B1.48 – Trenchless Technologies

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Introduction

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Chapter 1: Introduction

Technical Brochure Objective

- Review the range of trenchless technologies currently available for cable installation:
  - ✓ Horizontal Directional Drilling
  - ✓ Microtunneling / Pipe Jacking
  - ✓ Pipe Ramming and Auger Boring
  - ✓ Ploughing

  Large tunnels are not included in the scope of this Working Group.
- Review the technical constraints (thermal, mechanical, civil, geotechnical and environmental) relating to the trenchless installation of HV cable systems.
- Provide examples of where trenchless techniques have been used in the installation of HV cable systems, highlighting the benefits and adverse experiences in each case.

Chapter 1: Introduction

Trenchless Technologies Abstract

Trenchless Technology	Description	Pipes Diameters	Lengths	Pipes materials
Horizontal Directional Drilling	The normal HDD process consists of drilling a pilot hole in the ground, and then back reaming to open the pilot hole to take a casing pipe.	200 mm to 1800 mm	Up to 2000 m	Casing pipe material: HPDE or Steel.
	Conduits may then be pulled into the casing pipe and cables may then be pulled into these conduits.			Conduits material: HPDE
Microtunneling / Pipe Jacking	Casing pipes are installed by thrusting with hydraulic jacks at the entry shaft at the same time as excavation takes place at the tunnel face using a steerable shield.	150 mm to 3000 mm	Up to 2000 m	Casing pipe material: Concrete, steel, mortar-filled glass fibre reinforced plastic pipes.
	Microtunneling: Fully automated non-accessible entry tunnelling operations.			
	Pipe Jacking: Larger diameters requiring accessible-entry.			

Chapter 1: Introduction

Trenchless Technologies Abstract

Trenchless Technology	Description	Pipes Diameters	Lengths	Pipes materials
Pipe Ramming and Auger Boring	A steel casing is physically thrust through the ground by using pneumatic hammers. Auger boring: Thrusts a steel casing whilst simultaneously excavating the ground using a screw auger. Limitation on accuracy and not steerable.	100 mm to 4500 mm	Suitable for short lengths (less than 100 m).	Casing pipe material: Steel
Ploughing	This method of cable installation basically consists of pulling a plough through the soil and simultaneously installing a cable(s) or conduits at the depth of the plough. Mainly used for voltages up to 150 kV. It is not a trenchless technology but due to the speed of installation it has been considered in this Technical Brochure.	Ø not defined	Very long installation lengths.	Direct burial normally preferred. Plastic pipes possible.
Tunnel boring	Excavated by machine and depending on the geology are lined by concrete segments in the walls of the tunnel, as the excavation advances. Microtunnels above 3 m diameter cannot be readily managed on site owing to their size and weight. This is the reason for the cut-off point. This is already the subject of TB 403 Cables in Multipurpose or Shared Structure.	Large tunnels, typically above 3 meters diameter	This TB does not cover full tunnel installation.	Casing pipes material: Concrete

Chapter 2

Cable Rating in Trenchless Technologies

Chapter 2: Cable Rating in Trenchless Technologies

1- Depth of the installation

- Greater depth generally results in lower ratings in buried cable installation.
- Transient thermal ratings for HDD will be different from those for typical trench depths in terms of response.
- The current rating of shallow cables is influenced by daily, weekly and even yearly load variations. These effects are not so profound for cables installed at deep depths.
- The IEC Standard 60287-2-1 contains a statement about very deep installed cables: '*for cable circuits installed at laying depths of more than 10 m, an alternative approach for calculating the current rating is to determine the continuous current rating for a designated time period (usually 40 years) by applying the formulae given in IEC 60853-2. This subject is under consideration'.*
- Various papers have been published on ratings of cable installed at depth. A good summary and guidelines ca be found in IEEE Dorison et. Al. (2010) *Ampacity Calculations for Deeply Installed Cable PAS 2010*.
- The guidelines in CIGRE Technical Brochure 640 "A guide for rating calculations of insulated cables" consider the cable crossing through various soil layers with different thermal properties.

Chapter 2: Cable Rating in Trenchless Technologies

2- Separation between phases

Depending on depth and rating required it may be necessary to increase the separation between the phases in order to permit a greater heat flow into the surrounding medium.

3- Bonding

It is necessary to ensure that the bonding design is suitable for purpose.

HDD installations are normally quite long and the phase separations may be high. These conditions may result in very high sheath induced voltages under normal and short circuit operating conditions. In the case of solid bonding and cross bonding, any increase in separation between phases will lead to magnetic imbalance, circulating currents and may lead to a reduced ampacity rating in the circuit.

It will be necessary to ensure the outer serving design can tolerate these voltages and also to ensure that national limits for standing voltages, if they exist, are not exceeded.

Chapter 2: Cable Rating in Trenchless Technologies

4- Pipe materials and losses

Steel pipe/s may have magnetic losses that will reduce the rating of cable systems.

Close triangular spacing with optimization of separation from pipe wall can reduce the losses.

IEC60287-1-1 provides empirically-derived equations for calculating the Joule losses in steel pipes normally associated with pressurised pipe-type cables.

5- Conduits material losses

HPDE or PVC conduits are similar to the conduit in open trenched sections.

HPDE thick-wall conduits reduce the rating of cable systems.

Spacers can be designed to hold the conduits in the optimum position in the pipe to improve rating.

Usually conduits are not filled and only have air inside them. The thermal resistance might be high considering as a worst-case approximation stationary air when modelling the behaviour of such a conduit.

IEC60287 and TB640 "A Guide for Rating of Insulated Cable (Dec 2015)".

Chapter 2: Cable Rating in Trenchless Technologies

6- Pipe/conduit filling

It´s important to consider the thermal resistivity of the HDD pipe and conduit filling material.

Solid, solidifying or fluid filling materials may be used. In the former situation – a solid – heat transfer from the power cable is governed by conduction. This means that the heat transfer can be modelled with the means, as described in IEC 60287-2-1.

The filling pumpability and shrinkage properties must be considered to avoid any air space between installed conduit and/or pipe. HDD length and profile are key factors.

Horizontal – water – closed at both ends

A horizontal cable system in a perfect horizontal water filled pipe, closed at both sides, can be considered in the same way as above, though the properties of the fluid are of course significantly different. Possible axial heat transfer in the water-filled conduit in addition to the radial heat transfer should be considered.

Non horizontal

Will be axial heat in addition to the radial heat transfer. This means warmest locations are expected to be near the higher sides of the pipes and the heat transfer may be governed by convection and radiation, which are strongly temperature and geometry dependent.

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7- Thermal Resistivity (TR) of the Soil

Different soil layers with different thermal properties may be crossed during horizontal directional drillings.

Interesting issues regarding thermal resistivity properties are discussed in CIGRE Technical Brochure 640 “A Guide for Rating Calculations of Insulated Cables”:

- Non-homogeneous thermal properties by using finite element or conformal mapping technique.
- Multiple soil layers that may assist in removing heat in a longitudinal direction.

8- Distributed temperature sensing (DTS) systems

Distributed Temperature Sensing systems have special significance in trenchless technology where soil conditions, including temperature, may be difficult to predict. The following CIGRE Technical Brochures covers cable rating calculation using Thermal Monitoring:

-TB606 Upgrading and Uprating of Existing Cable Systems

-TB247 Optimisation of Power Transmission Capability of Underground Cable Systems using Thermal Monitoring.

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9- Drying of the soil

The design of the installation shall consider the possibility of drying out of the soil at the external surface of the pipe. This might result in a thermal runaway causing cable insulation failure, if the system is heavily and continuously loaded.

Drying out of the soil can be expected to start at a continuous temperature of 50 ºC depending on the soil characteristics.

10- Temperature of the soil/environment

The temperature at the upper surface layers (depths 0.2 – 1.0 m) varies over time depending on the sun's heat, wind, and air temperature.

The amplitude of the fluctuation in the soil temperature reduces with increasing depth and is nearly absent from roughly 7m in depth (depending on soil thermal properties).

At the typical depths HDDs reach (>10m) any daily, weekly or seasonal variation in the ambient temperature is thus absent, while at the entry and exit points of an HDD, these variations do have their effect on the current rating of a power cable. This is described in more detail in TB 640 "A Guide for Rating Calculations of Insulated Cables".

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Chapter 3
Surveys and Design

Chapter 3: Surveys and Design

General surveying

Surveying consists in obtaining all the information of interest for the design of the trenchless solution and evaluate the impact on the environment during the execution of the works. It normally includes the following scope:

- Topography: Necessary to prepare profile drawings and define the occupation of the working area.
- Use of existing mapping, underground cable/pipe locators, desktop consultations, trial pits, site visits, etc. for the location of other services.
- Identification of type of environment: rural, urban, protected spaces, traffic, water resources, etc.
- Geophysical investigations: Non-destructive methods that provide subsurface details by measuring certain physical properties and interpreting them. The most common geophysical methods are Electrical Resistivity Tomography, Ground Penetrating Radar and Seismic Tomography.
- Geotechnical investigations: Study of ground conditions.

Chapter 3: Surveys and Design

Geotechnical

Trenchless Technologies can be performed in most soil types, but the cost and complexity is strongly affected by soil conditions and variations in soil conditions along the borehole.

The number of geotechnical boreholes will depend on the homogeneity of the soil conditions in that area, but a common practice can be taken at potential launch and exit pits for lengths up to 100 m at a minimum. For longer operations, would be taken every 100-150 m.

The depth of the boreholes should be at least 5 m lower than the planned alignment.

Geotechnical boreholes should not be made directly above the proposed alignment, to avoid potential frack-out during construction. All boreholes should be properly backfilled and sealed.

Chapter 3: Surveys and Design

Geotechnical

A desk study should be carried out, assessing the available literature, maps, aerial photographs, utility plans and existing site investigations. The desk study is essential to help understand the broader geological and geotechnical issues, and should be used to determine the scope of any intrusive investigations.

SOIL	ROCK
Soil type and classification	Depth and extent of rock
Standard penetration tests (SPT)	Rock strenght and hardness
Particle size distribution analysis	Abrasiveness (Cerchar Abrasivity Test)
Water table variations (Piezometers)	Total Core Recovery
Mosture content	Rock Quality Designation (RQD)
Porosity/Permeability	
Atterberg limits	
Soil thermal analysis	

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Chapter 3: Surveys and Design

Design

- Soil thermal resistivity: Can vary along the trenchless profile:
  - Moisture content: higher moisture lower resistivity. Can be better at greater depths due to aquifers.
  - Soil density: Greater density results in lower resistivity.
  - Soil type: Important to perform site specific thermal resistivity measurements at various depths and locations.

  In situ and laboratory TR measurements should be performed. Cigre Working Group B1.41 “Long term performance of soil and backfill systems”.

- Stability of the soil: Settlement and unstable soil conditions present a risk to the effectiveness of trenchless operations.
  - Settlement: is a process where soils decrease in volume. Should be considered when crossing below an infrastructure, in particular HDD.
  - Unstable soils: Difficult to stabilise and maintain the drill borehole (very sandy soil conditions). Solutions like washover pipe, cashing installation or forward reaming are used in HDD operations. Stabilisation by grouting with cement in Pipe jacking/microtunnelling operations.
  - Cavities: Difficulty to follow the desired route and loss of the drilling fluid during the trenchless construction.

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Design

- Rock hardness: The hardness of soil has an impact on the effectiveness and progress rate of the drill.
- Ground water: Water table level will help decide on the thermal resistivity and should be considered on excavation stability (including pits) and if it can be altered during drilling operations.
- Acid sulphate soils: Are naturally occurring soils that are formed under waterlogged conditions. The exposure of these soils to air causes sulfites to react with oxygen to form sulfuric acid. This acid could create corrosion of metallic pipes.
- Non homogenous soils: Impact on the type of drilling bit (wear and tear) and the overall steerability of the bit for HDD.

Chapter 4
Conclusions

Chapter 4: Conclusions

Conclusions

It is not really possible to draw any conclusion on which is the preferable method of installation for High Voltage cables. This Technical Brochure addresses the factors to be considered when deciding which trenchless technology (HDD, Pipe Jacking/Microtunnelling, Pipe Ramming or Ploughing) is best suited to the circuit installation. In addition to these installation methods one must also consider:

- Direct laying
- Laying in ducts
- Submarine laying on or in the sea bed or in ducts in the sea bed
- Laying in a large tunnel
- Laying on a bridge

Each one of these may be possible and the final decision on which one to adopt for any particular route will be decided on the basis of risk, cost, programme, environmental impact, licensing/permitting, engineering suitability, operational aspects including availability, ability to cater for future expansion, reparability and end of life access/recoverability.

Chapter 4: Conclusions

Conclusions

To minimise risk, it is essential that as much information as possible is gathered before the chosen installation takes place. Notwithstanding, this does not guarantee that the installation will be successful.

The increasing demand for the development of projects in urban areas make that the trenchless techniques are increasingly an essential complement to traditional techniques. As a result, the continuous experience improvement in trenchless technologies makes them more and more reliable.

Thank you

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