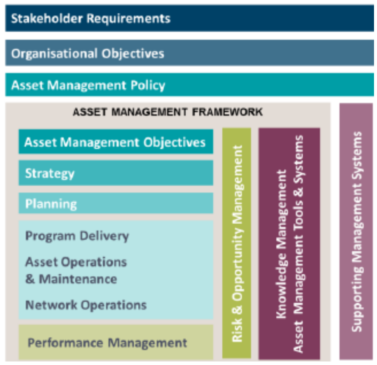
Transmission Underground Cable System Design

Design Standard



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Western Power's Engineering and Design Function is responsible for this document

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Revision Details

Version	Date	Summary of change
0	29/05/2013	Initial release
1	17/03/2017	Revised
2	18/09/2018	Amended EDM categories
3	17/06/2021	Updated to new template and minor revisions
4	05/03/2024	AMS format change

1. Introduction

The purpose of this document is to identify the requirements and criteria for the design and installation of transmission underground cable systems in accordance with the requirements of Western Power. The information is applicable to all cable systems consisting of single core polymeric insulated cables for voltages from 66kV to 330kV.

Specific information for the installation of a cable system will be issued in the form of specifications, drawings and site instructions to identify the requirements of each project.

1.1 Purpose and scope

This standard covers the minimum requirements for the design and installation of underground transmission cable systems to be connected to the Western Power Network. The standard is arranged in the following sections:

- Cable system design.
- Installation design.
- Cable laying.

1.2 Acronyms

Acronym	Definition
U_0	Rated power frequency voltage between phase and earth
U	Rated power frequency voltage between system phases
U_m	Maximum normal operating system power frequency voltage between any two phases

Operating voltages not defined as above are taken as the voltage between the system phases (U); otherwise the form of U_0/U (U_m) is used.

1.3 Definitions

Term	Definition
Acid sulphate soils	Organic soils which, when oxidised, form organic acids.
CYMCAP	Power cable ampacity rating software.
Cable system	The cable and its associated accessories (joints and terminations).
Cross Bonding System	A method of sectionalising the sheaths into minor sections and cross connecting them so as to approximately neutralise the total induced voltage in three consecutive sections.
Depth of burial	The distance below the ground level to the cable centres or to the centre of a trefoil formation.
Ducts	Thermoplastic ducts installed along the cable route to facilitate the installation of cables.
Elementary cable length	The length of cable with a continuous sheath between joints, terminations or joint and termination.
Flat formation	The method of laying the cables of a circuit in a horizontal plane with defined separation distances between the phases.
Joints	A fully protected insulated underground connection between two lengths of cable. The joint types include continuous sheath, interrupted sheath and transition joints.

Laying formation	Each cable circuit may be installed in touching trefoil or flat horizontal formation with a specified spacing between the phases.
Terminations	The means of connecting single core cable to other electrical equipment. Generally, terminations shall be suitable for either outdoor air insulated or GIS substation locations.
Trefoil formation	The method of laying the cables of a circuit in triangular formation.
Sheath standing voltage (SSV)	The voltage induced in the single core metallic cable sheath by the load current.
Single Point Bonded System	A method in arranging for the sheaths of the cables to be connected and earthed at one point along their length to prevent circulating currents.
Solid Bonded System	A simple method of connecting and earthing both ends of the sheath of a length of cable.
Special backfill	A backfill consisting of a mix of yellow brick layer's sand and cement (ratio of 14:1 sand / cement by volume) with a thermal resistivity equal or less than 1.0 °C.m/W.

1.4 References

References which support implementation of this document

Table 1.1 References

Reference No.	Title
ASTM D5334	Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure
AS/NZS 1125	Conductors in insulated electric cables and flexible cords
AS 1289.2.1.1	Soil Moisture Content Tests – Determination of the Moisture Content of a Soil – Oven Drying Method
AS/NZS 1429.2	Electric cables – Polymeric insulated Part 2: For working voltages above 19/33 (36)kV up to and including 87/150 (170)kV
AS/NZS 1660.2.1	Test methods for electric cables, cords and conductors Method 2.1: Insulation, extruded semi-conductive screen and non-metallic sheaths – Methods for general application
AS/NZS 1660.2.5	Test methods for electric cables, cords and conductors
AS 3808	Insulation and sheathing of electric cables
AS 3996	Access Covers and Grates.
AS4702	Polymeric cable cover
AS/NZS 60840	Power cables with extruded insulation and their accessories for rated voltages above 33kV (Um = 36kV) up to 150kV (Um = 170kV) – Test methods and their requirements
CIGRE WG B1.18	Technical Brochure 283 – Special Bonding of High Voltage Power Cables
IEEE Standard 575-2014	Guide for Bonding Shields and Sheaths of Single-Conductor Power Cables Rated 5kV through to 500kV
IEC 60228	Conductors of insulated cables
IEC 60287-1-1 Ed. 2.1	Electric Cables - Calculation of current rating – Part 1-1: Current rating equations (100% load factor) and calculation of losses – General
IEC 60853-2 Ed. 1	Calculation of the cyclic and emergency current rating of cables. Part 2: Cyclic rating of cables greater than 18/30 (36)kV and emergency ratings for cables of all voltages

ICNIRP	The International Commission on Non-Ionizing Radiation Protection (ICNIRP) - Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz -100 kHz)
	Code of Practice – Excavation WA 2022

2. Function Requirements

Cables are either directly buried in a controlled backfill installed in an open trench or in cable ducts.

A cable system shall be designed and installed for safe and reliable operation with a service life of at least 50 years.

3. Safety in Design

The transmission underground cable system design must consider all safety aspects that can arise from the construction, operation, maintenance and decommissioning of the underground cable system and other activities within the underground cable corridor.

The Transmission Underground Cable System Design Hazard Management Register (HMR)[1] captures and document what risks have been controlled by this Standard, and what residual risk may remain that should be considered at the project design stages and construction.

Every design is required to have its own project specific Hazard Management Register.

4. Cable System Design

4.1 General

A cable system consists of three insulated single core cables, joints, terminations, sheath earthing accessories and cable termination support structures.

The cable system design is based on a cable route that has been optimised by taking into consideration safety, environmental, site, technical, economic, security, maintainability and cable rating requirements.

Multiple single core cables shall be used for each phase if the cable rating requirements exceed the available cable conductor size.

Consideration should be given to the minimising of the cable trench widths and reduction of the magnetic fields by optimising the laying and spacing formation of the phase cables.

4.2 Power Cable

All new installations shall use cables with following requirements:

Table 4.1: Power Cable Requirements

Cable component	Requirements
Conductor	Copper
Conductor size (subject to load requirements)	400mm^2, 800mm^2, 1200mm^2, 1600mm^2, 2000mm^2 and 2500mm^2

[1] See Western Power's internal document

Cable component	Requirements
Metallic sheath	Corrugated aluminium or corrugated copper
Insulation	Cross-linked polyethylene (XLPE)
Oversheath	High density polyethylene (HDPE) with conductive coating/layer
Termite protection	Required (Nylon jacket)

The power cables shall be designed, manufactured and tested in accordance with AS/NZS 1125, AS/NZS 1429.2, AS/NZS 1660.2.1, AS/NZS 1660.2.5, AS/NZS 3808, AS/NZS 60840 and IEC 60228.

4.3 Cable System Rating

The cable system rating shall be designed to meet the requirements for normal operation, system and cable fault currents and transient voltages.

4.3.1 Insulation Levels

The insulation levels for the cable system shall be in accordance with Table 4.2.

Table 4.2: Insultation Levels[2]

System Voltage (kV)	Short Duration (1-minute) Power Frequency Withstand (kVrms)	Lightning impulse withstand voltage (kVpeak)
66	140	325
132	275	650
220	460	1050
330	520	1175

4.3.2 Cable Thermal Rating

The thermal rating of a cable is dependent on:

- Site conditions and native soil thermal resistivity.
- Laying formation
- Depth of burial
- Trench size and special backfill volume
- Phase spacing
- Sheath bonding system
- Proximity to other heat sources, such as other cable circuits

The installation of the cable system shall follow the design requirements otherwise the thermal rating will be compromised.

Cable thermal ratings shall be calculated in accordance with IEC 60287-1-1 and IEC 60853-2 with the inputs defined in Table 4.3

[2] See Western Power's internal document

Table 4.3: Cable Thermal Rating Input Parameters

Parameters		Summer	Winter
Maximum continuous conductor temperature		90° C	
Emergency rating		105° C	
Ambient ground temperature		28° C	18° C
Outdoor air ambient temperature		46° C	28° C
Special thermally stable backfill	Yellow sand – low clay (Concrete sand)	1.50° cm/W	0.549° cm/W
	Yellow Brickies sand	1.25° cm/W	0.458° cm/W
	Sand cement 20:1	1.10° cm/W	0.403° cm/W
	Sand cement 14:1	1.00° cm/W	0.366° cm/W
	Concrete	1.00° cm/W	0.366° cm/W
Native soil thermal resistivity		As per thermal resistivity test at a moisture content of 1% dry weight (summer) and 4% (winter)	
Load factor		100 %	

Sand cement 14:1 is the standard special thermally stable backfill used in Western Power for transmission cable.

CYMCAP is the preferred software for conducting cable rating studies.

Thermal resistivity testing shall be conducted along the cable route at regular intervals or at changes in soil types. All testing and measurement are to be performed in accordance with ASTM D5334 and AS 1289.2.1.1 with NATA accreditation.

4.3.3 Fault Current Rating

The conductor, cable sheath, sheath earth bonding cables and link boxes shall be rated in accordance with Table 4.4.

Table 4.4: Cable Fault Current Ratings

System Operating Voltage	330kV	220kV	132kV	66kV
Fault rating (kA)	50	25	40	25
Duration (second)	1	0.5	1	1

4.4 Cable Length

The elementary cable length shall be limited by the maximum cable sheath standing voltage (SSV) as well as the cable manufacturing capacity and transport limitations. The SSV for any elementary cable length for a circuit at maximum rated current shall not exceed 120V as per industry good practice for cables connected to the Western Power Network.

Cable joint locations shall therefore be determined by the available cable length, site requirements or by the maximum allowable sheath standing voltage and installation pulling tension.

4.5 Cable Installed in Air

Cables installed in air shall be supported by a suitable cleating system designed to support the cables, accommodate cable thermal movements and to restrain the mechanical and electrical forces during faults and switching operations.

The cables can be either rigidly supported and restrained or flexibly supported by snaking vertically or horizontally to permit limited cable movement.

4.6 Cable Sheath Bonding

4.6.1 Sheath Bonding Methods

Sheath bonding systems become economically justified for single cored cable circuits when the circuit load currents become significant (generally above 500A) or where heat generation has to be minimised. The sheath bonding and earthing systems will offset the reduction of cable rating due to the sheath losses which would otherwise occur. This is particularly apparent for cables laid in flat formation.

The bonding systems should be based on the single and cross bonding designs according to Cigre TB 283 and IEEE Standard 575.

The three types of cable sheath bonding and earthing systems are:

- Solid bonding.
- Single point bonding.
- Cross bonding

Solid Bonding

Solid bonding, sheaths bonded to earth at each end of the elementary cable length, shall be applied when the cable rating significantly exceeds system requirements.

For single core cable circuits carrying currents in excess of approximately 500A, special bonding is economically desirable as the reduction in losses allows an appreciable smaller conductor size to be used.

Single Point Bonding

In this arrangement, the cable sheaths are solidly bonded to earth at one end of each elementary cable length. The sheath at the remote end is isolated from earth through a sheath voltage limiter. The sheath and earth bonding system shall be electrically separate for each cable length.

A mid-point bonded system consisting of two single point bonded sections, may be used where the route length exceeds the available cable elementary length.

An earth continuity conductor is required to be installed parallel with the cable circuit to provide a return path for system fault currents.

Cross Bonding

A cross bonding system is required for longer circuits where the route is divided into groups of three equal elementary or minor cable lengths. The sheaths are cross connected to neutralise the total induced sheath voltage in three consecutive lengths. This requires the three minor lengths to be equal in length and identical laying formation. The cable sheaths are bonded to earth at the circuit ends and at the end of the three minor sections. Sheath voltage limiters shall be installed at the minor joint locations.

The sheaths of the three minor lengths of cable located in the same relative position in the trench shall be bonded together in series.

4.6.2 Sheath Bonding Components

Sheath Voltage Limiters

Sheath voltage limiters (SVL) shall be incorporated in the sheath earth bonding systems of single point and cross bonded cable circuits. The SVL shall limit the induced sheath transient voltage rise during switching operations, lightning impulses and cable circuit faults. The SVL shall not conduct during normal circuit operation or during external system faults.

The protective voltage level of SVL shall be selected to meet the above criteria. In addition, the SVL residual voltage shall be less than the adjusted breakdown voltage of the cable over sheath and less than half of the joint sectionalising withstands voltage. The adjusted breakdown voltage of the over sheath shall be 75% of the theoretical rated voltage withstand level to take into account ageing, temperature and surface damage incurred during installation.

The SVL shall be located in the link boxes.

Link Boxes

Link boxes containing removable links shall be installed at the ends of all elementary cable lengths to facilitate the testing of the sheath insulation. The boxes shall be rated for the system fault current levels and voltages.

Earth Bonding Cables

The single cored and concentric bonding cables used to connect the cable sheaths at terminations and joints to the link boxes shall be rated for the system fault current level and a DC test voltage of 15kV. Bonding cables with cross sectional areas closest to the required rating shall be used if the exact rating is not available. The bonding cable shall be as short as possible and shall not exceed 10m in length.

Earth Continuity Cable

A single cored insulated cable shall be installed in the cable trench and connected to ground at both ends of the single point bonding system. The cable shall be located next to the cables laid in trefoil or close flat formation or between an outer and inner cable (0.7 of the phase spacing biased to the outer phase) for flat formation.

The earth continuity cable shall be rated for the system fault current level and insulated for an AC voltage of 0.6/1kV.

For customer connections, two earth continuity cables must be installed with each rated for the full fault current[3].

4.7 Transposition of Cables

Cables circuits designed for cross bonding of the sheaths and laid in flat formation shall be transposed at the two minor joint locations. The sheath earth bonding designs requires the circuit cables to be

[3] This is to allow flexibility in the substation design to use these cables if required instead of relying on the cable sheath to ensure the customer's earthing systems are safe (where the customer can demonstrate that they are unable to design a safe earthing system without reliance on Western Power).

transposed to equalise the sheath induced voltages. Cable circuits shall be transposed on one side of each of the minor joint location. Circuit phasing requirements should be accommodated by crossing the cables at the base of the terminating structures.

An earth continuity cable installed as part of single point bonding system shall be transposed at the mid-point of the cable length.

4.8 Earthing

In conjunction with the cable sheath bonding design, an earthing design is required to manage the transfer of fault energy in such a manner as to limit the risk to people, equipment and system operations.

Further details are available in Transmission Line Earthing Design Standard[4].

4.9 Cable Joints and Terminations

The joints and terminations shall be selected to ensure that they are suitable for the installation, compatible with the cables and match the design lifetime of the cable system.

The termination insulators shall be polymeric material with a minimum leakage distance of 31mm/kV unless otherwise required.

4.10 Magnetic Fields

The magnetic fields generated by a cable circuit shall not exceed the recommended exposure limits required by INCIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1Hz to 100 kHz).the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). This applies in particular to cable circuits installed adjacent to facilities such as schools and public frequented areas.

Methods to mitigate magnetic fields shall be investigated where the excessive exposure to magnetic fields is unavoidable or where the circuit cannot be re-routed.

Prudent avoidance must be incorporated in all design.

4.11 Cable Circuit Monitoring Equipment

A distributed temperature monitoring system consisting of a fibre optic cable shall be considered for high load or critical circuits.

The temperature sensing cable shall be laid in the centre of a trefoil group of cables or on top of the centre cable when laid in flat formation. Joint boxes for the monitoring cable shall be installed at joint bays in dedicated pits for access and maintenance purposes.

5. Installation Design

Cables shall preferably be installed in ducts or directly buried in special backfill and laid in trefoil formation. Alternatively, the cables can be laid in flat formation with separated phases where the cable ratings are to be maximised. Flat formation cable circuits have higher levels of EMF, which should be investigated in areas frequented by the public.

[4] See Western Power's internal document

For installation in urban or congested areas, disruption to traffic and the public is to be minimise and thus installing the cables in ducts is preferred. In this instance, it is preferable to install the cables under the road carriageway, approximately 1.0m away from the kerb.

For certain application (typically lightly loaded cable circuits and where 3rd party requires specific methodology), trenchless excavation may be a feasible option. This needs to be assessed by taking into consideration the technical, constructability, safety, environmental, maintainability, cost and schedule requirements.

The cable system design shall identify the dimensions of the trench, laying formation, the spacing and the extent of the special backfill in the trench.

Subject to site constraints, additional lengths of cable shall be installed in the trench adjacent to joint and termination locations to permit a remake in the event of a joint or termination failure.

Joints shall not be installed within 10m of ducts, deviations of the cable route or terminations and near a road intersection. Anchoring clamps shall be used adjacent to the joints and terminations if the cables are installed in air or if considerable changes in elevation of the route exist.

Ducts to be installed under railway or major roads should cross at 90° to the facilities unless otherwise negotiated with the service operator. The duct design and installation depth shall comply with the relevant standards, regulations and codes.

5.1 Mechanical Forces

The thermo-mechanical forces and movements generated by the thermal expansion and contraction of the cable needs to be considered. The installation design needs to reduce the magnitudes of the cable forces and/or movements to acceptable limits for the required service life of the cable system.

5.2 Depth of Burial

The nominal depth of burial of a cable circuit shall be 1.0m below ground level. A minimum cover of 800mm may be permitted provided that site conditions are acceptable and adequate mechanical protection is provided.

The cables shall be installed at greater depths to provide additional protection or to avoid other services or obstructions. In these cases, the laying formation and cable phase separation distances may have to be modified to accommodate the reduction of cable rating. A mechanical barrier such as a concrete slab or polymeric cable cover may have to be installed to provide additional security between the services and cable. Services above the cable should be surrounded by yellow bricklayers sand (or other suitable backfill) and not the special backfill.

A minimum separation distance of 300mm is required between the circuit cables and any other services, unless otherwise required by the service operator.

5.3 Trench Excavation

For direct buried, the trench shall be open for at least one cable length between joints or terminations to permit laying and backfilling of the cable circuit. The radius of the trench shall be greater than the minimum laying bending radius of the cable set by the manufacturer.

For cables in ducts, the trench/duct installation shall be carried out in progressive short sections to minimise road disruption via appropriate traffic management plans.

Shoring shall be used in locations of poor soil stability or when the depth of the trench exceeds 1.5m. All trench shoring shall comply with Western Power's standard and Code of Practice – Excavation WA 2022.

Excavated material from the trench shall not be used as backfill and disposed at authorised sites unless specifically permitted. If the circuit is to be installed in contaminated soils, the prescribed method of removal, disposal and in the case of acid sulphate soils, neutralisation of the acids, shall be implemented.

For installing double circuit cables in parallel, the design of common trench shall be considered with a barrier to provide mechanical protection and outage requirement for other circuit when there is fault on one circuit.

5.4 Trenchless Excavation

Horizontal directional drilling (HDD) is the predominant technology used by Western Power for trenchless excavation.

The design shall include a cross section showing the details of the conduits in the underbore, full longitudinal profile providing bore depth along the entire length, details of entry and exit pits and any other information considered necessary to minimise any unexpected issues and costs that may arise during the construction phase.

Geotechnical investigation must be conducted to determine technical feasibility of the bore and to also establish the most efficient way to accomplish whilst avoiding surface disruptions.

The report shall as a minimum include following.

- Subsidence
- Soil strength and stability
- PE Pipe Dimension Ratio
- Design consideration for net external loads
    - External pressure due to earth pressure
    - Groundwater pressure
    - Surcharge and live loads
    - Internal pressure
    - Hydrostatic pressure of drilling slurry
    - Live loads (trucks/vehicles etc)
- Performance limits of HDD installed pipe
- Ring Deflection (Ovalisation)
- Unconstrained buckling
- Wall compressive stress
- Pullback Force
- Frictional Drag Resistance
- Conduit Stress
    - Bending stress
    - Thermal Stress
    - Torsion Stress

5.5 Cable Ducts

Ducts shall be installed to minimise traffic restrictions or where trenching is not technically feasible. The ducts shall be installed in an open trench with backfill or by horizontal directional drilling if excavation of a trench is not safe and technically not possible or permissible.

One duct shall be provided for each single cored transmission cable with additional ducts being installed for the sheath earthing and communications fibre optic cables as required.

Each duct shall be installed as straight as possible and the maximum duct length being limited by the permissible cable installation pulling tension.

5.5.1 Duct Design

The internal diameter of the duct for the transmission cables shall be adequate to allow the cable pulling eye to pass through the duct. Generally, the internal diameter of the duct shall be the cable diameter plus 100mm.

The material of the duct shall be thermoplastic material, preferably PVC (polyvinyl chlorine), polyethylene (PE) or high-density polyethylene (HDPE), depending on technical requirement and availability. The wall thickness shall be selected to withstand the compressive forces of the backfill, including additional loads such as road or rail traffic.

Duct sections may be joined together to form longer lengths. The joints shall not separate during installation or while in use and shall not impede the installation of the cables.

Duct depth and spacing shall be designed to comply with the cable system design requirements.

5.5.2 Duct Installation

Ducts shall be installed in an open trench or by horizontal directional drilling. Ducts installed in an open trench shall be backfilled with special backfill or concrete where extra mechanical protection is required.

Where several ducts are to be installed in a single bore under major roads or railway crossings, a lining or casing shall be used to support the ground and to house the individual ducts. Additionally, a bore lining shall also be adopted if the ground is not self-supporting.

Pipe jacking may also be considered where the cable rating is adequate to permit laying the cables in a single duct. A ferrous pipe may be used to attain sufficient strength for pipe jacking. Additional ducts shall be installed as sleeves for each cable to facilitate cable installation.

Where the cable circuit rating has to be maximised, the ducts shall be filled with removable backfill slurry consisting of Bentonite and sand.

All ducts shall be clean and dry prior to installing the cables. A draw wire or rope shall be left in each duct to facilitate the laying of the cables.

Ducts are not required for the sheath bonding and earthing cables at joint locations.

5.5.3 Communications Ducts

If communications fibre optic cables are required in the same trench, a continuous duct shall be installed for each cable. The outside diameters shall be 110mm for black with a white stripe polyethylene or 100mm for white polyvinyl ducts. The duct shall be continuous or joined to suitable pre-installed ducts so that the communications cable can be installed without restriction.

The communications ducts shall be installed at the same level as the cables or immediately below the protective concrete slab installed in the trench. A minimum cover of 600mm over the communications duct is required where the duct is installed outside the cable circuit trench.

5.6 Special Backfill

The backfill installed in the cable trench shall consist of yellow bricklayer's sand and cement mixed in a proportion of 14:1 by volume. The special backfill shall have a soil thermal resistivity equal to or less than 1.0^{o} C.m/W.

If the backfill is applied dry, the required compaction rate must be attained and all voids around the cables and ducts shall be eliminated. Alternatively, the backfill can be applied wet in the form of slurry.

The special backfill cross-sectional area shall be dimensioned to accommodate the 50 °C temperature isotherm within the upper surface of the special backfill to maintain the circuit rating during dry soil conditions. The backfill shall be installed below the protective slab/cover but in locations of poor thermal conductivity soils, the special backfill may be installed in the trench above the slab to within 200mm of the ground level.

Cables to be installed in acid sulphate soils (ASS) require special design considerations. To accommodate the potential degrading of the special backfill, the cable rating shall be designed based on a backfill of bricklayer's sand only. Alternatively, special acid resistant cement may be used.

5.7 Protection of Circuit

The cable trench is to be protected with the following:

- A slab 50mm thick N25 grade concrete shall be cast in-situ over the full width of the trench for the length of the cable circuit where special backfill has been installed. A minimum clearance of 300mm is required between the cables and the slab.

  OR

- A polymeric cable cover (minimum 8mm thickness) to be laid over the full width of the trench for the length of the cable circuit where special backfill has been installed. A minimum clearance of 300mm is required between the cables and the cover.
- Orange coloured plastic warning tape shall be installed longitudinally in the trench on top of the concrete slab/polymeric cable cover above the cables. One tape shall be installed directly over cables laid in trefoil or three tapes shall be used over cables laid in flat formation.

Where additional protection and security from third party damage is required:

- Install vertical barriers at the sides of the trench, or in between multiple circuits that are in close proximity.
- Cables may also be installed in concrete inverted culverts with or without backfill and suitably rated concrete covers.

Root barriers shall be installed where the cable trench is located within 3m of trees or in areas susceptible to tree root intrusion.

5.8 Cable Route Markers

Cable route markers shall be installed to indicate changes in direction in the cable route. Markers shall consist of white plastic posts or metal plates inscribed with a warning notice and installed where possible as route markers. For marking on trafficable surfaces (eg. footpaths, roads), plates shall be installed which is suitable for attaching to flat or vertical surfaces with special adhesive.

5.9 Joint Bays

5.9.1 General

Joint bays shall be installed to accommodate the cable joints and associated earthing components required along the cable route. Special backfill shall be installed and compacted around the joints and cables on completion of the cable jointing and sheath earth bonding connections. A concrete slab and warning tapes shall be installed over the width and length of the joint bay for protection and identification.

5.9.2 Construction

The dimensions of a joint bay are determined by the size, number and type of joints that are used on the circuit. The joint bay shall have a concrete base set below the cables to facilitate access and joint assembly activities. The cable separation distances shall be increased in the joint bay to facilitate the installation of the joints, which should be staggered to minimise the joint bay width. Cable supports shall be installed to support the cables during jointing and final installation of the joint bay backfill.

5.9.3 Additional Facilities

A link box pit shall be installed adjacent to the joint bay for the sheath bonding and earthing equipment. The sheath bonding concentric cables between the link box and the joints shall be as short as possible and not exceed 10m in length.

The link box pit with removable covers shall be prefabricated with the approval of Western Power. The pits shall not be located under trafficable surfaces but shall have trafficable covers rated for a maximum design load of 210 kN (AS 3996- Access Covers and Grates Class D).

The pits shall have a concrete base with a thickness of 100mm and be equipped with drain holes and earthing electrodes.

5.10 Cable Terminations

5.10.1 Substations

Cable terminations in substations shall be mounted on dedicated structures designed to support the cable terminations and sheath earth bonding equipment. Surge arresters shall be installed between the cable terminations and the substation primary equipment.

5.10.2 Cable to Overhead Line Transition

66kV and 132kV

A single steel transition structure shall be used to connect a cable circuit to an overhead line. The structure shall support the cable terminations and surge arresters as well as the sheath bonding equipment. An overhead earthwire terminating on the transition structure is required for a minimum distance of 270m or three spans of the overhead line. The transition structure and the adjacent line structures with an overhead earthwire shall be earthed to a ground electrode with a footing resistance of less than 10 Ω.

220kV and 330kV

A transition compound is required for the connection of an underground cable circuit to an overhead line. The size of the compound shall be adequate to contain a line termination structure or gantry, surge arresters, cable termination support structures and sheath earth bonding equipment.

5.10.3 Surge Arresters

Surge arresters shall be installed at the ends of the cable circuits. The arresters shall be selected to match the operating voltage, insulation level of the cable and the arrester line discharge rating. For 66 and 132kV systems, the arrester line discharge rating shall be a minimum Class 3.

System simulation studies should be carried out to identify the surge arresters to be used to protect 220 and 330kV cable installations.

6. Cable Laying

6.1 General

Cables shall be pulled singly along the route. For direct buried cables, the cables shall be pulled on rollers of a suitable size and spacing that support the cable clear of the bottom of the trench, using a winch rope attached to the end of the cable (nose pulling). Side rollers or skid plates shall be used to guide the cable around corners. Alternative methods of installing or assisting the pulling of cables include the use of synchronised power rollers or caterpillars, side winching and bond pulling.

6.2 Direction of Laying

The direction of drawing out the cable shall be selected to require the least pulling force at the end of the cable route or section. On sloping sites, the pulling winch shall be located at the low end of the section being pulled.

6.3 Cable Pulling Tensions

The pulling tensions required to draw out cables equipped with pulling eyes attached to the conductors, shall be calculated and monitored to ensure that the recommended tensions set by the cable manufacturer are not exceeded. The winch shall be equipped with a tension limiting device or a short length of rope with a known breaking strength. This rope shall be installed as a weak link between the winch rope and the cable pulling eye.

The winch rope shall be connected to the cable pulling eye by means of a swivel to prevent twisting of the cable during installation. The speed of the cable pulling shall be limited to ensure that full control of the cable progress and the ability to immediately stop the cable progress is possible.

6.4 Cable Sidewall Pressure

The cable sidewall pressure shall be calculated to ensure that the manufacturer’s allowable parameters are not exceeded. If necessary, additional side rollers or plates shall be installed to reduce the cable sidewall pressure.

6.5 Cable Laying Formation

The cable system design will determine the laying formation and phase spacing of the cables for the required cable rating.

All cable ducts shall be laid horizontally, and multiple stacking of ducts shall be avoided.

6.5.1 Trench Backfilling

All trench backfills shall be applied in 300mm layers and compacted to the required compaction rate using a soil penetrometer. As a minimum, the backfill compaction shall match the surrounding undisturbed soil. All air voids in the backfill and between the cables shall be eliminated.

Compacted native soil, road base material or other requirements identified in the circuit design shall be used as the trench backfill for a depth of 200mm below the ground level.

For hard to access areas or where mechanical compaction is not practical or feasible, fluidised thermal backfill (FTB) may be proposed instead.

6.5.2 Native Soil Backfill

Native soil may be used for backfilling above the concrete slab or as required by the installation design. The soil shall be free of stones, foreign objects and vegetable matter.

6.5.3 Communications Ducts

The communications ducts shall be located at the side of the trench at the same level as the cables or immediately below the protective concrete slab. The communications pits shall be located on the side of the trench furthest away from trafficable areas. For double cable circuits, the communications ducts should be located on the inner sides of the trenches to maximise security.

6.6 Cable Terminations and Joints

The joints and terminations required for the cable circuit shall be installed according to the manufacturer's instructions by qualified personnel using the appropriate equipment.

On completion of the joints and terminations, the installation contractor shall complete the installation of the backfill and reinstatement of the cable route prior to high voltage testing and commissioning.

6.7 Cable Accessories

6.7.1 Link Boxes

Underground Link Boxes

Boxes shall be installed centrally in the link box pits at least 100mm above the concrete base. Following installation of the earth bonding cables, the apertures through the side of the pit shall be sealed to prevent entry of soil or water. All link boxes shall be connected to a permanent earth electrode.

Substation Structure Mounted Link Boxes

Boxes shall be mounted on substation structures at a height of 1.5m above ground level.

Transition Structure Mounted Link Boxes

Boxes shall be located as close as possible to the lowest cable termination.

6.7.2 Cable Temperature Monitoring Facility

Distributed temperature sensing (DTS) cable if required shall be installed on the top of the centre cable for flat formation and in the centre of the cables for trefoil formation.

The DTS cable shall be attached to the cable using tape to ensure physical contact is maintained between the cables. Where the two cables are drawn together through a duct, care must be taken to ensure that the DTS cable remains attached and on top of the cable.

6.8 Cable Installation Survey

A survey of the cable system is required to record the "as-constructed" information before the cables are covered by backfill.

The survey information shall include all surface features adjacent to the cable route and co-ordinates of the cable circuit components at intervals of not greater than 10m where there is no change of alignment or variation of depth. Where the cable alignment or depths vary, the survey intervals shall be 1 m. Details of other services located within the trench shall also be noted and recorded. Duct locations including size, spacing and depth shall also be recorded.

The survey information shall be forwarded to Western Power at the completion of the cable circuit installation for record purposes.

6.9 Safety

The safety principles and processes set out in the Western Power Electrical System Safety Rules shall be followed when installing, maintaining and repairing cable circuits. In addition, when any conducting components of the cable are to be exposed during the jointing and terminating, the conducting components shall be connected to an earth mat and earth electrode.

Special precautions are required to protect personnel from potentially dangerous voltages and currents when working on cable circuits.

Dangerous voltages and currents are caused by the following:

- Incorrect identification of cables.
- Voltage transfer when the cable sheaths or conductors are connected to a different earthing area from the point of work.
- Induced voltages arising from load or fault currents in other high voltage circuits.
- Voltages induced in cables that are connected to overhead lines.

6.10 Easements

Refer to Network Standard – Transmission and Distribution Line and Cable Easement and Safety Clearance Zones[5].

[5] See Western Power's internal document