AMS 10-19 Plant and Equipment Maintenance

2023-27 Transmission Revenue Reset

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1 EXECUTIVE SUMMARY

AMS 10-19 outlines the plant and equipment maintenance strategies for management of assets in the Victorian electricity transmission network. This document provides background to the different categories of maintenance, condition monitoring and current maintenance techniques whilst exploring contemporary practice.

Through continual improvement and adoption of contemporary asset management practices a number of plant and equipment maintenance management initiatives are progressively being embedded in business process.

In summary, the strategic initiatives highlighted in AMS 10-19 include:

The following strategies will contribute to the management of network assets over their lifecycle.

- Ongoing commitment to ISO 55001 certification
- Enhanced focus on life cycle management of assets
- Development in plant and equipment performance and predictive analytics
- Refinement of condition assessment methodology to facilitate algorithmic condition assessments
- Development in reliability centred maintenance (RCM) modelling to inform maintenance, inspection, and replacement frequency
- Refinement in strategic spares assessment and ensure appropriate stocks are maintained

AusNet Services continues to perform plant and equipment maintenance in the most economic, efficient, and effective manner available under contemporary asset management techniques. AusNet Services' ongoing commitment to maintain ISO 55001 accreditation ensures an auditable asset management system facilitating customer's expectations to safely maintain the quality, reliability, and security of supply in an economic manner.

2 INTRODUCTION

2.1 Purpose

AMS 10-19 Plant and Equipment Maintenance (AMS 10-19) is intended to outline the mechanisms for plant and equipment maintenance on the Victorian electricity transmission network.

This document provides high level information regarding AusNet Services' existing plant and equipment maintenance techniques whilst establishing alignment with universally recognised standards and contemporary industry techniques.

In compliance with AusNet Services ISO 55001 Asset Management certification, progressive standardisation and increasing congruency in business process between transmission and distribution networks is being established.

AMS 10-19 is not intended to provide the same level of technical processes and maintenance frequencies that can be obtained from a Plant Guidance and Information (PGI), Standard Maintenance Instruction (SMI), Lines Practices and Procedures (LPP), Secondary Practices and Procedures (SPP) or a Field Work Practice (FWP) document.

2.2 Scope

This document covers the maintenance of AusNet Services electricity asset operating in Victoria including:

- Cables and Easements and Transmission Lines and Easements;
- Primary plant;
- Secondary plant; and
- Station equipment.

It does not cover the maintenance of the following:

- Communications equipment;
- SCADA master station equipment in CEOT[1];
- Asset management information systems[2].

2.3 Asset Management Objectives

As stated in *AMS 01-01 Asset Management System Overview*, the high-level asset management objectives are:

1. Maintain network performance at the lowest sustainable cost;
2. Meet customer needs now and into the future;
3. Be future ready;
4. Reduce safety risks;
5. Comply with legal and contractual obligations.

As stated in AMS 10-01 *Electricity Transmission Network Asset Management Strategy*, the electricity transmission network objectives are:

1. Maintain top quartile benchmarking;
2. Maintain reliability;
3. Minimise market impact;
4. Maximise network capability;
5. Leverage advances in technology and data analytics; and
6. Minimise explosive failure risk.

[1] Maintenance is managed by IT

[2] Maintenance is managed by IT

3 BACKGROUND

3.1 Risk Management

As assets degrade, their likelihood of failure increases which creates compliance, safety, and performance risks.

AusNet Services maintains a risk management system that has been designed to AS ISO 31000 *Risk Management – Guidelines* to ensure risks are effectively managed.

Risk are rated and prioritised under the following categories:

- Health and safety (Employees and public);
- Environment and community;
- Reputation;
- Customers;
- Regulation, legal and compliance;
- Management impact and people; and
- Financial impact.

The main aim of maintenance of plant and equipment is to retain or restore the functionality of plant and equipment and mitigate identified failure risks.

AusNet Services uses a range of techniques to identify and asset risk and thus determine the maintenance requirements of each asset class.

Further information is provided in AMS 01-09 *Asset Risk Assessment Overview.*

3.2 Reliability Centred Maintenance

Reliability Centred Maintenance (RCM) is a method of identifying and selecting failure management strategies to achieve the required safety, availability, and economy of operation efficiently and effectively for a given operating context.

RCM is structured around the following seven questions:

1. What are the *functions* and associated *performance standards* of the asset in its *operating context*?
2. In *what ways* does it *fail* to fulfil its *functions*?
3. What *causes* each *functional failure*?
4. What *happens* when each *functional failure* occurs?
5. In *what* ways does each *functional failure matter*?
6. What can be done to *predict* or *prevent* each functional failure?
7. What should be done if nothing can be done to predict or prevent a functional failure?

Questions 1, 2 and 4 resemble a Failure Mode, Effects and Criticality Analysis (FMECA). Questions 6 and 7 consider the activities that should, or should not, be undertaken to address the critical failure modes in an asset's specific operating context.

The purpose of RCM is to identify the most appropriate maintenance tasks to address the critical failure modes of an asset within its operating context.

The outputs of RCM analysis are be used to:

- Identify failure modes and maintenance tasks to be modelled in Availability Workbench (AWB) to determine asset risk levels and compare different maintenance and replacement strategies;
- Review maintenance instructions (SMIs, LPPs, etc) to ensure the most appropriate maintenance tasks are being undertaken;
- Determine measurement points to be included in asset inspections to allow trending of asset condition; and

- Review object, damage and cause codes in SAP to ensure that failure data is being captured as accurately as possible.

AS IEC 60300.3.11 *Dependability management – Part 3.11: Application guide – Reliability centred maintenance* defines two types of maintenance action:

1. Preventative; and
2. Corrective.

Preventative maintenance is undertaken prior to failure and is normally scheduled or based on a predetermined set of conditions. It can be condition-based (monitoring the condition until failure is imminent) or functional checks to detect hidden failures. It can be predetermined based on a fixed interval (such a calendar time, operating hours or number of cycles or operations).

Corrective maintenance restores the function of an item after failure has occurred or performance fails to meet stated limits and is unscheduled.

RCM identifies the optimal preventive and corrective maintenance tasks. Development in RCM modelling to inform maintenance, inspection, and replacement frequency.

Further details on RCM can be found in AMS 01-07 *Reliability Centred Maintenance (RCM) Application Guide*.

3.3 Maintenance Activity Types

3.3.1 Preventative Maintenance

Preventive maintenance is undertaken prior to failure and relates to maintenance carried out to reduce the probability of failure or to address the degradation of the functioning of an item.

Preventative maintenance can include:

- Inspection;
- Testing;
- Condition monitoring; and
- Proactive replacement or refurbishment.

Inspection

Inspection is the act of examining something, such as looking for visible asset defects or checking the thickness of a pole.

Testing

Testing is the act of testing something to check that it is functioning adequately, such as secondary injection testing of protection relays. Testing is performed to either identify equipment problems, diagnose equipment problems or to confirm that repair measures have been effective.

Condition Monitoring

Condition monitoring is the process of monitoring a parameter, or parameters, of a piece of equipment to identify a significant change which is indicative of a developing fault. It is a subset of inspection.

Appendix C provides examples of condition monitoring techniques aligning failure modes.

Proactive Replacement or Refurbishment

Plant and equipment that is maintenance intensive is selectively replaced or refurbished according to the technical and economic evaluation of proposals. Replacement alternatives include the rationalisation of line and switching arrangements in conjunction with the system planner.

The basis for fleet or sub-fleet specific repairs is usually design or manufacturing deficiencies that have been identified during inspection or maintenance activities on equipment which has been in service for several years.

3.3.2 Corrective Maintenance

Corrective maintenance is a task performed after a piece of equipment has failed, where failed may mean:

- an inspection identified a defect that needs rectification;
- a test identified a piece of equipment which is not functioning to specification; or
- condition monitoring identified a change in condition indicative of an imminent failure.

3.4 SAP Notification Types

There are several notification types within AusNet Services' asset management information system (SAP) to facilitate work to be undertaken on the assets. The notification types relevant to plant and equipment maintenance are:

1. ZA – Corrective or condition-based maintenance
2. ZB – Inspection/overhaul or scheduled maintenance
3. ZD – Discrete projects (Asset works)
4. ZE – Customer defect
5. ZK – Unscheduled (emergency) maintenance.

ZB notifications are classified as preventative maintenance. The other four notification types are corrective maintenance

Each of these is described in the following sections.

3.4.1 Corrective or Condition-based Maintenance (ZA)

A Corrective or Condition-based Maintenance ZA notification is raised to request maintenance work identified by inspection/overhaul or scheduled maintenance (ZB) work.

ZA notifications are also used to request of fault investigation and rectification work of AusNet Service assets.

3.4.2 Inspection/Overhaul or Scheduled Maintenance (ZB)

Work conducted under Inspection/Overhaul or Scheduled Maintenance ZB notifications are preventative maintenance activities undertaken according to a predetermined scope at predetermined intervals, which may include:

1. Inspection;
2. Testing;
3. Condition assessment; and
4. Preventative maintenance.

An inspection is the process of inspecting for defects.

Testing is a test that is performed to either identify asset problems, diagnose asset problems, detect hidden failures, or to confirm that repair measures have been effective.

Condition assessment is the process of assessing the condition of the asset.

Preventative maintenance is maintenance that is regularly performed on an asset to reduce the likelihood of it failing.

The scheduled maintenance program covers all AusNet Services' electricity transmission assets including primary, secondary, lines, communications, facilities, and easements.

The scheduled maintenance program is designed for efficient and effective delivery based on three main criteria:

1. Time;
2. Number of operations; and
3. Equipment condition.

The time criterion is the time elapsed (or interval) between scheduled overhauls, but also depends on opportunity[3] and/or inspection.

The number of operations criterion is the number of service operations and/or fault operations occurring on certain items of plant such as circuit breakers.

The equipment condition criterion is used to inform the base scope of works for maintenance of line easements and facilities.

Because of these three criteria, the scheduled maintenance program tends to be cyclic in nature.

Recommended scheduled maintenance intervals are documented in *PGI 02-01-02 Summary of Maintenance Intervals – Transmission*.

Scheduled maintenance intervals are regularly reviewed to ensure they are set at optimum levels. Scheduled maintenance programs are managed within SAP.

A maintenance plan listing all scheduled maintenance (ZB) tasks for the next 12 months is produced as a part of the budget process leading up to the new financial year. In addition, a maintenance forecast plan is derived for the following 12 months beyond the original maintenance plan but with less accuracy.

There is a degree of flexibility in the development of the annual maintenance plan, allowing for optimisation of the effectiveness of maintenance activities. A tolerance band is applied to the recommended maintenance intervals, enabling scheduled maintenance tasks to be brought forward or deferred without compromising maintenance standards and plant performance. This ‘bringing forward’ or deferring of scheduled maintenance allows for more efficient management of the overall program and allows AusNet Services to maximise the benefits of outages that may be required for other reasons, for example the coordination and efficient use of labour and the maximisation of asset availability.

Progress towards completion of the annual maintenance plan is tracked over the 12-month period to ensure satisfactory completion. As part of this tracking process, monthly progress reports are produced and circulated widely within AusNet Services.

Recurrent works are those maintenance activities that are of a regular and ongoing nature.

3.4.3 Discrete Projects (Asset Works) (ZD) and Customer Defect (ZE)

Discrete Projects (or Asset Works) ZD notifications are defined as Operating and Maintenance (O&M) projects which are outside the scope of the Scheduled Maintenance ZB notifications.

Customer Defect ZE notifications are used by AusNet Services to request customers to maintain their assets which are connected to AusNet Service’s Network.

Asset works, or non-recurrent works, are maintenance activities that cannot be capitalised under current financial guidelines and have a scope of work that is too large or specialised to be economically included in the routine maintenance plan/inspection.

They are neither time nor operation based and so, are generally non-repetitive one-off remedial actions, put in place to respond to specific problems.

There are exceptions to this generalisation, such as the corrosion mitigation program, which is expected to run for many years and may become a permanent task on the works program. Non-recurrent works can also include significant corrective maintenance work such as investigations and repair work.

3.4.4 Unscheduled (Emergency) Maintenance (ZK)

Unscheduled (emergency) maintenance ZK notifications are unscheduled and emergency maintenance work carried out to no predetermined plan and not in accordance with an established time schedule, but after reception of an indication regarding the condition of an item of equipment.

The difference between ZK and ZA notifications is the type of fault work order that it creates:

3 Opportunity is where the opportunity occurs to do scheduled maintenance work due to an unforeseen outage or a coordinated outage occurring. It should only be considered if the maintenance is due and can be performed cost effectively.

- ZK fault notifications are trouble orders triggered by the PowerOn (Fusion) or PowerOn (Gas) that will create a fault work order in the system. These are managed by CEOT.
- ZA notifications are a result of work prescribed in scheduled maintenance ZB notifications.

Unscheduled maintenance is generally due to breakdown or forced maintenance, however depending on the situation there can be opportunistic maintenance activities undertaken.

These opportunistic maintenance activities can be categorised into non-recurrent works. This is where an unexpected requirement or opportunity to access plant and equipment arises and the work is not prescribed by a scheduled maintenance (ZB) schedule of work.

Unscheduled maintenance includes carrying out corrective/repair works to plant and equipment under non-emergency conditions and vegetation management work online easements resulting from inspections. This type of work is not scheduled in SAP. A budget allowance for both unscheduled and breakdown maintenance is made in the annual maintenance plan.

Emergency maintenance is a subset of unscheduled maintenance and is repair work that is required to be performed within 24 hours of the trigger event, immediate or short-term action is required to rectify plant or equipment faults typically in order to restore the network.

Due to health, safety and environmental considerations and the high reliability required from transmission plant, it is desirable to minimise the amount of unscheduled and emergency maintenance performed.

4 DRIVERS

4.1 Electricity Safety Act

AusNet Services is subject to several explicit legislative obligations concerning worker safety.

The Electricity Safety Act 1998 requires AusNet Services, as a major electricity company, to:

> *design, construct, operate, maintain and decommission its supply network to minimise, as far as is practicable –*
>
> *(a) the hazards and risks to the safety of any person arising from the supply network; and*
>
> *(b) the hazards and risks of damage to the property of any person arising from the supply network; and*
>
> *(c) the bushfire danger arising from the supply network.*[4]

The *Electricity Safety Act 1998* defines "practicable" to mean having regard to:

> *(a) the severity of the hazard or risk in question; and*
>
> *(b) state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and*
>
> *(c) the availability and suitability of ways to remove or mitigate the hazard or risk; and*
>
> *(d) the cost of removing or mitigating the hazard or risk.*[5]

4.2 Occupational Health and Safety Act

The *Occupational Health and Safety Act 2004* requires AusNet Services, as an employer, to:

> *so far as far as is reasonably practicable, provide and maintain for employees of the employer a working environment that is safe and without risks to health.*[6]

For the purposes of the Occupational Health and Safety Act 2004, when determining what is (or what was, at a particular time), reasonably practicable in ensuring health and safety, regard be had to the following matters:

> *(a) the likelihood of the hazard or risk concerned eventuating;*
>
> *(b) the degree of harm that would result if the hazard or risk eventuated;*
>
> *(c) what the person concerned knows, or ought reasonably to know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk;*
>
> *(d) the availability and suitability of ways to eliminate or reduce the hazard or risk;*[7]

In economic terms, "practicable" and "reasonably practicable" requires AusNet Services to address safety hazards up until the point that the costs of remediation become grossly disproportionate to the benefits.

4.3 National Electricity Objective

The National Electricity Objective, as stated in the National Electricity Law is:

> *to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:*
>
> - *Price, quality, safety and reliability and security of supply of electricity*
> - *The reliability, safety and security of the national electricity system.*[8]

4 Electricity Safety Act 1998, section 98(a).

5 Electricity Safety Act 1998, section 3.

6 Occupational Health and Safety Act 2004, Section 21(1).

7 Occupational Health and Safety Act 2004, section 20(2).

8 National Electricity Law V1.7.2019, Part 1, Section 7

4.4 Network Impact

Significant maintenance work such as plant refurbishment or replacement may require outage coordination where live work is not an option.

Outage costs are currently defined by two schemes governed by the AER:

1. Service target performance incentive scheme (STPIS) – Service Component (SC); and
2. STPIS – Market Impact Component (MIC) (also known internally as market impact parameter scheme (MIPS)).

The STPIS-SC is focussed on reliability and the STPIS-MIC component provides an incentive for outage coordination that does not cause substantial network outage constraints in the National Electricity Market (NEM).

For network security and efficiency reasons, there is a requirement to coordinate maintenance work with other operational and construction tasks in order to minimise required outages.

Careful consideration to the criticality of network elements is required when prioritising the maintenance effort.

5 PROCESS AND SYSTEM STRATEGIES

5.1 Live Work

Where appropriate, the use of live working techniques can be used to reduce the outage requirements when conducting maintenance tasks.

The safe use of live maintenance work on transmission lines has matured and is appropriately utilised.

AusNet Services has explored the use of live maintenance works in terminal stations but has no immediate plans to introduce any such maintenance practices.

5.2 Outage Coordination

Outage coordination is a key aspect in minimising network impacts. Efficient operational and maintenance practices that result in coordinated planned outages may also reduce network impacts caused by unplanned outages. Ongoing communication between AusNet Services and distribution businesses (DBs) and generation companies to refine outage coordination for maintenance, construction and operations work is required.

To this end, regular meetings and discussions are held between relevant groups within AusNet Services and with distribution businesses (DBs) and generation companies.

Work plans are produced and optimised in order to minimise outages and coordinate work between AusNet Services field areas and with the various DBs, AEMO and generation companies. Wherever possible, scheduled maintenance tasks are planned in order to take advantage of other works, such as augmentation projects, so that outages and costs can be minimised, and the use of labour and the availability of plant can be maximised.

5.3 Spare Equipment

Spare equipment is held to ensure that, in the event of a network outage, the Mean Time to Repair (MTTR) and customer impact is reduced through the availability of an appropriate spare part or equipment. Refinement in strategic spares assessment and ensure appropriate stocks are maintained

Appropriate stocks of spare equipment are held at strategic locations to support both scheduled and unscheduled maintenance so that the reliability of the network is not compromised.

Depending on economics, equipment type, availability, and system reliance; strategic spares are available for specific assets.

Unlike general spare equipment being located in most stores, the strategic spares are located on specific sites to reduce logistical delays. Strategic spares are evolving in parallel to assets installed on the network and need to be continually reviewed.

The major failure of an asset may result in significant damage to the asset concerned and collateral damage to the surrounding equipment. Due to the long lead times and as manufactures do not provide a strategic spares service, it is necessary to have strategic spares for many of the major asset classes.

Further details can be found in AMS 10-128 *Spare Equipment Policy – Electricity Transmission and Sub Transmission Networks*.

5.4 Plant Defect Reporting

All AusNet Services employees have a responsibility for asset stewardship. Defect reports need to be issued when any abnormal conditions or defects are detected during planned maintenance, inspections or as a result of a breakdown.

All defects need to be recorded in the asset management system, SAP, to enable future analysis of defect trends and to plan mitigation strategies.

In addition, the defect management system integrates the System Incident Reports, Defective Apparatus Reports and SAP to provide a number of strategic asset management and maintenance activities.

Defects are investigated in an appropriate time frame and recommendations to minimise the occurrences of the same or similar defects are put forward.

For further information, refer to TOC 1201-09 *TOC Incident Reporting Procedure*.

5.5 Asset Management Information System (AMIS)

An appropriate asset management information system is required in order to progressively evolve a high level of understanding of asset health and performance. The AMIS supports various models that are used to predict an assets end-of-life, so that economic refurbishment or replacement can be achieved before the onset of low reliability or availability and applicable risk to customers. This would be used in the development of plant and equipment performance and predictive analytics.

The main asset management information systems are SAP for asset and work management, protection and control system information system (PACSIS) for protection and control relay settings, Ratings Database Repository (RADAR) for plant and equipment ratings and Field Mobile Inspections (FMI) for planning and recording asset inspections.

All maintenance reports should be entered and stored electronically in SAP so that the information presented can be readily used to determine the condition of the asset and hence make sound asset management decisions.

5.6 Condition Assessment

AusNet Services conducts condition assessments of plant and equipment which play an integral role in plant performance and condition-based maintenance works programs.

Equipment history including loading, temperature, operations, outages, and faults provides valuable information on the condition, performance, useful life, and remaining service potential of assets.

The current condition monitoring program combines visual inspections, offline and online monitoring and scanning to assess asset condition which is used in the development of risk-based asset replacement models and optimised maintenance schedules.

The information gathered is used to create several measures of condition (known as ‘asset health indices’) for each asset which are combined into a single ‘Condition Score’, measured on a scale of 1 to 5.

AusNet Services aims to progress towards more algorithmic condition assessment informed by condition data held within the asset management information systems.

The significant challenges to this objective include economic viability, cost efficiency and identifying the most effective approaches for a dynamic reliability-based inspection and maintenance regime over an asset’s lifecycle.

To capture key asset condition indices, further development of current techniques used for condition assessments is required. Refinement of condition assessment methodology to facilitate algorithmic condition assessments.

The following activities are progressively being applied to support condition-based monitoring and maintenance:

- Selectively increasing the use of online (and off-line) conditioning monitoring methods to predict the need for and extent of maintenance.
- Understanding and developing the use of diagnostic testing techniques to predict the need for and extent of maintenance on appropriate equipment.
- Where justified, new assets have built-in condition monitoring and self-testing facilities. This is in order to reduce the maintenance effort and drive maintenance costs below expected regulated levels.
- Ensure that existing, installed condition monitoring equipment is functional and the data provided is analysed and used effectively.
- Optimisation of maintenance based on time intervals, operations, or duty through the assessment of plant condition and performance.

5.7 New Technologies

Longer term, AusNet Services expects further utilisation of new technologies, for example, Smart Aerial Imaging and Processing (SAIP) and the use of robotics to conduct live inspections and live maintenance activities will be introduced where appropriate technologies are robust, tested, and proven.

5.8 Life cycle management

Life cycle management is an approach that can be used by all types of business in order to improve their sustainability performance. It can be used to target, organise, analyse, and manage produce-related information and activities towards continuous improvement along the product life cycle. It aims to assist in managing the growing demand and expectations in the field of life cycle management.

In a few of the key activities there was a focus on the quality of supply for the assets and maintaining procurement standards. Therefore, there is an enhanced focus on the life cycle management of the assets.

5.9 Standards

Until April 2014, the AusNet Services' asset management system conformed to the requirements of the British Standards Institute's Publicly Available Specification PAS 55-1:2008 for Asset Management. This asset management system now conforms to the requirements of ISO 55001 *Asset Management – Management System: Requirements*, which there will be an ongoing commitment to.

6 CURRENT MAINTENANCE ACTIVITIES

Transmission network assets are divided into the following categories:

- Cables and Easements and Transmission Lines and Easements;
- Primary plant;
- Secondary plant; and
- Station equipment.

The maintenance intervals are documented in PGI 02-01-02 *Summary of Maintenance Intervals – Transmission*.

6.1 Cables and Easements and Transmission Lines and Easements

6.1.1 Cables and Easements

There are two main categories of power cables within the transmission network:

1. Interconnecting cables; and
2. Station cables.

Interconnecting cables are utilised to connect one terminal station to another terminal station. AusNet Services owns and maintains the following interconnecting cables:

- One 220 kV interconnecting cable between Brunswick and Richmond;
- One 220 kV interconnecting cable between Eildon and Thomastown; and
- One 66 kV interconnecting cable between Loy Yang Substation and Loy Yang South Substation.

Station cables connect items of plant within a terminal station. There are approximately 210 station cables installed within the various terminal stations through Victoria operating at each voltage level of the transmission network depending on the plant to which the cable is connected.

The majority of power cables have been in service for 20 to 40 years.

The key asset management strategies for power cables are to combine cable replacement, where possible, with other capital works, otherwise, repair or replace based on condition. Additionally, a contingency plan for oil filled cables will be developed and implemented to help manage the impact of a fault on an oil filled cable.

Continue rigorous inspection regime of manufacturing plants to ensure the supply chain quality is maintained. Continue to enhance commission testing protocols, ensuring all new assets are effectively tested prior to being placed into service, thus giving a baseline for all future condition assessment test programs.

Continue to expand electrical condition assessment testing program to all transmission network cable circuits. The tests will include HV withstand, Partial Discharge (PD) and Dielectric Dissipation Factor (DDF).

Oil filled cables will have scheduled oil samples taken to test for DGA and dielectric withstand.

On-line continuous monitoring techniques are beginning to be employed across critical circuits utilising fibre optic technologies. These include but are not limited to the use of Distributed Temperature Sensing (DTS) and Partial Discharge (PD) systems.

Continue to update cable asset records and fault response plans.

Key strategies for cables include the regular inspection of all above ground cable assets incorporated into the station inspection program. This looks for obvious signs of deterioration of the main insulator, termination base stand-off insulators, connections and any other equipment associated with the terminations (e.g. link boxes). The inspection also covers the visual condition of the cable as it exits the ground, looking for obvious signs of mechanical damage, water ingress or the like.

For further information, refer to AMS 10-66 Power Cables.

6.1.2 Transmission Lines and Easements

Transmission line easements provide safe passage for line workers and machinery to transmission lines so that maintenance activities can be performed. These line easements are approximately 5,017[9] km in length and cover a total area of approximately 21,600 hectares. The volume of transmission line easements has increased marginally in recent years mainly to accommodate connections of new generators and the extension of the transmission network to the desalination plant at Wonthaggi.

There are different types of inspections and patrols:

- Condition Assessment – inspecting the tower and associated equipment by climbing it
- Inspection patrols – Line and easement patrols are regularly completed on the transmission lines and easements to identify defects or abnormalities
- Vegetation inspection - Routine inspection patrols of transmission line easements are conducted every 12 months using Light Detection and Ranging (LiDAR). technology. The easements are inspected to ensure clearances are maintained between vegetation and transmission lines and towers. In addition, an environmental survey is completed, and inspections identify unauthorised structures or fences within easements.

The lines and associated structures are inspected to identify if there is any superficial damage, drainage issues around the footings, insulator damage and other visible defects.

Other inspection and patrol types that are complementing the above inspections are:

- Smart Aerial Imaging and Processing (SAIP), and
- Infrared survey

Smart Aerial Imaging and Processing (SAIP) has been used to build robustness of the risk assessments of conductors and ground wire on lines. High resolution pictures are processed (through software) and abnormalities such as, broken strands, white powder or conductor thickness change are detected and flagged for review. This aerial inspection technique has been extended to majority of line easements.

Light Detection and Ranging (LiDAR) is a laser based surveying technique which can create a three dimensional digital topology of a transmission line and its easement corridor to quantify the physical clearances between the electrical phases of a transmission circuit, the extent of conductor movement and the physical clearances to vegetation, ground and encroachments in the line easement. This inspection technique has been introduced to assess the condition of vegetation and the adequacy of easement dimensions as well as validating conductor to ground clearances under varying loading conditions. Its usage will grow allowing a greater level of surety over vegetation clearances, electrical safety clearances and transmission line rating.

Infrared surveys are completed to identify overheating due to any developing high resistance joints or insulators defects or abnormalities requiring rectification maintenance activities.

For condition monitoring further research is being undertaken on introducing additional assessment tools for the transmission line conductor corrosion and the use of unmanned aerial vehicle (UAV) for condition assessment currently performed by climbing inspections.

The majority of AusNet Services' transmission assets are situated outdoors and therefore are exposed to the elements. Preventative measures (such as ground level painting and sacrificial anodes) are used to protect tower footings as the steel footings are buried directly into the earth and would eventually corrode if not protected. Sacrificial cathodic protection systems have also been applied to critical tower locations. There is a routine maintenance program in place to regularly check condition of the cathodic protection systems.

Some key asset strategies are continuing to assess the condition of transmission line insulators during structure climbing inspections conducted at regular intervals and during the annual line and easement inspections. Also continue to assess the condition of transmission line structures during structure detail inspections which are conducted at 3-, 6- or 9-yearly intervals. As well as continue improving the Smart

9 2018/19 Economic Benchmark RIN 3.7 Operating Environment

Aerial Image Processing (SAIP) technology to assess the condition of conductor, ground wire systems and associated hardware. A routine program of SAIP inspection is conducted on a 6 yearly inspection interval.

For further information, refer to the following strategies:

- AMS 10-65 Line Easements
- AMS 10-75 Transmission Line Insulators
- AMS 10-77 Transmission Line Structures
- AMS 10-79 Transmission Line Conductors
- AMS 10-78 Transmission Line Structure Foundations.

6.2 Primary Plant

Primary plant consists of:

- Capacitor banks;
- Instrument transformers;
- Disconnectors, isolators and earthing switches;
- Power transformers and on load tap changers;
- Surge diverters;
- Circuit breakers;
- Gas Insulated Switchgear, and
- Static VAR compensators.

Planned station rebuilds projects integrating network augmentation as directed by the Australian Energy Market Operator (AEMO) and requirements defined by distribution network service providers (DNSPs) will include the economic replacement of some critical primary plant assets over the period 2022 to 2027.

6.2.1 Capacitor Banks

Capacitor banks are primarily used to stabilise the network operating voltage particularly during heavy demand periods. Capacitor banks can also minimise electrical power losses, optimise the utilisation of transformers and lines augmentations and act as harmonic filters in static VAR compensators.

Typical maintenance activities aim to identify loose connections, oil leaks, swelling of cans and condition of paintwork.

Key activity for new assets includes to continue to purchase capacitor banks to the latest specification with capacitors internally fused and capacitor bank detuned against harmonic resonance.

Other key strategies for continuing maintenance of capacitor banks include continuing to maintain capacitor banks in accordance with PGI 02-01-02 and to continue to monitor the failure rate.

For further information, refer to AMS 10-53 Capacitor Bank.

6.2.2 Instrument Transformers

Instrument transformers include:

- Current Transformers (CT);
- Voltage Transformers; and
- Capacitive Voltage Transformers (CVT).
- Capacitive Voltage Dividers (CVD)

They provide accurate measurements of the operating voltages and currents necessary for the safe, reliable, and economic protection and control and have a relatively light maintenance regime in comparison to other primary plant.

The volume of instrument transformers in service continues to increase with expansion of the network.

There have been significant replacements of both current transformers and voltage transformers as part of major asset replacement projects and in smaller projects focused on managing specific supply risks to consumers, safety risks to workers and collateral plant damage risks within terminal stations.

Key strategies include to maintain instrument transformers are to continue visual inspection during regular station inspections.

For further information, refer to AMS 10-64 Instrument Transformers.

6.2.3 Disconnectors, Isolators and Earthing Switches

The purpose of an earth switch is to electrically connect selected isolated equipment to the station earth grid. This ensures that the "earthed" equipment is at the same potential to that of the station earth grid.

The combined use of disconnectors and earth switches creates a safe working environment for maintenance or associated works, by preventing the formation of an electrical potential on the selected equipment.

There are three levels of overhauls associated with isolators and earthing switches:

1. Inspection and lubrication;
2. Minor adjustments, dismantling and lubrication; and
3. Major overhaul consisting of dismantling all contacts, pivots and bearings for thorough cleaning and re-lubrication.

Design modifications to these earthing switches need to be continued to eliminate the health and safety risk and improve performance.

A key activity for new assets includes to continue to purchase fully type tested disconnectors and earth switches to the latest specifications.

Other key strategies for continuing maintenance of the disconnectors and earth switches are continuing maintaining disconnectors and switches in accordance with PGI 02-01-02.

For further information, refer to AMS 10-59 Disconnectors and Earth Switches.

6.2.4 Power Transformers and On Load Tap Changers

Power transformers are required to transfer power between circuits to maintain quality and security of supply in a safe manner. They are utilised to transform voltage levels depending on their specification and use in the network.

Transformers in Victoria are operated at high utilisation levels as a result of the probabilistic planning criteria that are used to plan the transmission network in Victoria.

The long-term targeted replacement and component refurbishment programs are demonstrating positive outcomes in effective management of the fleet's reliability.

To maintain a high level of reliability and ensure that every transformer is capable of operating satisfactory, a certain level of maintenance is required.

Continued investment in power transformer refurbishment and replacement is necessary to economically manage failure risks which are being driven by the value of unserved energy, declining reliability, and measurable deterioration.

Other activities including carrying out routine monitoring and testing of a transformer on a periodic basis to detect incipient failure behaviour and assess general condition and continue the program to repair significant oil leaks and oil damaged wiring on transformers.

Online gas and moisture monitors are techniques that monitors gas composition and moisture in power transformers in real time.

Condition monitoring of power transformers using six yearly testing of bushings, windings, insulation, and surge arresters. These tests are conducted on the winding impedance/resistance, ratios across all taps and frequency response analysis for power transformer and oil filled reactors winding condition assessment.

Other tests conducted on the bushings, insulation, and surge arrestors include capacitance and dielectric dissipation factor and partial discharge.

All these tests together provide information on the condition and integrity of transformer components. The deterioration rates of at-risk transformers are tested on a more frequent basis to schedule interventions or alter alarm and protection system parameters, cooling systems and operating temperatures.

Key strategies for Power transformers and oil-filled reactors include continuing to maintain them as per their scheduled maintenance inspections.

For further information, refer to AMS 10-67 Power Transformers and Oil-filled Reactors.

6.2.5 Surge Diverters

Surge diverters are used on electrical power systems to protect expensive from over voltage caused by lightning strikes or transient switching voltages. Surge diverters are sacrificial items of equipment and are meant to operate and if necessary, fail in order to protect the expensive plant equipment such as transformers.

The key activity for new assets for surge diverters is to continue to purchase gapless polymer housed metal oxide surge arresters.

Other key strategies in continuing to maintain surge diverters are to continue with routine visual inspection and annual thermo-vision scans.

For further information, refer to AMS 10-73 Surge Diverters.

6.2.6 Gas Insulated Switchgear

Gas insulated switchgear (GIS) is an alternative construction technique to AIS as it encloses all live parts within an SF_6 filled metal enclosure. It is typically used when a compact layout is required. The use of GIS is limited as the equipment cost is significantly higher in comparison to AIS due to its compactness, the insulation medium and switching mechanism technology.

The switching mechanism in GIS equipment has a quicker operating time which may be more appropriate to be used when switching out key plant items, such as generators and transformers. Oil insulated switchgear equipment allow arc energy to be contained and safely controlled.

These assets are maintained due to the number of operations or a time-based scheme.

There are three levels of maintenance associated with switchgear:

1. Inspection and lubrication.
2. Minor adjustments, dismantling and lubrication.
3. Diagnostic tests and dismantling of poles if diagnostic tests indicate a problem.

The condition monitoring for switchgear installations requires regular moisture and SO_2 checks. This condition information is to avoid imminent failure as well as to develop trends for failure probability. This is a discreet method and there is a residual risk of a fault developing between the gas sampling windows. This risk is further mitigated by developing regular non-invasive scanning programs. Ultra-High Frequency Partial Discharge detectors are used for real time monitoring of GIS.

. A key asset strategy is to continue maintaining Gas Insulated Switchgear in accordance with PGI 02-01-02.

For further information, refer to AMS 10-62 Gas Insulated Switchgear.

6.2.7 Circuit Breakers

Due to the consequence of circuit breaker bushing failures, an active program for increased condition monitoring and replacement of problematic bushings is in place. Bushing condition is identified through inspections and diagnostic tests including Infrared Thermography Imaging. An oil sample is taken then tested for DGA, moisture content / dew point temperature and acidity.

Some of the key asset strategies are to continue scheduled preventative maintenance as per specific Standard Maintenance Instructions for each circuit breaker type

For further information, refer to AMS 10-54 Circuit Breakers.

6.2.8 Static VAR Compensators

Static VAR Compensators (SVC) provide reactive support for voltage stability on the Victorian electricity transmission network. SVCs are required for dynamic voltage control at critical locations on transmission network. The use of the SVC facilitates continuous voltage stability enabling the network to withstand unplanned outage events such as the loss of a line following lightning strikes.

Obsolescence of the control systems increases existing risks associated with failure as fault rectification works are slow and difficult resulting in extended unplanned outages.

There are currently no formal condition monitoring activities for the SVC.

The key asset strategy for SVCs is to continue maintaining them in accordance with PGI 02-01-02.

For further information, refer to AMS 10-71 Static VAR Compensators.

6.3 Secondary Plant

Secondary plant consists of:

- DC supplies;
- metering;
- protection schemes;
- controls and instrumentation;
- communication equipment; and
- AC switchboards.

Protection and control assets are maintained in accordance with PGI 02-01-04 and SPP 02-00-01. Regular inspection, testing and maintenance facilitate timely diagnosis of asset failures with the potential to lead to false operation, system unavailability or other operational instability. Secondary assets include devices to measure the network's electrical operating parameters and monitor the function and condition of selected primary network assets.

Secondary assets become obsolete within a typical timeframe of 15 years when they are no longer supported by manufacturers, are technically incompatible with interfacing equipment or are no longer able to provide the functionality established in industry standards or regulation.

An overarching strategy is to integrate secondary asset modernisation projects within Terminal Station rebuild projects or major primary asset replacement projects wherever economic.

The serviceability of the system is defined as the ability of a secondary system to deliver its expected function appropriately and is assessed according to three strategic replacement criteria:

1. Compliance;
2. Modernisation; and
3. Obsolescence.

The DC power supplies are located in terminal stations to provide critical DC power for the operation of electrical protection, control, metering and SCADA systems associated with the electricity transmission network.

Key issues are performance risks and functionality limitations of deteriorating batteries and chargers beyond their economic service life and establishment of a condition monitoring program for economic management of DC power supplies.

Communication systems primarily provide electrical protection signalling between generating stations and terminal stations, and between terminal stations and other terminal stations.

The systems also provide operational voice and business communication between Network Operations Centre (NOC), offices, Customer Energy and Operations Team (CEOT), depots, terminal stations, generating stations, distribution zone substations, connected interstate transmission and generating stations and AEMO.

All new and replacement assets will be designed in accordance with the Station Design Manual and current design standards, undertake replacement of complete protection system associated with individual items of primary plant/network sections, rather than individual protection schemes/relays.

Replacement activities shall be incorporated within primary plant replacement, station refurbishment or network augmentation activities as far as practicable, in order to maximise operational efficiency and minimise network disruption.

Integrate secondary asset modernisation projects within terminal station rebuilt project or major asset replacement projects whenever economic.

The key asset strategies are to replace the end of life products/platforms and establish redundant (independent) communications bearers where justified.

For further information, refer to the following strategies:

- AMS 10-68 Secondary Systems
- AMS 10-52 DC Power Supplies
- AMS 10-56 Communication Systems

6.4 Station Equipment

Station equipment consists of:

- Civil infrastructure;
- Diesel generators;
- Fire protection;
- Station earth grid; and
- Oil containment and water treatment systems.

6.4.1 Civil Infrastructure

Assets within the classification of civil infrastructure are generally situated within the boundaries of terminal stations. Civil infrastructure includes buildings, roads, footpaths, surfaced areas, foundations, support structures, signage, fences, cable ducting and trenching, water pipes, sewerage pipes and drains.

Aside from major augmentation and asset replacement projects, additional civil infrastructure assets have been upgraded as a part of targeted programs focussed on managing failure risks.

The key strategies are aimed at ensuring the effective, economic, and consistent management of civil infrastructure assets in all terminal stations.

For further information, refer to AMS 10-55 Civil Infrastructure.

6.4.2 Diesel Generators

Diesel generators provide emergency, auxiliary 415 V AC supply at critical locations (terminal stations and communications sites) in the event of total loss of normal auxiliary supplies.

The majority of diesel generators located at terminal stations are provided for black start capability and those at remote communication sites are required to reduce the risks associated with the loss of critical network communication systems.

Issues limiting the functionality of diesel generators include faulty generator controls. Fuel tank replenishment is triggered by reactive maintenance.

In order to mitigate the issues limiting functionality, visual inspections, manual test runs, and operating parameter tests can be performed.

Some installations require fuel spill bunding in order to capture diesel or oil leaks to prevent environmental impacts due to the operation of this equipment.

Key asset management strategies are continuing with current maintenance and operational practices, develop and apply a quantitative condition assessment methodology and economically replace diesel generators based on condition.

For further information, refer to AMS 10-58 Diesel Generators.

6.4.3 Fire Protection

Fire detection and suppression systems are required to minimise asset damage in case of insulating oil fires, battery fires or control building fires.

All terminal stations in the Victorian electricity transmission network are provided with fire detection and suppression systems. These are focussed on transformers and secondary equipment in control buildings.

Fire suppression has been achieved using different systems such as water deluge systems, fire hydrant systems and gaseous fire suppression systems.

There are standard maintenance instructions for all fire protection equipment, testing is performed at specific intervals in accordance with AS 1851[10].

Basic compliance testing and maintenance is performed by AusNet Services personnel and the more significant testing is performed by professional fire service contractors as part of the key asset strategies.

For further information, refer to AMS 10-61 Fire Detection and Suppression.

6.4.4 Station Earth Grid

Station earth grids are installed below ground level in all AusNet Services terminal stations and communication sites. Earthing systems consist of buried main earth grid electrodes and earthing conductors that are connected to equipment or other infrastructure from main earth grid electrodes within terminal stations. The crushed rock switchyard surface placed over earth grids is an integral part of design and is required to provide added electrical resistivity.

The condition of the earth grid electrodes is generally good, and the condition of some station overhead earth wires is showing a level of deterioration due to surface corrosion and is monitored during inspection.

The key asset strategies include current injection testing and inspection of terminal station earth grids are performed in compliance with the electricity safety management scheme to ensure that the earth grid step and touch voltage hazard limits are consistent with international limits[11].

For further information, refer to AMS 10-60 Earth Grids.

6.4.5 Oil Containment and Water Treatment Systems

AusNet Services maintains ISO 14001 Environmental Management System (EMS) certification for its electricity transmission assets. There are oil containment and water treatment systems installed in terminal stations to mitigate risks in the event of a spill.

In order to facilitate the ongoing sampling of groundwater, permanent sampling wells have been installed in a number of terminal stations[12].

The key asset strategies include testing is undertaken during environmental upgrade projects. Periodic sample testing is conducted to ensure that oil and water separator systems are operating correctly to comply with required AusNet Services' practices.

For further information, refer to AMS 01-10 Environmental Management.

10 AS1851 Maintenance of fire protection systems and equipment

11 In accordance with IEC 61936-1 Power installations exceeding 1kV a.c. – Part 1: Common Rules and IEEE 80 Earthing

12 Refer to Section 3.1.2 Oil Containment (AMS 10-14 Environmental Management)

7 STRATEGIES

The provision of a superior network requires the management of network assets over their lifecycle. This will be achieved by sound risk management and the continuous improvement practices of our integrated safety, health, environment, quality, and asset management systems.

The following strategies will contribute to the management of network assets over their lifecycle.

- Ongoing commitment to ISO 55001 certification
- Enhanced focus on life cycle management of assets
- Development in plant and equipment performance and predictive analytics
- Refinement of condition assessment methodology to facilitate algorithmic condition assessments
- Development in reliability centred maintenance (RCM) modelling to inform maintenance, inspection, and replacement frequency
- Refinement in strategic spares assessment and ensure appropriate stocks are maintained

APPENDIX A SCHEDULE OF REVISIONS

Issue	Description
5	Updated
6	Updated
7	Updated
8	Updated to include AMS 10-13 Condition Monitoring document

APPENDIX B ACRONYMS

AC	Alternative Current
AEMO	Australian Energy Market Operator
AIS	Air Insulated Switchgear
CEOT	Customer Energy and Operations Team
DB	Distribution Business
DC	Direct Current
DGA	Dissolved Gas Analysis
DNSP	Distribution Network Service Provider
EMS	Environmental Management System
FMECA	Failure Mode, Effects and Criticality Analysis
FMI	Field Mobile Inspectors
FWP	Field Work Practice
GIS	Gas Insulated Switchgear
LiDAR	Light Detection and Ranging
MIPS	Market Impact Parameter Scheme
MTTR	Mean Time To Repair
NEM	National Electricity Market
NOC	Network Operations Centre
O&M	Operation and Maintenance
PACSIS	Protection and Control System Information System
PGI	Plant Guidance and Information
QRA	Quantitative Risk Assessment
RADAR	Ratings Database Repository
RCM	Reliability Centred Maintenance
SAIP	Smart Aerial Imaging and Processing
SAP	AusNet Services' asset management information system
SC	Service Component
SCADA	Supervisory Control and Data Acquisition
SMI	Standard Maintenance Instruction
SQRT	Semi-Quantitative Risk Technique
STPIS	Service Target Performance Incentive Scheme
SVC	Static VAR Compensator
UAV	Unmanned Aerial Vehicle
VAR	Volt Ampere Reactive
XLPE	Cross Linked Polyethylene
ZA	Corrective or condition-based maintenance

ZB	Scheduled Maintenance
ZD	Discrete Project (Asset Works)
ZE	Customer Defect
ZK	Unscheduled (Emergency) Maintenance

APPENDIX C CONDITION MONITORING TECHNIQUES

Table 1 illustrates a typical asset blueprint for condition monitoring techniques aligning failure modes.

Table 1: A Typical Asset Blueprint using Failure Mode Analysis

Diagnostic Techniques	Failure Mode																					Issues	Effectiveness			Reliability	
	Does not close	Does not Open	Self Close	Self Open	No current make	No current break	Internal Breakdown	External Breakdown	Pole discrepancy	Slow Open	Bushing Fault	Hydraulic Fault	Air Fault	SF_6 Leak	Spring Change	Overheating Contacts	Secondary	Mechanical drive / integrity failures	Oil condition	Arc erosion of contacts	Restriking		Technical	Costs M	Costs OLM	Score M	Score OLM
Traveltime Curve	•	•			•	•			•	•		•					•	•					H	H	L	5	3
Contact Timing	•	•			•	•			•	•							•						H	H	L	6	
Dynamic Resistance	•				•	•										•				•			H	H	L	8	
Phase Current	•	•	•	•	•	•				•	•					•					•		M	L		5	
SF_6 Density – Transducers							•				•			•									H	M		4	
Oil DGA – Oil Breakdown							•			•	•												H	L		3	
Ultrasonic Leak												•	•										M	L		5	
Operation Counters			•	•														•		•			M	L		4	
Ultrasonic Timing / Vibrator	•	•			•	•			•	•													M	H		7	
Bushing DGA							•				•												H	H		5	
RF Scan							•	•		•	•												M	M	H	6	
Motor Current															•		•						L	M	M	8	8
Running Time / Pumps / Compression													•		•								H	L		3	
Alarms / Indicators	•	•	•	•	•	•	•		•	•		•	•	•	•		•			•			H	L		3	
Contact Wear Inspection					•	•				•											•		H	L		5	
Circuit Supervision / Battery Supply	•	•	•	•						•					•		•						H	H		3	
Coil Current			•	•											•		•			•			M	M	L	6	5
Operation Check	•	•	•	•			•		•	•		•									•		H	H		6	
Ductoring	•	•			•	•					•					•				•			H	H		5	
Bushing DLA + PD – online and offline											•												H	H		5	
IR Test / Megger					•	•	•	•			•						•						H	H		5	
Operational Checks	•	•	•	•						•			•		•		•						M	L		4	
Oil breakdown / particle test + DGA							•			•	•																
Thermovision / Infrared							•				•					•							H	M		4	
CB Management	•	•	•	•	•	•			•	•													M	H		6	
Pump Starts Counter (Hydraulics)																											