Asset Management Plan

High Voltage Regulators

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Responsibilities

This document is the responsibility of the Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

Please contact the Asset Strategy Team Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

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Record of Revisions

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1 Purpose

The purpose of this asset management plan is to define the management strategy for High Voltage Regulators. The plan provides:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans
- The key projects and programs underpinning its activities
- Forecast CAPEX and OPEX, including the basis upon which these forecasts are derived

2 Scope

This document covers the high voltage (HV) regulators sites, including the regulators, their associated enclosures and earthing systems.

The following assets are not covered under the High Voltage Regulator – Asset Management Plan:

- Connecting overhead lines, cables and switchgear
- Control equipment
- Capacitor banks

3 Strategic alignment and objectives

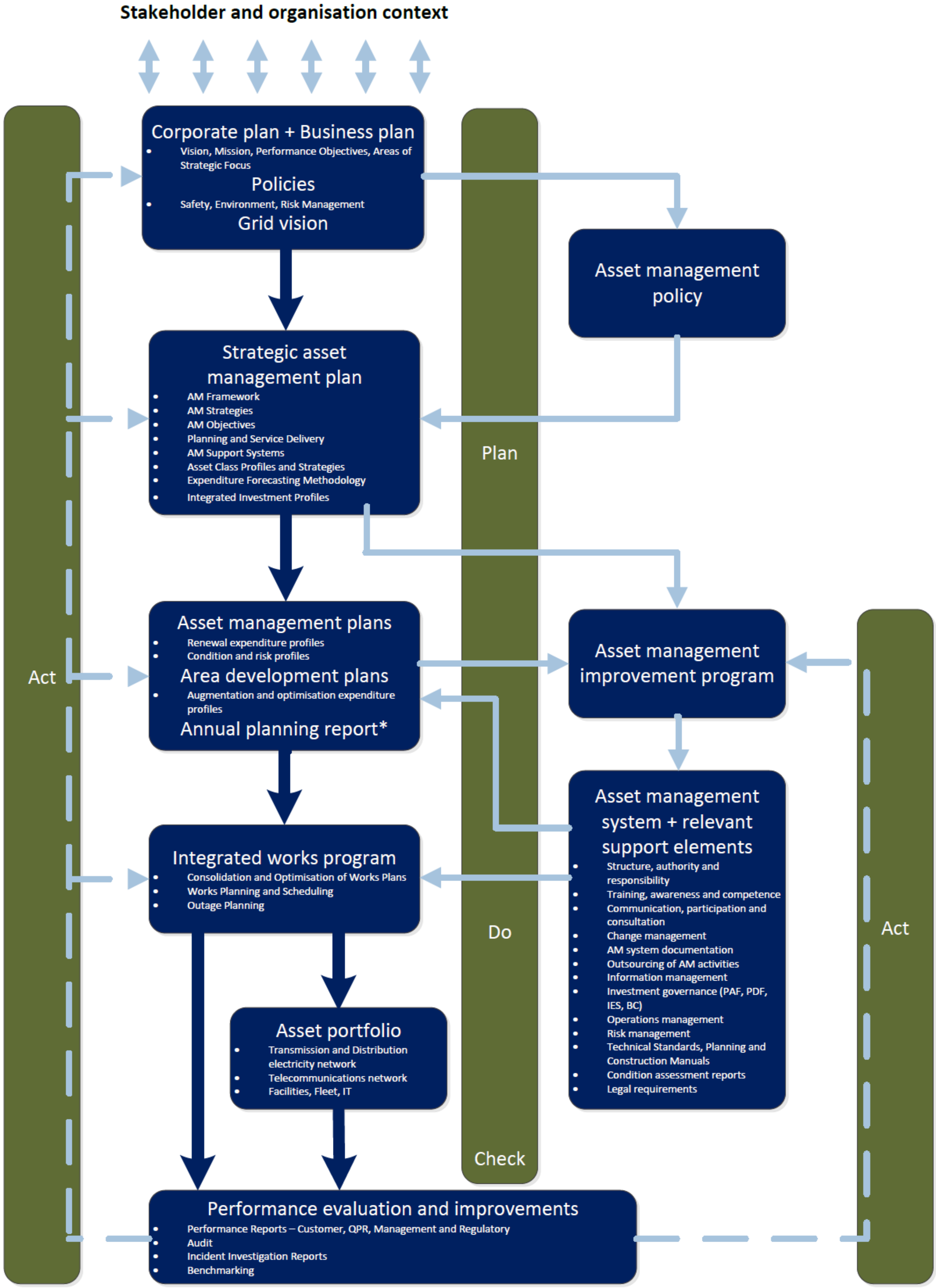
This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives.

The asset management policy, contained within the Strategic Asset Management Plan, states 'Consistent with our vision and purpose, we strive for excellence in asset management and are committed to providing a safe working environment, value for our customers, sustainable shareholder outcomes, care for our assets and the environment, safe and reliable network services, whilst effectively and efficiently managing our assets throughout their life-cycle'.

It is part of a suite of documentation that supports the achievement of TasNetworks strategic performance objectives and, in turn, its mission. The asset management plans identifies the issues and strategies relating to network system assets and detail the specific activities that need to be undertaken to address the identified issues.

Figure 1 represents TasNetworks documents that support the asset management framework. The diagram highlights the existence of, and interdependence between, the Plan, Do, Check, Act components of good asset management practice.

Figure 1 – TasNetworks asset management documentation framework



* The Annual Planning Report (APR) is a requirement of sections 5.12.2 and 5.13.2 of the National Electricity Rules (NER) and also satisfies a licence obligation to publish a Tasmanian Annual Planning Statement (TAPS). The APR is a compilation of information from the Area Development Plans and the Asset Management Plans.

The asset management objectives focus on six key areas:

- Zero Harm will continue to be our top priority and we will ensure that our safety performance continues to improve
- Cost performance will be improved through prioritisation and efficiency improvements that enable us provide predictable and lowest sustainable pricing to our customers
- Service performance will be maintained at current overall network service levels, whilst service to poorly performing reliability communities will be improved to meet regulatory requirements
- Customer engagement will be improved to ensure that we understand customer needs, and incorporate these into our decision making to maximise value to them
- Our program of work will be developed and delivered on time and within budget
- Our asset management capability will be continually improved to support our cost and service performance, and efficiency improvements

4 Asset support systems

4.1 Systems

TasNetworks utilises Asset Management Information Systems to manage asset records for its network. The systems are maintained to contain up to date, detailed information for the high voltage regulator sites.

The asset information related to the regulator sites is managed using a spatial data warehouse (G/Tech). This data base stores critical attributes for each site, including the site location and its interconnection to the network.

A works management system (WASP) is used to manage asset management activities and for the recording of asset performance.

4.2 Asset information

Asset related information is stored and accessed through the asset management systems. Where asset information is insufficient audits are undertaken to gather the information.

5 Description of the assets

The High Voltage Regulator Asset Management Plan covers the high voltage regulator sites. The sites comprise the following major components:

- **High voltage regulators:** to maintain acceptable voltage levels along high voltage feeders
- **Earthing system:** to ensure personnel and public safety and to ensure correct operation of protection equipment
- **Enclosures:** to provide a safe and secure location for the high voltage regulators and associated equipment

5.1 High voltage regulators

Voltage regulators are installed on high voltage feeders where voltage regulation is required to maintain voltage levels within the limits defined by the National Electricity Rules i.e. within 6% of nominal voltage. HV Regulators sites are generally located on rural 11 kV and 22 kV feeders where the feeder load and length from the source would result in a noncompliant voltage without their presence.

Voltage regulator installations can achieve a voltage regulation of between 10 and 15% of nominal voltage, depending on the configuration of the site. This voltage regulation is achieved through the use of an autotransformer and on-load tapchanger. The service life of a regulator is typically 45 to 55 years, but the life can vary due to a variance in the expected rate of deterioration of the units.

Capacitor banks provide a means to provide voltage regulation on the network, but with a reduced level of regulation.

HV Regulators are divided into two main categories:

- Pole mounted: These comprise single phase units installed in an open-delta configuration (two tanks). Figure 5 is an example of a typical overhead HV regulator site.
- Ground mounted: These are typically older three phase units installed in a fenced enclosure. An example of a ground mounted three phase regulator site is provided in Figure 6. Single phase regulators are all installed on the ground in fence enclosures.

Tables 1 and 2 list the different types of HV regulators currently installed in the TasNetworks system.

Table 1: HV regulators sites on TasNetworks' distribution network using single phase regulators (as at Sept 2015)

Regulator type	Manufacturer	Mounting	Voltage (kV)	Size	Installation Period	Number Installed
Single Phase Regulators	Cooper	Pole and Ground	11	100	2000 to Present	1
				150		1
				200		6
			22	100		4
				150		1
				200		31
		Ground	22	300		4
					Total	48

Table 2: HV regulators sites on TasNetworks' distribution network using three phase regulators (as at Sept. 2015)

Regulator Type	Manufacturer	Mounting	Voltage (kV)	Rating (A)	Installation Period	Number Installed
Three Phase Regulators	Crompton Parkinson	Ground	11	52	1970	1
	Wilson / Ferranti		11	52	1978	1
				105	1966-1998	2
				157	1980-1982	3
				262	1976-1978	4
			22	80	1982-1988	3
				131	1976-1984	4
	ABB		22	131	1993-1999	7
				197	1995-1999	2
				262	1998	1
	English Electric		11	52	1978	1
	Tyree		22	79	1997	1
				131	1982-1984	1
	Wilson Fuller		22	52	1999	1
					Total	40

Figure 2 and 3 provide a summary of the number of HV regulator sites by manufacturer, type and size on the network.

Figure 2: Single phase regulator sites by manufacturer, type and size

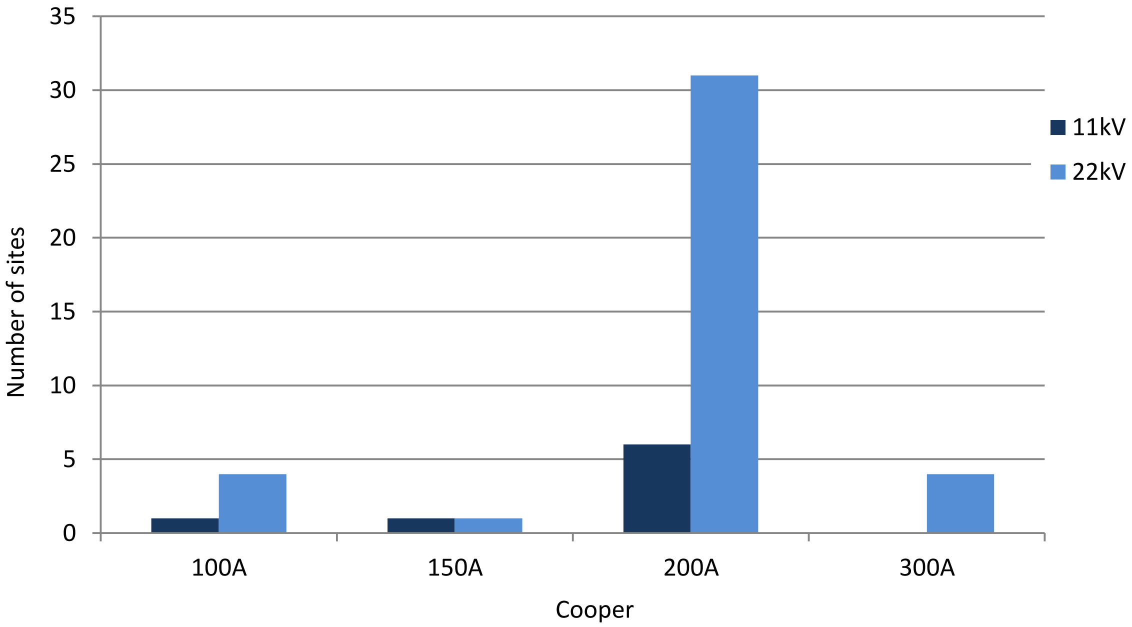
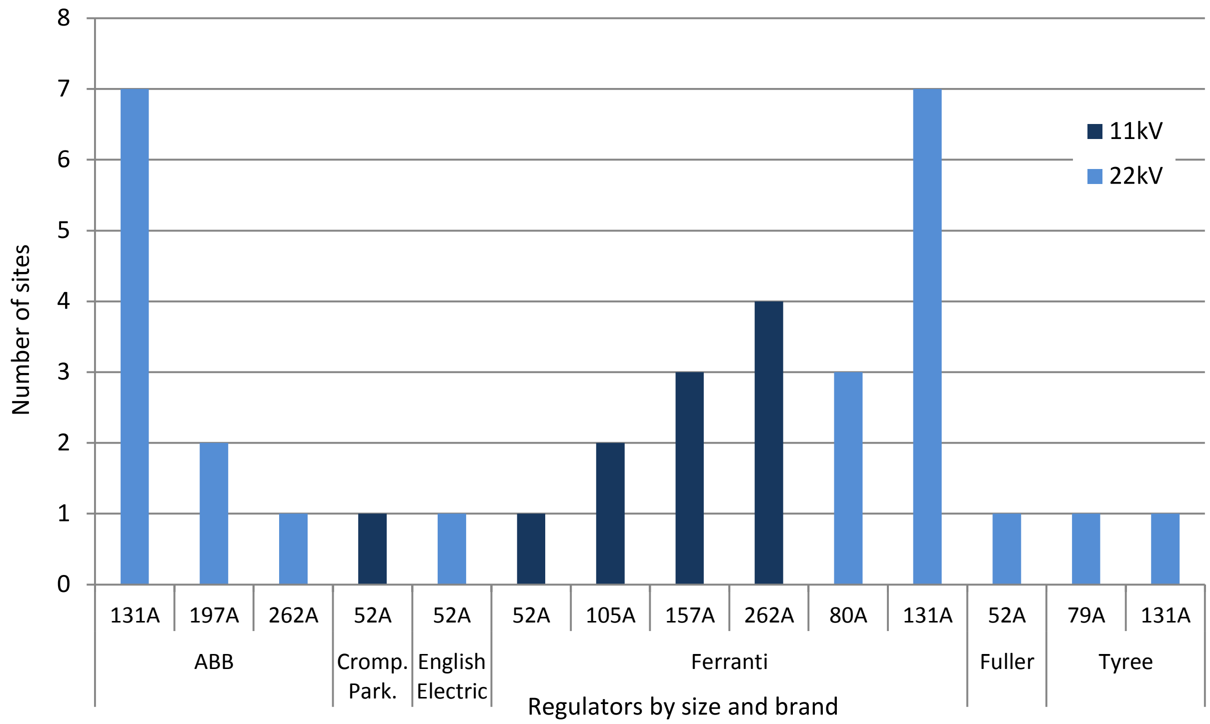
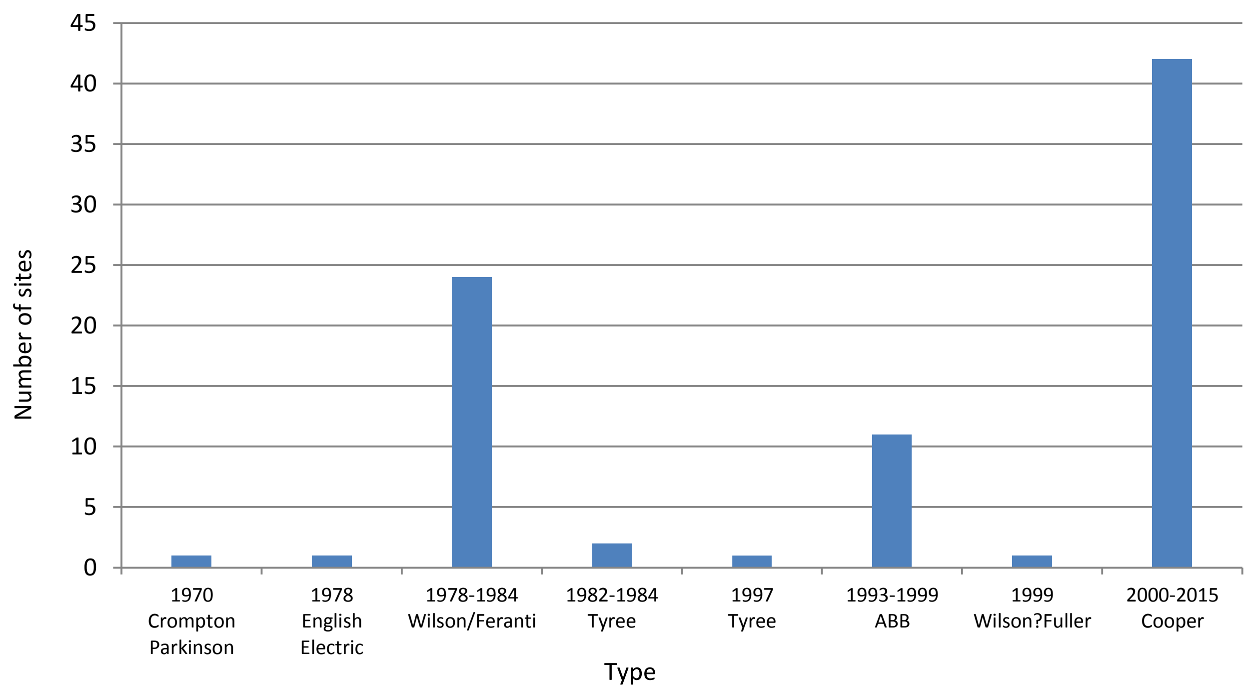


Figure 3: Three phase regulator sites by manufacturer, type and size



The age profile data for HV regulators was compiled using a combination of data from a 2009 audit.

Figure 4: HV regulator age profile



There has been an increase in the number of regulator sites installed since 2000 to address voltage compliance issues. The installations have been undertaken to defer larger network investment such as network augmentation.

Figure 5: Typical pole-mounted single phase open-delta regulator site

Figure 6: Typical three phase HV regulator site

5.2 Earthing systems

The integrity of the earthing system is essential for maintaining personnel and public safety and for the correct operation of protection equipment. The fault level, protection clearing time and soil resistivity at site dictates the extent of earthing required. Australian Standard AS 2067

(Substations and high voltage installations) dictates the earthing requirements of high voltage sites, with the appropriate safety criteria for earthing systems being chosen from Energy Networks Australia, Document 25, EG-0 Power System Earthing Guide Part 1: Management Principles.

5.2.1 Ground mounted earthing systems

The earthing system for ground mounted regulator installations is typically a copper earth grid and it may also include earth rods. All metallic components of the installation including the wire fence enclosure and lightning protection are connected to the earthing system.

5.2.2 Pole mounted earthing systems

The earthing system for a pole-mounted regulator installation is typically a series of earth rods driven into the ground and connected by copper conductor.

5.3 Enclosures

5.3.1 Ground mounted enclosures

Ground mounted regulator sites are surrounded by a chain wire fence enclosure topped with barbed wire. The purpose of the enclosure is to provide a secure location for the equipment and to provide for public safety. A possum guard and warning signs are also installed on the fence. Typically there are two access gates installed in the enclosure fence.

At some ground-mounted sites, oil containment is provided to contain the oil in the event of loss of oil from the regulator unit.

5.3.2 Pole mounted enclosures

Typically the pole-mounted sites are mounted high enough to prevent public access and possum guards are installed on the poles to prevent wildlife access. This type of installation does not usually contain an enclosure. There is no oil containment system at pole-mounted sites.

6 Associated risk

Assessment of risk associated with High Voltage Regulator sites have been made in accordance with TasNetworks' risk management framework. For each asset in this class a detailed risk assessment have been undertaken against the following criteria:

- Condition of high voltage regulator sites currently in service across the network.
- Criticality of high voltage regulator sites and associated assets.
- Probability of failure (not meeting business requirement)
- Consequence of failure
  - Performance
  - Safety
  - Environment
  - Customer

The level of risk was such that treatment plans were necessary to maintain the risk at a manageable level.

6.1 Asset risks

HV regulators currently in service in the TasNetworks system are prone to several specific issues that present risks that need to be appropriately managed, these being:

6.1.1 Safety

Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) were used in transformers and capacitors amongst other things from the 1930s to the 1970s. There are a toxic and are also a carcinogen. As a result, they were banned in Australia in the 1970s.

Whilst records indicate that no distribution transformers were purchased with PCB insulating material, contamination has occurred over time where oil management was undertaken using equipment also used for oil management of PCB-contaminated assets (such as Extra High Voltage instrument transformers). This has led to the possibility that regulator sites could be contaminated with PCBs.

TasNetworks manages PCBs in accordance with Aurora's Procedure EM-M09 Management of PCB's, which reflects the requirements of the Australian and New Zealand Environment and Conservation Council (ANZECC) Polychlorinated Biphenyls Management Plan [4] and the Environmental Management Pollution Control Act 1994 [5].

In the event PCBs contamination is found, the disposal process will be conducted as detailed in section 7.10.

Earthing

At ground-mounted sites, the operator is on the ground when operating and may be exposed to step and touch potentials while they are within the enclosure. Pole-mounted regulators are operated from an insulated ladder, significantly reducing the exposure of the operator to step and touch potentials while they are undertaking operational work.

TasNetworks is proposing to conduct an earthing audit performance testing on the earthing systems of ground mounted-sites, including a key performance measurements to determine whether there is any deficiencies with the earthing system at these sites.

The results of these studies will determine whether there is a risk associated with the earthing at ground-mounted sites

6.1.2 Reliability/environmental - Rust issues with single phase units

Prior to 2009, single phase Cooper regulator units were purchased with tanks constructed from mild steel. For locations that are prone to rust, such as near coastlines, this has proved troublesome as significant rusting can occur. In some cases, units have rusted to an un-repairable state in as little as six years. If the rust results in a hole within the main oil tank it will result in loss of oil, failure of the unit and an environmental incident. The presence of rust on tanks is monitored during asset inspections, with treatment on an as required basis.

6.1.3 Environmental - Oil containment

Prior to 2009 and a legislative requirement to comply with the terms of the high voltage substation standard AS2067, HV regulator sites did not have an oil containment system. Since 2009 new installations have had oil containment system that is compliant with the requirements of AS2067.

Future installations may be of either of a ground mounted or overhead configuration. Ground mounted installations shall comply with the requirements of AS2067, with overhead installations complying with the requirements of the overhead line design standard AS/NZS 7000.

Where possible new installations shall be of an overhead configuration as it provides a more cost effective solution.

The design of each new installation will align with TasNetworks guideline ‘Guideline - Bunding of Oil-Filled Assets’ [10], the TasNetworks Group Integrated Risk Management Model and the TasNetworks HSEQ Integrated Management System.

6.1.4 Operational limitations - Open delta configuration

Most single phase regulator sites have been installed in open-delta configuration. One of the advantages of this configuration is that it only requires two single phase units per site to regulate three phases. This results in a significant cost saving.

A limitation of the open-delta configuration is that the regulator must be switched to the neutral tap position when paralleling with other feeders. This requirement can increase the time required to undertaken network reconfiguration for planned outages and it can cause significant voltage issues during unplanned outages and load restoration.

There are also a number of sites where the load is such that the regulators cannot be brought back to neutral tap because this would lead to unacceptable voltage drops which eventually could lead to black outs.

The switching can also be labour intensive if there are a number of open-delta regulator sites on the feeders to be paralleled, as operators are required to visit each site to switch the units to neutral tap.

Distribution Operations have highlighted a number of regulator sites that cause frequent operational issues because of their open-delta configuration [7].

For future installations the operational impacts shall be considered when deciding on the configuration.

6.1.5 Criticality of asset

The failure of a HV regulator can result in partial of full loss of a high voltage feeder. Where installed, if a regulator is removed from service, non-compliant network voltages will often result. Load shedding or reconfiguration of the network may be required to achieve compliance.

6.1.6 Probability of failure

TasNetworks experiences a number of high voltage asset each year, but the frequency and specific types of failure for HV Regulators is at a manage level in accordance with TasNetworks’ risk framework [0].

6.1.7 Consequence of failure

The results of HV Regulator failures can be categorised under the following main groups

- Safety Risk due to loss of oil
- Performance on Power Quality
- Environmental hazards due to oil spills.
- Disruption to Customer Supply

7 Management plan

7.1 Historical

TasNetworks’ asset management practices for these assets have been stable for a number of years and are generally considered to be providing a well-balanced trade-off between maintenance and capital expenditure. In-service failures are rare and the assets are achieving and exceeding their expected service life.

For this class of assets the area off particular concern is the three phase regulators that are approaching, or have exceeded their normal expected service life. The deteriorating condition of the assets is making ongoing maintenance uneconomical.

TasNetworks has also experienced significant increase in routine maintenance costs over the last few years due to the work place safety management scheme necessitating that two operational personnel to attend energised sites instead of one.

Since 2011 oil testing of the main oil tank in ground mounted three phase regulators has been undertaken as part of the routine mechanical maintenance. This testing provides a greater understanding of the asset condition allowing for an improvement in the prioritisation of asset replacements.

Changes to the Occupational Licensing Act 2005 that became effective on 19 January 2009 requiring TasNetworks to be compliant with C(B)1 in the construction and operation of its distribution network. The Occupational Licensing (Standards of Electrical Work) Code of Practice 2013 sets the minimum standards for electrical work in Tasmania.

Incorporated into this Code of Practice are:

- AS 2067 - Substations and high voltage installations exceeding 1kV
- AS/NZS 3000 – Wiring rules
- AS/NZS 7000 - Overhead line design standard
- Any additional obligations imposed by AS 2067, AS/NZS 3000 and AS/NZS 7000 referring to further Australian Standards or documents, including any amendments or revisions of those Australian Standards or documents from time to time

The Code of Practice requires any person performing electrical work within Tasmania to comply with these Australian Standards.

The change that occurred in 2009 to comply with AS2067 created a requirement to move from an overhead configuration to a ground mounted configuration. However, based on TasNetworks’ Risk Framework the overhead configuration can prove to still be acceptable in some situations.

7.2 Strategy

7.2.1 Routine maintenance versus non-routine maintenance

There is a fundamental requirement for TasNetworks to periodically inspect the assets to ensure their physical state and condition does not represent a hazard to the public. Other than visiting the site, there is no other economic solution to satisfy this requirement. Periodic inspections also provide a means to ensure that asset reliability is maintained by identifying and rectifying defects prior to an asset failure occurring.

Routine maintenance of the tap changer units is required to prevent failures that can result in serious or catastrophic damage, especially in the older three phase units. The maintenance can range from cycling of operating mechanisms through to replacement of worn components.

7.2.2 Refurbishment

Where HV regulators are removed from the network in good operating condition by activities such as capacity and power quality drivers, these assets are assessed for redeployment back into the network where it is deemed an economic proposition.

7.2.3 Planned asset replacement versus reactive asset replacement

Regulators are an essential element in the network infrastructure that generally do not have redundant or alternate elements in the system design. Reactive replacement under fault conditions is avoided to minimise consumer disruption for extended periods and network voltage at non-compliant levels.

7.2.4 Non-network solutions

Regulators are generally installed as a cost effective alternative to upgrading other infrastructure on the network.

Other options do exist for providing network support under fault conditions, including the use of temporary mobile generation substitution. TasNetworks currently has several mobile generation substitutions and has leasing arrangements in place to source additional units as required.

7.2.5 Network augmentation impacts

TasNetworks' requirements for developing the power transmission system are principally driven by five elements:

- Demand forecasts
- New customer connection requests
- New generation requests
- Network performance requirements
- National electricity rules (NER) compliance

The installation of HV Regulators assists to defer significant network augmentation.

7.3 Routine maintenance

Asset condition information is recorded and communicated from the field via maintenance and operational check sheets which are used during inspections of HV regulator assets. These check sheets are reviewed regularly to monitor the condition of the regulators to assess if strategic action is necessary.

7.3.1 Three phase regulator – Load checks (AIGRE)

A three monthly load and operational check is conducted on three phase regulators to capture load information and check the units are tapping correctly. Historically, three phase regulators have exhibited the following failure modes:

- Contactors sticking – the relays that pass the motor current during a tap change sometimes get stuck causing the tap changer to run away to either top or bottom tap, resulting in unacceptable voltages for downstream customers
- Blown resistors in the timing boards (Wilson/Ferranti)
- Burnt out timing boards (Wilson/Ferranti)
- Faulty Automatic Voltage Relay (AVR) for older type ground mounted units
- Water getting into the control cubicle causing shorting problems (especially on the ABB units); and

- Springs and other parts have come adrift especially on the braking systems.

All of these failure modes result in incorrect tapping of the units and ultimately voltage problems on the system.

The methodology used to develop the maintenance program has been adjusted to meet the historical performance criteria set out in the risk framework [0].

7.3.2 Three phase regulator – Operational checks, full mechanical and civil maintenance (RMGRE)

The routine maintenance of three phase regulator units has three components:

- Operational checks
- Full mechanical maintenance
- Civil maintenance

Each of these are described in the following sections.

Operational checks
Quarterly operational checks and asset inspections are conducted on every ground mounted regulator site. The operational checks and asset inspections consist of:

- Load and tap information check: to collect load data
- Operational check: to ensure the unit is tapping properly
- Asset inspection: to inspect the asset condition

This inspection is conducted in conjunction with the inspection program (section 7.3.1) and civil maintenance.

Full mechanical maintenance
Full mechanical maintenance is required to inspect the mechanical components of the tap changer. Over time the tap changer contacts corrode due to normal operation and the insulating oil develops a build-up of carbon and foreign particles, reducing its dielectric strength, cooling properties and arc-quenching ability.

At routine full mechanical maintenance the tap changer contacts and other mechanical parts are inspected and replaced if required and the insulating oil is replaced.

The routine mechanical maintenance for three phase regulators is conducted every four years, with the frequency developed from historical performance of the assets. The maintenance is performed on site and requires de-energising of the unit. No transportation to a workshop is required.

Three phase units have separate main tank and tap changer compartments and as part of the maintenance of three phase units the oil is changed in the tap changer compartment. Due to this separation, the condition of the main autotransformer can be effectively monitored through oil testing to detect hot spots, arcing, paper deterioration or oil quality issues. The oil from the autotransformer tanks are therefore tested as part of the routine mechanical maintenance.

Civil maintenance
Civil maintenance of ground mounted regulator sites is conducted quarterly to address environmental, safety and security issues and undertake site maintenance tasks such as weed spraying and painting as required. The frequency is based on TasNetworks previous experience to make sure that sites are safe and clean. This maintenance is conducted in conjunction with the inspection program (Section 7.3.1) and Operational Checks and Asset Inspections (Section 7.3.2)

Earthing performance
Ground mounted HV regulators sites have a full earthing performance and continuity tests conducted every ten years to ensure the earthing system is in sound condition and compliant with the relevant standards and guides. The frequency is based on existing industry best practice, the results of routine auditing and the increased probability of exposure to hazards due to the other routine inspections requiring staff to attend the site. Typical earthing tests undertaken at each audit include:

- Earth Potential Rise Measurements
- Potential Measurements
- Continuity test on primary equipment
- Visual inspection of the localised earth grid

Table 3: Load checks, operational checks and civil maintenance

Classification	Frequency
Load Checks	Quarterly
Operational Checks	Quarterly
Civil Maintenance	Quarterly
Earthing Audit	10 years (nominally)

7.3.3 Single phase regulator – Operational checks and oil checks (RMORE)
The routine maintenance of single phase regulator units has two components:

- Operational checks
- Oil checks

Each of these is described in the following sections.

7.3.3.1 Operational checks
Quarterly operational checks and asset inspections are conducted on every pole mounted regulator site. The operational checks and asset inspections consist of:

- Load and tap information check: to collect load data
- Operational check: to ensure the unit is tapping properly
- Asset inspection: to inspect the asset condition

7.3.3.2 Oil checks
Single phase HV regulators have their oil changed during full mechanical maintenance. Oil testing between refurbishments has been discontinued on these units for the following reasons:

- The tap changer and transformer cores are all immersed in the same tank and oil. This means any dissolved gasses resulting from heat or arcing will be masked by the gasses generated by tapping
- The current fleet of Cooper regulators are too young to justify paper condition (furan) testing
- Recent refurbishments have indicated that the oil quality is still good after approximately 100,000 taps, implying a low risk of dielectric breakdown strength issues

It is expected that oil testing of these units may become appropriate once the fleet ages or any specific issues arise that can be monitored for through oil testing.

7.4 Non-routine maintenance

7.4.1 Minor and major asset repairs (ARURE)

Specifically identified defects, during asset inspections and routine maintenance or through other ad-hoc site visits or customer reports, are prioritised and rectified through the general asset defects management process and specifically identified maintenance programs.

The methodology used to develop the maintenance program has been adjusted to meet the historical performance criteria set out in the risk framework, with the objective to return to service and prevent asset failure.

7.5 Reliability and quality maintained

7.5.1 Full mechanical refurbishment (REURG)

The routine full mechanical refurbishment of single-phase units is conducted every fifteen years or 100,000 tapping operations (whichever occurs first) to ensure asset reliability is maintained and service life is maximised. The timing of the refurbishment is influenced from to oil testing results during the routine inspections.

The refurbishment requires the unit to be removed from the system and transported to workshop for refurbishment. To perform this work without impacting on customer power quality, the replacement units are required to be installed and commissioned at the time the old units are removed from site.

The refurbishment entails inspection of the mechanical components within the tap changer. Over time the tap changer contacts corrode due to normal operation and the insulating oil develops a build-up of carbon and foreign particles, reducing its dielectric strength, cooling properties and arc-quenching ability. Where necessary worn components are replaced. The insulating oil is also replaced

Table 4: Single phase regulators – Operational checks, oil checks and full mechanical refurbishment (REURG

Classification	Frequency
Full mechanical refurbishment	15 Years (based on condition – nominally)

7.5.2 Other issues addressed during single phase regulator refurbishment

The following issues are also addressed during the routine refurbishment of single phase regulators:

- Tap position indicators
- Tap changer motor drive capacitor
- Moisture ingress into control cable

7.5.2.1 Tap position indicators

To address the issue of older style tap position indicators on the single-phase regulators suffering from corrosion and water ingress, it is proposed to replace the tap position indicators during full mechanical maintenance.

Whilst the tap position indicators can be replaced on site, it is more efficient to address this issue as part of the routine refurbishment, as on-site replacement requires the units to be de-energised.

7.5.2.2 Tap changer motor drive capacitor

Single phase regulators were introduced into the distribution system in 2000. TasNetworks has one recorded incident in 2006 were two tanks failed in service due to faulty tap changer motor drive capacitors.

In early models of the single phase regulators, installed with a CL-5 controller, the motor drive capacitor is located within the regulator tank. Thus, a faulty motor drive capacitor requires the unit to be removed from site and de-tanked to replace the capacitor.

Knowing that this failure mode exists in earlier models, it is desirable for future models to have the motor drive capacitor located outside the tank to remove the need to de-tank the regulator for capacitor failures.

The manufacturer has advised that it is possible to relocate the tap changer motor drive capacitor from inside the tank to the control cubicle. As part of refurbishment work the tap-changer motor drive capacitor to the control cubicle will be replaced with an internal capacitor.

7.5.2.3 Moisture ingress into control cable

There is a known issue with all regulators manufactured between 1998 and March 2012 where moisture can ingress into the cable connection on the control cables.

In 2013, Cooper released a safety alert stating the following:

Cooper Power Systems recently became aware of a small number of instances in which moisture entered one or both cable connections of the control cable on certain regulators. The moisture ingress into the connection corroded the pins, which degraded the cable's electrical connection and caused the "NEUTRAL Light Indicator" to turn on even though the unit was not in the neutral position.

Units with this condition pose a safety risk in that if someone attempts to remove a regulator from service and does not follow all necessary steps to verify the regulator is in neutral, they may incorrectly assume the regulator is in neutral when it is not. Removing a regulator when it is not in the neutral position may lead to internal arcing and tank rupture, which may cause the emission of superheated or burning oil resulting in severe injury or death.

Despite the high severity of this event, the likelihood is extremely rare as Cooper were only notified of three instances out of 100,000 units which were affected.

This problem is easily corrected by resealing the control cables using gasket kits provided by Cooper. These kits are to be retrofitted to existing units during routine mechanical maintenance.

TasNetworks is proposing a pilot sample being conducted to assess the benefits of rectifying these issues at HV regulator sites.

Full details of this safety alert can be found in [9].

7.5.3 Maintenance improvements

The CL-6 controller, installed on some single phase regulators (those with quick-drive tap changers) has two features, which may improve single phase regulator maintenance, namely:

- Duty Cycle Monitoring
- Preventative Maintenance Tapping

By utilising TasNetworks remote control capabilities and historian data collection it will be possible to log the effects of these two features. It is proposed that both options of this feature will be trialled at TasNetworks Training School and at one other field regulator site for further analysis before rolling it out to the entire CL-6 population.

7.5.3.1 Duty cycle monitoring

Duty cycle monitoring calculates the worst case value of used life as a percentage for each arcing surface contact on the tap changer based on measured current, voltage, power factor and tap position. The manufacturer recommends that routine mechanical maintenance be scheduled once the duty cycle monitor reaches 75%.

This feature may be used to allow for more efficient scheduling of routine mechanical maintenance, as the maintenance is scheduled based on the estimated condition inferred from the measured duty of the tap changer rather than at set time intervals.

7.5.3.2 Preventative maintenance tapping

The Preventative Maintenance Tapping feature automatically operates the tap changer periodically to prevent a build-up of carbon, known as coking, on the tap changer contacts.

Two Preventative Maintenance Tapping options are available:

- Tap up once, down twice, then up once again to remove carbon from the tap position contacts
- Tap past the neutral tap position by one to remove carbon from the reverse switch contacts

It is expected that preventative maintenance tapping can be used to ensure the reverse switch is cocked at appropriate intervals (for example every three months) at a time when tapping past neutral will not adversely affect customer voltages due to low load. This action is not always possible during operational checks during the day.

Table 5: Maintenance improvement

Classification	Frequency
Single Phase Regulator	3 months
Three Phase Regulator	3 months

7.6 Regulatory obligations

7.6.1 Safety and environmental issues in regulators (SIREG)

This program has been developed to address environmental risks associated with regulator sites by minimising the impact of an oil spill at the sites. The standard solution is to install an oil containment system that can contain all spills within the site.

A prioritised list of regulator sites was developed to evaluate the environmental risk at each regulator site [2]. A weighted risk analysis has determined the risk of each site according to:

- Regulator age
- Vicinity to roads and traffic
- Bushfire risk
- Vicinity to waterways (when less than 100 m)
- Significance of particular waterway

This analysis has identified the regulator sites that had the highest environmental risk on the network. These sites are inspected and evaluated annually to confirm the risk remains at a manageable level. Where the risk level is unmanageable the site will be upgraded or relocated to reduce the risks identified.

TasNetworks proposes to address on average one site each year.

The methodology used to develop the program has been developed in compliance with TasNetworks' risk framework.

7.6.2 Remote control

Where it is shown to be an economic proposition, remote monitoring equipment is installed at single phase regulator sites. This equipment will be used to monitor the voltages, currents and operation of the equipment and will be used to remotely control the regulators.

The information gathered from remote monitoring assists in the planning and optimisation of maintenance activities e.g. if remote monitoring reveals that a regulator is operating frequently due to a high feeder loading, then routine maintenance may occur more frequently, and conversely where tap-changing is at a lower frequency maintenance frequencies may be extended.

To date, eight Cooper regulator sites have been installed with remote control capability.

At these sites historical load and tapping information now exists in TasNetworks' PI historian system and is readily accessible for asset management purposes. This will greatly optimise planning for routine maintenance and allow remote monitoring to ensure regulators are tapping effectively within an appropriate range.

The installation of remote control functionality at the older three phase regulator sites will be investigated once the program has been completed at all the single phase regulator sites.

7.7 Replacement

7.7.1 Replace three phase regulator (REGMR)

Due to known failure modes with three phase regulators and the high preventative maintenance costs associated with these assets (monthly load and operational checks, four yearly routine mechanical maintenance, etc.), TasNetworks has made the decision to replace these units as deemed appropriate by their condition, or if they require significant maintenance or refurbishment work.

TasNetworks proposes to replace on average one site each year based on the condition of the assets.

The methodology used to develop the maintenance program has been adjusted to meet the performance criteria set out in TasNetworks' risk framework.

7.7.2 Replace single phase regulator (REURG)

At several of the single phase regulators that were supplied with mild steel tanks less than ten years ago the units are showing severe signs of rusting.

To address the issue of rusted tanks on the single phase regulator units, TasNetworks investigated remediation options including:

- Replacing the existing tanks with stainless steel tanks as part of routine mechanical refurbishment
- Refurbishing and galvanising the existing tanks as part of routine mechanical maintenance
- Repairing and recoating the existing tanks as part of routine mechanical maintenance

The cost for a new stainless steel tank is approximately $22 000 per tank. Tanks were historically being repaired and galvanised, but the loss of a local providers to undertake this work has resulted in this no longer being a cost effective solution. The cost of repairing of the tank and providing protective coatings (Epoxy paint with C4 rating) is approximately $3 000 per tank.

The preferred option is to repair all tanks and apply a protective coating as part of the refurbishment program. When refurbishment occurs the tanks are rotated through the network and at sites which are prone to rust the replacement tanks will be stainless steel. The removal of corroded mild steel tanks will drive refurbishment prioritisations and schedules until the entire mild steel tank at coastal sites have been removed.

The manufacturer of the single phase regulators can provide the regulator in stainless steel (304 grade). All new single phase regulators will be supplied with stainless steel tanks.

7.8 Investment evaluation

Where investment is required to achieve compliance with TasNetworks' business objectives an options analysis is undertaken to determine the most appropriate solution.

Economic analysis is undertaken using TasNetworks' investment evaluation tool.

7.9 Spares management

Strategic spares for HV regulators are managed in accordance with the Spares Management Strategy[1].

7.10 Disposal plan

Materials that pose a risk to human health as well as being a possible environmental hazard are disposed of in accordance with the Environmental Management Pollution Control Act 1994 [5], TasNetworks' internal safety and environmental management plan and ANZECC [4].

7.11 Summary of programs

Table 6 provides a summary of all of the programs described in this management plan.

Table 6: Summary of High Voltage Regulator Programs

Work Program	Work Category	Project/Program
Routine maintenance	Inspection and monitoring (AIGRE)	Three Phase Regulator – Load and Operational Checks
		Ground Mounted regulators earthing performance testing
	Ground mounted regulators routine maintenance (RMGRE)	Three phase regulator – Routine maintenance (Operational checks, full mechanical maintenance and civil maintenance)
	OH regulators routine maintenance (RMORE)	Single phase regulator – Routine maintenance (Operational checks, oil checks and civil maintenance)
Non-routine maintenance	Asset repair (ARURE)	Minor and major asset repairs

[1] Spares Management Strategy – Distribution Substations R247679

Work Program	Work Category	Project/Program
Reliability and quality maintained	Replace single phase regulators (REURG)	Full mechanical refurbishment of single phase regulators
	Other Issues addressed during single phase regulator full mechanical maintenance	Tap position indicators
		Tap changer motor drive capacitors
		Moisture ingress into control cable
	Maintenance improvements	Duty cycle monitoring
		Preventative maintenance tapping
Replacement	Replace regulator (Three phase) (REGMR)	Replace regulator ground mounted three phase
	Replace regulator (Single phase) (REURG)	Replace regulator ground mounted single phase
Regulatory obligations	Safety and environmental Issues in regulators (SIREG)	Safety and environmental Issues in regulators
	Remote Control	Installation of remote monitoring and control on new and old installations

8 Financial summary

TasNetworks is satisfied that its current practices are performing adequately. In-service failures are rare and the assets are achieving and exceeding their expected service life. It is proposed to continue with the current asset management practices, but with some additional expenditure due to an increase in routine maintenance.

Inspection levels and routine maintenance programs shall continue at current levels due to the critical nature of these assets and the need to ensure their reliable operation.

TasNetworks' makes a concerted effort to prepare a considered deliverability strategy based on the planned operational and capital programs of work for distribution network assets. A number of factors contribute to the successful delivery of the program of work. These factors are utilised as inputs to prioritise and optimise the program of work and to ensure sustainable and efficient delivery is maintained. This program of work prioritisation and optimisation can impact delivery of individual work programs in favour of delivery of other programs. Factors considered include:

- Customer-driven work we must address under the National Electricity Customer Framework (NECF).
- Priority defects identified through inspection and routine maintenance activities.
- Identified asset risks as they relate to safety, the environment and the reliability of the electrical system.
- Adverse impacts of severe storms and bushfire events.
- System outage constraints.
- Changes to individual project or program delivery strategy.
- Size and capability of its workforce.
- Support from external contract resources and supplementary service provision.
- Long lead equipment and materials issues.
- Resolution of specific technical and functional requirement issues.
- Complex design/construct projects with long lead times.

- Approvals, land acquisition or wayleaves.
- Access issues.

Specific to HV regulators asset management plan, these factors have had minimal impact on the delivery of the operational programs of work, but have resulted in delayed delivery of the capital programs of work.

8.1 Proposed OPEX expenditure plan

The current asset management practices will continue at the current rates, but with some additional expenditure forecast.

Inspection levels on the older units will continue at current levels as there is concern surrounding their reliable operation. The increase in proposed OPEX expenditure is attributed to the increased corrective maintenance and routine maintenance costs on these units and the volume of new units entering the system.

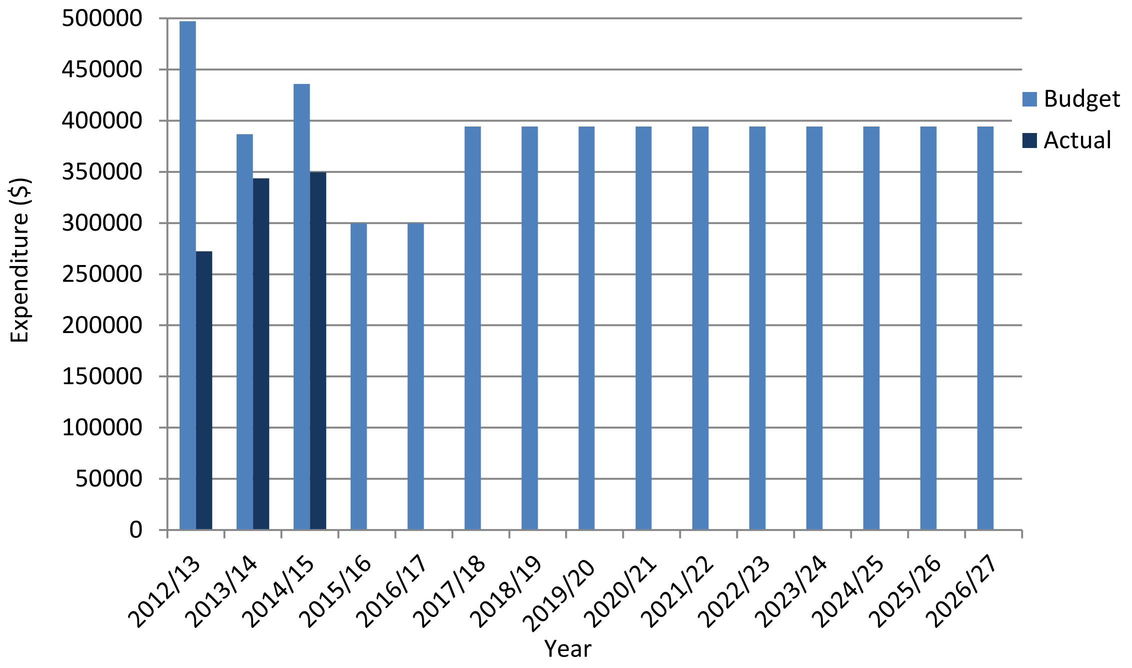
Due to the ageing condition of many of the ground mounted sites a routine program to test earthing systems will be introduced in the 2016/17 financial year. This program is required to ensure the performance of the earthing system is within limits.

Table 7 and figure 6 provide a summary of the historical operational expenditure on HV regulators and the proposed future spend.

Table 7: OPEX for period between 2012/13 and 2019/20 financial years

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
Budget ($)	497 180	386 929	435 901	299 946	327 946	394 370	394 370	394 370
Actual ($)	272 521	343 770	349 659					

Figure 6: OPEX expenditure profile



8.2 Proposed CAPEX Expenditure Plan

The capital programs and expenditure identified in this management plan are necessary to manage operational and safety risks and maintain network reliably at an acceptable level. All capital expenditure is prioritised expenditure based on current condition data, field failure rates and prudent risk management.

TasNetworks' proposed capital expenditure for the next regulatory period is $3.8m. This expenditure is required manage these assets in accordance with this management plan. Where asset renewal or replacement is necessary it will be driven by a condition and risk based approach, seeking to:

- Reduce the risk of in service failure and gain maintenance efficiencies by replacing only substandard condition three phase regulators
- Reduce the risk of TasNetworks' oil filled regulators located close to waterways, drinking water and sensitive areas causing environmental damage
- Improve the condition of the rusting single phase tanks to achieve the expected asset life

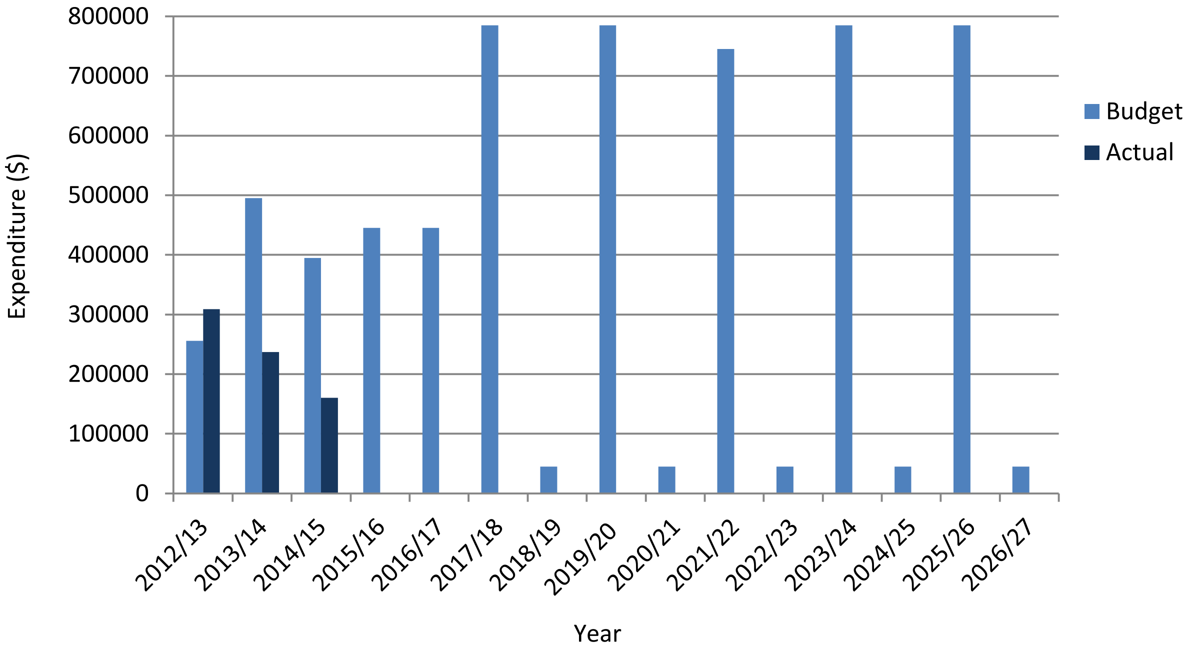
Replacement of the regulator sites is scheduled to occur at a rate of two sites every second year. The grouping of the replacement work should result in efficiency gains in the delivery of the work.

Table 8 shows the historical capital expenditure on HV regulators and the proposed future spend.

Table 8: CAPEX for period between 2012/13 and 2019/20 financial years

	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
Budget ($)	330 621	546 348	395 000	445 000	445 000	785 000	45 000	785 000
Actual ($)	308 830	237 039	160 246					

Figure 7: CAPEX expenditure profile



8.3 CAPEX–OPEX trade offs

The operating expenditure programs are essential for identifying assets the require replacement for condition-based reasons. An example of this is the inspection and routine maintenance of three phase regulator sites, which may lead to a requirement for capital expenditure to replace the regulator due to uneconomical maintenance costs and impending asset failure.

There is a positive relationship between these two categories in that regular inspection programs gather continuous condition information of the assets to better target asset replacements and identify any asset trends. Maintenance and repair activities also defer the requirement for capital expenditure and increase the likelihood of the asset operating for as long as possible within the network.

9 Responsibilities

Maintenance and implementation of this management plan is the responsibility of the Asset Strategy Team.

Approval of this management plan is the responsibility of the Asset Strategy & Performance Leader.

10 Related standards and documentation

The following documents have been used to either in the development of this management plan, or provide supporting information to it:

1. TasNetworks Strategic Asset Management Plan (R248812)
2. High Voltage Regulator Audit Review 2009 (NW30062708)
3. AS 2067 Substations and high voltage installations exceeding 1 kV AC.
4. Australian and New Zealand Environment and Conservation Council (ANZECC) Polychlorinated Biphenyls Management Plan (Revised Edition April 2003)
5. Environmental Management Pollution Control Act 1994
6. AS 1940: The storage and handling of flammable and combustible liquids, Appendix H
7. Regulator Operational Issue – Feeder Parallel (NW30064060)
8. Spares Management Plans: Regulators (NW30087907)
9. Cooper Regulator Cable Safety Notice (NW30449547)
10. Guideline - Bunding of Oil-Filled Assets (NW30179134)
11. High Voltage Regulator Sites - Oil Bunding Requirements (NW30575129)
12. DS D OH 01 Distribution Overhead Line Design and Construction Standard
13. TasNetworks Risk Management Framework (R209871)

11 Appendix A – Summary of programs and risk

Description	Work category	Risk level	Driver	Expenditure type	Residual risk	12/13 ($)	13/14 ($)	14/15 ($)	15/16 ($)	16/17 ($)	17/18 ($)	18/19 ($)
Inspection and monitoring	AIGRE	Medium	Safety/ Reliability	Opex	Low	46 478	114 334	123 441	101 677	110 000	110 000	110 000
Earthing audits	AIGRE	Medium	Safety/Reliability	Opex	Low							
Asset repair	ARURE	Medium	Safety/ Reliability/ Environment	Opex	Low	98 827	18 877	102 013	50 000	99 370	99 370	99370
Other issues addressed during single phase regulator full mechanical maintenance	ARURE	High	Safety/ Reliability	Opex	Low							
Replace Regulator (Three Phase)	REGMR	Medium	Safety/ Reliability	Capex	Low	1112	0	2692	145 000	0	350 000	0
Ground mounted regulator routine maintenance	RMGRE	Medium	Safety/ Reliability	Opex	Low	110 951	167 262	120 000	78 269	116 000	116 000	113 000
Maintenance improvements	RMGRE	Medium	Safety/ Reliability	Capex	Low							
OH regulators routine maintenance	RMORE	Medium	Safety/ Reliability	Opex	Low	87 513	96 914	92 321	70 000	85 000	85 000	85 000
Replace Regulator (Single Phase)	REURG	Medium	Safety/ Reliability	Capex	Low	45 975	21 982	62 754	60 000	45 000	40 000	45 000
Safety and Environmental Issues in Regulators	SIREG	Medium	Safety/ Reliability/ Environment	Capex	Low	261 742	215 057	94 800	240 000	0	350 000	0