Substation Renewal and Maintenance Strategy

Summary

This strategy guides the management of TransGrid's existing Substation assets.

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1. Purpose

This document defines the renewal and maintenance strategies for TransGrid's Substation fleet. In doing this it applies the overarching asset management strategy and objectives, and relevant Lifecycle Strategies.

The document identifies the emerging issues with TransGrid's Substation assets, and details the renewal and maintenance initiatives to be implemented in response to these issues. The output of the strategy is the asset management program of works, which is derived via distinct paths as follows:

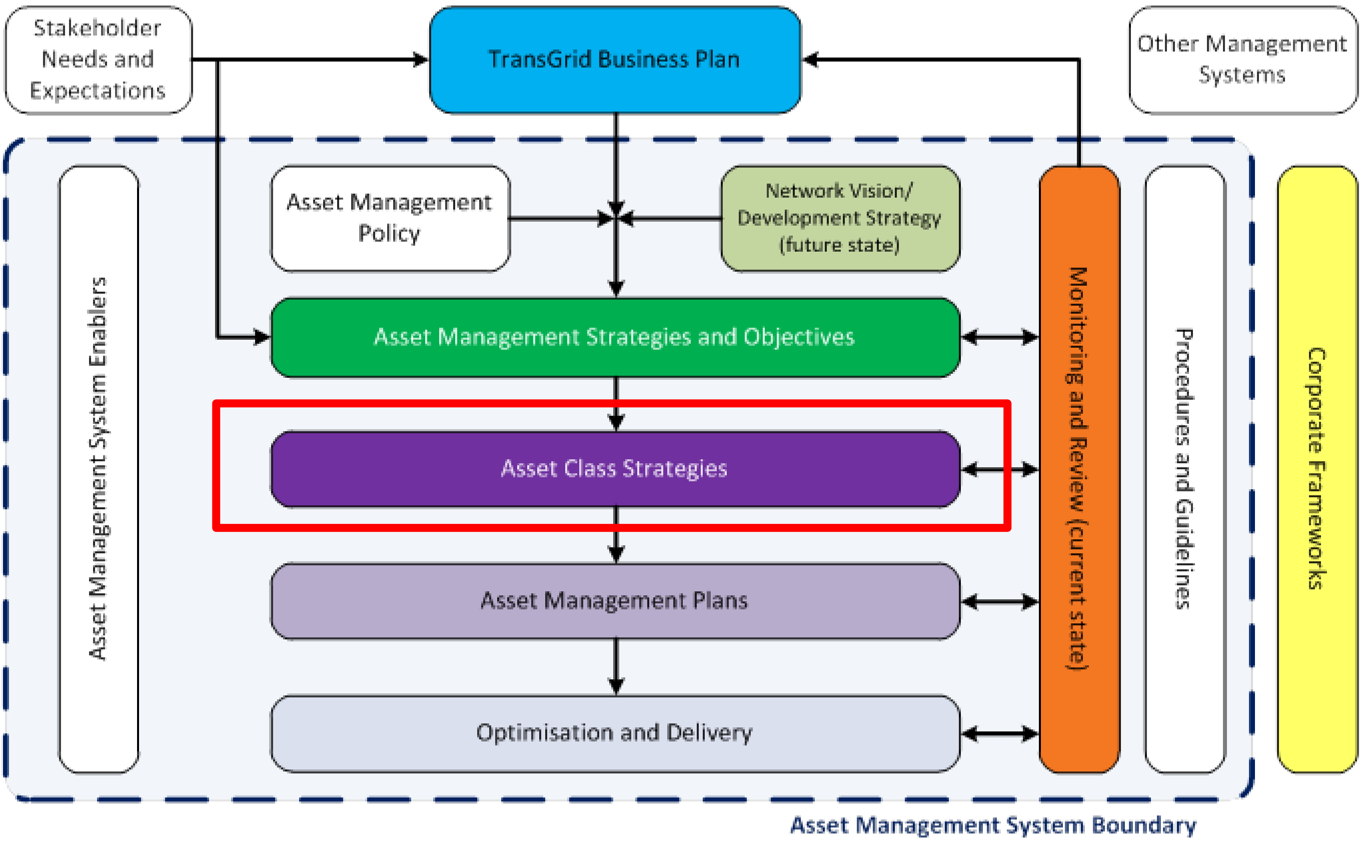
- The renewal and disposal initiatives are considered through the prescribed capital investment process and managed through the Portfolio Management group, which then which then leads to the resource-optimised capital works program.
- The maintenance initiatives directly drive the maintenance regimes which are detailed within the Substation Maintenance Plan. The maintenance plans are then resource-optimised through TransGrid's Enterprise Resource Planning (ERP) system, *Ellipse.*

The strategies contained in this document cover the period to June 2023.

2. Positioning within the Asset Management Framework

The *Substation Renewal and Maintenance Strategy* document is one of several that comprise the Asset Management Strategies within TransGrid's Asset Management System. This document sits below the Asset Management Strategy and Objectives document as shown in *Figure 1*.

Figure 1: Asset Management System Document Hierarchy



3. Definitions

Table 1: Definitions

Term	Definition
Asset Management Objectives	• Specific and measurable outcomes required of the assets in order to achieve the Corporate Plan and objectives; and/or • Specific and measurable level of performance required of the assets; and/or • Specific and measurable level of the health or condition required of the assets; and/or • Specific and measurable outcomes or achievement required of the asset management system.
Key Hazardous Events	They events of most concern associated with the assets that prevent the achievement of the corporate and asset management objectives.
Emerging Issues	Newly identified issues with an asset that pose a risk to the achievement of the corporate and asset management objectives.
Fault Outage	AER defined term - Fault outages are unplanned outages (without notice) on the prescribed network from all causes including emergency events and extreme events.
Forced Outage	AER defined term - Forced outages are outages on the prescribed network where less than 24 hours notification was given to affected customers and/or AEMO (except where AEMO reschedules the outage after notification has been provided). Forced outages exclude fault outages.
Asset Management Plans	Documents specifying activities, resources, responsibilities and timescales for implementing the asset management strategy and delivering the asset management objectives.
RP1	Regulatory Period 2014/15 – 2017/18
RP2	Regulatory Period 2018/19 – 2022/23

4. Asset Management Strategy 'Line of Sight'

The renewal and maintenance strategic initiatives set out in this document support the achievement of the strategies set out in the Asset Management Strategy and Objectives document. The strategic alignment of the initiatives in this document to the Asset Management Strategy and Objectives document is shown in the tables below.

Table 2: Substation Asset Outcomes

Asset Management Objectives	Asset Management Performance Indicators

▪ Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)
▪ Manage substation related bushfire risks (people safety) to ALARP/SFAIRP
	1. Zero substation related LTIs
	2. Zero substation related fire starts
	3. Key Hazardous Events at 5 year average level:
	    1. Catastrophic plant failure
	    2. Conductor drop (Substation HV Connections)
	    3. Structure failure (Substation Gantries)
	    4. Uncontrolled discharge/contact with electricity
	4. Maintain average age of asset class population to a sustainable level

Minimise environmental harm and property damage	5. Maintain 5 year level of substation related environmental incidents 6. Maintain 5 year level of environment related Key Hazardous Events (contaminant or pollutant release) 7. Maintain average age of asset class population to a sustainable level
Maintain network reliability	8. Maintain 5 year average level of loss of supply events due to substation faults 9. Maintain 5 year average level of unplanned outage related Key Hazardous Event 10. Maintain average age of asset class population to a sustainable level

Table 3: Substation Asset Contribution to Financial Outcomes

Asset Management Objectives	Asset Management Performance Indicators
Improve CAPEX Performance	11. Improve Capital project performance
Improve OPEX Performance	12. Perform within -5/+10% of the Asset Management Program of Works budget

Asset Management Objectives	Asset Management Performance Indicators
Pursue STPIS revenue where cost effective	13. Better than average performance of the STPIS measures: a. Transformer Fault and forced outage rates b. Reactive Plant Fault and forced outage rates

5. Review of Previous Renewal, Disposal and Maintenance Strategies

This section discusses the progress of the previous renewal and maintenance strategic initiatives, and their effectiveness at meeting the asset management objectives.

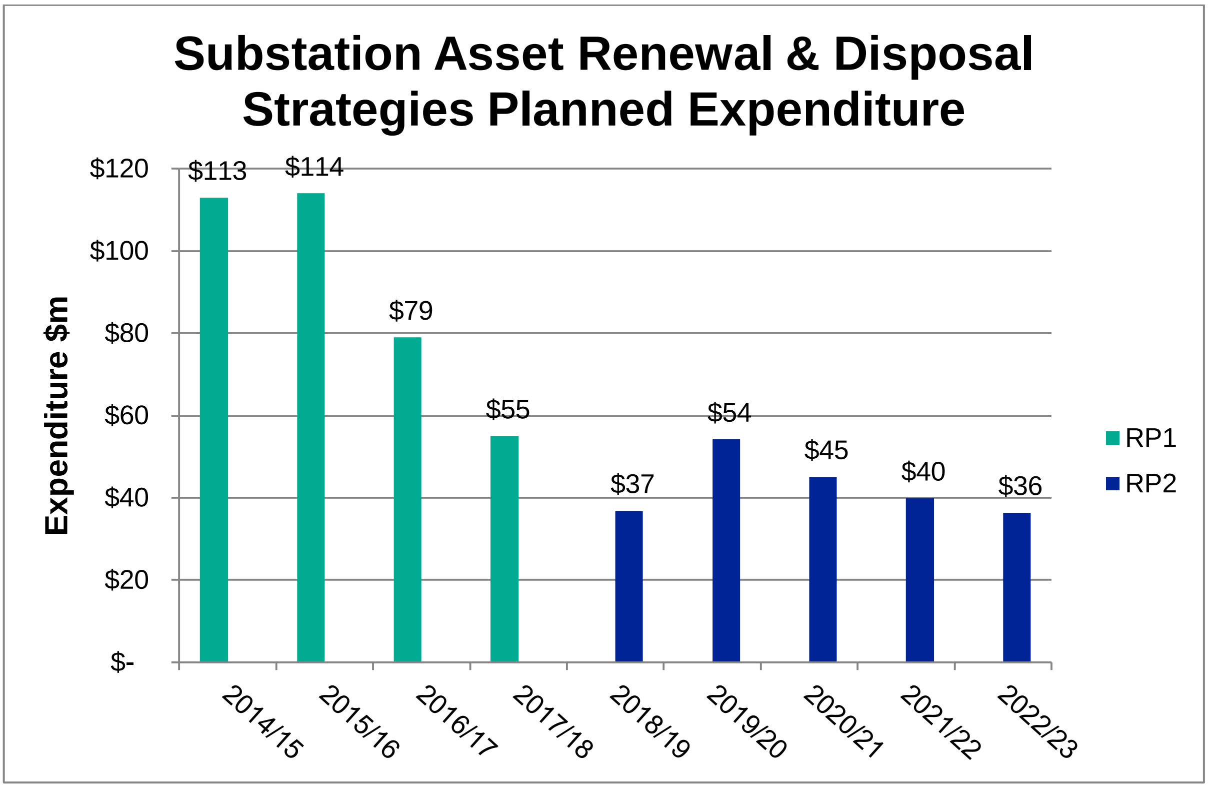
5.1 Historical Expenditure

TransGrid's renewal program for the regulatory period 2014/15 – 2017/18 (RP1) has been reviewed by the Australian Energy Regulatory (AER). The resulting AER approved expenditure forms the capital works program for RP1.

The regulatory period 2018/19 – 2022/23 (RP2) is in the process of being developed for submission to the AER.

Figure 2 shows the current planned expenditure relating to the substation asset renewal and disposal strategies for the current regulatory period (RP1) and the next regulatory period (RP2).

Figure 2 Substation Asset Renewal & Disposal Strategy Planned Expenditure (RP1 and RP2)



5.2 Review of Renewal and Maintenance Initiatives

Delivery of the existing Renewal and Maintenance Initiatives has continued to target the replacement of assets assessed to be at risk of failure based on analysis of condition data. In doing so, high risk assets are replaced with modern equipment which typically deliver higher reliability.

Asset replacements are resulting in a greater number of modern assets which reduce defect rates and lower maintenance costs. Review of the Substation Maintenance Plan has considered the reduced maintenance requirement for modern equipment and the use of online monitoring (where installed) to deliver improvements in maintenance expenditure over time.

Performance data is shown in section 5.4 below which demonstrate the effectiveness of the Renewal and Maintenance Initiatives in maintaining low levels of substation asset failures and outages.

Existing and ongoing Renewal and Maintenance Initiatives are listed together with the Emerging Issues, and Renewal and Maintenance Initiatives tables for the relevant asset classes discussed in Section 7.

5.3 Review of Maintenance Program

Routine maintenance regimes are reviewed annually and are adjusted to minimise total cost including risk cost.

Routine maintenance regimes were first established based on manufacturer recommendations, and then refined as TransGrid's experience with each asset type has developed through the asset lifecycle.

With each re-evaluation of the Substation Maintenance Plan, opportunities to refine the processes are considered. They are based on consideration of the specific asset failure modes, and seek to strike an optimised balance between preventative and reactive maintenance in order to maximise performance and minimise risk whilst minimising costs over the life of the equipment. The following factors are considered:

- Failure mechanisms
- Impact of failure
- Expected frequency of failure
- Means to monitor or prevent
- Impact of the proposed maintenance action (could actually introduce an increased risk)
- Cost of the maintenance action against risk reduction
- In general terms, the primary maintenance approach will fall into one of two categories:
  - High-value assets and assets with mechanical components: these assets typically require routine preventative maintenance, and reactive (defect) maintenance as required.
  - Low-value assets and assets with static components: these assets typically require routine inspection only (i.e. no routine maintenance), and reactive maintenance as required.

TransGrid's routine maintenance is summarised as follows:

- Half-yearly and annual substation site inspections and defect review
- Annual thermographic surveys
- Periodic minor and major maintenance of substation primary plant
- Periodic diagnostic testing of primary plant
- Online condition monitoring

The current maintenance regime is based upon periodic inspections, checks and measurements to monitor the condition of plant or equipment. Maintenance activities are based upon component failure risk analysis which ensures alignment between potential component failures and preventative maintenance activities prescribed to diagnose them. The maintenance regime aims to identify leading indicators of declining asset health in order to reduce reactive defects and prevent asset failure whilst remaining cost effective.

A major review of maintenance activities was conducted in the 2015/16 financial year which included working groups with representatives from across the business. Following the review, a number of optimisation improvements to asset stream Maintenance Plans were identified and implemented from the 2016/2017 financial year.

The improvements implemented in the asset stream Maintenance Plans are set out within the following document - Asset Management Instruction AS0001. The full details of TransGrid's substation maintenance activities are detailed within GM AS S1 001 *Maintenance Plan – Substation Assets*.

Table 4: Substations Asset Maintenance Expenditure

Financial Year	Inspection and Routine Maintenance		Corrective Maintenance (defect)	
	Budget	Actual	Budget	Actual
FY2014/15	**$7.140M**	**$5.567M**	**$4.465M**	**$4.469M**
FY2015/16	**$5.692M**	**$5.771M**	**$4.380M**	**$5.254M**

5.4 Past Performance – Asset Management Performance Indicators

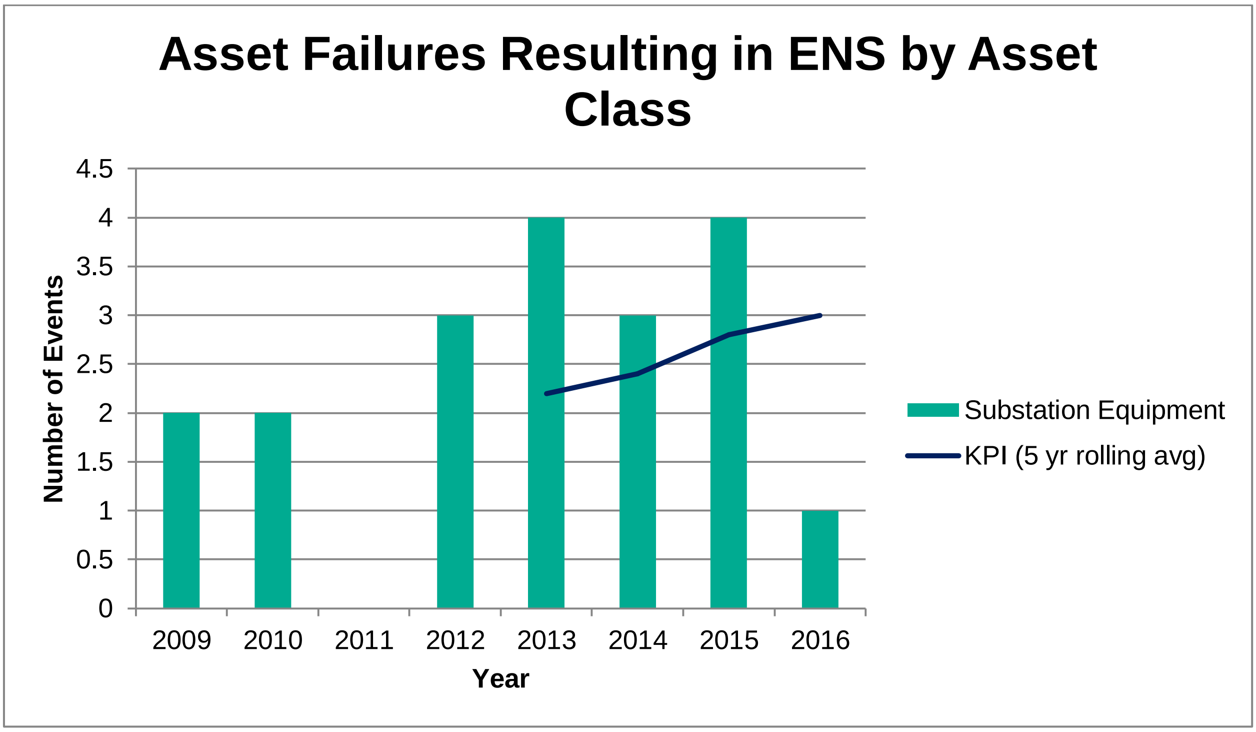
The KPIs that demonstrate the effectiveness of this Renewal and Maintenance strategy to mitigate the network related safety, reliability environment, financial, compliance, and reputational risks in support of the achievement of the asset management targets and objectives are the number of explosive/catastrophic failures as shown at Figure 3 and Figure 4. These measures have been maintained at a low level over the past seven years, indicating the Renewal and Maintenance strategies have been effective at mitigating the risks and achieving the asset management objectives. Catastrophic failures present a major risk to meeting the organisational performance objectives, and as such similar expenditure to that in the past is forecast.

Table 5: Performance against Asset Management Performance Indicators

Asset Management Objectives	Asset Management Performance Indicator	Performance Result
▪ Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) ▪ Manage substation related bushfire risks (people safety) to ALARP/SFAIRP	1. Zero substation related LTIs 2. Zero substation related fire starts 3. Key Hazardous Events at 5 year average level: a. Catastrophic plant failure b. Conductor drop (Substation HV Connections) c. Structure failure (Substation Gantries) d. Uncontrolled discharge/contact with electricity	• Zero LTI due to asset failure • Zero substation related fire starts • Key hazardous event trending as below
Minimise environmental harm and property damage	4. Maintain 5 year level of substation related environmental incidents 5. Maintain 5 year level of environment related Key Hazardous Events (contaminant or pollutant release)	• Environmental trending as below • Key hazardous events as below
Maintain network reliability	6. Maintain 5 year average level of loss of supply events due to substation faults 7. Maintain 5 year average level of unplanned outage related Key Hazardous Event	• ENS events trending as below • Key hazardous event trending as below
Pursue STPIS revenue where cost effective	8. Better than average performance of the STPIS measures: a. Transformer Fault and forced outage rates b. Reactive Plant Fault and forced outage rates	• STPIS measure trending as below

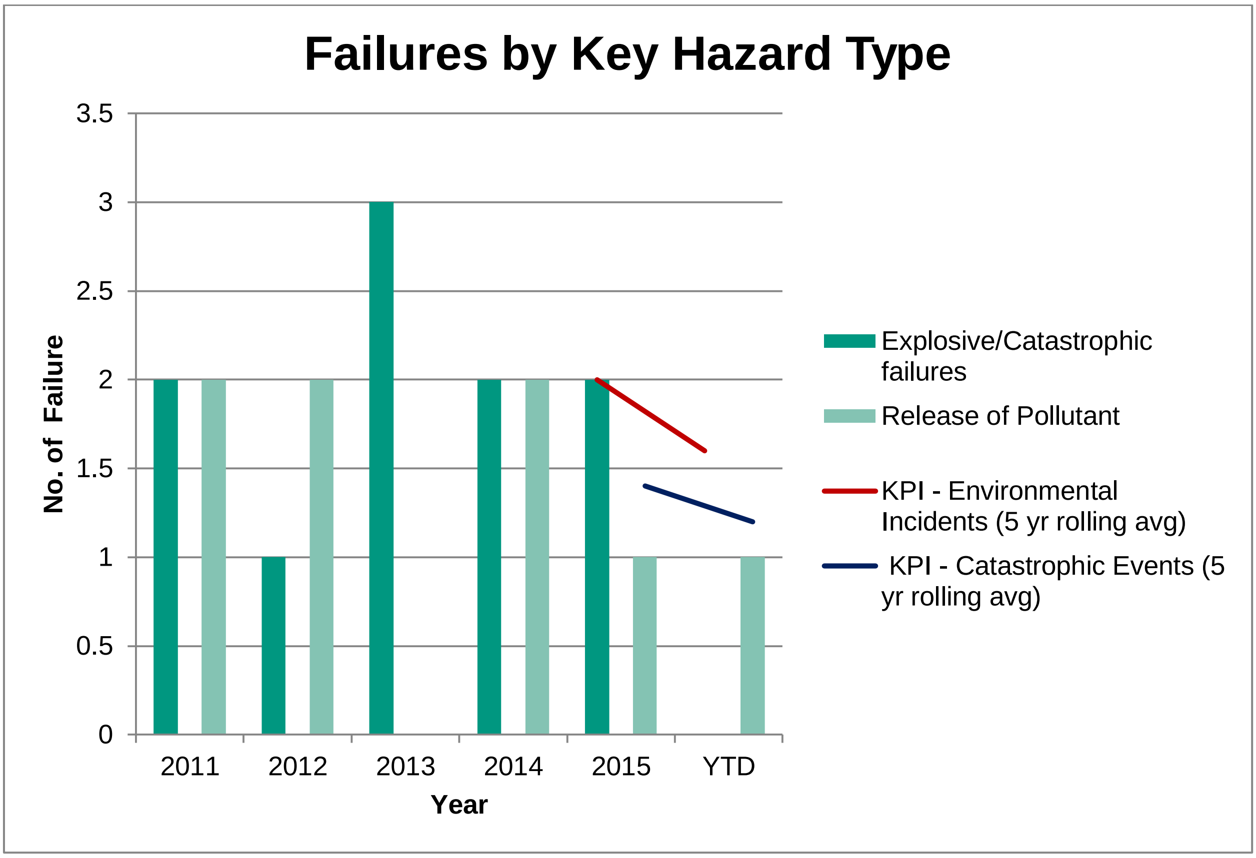
ENS events due to substation faults in the 2015 calendar year were above the 5 year average. The 2016 year to date performance is trending favourably to be below the 5 year average.

Figure 3: Asset Failures Resulting in ENS by Asset Class



Key Hazardous Events due to substation faults in the 2015 calendar year were in line with the 5 year average. The 2016 year to date performance is trending favourably to be below the 5 year average.

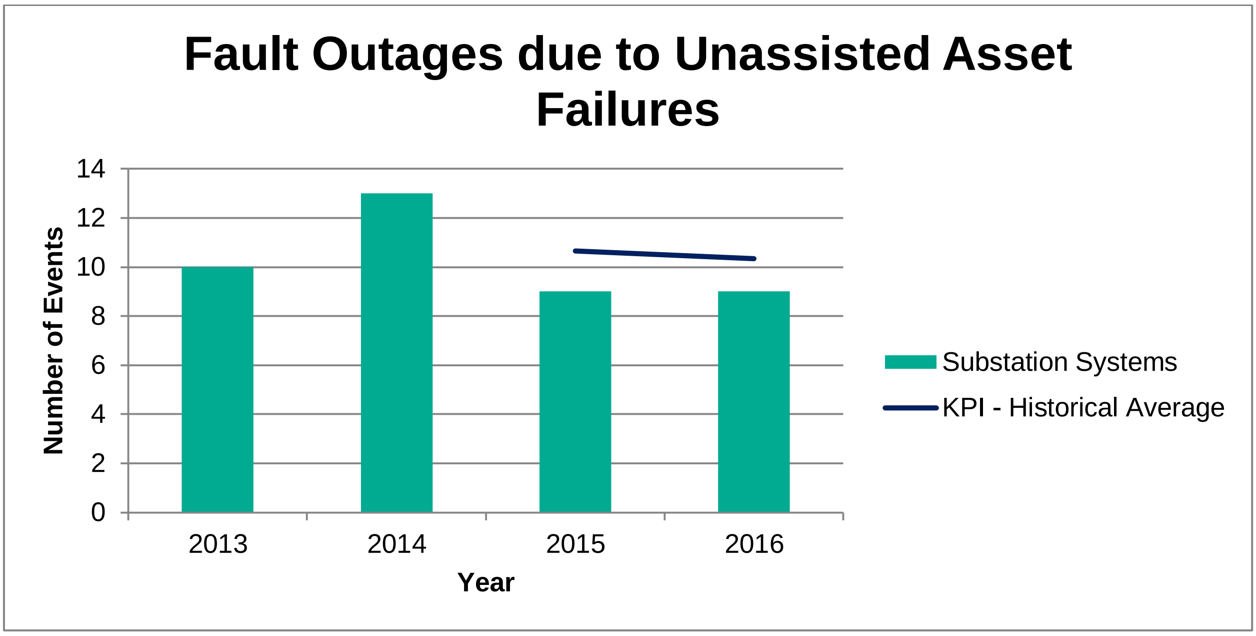
Figure 4: Failures by Key Hazard Type



Fault Outages event data due to Unassisted Asset Failures in the 2015 calendar year were below the historical average. The 2016 year to date performance is nearing the average, however is presently below the historical average.

Historical data for Fault Outage and Forced Outage events is limited to 2013; this window is relatively small however performance over this period is consistent.

Figure 5: Fault Outages due to Unassisted Asset Failures



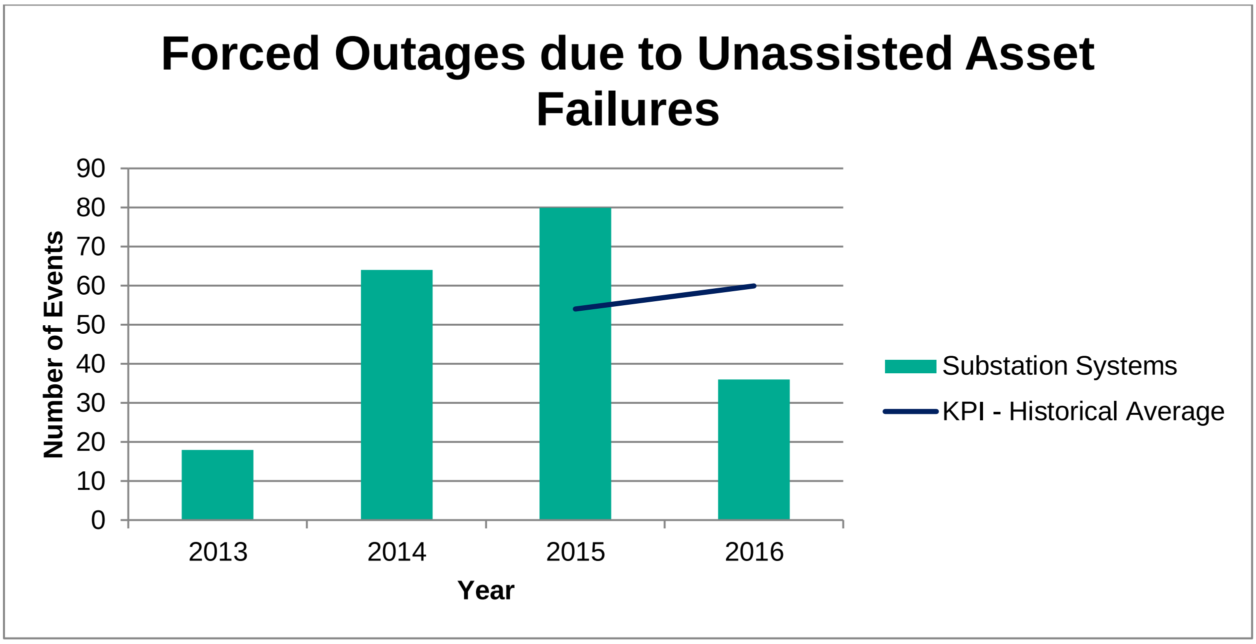
Note: Data is a subset of AER published RIN data.

Forced Outages event data due to Unassisted Asset Failures in the 2015 calendar year were above the historical average.

2016 year to date performance is trending favourably to be below the historical average.

Review of the contributing data shows a number of assets that are identified for replacement under existing and proposed renewal initiatives are targeted. As such ongoing implementation of the identified renewal initiatives is anticipated to progressively address the increasing Forced Outage event rate.

Figure 6: Forced Outages due to Unassisted Asset Failures



Note: Data is a subset of AER published RIN data.

6. Substation Asset Overview

6.1 Scope of Assets

The following assets are within the scope of this strategy:

- Primary plant
- Rigid and Flexible busbar and fittings
- Instrument transformers
- Reactive equipment
- Online condition monitoring
- Other ancillary equipment
- Basic site infrastructure
- Footings and Structures

The following assets are outside the scope of this strategy:

- Protection; metering; communication; DC and LV AC supplies; and control and substation systems are not included in the scope of this document – these are covered by the *Renewal and Maintenance Strategy*, the *Substation Automation Systems and Renewal and Maintenance Strategy*, and the *Telecommunications Terminal Equipment* documents.
- Buildings are managed by the Asset Manager – Property & Environment and are excluded from this document.

A breakdown of Substation equipment with an explanation of coverage under this strategy is included in Attachment 1 - Substation Asset Breakdown.

6.2 Asset Base

TransGrid has a total of 99 substations and switching stations within its network which operate at voltages from 132kV, 220kV, 330kV to 500kV. Six of these sites are negotiated and the remainder are prescribed. Their locations vary from coastal to rural, sub-tropical to dry-desert, sea level to high altitude, and corrosive locations to stable atmospheres.

Each substation or switching station contains a range of different plant and equipment. The substation assets included within the scope of this document are identified in Table 7.

Table 6: Substations Asset Base

Asset	Quantity	Description
Substation sites and associated site.	99 Sites	• TransGrid's substations are located throughout NSW, in climates which include coastal to rural, sub-tropical to dry-desert, sea level to high altitude, corrosive locations to stable atmospheres
Power Transformers	221	• Power Transformers power range from 30 MVA up to 1200 MVA • Power Transformers voltage range from 132kV to 500kV • Oil filled and SF6 filled.
Reactors	103	• Oil Filled Reactors up to 330kV • Air Cored Reactors up to 132kV • SF6 Filled Reactors up to 330kV • Series and Shunt Arrangement • Three Phase and Single Phase

Asset	Quantity	Description
Circuit Breakers	1560	• A range of circuit breakers across the network from 11kV up to 500kV. • SF6, Oil, Small Oil Volume, Vacuum types • Live Tank and Dead Tank types
Gas Insulated Switchgear (GIS)	4 Sites	• GIS sites ranging from 132kV up to 330kV • Several different manufacturers (ABB, Siemens, Alstom)
Instrument Transformers	6035	• Current Transformers and Voltage Transformers • SF6 and Oil insulated types • Voltages ranging from 11kV up to 500kV
Static VAr Compensators (SVC)	5	• A set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks.
Shunt Capacitors	119	• Shunt Capacitors ranging from 33kV up to 330kV
Surge Arrestors	2020	• Zinc oxide types across the network
Online Condition Monitoring	66 Sites	• Online condition monitoring (OLCM) deployed across the state. • Online monitoring of transformers, CBs, Instrument Transformers

The nominal lifespan of a substation varies depending upon its individual components, the operational characteristics of the site and the external environment to which it is exposed. The individual components can be broadly categorised as per Table 7 above. The nominal lifespans for substation components are provided in Table 8.

Table 7: Nominal Lifespan of Substation Components[1]

Component	Nominal Lifespan (years)
Power Transformers	45
Reactors	30
Circuit Breakers	40
Gas Insulated Switchgear	40
Instrument Transformers	40
Static VAr Compensators (SVC	20
Shunt Capacitors	25 – 35 Years
Surge Arrestors	40 Years
Online Condition Monitoring	10 – 15 Years
Ancillary Equipment	10 – 50 Years

[1] The Nominal Lifespan of Substation Components is provided as an input into the RIN to provide a long term forecast for asset renewal.

7. Substation Asset Review

This section details the current and emerging risks with the Substation assets, and the renewal and maintenance initiatives to be implemented to manage these risks. These are derived through the renewal and maintenance decision process outlined in the *Asset Management Strategy and Objectives* document.

All strategic initiatives with respect to TransGrid's Substation assets are outlined in this section, including the renewal and maintenance initiatives that contribute to the asset management program of works. Further details can be found in the relevant Substation Maintenance Plan, and the referenced governance documents.

7.1 Implementation of the Renewal and Maintenance Decision Process

TransGrid undertakes performance, cost, risk and compliance analyses to capture the range of current and emerging issues that are apparent with respect to individual assets and asset groups. The analysis takes into consideration:

- Population age profiling against nominal asset lifespan for long term planning;
- Asset inspection and condition assessments;
- Diagnostic testing – such as electrical, structural and oil testing;
- Failure mode;
- Failure and defect rates;
- Failure investigations;
- Maintenance program outcomes;
- Real-time asset information – through OLCM and the Asset Monitoring Centre;
- Asset Management Committees and working groups; and
- Information through the industry (manufacturers, peers etc.).

Once asset data and information is analysed, the asset manager will consider options and determine the most appropriate course of action to meet the Asset Management Objectives and address the issues and associated risks. The decision making process is described further in the *Asset Management Strategy and Objectives* document (refer to *Figure 1*) and in the *Prescribed Capital Investment Governance Arrangements* procedure.

Disposal initiatives are also developed through TransGrid's Network Investment Process. Disposal of goods and materials are managed in accordance with TransGrid's:

- *Grid Policy Disposal of Goods and Materials*
- Disposal Strategy as defined in the parent *Asset Management Strategies and Objectives* document

7.1.1 Health Index

With consideration of these factors, a Health Index (HI) has been developed under the *Network Asset Health Framework (NAHF)* in order to assess the condition of the population of each major asset classes, being Transformers, Reactors, Circuit Breakers and Instrument Transformers.

The Health Index is based on parameters such as chronological age, operation duty, condition monitoring results, defect frequency, defect costs, and known design issues. Parameters are selected for each asset class that are suitable for representing asset condition and then weighted based on their assessed relative impact on asset health. The resulting health index score provides a broad ranking of assets within the class.

A statistical model is then built for the asset class population to evaluate a calculated age for each asset from the Health Index score. A smaller number of assets are required to calibrate the statistical model and should be chosen from across the asset age and condition spectrum. The chosen assets require a more detailed condition assessment to be conducted in order to determine condition and remaining life.

The asset class population is mapped to the modelled curve to assess the condition adjusted remaining life and therefore the calculated asset age with reference to the technical asset life for the class.

The calculated age figures are compared to failure curves which are built from TransGrid and industry asset failure data (sourced from CIGRE) to evaluate the condition adjusted Probability of Failure (PoF) for each asset.

Finally, the evaluation of asset criticality provides an evaluation of the failure consequence (expressed as a cost), together with the PoF, providing an annualised risk cost for each asset based on condition. This tool is then used to identify assets for renewal consideration.

The remaining substation asset classes do not have Health Index methodologies created as there is insufficient data that is suitable for trending to assess condition. These assets are therefore assessed based on defect data and type issues with consideration of chronological age.

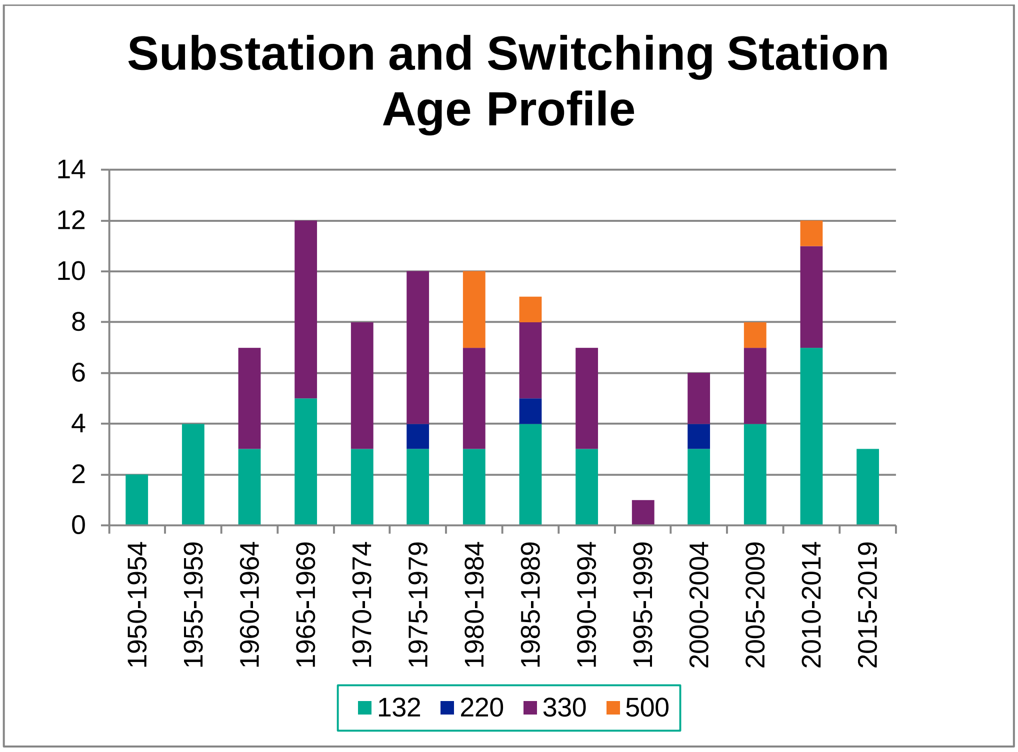
7.2 Substation Site Asset Review

7.2.1 Population Review

TransGrid has a total of 99 substations and switching stations within its network ranging in voltage from 132kV, 220kV and 330kV, to 500kV. Their locations vary from coastal to rural, sub-tropical to dry-desert, sea level to high altitude, and corrosive locations to stable atmospheres. Generally, the substations in coastal areas are more prone to accelerated deterioration.

The age profile of TransGrid's substations is illustrated below – where substations are separated by their voltage ranges from 132kV through to 500kV. It can be seen that 25% of TransGrid's substations and switching stations were commissioned before 1970, with the oldest commissioned in 1950 and the most recent in 2016.

Figure 7: Substation and switching station age profile



Asset health and obsolescence at a total population level is used to determine long term forecasts of asset replacement requirements and average age. Replacement decisions are based on an evaluation of equipment condition.

Factors that will affect the future substation age profile are as follows:

- *Ongoing Piecemeal Replacement*:

  Historically TransGrid has managed the end of life of substation equipment through strategic replacement or overhaul (where feasible) of plant items as issues have arisen with their reliability, performance or safety. Individual plant replacement assumes that the underlying infrastructure of a site is in sound condition.

For the affected locations, a blend of old and new equipment will result, with the substation infrastructure continuing to age at rates affected by the location.

- *Substation Reconstruction*:

  A total substation replacement is the preferred option where the asset renewal work scope is substantial enough to yield greater cost efficiencies in project delivery compared to piecemeal replacements. The total site establishment costs are reduced and in addition larger projects are more amenable to competitive tender.

  The three general approaches to substation renewal have been identified:

  - Entire substation replacement (could be adjacent, remote or overlapping);
  - Bay-by-bay replacement; and
  - Targeted package of work to address a wider than usual range of key substation issues at a single site in a coordinated way that exploits efficiency of scale.

- *Augmentation:*

  A need for network augmentation arises from changes to network demand such as load growth that exceeds the capacity of a substation or elements within it.

  Network planning developments are considered when renewal initiatives are evaluated, and similarly opportunities to package asset renewal needs are considered during the evaluation of the augmentation need. This can result in the construction of new substations to meet network and load requirements.

- *Negotiated and Unregulated Assets:*

  This will result in the construction of new substation bays and in some cases new substations due to new generator, load or other network assets. These sites are not covered under this strategy.

The renewal of substations and substations equipment, together with the creation of new assets will have impacts on the technology installed within the network. Continuous development of high voltage substation equipment and design standards offer improvements to asset performance with the use of state of the art technology available at the time of asset renewal. Improvements include:

- Improved safety performance (e.g. move to polymer insulators)
- Improved environmental performance (e.g. move to small oil volumes and use of SF_6)
- Reduced preventative maintenance requirements and costs (e.g. longer maintenance time intervals)
- Reduced capital expenditure and asset risk (e.g. need for separate post CTs removed with integration into dead tank circuit breaker utilising toroidal CTs)
- Increased integration of digital control and monitoring technologies which replace outage based preventative maintenance
- Where substation reconstruction is required in a space constrained location, increased use of compact switchgear (GIS) will be required to achieve reconstruction

7.2.2 Emerging Issues, and Renewal and Maintenance Initiatives – Substation Site

The factors that taken together are significant in determining a need to take broader action at a particular substation site are detailed in each of the substation areas reviewed in the remainder of this document. However, general issues that may have an impact on a decision to reconstruct a substation site are as follows.

7.2.2.1 Compliance Requirements

Substations are designed and constructed to meet the regulatory requirements and design standards that are in effect during the project development and construction phase of the project. Throughout the life of the asset, development of design standards, improvement of work practices, and changes to regulatory requirements will result in compliance issues.

Each situation is assessed on its individual circumstances, whether it affects an individual asset or substation, or a group of assets or substations.

The significant issues that have been identified as potentially putting TransGrid in breach of its regulatory compliance requirements are as follows:

- Mobile plant access: Current safe work practices require access using mobile plant (e.g. elevating work platforms, cranes). Early substation designs assume ladder access and allowing for mobile plant access has impacts on bench, drainage design and safe physical access for the mobile plant.
- Cable trench design: Older designs incorporating drainage with the cable trench are prone to cable damage by rodents. Damaged cables represent a risk to staff and network reliability.
- Environmental pollution: Environmental design standards have increased since the construction of many substations requiring improvements to pollution control measures such as oil and noise containment.
- Design clearances: Electrical clearances at some substations are identified as not meeting current design standards. A review of the asset base is required, followed by a work program for corrective action.

7.2.2.2 Asset Health and Obsolescence

Wide spread deterioration of asset health within a Substation is a driver for consideration of a site wide substation renewal initiative such as a substation reconstruction:

- HV assets at a substation will typically decline in condition at a similar rate. Individual assets with poor health have an increased failure risk which will reduce the reliability of an element within a substation, however wide spread declining asset health across an entire site greatly increases the probability of failure and risk of cascading failures.
- Substation infrastructure is presenting signs of declining condition approaching end of life in the older substation population and includes infrastructure at substation sites where piecemeal asset renewal works have been undertaken. These substation components are more difficult to replace in a piecemeal fashion and have longer asset lives than HV assets.

The technology used in these substations has also shifted over time and support/expertise may be no longer available.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 8: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Substation Sites Compliance Requirements	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Suitability of existing substation design and layout to meet functional requirements and comply with evolving design standards • Suitability of new substation design and layout to meet functional requirements and comply with evolving design standards	Ongoing review of Substation functional specification and design standards.	**Ongoing**	Substation Design Manual
Substation Sites Compliance Requirements – Electrical Clearances	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) •	• Existing substation assets built to historical design standards may not meet safe approach distances specified in the Power System Safety Rules.	**Operational Initiative:** Substation Laser Survey of all sites. This initiative is anticipated to generate additional work packages for corrective works as they are identified.	**RP1** Underway PC 30/12/17	Need No: 1605
Broken Hill 22kV Switchyard	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• A majority of the 22kV switchyard HV assets are identified for replacement through existing and proposed renewal initiatives. • A secondary systems renewal has been identified based on declining asset condition at site.	**Renewal initiative:** Primary and Secondary Systems replacement to be completed addressing the emerging.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1193

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Yanco 33kV Busbar Clearance	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability	• The 33 kV bus at Yanco Substation does not meet TransGrid Design Safety Clearances and does not meet clearances required under AS2067 at 33 kV busbar earthing stirrups.	**Renewal initiative:** Raise the existing busbar Replace Section 2-3 busbar with flexible connections.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1606
Newcastle Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled access to sites • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Reviewing renewal options. Critical assets within piecemeal business case have been replaced under other projects.	**RP1 - Closed**	Need No: 74 Project No: P0004220
Forbes Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability	• Explosive failure of primary plant. • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Reviewing renewal options. Scope is reduced to replacement of selected assets and included in other relevant asset based renewal initiatives	**RP1 - Closed**	Need No: 196

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Tamworth 132-66kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Substation rebuild on adjacent site	**RP1 - Completed** PC: 8/7/16	Need No: 81 Project No: P0001217
Burrinjuck 132-11kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Uncontrolled access to sites • Fires under or in proximity to transmission lines and/or substation sites • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Scope of renewal currently being reassessed.	**RP1** Undergoing scoping PC: est. Q3 2019	Need No: 128 PSS-0502
Wagga 132-66kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled discharge or contact with electricity • Contamination /pollution by	**Renewal initiative:** Substation rebuild on existing site	**RP1 - Underway** PC: 30/11/16	Need No: 134 Project No: P000950

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high. • Failure of major steelwork.			
Yanco 132-33kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Substation rebuild on existing site	**RP1 - Complete**	Need No: 138 Project No: P0000958
Orange 66kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled discharge or contact with electricity • Safe working access to equipment is impeded. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Substation rebuild on existing site	**RP1 - Underway** PC: 30/4/17 Delayed by the discovery of asbestos in the new switchboard building.	Need No: 208 Project No: P0000998

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Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Improve OPEX Performance				
Cooma 132/66kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Substation rebuild on adjacent site	**RP1 - Complete**	Need No: 209 Project No: P0001649
Vales Point 330-132kV Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** • Replacement of secondary systems • Replacement of all primary plant in the 1-4 330kV switchyard • Targeted asset replacement of plant in the 5-6 330kV switchyard and 132kV switchyard • Repair of the existing drainage • Demolition and disposal of redundant plant and equipment	**RP1 - Underway** PC: 22/5/18	Need No: 231 Project No: P0001002

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Canberra Substation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Explosive failure of primary plant. • Secondary Cable fault defect • Uncontrolled discharge or contact with electricity • Contamination /pollution by oil/chemical spillage SF6 leak etc. • Noise issue with near neighbour. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Piecemeal replacement works	**RP1 - Underway** PC: 12/8/19	Need No: 238 Project No: P0001099
Munmorah 330kV Substation Condition	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Structure fall over. • Explosive failure of primary plant. • Defect rate unmanageable • Failure risk is high.	**Renewal initiative:** Piecemeal replacement works	**RP1 - Underway** PC: 30/7/18	Need No: 269 Project No: P0000789
Beaconsfield Redevelopment Stage 2	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related	• Transformer condition – as final stage of substation reconstruction.	**Renewal initiative:** • Replacement of No.1 & No.2 Transformers • Replacement of No.1 Reactor • Removal of existing 132kV GIS	**RP1 - Underway** PC: 31/12/17	Need No: 53 Project No: P0001197

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance				
Sydney East 330kV Substation – 330kV Switchgear Holding Down Bolts	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Maintain network reliability • Improve OPEX Performance	• Corrosion of holding down bolts and support structures reducing strength and stability of the structure.	**Renewal initiative:** Piecemeal replacement of structures and holding down bolts.	**RP1 - Complete**	Need No: 495
Taree Substation 33kV Switchyard Condition	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Manual handling issues • Defect rate unmanageable • Failure risk is high. • Contamination /pollution by oil/chemical spillage SF6 leak etc.	**Renewal initiative:** Included with Secondary Systems Replacement project works	**RP1 - Underway** PC: 29/6/18	Need No: 531 Project No: P0000877

7.2.3 Maintenance Program – Substation Sites

Component failure risk analysis is performed on existing equipment to develop a complete maintenance plan in the aim of improving and sustaining the reliability of the asset and the management of asset risk.

The maintenance initiatives directly drive the routine maintenance regimes which are detailed within the Substation Maintenance Plan.

Substation site maintenance is implemented through a series of substation inspections. The inspection schedule is as follows:

- 6 monthly inspections
- 12 monthly inspection with additional checks added
- 12 monthly thermo-vision inspection

The following refinements to the Maintenance Plan have recently been implemented:

- A reduction in substation Inspections.
- An increase in maintenance intervals (discussed further within each asset class).
- Removal of fire hydrant maintenance including fire pumps and water valves (hydrants to be decommissioned)
- Non HV network property costs – reallocated to Substation and Radio Repeater Sites Facility Maintenance Plan

Details are included in D2016/10417 – Asset Management Instruction AMI AS0001 Maintenance Plan Amendments July 2016.

7.3 Infrastructure Asset Review

7.3.1 Population Review - Infrastructure

There are a range of assets forming part of a substation infrastructure that are required to perform well in a successfully functioning substation. This includes:

- Site surrounds (buffer areas, roads etc)
- Civil infrastructure (major steel, drainage, cable trenches, footings, walls, bench design etc)
- Buildings and amenities
- AC supplies
- Lighting
- Cabling
- Oil containment and drainage
- Earthing systems
- Internal roads
- Fire systems

The design and condition of the infrastructure required to operate substations varies with the time of its construction and environmental factors.

7.3.2 Emerging Issues, and Renewal and Maintenance Initiatives – Infrastructure

Significant issues affecting Substation infrastructure include:

7.3.2.1 Steelwork - Corrosion

Corrosion will become an important issue in substations particularly those located near the coast, industrial areas or inland bodies of water, and those built in the 1960's. Surface rust is becoming obvious on galvanised steel surfaces and fasteners (bolts and nuts) are failing progressively. There are cases of localised corrosion – most particularly on gantry and switchgear structure holding down bolts – that if left untreated, will lead to failure of the structure.

Major and minor steelwork supports overhead strain conductors (gantry structures), rigid and flexible busbars, and equipment and plant. Of greatest concern is the major steel used to support overhead strain conductors and strung busbars. These cannot easily be treated, painted or replaced due to the outages required to access them. Failure of these structures would have a major impact on the substation and will present unacceptable reliability and safety risks in the longer term.

There are three identified issues affecting substation steel:

- Corrosion at ground level affecting holding down bolts and structure base plates. This can occur due to localised problems including for example: poor grouting materials or application; poor grout in combination with incorrect routing of the earth strap can acerbate corrosion; poor design leading to collection of silt and grit or pooling of water.

  The resulting corrosion will lead to loss of strength and ultimately to failure of major steel structure(s) in a substation. The resulting failure would have major impacts on the substation and is expected to be difficult to repair.

- Corrosion of fasteners may occur in advance of corrosion of steel members in a lattice structure (most sites affected by corrosion have this type of construction). This arises due to way in which nuts and bolts are made. Nuts are pressed and a thread is cut. The galvanising is not as thick as on the steel members forming part of a lattice structure.

  The result is that nuts may 'blow' off ahead of major corrosion of steel members and lose all strength. Replacement is the preferred strategy but this requires a stage approach, particular weather conditions, bracing, and/or outages.

- Corrosion of the steel members in a lattice structure is a final issue. Lattice structures were specified with a galvanising layer that would permit a life of up to 40 years in a coastal environment. When the galvanising layer has been consumed, the underlying steel will corrode at an increased rate. Erosion of the galvanising layer may not be even across a structure and exposed sections or those with thinner galvanising layers will be affected first.

  Once galvanising has been consumed across a gantry, options to treat are limited. In situ replacement of major steel is not likely to be easily feasible. Treatment and painting may be possible but would need to be applied prior to major corrosion occurring, is likely to require outages of multiple system elements and does not provide the same level of protection against corrosion as galvanising. Site reconstruction is the remaining option, but should be avoided by earlier intervention

The high cost of replacing the major substation steelwork places a greater emphasis on adequately monitoring the steelwork condition. The data collection requirements of steelwork inspections have been clarified in the Substation Maintenance Plan and further improvements in this process will be implemented.

7.3.2.2 Insulators and Other Fittings

In a similar group of substations, insulator strings used to support overhead strain conductors are often of unknown type but are suspected to be of a type retired from transmission lines due to concerns regarding reliability. This is of less concern in this application because of the much smaller mechanical loads but represents and increased risk factor and may lead to failure with further deterioration.

The above is complicated by corrosion of the pin and sockets of the insulators strings and of other fittings used to attach equipment to steelwork.

Failure of these insulators and fittings will result in safety risks to personnel, extensive outages and damage.

The requirements for the inspection of insulators and fittings is included to ensure the ongoing monitoring of these assets and rectification where required.

7.3.2.3 Switchyard Surface - Grass in Switchyards

A number of substation sites constructed in the 1960's do not have gravelled switchyards and this has the following issues:

- Grass-cutting is necessary and this normally requires that contractors be employed to cut the grass on ride on mowers. This has inherent risks in using contractors with relatively low levels of HV knowledge throughout switchyards. There are (managed) risks to the personnel carrying out the work; and to equipment. A common example has been damage to earth grid straps caused by the mowers.
- Rabbit damage to control cabling has been a serious issue at some sites and it is thought that the presence of grass in the switchyard provides a source of food to sustain even those rabbits trapped inside the switchyard by meshing installed on the substation perimeter to reduce rabbit impact.
- Rabbits can also burrow within grass switchyards which can present a safety hazard for staff onsite. These are managed through the defects process.
- Gravel provides an additional level of safety from step and touch potential risks due to the extra resistive layer that it provides.

Where other significant work is planned on a grassed site, conversion of grassed areas to gravelled is included in project planning if feasible.

7.3.2.4 Oil Containment

Older oil containment systems fitted to power transformers and oil filled shunt reactors were often based on a fixed non-draining bund. This type of containment system may delay the release of oil to the environment, allowing time to introduce additional measures, but ultimately is expected to fail. Direct damage may occur to the bunds during the failure leading to oil release and fire and after exposure to heat, the bund is expected to fail.

The transformer brickwork bunds used are inherently not oil tight due to the original construction method and the effects of aging.

The addition of firefighting water or foam may result in oil overflow of the bund wall.

A small number of cases exist where increased risk is seen for other reasons.

Oil containment systems at older sites have been progressively addressed to reduce risk exposures to acceptable levels. This has been undertaken in the course of transformer/reactor replacement projects or in separately justified projects. A small number of sites remain to be further considered under the risk based design guidelines.

7.3.2.5 Cable trenches

Older brick type cable trenches also provide subsoil drainage under the cable tray. These trenches have the following issues:

- Deterioration of brickwork mortar and damage from traffic leading to collapse. This may be complicated by plastic/reactive soil types.
- Exposure to damage by rodents from below.

At least two major control cable fires with severe impacts on the affected substations have occurred due to a combination of rabbit damage and the routing of large capacity 415 V supplies together with control and protection wiring. Design standards have been altered to require separation of major AC supplies from control and protection cabling.

At older sites, cable trenches are becoming overfull at pinch points such as immediately prior to entry to the control building and at Sydney North, Sydney South and Dapto substations, large cable basements present a point of possible single point failure for the site in the case of a cable fire.

7.3.2.6 Earthing Systems

Earth Grid design standards and techniques have matured significantly since the construction of many original sites. A design review is required to be completed 30 years after commissioning, the completion of these surveys is anticipated to identify defects due to insufficient original design and age related deterioration; a package of works will require development to address the identified defects.

Earthing systems on older substation sites can be affected by the following:

- Increased fault level due to additional connections leading to levels beyond the original design fault level
- External influences causing transferred voltages (eg: fences or pipes coming on to the site)
- Damage to earth grid conductors caused by excavation associated with works on the site.
- A number of 132 kV sites use steel stakes as a component of the earthing system and these may corrode below ground.

Modern design methods for earthing systems rely on detailed information on grid construction, soil resistivity models and detailed performance test data. This is not complete for some older sites.

7.3.2.7 EMF Performance

Incomplete information exists for EMF performance of older sites. There is no evidence for health impact from the electromagnetic field levels normally experienced in accessible areas of TransGrid's substations, however development of appropriate EMF substation models and analysis is required.

7.3.2.8 Asbestos

Asbestos surveys have been conducted at all TransGrid substation sites and where possible, the substance has been removed. Some amounts of bonded asbestos remain where it is stable and safe and is not feasible to remove. This is included in a register and is monitored and maintained. Where opportunity arises in major works, the material is removed.

7.3.2.9 Other building and Infrastructure Issues

Each of TransGrid's substations and switching stations include a control room building, which vary in size from a small single-level house sized building to large multi-level establishment. These buildings generally contain a relay room, battery room, communication room, amenities room and workshop. For new installations of secondary equipment, prefabricated buildings have been used to house the control, protection and metering equipment.

Sites also contain fencing, roads, drainage systems, landscaping, environmental buffer zones and other services, which need to be kept in good order.

Current and emerging issues related to substation buildings and site infrastructure includes:

- Degradation or ineffective design of drainage systems.
- Degradation of road systems.
- Changed requirements for lighting or deterioration of light fittings.
- Building defects such as roof leaks, footing issues.

Issues with property, buildings and site infrastructure are identified through substation maintenance and inspection activities. Minor issues can be addressed through the defect management system (i.e. defect maintenance).

Building and property issues are included under the Substation and Radio Repeater Site Facility Assets Renewal and Maintenance Strategy.

7.3.2.10 High Voltage Cabling

Switchyard cabling at 66 kV and above is covered in the Cable Renewal and Maintenance Strategy. However, cables from 11 kV up to 66 kV are used in substations to connect auxiliary transformers, to connect capacitor banks and as part of feeder connections.

The older generation of these cables are typically MIND (mass impregnated non draining) paper cables with lead sheathing. The serving on these cables can be deteriorated and sealing end connections may deteriorate due to weather exposure and ageing. Replacement may become necessary for ongoing reliability.

7.3.2.11 Transformer Hebel Walls

Hebel panel walls are installed around some transformers to reduce sound levels and ensure that fire does not spread between assets. Previous generations of Hebel panel fire walls have result in some panels being insufficiently secured and has resulted in sections of wall falling down. This results in a safety and reliability risk due to the potential of the panels to strike a person or another asset.

7.3.2.12 Concrete Footings

Concrete footings for substation gantries and switchgear are essential to the essential to the required capacity and function of the asset they support.

The gantry footings at Upper Tumut are subjected to stress due to repeated freezing and thawing due to the local climate. The condition of the footings is deteriorating and there is a risk that the footing will become irreparable.

7.3.2.13 Substation Flood Risk

Previous instances of flooding, or close to flooding, at TransGrid substations indicates a risk of flooding. Flooding of a substation may cause damage to HV and LV assets and have network reliability impacts. The risk of future floods should be quantified and compared options to reduce the risk.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 9: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Murray and Lower Tumut 11kV Switchboard Replacement / refurbishment	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability	• Type faults due to previous explosive circuit breaker failures in other organisations • Interrupter contact resistance of existing oil filled circuit breakers is increasing beyond acceptable limits • These circuit breaker types are no longer supported • The existing circuit breakers have asbestos arc chutes on the control circuit breakers (110V). • VTs used for meeting do not comply with accuracy requirements	**Renewal initiative:** Replace/refurbish 11kV switchboards at MUR and LT1 as follows: • Install blast panels; • Replace VT's and; • Replace Oil Filled Circuit Breakers	**RP1 - Complete**	Need No: 248/538
Gantry Steelwork, holding down bolts and fasteners: • Sydney East • Sydney North (earth wire peaks) • Sydney South • Albury • Dapto • Tomago • Hume • Wagga 132kV (only steelwork not previously addressed)	• Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	• The gantry steelwork at a number of sites is approaching the end of its life due to the loss of protection (galvanising and/or painting) and is required to be addressed • Fasteners are losing strength in increasingly quantities and require replacement • The construction of holding down bolt interfacing is leading to corrosion of the bolt and base plate.	• The steelwork will be addressed through painting of steelwork, replacement of fasteners and treatment of holding down bolt and grouting interface.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1358

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
• Upper Tumut					
Upper Tumut Gantry Footings	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	• The gantry footings are significantly degraded due to repeated freezing and thawing and potentially inferior construction methods.	• The gantry footings will be treated along with the steelwork to ensure sufficient remaining life.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1358
Sydney East Substation 132kV equipment HD bolts	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability • Improve OPEX Performance	• Similar to the other steelwork assets at Sydney East, the 132kV substation equipment holding down bolts are severely corroded and require rectification to ensure sufficient remaining life.	• Rectification of equipment HD bolts	**RP1** Due to commence in 2016/17 PC expected 2017/2018	Need No: 1300
Oil Containment - Beryl	• Minimise environmental harm and property damage	• Brick bunds may leak in the event of a major transformer failure. • Primary containment is insufficient to fully reduce risk to environment in event of major transformer failure.	Upgrade containment system: • Repair existing transformer bunds • Install new primary containment tank • Install new spill oil pipework	**RP1** Due to commence in 2016/17. PC expected 2017/2018	Need No: 462

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Oil Containment – Mount Piper 132	• Minimise environmental harm and property damage	• Brick bunds may leak in the event of a major transformer failure. • Primary containment is insufficient to fully reduce risk to environment in event of major transformer failure.	Upgrade containment system: • Repair existing transformer bunds • Install new flame traps • Install new primary containment tank • Install new spill oil pipework	**RP1** Due to commence in 2016/17. PC expected 2017/2018	Need No: 468
Oil Containment - Deniliquin	• Minimise environmental harm and property damage	• Brick bunds may leak in the event of a major transformer failure. • Primary containment is insufficient to fully reduce risk to environment in event of major transformer failure.	Upgrade containment system: • Repair existing transformer bunds • Install new primary containment tank • Install new spill oil pipework	**RP1** Due to commence in 2016/17. PC expected 2017/2018	Need No: 464
Oil Containment - Murrumburrah	• Minimise environmental harm and property damage	• Brick bunds may leak in the event of a major transformer failure. • Primary containment is insufficient to fully reduce risk to environment in event of major transformer failure.	Upgrade containment system: • Repair existing transformer bunds • Install new flame traps • Install new primary containment tank • Install new spill oil pipework	**RP1** Due to commence in 2016/17. PC expected 2017/2018	Need No: 465
Oil Containment - Muswellbrook	• Minimise environmental harm and property damage	• Brick bunds may leak in the event of a major transformer failure. • Primary containment is insufficient to fully reduce risk to environment in event of major transformer failure. • Current pipework is plastic and may fail in event of major transformer failure.	Upgrade containment system: • Repair existing transformer bunds • Replacement existing pipework • Modify existing primary containment tank to increase capacity	**RP1** Due to commence in 2016/17. PC expected 2017/2018	Need No: 466

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Oil Containment - Inverell	• Minimise environmental harm and property damage	• Brick bunds may leak in the event of a major transformer failure. • Primary containment is insufficient to fully reduce risk to environment in event of major transformer failure.	Upgrade containment system: • Repair existing transformer bunds • Install new flame traps • Install new primary containment tank • Install new spill oil pipework	**RP1** Due to commence in 2016/17. PC expected 2017/ 2018	Need No: 475
Oil Containment Clean Out	• Minimise environmental harm and property damage	• The effectiveness of existing oil containment systems may be limited due to significant weed growth in dams or siltation in containment tanks.	• Review condition of existing systems and prioritise discrete maintenance projects as required.	Not yet commenced. Estimate: Not yet prepared.	Need No: 1680
Transformer Hebel Walls	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability	• The existing Hebel type transformer fire walls are not fixed sufficiently and may fall.	• Identify and rectify poorly designed walls to ensure secure fastening of all sections.	Planned to commence in 2016/17. Estimate not yet prepared.	Need No: 1668
Ingleburn Flood	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability	• Ingleburn substation experienced minor flooding June 2016. Some issues with adequacy of the building compound deluge pumps and the existing drainage system have been identified and should be rectified.	• Identify and rectify the site issues in order to improve the reliability of the site during flood events. Scope is dependent on determining likely reoccurrence of flooding.	Potential for RP1 or RP2 depending on scope developed. Estimate not yet prepared.	IWR0106
Darlington Point Flooding	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability	• Flooding in 2012 almost resulted in operation impact and a review of the site has identified areas which may need to be addressed in order to eliminate the risk of future flooding.	• Identify and rectify the site issues in order to improve the reliability of the site during flood events.	Potential RP2 project. Estimate not yet prepared.	Need No: 1597

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Earthing Systems	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Maintain network reliability	• A number of substations have not had earthing system tested and may have unknown risks due to unsafe Earth Potential Risk (EPR).	**Operational Initiative:** Earth Grid assessment to be completed at 36 nominated sites. • This initiative is anticipated to generate additional work packages for corrective works as they are identified.	**RP1 - Underway** PC 30/6/17	Need No: 1638
Substation Sites – EMF levels within switchyards.	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	• Confirmation is required that EMF levels are within safe levels.	**Operational Initiative:** Desktop survey of sites.	**RP1 - Underway**	

7.3.3 Maintenance Program - Infrastructure

Maintenance for site infrastructure is largely defect based and depends on review and rectification of defects raised during substation inspection activities. These include:

- General substation inspections
- Steelwork inspections
- Oil containment inspections
- Earthing system inspection and testing

7.4 Transformer Asset Review

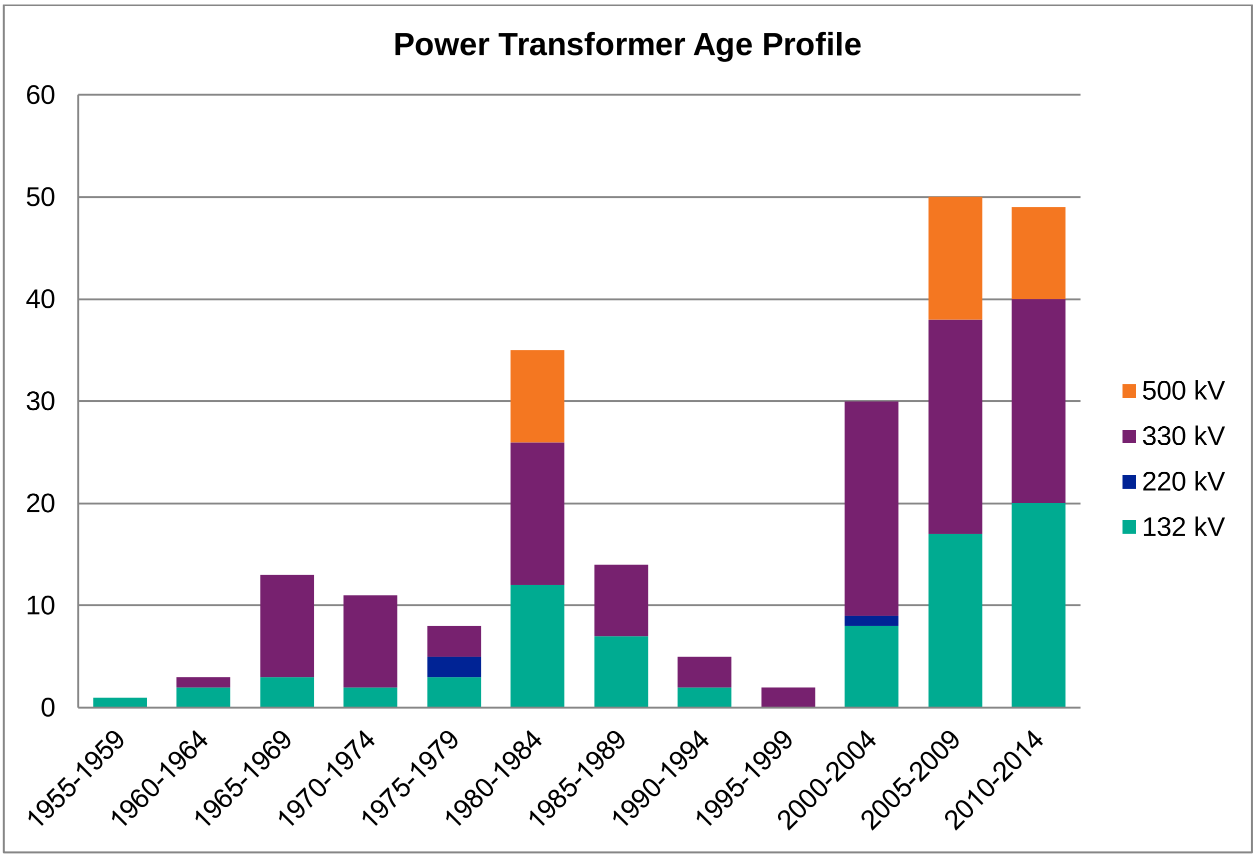
7.4.1 Population Review - Transformers

TransGrid's power transformer population is comprised of 221 individual units. Of these:

- 70% are rated above 100MVA with a primary voltage of 132kV or higher.
- 24% are single-phase units.
- 86% of three phase equivalent transformer installations have on-load tapchangers.

The power transformer age profile is shown in Figure 3. It shows that 9% were commissioned before 1971, and have thus exceeded their nominal lifespan of 45 years. Some of the oldest units were manufactured in 1955. The average age of TransGrid's transformer fleet is approximately 20 years.

Figure 8: Power transformer – age profile



7.4.2 Emerging Issues, and Renewal and Maintenance Initiatives

As power transformers are generally the most expensive single item of substation plant, significant maintenance and monitoring attention is directed to them and hence these plant items have the most comprehensive set of condition data.

TransGrid has a transformer health index based on the available data that is used to identify those transformers with the highest risk of failure. Using this information as a guide, detailed condition assessments are prepared for a broad range of higher risk transformers, which are then analysed to determine the need for corrective action. The analysis takes into consideration:

- Population age profiling against nominal asset lifespan.
- Other service history information such as tapchanger history and operations
- Physical condition (eg: leaks, paint condition, corrosion etc).
- Diagnostic testing results – such as electrical, structural and oil testing – main windings and bushings
- Type issues.
- Failure and defect rates.
- Failure investigations.
- Maintenance program outcomes.
- Any on-line condition monitoring equipment available and the data it provides.
- Criticality

Issues may develop with the condition of power transformers and oil filled reactors that may limit their life or affect their reliability. Of the known, current and emerging issues – the following general condition issues have been identified:

- Accelerated deterioration of insulating paper quality - excessive paper moisture content, oil acidity and oxygen content are factors that will promote the chemical reactions and lead to rapid deterioration of paper strength.
- Combustible gases in oil – high levels of dissolved volatile gases in oil samples are an indication of abnormalities which may lead to the development of a significant internal fault
- Tap-changer condition or type faults – Tap-changer failure (particularly diverter switches – which result in total failure of the TX) have been responsible for around 37% of TransGrid's major transformer failures in the available records. Particular issues are:
    - The development of silver sulphide on the silvered contacts of selector switches on some transformers is an emerging issue. This problem may be related to corrosive compounds in oil created in the process of Fuller's earth treatment of oil in past refurbishment works. The problem was found during internal inspection made in the course of transformer refurbishment.
    - If the development of silver sulphide is allowed to progress without interruption, pieces of conductive silver sulphide may lead to a rapidly developing internal fault and transformer failure.
    - Cleaning of contacts has been completed where the problem was found in refurbishment. Options to identify and treat affected transformers are being investigated.
    - A small number of transformers have been found with anomalous winding resistance results through the tapping range. These results have been improved by repeatedly running the tapchanger through the tap-range. The affected transformers typically only operate in a narrow tapping range. Internal inspection will be required for at least one of these transformers to determine the underlying cause.
    - Leaking tap-changer barrels – Certain tap-changer diverter switches have been manufactured with insufficient sealing between the main transformer tank diverter switch tank oil volumes. The resulting cross-contamination results in abnormal levels of dissolved gases in the main tank, obscuring any effective DGA – which remains our key diagnostic tool.

  - Carbon contamination has also been noted in transformers with leaking tapchanger barrels. This has the potential to shorten the life of transformers due to the unpredictable effect of quantities of carbon inside the main transformer tank.
  - Diverter switch failure due to failed components or differential wear of contacts.

- Bushing failures - Bushing failure has caused approximately 39% of major transformer failures in TransGrid's records, an issue which is compounded by a lower nominal lifespan for bushing insulation systems than that of the transformer in which they are installed.

  There are some significant issues that have been identified with respect to transformer bushings:

  - Oil Impregnated Bushings (OIP) are sealed with gaskets which are susceptible to failure through brittleness brought on by age and weather exposure. Entry of even a very small amount of water into the small oil volume of a bushing will eventually lead to explosive failure - and could be expected to result in the catastrophic failure and loss of the associated transformer through fire.
  - A model of 132 kV OIP bushing fitted to 23 recently supplied 330 kV 375 MVA transformers has been identified as suspect, likely due to a manufacturing or design defect. Two bushings with well-developed faults that would have led to failure have been detected by on-line monitoring systems, narrowly averting explosive failures that would have resulted in the loss of the associated transformer. The bushing failures were characterised by extensive internal carbonisation damage, found when the bushings were stripped. Additional monitoring of these bushing types using oil sampling/Dissolved Gas Analysis has found possible signs of developing failure in a further 7 bushings. All of these bushings are being replaced. There are 8 sets left to be replaced by end of FY17/18.
  - Micafil Synthetic Resin Bonded Paper (SRBP) bushings have been identified as a type with a potentially higher risk of failure due to a known mechanism. Delamination of the bonded paper layers comprising the insulation system (thermal cycling issue) can lead to partial discharge activity and breakdown of the primary insulation. TransGrid have removed all 330kV bushings of this type, but have 42 which remain in-service at 66 kV and 132 kV only. Approximately 170 of these bushings are either being directly replaced based on condition assessment, or will be removed from service with transformer renewal.

- Corrosion – Failure of paint systems will lead to corrosion of the tank, pipe work, radiators and fittings. This can result in mechanical failure of the main tank wall, leading to oil leaks and moisture ingress. Radiators are particularly vulnerable due to the thin cross-section steel walls used in coolers (for effective heat transfer).
- Paint system deterioration - Some recently supplied major transformers have paint systems that are already showing signs of deterioration after less than 5 years of service. The problem appears to be related to a defect in the paint system used by one major transformer supplier only. Repainting is being planned.
- Oil leaks – Gaskets on transformers may become brittle with age and exposure and fail. Chronic oil leaks result in pools of oil around the transformer, which present a fire risk. Leaks are a source of water entry. Chronic leaks may result in contamination of the ground around the transformer with commensurate potential environmental issues.
- Oil contamination – Oil may become contaminated with particles or other materials and this will affect dielectric performance.
- PCB contamination – Some TransGrid transformers remain with low levels of PCB. However, in the event of a failure involving fire and oil release there may be repercussions and reputational impacts to the organisation due to the high profile of the chemical, regarding the potential for environmental damage.
- Worn ancillary components – in particular fans and pumps. Full transformer rating is only available with all fans and pumps in good condition.

A small number of site specific issues exist that result from isolated specific issues. These are analysed and site specific plans are prepared.

The following planning issue has become an issue with the implementation of the transformer refurbishment plan:

- Two transformer rural sites may not have sufficient backup capacity to accommodate a long transformer outage with an extended emergency return to service time. This occurs where a midlife refurbishment or major overhaul is required. The problem is most significant if a dry out is required as this greatly extends the recall time.

Where it is considered that a transformer or reactor has unacceptable risk, a Need is documented and options are developed and evaluated in accordance with the corporate governance process. The course of action is generally to either: observe the asset; undertake maintenance or modification; replace; or dispose of the asset.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 10: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Transformer and Reactor Bushing Replacement Program.	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Moisture ingress • Aging prematurely • Type issues • Extreme high consequence of failure	**Renewal initiative:** Replace Trench TCHCOT650 bushings on 15 transformers in RP1	**RP1** Underway PC June 2017	Project No. P0006567 PAD-569
Transformers & reactors paint system	• Maintain network reliability	• Deterioration prematurely • Type issue	**Renewal initiative:** Repaint selected transformers	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1483
Beaconsfield Substation – Replacement of No.1 and No.2 330-132kV Transformers.	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Serious oil leaks. • Abnormal moisture levels in paper. • Increased furan levels.	**Renewal initiative:** Replacement works are included within the Beaconsfield Redevelopment Stage 2 Project.	**RP1 - Underway** PC 18/12/17	Need No: 53 Project No. P0001197
Tamworth 132kV No.1, 2 & 3 Transformers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	• Serious oil leaks. • Abnormal moisture levels in paper.	**Renewal initiative:** Replacement works are included within the Forbes Substation Rebuild.	**RP1 - Completed**	**Transformers** Need No. 432/433/434 **Substation Rebuild** Need No: 81 Project No. P0001217

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability				
Wagga Wagga 132kV No.2 & 3 Transformers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Poor paper insulation condition. • A moderately high moisture in paper estimate. • High furans. • Poor oil condition. • Transformers contain unscheduled PCB contamination.	**Renewal initiative:** Replacement works are included within the Wagga 132kV Substation Rebuild.	**RP1 - Underway** PC 29/6/2018	**Transformers** No.2 Tx 6379 ARPE No.3 Tx Need No. 436 **Substation Rebuild** Need No: 134 Project No. P0000950
Transformer and Reactor Refurbishment Program.	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Based on a compilation of condition monitoring data • Serious oil leaks. • Unsatisfactory oil quality parameters. • Moisture in oil measurements (used to estimate moisture in paper) for all units listed are considered to be abnormal. • Type fault in the SRBP high voltage bushings. • Poor oil quality which will significantly adversely impact the paper insulation quality	**Renewal initiative:** Refurbish 12 transformers identified with high moisture content.	**RP1 - Underway** 5 units completed PC 22/6/18	Need No: 491 Project No. P0004183

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Forbes No.1 & 2 Transformers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Worn ancillary components • Carbon contamination in oil • Unsatisfactory oil quality parameters.	**Renewal initiative:** • Staged replacement of the No.1 and No.2 transformers with new units and associated works. • Removal and disposal of the old transformers.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: DCN276
Sydney East No.1, 2, and 3 Transformers.	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Worn ancillary components • Carbon contamination in oil • Unsatisfactory oil quality parameters.	**Renewal initiative:** Replacement of two units and retirement of one by the 2018/19-2022/23 regulatory period.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 548
Marulan No.4 Transformer	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Worn ancillary components • Serious oil leaks. • Unsatisfactory oil quality parameters. • Single transformer site – very high consequence of failure	**Renewal initiative:** Replacement of the transformer with a spare transformer	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1219

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Transformer and Reactor Refurbishment Program. 2018/19-2022/23 regulatory period	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Pursue STPIS revenue where cost effective	• Based on a compilation of condition monitoring data • Serious oil leaks. • Unsatisfactory oil quality parameters. • Moisture in oil measurements (used to estimate moisture in paper) for all units listed are considered to be abnormal. • Poor oil quality which will significantly adversely impact the paper insulation quality	Health Index (HI) data combined with Probability of Failure and criticality data identified assets with positive cost benefit evaluation for renewal when weighed against evaluated ongoing risk cost. **Renewal initiative:** Refurbish transformers identified	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1354
Transformer and Reactor Bushing Replacement Program. 2018/19-2022/23 regulatory period	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Moisture ingress • Aging prematurely • Type issues • Extreme high consequence of failure	Health Index (HI) data combined with Probability of Failure and criticality data identified assets with positive cost benefit evaluation for renewal when weighed against evaluated ongoing risk cost. **Renewal initiative:** Replace identified bushings	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1525

7.4.3 Maintenance Program – Transformers and Reactors

7.4.3.1 Component Failure Risk Assessment – Transformers and Reactors

A component failure risk assessment has been conducted for the Transformer and Reactor asset class and is shown in the table below. The analysis is compared with the Substation Maintenance Plan for the asset class to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them.

Table 11: Component Failure Risk Assessment - Transformer & Reactor

			Risk			Preventative				Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling	Planned maintenance	OLCM	Business Plan Objectives
Bushings - Oil impregnated	insulation breakdown type fault/damage/water	Tx loss	3	3	9			Bushing DDF/Capacitance	Bushing monitor – selected bushings only	Safety Reliability Environment
	Water ingress	Tx loss	3	3	9			Megger IR point/Dirana		
	Hot joints	Tx loss	2	3	6	Thermovision				
	Oil loss/external damage	Tx loss	1	3	3	Inspection				
Bushings - Resin Impregnated	insulation breakdown type fault/damage/water	Bushing loss	3	2	6			Bushing DDF/Capacitance		
	Water contamination	Bushing loss	1	2	2			Megger IR point/Dirana		
	Hot joints	Bushing loss	2	2	4	Thermovision				
	External damage	Bushing loss	1	2	2	Inspection				
Winding/Main insulation	Fault - various causes - lightning damage, type fault etc	Tx loss	1	3	3		DGA - signature gasses			Safety Reliability Environment
	Core fault causing overheating	Tx damage	0.5	2	1		DGA	Core IR		Reliability

			Risk			Preventative				Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling	Planned maintenance	OLCM	Business Plan Objectives
	Degradation - due to oil condition and ageing reactions	Tx loss	1	3	3		OQ and DGA			Safety Reliability Environment
	Low oil	Trip	3	1	3	Inspection				Reliability
Tapchanger	Selector hot joints	Tx loss	1	3	3	cyclo	DGA	Winding Resistance	Oil monitor	Safety Reliability Environment
	Selector mechanical wear and unseen problems	Tx loss	2	3	6	cyclo		Internal inspection based on cyclo		
	Oil Diverter switch wear	Tx loss	3	3	9	cyclo		Internal inspection/measurement		
	Oil Diverter switch oil breakdown or tracking	Tx loss	2	3	6	cyclo		Internal inspection/oil change		
	Oil Diverters switch mechanical failure	Tx loss	3	3	9	cyclo		Internal inspection and maintenance activities		
	Vacuum Diverter switch wear	Tx loss	1	3	3	cyclo				
	Vacuum Diverter switch oil breakdown or tracking	Tx loss	2	3	6	cyclo	OQ			
	Vacuum Diverters switch mechanical failure	Tx loss	1	3	3	cyclo				
Cooling	Pump failure (wear, electrical failure etc)	Rating restriction and possible overheating	1	1	1	Check operation			Traditional thermal protection - universal	Reliability
	Fan Failure (wear, corrosion, electrical failure etc)	Rating restriction and possible	3	1	3	Check operation				

			Risk			Preventative				Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling	Planned maintenance	OLCM	Business Plan Objectives
		overheating								
Oil condition	Water ingress - breather	Degradation of main insulation	2	1	2	Inspection/Breather maintenance	OQ tests		Oil moisture monitor. Selected	Reliability
	Water ingress - leaks		2	1	2	Inspection/defect repair	OQ tests			
	Water ingress - corrosion		2	1	2	Inspection/defect repair	OQ tests			
	Loss of inhibitor - where appropriate		2	1	2		test in OQ			
	Contamination		2	1	2		OQ tests			

7.4.3.2 Maintenance Program Amendments – Transformers and Reactors

Transformer and reactor maintenance has recently been reviewed and changes in frequency were made based on a consideration of the above risks. The objective of the change is for efficiency gains in the delivery of equipment maintenance.

The changes in maintenance affecting transformers include:

- A reduction in inspections.

  Substation inspections are now scheduled at 6 monthly intervals for most substations and 12 months for substations less than 10 years old. The impacts on transformer reliability arising from this are expected to be minor. From the table above, the items impacted by inspection maintenance are lower ranked risks.

- An extension of the time between major maintenances

  The interval for maintenance of transformers was formerly 4 years and this has been extended to 6 years with the following restrictions:

  - The interval remains at 4 years for oil impregnated bushings unless they are equipped with functioning on line bushing monitors. This recognises the potentially high risk associated with bushing failure of oil impregnated bushings. Failure of resin impregnated bushings are not expected to result in loss of the transformer.
  - Maintenance of tapchangers may still be required on an operations basis.

Details of the changes are included in AMI-AS0001 – Maintenance Plan Amendments July 2016 in file D2016/10692.

7.4.4 On Line Condition Monitoring – Transformers and Reactors

The principal options considered for on line condition monitoring (OLCM) of transformers and oil filled reactors include:

- Bushing monitors – which compare the bushing insulation leakage current between a three phase set to identify changes and raise alarms for a fast or large change.
- Dissolved Gas monitoring. There are a range of devices available ranging from devices such as 'Hydrans' which are sensitive mainly to hydrogen gas, through to what is effectively an online full gas chromatograph. These can detect changes in gas levels and provide alarming.
- Moisture monitors can be used to estimate the water in paper content of transformers/reactors. This can be difficult to estimate from water in oil measurements due to the need to reach a high enough equilibrium temperature over a time period.
- Partial discharge monitors. These devices are aimed at detecting partial discharge occurring within the transformer but have not been found to be effective in past trials.
- Fibre-optic temperature measurement. A measurement of transformer 'hot-spot' temperature can be made directly using fibre optic probes. This is dependent on the accuracy of transformer design models for placement of the probes. These devices have been found to be unreliable for long term service in previous installations although they may still have some value in confirming transformer thermal designs in factory acceptance testing.
- Tapchanger monitors may monitor mechanical action and motor drive currents etc. These have been found to be too expensive in past experience with minimal risk reduction compared to proper attention to maintenance practice.

TransGrid previously had a practice to install gas monitors (hydran type) with moisture monitoring; and bushing monitors. Future new transformers will not be specified with these devices, with RIP bushings to be installed to minimise bushing failure risks.

Where OLCM equipment is installed on oil filled reactors and transformers, there is a reduced maintenance requirement recognising the risk reduction that results.

7.5 Reactors Asset Review

7.5.1 Population Review - Reactors

TransGrid has a population of 103 reactor units equivalent to 53 three phase reactors that is comprised of 37 (31 three phase equivalents) oil-filled types, 3 (1 three phase unit) SF_6 insulated types and 63 (21 three phase sets) air-cored types. Of the air cored types, 21 (7 – three phase) are line series reactors.

When in service, shunt reactors are operated at around 100% of design loading. This is in contrast to transformers that are in service continuously but are normally designed to supply a peak load using n-1 reliability criteria. Shunt reactors may typically be switched daily, leading to additional internal stresses – and may operate for some hours each day. As Reactors operate at full load temperatures constantly (whilst energised) their insulation systems deteriorate at a faster rate than transformers and this is reflected in a lower expected nominal life compared to transformers.

TransGrid Oil-filled Reactor population is comprised of

- Two 330kV series reactors.
- Twenty-nine three-phase equivalent shunt reactors; consisting of:
  - Nineteen 330kV single-phase units.
  - Seventeen 330kV three-phase units.
  - Five 220kV three-phase units.
  - Four 132kV three-phase units

SF_6 Reactor population is comprised of:

- Three single-phase SF6 gas insulated reactors at Haymarket

Air-cored Reactor population is comprised of:

- Twenty-one single-phase air-cored series reactors at 132kV
- Nine single-phase air-cored shunt reactors at 132kV
- Thirty-three single-phase air-cored shunt reactors at 33kV

The age profile for oil filled reactors is shown in Figure 8 below. However, given the small number of SF6 insulated reactors and their relatively uniform operating life, graphical data regarding their age profile has not been included. Whilst the average age of the oil filled reactor population is approximately 17 years, 11% were commissioned before 1986 and have thus exceeded their nominal lifespan of 30 years, with the oldest units manufactured in 1978. Of the other reactors currently in service, the SF_6 reactors are installed in the Haymarket Indoor GIS Substation which was commissioned in 2004 and all are in an early stage of their life.

Figure 9: Oil Filled Reactors – age profile

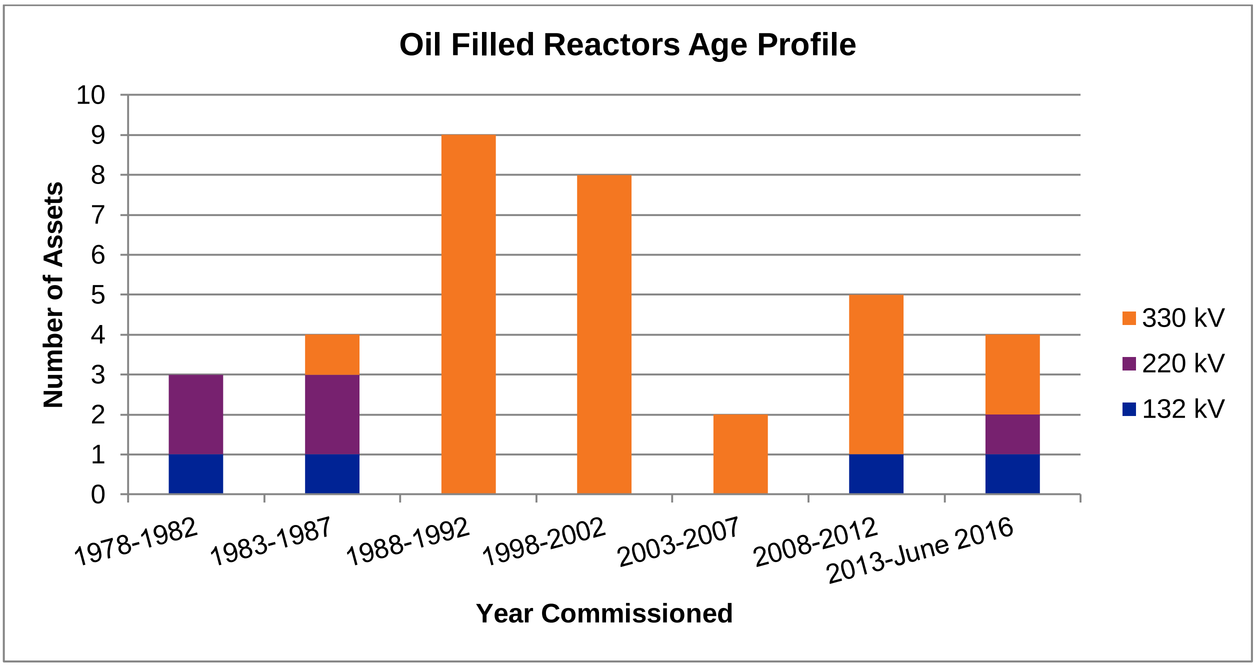
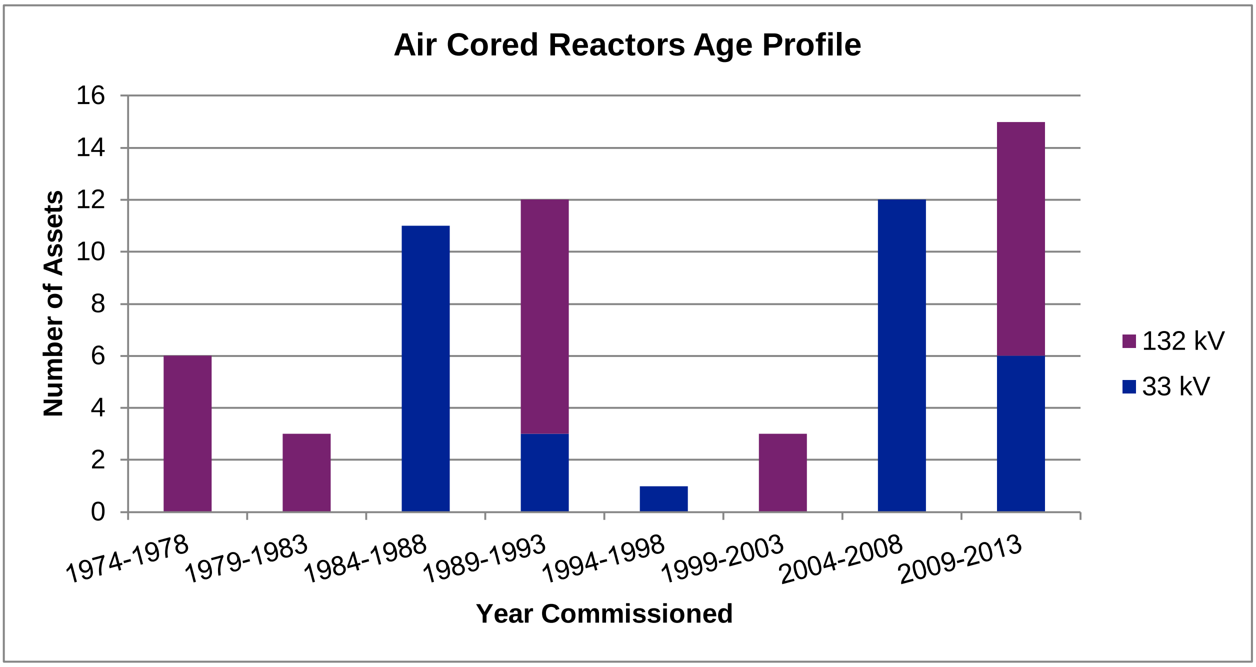


Figure 10: Air Cored Reactor – age profile



7.5.2 Emerging Issues, and Renewal and Maintenance Initiatives

7.5.2.1 Oil Filled Reactors

Aside from the considerations related to the loading cycle of reactors, the issues that affect oil filled reactors are very similar to those impacting on similarly insulated power transformers, as detailed in Section 7.3.2.

A similar range of diagnostic data is available for oil filled reactors as a result of their similar construction and capital value compared to power transformers. A health review is used to identify reactors with the highest risk of failure and using this information, detailed condition assessments are prepared for a range of higher risk reactors, which are then analysed to determine the need for corrective action.

Issues may develop with the condition of oil filled reactors that may limit their life or affect their reliability:

- Accelerated deterioration of insulating paper quality - excessive paper moisture content, oil acidity and oxygen content are factors that will promote the chemical reactions and lead to rapid deterioration of paper strength. In the case of oil filled shunt reactors this is affected by their loading cycle.
- Combustible gasses in oil – high levels of dissolved volatile gases in oil samples are an indication of abnormalities which may lead to the development of a significant internal fault
- Bushing failures - Bushing failure has caused approximately 20% of major transformer failures in TransGrid's records and a similar risk exists for bushings fitted on reactors.
    - Oil Impregnated Bushings (OIP) are sealed with gaskets which are susceptible to failure through brittleness brought on by age and weather exposure. Entry of even a very small amount of water into the small oil volume of a bushing will eventually lead to explosive failure - and could be expected to result in the catastrophic failure and loss of the associated reactor through fire.
- Corrosion – Failure of paint systems will lead to corrosion of the tank, pipe work, radiators and fittings. This can result in mechanical failure of the main tank wall, leading to oil leaks and moisture ingress. Radiators are particularly vulnerable due to the thin cross-section steel walls used in coolers (for effective heat transfer).
- A defect in the paint system used by one major supplier has resulted in faster than normal deterioration of paint for a small number of reactors. Repainting is being planned.
- Oil leaks – Gaskets on transformers may become brittle with age and exposure and fail. Chronic oil leaks result in pools of oil around the transformer, which present a fire risk. Leaks are a source of water entry. Chronic leaks may result in contamination of the ground around the transformer with commensurate potential environmental issues.
- Oil contamination – Oil may become contaminated with particles or other materials and this will affect dielectric performance.
- Worn ancillary components – in particular fans and pumps. Full rating is only available with all fans and pumps in good condition.

Where it is considered that a reactor has unacceptable risk, a Need is documented and options are developed and evaluated in accordance with the corporate governance process. The course of action is generally to either to: observe the asset; undertake maintenance or modification; replace; or dispose of the asset.

7.5.2.2 Air Cored Reactors

There have been two recent failures of air cored 33kV shunt reactor coils at Kemps Creek Substation. These reactor banks are rated at 137 MVAr and are connected to the tertiary of the main transformers.

The reactors failed following deterioration of their paint coating. This is thought to have allowed embrittlement of the mylar interturn insulation once water sealing of the insulating material was lost with failure of the painting system. Thermovision was completed on the remaining reactors at Kemps Creek and Eraring and this confirmed the presence of hotspots throughout the remaining reactor coils.

In the longer term, the issue has potential to also affect the newer air cored reactors installed in the 500 kV sites (Bannaby, Mt Piper and Bayswater).

There have also been unexplained failures of reactor coils at Darlington Point and these may be due to manufacturing issues.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 12: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Air Cored Reactors	• Maintain network reliability	• Insulation failure	**Renewal initiative:** Replacement of failed reactors in 500kV substations	**RP1** PC: Dec 2016 Proposed additional replacements in RP2	Need No: 1279 Need No: 1367
Buronga X2 220kV Reactor	• Minimise environmental harm and property damage • Maintain network reliability	• The reactor is in poor condition and is not suitable for refurbishment due to the condition of the insulating paper as indicated by the furan level in the insulating oil. Furan levels are at 3.79 ppm, • Other oil quality measures have been poor over an extended period. • These results are consistent with a high proportion of time in service over a 30 year life to date and indicate that it is approaching end-of-life.	**Renewal initiative:** Reactor Replacement including oil containment upgrade.	**RP1 - Complete**	**Reactor** Need No: 149 **Oil Containment** Need No: DCN469
Broken Hill No.1 & No.2 220kV Reactor	• Minimise environmental harm and property damage • Maintain network reliability	• Insulation degradation (oil and paper) • Oil contamination	**Renewal initiative:** Reactor Replacement	**RP1 - Complete**	Need No: 150
Beaconsfield West No.1 132kV Reactor	• Minimise environmental harm and property damage • Maintain network reliability	• Insulation degradation (oil and paper) • Oil contamination • Oil leaks	**Renewal initiative:** Reactor Replacement	**RP1 - Complete**	Need No: DCN283 Project No:P0001118
Wellington No.1 Reactor	• Minimise environmental harm and property damage • Maintain network reliability	• Insulation degradation (oil and paper) • Oil contamination • Oil leaks	**Renewal initiative:** Reactor Replacement	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1282

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Armidale No.2 Reactor	• Minimise environmental harm and property damage • Maintain network reliability	• Insulation degradation (oil and paper) • Oil contamination	**Renewal initiative:** Reactor Replacement	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1607
Transformer and Reactor Bushing Replacement Program.	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Moisture ingress • Aging prematurely • Type issues • Extreme high consequence of failure	Health Index (HI) data combined with Probability of Failure and criticality data identified assets with positive cost benefit evaluation for renewal when weighed against evaluated ongoing risk cost. **Renewal initiative:** Replace identified bushings	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1525
Transformers & reactors paint system	• Minimise environmental harm and property damage • Maintain network reliability	• Deterioration prematurely • Type issue	**Renewal initiative:** Repaint selected reactors	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1483

7.5.3 Maintenance Program - Reactors

See section 7.4.3.

7.5.4 On Line Condition Monitoring – Reactors

See section 7.4.4.

7.6 Circuit Breakers Asset Review

7.6.1 Population Review

TransGrid's circuit breaker (CB) population comprises 1,560 units in the voltage range from 11kV to 500kV. The types of CBs used include Bulk Oil (BO), Small Oil Volume (SOV), Vacuum and SF_6. BO and SOV CBs are old technologies. However, BO CBs are still in service in small numbers at lower voltages (11 kV and below), while SOV circuit breakers are mainly in use up to 132 kV.

Recently supplied CBs are either SF_6 type or vacuum type, where SF_6 is used to provide primary insulation. Vacuum interrupter CBs are presently used in CBs up to 33 kV. Most of TransGrid's CBs are of the SF_6 type and there is an evolution moving from older puffer types with hydraulic mechanisms that suffered from gas leaks through to lighter spring operated 'self-blast' puffer types.

The CB age profile and population breakdown are shown in the Figure 7 and Figure 8. They show that 3.2% of the units were commissioned before 1976, and have thus exceeded their nominal lifespan of 40 years. The oldest units were manufactured in 1959. The CBs have an average age of approximately 16.5 years.

The following Figure 12 shows the distribution of circuit breaker types against voltage level:

Figure 11: Circuit breaker – age profile

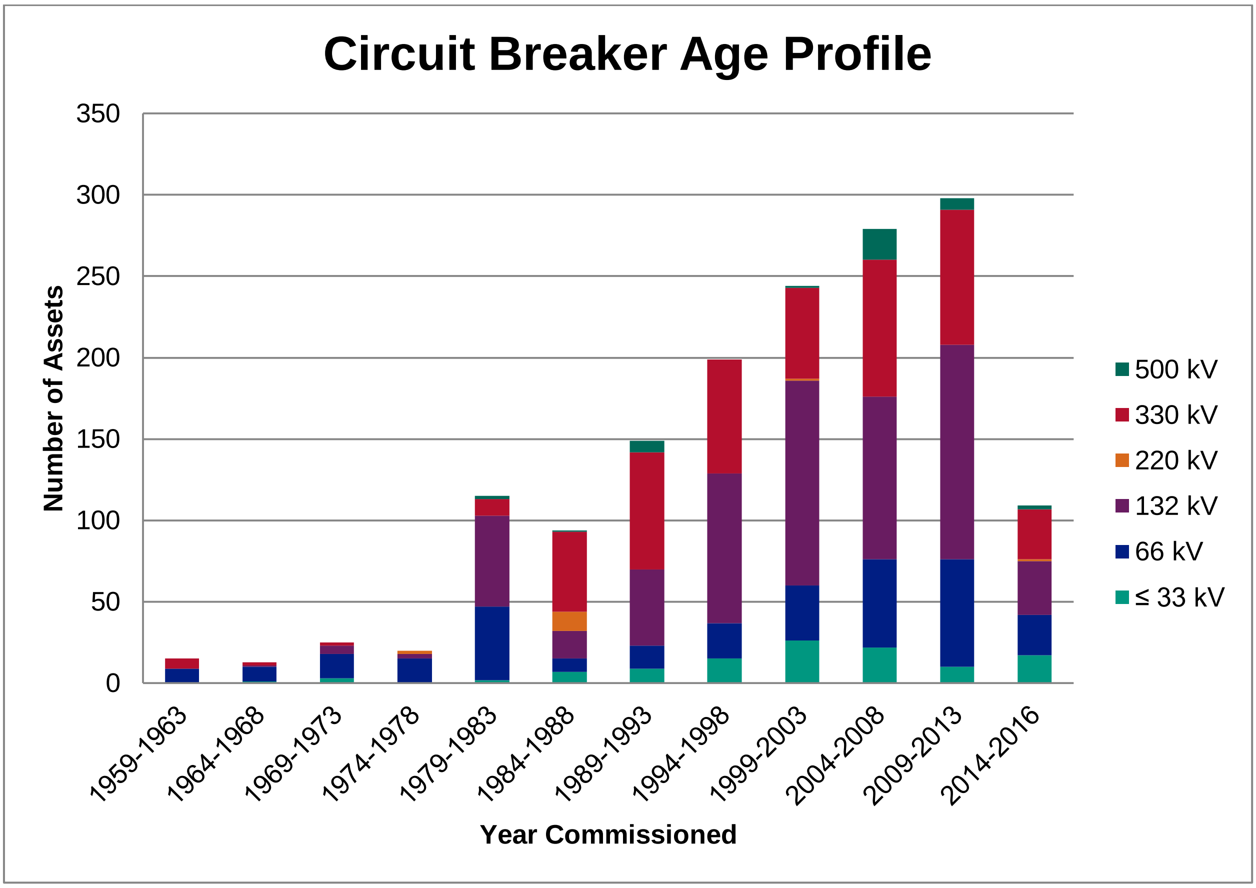


Figure 12: Circuit breaker – population breakdown

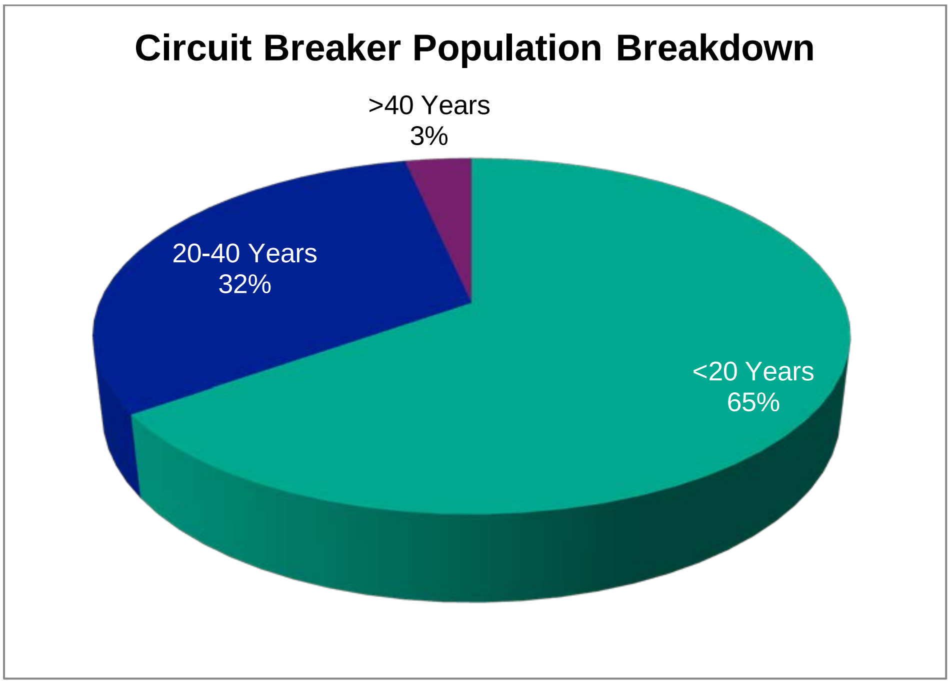
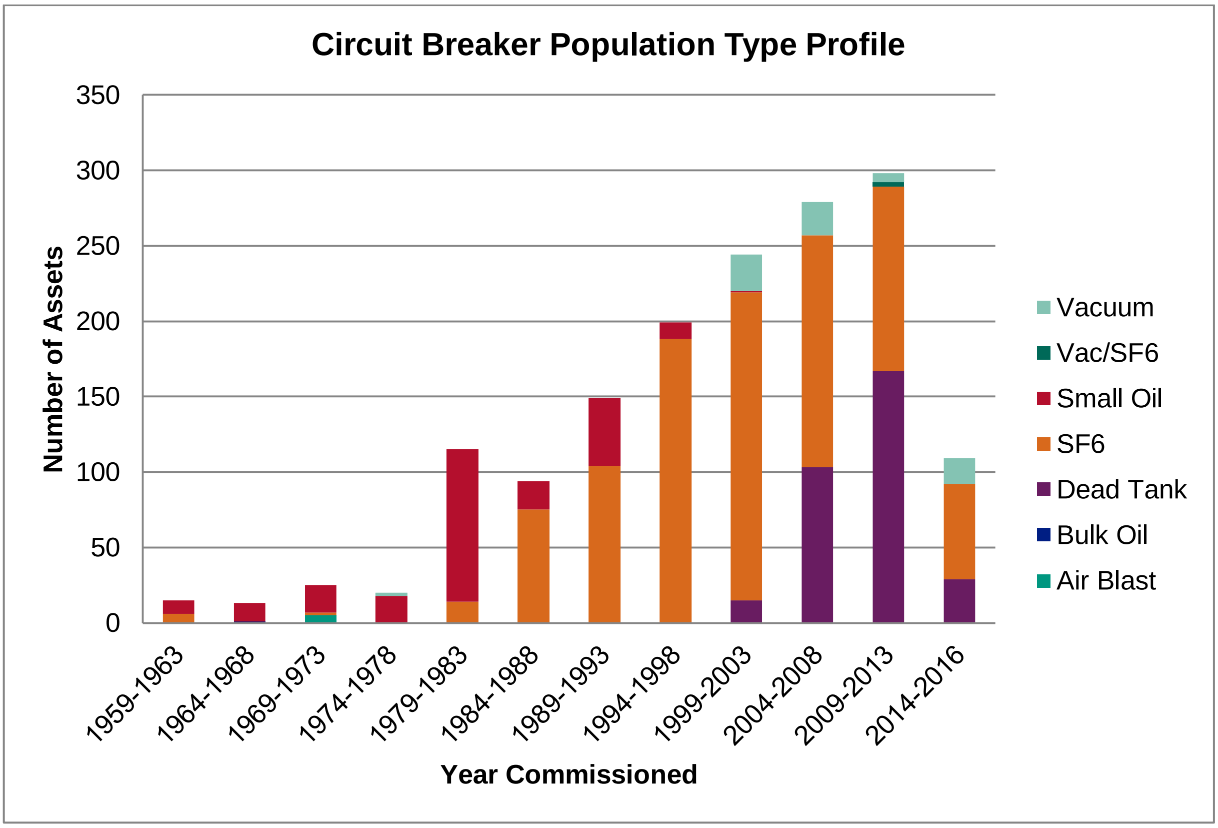


Figure 13: Circuit breaker – Population profile by type



There have been 77 circuit breakers identified for retirement in the 2015/16 to 2017/18 period as a result of project works and type based replacement programs. This represents 4.94% of the circuit breaker population.

There have been 238 circuit breakers identified for retirement in the 2018/19 to 2022/23 period as a result of replacement programs arising from Health Index and risk review. This represents 15.26% of the circuit breaker population.

7.6.2 Emerging Issues, and Renewal and Maintenance Initiatives

The current circuit breaker population has been supplied over a 40-50 year time frame and there has been development of technology over that time. The following groupings are noted:

- Small oil volume circuit breakers which are now an unsupported technology with limited or no technical or spares support from the supplier. These are also the oldest of the circuit breaker 'fleet'.
- Early generation SF_6 circuit breakers using puffer technology for arc extinguishing but requiring hydraulic or powerful clock spring mechanisms to provide the necessary energy to operate.
- More recent SF_6 types utilising arc energy to assist with operation of the circuit breaker. These devices are lighter in construction and spring operated and reliability has been generally good.
- Point on wave capability has been included in SF_6 circuit breakers installed on capacitors. This has been achieved using a single output switching relay and ganged mechanisms or by individually switched poles with 3 switching impulses.
- Dead tank SF_6 circuit breakers are becoming available for higher voltages and experience with these has been very good to date.
- Vacuum circuit breakers are used at lower voltages (33 kV) using SF_6 for primary insulation. One vacuum circuit breaker remains in service at 220 kV at Broken Hill but is to be replaced following failure of the only other circuit breaker of this type in the network.

An approach based on an assessment of circuit breaker condition using available condition data is now used to estimate failure risk; demonstrate any requirement for action; and to rank the priority of work that results. This approach is referred to as the Health Index (HI) and is further described in section 7.1.1 above, or in D2016/02430 – Circuit Breaker Health Index Method Description. Factors used to evaluate Circuit Breakers in the HI system include:

- Cyclo operations
- Defect counts
- Defect cost
- Reactive plant switching duty
- Diagnostic test data
- Insulation type
- Mechanism type

The emerging issues considered in the HI system when evaluating Circuit Breakers are as follows:

- Small oil volume (SOV) Circuit Breakers – SOV CBs are an obsolete technology that has limited manufacturer support. The availability of new spares is limited and may be expensive. Personnel who were involved in design of these circuit breakers have typically retired or moved to other roles.

  Mechanism problems are appearing with these circuit breakers that lead to slow operation; failure to trip; out of tolerance condition monitoring results; and 'shoot through'. Oil leaks are found on these units and they require intrusive maintenance – affected by the number of fault operations.

  Past strategies based on circuit breaker type have targeted the following specific circuit breaker models:

  - ASEA 132 kV HLD Oil
  - Delle HPGE 66kV Oil
  - ASEA HLR84 66 kV Oil
  - Magrini MAG38MGE-0 33kV Oil
  - ASEA HLR170 132kV Oil (Replacement Completed)
- Merlin Gerin FA1, FA2 and FA4 Circuit Breakers – These CBs were the first generation of SF6 circuit breakers supplied between 1975 and 1987 and suffer from type faults leading to corrosion of flanges and SF6 gas leaks. Refurbishment has been unsuccessful and replacement is underway:

- M&G FA1 330kV Hydraulic (completed)
- M&G FA2 330kV Hydraulic
- M&G FA4 500kV Hydraulic SF6

- Hydraulic and Heavy Spring Circuit Breakers - There have been indications that a second 'grouping of SF6 circuit breakers supplied up until the early 1990's are developing mechanical issues and manufacturer's support is limited/expensive. These circuit breakers employ hydraulic operating mechanisms due to the high forces that must be provided by the operating mechanism during fault operation. The interrupters themselves are heavier than more recent types and damping may hence be more critical. Examples of the problems that have occurred include:
  - Numerous defects on circuit breakers with hydraulic operating mechanisms and some cases of slow operation in service. This has been due to leaks, contamination of hydraulic fluid and deterioration of seals.
  - Mechanical failure of insulated operating rods.
  - Maloperation due to damper failure.
  - Leaking grading capacitors – which can be expensive to replace and can no longer be refurbished.
  - SF6 leaks.

  Previous replacement strategies have targeted the following types:
  - Siemens 3AS2 330 kV Hydraulic SF6
  - Siemens 3AQ2 330 kV Hydraulic
  - Sprecher Schuh HGF215 330kV Spring (large) SF6
- High Operation Count/Frequency Circuit Breakers:
  - With the acquisition of the Snowy Hydro sites it has been found that at these sites the circuit breakers may operate more than once per day. This is a much more frequent duty than for a typical transmission system circuit breaker and it will result in a greatly reduced life for these circuit breakers. A 10 year life span is expected.
  - Reactive plant circuit breakers work harder than other typical transmission circuit breakers. This results from high frequency switching and from the type of load being switched. Deterioration can occur quickly and accumulated damage may be enough that repair is no longer economic and an individual replacement may be required.

Further emerging issues with the circuit breaker asset class are as follows:

- AEMO have implemented an automated reactive plant dispatching system called VDS (VAr Dispatching System) which automatically requests TransGrid reactive plant switching operations. Experience from System Operators indicates that since the implementation of VDS, reactive plant switching operations have increased 30%-40%. Further investigation is required to quantify the impacts of VDS.
- Reactive current breaking capacity of Reactor Circuit Breakers – Through the investigation of the failure of the Eraring No.2 Reactor Circuit Breaker, it was identified that the installed circuit breaker was not adequately rated for the reactive current switching duty experienced in the installed location. Further review of similar high reactive current installations is required.
  - A special case of this is the reactor circuit breakers on the 33 kV 137 MVAr air cored shunt reactor banks at Kemps Creek, Eraring, Bayswater, Bannaby and Mount Piper 500 where normal load current as a proportion of circuit breaker rating is very high compared with other circuit breakers (2,400A inductive load vs 3,150A CB normal current rating); additionally, the Kemps Creek and Eraring circuit breakers are switched in the order of 1000 times per year. Coupled with the load type that they are switching, these circuit breakers require a higher frequency of maintenance and replacement than other reactive plant circuit breakers.
- A factor that is affecting the circuit breaker replacement program is the adoption of dead tank circuit breakers. These have been installed over the last 20 years and have proven to be successful. Dead tank CBs have in-built instrument transformers and do not require external CT posts. There is benefit in the elimination of separate post current transformers with their associated failure risk and maintenance costs.

- A policy has been developed to replace circuit breakers with dead tank type when circuit breaker replacement is required and the risk associated with the adjacent current transformers is sufficient to justify the increased capital costs. This is justified on the basis of the maintenance cost saving, reduction in future outages and reduced operational risk. Details of benefits are in D2015/07219: Issue Paper – Dead Tank CBs.

- SF_6 leaks in the circuit breaker population are an ongoing concern - SF_6 insulation in HV circuit breakers is the current technology being procured for CB installations which are increasing the total number of SF_6 insulated CBs in service and the total installed holding of SF_6. Leaks are monitored by the Asset Monitoring Centre through review of resulting alarms and online monitoring data and reported to Asset Strategy. Unless a type issue can be identified, SF_6 leaks are managed through defect repairs and as per the Substation Maintenance Plan.
  - The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gas emissions. The agreement has the potential to result in government and regulatory pressure to set a more conservative benchmark on allowable losses or remove SF_6 from service.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 13: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Circuit Breakers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	• Circuit Breaker asset health has been evaluated to determine the effective remaining life adjusted by condition parameters for the total population. • Factors such as those described in section 7.5.2 above are taken into in the evaluation of individual asset health – SOV Circuit Breakers – Type/Model (FA series, Hydraulic, Heavy Spring) – Operation Count	Health Index (HI) data combined with Probability of Failure and criticality data identified assets with positive cost benefit evaluation for renewal when weighed against evaluated ongoing risk cost. **Renewal initiative:** Replace 238 circuit breakers based on economic and ALARP/SFAIRP evaluations to address associated risks.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1337
Dead Tank Circuit Breakers	• Improve CAPEX Performance • Improve OPEX Performance	There is benefit in installing Dead Tank CBs with the elimination of separate post current transformers eliminating their associated failure risk and maintenance costs. • DTCBs present maintenance cost saving, reduction in future outages and reduced operational risk.	Replacement of circuit breakers with dead tank type when circuit breaker replacement is required and the associated current transformers also have significant risk.	**Ongoing**	D2015/07219: Issue Paper – Dead Tank CBs
SF_6 Circuit Breakers	• Minimise environmental harm and property damage • Maintain network reliability • Improve OPEX Performance	Emergence of recurring or unrepairable SF_6 leaks from Circuit Breakers	**Renewal initiative:** Replace circuit breakers with unrepairable SF_6 leaks as identified.	**Ongoing** Nil identified to date	Need No: 503 D2003/2312 – Maintenance Plan – Substation Assets

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
SF_6 Circuit Breakers	• Minimise environmental harm and property damage • Improve OPEX Performance • Improve CAPEX Performance	UNFCCC - Paris Agreement; impact on SF_6 emissions and holdings.	**Asset manager to undertake further analysis:** • Review Substation Renewal and Maintenance Strategy based on outcome of agreement and Government/Regulatory requirements.	Awaiting developments	N/A
Reactor Circuit Breakers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	Reactive current breaking capacity of circuit breakers installed in reactor bays may not be adequate.	**Asset manager to undertake further analysis:** • Review the population of installed Reactor Circuit Breakers to verify suitably rated.	**Underway**	N/A
Circuit Breakers - OLCM Devices	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage	• Deployment of OLCM devices onto low or non-critical circuit breakers • Population of high criticality and remote circuit breakers have no online condition monitoring installed.	**Operational Refurbishment Project:** Relocation of 39 OLCM devices from low criticality CBs to nominated CBs based on operating duty, location and criticality.	**RP1** NOS issued PC 2020	Need No: 1681

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance				
Point on Wave Switching for Capacitor Banks	• Maintain network reliability	Switching of Capacitor Banks presents risks that unacceptable levels of switching transients may be generated and cause damage to network and customer equipment.	**Renewal initiative:** Replace 27 non Point on Wave Circuit Breakers	**RP1 - Ongoing** 9 of 27 completed PC: 30/1/18	Need No: 1012 Project No: P0003923
Replace ASEA 132kV HLD Circuit Breakers	• Maintain network reliability • Improve OPEX Performance	• These circuit breakers have problems that reduce their reliability, including: – Wear of mechanism components, leading to unreliable operation. – Oil leaks. – High contact resistance. – Moisture ingress through free breathing interrupter chamber. • The rate of defects is increasing. • Major parts supply is no longer available from the supplier.	**Renewal initiative:** Replace 8 HLD Circuit Breakers	**RP1 - Ongoing** 5 of 8 completed PC: June 2018	Need No: 455 Project No: P0004234
ASEA HLR84 66kV Oil Circuit Breakers	• Maintain network reliability • Improve OPEX Performance	• Some of these circuit breakers are starting to show signs of reduced reliability due to operational malfunctions. • Defects raised on these circuit breakers include: – Nitrogen leaks. – Wear of mechanism components, leading to unreliable operation.	**Renewal initiative:** Replace 4 ASEA HLR circuit breakers	**RP1 - Ongoing** 3 of 4 completed PC: June 2018	Need No: 490 Project No: P0004228

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		– Oil leaks. – Contact wear and contact resistance issues. • Major parts supply is no longer available from the supplier.			
Merlin Gerin FA4 500kV Circuit Breakers	• Minimise environmental harm and property damage • Maintain network reliability • Improve OPEX Performance	• M&G breakers suffer from a type fault in respect of the poor tank sealing arrangements leading to a loss of SF_6 gas. • These breakers also have suffered numerous defects related to the hydraulic operating mechanism.	**Renewal initiative:** Replace 11 FA4 circuit breakers	**RP1 - Ongoing** 2 of 11 completed PC: June 2018	Need No: 492 Project No: P0004192
Sprecher & Schuh HGF215 330kV Circuit Breakers	• Minimise environmental harm and property damage • Maintain network reliability • Improve OPEX Performance	• Type faults leading to premature gap corrosion problems and SF_6 gas leaks. • One case found where the guide rails located in the circuit breaker head became dislodged due to undamped operation. This also has the potential to lead to a serious failure.	**Renewal initiative:** Replace 4 HGF215 circuit breakers	**RP1 - Ongoing** 1 of 4 completed PC: June 2018	Need No: 504 Project No: P0004208
Alstom SF_6 Circuit Breakers - Molong Substation	• Maintain network reliability	• These Alstom circuit breakers fitted with SICU modules are proving unreliable resulting in increasing defects. • The withdrawal of spare parts and technical support by the manufacturer.	**Renewal initiative:** Replace 7 SICU modules on Alstom circuit breakers.	**RP1 - Complete**	Need No: 505
Delle HPGE9 66kV Circuit Breakers	• Maintain network reliability • Improve OPEX Performance	• These circuit breakers have three significant issues that increase their probability of failure: – Wear of mechanism components, leading to	**Renewal initiative:** Replace 13 HGF215 circuit breakers	**RP1 - Ongoing** 1 of 13 completed PC: June 2018	Need No: 506 Project No: P0004238

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		unreliable operation. – Oil leaks. – History of failure to trip caused by slow operation of mechanism.			
Siemens 3AS2 330kV Circuit Breakers	• Minimise environmental harm and property damage • Maintain network reliability • Improve OPEX Performance	• The Siemens breakers suffer from a type fault in respect of the poor sealing arrangements of the hydraulic operating mechanisms leading to a loss of SF_6 gas. • These breakers also have suffered numerous defects related to the hydraulic operating mechanism and some instances of mal-operation in service that have not been able to be addressed by normal maintenance practices.	**Renewal initiative:** Replace 6 3AS2 circuit breakers	**RP1 - Ongoing** 3 of 6 completed PC: June 2018	Need No: 507 Project No: P0004200
Siemens 3AQ2 330kV Circuit Breakers	• Minimise environmental harm and property damage • Maintain network reliability • Improve OPEX Performance	• The Siemens breakers suffer from a type fault in respect of the poor sealing arrangements of the hydraulic operating mechanisms leading to a loss of SF_6 gas. • These breakers also have suffered numerous defects related to the hydraulic operating mechanism and some instances of mal-operation in service that have not been able to be addressed by normal maintenance practices.	**Renewal initiative:** Replace 3 3AQ2 circuit breakers	**RP1 - Ongoing** 0 of 3 completed PC: June 2018	Need No: 508 Project No: P0004204
Merlin & Gerin FA2 330kV Circuit Breakers	• Minimise environmental harm and property damage • Maintain network reliability • Improve OPEX Performance	• M&G breakers suffer from a type fault results in SF_6 gas leaks from the flanges from an early age. This results in an unacceptable number of forced and planned outages to attend to SF_6 gas leaks. The	**Renewal initiative:** Replace 20 FA2 circuit breakers	**RP1 - Ongoing** 12 of 20 completed PC: June 2018	Need No: 509 Project No: P0004196

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		leakage is attributed to a design flaw that allows moisture to penetrate between the sealing O-ring and the weather seal, leading to corrosion of the flange surfaces.			
Magrini MAG38MGE-0 Circuit Breaker Replacements	• Maintain network reliability • Improve OPEX Performance	• These breakers are exhibiting end of serviceable life characteristics that increase their probability of failure: – Wear of mechanism components, leading to unreliable operation. – Oil leaks. – Low Insulation Resistance (IR) of the high voltage components. – Poor spare parts availability.	**Renewal initiative:** Replace 11 MAG38MGE circuit breakers	**RP1 - Ongoing** 0 of 11 completed PC: June 2018	Need No: 541 Project No: P0004216

7.6.3 Maintenance Program – Circuit Breakers

Circuit Breakers are primarily mechanical devices with significant impacts in the case of failure. Routine maintenance activities are structured to derive full operating functionality from each unit for the duration of their design life. However, it is clear that individual units can develop problems requiring specific treatment or maintenance requirements. Where issues are identified, maintenance activities will be modified in order to collect sufficient information and measurement data to support thorough continuing analysis.

In the main, Routine Maintenance activities are designed to identify abnormalities with Circuits by comparing measurement data and inspection information with limits and requirements described in D2014/19504 - Substation Condition Monitoring Manual. Where an abnormality exceeds a predetermined allowable value, a range of escalated actions are described, designed to address each abnormality.

TransGrid will collect the range of measurement data required for analysis through the use of routine, scheduled inspections and planned offline maintenance activities consistent with the following principles:

- Maintenance is to be minimised consistent with reliable plant performance
- Maintenance costs are to be minimised consistent with corporate objectives of safety, reliability, availability and risk management.
- To ensure compliance with limits for acceptable equipment service condition documented in the Substation Condition Monitoring Manual (and manufacturers manual where applicable)
- Condition monitoring by external diagnostic testing is preferred to disassembly and inspection.
- Implementation of new technology to develop continuous on-line condition monitoring systems is to be pursued where benefits can be achieved consistent with the aforementioned principles.
- New plant is to be of a proven safe, reliable and low maintenance design fitted with online monitoring devices where benefits have been identified

7.6.3.1 Component Failure Risk Assessment - Circuit Breakers

A component failure risk assessment has been conducted for the Circuit Breaker asset class and is shown in the table below. The analysis is compared with the Substation Maintenance Plan for the asset class to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them.

Table 14: Component Failure Risk Assessment – Circuit Breakers

			Risk			Preventative			Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling Planned maintenance	OLCM	Business Plan Objectives
Mechanism including trip coils, operating rods and linkages	Failure to operate	uncleared fault Inability to restore load	2	2	4	Inspection - particularly in bottom of mech box	Timing, operation checks, mech checks	Timing measured on each operation. Coil currents	Safety Reliability Environment
	Latching issues	uncleared fault Inability to restore load	2	2	4	Inspection	Timing, operation checks, mech checks		
	Slow operation	System impact	2	1	2	Inspection	Timing, operation checks, mech checks		
	Pole discrepancy (eg: failed operating rod)	CB failure	1	3	3	Inspection (will not help operating rod)			
	Damping failure	CB damage and failure	2	2	4	Inspection	Timing		
Interrupters	Worn contacts	CB failure	2	3	6		Timing, dynamic contact resistance, micro-ohm	gas pressure alarms, pressure monitoring, Timing on each operation	Safety Reliability Environment
	Punctured arc shield/ damaged turbulator	CB failure	1	3	3	internal as appropriate			
	High micro-ohm	CB failure	3	1	3		micro-ohm		
	Contamination of insulating fluid	CB failure	1	3	3		megger		
	Leaking grading	uncleared	3	1	3	inspection			

			Risk			Preventative			Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling Planned maintenance	OLCM	Business Plan Objectives
	capacitors	fault							
	Failure of porcelain	CB failure	1	3	3	inspection			
	Leaks - low pressure or low oil	CB failure	3	1	3	inspection			
Insulation	Contamination of insulating fluid	CB failure	1	3	3		megger	gas pressure alarms, gas pressure monitoring	Safety Reliability Environment
	Tracking	CB failure	1	1	1		megger		
	Porcelain	CB failure	1	3	3	inspection			
	Leaks	CB failure	3	1	3	inspection			
Control	Stuck SF6 Gauge Contacts	CB failure	2	1	2	inspection	Functional checks	gas pressure alarms, gas pressure monitoring	Safety Reliability Environment

7.6.3.2 Maintenance Program Amendments – Circuit Breakers

Circuit Breaker maintenance has recently been reviewed and changes in frequency were made based on a consideration of the above risks. The objective of the change is for efficiency gains in the delivery of equipment maintenance.

The changes in maintenance affecting Circuit Breakers include:

- A reduction in inspections.

Substation inspections are now scheduled at 6 monthly intervals for most substations and 12 months for substations less than 10 years old. The impacts on transformer reliability arising from this are expected to be minor. From the table above, the items impacted by inspection maintenance are lower ranked risks.

- An extension of the time between detailed inspections

The interval for detailed inspections of SF_6 interrupter live head design and Mitsubishi Dead Tank design circuit breakers was formerly 4 years and this has been extended to 6 years, excluding reactive plant circuit breakers.

  - Circuit breakers within this group which have OLCM devices fitted will not require this maintenance.
  - Reactive plant circuit breaker detailed inspections are not performed due to shorter timeframe minor maintenance intervals.

- An extension of the time between minor maintenances

The interval for minor maintenance of all non-reactive plant circuit breakers has been extended.

  - Minor Maintenance for SF_6 live head and dead tank design circuit breakers was formerly 8 years and this has been extended to 12 years.
  - Minor maintenance for oil filled and vacuum circuit breakers was formerly 4 years and has been extended to 6 years with emphasis on the need to correctly monitor operation duty through cyclo readings in order to schedule operations based maintenance.
  - Circuit breakers within this group which have OLCM devices fitted will not require this maintenance.

Details of the changes are included in AMI-AS0001 – Maintenance Plan Amendments July 2016 in file D2016/10692.

7.6.4 Online Condition Monitoring – Circuit Breakers

Where already fitted the likely benefits occurring from on-line condition monitoring systems and in particular the potential for improved reliability and availability of Substation Plant are to be considered when identifying appropriate maintenance activities for Circuit Breakers. Where reliable on-line systems are in place, certain periodic diagnostic or invasive maintenance requirements may become redundant.

Where on-line condition monitoring systems are installed, identified maintenance routines will be amended with the approval of the Asset Manager. Minimum prerequisites for such amendments are:

- Installation of reliable sensors
- Adequate communication systems to facilitate the collection of condition monitoring data,
- Robust systems for the specification and implementation of settings and alert thresholds, and
- Effective asset management processes and resources to monitor, assess and action the on-line condition monitoring data.

7.7 Gas Insulated Switchgear (GIS) Asset Review

7.7.1 Population Review

TransGrid owns 4 Gas Insulated Switchgear (GIS) facilities:

- Beaconsfield West substation was commissioned in 1979 and the GIS substation was replaced in 2012.
- Haymarket substation was commissioned in 2004.
- Holroyd Substation which was commissioned in 2014.
- Rookwood Substation which was commissioned in 2014.
- Orange substation is in construction stage. Asbestos has been detected in the switchgear housing and this has delayed project completion.
- Taree 33kV switchyard is planned to be replaced with GIS by June 2018

7.7.2 Emerging Issues, and Renewal and Maintenance Initiatives

The emerging issues considered in the HI system when evaluating Circuit Breakers are as follows:

- Maintenance of GIS was in the past based on air insulated switchgear. The number of GIS sites has expanded and a targeted maintenance approach has now been included in the maintenance plan in recognition of the different requirements and performance of GIS equipment.
- A number of GIS chambers are being identified through the online condition monitoring data as having slow SF6 leaks. Leaks are an ongoing concern from a cost and environmental impact standpoint, however leak rate data suggests that even minute leaks exist from every chamber and increased leaks can develop through the operating life of the equipment. To date, leaks identified through online condition monitoring have been addressed as warranty repairs, however the population of GIS installations have now moved out of their respective warranty periods, necessitating consideration of allowable leak rates.
    - As described in section 7.6.2, the Paris Agreement may have an impact on SF_6 utilised as the insulation medium within GIS installations.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 15: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
GIS Circuit Breakers	• Maintain network reliability • Improve OPEX Performance	• GIS CB maintenance requirements are in line with AIS CB maintenance. • Review of preventative maintenance intervals and scope is required for GIS CB population.	**Maintenance Initiative:** GIS Maintenance intervals reviewed and specified	**Implemented**	D2003/2312 – Maintenance Plan – Substation Assets
GIS Circuit Breakers	• Maintain network reliability • Minimise environmental harm and property damage • Improve OPEX Performance	• SF_6 leaks are being identified from GIS chambers, identified by online condition monitoring devices through density trending.	**Asset manager to undertake further analysis:** • GIS allowable leak rates **Maintenance focus:** • Corrective works issued for excessive leak rates as identified.	**Ongoing**	D2003/2312 – Maintenance Plan – Substation Assets
GIS Circuit Breakers	• Minimise environmental harm and property damage • Improve OPEX Performance • Improve CAPEX Performance	• UNFCCC - Paris Agreement; impact on SF_6 emissions and holdings.	**Asset manager to undertake further analysis:** • Review Substation Renewal and Maintenance Strategy based on outcome of agreement and Government/Regulatory requirements.	**On Need**	N/A
Haymarket GIS	• Maintain network reliability • Improve OPEX Performance	• Premature failure of Haymarket GIS SICAM electronic control module components. • GIS CB operation is disabled when SICAM module fails.	**Renewal initiative:** Replacement of SICAM modules at Haymarket	**RP1 - Ongoing** PC: 30/4/17	Need No: 447 Project No: P0001250
Beaconsfield West GIS	• Minimise environmental harm and property damage • Improve CAPEX Performance	• Full retirement and removal of Beaconsfield West switch room	**Renewal initiative:** Associated with Beaconsfield Redevelopment Stage 2	**RP1 - Ongoing** See Substation Sites 7.2.2	Need No: 53 Project No: P0001197

7.7.3 Maintenance Program – GIS

Based on the overall performance of the GIS asset fleet to deliver the required overall network reliability and performance levels and the effectiveness of the current maintenance and inspection activities to identify and address current and emerging issues in the past, a reduction in GIS maintenance is proposed and approved in June 2015, refer to Proposal on Maintenance Savings (D2015/06734) and GM AS S1 001 Maintenance Plan – Substation Assets for details.

7.7.4 Online Condition Monitoring – GIS

All TransGrid's GIS substations are fitted with SF_6 gas density monitors, all of which are connected to OLCM central server. There have been a number of instances where SF6 gas leaks from GIS compartment were detected by OLCM system. On line monitoring of gas compartment pressure has been very effective in enforcing contract leak rate requirements on GIS suppliers.

7.7.5 Disposal Initiatives – GIS

Disposal of aged or no longer needed GIS equipment at old Beaconsfield West substation will follow an approved Asset Disposal process where re-use is no longer feasible. Asset disposal will include decommissioning of the asset, and decisions on whether to sell as scrap or dispose at a waste management facility. The process shall also address the following related issues:

- Safe work practices during de-commissioning and dismantling
- Appropriate probity considerations
- Consideration of environmental risks associated with remaining aged insulating oil or gas
- Requirements for treatment and re-use of SF_6 gas

7.8 Instrument Transformers Asset Review

7.8.1 Population Review – Instrument Transformers

TransGrid manages a total instrument transformer population of approximately 6,035 units ranging in voltage from 11kV to 500kV. The instrument transformer population is comprised of:

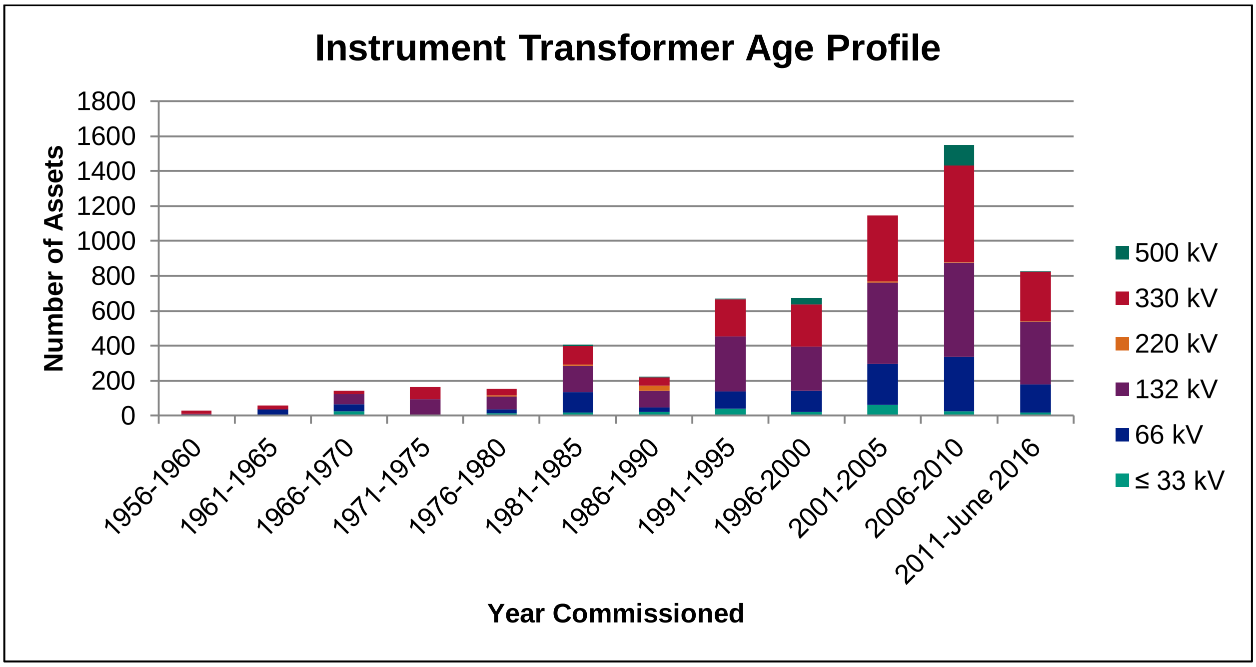
- 3,581 Current Transformers (CT) – this accounts for approximately 59% of the total population.
- 884 Magnetic Voltage Transformers (MVT) – this accounts for approximately 15% of the total population.
- 1,570 Capacitor Voltage Transformers (CVT) – this accounts for approximately 26% of the total population.

All of these CTs are of the post freestanding type i.e. any instrument transformers embedded within metal clad switchgear, gas insulated switchgear, power transformers and oil filled reactors are not included in the above statistics.

The majority of units are constructed of oil/paper insulation, although SF_6 insulated equipment has been installed since the 1990's. There are also a small number of solid insulated (epoxy) instrument transformers.

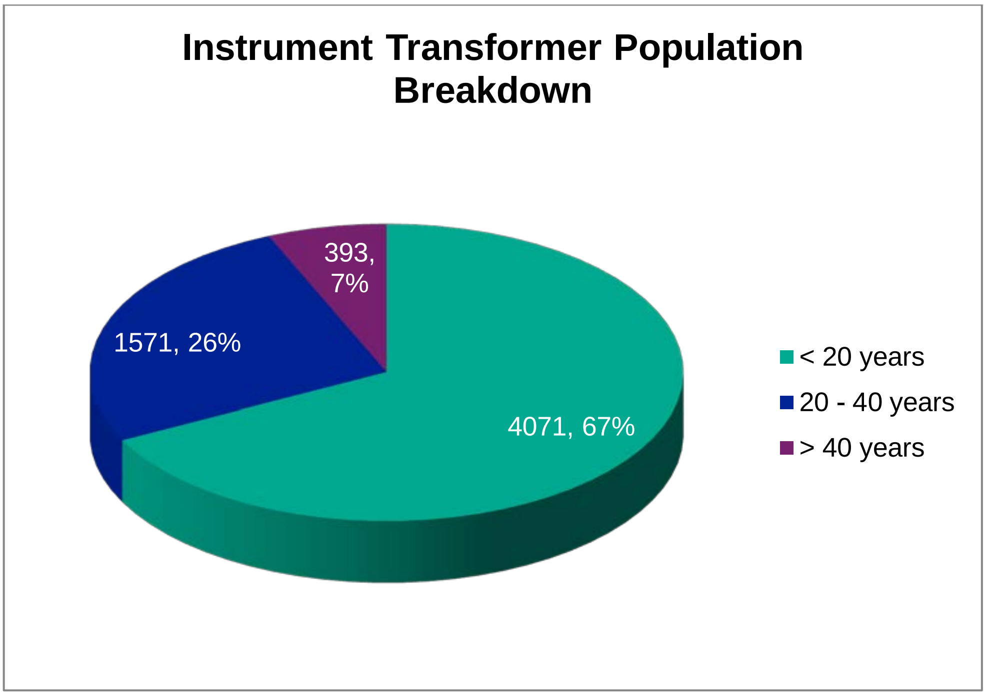
The instrument transformer age profile is shown in the Figure 15. It shows that approximately 7% of the units were commissioned before 1976, and have thus exceeded their nominal lifespan of 40 years. The oldest units were manufactured in 1956. The instrument transformers have an average age of approximately 17 years.

Figure 14: Instrument transformer – age profile



The following Figure 16 shows the division of instrument transformers by age groups.

Figure 15: Instrument transformer – population age breakdown



Instrument transformers are in general, considered to be reliable, low maintenance items of plant. However, the failure mechanism will typically be catastrophic and in the case of older oil filled units, there is associated risk to personnel in the vicinity due to shards of porcelain ejected with great energy. This type of failure presents unacceptable safety risks, and maintenance programs are designed to monitor instrument transformer condition and avoid this type of failure while minimising cost.

7.8.2 Emerging Issues, and Renewal and Maintenance Initiatives – Instrument Transformers

The instrument transformer population has been affected with changes in technology over time and the following categories exist:

- Older oil hairpin type CTs with porcelain insulators and condenser type paper foil insulation systems. These types have relatively large volumes of oil and a history of catastrophic failure.
- Older oil insulated MVTs with porcelain insulators. These units have been generally reliable but failure consequence may also be severe.
- CVTs using porcelain insulators for older units and polymer for more recently supplied posts. These are generally reliable although type issues are appearing in older types.
- Gas filled CTs and MVTs with polymer insulators which have been supplied since the mid-late 1990s. Low failure consequence. The CTs are live head type with smaller cores than traditional hairpin types.
- Newer oil filled CTs and MVTs with polymer insulators and smaller oil volumes. The CTs are live head type with smaller cores than traditional hairpin types.
- A small number of epoxy insulated units at voltages up to 66 kV.

The current and emerging issues associated with instrument transformers are as follows:

- Leaks:
    - Oil-filled instrument transformers are generally older and are fitted with rubber-cork gasket seals. These seals become brittle with age and movement may cause them to split and leak. Workshop overhaul may be required to address a leak.
    - Some older instrument transformer types are fitted with brass or synthetic rubber expansion bellows to allow oil expansion while excluding atmosphere and water. These bellows may crack and they are not replaceable.
    - Corrosion of steel components may result in leaks or intrusion of water, which will cause catastrophic failure if not addressed.
    - SF6 instrument transformers may develop leaks over time and this will need to be managed to ensure the reliability of equipment and to manage the cost and environmental impact of SF6. There is an example of this which is related to a type issue for a particular CT model.
- DGA monitoring results: Where oil sample analysis shows an instrument transformer to have elevated combustible gasses, action is taken depending on the levels found. Levels in excess of monitoring limits will typically result in additional oil sampling – with impacts on additional outages and maintenance work. This may be particularly significant for critical or radial supplies. Elevated gas levels indicate that the affected instrument transformer is at high risk of developing a fault that will lead to explosive failure. Higher combustible gas levels may require immediate replacement.
- Post type ITs provided prior to the 1990s will generally be of an oil insulated hairpin type construction fitted with a porcelain insulator. These types pose the most significant risk to safety, reliability and potential environmental damage. Insulation failure of these types will result in the release of large amounts of energy and ejection of porcelain at high velocity. These units are presently the greatest concern with regard to the DGA gas levels and oil leaks/deterioration. Repair or refurbishment of these units is not feasible and as the units age, more aggressive replacement action may become necessary.
- Performance: Some cases have been found where secondary insulation resistance on CTs has fallen to levels that threaten the reliability of protection systems and could result in false tripping or failure to trip for a fault.
- Sampling points:
    - There is a small number of oil filled instrument transformers that do not have sampling points and these cannot be monitored effectively by DGA.
    - A problem exists with gate valve sample points on older oil filled instrument transformers that are believed to result in water contamination of oil samples, making water content measurement unreliable for these units.

- Non-standard CTs: Some older current transformers may not have suitable ratios available, requiring the use of interposing CTs.
- CVTs: Cascade failure of the capacitor elements used to divide the high voltage is a typical failure mechanism for CVTs and this is managed using a monitoring system as described below. Other issues may arise that are related to the magnetic unit at the base of the CVT. These can include:
    - Ingress of water.
    - Ferroresonance problems causing overheating and failure.
    - Tracking on the secondary terminal board.
- CVT's are effectively run to failure, relying on detection of faults through on-line monitoring of secondary voltage imbalance. Faulty units detected by monitoring are replaced. A periodic review of CVT replacements is carried out and this may reveal a trend of increasing failures in a particular grouping of CVTs that requires additional action.
- Gas Pressure monitoring: Faults have been found in gas pressure switches on gas filled current transformers. Faulty gauges or switches will be rectified on a defect basis.
- Type issues: There have been cases where groupings of instrument transformers are considered suspect due to failure history or known type issues related to design faults or manufacturing quality control issues. In these cases, the affected units may be considered at higher risk of failure and if of the oil filled type, may be prone to fail explosively.

  There is presently an issue with Tyree/ABB hairpin CT posts that were refurbished during the 1990's to overcome previous quality control issues in their construction that was leading to high failure rates. There has now been a series of failures of these types and there is concern centred around the 330 kV units of this group in particular.

  A catastrophic failure at Ingleburn Substation caused damage to adjacent equipment and a fire, with porcelain shards spread over a large area. DGA testing gave little warning of the failure and this is the key tool used for detection of failure risk.

  It is considered that this group of CT should be removed from service and replaced with safer and more reliable modern types.
- Known problems exist on certain models of CVTs manufactured by TRENCH and HAEFELY. Specific initiatives in the form of a TWR have been issued to inspect these items with replacement recommended for those items found defective.
- Routine testing scope for polymer insulated small oil volume CTs requires review:
    - Small oil volume and polymer insulation design reduces failure risks.
    - Supplied oil volume is often not sufficient for routine oil sampling throughout the service life of the asset.
    - Live head CT designs typically have small capacitances, resulting in unreliable DDF test results.

An approach based on an assessment of instrument transformer condition using available condition data is now used to estimate failure risk; demonstrate any requirement for action; and to rank the priority of work that results. This approach is referred to as the Health Index (HI) and is further described in section 7.1.1 above, or in D2016/026703 – Instrument Transformer Health Index Method Description. Factors used to evaluate instrument transformers in the HI system include:

- DGA
- Moisture
- Type issues
- Age

This method cannot be applied to epoxy or gas instrument transformers or to CVTs as there is no useful condition data available to assess. Gas and epoxy types have not developed major issues at this point and CVTs have a monitoring system as described above.

Where applicable, the health index is being used going into the next regulatory period to develop a ranked listing of instrument transformers based on their probability of failing and their criticality in the network.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 16: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Instrument Transformers with PCB >30ppm	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability	• Existing population of known contaminated units. • Increasing risk of leaks with aging equipment. • Possibility of additional units added from improved test methods or previously unsampled units.	**Renewal initiative:** Replacement of 10 identified items.	**RP1 – Ongoing** 10 of 10 identified units replaced. Current works complete	Need No: 575 Project No: P0004188
Instrument Transformers with no monitoring facility	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage	• Unknown condition of oil insulation system. • Increasing risk of leaks with aging equipment. • Possibility of PCB contaminated items identified during removal and disposal procedure.	**Renewal initiative:** Replacement of 22 identified items.	**RP1 – Ongoing** 13 of 22 identified units replaced. PC June 2018	Need No: 647 Project No: P0004324
Instrument Transformers with other condition issues	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage	Instrument Transformers requiring replacement due to: • End of economic service life. • DGA limits exceeded. • Severe corrosion. • Spare parts not available. • Increasing risk of leaks with aging equipment. • Possibility of PCB contaminated	**Renewal initiative:** Replacement of 17 identified items.	**RP1 – Ongoing** 10 of 17 identified units replaced. PC June 2018	Need No: 648 Project No: P0004347

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Maintain network reliability •	items identified during removal and disposal procedure.			
132kV Instrument Transformers with high DGA	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	132kV Instrument Transformers with Routine Maintenance oil sample results that exceed Condition Monitoring Manual DGA limits.	**Renewal initiative:** Replacement of 11 identified items.	**RP1 – Ongoing** 7 of 11 identified units replaced. PC June 2018	Need No: 649 Project No: P0004328
220kV and above Instrument Transformers with high DGA	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	Instrument Transformers >220kV with Routine Maintenance oil sample results that exceed Condition Monitoring Manual DGA limits.	**Renewal initiative:** Replacement of 24identified items	**RP1 – Ongoing** 10 of 24 identified units replaced. PC June 2018	Need No: 650 Project No: P0004332
Replacement of High DGA Instrument Transformers – 66kV and below	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	Instrument Transformers <66kV with Routine Maintenance oil sample results that exceed Condition Monitoring Manual DGA limits.	**Renewal initiative:** Replacement of 9 identified items.	**RP1 – Ongoing** 5 of 9 identified units replaced. PC June 2018	Need No: 651 Project No: P0004337

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	• Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective				
Replacement of High DGA Instrument Transformers – Not yet identified	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	Instrument Transformers requiring replacement due to: • Equipment identified as being unfit for operational purposes. • DGA limits exceeded in MVTs • Misfiring of ferroresonance circuit in CVTs.	**Renewal initiative:** Replacement of 11 identified items.	**RP1 – Ongoing** 2 of 11 identified units replaced. PC June 2018	Need No: 652 Project No: P0004342
Current Transformers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	• Current Transformer asset health has been evaluated to determine the effective remaining life adjusted by condition parameters for the total population. • Aged based condition issues including leaks • Hairpin type CTs assessed as being closer to end of life in health assessment process. Priority will be given for early replacement of key types (e.g. Tyree 330kV CTs) • DGA levels are monitored and are	Health Index (HI) data combined with Probability of Failure and criticality data identified assets with positive cost benefit evaluation for renewal when weighed against evaluated ongoing risk cost. **Renewal initiative:** Replace 305 Current Transformers (single phase) based on economic and ALARP/SFAIRP evaluations to address associated risks. CTs requiring replacement installed next to a CB also requiring	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1338

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		used in health index and to initiate urgent replacements if required.	replacement will result in a combined DTCB, and are not included in this quantity.		
Voltage Transformers	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	• Voltage Transformer asset health has been evaluated to determine the effective remaining life adjusted by condition parameters for the total population. • CVT type issues on Trench and Haefely included in population risk assessment • VTs without sampling points assessed based on age to determine risk level. • DGA levels are monitored and are used in health index and to initiate urgent replacements if required.	Health Index (HI) data combined with Probability of Failure and criticality data identified assets with positive cost benefit evaluation for renewal when weighed against evaluated ongoing risk cost. **Renewal initiative:** Replace 298 Voltage Transformers based on economic and ALARP/SFAIRP evaluations to address associated risks.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1442
Current Transformers - Polymer Insulation	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Minimise environmental harm and property damage • Improve OPEX Performance	• Small oil volume of polymer insulation design reduces failure risks. • Supplied oil volume is often not sufficient for routine oil sampling throughout the service life of the asset. • Live head CT designs typically have small capacitances, resulting in unreliable DDF test results.	**Asset Manager to undertake further investigation:** Assess routine testing scope for population.	Investigation underway	

7.8.3 Maintenance Program – Instrument Transformers

Instrument Transformers are relatively low cost items and routine maintenance activities are structured to derive full operating functionality from each unit, for the duration of their design life. However, it is clear that individual units can develop problems requiring specific treatment or maintenance requirements. Where issues are identified, maintenance activities will be modified in order to collect sufficient information and measurement data to support thorough continuing analysis.

In the main, Routine Maintenance activities are designed to identify abnormalities by comparing oil sample data, inspection information and offline diagnostic data with limits and requirements described in the Substation Condition Monitoring Manual – GM AS S1 008. Where an abnormality exceeds a predetermined allowable value, a range of escalated actions are described, designed to address each abnormality.

Specific initiatives will address concerns associated with instrument transformer insulation systems, determined by:

- Insulating oil quality, dissolved gas and moisture content (where oil sampling is possible)
- Capacitance and Tanδ measurements (where measurements are possible)
- Mechanical considerations (Corrosion, Oil leaks)
- SF_6 Insulating gas leaks and gas quality – where poor quality is indicated
- Online Monitoring – Where the insulating medium is SF_6, online monitoring of the gas density will be implemented for all new instrument transformers, to enable TransGrid to meet the 0.5% Annual Gas Loss target and manage low gas call-out frequencies. The Asset Manager may amend Maintenance routines based on experience with SF_6 monitoring systems and benefits have been identified.

7.8.3.1 Component Failure Risk Assessment – Instrument Transformers

A component failure risk assessment has been conducted for the Instrument Transformer asset class and is shown in the tables below. The analysis is compared with the Substation Maintenance Plan for the asset class to demonstrate alignment between potential component failures and preventative maintenance activities prescribed to diagnose them.

Table 17: Component Failure Risk Assessment – Oil Filled Instrument Transformers

			Risk			Preventative			Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling	Planned maintenance	Business Plan Objectives
Main insulation system	Insulation breakdown, type fault	Failure of IT *	2	3	6		DGA, oil moisture	IR, DDF, Capacitance	Safety Reliability Environment CAPEX Performance STPIS Performance
	Water or other contamination	Failure of IT *	1	3	3				
	DLA point unearthed (CT only)	Damage to insulation leading to failure of CT *	1	3	3	Inspection			
	Corrosion of metal housing, breakdown of paint system, failure of gaskets	Damage to IT leading to contamination	1	1	1	Inspection	DGA, oil moisture	IR, DDF, Capacitance	
Palm and head of IT	Poor HV connection leading to overheating and damage to IT	Damage to IT, potential failure	1	2	2	Thermovision			
	Functional failure of component, contamination, undetected leaking	Damage to IT, reduction in insulation functionality	1	1	1	Inspection			
Bellows, gauges etc	Undetected loss of insulation	Failure of IT *	1	3	3	Inspection			
Cores	Failure leading to CT error or protection	Uncleared fault	1	2	2			Megger during protection	Reliability STPIS

Warning: A printed copy of this document may not be the current version

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			Risk			Preventative			Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Oil sampling	Planned maintenance	Business Plan Objectives
	failure							maintenance	Performance

- - **porcelain insulator is assumed here which increases the consequence of failure**

Table 18: Component Failure Risk Assessment – Gas Insulated Instrument Transformers

			Risk			Preventative			Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Planned maintenance	OLCM	Business Plan Objectives
Main insulation system	Insulation breakdown, type fault	Failure of IT	1	2	2		Gas decomposition		Safety Reliability Environment CAPEX Performance STPIS Performance
	Water or other contamination	Failure of IT	1	2	2		Dewpoint		
	Corrosion of metal housing, breakdown of paint system, failure of gaskets	Damage to IT leading to contamination	1	2	2	Inspection		Gas pressure alarm	
Palm and head of IT	Poor HV connection leading to overheating and damage to IT	Damage to IT, potential failure	1	1	1	Thermovision			
Gas pressure gauge	Undetected loss of insulation	Failure of IT	1	2	2	Inspection	Test gauge	Gas pressure alarm	
Cores	Failure leading to CT error or protection failure	Uncleared fault	1	2	2		Megger during protection maintenance		Reliability STPIS Performance

Table 19: Component Failure Risk Assessment – CVTs

			Risk			Preventative			Linkage
Component	Problem	Outcome	Likelihood	Consequence	Rank	Inspection	Planned maintenance	OLCM	Business Plan Objectives
Main insulation system - capacitor section	Insulation breakdown, type fault	Failure of IT	2	3	6			CVT unbalance monitoring	Safety Reliability Environment CAPEX Performance STPIS Performance
	Water or other contamination	Failure of IT	1	3	3				
	Corrosion of metal housing, breakdown of paint system, failure of gaskets	Damage to IT leading to contamination	1	3	3	Inspection			
Main insulation system - magnetic unit	Insulation breakdown, type fault	Failure of IT	2	2	4	Thermovision			
	Water or other contamination	Failure of IT	1	1	1	Thermovision			
	Corrosion of metal housing, breakdown of paint system, failure of gaskets	Damage to IT leading to contamination	1	1	1	Inspection			
Ferroresonance circuit	Functional failure of component. Undamped ferroresonance	Damage to IT	1	1	1				
Secondary	Failure leading to metering error or protection failure	Uncleared fault	1	2	2		Megger during protection maintenance		Reliability STPIS Performance

7.8.3.2 Maintenance Program Amendments – Instrument Transformers

Instrument Transformer maintenance has recently been reviewed and changes in frequency were made based on a consideration of the above risks. The objective of the change is for efficiency gains in the delivery of equipment maintenance.

The changes in maintenance affecting instrument transformers include:

- A reduction in inspections.

  Substation inspections are now scheduled at 6 monthly intervals for most substations and 12 months for substations less than 10 years old. The impacts on instrument transformer reliability arising from this are expected to be minor. From the table above, the items impacted by inspection maintenance are lower ranked risks.

- An extension of the time between maintenance intervals.

  The maintenance interval for Instrument Transformers was formerly 4 years and this has been extended to 6 years.

    - Hairpin design CTs oil sampling interval has been reduced to 3 years with consideration for increased risks and need for additional monitoring.

Details of the changes are included in AMI-AS0001 – Maintenance Plan Amendments July 2016 in file D2016/10692.

7.9 Static VAr Compensators (SVC) Asset Review

7.9.1 Population Review – SVCs

TransGrid has 5 Static VAr Compensators (SVCs):

- 2 at Broken Hill substation (each -25/+25 MVAr) commissioned 2015;
- 1 at Lismore (-100/+150 MVAr) commissioned 2000;
- 1 at Armidale (-120/+280 MVAr) commissioned 2000; and
- 1 at Sydney West (-100/+280 MVAr) commissioned 2004.

7.9.2 Emerging Issues, and Renewal and Maintenance Initiatives – SVCs

SVC's are specialised and expensive installations based on a complex technology but are becoming essential for the stable operation of power systems. SVC's have a nominal life of 20 years. The technology used in SVCs has been advancing and support for earlier generations may be limited.

A limiting factor on the service life of SVCs that is emerging is the life of the associated control system. The control system in an SVC is highly integrated with the thyristor valves and replacement of the control system typically entails replacement of the valves. This may also require renewal of the cooling system as it is provided to suit the service requirements of the thyristor valves. The high voltage components may be re-used in such a reconstruction.

SVC's require water cooling of the thyristor valves to operate and the cooling system requires a continuous AC supply to run pumps. SVCs are also designed to operate and preserve the stable operation of the power system during disturbances. It is essential that the cooling system pumps remain in operation during a system disturbance or the function of the SVC will not be provided when required.

There are some examples of poor SVC reliability has been caused by slow 415V changeover or by an insufficiently robust cooling control system.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 20: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
SVCs	• Maintain network reliability	• Obsolescence and spare parts availability. • Vendor support.	**Asset manager to undertake further analysis:** • Continue to inspect and monitor the identified issues through defect management and defect maintenance. • Further action to be taken if issues progress such that the safe and reliable operation of the substation is jeopardised and/or risks are increased.	**Ongoing**	Maintenance, inspection and analysis work is ongoing.
Armidale SVC	• Maintain network reliability	• Control system and thyristor valve reliability. • Obsolescence and spare parts availability. • Vendor support discontinued	**Renewal Initiative:** Replacement of SVC Control system and valves	**Complete**	Need No: DCN8 PAD-1008
Broken Hill SVC	• Maintain network reliability	• Control system and thyristor valve reliability. • Obsolescence and spare parts availability. • Vendor support discontinued	**Renewal Initiative:** Refurbishment of SVC Control system and valves	**Complete**	Need No: DCN39

7.9.3 Maintenance Program – SVCs

Because of the specialised nature of these installations, SVC maintenance is determined for each case. The maintenance requirements are summarised in an attachment to the Substation Maintenance Plan.

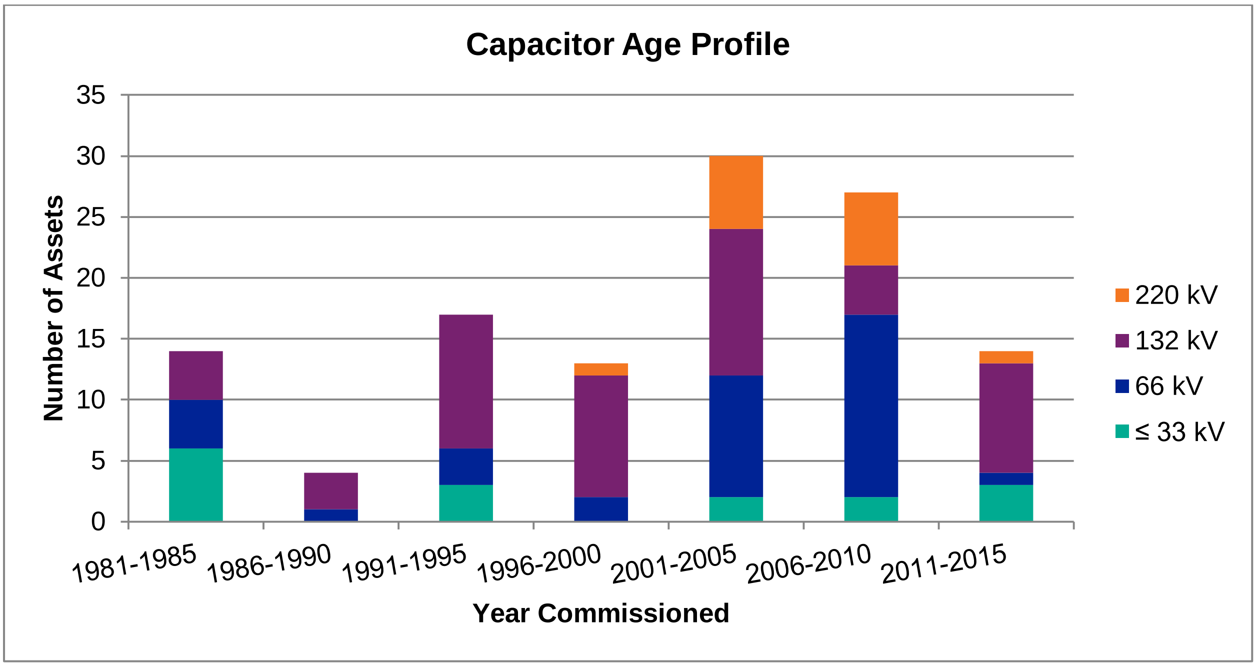
7.10 Shunt Capacitors Asset Review

7.10.1 Population Review – Capacitors

TransGrid has a total of 119 shunt capacitor banks in service within the network with an installed capacity of 6,883 MVAr. The banks range in voltage from 33kV to 330kV. The nominal lifespan of the capacitors ranges from 25-35 years, and approximately12% of the capacitors in service have exceeded a 30 year life.

The majority of the capacitor units installed are of the internal fuse type but some externally fused units have also been used. All PCB filled capacitors have been replaced and it is for this reason that all of existing capacitors have been manufactured and installed since 1980.

Figure 16: Capacitor Bank – Age profile



7.10.2 Emerging Issues, and Renewal and Maintenance Initiatives – Capacitors

Capacitor banks are reliable items of plant that have minimal maintenance requirements. Current and emerging issues that have been identified with respect to the capacitor banks are as follows:

- Increasing can failures that can indicate end of life for the bank and can lead to exhaustion of available spares.
- Where spares have been exhausted, further can failures will result in de-rating of the bank. It may be possible in some cases to obtain specially manufactured replacement cans but replacement spares have may contain a different dielectric from the rest of the bank, with a different thermal characteristic. This can lead to changes in spill current with temperature and result in bank alarms or trips.
- Cans can be affected by corrosion, leaks and broken brackets etc across the bank.
- Switching reactors may deteriorate (normally requires recoating).
- Older banks are not tuned type and may have a higher impact on the network during switching.
- Older banks are not paved inside the HV cage and are subject to forced outages caused by weed growth and/or additional planned outages to manage weed growth.

- Outages caused by bird strike. This is addressed in new banks with the provision of insulated connections. There is a negative impact from this in that thermovision is no longer effective on bank connections.
- Hot joints may become an issue. These are detected by thermovision and addressed as defects. There have been cases of whole banks being affected by hot joints and modification of connections has been required.
- A capacitor bank earthing connection failure occurred at Kemps Creek that resulted in a sustained fault that was undetected by protection. The cause was found to be poor design where earth grid strap at ground level was used to carry full phase current at ground level.   A limited number of similar cases were found and a modification is required to ensure that all load currents are carried in appropriate conductors.
- Capacitor banks can be made unavailable due to issues with neutral unbalance alarms.

  Can failures and physical deterioration are related to time in service, switching and physical exposure compounded by design susceptibilities. Older banks will hence be more affected.

  Older capacitor banks may consume available spare capacitor cans through failures and if replacement cans are no longer available, it will become impossible to ensure that the full rating of the bank is maintained for any future failures. It may be possible in such cases to accept a de-rating in the capacitor bank rating to allow ongoing operation. De-rating will allow cans to be removed from an affected bank in the case of a failure so that the bank remains balanced. Spares are also generated for future failures.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 21: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Shunt Capacitor Banks	• Minimise environmental harm and property damage • Maintain network reliability	• Leaking insulator fluid. • Obsolescence and a lack of spares.	**Asset manager to undertake further analysis:** • Continue to inspect and monitor the identified issues through defect management and defect maintenance. • Further action to be taken if issues progress such that the safe and reliable operation of the substation is jeopardised and/or risks are increased.	**Ongoing**	Maintenance, inspection and analysis work is ongoing.
Shunt Capacitor Banks	• Maintain network reliability	• Capacitor Bank associated circuit breakers • Issue with neutral unbalance alarms • Issue with automatic voltage control		**Ongoing**	Maintenance, inspection and analysis work is ongoing.
Capacitor Banks	• Maintain network reliability	• Neutral unbalance alarms causing unavailability of capacitor banks	**Operational/Renewal Initiative:** Review of capacitor bank defects to trigger further investigation and condition assessment. Outcome of condition assessment will determine maintenance or renewal initiative.	**Ongoing**	Maintenance, inspection and analysis work is ongoing.
Shunt Capacitor Banks	• Maintain network reliability	• Poor neutral earthing bar design (330kV Capacitor Banks)	**Operational initiative** Modify the affected capacitor banks to remove the issue	**Ongoing**	TWR121
Sydney North No.1 & No.2 Capacitor Condition	• Maintain network reliability	• Significant number of can failures in the two 'A' banks forming part of No. 1 and No. 2 Capacitors at Sydney North. • Many of the cans are leaking and the insulating fluid (DOW C4) is of some concern due to its chemical similarity to polychlorinated	**Renewal initiative:** Decommission and removal of capacitor banks No. 1 and No. 2 at Sydney North substation.	**RP1** PC: 2017	Need No: DCN 285

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
		biphenyl (PCB). • Subject to defects for hot joint repair, unbalance alarms and trips and for weed control.			
Broken Hill No.3 22kV Capacitor Condition.	• Maintain network reliability	• Technical obsolescence - a lack of spares availability places doubt over the ability to return the capacitor bank to service if any capacitor can elements are to fail.	**Maintenance initiative:** Additional spares identified, mitigating renewal need. Ongoing management through maintenance plan.	**Withdrawn**	Need No: DCN151 & DCN296 D2003/2312 – Maintenance Plan – Substation Assets

7.10.3 Maintenance Program – Capacitors

Capacitor banks are static items of plan with minimal maintenance requirements. Maintenance consists of inspection to identify physical defects and thermovision where possible to identify hot joints. Defect maintenance may result from unbalance alarms or trips.

7.11 Surge Arrestors Switches Asset Review

7.11.1 Population Review – Surge Arrestors

Surge arrestors are used to protect expensive items of plant (such as transformers and reactors) from failure due to transient voltage surges or lightning strikes. There are over 2,020 surge arrestors installed across TransGrid's system.

The most significant issue concerning surge arrestors has been the potential for explosive failure of older Silicon Carbide types that contain spark gaps provided to limit the 50Hz current drain during normal operating conditions, with water ingress often resulting in explosive failure of the surge arrestor. Elimination of gapped surge arrestors is a replacement program that has been operating over a number of years and is nearing completion.

Newer Zinc Oxide types do not contain spark gaps. There is no suitable method presently available for the routine monitoring of zinc oxide surge arrestor condition.

7.11.2 Emerging Issues, and Renewal and Maintenance Initiatives – Surge Arrestors

The only emerging issue associated with surge arrestors is the removal of gapped surge arrestors which was outlined above.

Table 22: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Gapped Surge Arrestors	• Maintain network reliability • Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	The remainder of the gapped surge arrestor population present a risk of failure resulting in reliability and safety risks.	Replacement of the remaining gapped surge arrestors.	Expected completion: 2016/17 Estimate: Not yet completed.	Need No: 1299

7.11.3 Maintenance Program – Surge Arresters

Surge arresters are essentially maintenance free due to the lack of moving parts and their solid insulation system. Cleaning of insulators is completed during the associated bay maintenance.

Substation inspections will identify any issues which will be rectified on a defect basis.

7.12 Disconnectors and Earth Switches Asset Review

7.12.1 Population Review – Disconnectors and Earth Switches

TransGrid manages a total disconnector and earth switches population of 5,343 units ranging in voltage from 11kV to 500kV. The disconnectors and earth switches population is comprised of:

- 2,185 Earth Switches (ESW) – this account for approximately 41% of the total population.
- 3,158 Disconnectors (DISC) – this account for approximately 59% of the total population.

The disconnectors and earth switches age profile is shown in Figure 17 and Figure 18. It shows that approximately 25% of the units were commissioned before 1976, and have thus exceeded their nominal lifespan of 40 years. The oldest units were manufactured in 1950. The disconnectors and earth switches have an average age of approximately 27 years.

Earth switches are usually integrated with disconnectors, being procured at the same time from the same manufacturer. Replacement of the disconnector routinely requires the replacement of the associated earth switch where the disconnector and earth switch are a single integrated structure.

Figure 17: Disconnectors and Earth Switches – population profile

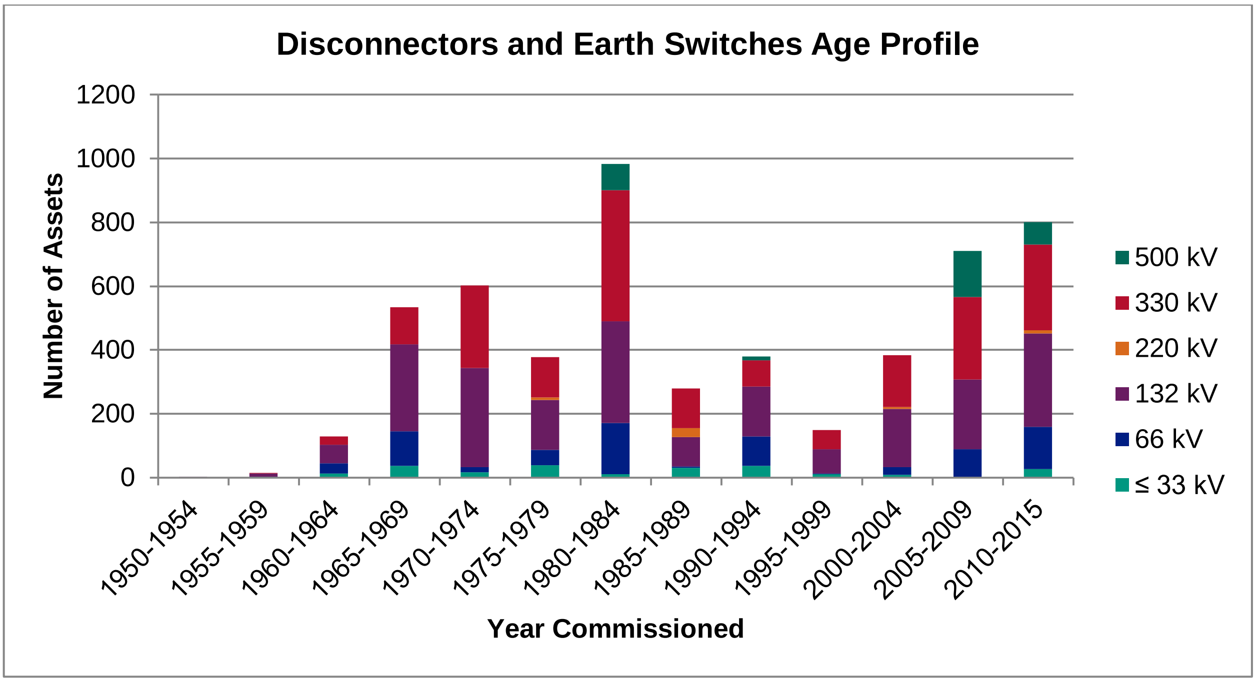
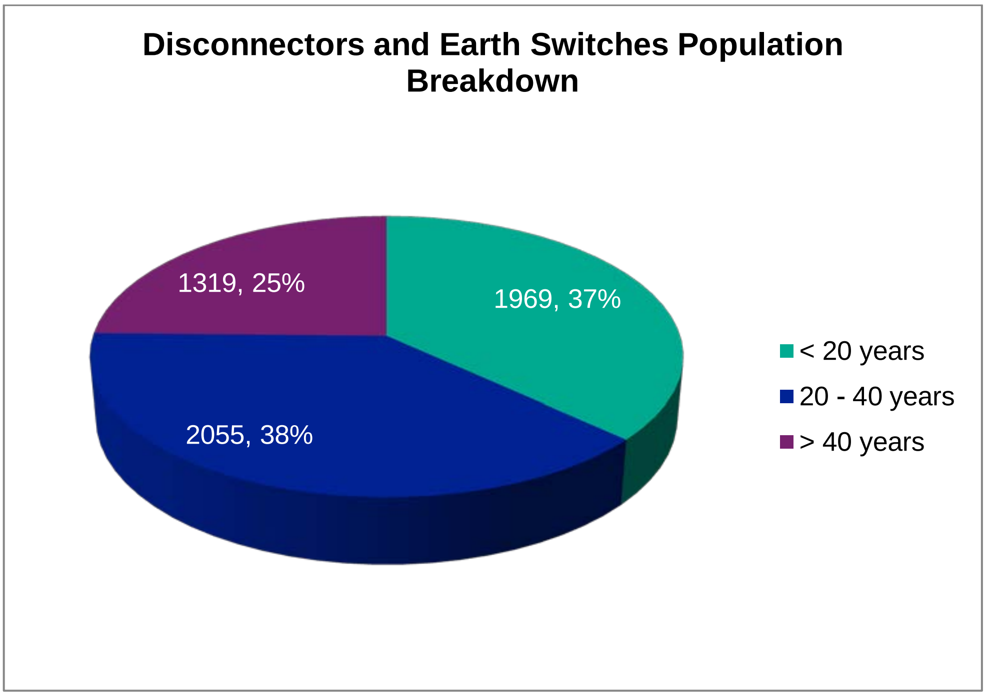


Figure 18: Disconnectors and Earth Switches – population breakdown



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7.12.2 Emerging Issues, and Renewal and Maintenance Initiatives – Disconnectors and Earth Switches

The following current and emerging issues have arisen with regard to disconnectors and earth switches.

Use of disconnectors in an air insulated switchyard with associated equipment having much lower maintenance requirements is a significant problem. Disconnectors are provided essentially to allow safe access to other high voltage equipment.

The reliability of disconnectors/earth-switch is becoming an issue, which is due to two main causes:

- Newer types of disconnectors have not been performing well, with concerns regarding the robustness of their design. This is being addressed through attention to specifications used and inclusion of additional requirements related to robustness.
- There have been cases of mechanical failures and failures of contacts on older disconnectors/earth-switches and deterioration is occurring due to their length of service and exposure to weather. Refurbishment or replacement may become necessary.

The most common of these two issues is the second which is due to the aging of the disconnectors, which leads to the following:

- Difficulty or inability in operation due to corrosion or poor contact alignment
- Failure of mechanical drive components including turnbuckles, bearings and motors.
- Degradation of contacts leading to sticking or hot joints.
- Lack of manufacturer support and the inability to procure required parts for maintenance activities.
- Oil leakage from viscous couplings
- Failure of indicating lamps

The original design of some older disconnectors can also include the unsafe location of the isolating fuses within the control box which are in the proximity of other electrical terminals.

The current and emerging issues, and renewal and maintenance initiatives, are summarised in the table below.

Table 23: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Disconnectors & Earth Switches	• Improve OPEX Performance • Maintain network reliability • Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP)	Disconnector condition issues are developing arising from age related deterioration. • Difficulty or inability in operation due to corrosion or poor contact alignment • Failure of mechanical drive components including turnbuckles, bearings and motors. • Degradation of contacts leading to sticking or hot joints. • Lack of manufacturer support and the inability to procure required parts for maintenance activities.	**Renewal initiative:** Replace 62 disconnectors based on economic and ALARP/SFAIRP evaluations to address associated risks.	**RP2** Included in 2018-23 Revenue Reset Submission	Need No: 1357
Disconnectors & Earth Switches - 220kV and above	• Improve OPEX Performance • Maintain network reliability	Disconnectors are inoperable and parts are not available to restore them.	**Renewal initiative:** Replacement of 8 disconnectors and associated earth switches	**RP1 - Ongoing** 3 of 8 completed PC: June 2018	Need No: 585 Project No: P0004224
Disconnectors & Earth Switches – 132kV	• Improve OPEX Performance • Maintain network reliability	Disconnectors are inoperable and parts are not available to restore them.	**Renewal initiative:** Replacement of 3 disconnectors and associated earth switches	**RP1 - Ongoing** 0 of 3 completed PC: June 2018	Need No: 586 Project No: P0004316
Disconnectors & Earth Switches – 66kV	• Improve OPEX Performance • Maintain network reliability	Disconnectors are inoperable and parts are not available to restore them.	**Renewal initiative:** Replacement of 6 disconnectors and associated earth switches	**RP1 - Ongoing** 3 of 6 completed PC: June 2018	Need No: 587 Project No: P0004320

7.12.3 Maintenance Program – Disconnectors and Earth Switches

Maintenance for disconnectors and earth switches is largely defect based and depends on review and rectification of defects raised during substation inspection activities. These inspections include:

- Thermovision inspection
- Substation inspection

In addition to inspections, some routine maintenance is implemented as follows:

- Operational checks
- Checking of rod gap spacing
- Minor servicing if efficient to complete during other works
- Servicing of Taplin and ALM types to implement known solutions to identified issues.

Disconnector and Earth Switch maintenance has recently been reviewed and changes in frequency were made based on a consideration of the associated risks. The objective of the change is for efficiency gains in the delivery of equipment maintenance through alignment with associated bay equipment maintenance intervals.

The changes in maintenance affecting disconnectors and earth switches include:

- An extension of the time between maintenances

  The interval for maintenance of disconnectors and earth switches was formerly 4 years and this has been extended to 6 years

Details of the changes are included in AMI-AS0001 – Maintenance Plan Amendments July 2016 in file D2016/10692.

7.13 OLCM Equipment Asset Review

7.13.1 Population Review - OLCM

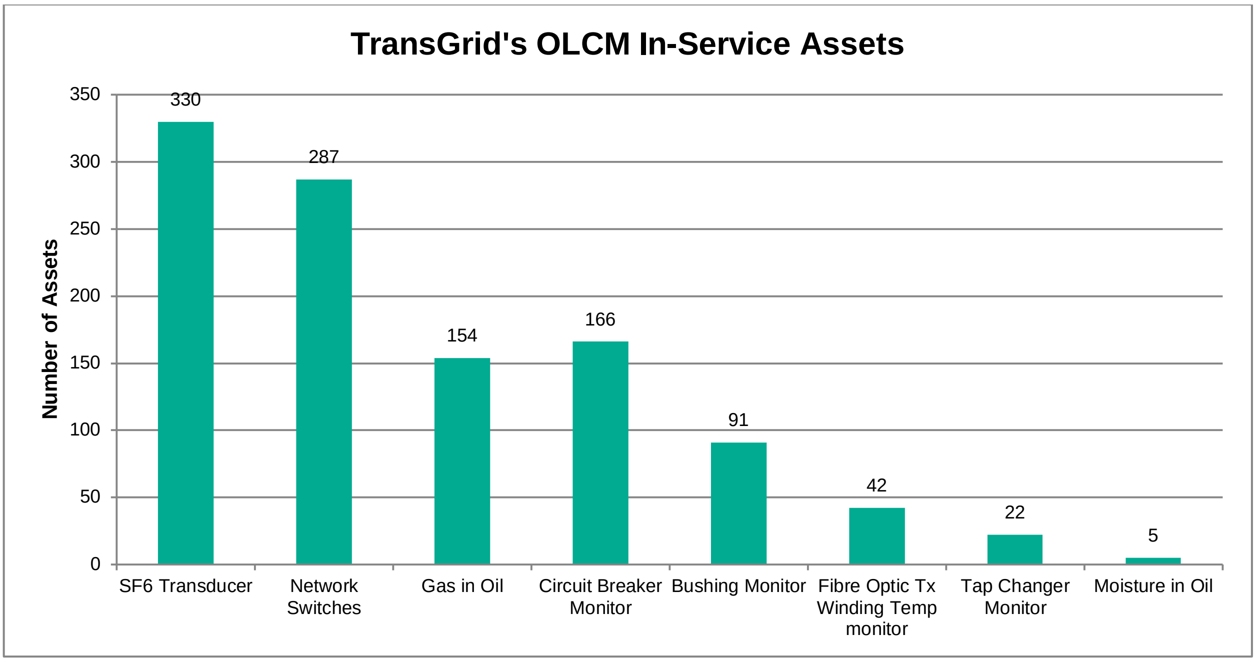
Online condition monitoring in TransGrid is continuous, in-service monitoring that returns information about key equipment parameters or indicators, generally through the use of specialised sensors or devices. TransGrid implemented Online Condition Monitoring in response to a 2002 Transformer Failure Investigation, after identifying the following potential benefits in the use of this type of equipment:

- Avoidance of failure through more intensive monitoring of key condition characteristics.
- A reduction in off line maintenance requirements where on line monitoring provides sufficient information and confidence
- A reduction in costs (and WHS benefits) where predictive loss of insulating gas functionality can be employed, replacing defect call-outs with scheduled top-up activities
- Potential to increase the time to replacement for equipment that would otherwise need to be removed to ensure no failure in service.
- Safety benefits for sites where electrostatic field strengths are known to have significant induction hazards

TransGrid have chosen devices that monitor a range of quantities on different equipment, including:

- Transformers:
  - Hydrogen (or volatile dissolved gases) in oil.
  - Moisture in oil
  - Bushing Tanδ and Capacitance
  - Diverter Switch drive torque
- Circuit breakers:
  - Timing and travel (during operation)
  - Operating mechanism current consumption
  - Insulating gas density
- Instrument transformers and GIS:
  - Insulating gas density

Figure 19: OLCM population profile



The condition monitoring system is integrated into the TransGrid control system, with this IT network managed by the Secondary Systems Asset Manager. In order to establish clear responsibilities, Substation Assets do not include any site servers or network servers in the OLCM device population.

The OLCM system has been in place for the last 7 years with two significant successes where online bushing monitoring has prevented the failure of the associated 330kV 375MVA transformers.

7.13.2 Emerging Issues, and Renewal and Maintenance Initiatives - OLCM

Some component replacements have already been necessary due to end of life conditions. Other issues include:

- Reliability of the monitoring device itself. There have been a number of false alarms from condition monitoring equipment leading to unnecessary outages and offline testing.
- The life of condition monitoring sensors is thought to be 10-15 years. An example of this that is now being encountered is the failure of hydrogen in oil monitors as the electrochemical sensor ages.
- Increasing number of plant types with known abnormalities which would benefit from OLCM monitoring
- Increasing installed volume of SF_6 gas (GIS in particular)
- The capital cost of additional installations needs to be offset against the possible gains.

Table 24: Emerging Issues, and Renewal and Maintenance Initiatives

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
Online Condition Monitoring (OLCM)	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where cost effective	• Reliability of OLCM devices and sensors. • Modifications to data requirements to meet increasing demands from users • Bushing types with known defects • Aging Transformer/Reactor units with unacceptable moisture/gas content • Increasing volume of SF_6	• Continue to inspect and monitor the identified issues through defect management and defect maintenance. • Further action to be taken if issues progress such that the safe and reliable operation of the substation is jeopardised and/or risks are increased • Install OLCM devices to monitor required quantities	**Ongoing**	
Online Condition Monitoring (OLCM)	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance • Pursue STPIS revenue where	• Monitoring of SF_6 gas densities to identify plant that is losing gas and the rate of leakage. • Monitoring of transformer bushings to detect a developing failure and potentially eliminate the need for routine manual testing. • Measurement of combustible gasses in oil insulated plant for early fault detection. • Measurement of water in paper to support future refurbishment options. • Monitoring of 500 kV CB's to eliminate safety issues related to	**Renewal initiative:** Install and/or replace OLCM devices at 32 nominated sites.	**RP1 - Ongoing**	Need No: 527

Assets	Asset Management Objective	Emerging Issues	Strategic Initiative	Progress (completion and expenditure)	Reference Documents
	cost effective	induction hazards and obtain savings in maintenance.			
Circuit Breakers - OLCM Devices	• Manage substation related public and staff safety risks to As Low As Reasonably Practicable (ALARP)/So Far As Is Reasonably Practicable (SFAIRP) • Manage substation related bushfire risks (people safety) to ALARP/SFAIRP • Minimise environmental harm and property damage • Maintain network reliability • Improve CAPEX Performance • Improve OPEX Performance	• Deployment of OLCM devices onto low or non-critical circuit breakers • Population of high criticality and remote circuit breakers have no online condition monitoring installed.	**Operational Refurbishment Project:** Relocation of 39 OLCM devices from low criticality CBs to nominated CBs based on operating duty, location and criticality.	**RP1** See Circuit Breakers Section 7.6.2	Need No: 1681

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7.13.3 Maintenance Program – OLCM

The likely benefits occurring from on-line condition monitoring and in particular the potential for improved reliability and availability of Substation Plant are considered when identifying appropriate maintenance activities for Substation plant. Where reliable on-line systems are in place, certain periodic diagnostic or invasive maintenance requirements may become redundant with the approval of the Asset Manager. Minimum prerequisites for such amendments are:

- Installation of reliable sensors
- Adequate communication systems to facilitate the collection of condition monitoring data,
- Robust systems for the specification and implementation of settings and alert thresholds, and
- Effective asset management processes and resources to monitor, assess and action the on-line condition monitoring data

In the main, Routine Maintenance activities are designed to identify abnormalities in plant and equipment by comparing measurement data and inspection information with limits and requirements described in the Substation Condition Monitoring Manual – GM AS S1 008. Where an abnormality exceeds a predetermined allowable value, a range of escalated actions are described, designed to address each abnormality.

Condition monitoring devices are capable of collecting a range of similar measurement data and information online, resulting in reductions in maintenance costs and some benefits in safety, particularly on 500kV circuit breakers. Where devices are installed on Transformers and Reactors, benefits can be derived where the devices are monitoring existing abnormal conditions or defects.

Installation of Condition Monitoring however, must be consistent with the following principles:

- Maintenance is to be minimised consistent with reliable performance
- Maintenance costs are to be minimised consistent with corporate objectives of safety, reliability, availability and risk management.
- New devices are to be of a proven safe, reliable and low maintenance design fitted with sensors with known long term operating life

Where known issues apply to a Condition Monitoring device, specific maintenance initiatives will be implemented whilst continuing to ensure that any maintenance initiative designed to address specific concerns adhere to the principles outlined above.

8. Future Outlook

8.1 Forecast Expenditure

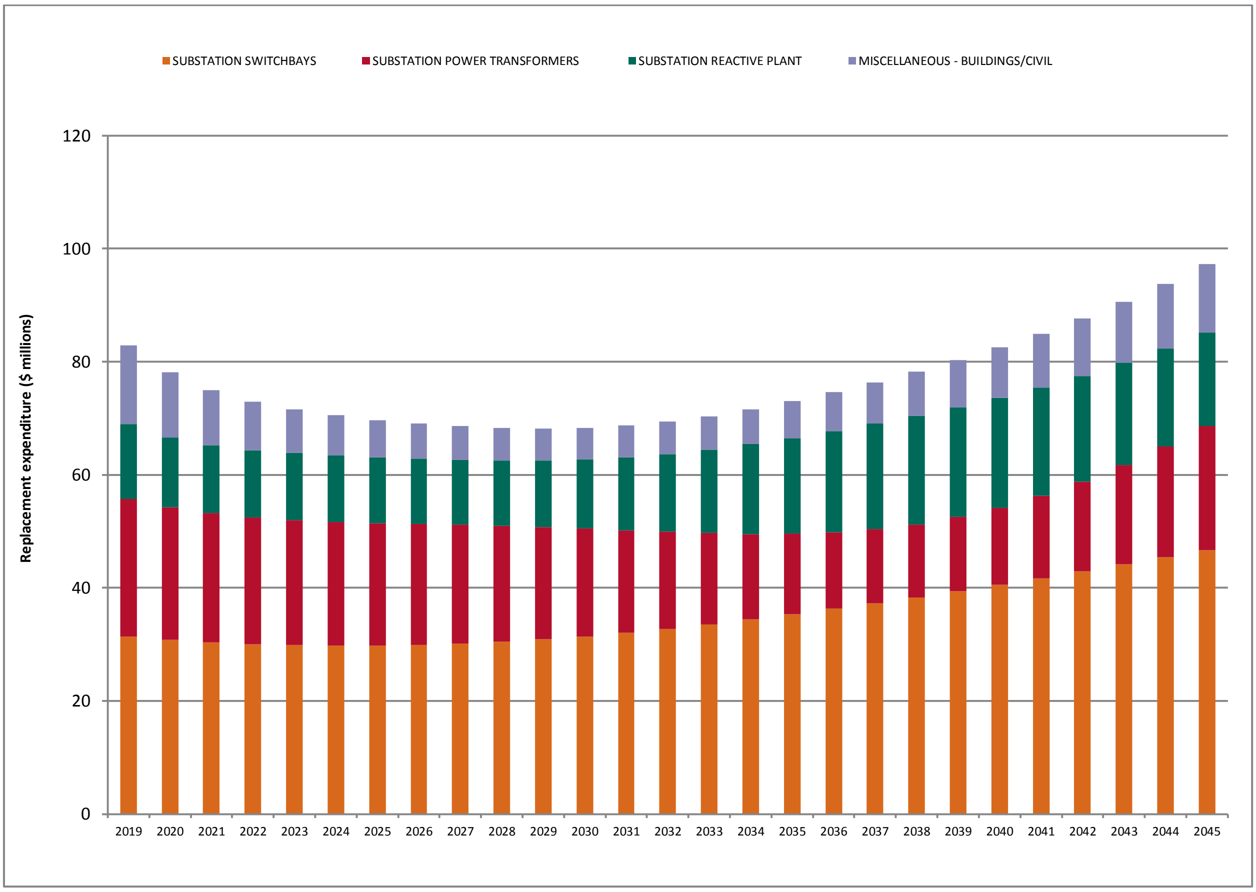
A review of expected replacement profiles of substation equipment using nominal expected life has been undertaken to obtain an expected ongoing replacement profile in the future. Nominal life has been used as it is not feasible to project replacements on a condition basis for this length of time into the future. Replacements are undertaken on a condition basis and that the projections made using nominal life may not reflect actual outcomes.

The outcomes of the review are shown in Figure 20 - Anticipated expenditure profile - below, which shows the future renewal, disposal and maintenance expenditure on an aged based assumption in 2016/17 dollars.

This high level review indicates that the ongoing maintenance of substation equipment performance levels for at least a ten year timeframe is sustainable with ongoing injection of capital and maintenance expenditure at levels similar to the present.

A possible risk to longer term stability of expenditure levels is related to deterioration of steelwork. A strategy is being implemented to address this concern and the graphs below assume success of this strategy. Failure of the strategy is expected to result in the need for large expenditure to either reconstruct the affected sites or to undertake major works in situ.

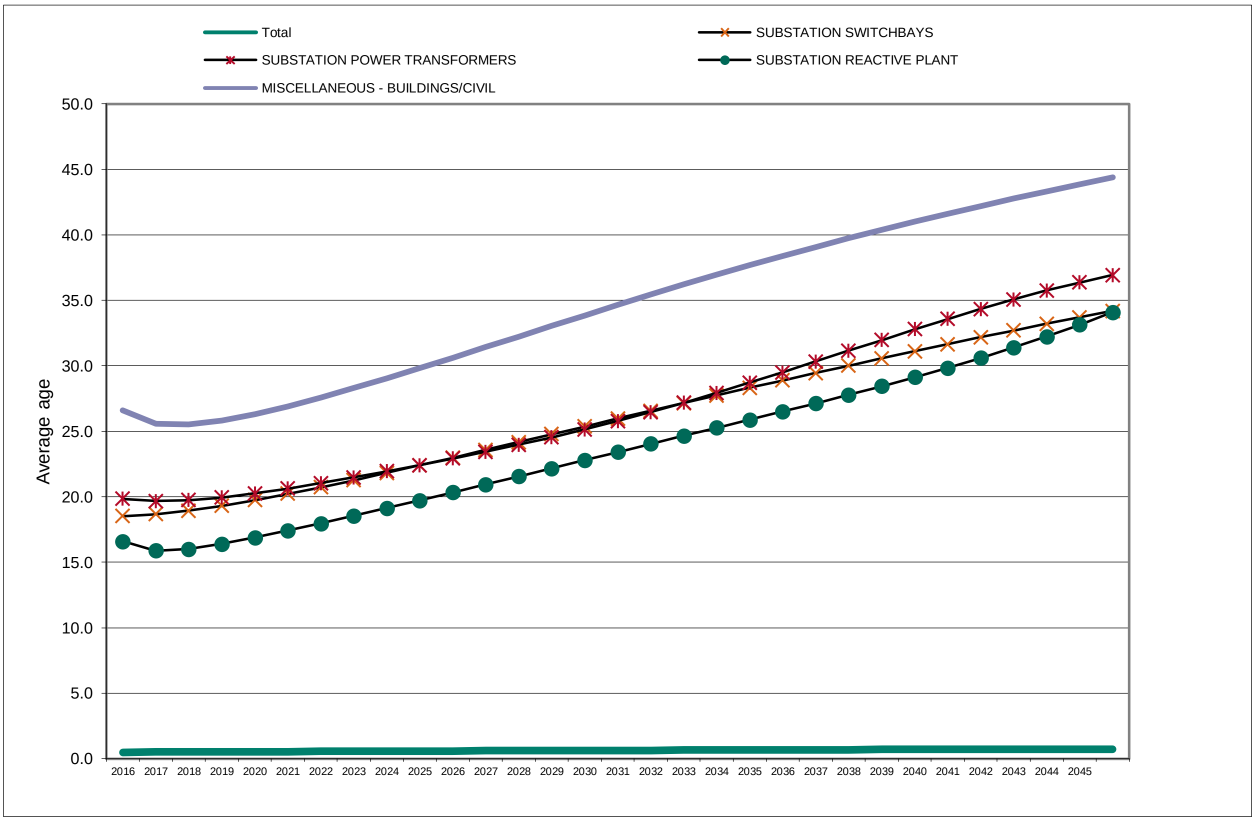
Figure 20 - Anticipated expenditure profile



8.2 Anticipated Changes to the Asset Base

Using the same age based model, the average age of substation equipment profiles has been projected and is included below in Figure 21 - Projected average age. Over the longer term, an increase in average age can be seen. This has the potential to increase failure rates and lower the overall performance of the network. Additional measure may become necessary to manage the additional risk. The increase is gradual and not significant in a ten year time frame but the situation will be monitored.

Figure 21 - Projected average age



9. Spares

Spares are items of serviceable equipment that are booked into and stored in TransGrid's storage facilities for maintenance and project purposes. This document does not cover the spares required for project purposes.

TransGrid has purchased a range of strategic spare equipment to improve the organisations ability to restore supply and system security in a timely manner, following the major failure of an in-service unit.

Substation spares are managed in accordance with the following documents:

- GM AS S5 001 Spare Power Transformers Policy
  This establishes the required system spare transformers to be held by type based on a probabilistic analysis.
- GM AS S1 009 – In Service and Spare Transformers and Reactors
  Lists in service transformers and reactors and identifies suitable spares from the spare transformer fleet.
- GM AS S2 012 – Substation Spares Policy
  Establishes standard spares holdings by plant category and in consideration of the number in service.
- GM AS S2 014 – Procedures for Management of Substation Spares Inventory
  Establishes processes to achieve the spares policy.

10. Asset management capability and continual improvement

Asset Management Objectives	Asset Management Actions	Initiatives / Reference
Deliver a successful revenue determination	1. Documentation required for RP2 submitted	All documentation completed by deadline.
▪ ISO 55001 Compliant ▪ Continually improve the Asset Management System	2. Asset information improvements (governance, data, reporting and systems) implemented 3. Asset replacement life optimised 4. Asset maintenance scope and frequency optimised 5. Asset management competency enhanced 6. Plant and design standards optimised	• Asset Data Library - Asset Information Strategy • AIM Stage 2 • Continue improvement to asset health indexes • Refine FMECA analysis for all key substations asset classes • Internal and external training for asset strategists • ACE initiatives implemented
▪ AS 5577 compliant ▪ Continually improve the Electricity Network Management System	7. Formal Safety Assessments complete and externally audited	• Refine monitoring change of operating conditions and remaining asset life review • Improve asset record keeping
Improve CAPEX performance	8. REPEX and risk scenarios understood 9. Investment governance/prioritisation/optimisation process enhanced	• Utilisation of the risk tool to provide a more granular view of the pre and post-investment risks associated with building new or replacing assets. • ALARP analysis completed for proposed RP2 renewals. • NPV analysis completed on all solutions to ensure value for money.

Table 25: Continual Improvement Initiatives

Asset management capabilities are those elements that facilitate best practice asset management decision making. These include:

- Risk management practices.
- Asset information.
- Staff skills and competency.
- Continual improvement initiatives for the system.

11. Implementing the Strategies

To implement the strategic renewal and maintenance initiatives stemming from this document, actions are to be established via the:

- Maintenance Plan – Substation Assets: The maintenance plan outlines the routine maintenance tasks and frequencies for each asset type.
- Capital Works Program: The capital works program outlines the approved asset renewal and disposal projects.

The Substation Asset Manager is responsible for preparation of the maintenance plans and referring the renewal and disposal initiative to the network investment process. Field Services is responsible for delivering the maintenance plans as per the Service Level Agreements, and Portfolio Management group/Project Services are responsible for delivering the renewal and disposal initiatives detailed in the approved capital works program.

12. Monitoring and review

Implementation of the Substation Renewal and Maintenance Strategy is monitored and reviewed by the Substation Asset Manager, Manager/Asset Strategy and Executive Asset Strategy Committee annually.

13. Roles and Responsibilities to Develop this Asset Strategy

The roles and responsibilities of those responsible for the development of this asset strategy are as follows:

- The Manager/Asset Strategy is responsible for the approval of this strategy.
- Substation Asset Manager is responsible for the development and regular review of this strategy. The document will be reviewed biannually and as significant changes to investment needs become apparent.

14. Change history

Revision no	Approved by	Amendment
4	T. Gray Act Manager/Asset Planning	Minor editing only for consistency of format. No change in content.
3	L.Wee Group Manager/Asset Strategy	Review and update to deliver the 2016/17 Business Plan and further enhance the strategy.
2	L.Wee Group Manager/Asset Strategy	Review and update to deliver the 2015/16 Corporate Plan and further enhance the strategy.
1	Garrie Chubb Group Manager/Asset Performance	Updated to reflect the continual improvement in the "top down" approach for the line of sight to the Asset Management Strategy and the Corporate Plan and an enhanced description of the asset management decision process and the strategic initiatives to be undertaken.

15. References

Asset Management Strategy and Objectives

Asset Management System Description

Maintenance Plan – Substation Assets

16. Attachments

Attachment 1 - Substation Asset Breakdown

Attachment 1 - Substation Asset Breakdown

The following gives a structured breakdown of Substation related assets and where in the Renewal and Maintenance Strategy documents they can be found:

Item	Asset Strategy Coverage
Site	
Surrounds	
Oil containment dams	7.3 Site/Infrastructure
Fire buffer	See Property RMS Document
Grassed areas	See Property RMS Document
Drainage outlets	7.3 Site/Infrastructure
Transmission line structures	See Mains RMS Document
Land ownership/easement	See Property RMS Document
Boundary fences	See Property RMS Document
Roads	See Property RMS Document
Switchyard	
Earthgrid	7.3 Site/Infrastructure
Main grid	7.3 Site/Infrastructure
Earth connections	7.3 Site/Infrastructure
Isolations (from outside sources)	7.3 Site/Infrastructure
Civil	
Bench	
Oil containment including compounds and bunds etc	7.3 Site/Infrastructure
Normal drainage	7.3 Site/Infrastructure
Covering(gravel/grass)	7.3 Site/Infrastructure
Roads and access (internal)	See Property RMS Document
Cable Trenches	7.3 Site/Infrastructure
Footings	Su Site/Infrastructure stations
Steel (includes fitting and holding down bolts etc)	7.3 Site/Infrastructure
Equipment structures	7.3 Site/Infrastructure
Main structures	7.3 Site/Infrastructure
Kiosks and boxes	See Sec. Sys. RMS Document
AC and DC distribution (switchyard boxes)	See Sec. Sys. RMS Document
BMK	See Sec. Sys. RMS Document
VT and CT marshalling boxes	See Sec. Sys. RMS Document
BBP summation	See Sec. Sys. RMS Document

Item	Asset Strategy Coverage
Ancillary Equipment	
Cabling – control - low voltage	See Sec. Sys. RMS Document
Security	
Access Systems	See Security Assets RMS Document
Keys and locks	See Security Assets RMS Document
Fences and gates	See Property RMS Document
Alarm systems	See Security Assets RMS Document
Camera systems	See Security Assets RMS Document
Fire	7.3 Site/Infrastructure
Fire pumps	7.3 Site/Infrastructure
Fire tanks	7.3 Site/Infrastructure
Hydrant systems	7.3 Site/Infrastructure
Fire alarm system	7.3 Site/Infrastructure
VESDA	7.3 Site/Infrastructure
Sprinkler systems (compressors, pipes, etc)	7.3 Site/Infrastructure
Fire kiosks	7.3 Site/Infrastructure
Gas systems	7.3 Site/Infrastructure
Deluge system	7.3 Site/Infrastructure
AC Supplies	See Sec. Sys. RMS Document
Switchboards	See Sec. Sys. RMS Document
Alternators	7.3 Site/Infrastructure
Switchyard cabling	See Sec. Sys. RMS Document
Outlets	See Sec. Sys. RMS Document
Local boxes	See Sec. Sys. RMS Document
DC supplies	See Sec. Sys. RMS Document
Chargers	See Sec. Sys. RMS Document
Batteries	See Sec. Sys. RMS Document
Distribution boards	See Sec. Sys. RMS Document
GIS	
Building related	
Cranes	See Property RMS Document

Item	Asset Strategy Coverage
Gas warning systems	7.3 Site/Infrastructure
Gas collection (Haymarket only)	7.3 Site/Infrastructure
Mechanical ventilation/chillers etc	7.3 Site/Infrastructure
Lifts	See Property RMS Document
Building management systems	See Property RMS Document
Fire systems	7.3 Site/Infrastructure
Air conditioning	7.3 Site/Infrastructure
Primary Plant	
Circuit breakers	7.6 Circuit Breaker
Current Transformers	7.8 Instrument Transformer
Hairpin	7.8 Instrument Transformer
Live head gas/oil	7.8 Instrument Transformer
Torroids (e.g. dead tank CBs)	7.8 Instrument Transformer
Neutral unbalance CTs	7.8 Instrument Transformer
Other types	7.8 Instrument Transformer
Voltage Transformers	7.8 Instrument Transformer
MVT gas/oil/epoxy	7.8 Instrument Transformer
CVT	7.8 Instrument Transformer
Disconnectors	7.12 Disconnector/Earth Switch
Earth Switches	7.12 Disconnector/Earth Switch
Power Transformers	7.4 Transformers
Windings	7.4 Transformers
Tapchanger	7.4 Transformers
Bushings	7.4 Transformers
Fans and pumps	7.4 Transformers
Tank	7.4 Transformers
Radiator	7.4 Transformers
Conservator	7.4 Transformers
Valves	7.4 Transformers
Aux transformers	7.4 Transformers
Reactive plant	7.5 Reactors

Item	Asset Strategy Coverage
Reactors	7.5 Reactors
Oil filled	7.5 Reactors
Windings	7.5 Reactors
Bushings	7.5 Reactors
Fans and pumps	7.5 Reactors
Tank	7.5 Reactors
Radiators	7.5 Reactors
Conservator	7.5 Reactors
Valves	7.5 Reactors
Air core	7.5 Reactors
Neutral Earthing	7.5 Reactors
Capacitors	7.10 Capacitors
SVCs	7.9 SVC
GIS Equipment	
Circuit Breakers	7.7 GIS
Three position switch	7.7 GIS
VT	7.7 GIS
CT	7.7 GIS
Insulating earth switch	7.7 GIS
Gas compartment	7.7 GIS
Surge arrestors	7.7 GIS
Duct	7.7 GIS
Conductors	7.7 GIS
Barriers	7.7 GIS
Burst disks	7.7 GIS
Gas monitoring sensors	7.7 GIS
Gas Insulated Transformers/Reactors	
Tanks	7.4 Transformers / 7.5 Reactors
Monitoring	7.4 Transformers / 7.5 Reactors
Cooling system	7.4 Transformers / 7.5 Reactors
Blowers	7.4 Transformers / 7.5 Reactors

Item	Asset Strategy Coverage
Tapchangers	7.4 Transformers / 7.5 Reactors
Others	7.4 Transformers / 7.5 Reactors
Line traps	See Sec. Sys. RMS Document
Surge arrestors	7.3 Site/Infrastructure
Cables	
<66kV	7.3 Site/Infrastructure
>=66 kV	See Cables RMS Document
Fault throwing switch	7.12 Disconnector/Earth Switch
Earthing transformer	7.8 Instrument Transformer
HV Connections and fittings	7.3 Site/Infrastructure
Line traps	See Sec. Sys. RMS Document
PLC coupling equipment	See Sec. Sys. RMS Document
Other	7.3 Site/Infrastructure
Secondary Systems	
Tunnelboards or equivalent	See Sec. Sys. RMS Document
Control and alarms	See Sec. Sys. RMS Document
Protection	See Sec. Sys. RMS Document
Metering	See Sec. Sys. RMS Document
OLCM infrastructure	See Sec. Sys. RMS Document
Communications	
Towers	See Sec. Sys. RMS Document
Antennae	See Sec. Sys. RMS Document
Waveguides	See Sec. Sys. RMS Document
Terminal equipment	See Sec. Sys. RMS Document
Optic fibre marshalling boxes	See Sec. Sys. RMS Document
fibre	See Sec. Sys. RMS Document
OLCM	
Devices	7.12 OLCM
infrastructure	See Sec. Sys. RMS Document

Item	Asset Strategy Coverage
Buildings associated with Switchyards:	
Building standard control building and internal switchyard buildings and sheds	
Building structure and roof permanent fixtures	See Property RMS Document
Control Room	See Property RMS Document
Amenities	See Property RMS Document
Workshop	See Property RMS Document
Cranes	See Property RMS Document
Storage including switchyard storage areas	See Property RMS Document
Air conditioning	See Property RMS Document
Plumbing	See Property RMS Document
Telstra lines	See Sec. Sys. RMS Document
Battery Room	See Property RMS Document
Lighting normal and emergency – switchyard and building	See Property RMS Document
Car park/paved areas	See Property RMS Document