular to the cable route.

The lowest and highest ambient temperatures during installation are specified by the cable manufacturer.

Annex D Approximate maximum values of induced shield voltages in SPB and CB earthing systems

Earthing system	short circuit	formation	sym. wire	d/rg	E
				-	kV/km/kA
SPB	1p earth		in a bundle with p	10	0.188+0.126 ln (s/d)
SPB	1p earth		in a bundle with p	15	0.214+0.126 ln (s/d)
SPB	1p earth		adjacent and down	10	0.239+0.126 ln (s/d)
SPB	1p earth		adjacent and down	15	0.265+0.126 ln (s/d)
SPB	1p earth	ooo	In between by the side of p.	10	0.145+0.126 ln (s/d)
SPB	1p earth	ooo	In between by the side of p	15	0.170+0.126 ln (s/d)
SPB	1p earth		only 2xFEZn		0.53
SPB	1p earth	ooo	only 2xFEZn		0.54
SPB	3p - earth				0.044+0.063 ln (s/d)
SPB	3p - earth	ooo			0.073+0.061 ln (s/d)
SPB	2p				0.044+0.063 ln (s/d)
SPB	2p	ooo			0.087+0.063 ln (s/d)
CB	1p in between				0.044+0.063 ln (s/d)
CB	1p in between	ooo			0.087+0.063 ln (s/d)
CB	2p in between				0.087+0.063 ln (s/d)
CB	2p in between	ooo			0.174+0.126 ln (s/d)
CB	3p in between				0.075+0.109 ln (s/d)
CB	3p in between	ooo			0.126+0.105 ln (s/d)
CB	1p earth				Rshielding+jE1fin between
CB	1p earth	ooo			Rshielding+jE1fin between

s axial distance of phases (mm)

d mean shield diameter

rg geometric diameter of earth conductor, rg = 0.75 of the diameter conductor for other ratio d / rg than E is for d / rg = 10

: or 15 in the table, add or deduct the value of the difference to E (10 or 15):

= 0.0628 . (ln (10 or 15) - ln (d/rg)

For the CB system, the active shielding resistance is not neglected for higher 1-phase short-circuit currents:

E = I1fk .(Rst + j X), X (Ω/km) is the calculated value of E from the table (the module complex no. E is used).

Annex E Recommended sizes of cable protective casing

Diameter of a single core EHV cable d_k(mm)	Recommended inner size of the cable protective casing Ø D/d (mm)
cables with Ø d_k do 80mm	130 minimum
cables with Ø d_k od 80- do 100 mm	170-190
cables with Ø d_k od 100-120 mm	≥190

Tab. E-1 - Recommended sizes of cable protective casing

Annex F Comparison of EHV cable configuration properties

Configuration	**Tight triangle**	**Adjacent**
laying space	smaller	larger
load capacity	higher with BEB	lower with BEB
	lower with CB, SPB	higher with CB,SPB
losses in the conductor	lower	higher
losses in shielding	lower	higher
external thermal resistance of the cable	higher	lower
magn. field over cable	lower	higher
interference to the environment	lower	higher

Tab. F-1 - Comparison of EHV cable configuration properties

Annex G – Operational effects on EHV cables

During operation, the cables are subjected to 2 internal mechanical influences which could cause damage to the cable. During operation, the cables are subjected to 2 internal mechanical influences which could cause damage to the cable.

a) Thermomechanical influence

The cables become warm during operation and the thermal expansion of the materials prolongs them, which can cause the cable to deflect or be subjected to axial force stress. When the cable cools down, it shortens itself. These processes can damage cables, cable clamps, or support structures.

b) Electromagnetic influence

In the event of short circuits, forces acting on the cables due to surge short-circuit currents could cause large deflection, deformation and damage to the cables. In addition, mechanical damage to the clamps, supporting structures and endangering the safety of persons can occur.

c) Influence of laying on the action of forces

When laid in the ground, it is sufficient to lay the cables with a slight corrugation and the pressure of the surrounding soil will not allow any excessive deflection of the cable when extended by warming. The process of warming is mitigated by the large temperature capacity of the surroundings. Greater attention must be paid to the entering passages of the cables to the couplings in the connector boxes.

Also, the dynamic forces in the event of short circuits are attenuated by the pressure of the soil when laid in the ground, and the cables laid in a triangular formation are bundled rather to maintain the shape of the configuration during laying.

The situation is different when laying cables in the air, on poles, on cable trays, metal grids, bridges, etc. Cables must be laid, fastened and bundled so that they maintain their position and are not damaged by thermal extensions or dynamic forces in the event of short circuits.

Annex H Extension of EHV cables due to warming

The installation of the cable line is usually carried out under normal temperature conditions at ambient temperature above zero. During operation of the cable, the thermal expansion of the cable occurs compared to these temperatures. On the other hand, the cable line is shortened when switched off and at temperatures below zero.

In order to avoid high values of longitudinal forces and inadmissible deflection and displacement of cables during cable extension by heating or shortening during cooling, single-core cables are laid with slight corrugation (deviation of cable axis from straight direction h0 = 0.5 DE to DE) and are fastened in distances ℓT = 50 DE, where DE is the outer diameter of the cable in mm. In the event of maximum deflection of the cable during operation, the cables must have sufficient space on the footbridge or metal grid. The calculation assumes sinusoidal corrugation of the cables and is based on the initial corrugation and elongation of the cable from the lowest ambient temperature.

Transverse deflection (displacement) of the hT cable (mm) at a given heating (ambient temperature during laying or operational heating of the conductor) is:

$$h_T = \frac{2l}{\pi}\sqrt{\alpha\mathrm{th}.\,\Delta\nu}$$

l length between the points of fixed attachment of the cable to the structure (mm)

α_{th} coefficient of thermal expansion of the conductor material (1/K), for Cu it is 17.10-6 (1/K) and for Al it is 24. 10-6 (1/K)

Δδ temperature difference: operating temperature of the conductor - ambient temperature or temperature during installation if it was lower (K),

Relative longitudinal elongation l_0 (%) it does not depend on the conductor material when laying with corrugation

$$\Delta l_0 = \{(\pi.\ h_0/2.\ \ell_T)^2\}\ .\ 100\ (\%),$$

For h_0 = 0,5 D_E a ℓ_T = 50 D_E je Δl_0 = 0,025 %, for h_0 = D_E je Δl_0 = 0,1 %,

h_0 cable deflection (mm)

D_E outer diameter of the cable (mm)

Axial force on the clip when fixing the cable without the possibility of axial or radial (deflection) movement:

$F_{th} = S.\alpha_{th}..E.\ \Delta\delta$ (kN)

S conductor cross-section (mm^2)

E modulus of elasticity of the conductor material (kN/mm^2) for Cu it is 115 (kN/mm^2), for Al it is 65 ($kN/m\ m^2$)

Annex I Dimensioning of cables in terms of dynamic effects of short-circuit current

The calculation of the magnitude of short-circuit currents is performed according to ČSN EN 60909-0, for the calculation of the dynamic effects of short-circuit current, the maximum surge short-circuit current flowing through the conductor is applied.

The calculation of forces for dimensioning the strength of fastening elements and the distances between them in terms of dynamic effects of short-circuit currents can be based on ČSN EN 60865-1, and ČSN EN 61914.

The specific force between the conductors is:

$F = 0,2\ I_{km}^2 / s$; where

F is the dynamic force between conductors [kN/m]

S is the axial distance of conductors [mm]

I_{km} is the maximum surge short-circuit current flowing through the conductor [kA]

Radial and tangential forces act on the cable, clips and bundles:

Radial force:

$F_R = 0,17.\ I_{km}^2 / s$ [kN/m] or (N/mm)

Tangential force:

$F_T = 0,1\ I_{km}^2 / s$ [kN/m] or (N/mm)

The radial force acts on:

- cable (conductor, insulation, shielding and sheath),
- fastening elements (clamps) of individual single-core cables,
- parts of single-core cable clamps, screws, sleeves, etc.,
- insulation, by pressing the fastening element against the cable core.

The tangential force acts on:

- bundles of single core cable systems.

Calculation of mechanical stress of the cable

The distance between the individual bundles or cable fixings lp (mm) must be such that deformation or damage to the cable does not occur under dynamic short-circuit forces. There are a number of methods for calculating the allowable distance, based on checking the strength of the cable during bending.

One of the simpler methods (SRN) considers the cable between fastenings or bundles to be a rigid, and the beam to be evenly loaded and derives the distance between the clamps from the allowable deflection of the cable at a given stress caused by a dynamic force in the event of short-circuit stress using known mechanics formulas. The level of allowable cable deflection is based on the allowable cable bend and it is 5% of the distance between bundles or fastenings for plastic cables.

The strength of the clamps and their parts is calculated using the relations for checking the strength from the mechanics.

The distance between the clamps or bundles must also be checked with regard to the permissible pressure of the fasteners on the insulation.

The required bundle width bs (mm) with respect to the insulation pressure is calculated from the permissible insulation pressure, which must not exceed 6 N / mm² for XLPE cables, according to the formula:

$b_s = F_R\ .\ l_p\ ./\ (6\ .\ D_C\ .\ t_{iz})$ (mm)

D_C conductor diameter (mm),

t_{iz} insulation thickness (mm)

Conversely, for a given clamp width bp (mm), the distance between the clamp or bundle lp is permissible due to the permissible insulation pressure. (mm):

$l_p .= (6\ .\ b_p\ .\ D_C\ .\ t_i) / F_R$ (mm)

The strength of the fastening element must be at least 2 times higher (safety factor) than the tangential force of the bundle.

Annex J Influences on EHV cable dimensioning

Comparison of load capacities of different ways of bonding of EHV cables

Bonding	**BEB**		**SPB**		**CB**	
Configuration	tight triangle	adjacent	tight triangle	adjacent	tight triangle	adjacent
load capacity	higher	lower	lower	higher	lower	higher
losses in shielding	lower	higher	low	low	low	low
shielding voltage	NO	NO	YES	YES	YES	YES
magn. field above the cable	lower	lower	higher	higher	higher	higher
interference in the environment	lower	lower	higher	higher	medium	medium
connection	simple	simple	simple	simple	complex	complex
coupling	simple	simple	simple	simple	complex	complex
surge protectors	NO	NO	Depends on the length		YES	YES

Tab. J-1 - Comparison of the properties of the bonding methods of EHV cables

material	**Al**	**Cu**
Cross-section	240	240
	300	300
	400	400
	500	500
	630	630
	800	800
	1000	1000
	1200	1200
	1400	1400
	1600	1600
	2000	2000
		2500

Tab. J-2 - The usual series of cross-sections of EHV cable conductors (mm^2)

Conductor material		**Al**		**Cu**		**Al, Cu**	**Al**	**Cu**
Bonding type		**SPB, CB/BEB**		**SPB, CB/BEB**		**SPB,CB**	**BEB**	
Configuration		**triangle**	**ooo**	**triangle**	**ooo**	**ooo/ trian.**	**trian./**	**ooo**
Cross-sections (mm^2)	up to 800	1.06	1.21	1.10	1.33	1.05	1.10	1.15
	1000 to 1400	1.12	1.36	1.21	1.56	1.06	1.15	1.22
	above 1400	1.16	1.46	1.31	1.78	1.06	1.18	1.27

Tab. J-3 - Orientational comparison of mean values of load capacities of SPB, CB and BEB systems

Influence	Normal condition	Limits of the condition	Load Coefficient
Depth of coverage	1.3 m	1.3 – 2.5 m	1 – 0.93
Specific thermal resistance of soil	1 Km/W	0.7 - 3 Km/W	0.7 – 0.61
Dried cable beds		2.5 Km/W	0.67
Ambient temperature - earth (core temperature 90 ° C)	20°C	10 - 30°C	1.07 – 0.93
Ambient temperature - air	35°C	10 - 50°C	1.24 – 0.83
Axial distances of phases - side by side CB, SPB	200 mm	200 - 400 mm	1 – 1.07
PE or PVC cable protective casings	according to laying	ooo – tringl.	0.94 – 0.9
Cable protective casings in a steel tube			0.8

Tab. J-4 - Orientation effects of EHV cable laying conditions

For a normal storage condition, the load coefficient is 1

Type	Laying type	Depth	Surface	Temperature (°C)		Temp. resistance (°Cm/W)	
		overlayer (m)		outskirts	centre	average	maximum
Excavation	stabilized cable bed	1.3	permeable unpaved	22	25	1.5	2
Excavation	stabilized cable bed	1.3	impermeable asphalt, concrete	25	30	1.2	1.5
Communication	Cable protective casing in concrete	1.3	impermeable asphalt, concrete	30	30	1.2	1.5
Extrusion	Cable protective casing	2	impermeable	20	20	1	1

Tab. J-5 Warm period 2014 - 2018, approximate values of temperature and specific resistance of the soil

Calculation of induced shield voltage in a 3-phase system with ungrounded shield ends between phases:

$U = \sqrt{3}\, \bar{I}\, X_m$ (V/km)

where I – permissible core current according to ČSN IEC 60287-1-1 + A1 Art. 1.4

Xm – mutual reactance between shield and core per unit length (Ω/m).

For laying in the triangle $X_m = 2 .\ \omega .\ 10^{-4} .\ \ln\frac{2s}{D}$ ((Ω/km)

For laying side by side $X_m = 2 . \sqrt[3]{2}\ . \omega . 10^{-4} .\ \ln\left(\frac{2s}{D}\right)$ (Ω/km)

kwhere s - axial distance of conductors (mm), for side-by-side installation

D - average shield diameter (mm)

Annex K Approximate values of the magnetic field above the EHV cables

Based on the report of the study group WG 21-17 CIGRE from 2000, the following magnetic field values can be assumed at a height of 1 m above the ground, directly above a 3-phase EHV cable system with a symmetrical phase load, laid with an overlayer depth of 1.3 m:

- 1 EHV cable - flat storage with axial spacings of 200 mm, up to 20 µT / kA,
- 1 HV cable - triangular laying, up to 5 µT / kA.

If the axial phase spacings of the coupling stations according to Fig. B 2-4 and B 2-5 are observed, the field values should not exceed 40 µT, / kA, any shield terminals must be placed as close as possible to each other.

With the concurrence of 2 EHV cable lines (axial distance of systems 0.7 m), the phase sequence must vary for the two systems (e.g. ABC - CBA), the values of the magnetic field above the cables are then approximately 2 times higher than for 1 cable.