Typical Underground Cable Arrangements

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This functional requirements document is in line with the organisation's 1-03-ACS-08 Underground High Voltage Transmission Cable Asset Class Strategy.

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1. Definitions

In this document the following words and expressions will have the following meanings:

Item	Meaning
AIS	Air Insulated Switchgear
Cable system	Inclusive of cable, accessories, and ancillary equipment
CMS	Condition Monitoring System
Cu	Copper
DTS	Distributed Temperature Sensing
GIS	Gas Insulated Switchgear
HV	High Voltage
kV	Kilo-Volt
NER	National Electricity Rules
PD	Partial Discharge
XLPE	Cross-linked Polyethylene

2. Purpose

The purpose of this document is to provide a high-level summary of the various components which make up ElectraNet's underground power cable circuits. Primary and secondary functions of cable circuit components are provided for context.

3. Introduction

The key function of an underground cable is to transfer power between locations including generation sources, substations, load centres, within substations, and as integration into an existing overhead line. ElectraNet owns, manages and operates underground cables at 275kV, 132kV and 66kV.

Underground cable circuits are made up of various components, namely power cables, joints, terminations, associated structures, temperature & condition monitoring systems, and earthing systems. These components are described in more detail in this document.

4. HV Underground Cables

4.1 HV Underground Cable Primary & Secondary Functions

The primary functions of transmission HV cables are to transfer electrical power between designated locations, within prescribed performance, operating and environmental conditions and to insulate energised components from earthed structures at rated operating voltages and specified switching and lightning impulses.

Secondary functions of transmission HV cables are to:

a) Maintain electrical safety and minimise adverse effects on the environment; and

b) Provide a whole-of-life cost-effective service.

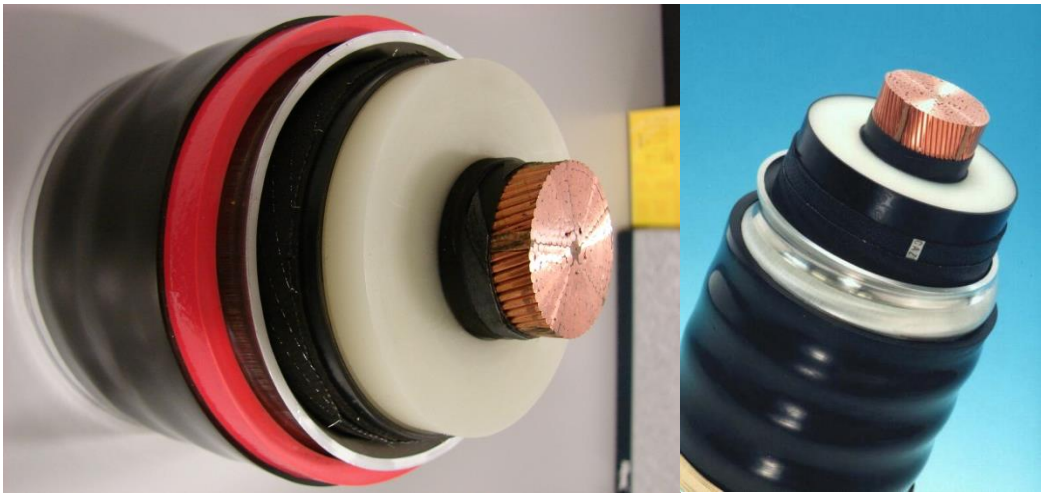


Figure 4-1 Typical HV XLPE Insulated Power Cables

4.2 HV Underground Cable System

The major components of an underground HV Cable system include;

- Above ground terminations (either GIS or AIS);
- Buried HV cable and joints;
- Earthing and bonding system to manage safety and minimise losses; and
- Monitoring system components (for cable temperature monitoring and joint PD measurements).

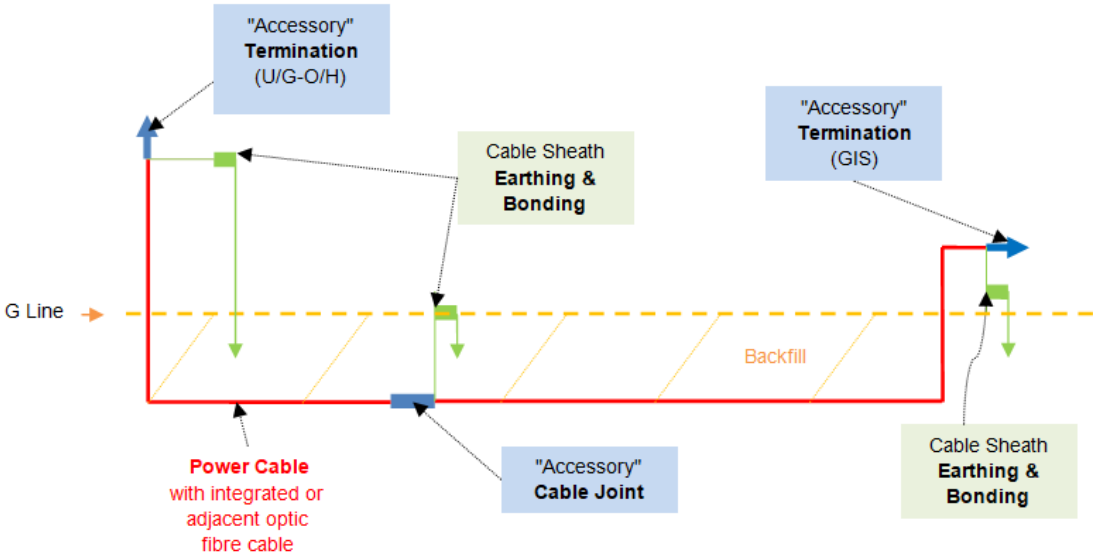


Figure 4-2 Typical Underground Cable System

4.2.1 HV Cable – Component Parts and Functionality

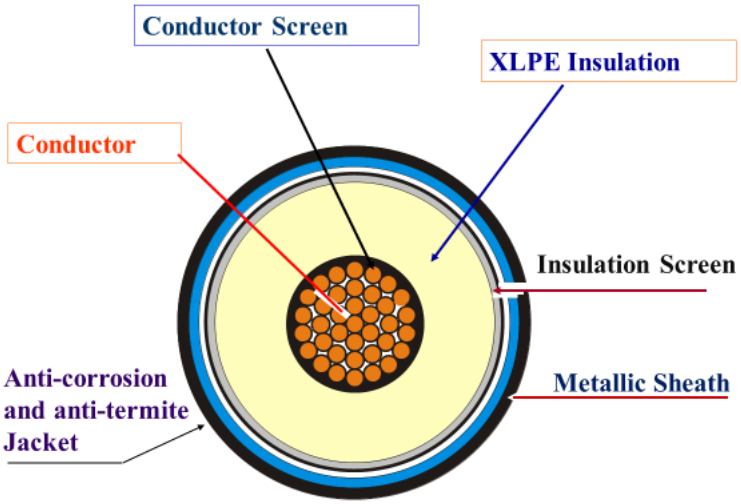


Figure 4-3 HV Power Cable Components

The functions of particular cable components are as follows:

- Conductor: transport electric current;
- Conductor screen: provide for uniform electric field in cable insulation;
- XLPE insulation: electrical separation between the cable conductor at high voltage and cable sheath at ground potential;
- Insulation screen: containment of electric field;
- Metallic sheath: water barrier and mechanical protection of cable-core. Provide for the flow of fault currents; and
- Anti-corrosion and anti-termites jackets: Protect cable metallic sheath and insulate the sheath to withstand induced and transient voltages.

4.2.2 Cable Rating

Thermal losses in the cable conductor, XLPE insulation, and metallic sheath due to current flowing in the cable system, combined with the thermal resistance of the cable component materials and the surrounding environment, cause the cable temperature to rise above the surrounding ambient temperature. Figure 4-4 shows a typical thermal model of the heat losses and thermal resistances. Cable rating (maximum allowable load current) is limited by the maximum allowable cable insulation temperature rise.

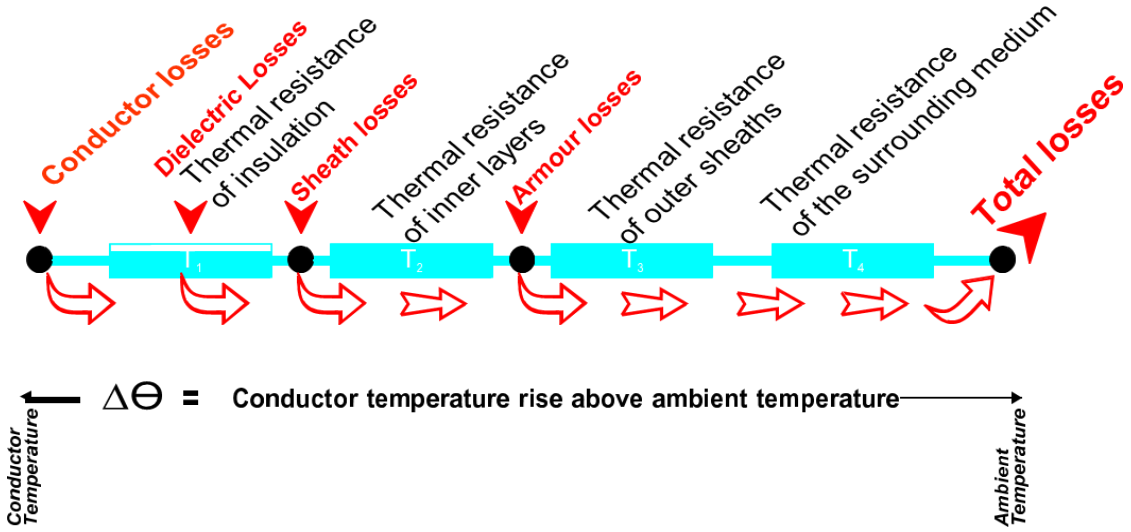
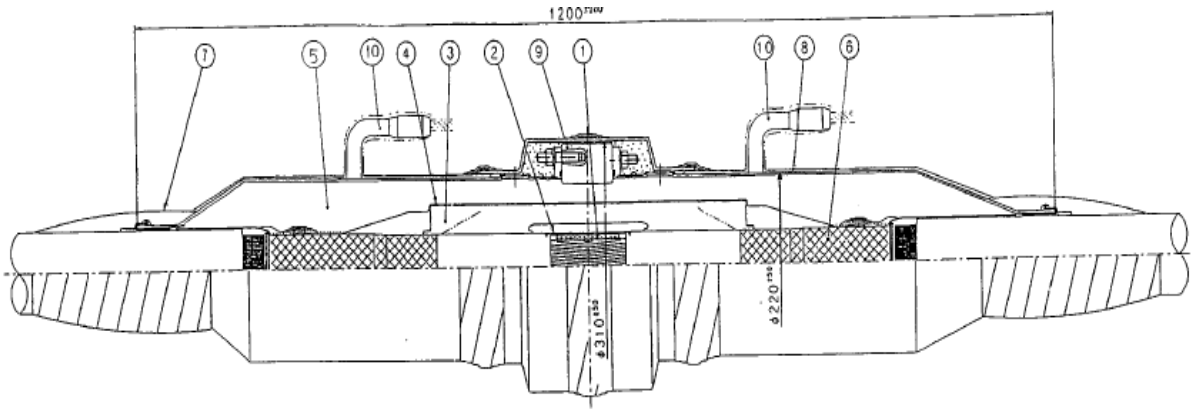


Figure 4-4 Temperature Rise of Cable Conductor Above Ambient

4.2.3 HV Underground Cable Joints

The primary function of cable joints is to provide electrical and mechanical connections between power cable sections.



(1) & (2) – Ferrule & corona shield;
(3) & (4) – Insulation mould assemble
(5) – Inner joint casing filled with dielectric/sealing compound;
(6) – Cable insulation screen;
(7) – sealing wiping;
(8) – Cu casing;
(9) – Casing sectionalising flange;
(10) – Lugs for link box bonding leads.

Figure 4-5 Joint for XLPE Cable – Diagrammatic Representation

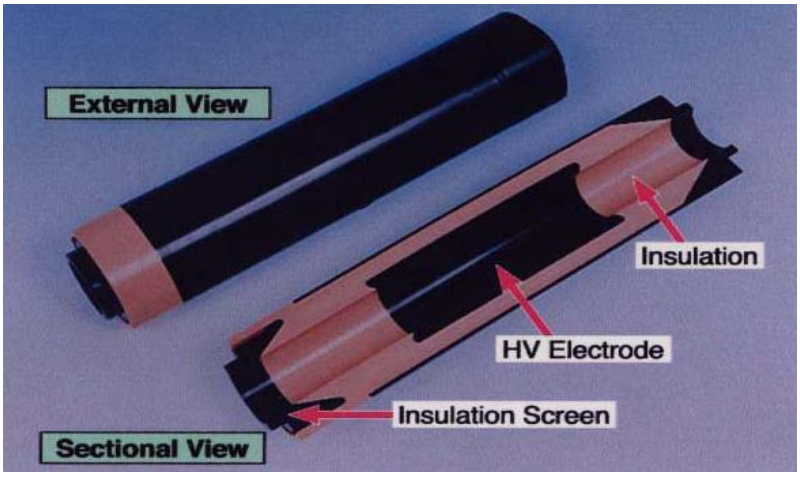


Figure 4-6 Joint for XLPE Cable – Joint Insulation Mould Assembly

4.2.4 HV Underground Cable Terminations

The primary function of cable terminations is to provide an electrical connection between power cables and other electrical plant, principally overhead lines or substation infrastructure.

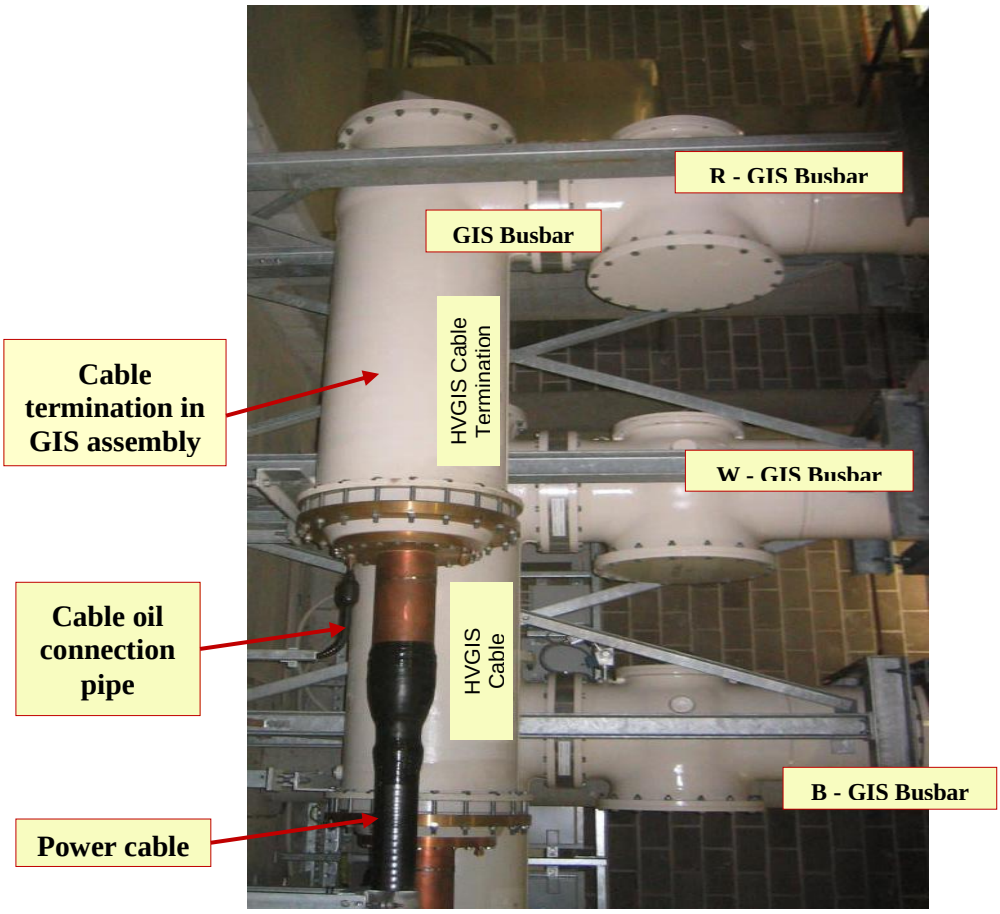


Figure 4-7 GIS Cable Terminations

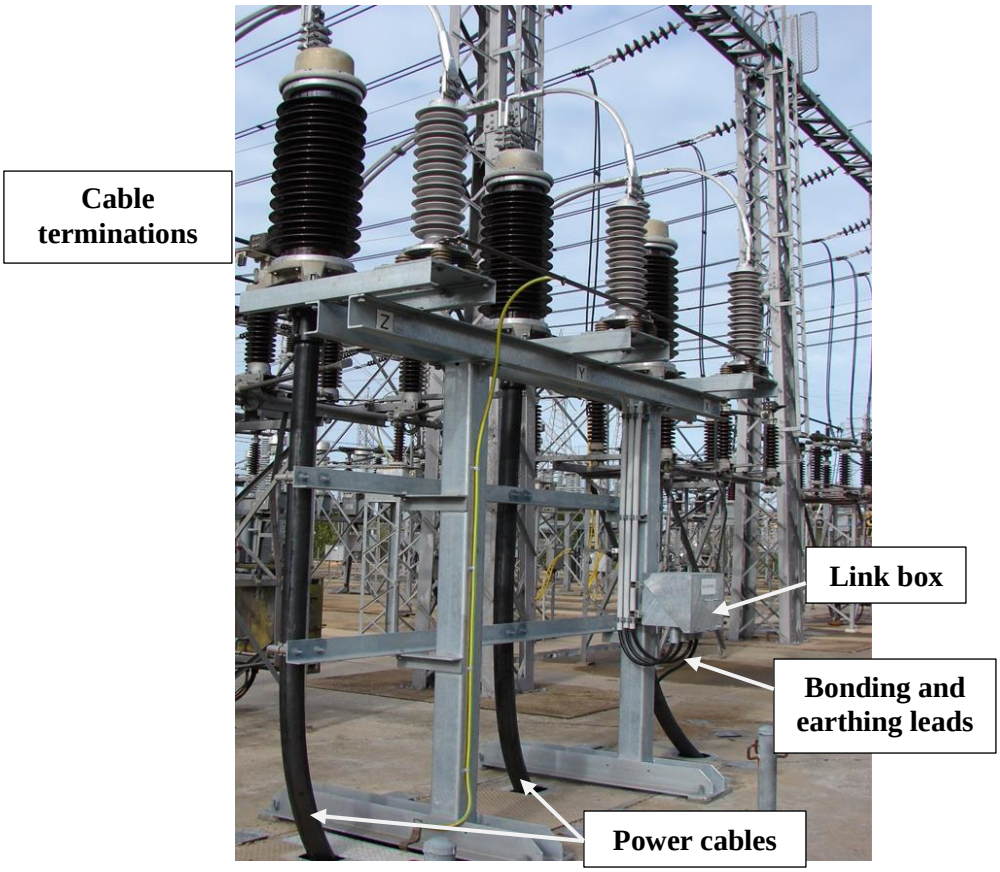


Figure 4-8 Outdoor Cable Terminations

4.2.5 HV Underground Cable Link Box

The primary function of a cable link box is to provide a waterproof, accessible, and explosion proof enclosure for components forming part of a cable bonding and earthing system including surge arrestors, stand-off insulators and removable links for testing purposes. Bonding systems may include cross-bonding, single point bonding and mid-point bonding.

Figure 4-9 Typical Arrangement of Link-Box in Underground Concrete Pit

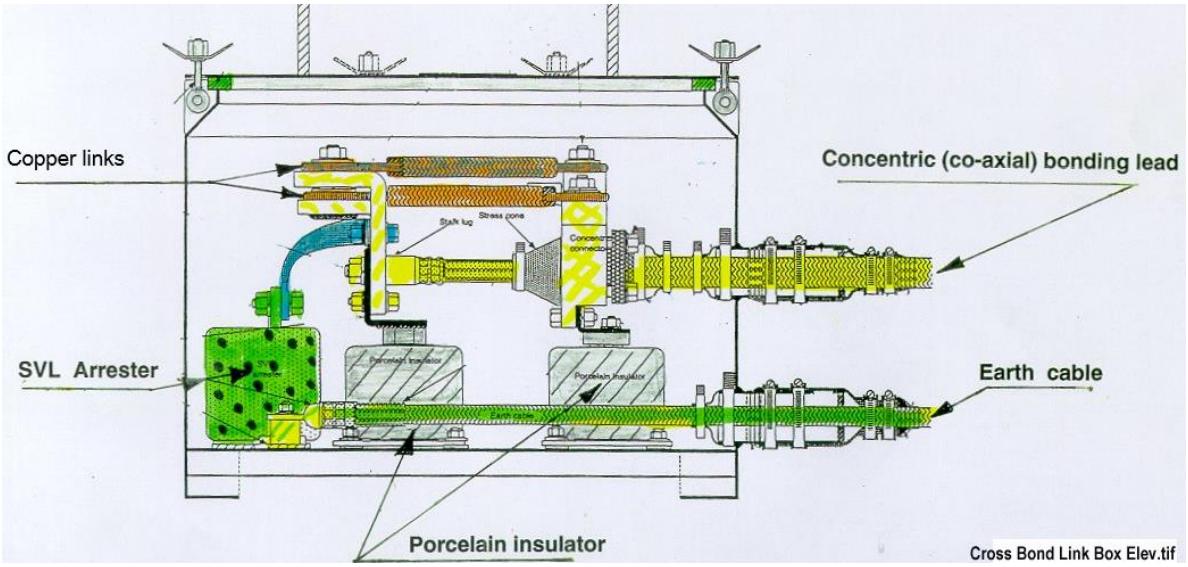


Figure 4-10 Typical Diagram of Link-Box in Underground Concrete Pit (courtesy of AK Power Solutions)

4.2.6 HV Underground Cable Partial Discharge (PD) Box

The primary function of a cable PD box is to provide a waterproof, accessible, enclosure for electrical wiring connected to PD detectors at cable joints and terminations.

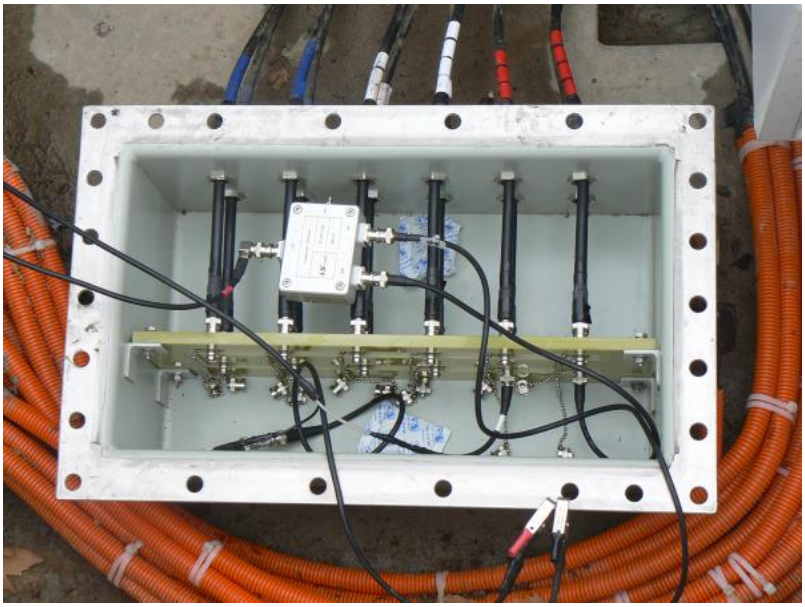


Figure 4-11 Partial Discharge (PD) Sensor Terminal Box

4.2.7 Optical Fibre Cables

Optical fibre cables are part of the power cable system ancillary equipment in form of communication, data transfer and temperature sensing systems. For mechanical protection these cables are drawn in hard materials micro-duct assemblies.

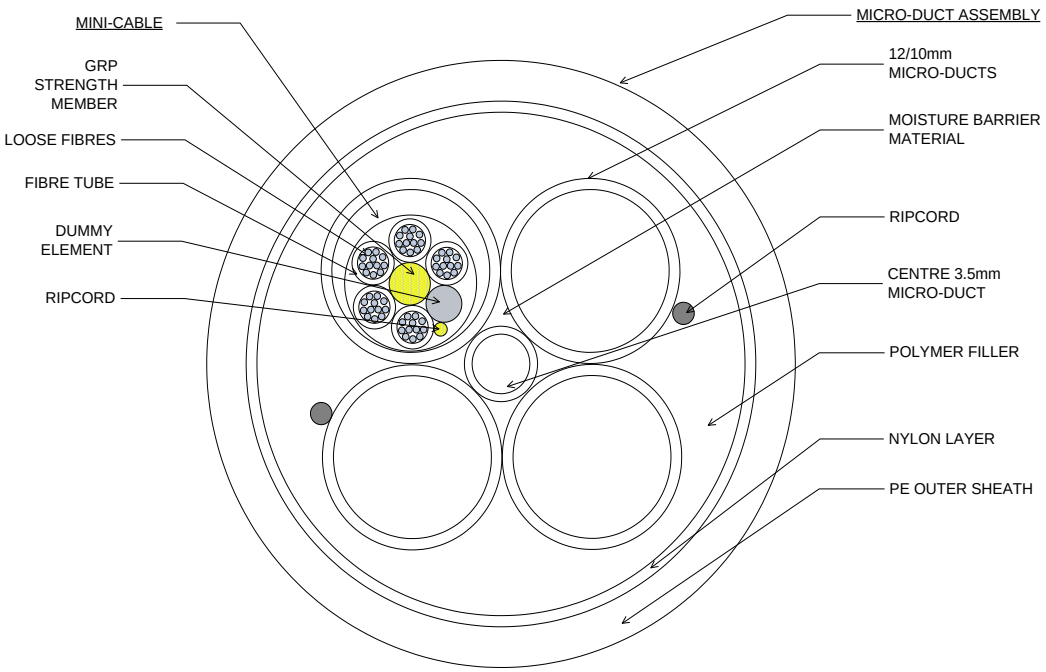


Figure 4-12 Typical Micro-duct Assembly for Communication and CMS Optical Fibre Cables

4.2.8 HV Underground Cable Condition Monitoring System (CMS)

The primary function of a cable CMS system is to monitor cable and ground temperature throughout a cable route utilising a distributed temperature sensing (DTS) system, and a microprocessor-based system with distributed intelligence.

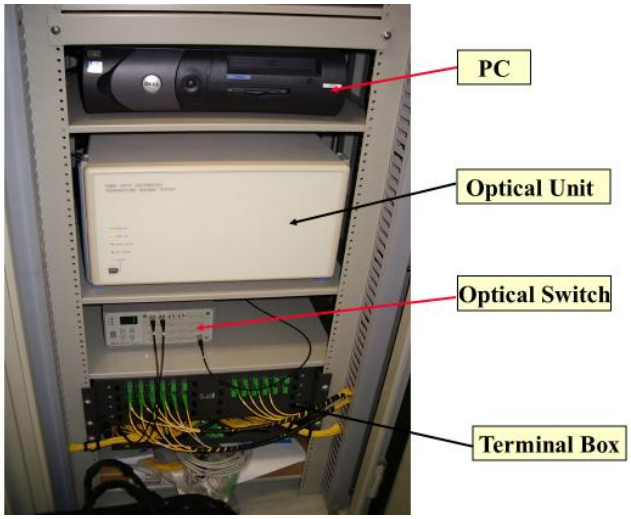


Figure 4-13 Distributed Temperature Sensing (DTS) Module

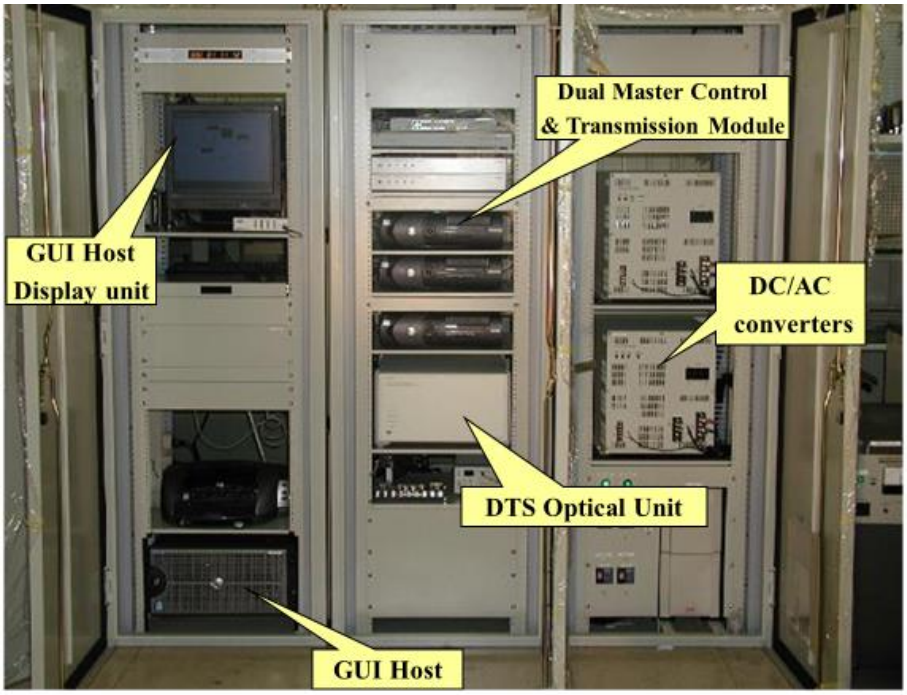


Figure 4-14 Condition Monitoring System (CMS) Module

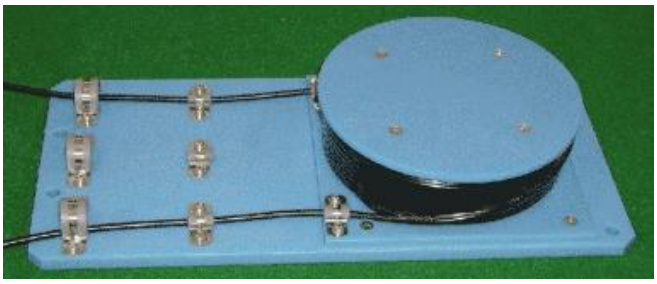


Figure 4-15 Optical Fibre Ambient Temperature Sensor

4.3 HV Underground Cable Structures

The primary function of underground cable structures is to provide structurally sound enclosures for cables and cable system components that are located below ground for reasons including safety, local planning requirement and traffic consideration.

4.3.1 Trench with Controlled Backfill

The primary function of a cable trench is to provide a below ground environment for the placement of power cable in a variety of situations including roadways, parks, and reserves while meeting requirements related to cable rating and physical protection fundamentals, stability, and local planning considerations.

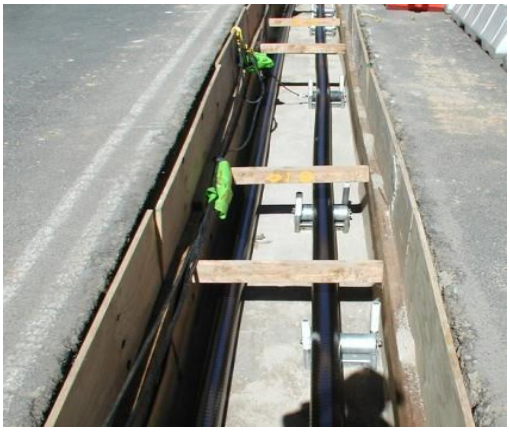


Figure 4-16 Typical Cable Trench in Concrete Roadways

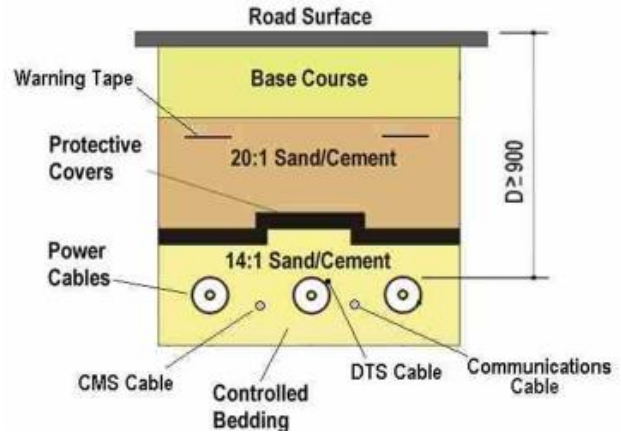


Figure 4-17 Typical Cable Trench Cross-Section

4.3.2 Joint Bays

The primary function of a cable joint bay is to provide a clean, secure environment for the assembly of cable joints, bonding and earthing leads and PD sensors. When jointing is complete and the joint bay buried, the joint bay structure provides ongoing physical protection for the life of these cable components.

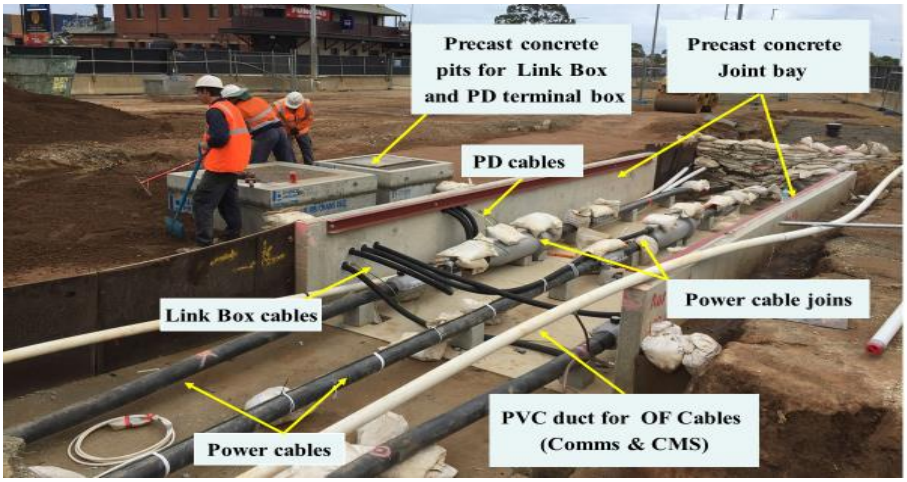


Figure 4-18 Joint Bay – General View during Construction

4.3.3 Link Box Pits

Link box pits are typically of concrete (either pre-cast or cast-on-site). The primary function of a link box pits is to provide a life-long, water resistant enclosure for link boxes.

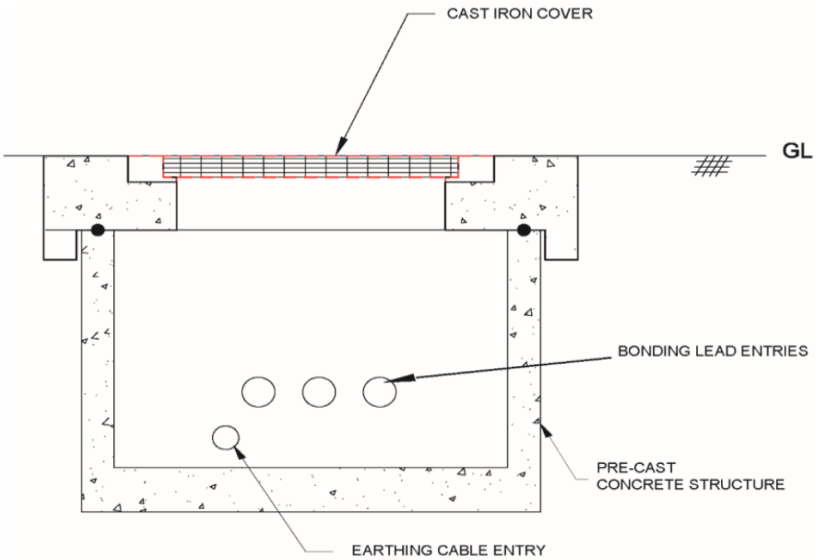


Figure 4-19 Typical Precast Concrete Pit

4.3.4 Expansion Chambers

The primary function of expansion chambers is to absorb and manage longitudinal cable movement.

Expansion chambers form part of a cable installation involving cable transitioning from a bridge environment to a conventional below ground installation or other conditions.

4.4 Special Bonding and Earthing Systems

The primary function of a cable earthing and bonding system is to:

a) Enable performance of cable sheath bonding system to provide security and minimise cable losses;

b) Provide an electrical path for lightning and fault currents to earth, to ensure safety of people, assets and the environment;

c) Ensure cable circuit components are not damaged; and

d) Provide an earth (i.e. zero) potential reference to ground under normal circuit conditions for the dissipation of leakage currents.

The earthing shall be designed to meet NER time limits.

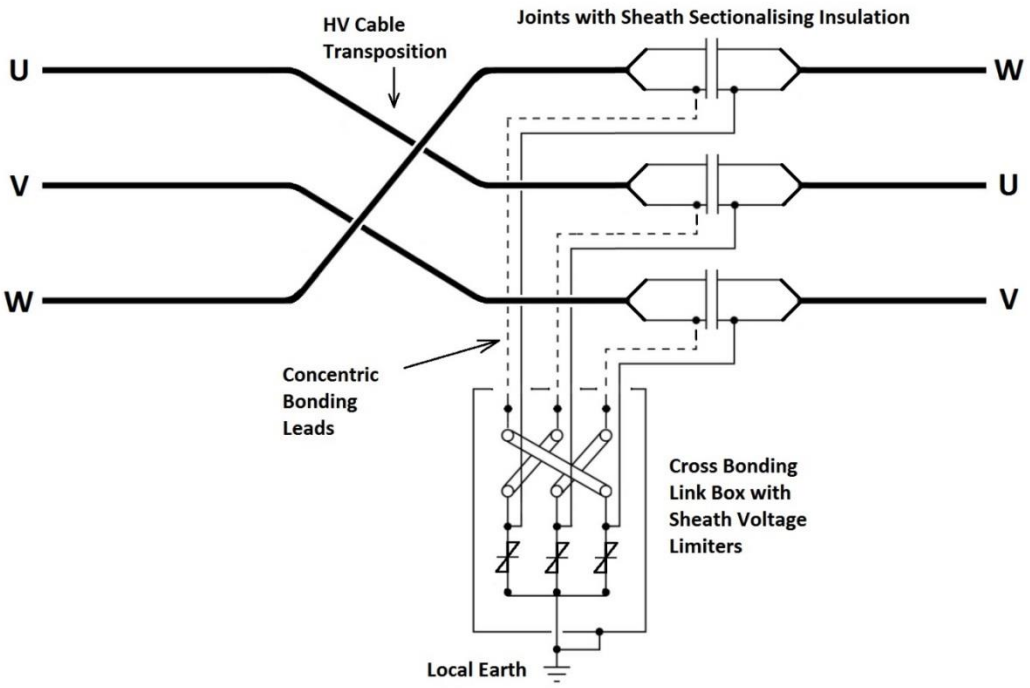


Figure 4-20 Typical Diagram of Cross-bonding System with Cable Transposition

4.5 Above Ground Cable Structures

The primary function of support structures is to provide a basis for the fitting of cable terminations and associated components (lightning arrestor, above-ground link boxes) and power cable fixing clamps.

Support structures may be in the form of poles (as in "Stobie Pole") or steel lattice structure (as in "Overhead Transmission Line Structure") or of other form to suit specific need such as for GIS and outdoor terminations, purpose-built cable bridges and cable trays.

Figure 4-21 Typical Purpose-Built Cable Bridge Construction

ElectraNet

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