AMS – Victorian Electricity Transmission Network

Power Cables (PUBLIC VERSION)

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Disclaimer

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1 Executive Summary

This document describes major factors affecting the Victorian electricity transmission network's population of power cables and lists the current strategies for managing these assets.

There are two main categories of power cables within the transmission network, namely Interconnecting and Station cables. Interconnecting cables are utilised to connect one station to another station, for example Brunswick to Richmond, while Station cables connect items of plant within a particular station.

Within the Victorian electricity transmission network, AusNet Services owns and maintains two 220 kV interconnecting cables between Brunswick – Richmond and Eildon – Thomastown and one 66 kV interconnecting cable between Loy Yang Sub-station and Loy Yang South sub-station.

There are approximately 172 Station cables installed within various terminal stations throughout Victoria operating at each voltage level of the transmission network depending on the plant to which the cable is connected.

The majority of the power cable population has been in service for 20 to 40 years and is mainly in average to poor condition, with no cables in very poor condition. The strategic factors affecting the management of power cables are the change from oil filled cables to XLPE cables and the spares management for obsolete cables.

AusNet Services' key asset management strategies for power cables include:

- Combine cable replacement, where possible, with other capital works. Otherwise, repair or replace based on condition.
- Develop and implement an oil filled cable contingency plan to help manage the impact of a fault on an oil filled cable.
- Update cable asset records and fault response plans.
- Undertake a full review of cable spares to address the risks associated with cable failure.
- Enhance Commission and Condition Assessment test techniques including the introduction of DTS.

2 Introduction

There are two main categories of power cables within the transmission network, Interconnecting and Station cables. Interconnecting cables are utilised to connect one station to another station, for example Brunswick to Richmond, while Station cables connect items of plant within a particular station.

2.1 Purpose

The purpose of this document is to set-out and explain the key asset management strategies for power cables in the Victorian Transmission Network.

2.2 Scope

This asset management strategy applies to all power cables managed by AusNet Services on the transmission network, including their terminations and joints and their immediate environments.

The strategies in this document are limited to maintaining the existing cables and their capacity. Strategies for increasing installed capacity are not included.

3 Asset Summary

There are a total of 175 circuits of power cable installed on the electricity transmission network. Table 1 shows the summary of the power cable population.

Cable Voltage	Circuits (each)	Installed Length (km)
Extra High Voltage (220 kV)	15	10.932
High Voltage (66 kV)	17	5.316
Medium Voltage (22 kV)	101	3.955
Medium Voltage (11 kV)	30	1.530
Medium Voltage (6.6 kV)	12	0.420

Table 1 – Power Cable Summary[1]

There is approximately 22 km of power cables installed, Figure 1 summarises the population by voltage level and insulation design. EHV power cable contribute 49% of the population, 24% are HV and the remaining 26% are MV.

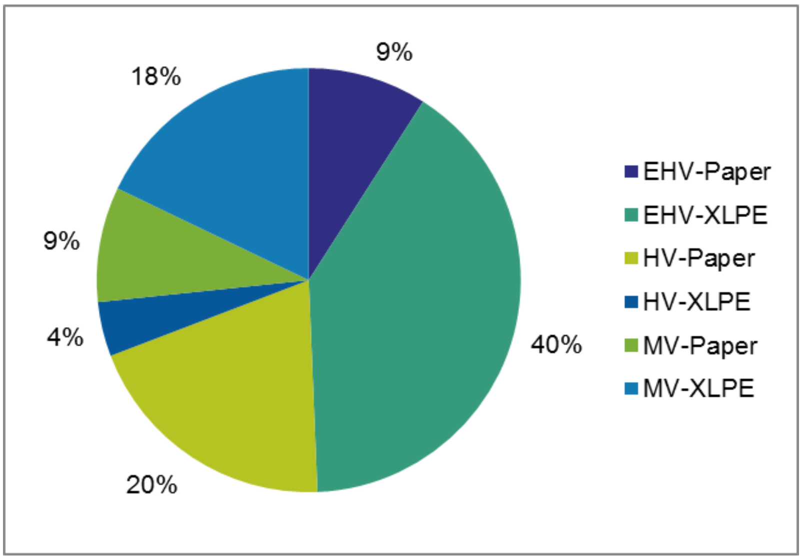

Figure 1 – Power Cable Population

Within the Victorian electricity transmission network, AusNet Services owns and maintains two 220 kV interconnecting cables and one 66 kV interconnecting cable. The 220 kV interconnecting cables operate between Brunswick (BTS) – Richmond (RTS) and Eildon (EPS) – Thomastown (TTS). Both contain sectionalised joints and the associated metallic sheath cross-bonding system at each joint bay. The 66 kV interconnecting cable operates between Loy Yang Sub-station (LY) and Loy Yang South sub-station (LYS) and also incorporates sectionalised joints and the associated metallic sheath cross-bonding system at the centrally located joint bay.

All three interconnecting cables are single core construction with the 220 kV BTS-RTS cable being XLPE insulated while the other two cables are paper/oil insulated.

There are approximately 172 Station cables installed within various terminal stations throughout Victoria. They are all single length cables, containing no joints, and are typically, but not solely, single core construction with a dispersion of XLPE or paper/oil insulation material.

[1] AHR 10-66 – Power Cable

3.1 Asset Age Profile

The majority of the power cable population has been in service for 20 to 40 years. The MV paper/oil power cable fleet is the oldest of the population and has been and will continue to be progressively replaced, as shown in Figure 2, by the quantity of MV XLPE cables which are less than 20 years in service.

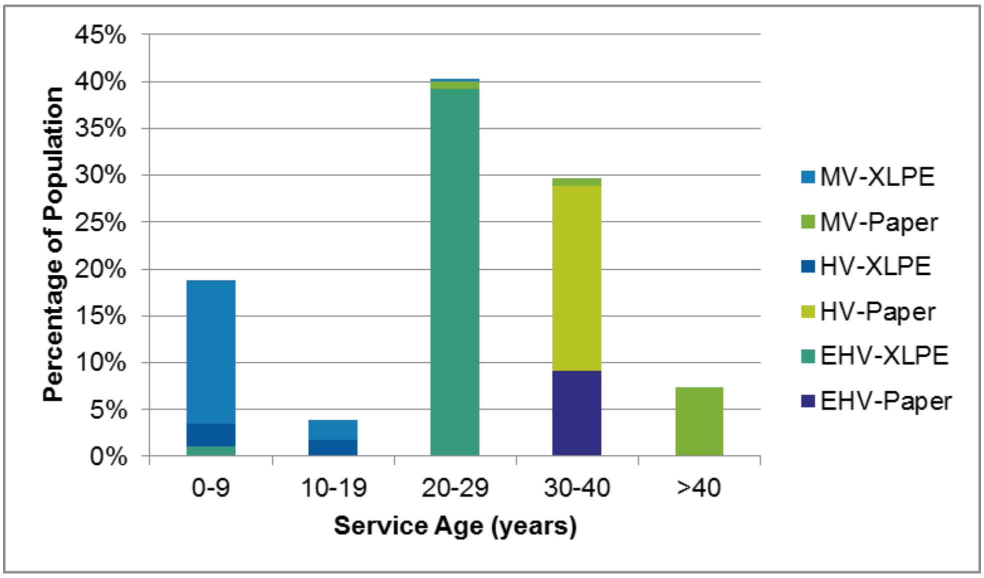

Figure 2 – Power Cable Service Age Profile

The service ages for Station cables generally correspond with the installation of the plant and equipment to which they connect. Many interplant connections have been replaced as part of asset replacement programs over the last ten years. Existing underground cables have an expected life of 60 years depending on the operating and environmental conditions.

3.2 Condition

The condition of the entire population of power cables has been assessed using a consistent condition methodology that uses the known condition details of each asset and grades that asset against the common asset condition criteria.

The condition of the cable systems is determined by age and insulation material, where known, in absence of a more precise determination of condition. Table 2 provides the qualitative assessment of the condition scoring for all transmission cables. The condition of each cable system has been scored ranging from condition C1 (very good) to condition C5 (very poor) accordingly by applying the criteria.

Condition Scorecard			
Condition Score	**Condition Description**	**Summary of details of condition score**	**Remaining Life**
C1	Very good	These cables are in good operating condition with no past history of significant defects or failures.	95%
C2	Good	This category includes cables in better than average condition.	70%
C3	Average	This category includes cables in average condition.	45%
C4	Poor	This category includes cables in worse than average condition. Cables with unknown critical details and/or unknown condition assessment will typically be scored in this category until evidence is found to confirm condition. Action is required to confirm cable details and/or condition.	25%
C5	Very Poor	This category includes cables which are typically maintenance intensive and have history of problematic interruptions. These cables are approaching the end of technical life. The maintenance that can be performed to restore the condition is very limited. The maintenance of cables in this category is typically no longer economical compared to asset replacement.	5%

Table 2 – Power Cable Condition Scorecard[2]

Figure 3 illustrates the overall condition of the power cable population. This condition assessment has highlighted that there are no power cables in the worst condition, C5. However there are EHV XLPE cables in condition C4 which is the worst condition of the entire population.

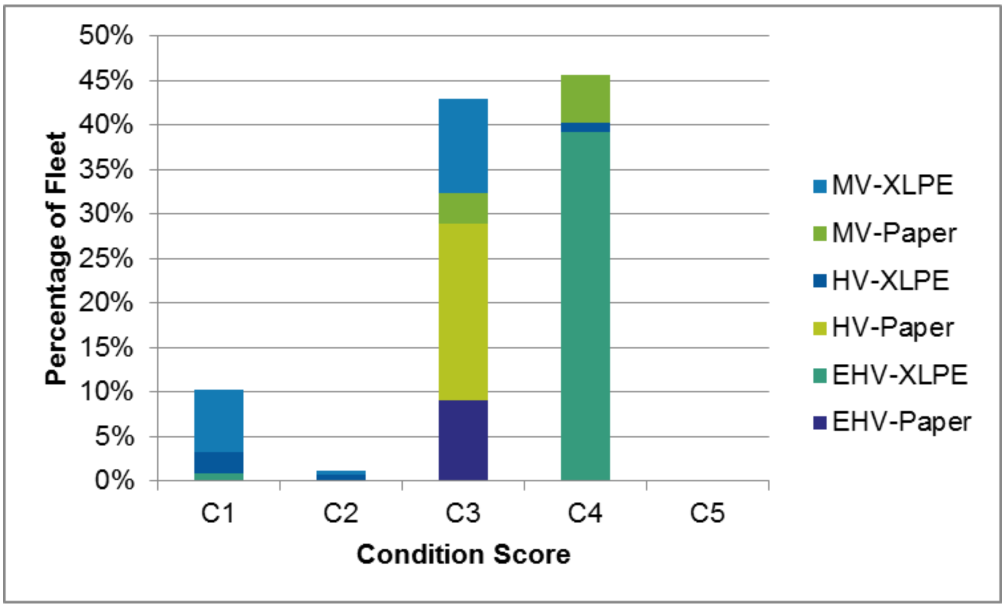

Figure 3 – Power Cable Condition Profile

[2] AHR 10-66 – Power Cable

The BTS-RTS cable has proven reliable but original oil filled joints with historic condition issues were recently replaced as shown in Figure 4. The remaining oil filled terminations are planned for replacement with SF_6 cable terminations as part of the BTS and RTS station re-build projects. This should ensure reliable future service on this line.

Figure 4 – Typical BTS-RTS Joint Bay (#12 shown) after cable joint replacement

4 Cable Testing

Testing of cables is carried out at different stages of the cable's life. The lower arrows in Figure 5 represent the opportunities that the asset manager has to measure the insulation degradation of the cable system with the desire to accurately predict the end of life. The upper arrows represent when detrimental influences to a cable's lifecycle can occur.

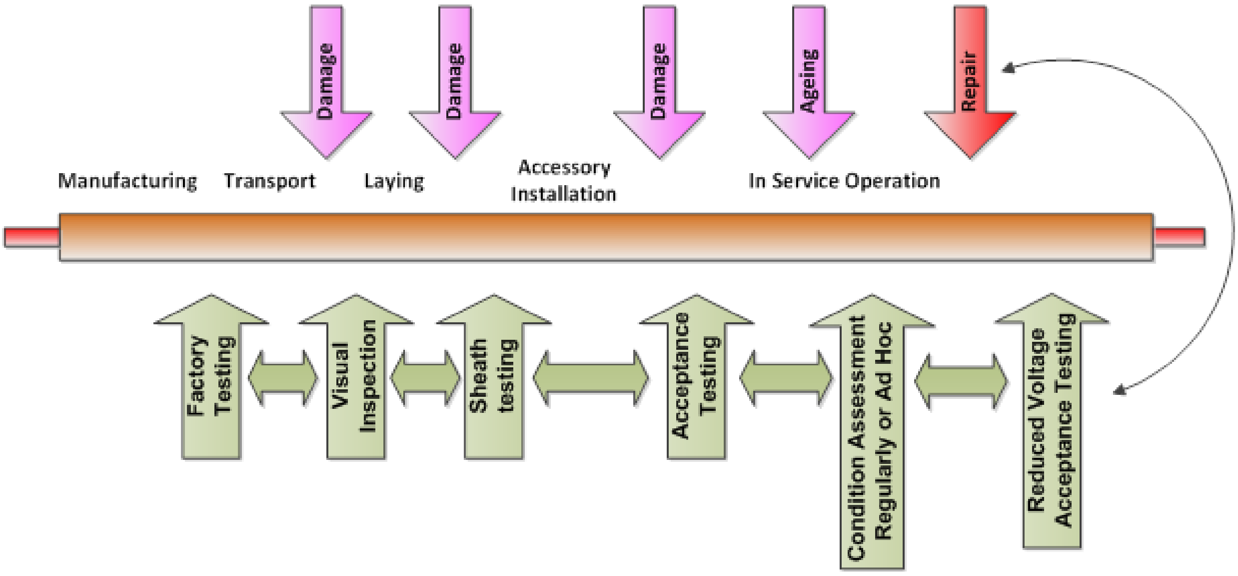

Figure 5 – Testing opportunities in a cables' lifecycle

Acceptance tests are undertaken during commissioning to ensure that the installed asset is fit for service by adequately measuring the voltage withstand and current carrying capabilities of the entire cable system. Additional tests are done to determine if any damage to the outer protection sheaths has occurred during the installation process. These tests give a 'benchmark' or 'fingerprint' of the condition for the insulation and protection layers.

The acceptance tests form an integral part of the quality assurance system surrounding the correct installation of the cable and accessories. They go toward ensuring that consistent, high quality installation practices are followed at all times for both the cable and the accessories

The electricity network is typically a 3 phase network, allowing an immediate comparison to be made of measurements between phases.

Acceptance criteria for the individual tests is typically stipulated to be:

a) Below a maximum or above a minimum value;
b) Comparable with design values; and
c) Consistent between phases.

Cables operate in a homogeneous insulation system so there should be no significant differences between the measurements made on the various phases. All 3 phases operate at the same voltage, carry approximately the same current, are installed in the same trench, and covered with the same backfill.

4.1 Testing techniques

In general, tests can be categorised as non-invasive or invasive.
Non-invasive testing techniques can be in the form of:

- Visual Inspection in accordance with SMI 67-20-01 Primary Asset inspections;
- Thermal Inspection in accordance with SMI 67-20-01 Primary Asset inspections;
- On-line Partial Discharge (PD) test if the correct measurement equipment is fitted;
- Temperature profiles along the cable route utilising a DTS (if fitted).

Invasive testing techniques can be in the form of:

- Outer Sheath integrity tests;
- Cross Bonding system tests;
- Oil sampling (on oil filled cables and terminations);
- Off-line HV withstand and Partial Discharge (PD) test.

4.2 Commission Tests

Commission tests typically comprise of all of the non-invasive and invasive tests. This allows a “fingerprint” of the assets health condition to be established and be used as a baseline for future condition assessment and deterioration assessment.

4.3 Condition Assessment Tests

Condition assessment tests are typically all of the non-invasive tests together with the annual sheath and bonding system tests. Undertaking these tests on an annual basis goes towards ensuring a reliable cable system is maintained.

In addition to these annual tests, a periodic (10 yearly) condition assessment of the cable system’s HV withstand capability and more importantly detection of any PD activity.

4.3.1 Distributed Temperature Systems (DTS)

DTS systems utilise a fibre optic cable laid in close proximity to the power cable to measure the temperature of the power cable. The temperature is important as the insulation material can only operate up to a maximum value, after which it deteriorates at an accelerated rate, compromising the life expectancy of the cable. As power flow generates heat due to the resistance of the conductor and metallic sheath, the temperature of the cable therefore is a governing factor in what power flow can be delivered by the circuit.

Although DTS is not currently used as the older cables do not have a DTS installed, the present practice is to install fibre optics with new cables to allow the introduction of future DTS systems.

5 Strategic Factors

This section describes the factors which were considered when developing these asset management strategies for power cable fleets.

5.1 Cable replacement / retirement is often driven by the parent assets

Station cables are associated with the primary plant in switchyards and decisions regarding replacement of the cable and plant can be linked as the design life of both assets is similar, particularly in a station rebuild scenario. If the primary plant is to be removed from the network, this may infer that the associated cables will also be retired. Where the primary plant is to be replaced at the end of its life, the condition of the cables is critically assessed to ensure that they will provide reliable future service or, as required, they are replaced.

5.2 Repairing oil filled cables

AusNet Services has a small population of oil filled cables. Although a major fault on one of these cables is currently unlikely, the consequences of such a fault could be severe. Maintaining an inventory of good condition spares and access to appropriately skilled labour will help ensure a rapid response to faults and reduce the overall impact on reliability.

Oil filled cables are no longer being installed on the network and with the loss of expert knowledge on repair protocols, the probability of effecting a reliable repair on such a cable is low. Work is currently underway to develop a strategic cable replacement program that would be implemented utilising modern cable types, techniques and designs to economically replace cables when appropriate. Undertaking a load flow study of the individual circuits will assist in determining suitable XLPE equivalent replacement options and indicate the appropriate strategic spare levels.

5.3 Spares

The [C.I.C] has been selected to house all spare strategic HV and EHV cable accessories while the storage of strategic spare cable on drums will primarily be at the [C.I.C] . All spare power cables are to be recorded in the asset management database (SAP). A full review of cable spares is planned in order to address the risks associated with cable failure. Gaps between necessary and actual will be identified and a plan established to order/stock appropriate spares.

6 Key Issues

This section describes the key issues associated with the fleet of power cables. These issues have been categorised into voltage levels. More detailed information is available in the Asset Health Report, AHR 10-66 Power Cables.

6.1 220 kV Cable Issues

The 220 kV cable population has key issues associated with WMTS, SMTS and the BTS-RTS cable.

The 220 kV cable at WMTS has known issues with the terminations and these are due to be replaced as part of the rebuild of the station. The 220 kV cable at SMTS has known issues due to a significant disturbance of thermal backfill sand from the joint bay and adjacent ground due to animals burrowing. This is currently being monitored and remedial actions are to follow to rectify this issue.

The three main issues with the BTS-RTS cable are associated with sheath insulation resistance (IR) tests, air insulated terminations and access to joint bays. Recent sheath IR tests are returning lower than expected levels which will require further testing to establish the severity of insulation deterioration.

Under the BTS and RTS rebuilds, existing air insulated terminations are to be replaced and incorporated into the new GIS systems. This will eliminate any current issues associated with these older terminations.

Many of the BTS-RTS cable joint bays (JBs) are located on or adjacent to major roads or freeways, for example JB 6, JB 8 and JB 9 are located in the [C.I.C] , and present traffic management issues and a difficult work environment for routine inspection or maintenance activities. To minimise the interruption to traffic flow, the annual sheath tests are undertaken during early hours of the morning. Figure 6 illustrates the location of JB 8 and its associated link box in [C.I.C] (adjacent to the median strip).

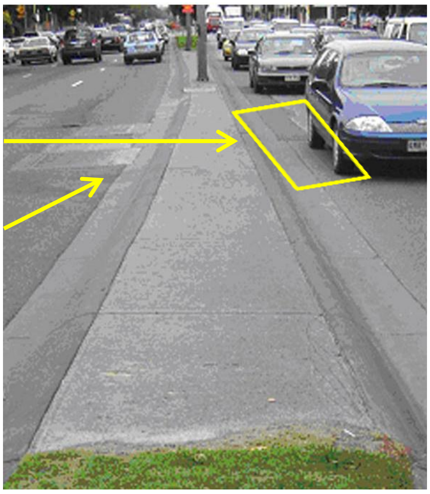

Figure 6 – [C.I.C] BTS-RTS Cable

6.2 66 kV Cable Issues

The key issue associated with the 66 kV cable population is the insulation integrity of three cables installed at WMTS. These cables were purchased from a supplier that is no longer a preferred supplier due to quality control issues. These cables will be monitored using advanced diagnostic techniques.

6.3 22 kV, 11 kV and 6.6 kV Cable Issues

There are minimal testing and recorded issues on the 22 kV, 11 kV and 6.6 kV fleets. An opportunity exists to improve understanding of asset condition by using a more disciplined and objective asset health information capturing system. This will involve condition assessment testing and analysis to determine and confirm rate of degradation of the asset. Test results can inform the condition of the cable and can indicate if an asset is approaching the end of its useful life, which will provide a basis for asset replacement.

Due to the age, condition and the constrained ability to repair the paper insulated cable fleet, there is a concerted effort to transition from Paper/Oil to XLPE insulated cables.

7 Strategies

The following key strategies guide the management of power cables:

- Combine cable replacement, where possible, with other capital works. Otherwise, repair or replace based on condition.
- Develop and implement an oil filled cable contingency plan to help manage the impact of a fault on an oil filled cable.
- Update cable asset records and fault response plans.
- Undertake a full review of cable spares to address the risks associated with cable failure.
- Enhance Commission and Condition Assessment test techniques including the introduction of DTS.

Appendix A – Related documents

PGI 02-01-02 “Summary of Maintenance Intervals” document records policy on inspection intervals.

PGI 12-01-01 “Power Cable Maintenance” document provides details of cable installations and guidance for maintenance and testing.