Asset Management Plan

Transmission Protection

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Authorisations

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Responsibilities

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

The approval of this document is the responsibility of the Team Leader, Substations Asset Strategy.

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

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

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Reference documents

R954721 – TasNetworks Strategic Asset Management Plan

R40766 – TasNetworks Asset Management Policy

R909655 – TasNetworks Risk Management Framework

Record of revisions

Revision	Details	Date
1.0	Revised for R19	28/11/2017
2.0	Updated based on R19 submission	02/03/2018
3.0	Revved up due to IM administrative work	09/03/2018
4.0	Revised for R24	07/10/2022

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1. Purpose

The purpose of this document is to describe for transmission protection and related assets:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans;
- The key projects and programs underpinning its activities; and
- Forecast capital (**capex**) and operational (**opex**) investment, including the basis upon which these forecasts are derived.

2. Scope

This document covers the key protection equipment installed in the Tasmanian transmission system that are used for protection of the following primary circuits:

- bus couplers;
- busbars;
- capacitor banks;
- distribution feeders;
- transformers; and
- transmission lines.

3. Management strategy and objectives

This asset management plan has been developed to align with TasNetworks' Asset Management Policy, Strategic Asset Management Plan and Strategic Objectives. This management plan describes the asset management strategies and programs undertaken to manage transmission protection assets.

The asset management objectives are to:

- manage and meet the strategic goals, measures and initiatives outlined in the TasNetworks Business Plan;
- comply with relevant legislation, licences, codes of practice and industry standards; and
- continually adapt benchmark, improve asset management strategies and practices, and apply contemporary asset management techniques, consistent with industry best practices.

4. Description of the asset portfolio

Protection relays detect and isolate faults on the power system, minimising damage to primary equipment, maintaining stability of the power system and reducing the risk of injury or death to members of the public, TasNetworks personnel or contractors. Protection relays can also provide control and monitoring of primary equipment through the Supervisory control and data acquisition (**SCADA**) system and functions such as disturbance recording and fault location.

A protection scheme includes one or more protection relays used to protect a defined transmission circuit. Historically this was to provide sufficient fault detection functionality although, more recently, it is to provide a level of redundancy for power system security.

The programs under the transmission protection asset class pertain to asset maintenance and replacement activities, to ensure they are always in good working order to disconnect primary plant in the event of a network fault. The drivers behind these programs are various and relate to:

- age;
- condition;
- in-service failure;

- replacement based on obsolescence/lack of product support;
- spares management and maintainability; and
- network performance improvement.

TasNetworks' asset economic lives are sourced from TasNetworks' Regulated Asset Base. In the case of protection relays, the economic life is 15 years.

This section provides high-level information on TasNetworks' transmission protection assets, including an age profile.

4.1 Bus coupler protection

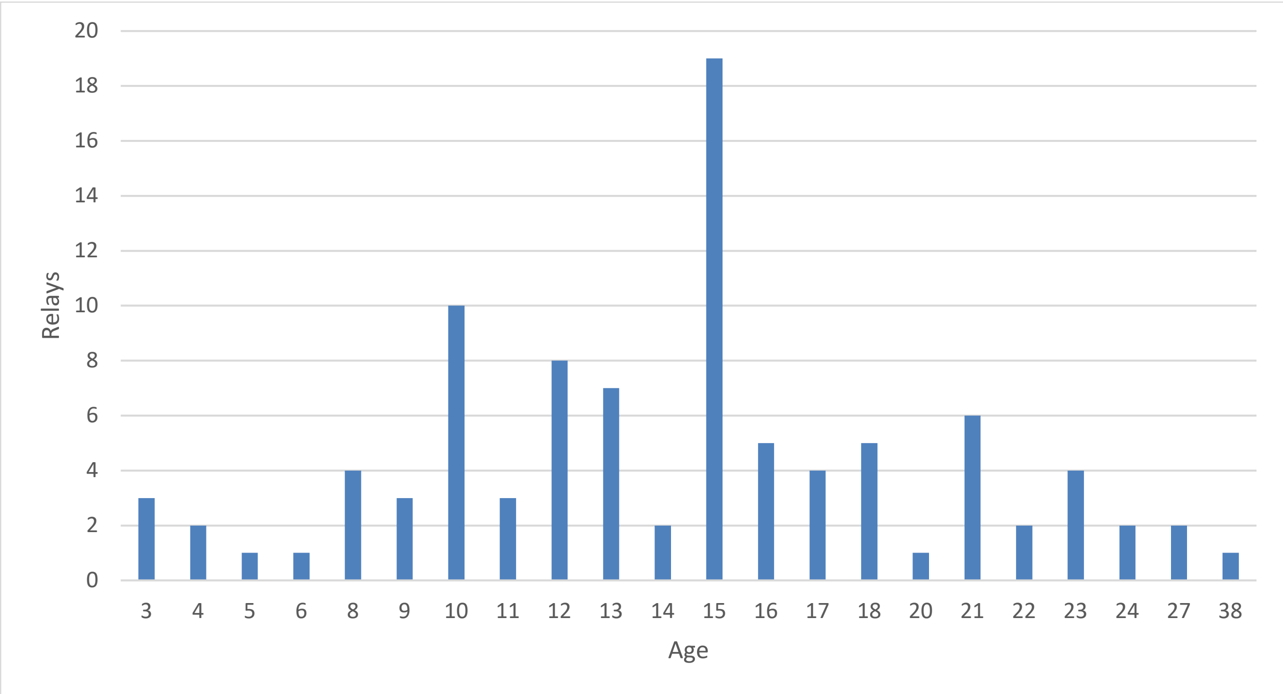
EHV bus coupler protection schemes primarily provide control of the bus coupler breaker. However, where a single EHV busbar protection scheme is installed, non-directional impedance protection is applied to the bus coupler multifunction relay to split the busbars before the operation of remote backup protection.

HV bus coupler protection provides backup to the busbar and feeder protection and is graded with the bus incomer protection to minimise disruption to the substation. A single multifunction relay performs all control and metering of the bus coupler circuit as well as protection.

Table 1: Bus coupler protection asset volumes

Description	Schemes	Relays
EHV Bus Coupler	39	44
HV Bus Coupler	45	51

Figure 1: Bus coupler protection age profile



4.2 Busbar protection

Most EHV busbar protection schemes are not duplicated like transmission line and transformer protection schemes, due to the installation cost of a complete busbar protection scheme. However, based on system stability studies, in some instances the fault clearance time of backup protection is not sufficient to meet the requirements of the National Electricity Rules (**NER**) and a duplicate EHV busbar protection scheme is required. The duplicate busbar protection scheme will be of a different model to the main scheme to ensure full redundancy.

Most EHV busbar protection schemes are a low impedance measurement type, although, on non-selectable busbar arrangements, where instrument transformer secondary circuits are not required to be switched, high impedance protection is preferred due to the lower installation and maintenance costs.

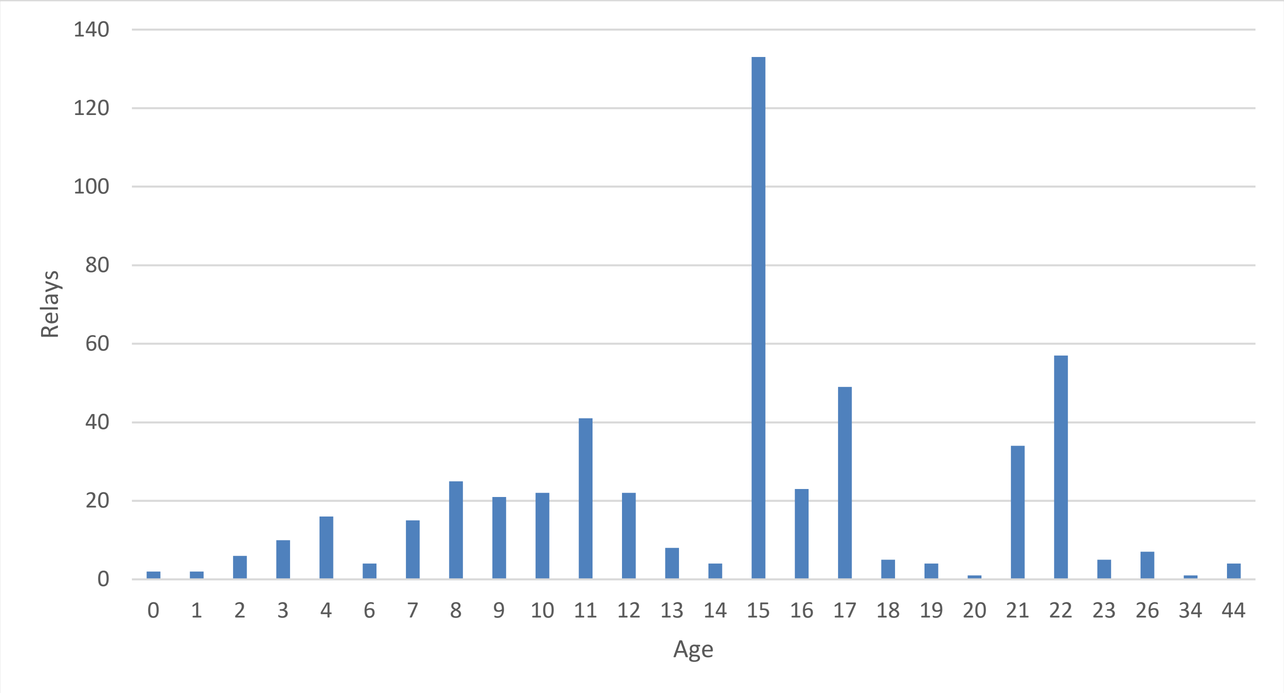
HV busbar protection schemes do not require bus selection logic like most EHV busbar protection schemes and, as such, can be much simpler in their construction and operation. The main types in use in TasNetworks' HV substations include:

- low impedance differential protection;
- high impedance differential protection;
- frame leakage protection with transformer neutral current check;
- switchboard arc detection with current check; and
- switchboard pressure surge with current check.

Table 2: Busbar protection asset volumes

Description	Schemes	Relays
EHV Busbar	41	305
HV Busbar	40	216

Figure 2: Busbar protection age profile



4.3 Capacitor bank protection

A typical capacitor bank protection and control scheme includes the following functions:

- overcurrent and earth fault protection;
- over and under voltage protection;
- neutral unbalance protection;
- harmonic overload protection;
- point-of-wave circuit breaker control (EHV installations only); and

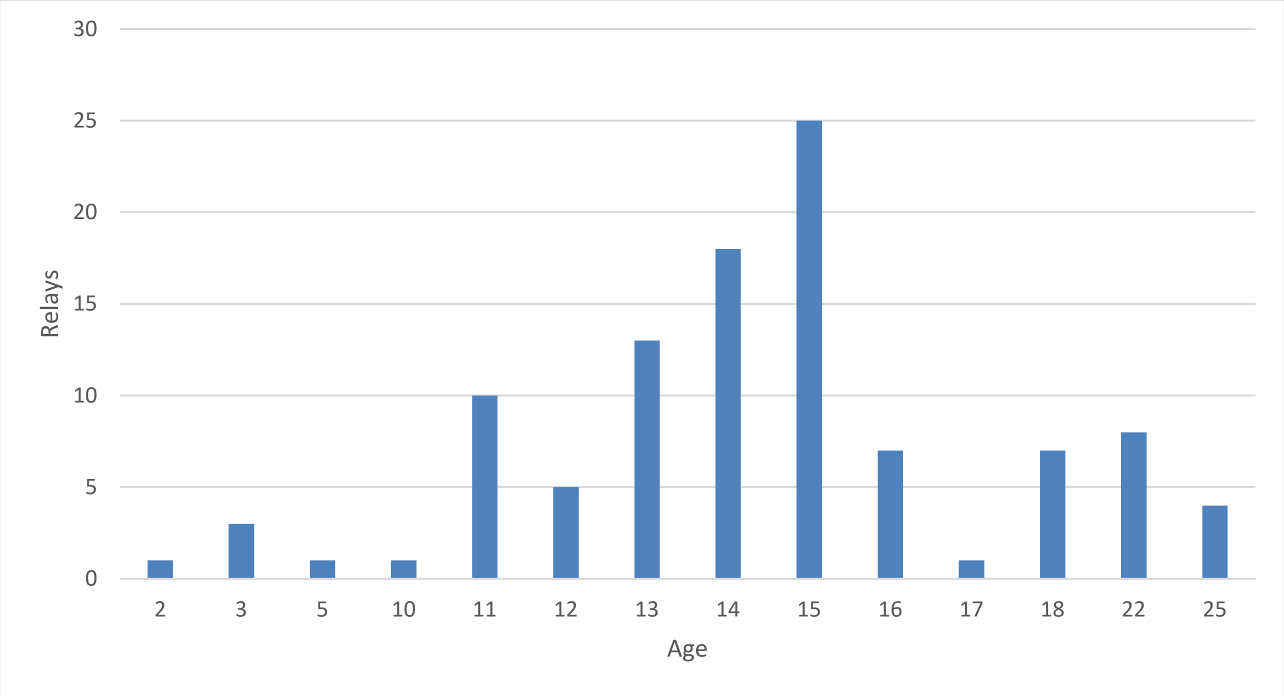
- bay interlocking and control.

In addition, HV capacitor bank protection schemes include a control relay to automatically switch in and out the capacitor bank(s), based on voltage or MVAr set points, and cycle multiple capacitor banks to ensure even usage.

Table 3: Capacitor Bank protection asset volumes

Description	Schemes	Relays
EHV Capacitor Bank	13	46
HV Capacitor Bank	23	58

Figure 3: Capacitor Bank protection age profile



4.4 HV feeder protection

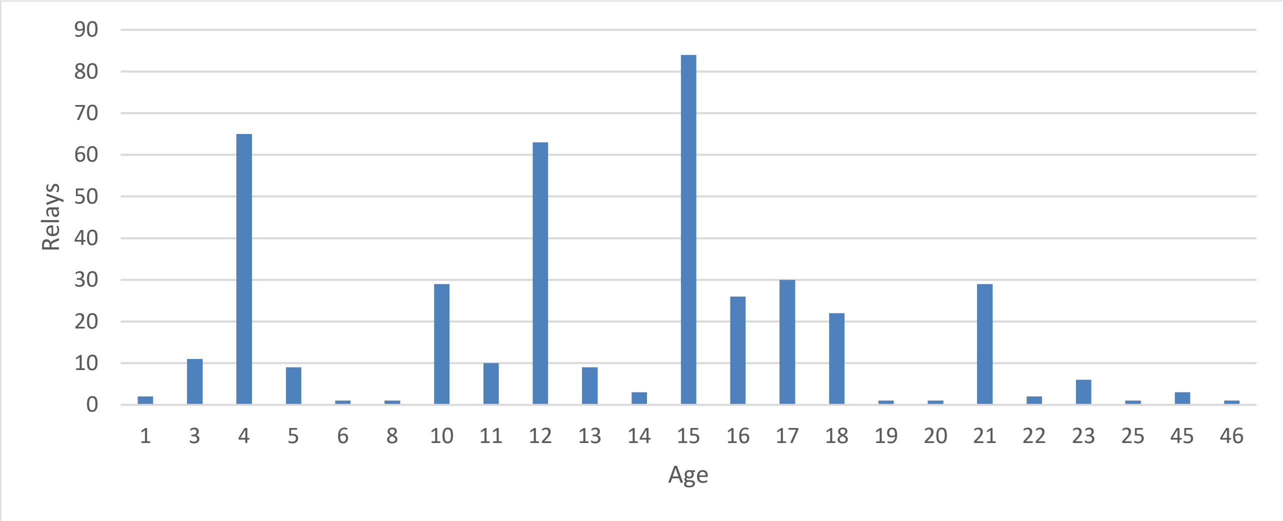
The HV feeder protection borders at the end of the transmission network but protects the beginning of the distribution network with feeder voltage levels between 6.6 kV and 44 kV, but mostly 11 kV and 22 kV. A feeder protection and control scheme typically includes overcurrent, earth fault and sensitive earth fault protection, as well as automatic breaker re-closure functionality. These schemes do not require redundancy under the NER and in modern installations the protection and control functions are incorporated within a single relay. Backup protection is provided by the transformer protection scheme.

Line differential protection is applied to sub-transmission feeders or on feeders suppling the Hobart CBD building substations, although this protection is documented in the *Distribution Protection Asset Management Plan*. Line differential protection is also installed on some major industrial customer feeders, however, ownership and management of the differential protection is the responsibility of the feeder circuit owner, as the connection point is usually at the cable connection of the HV switchboard.

Table 4: HV Feeder protection asset volumes

Description	Schemes	Relays
6.6 kV – 22 kV	328	356
33 kV – 44 kV	44	53

Figure 4: HV Feeder protection age profile



4.5 Frequency protection

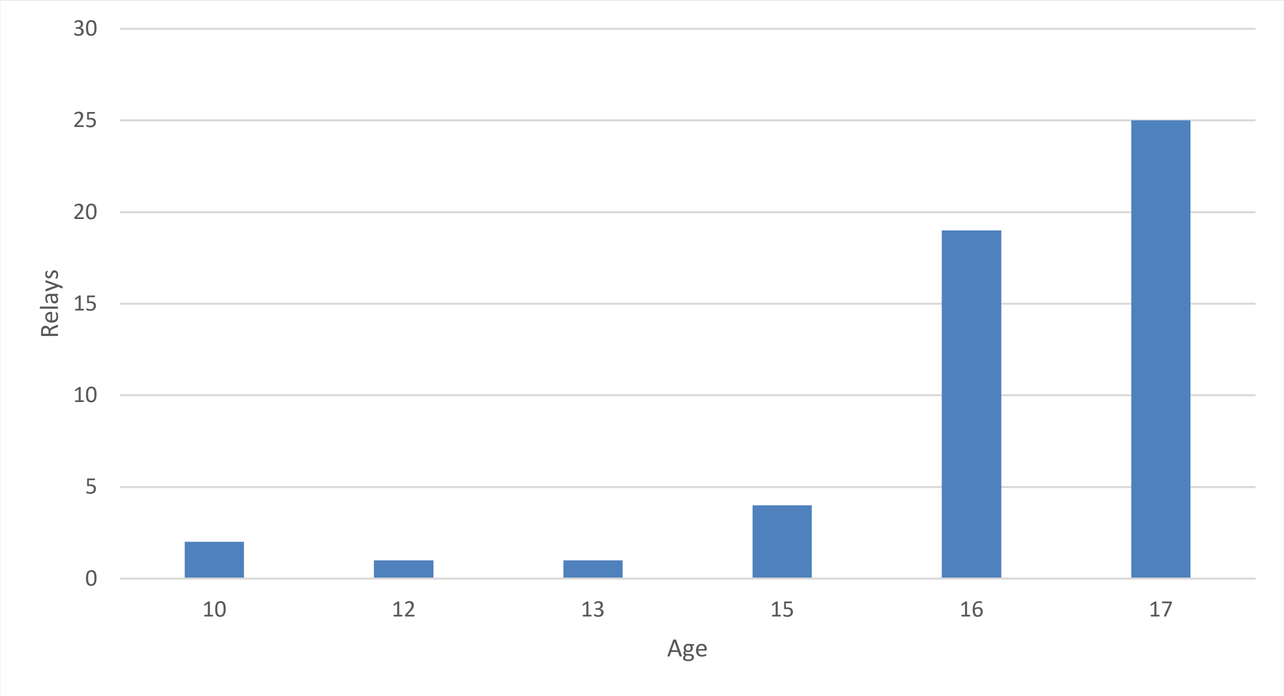
Since 1985 Tasmania has installed Under Frequency Load Shedding **(UFLS)** protection around the network to monitor the system frequency and disconnect defined blocks of load, to maintain power system stability after the loss of large generators. Some of these schemes are located within major industrial customer's sites to provide better load selection for the customer.

Similarly, Over Frequency Generator Shedding **(OFGS)** protection has been installed in two major substations to disconnect generators from the network to maintain system stability following the loss of large loads.

Table 5: Frequency protection asset volumes

Description	Schemes	Relays
Under Frequency Load Shedding	22	44
Over Frequency Generator Shedding	2	8

Figure 5: Frequency protection age profile



4.6 Transformer protection

A typical transformer protection scheme includes duplicated multifunction relays to provide the following functions:

- Low impedance biased current differential protection;
- Low impedance biased restricted earth fault protection;
- Overcurrent and earth fault protection; and
- EHV busbar backup impedance protection (network transformers only).

The bay interlocking and control functions are incorporated within one of the multifunction relays to minimise the relay count.

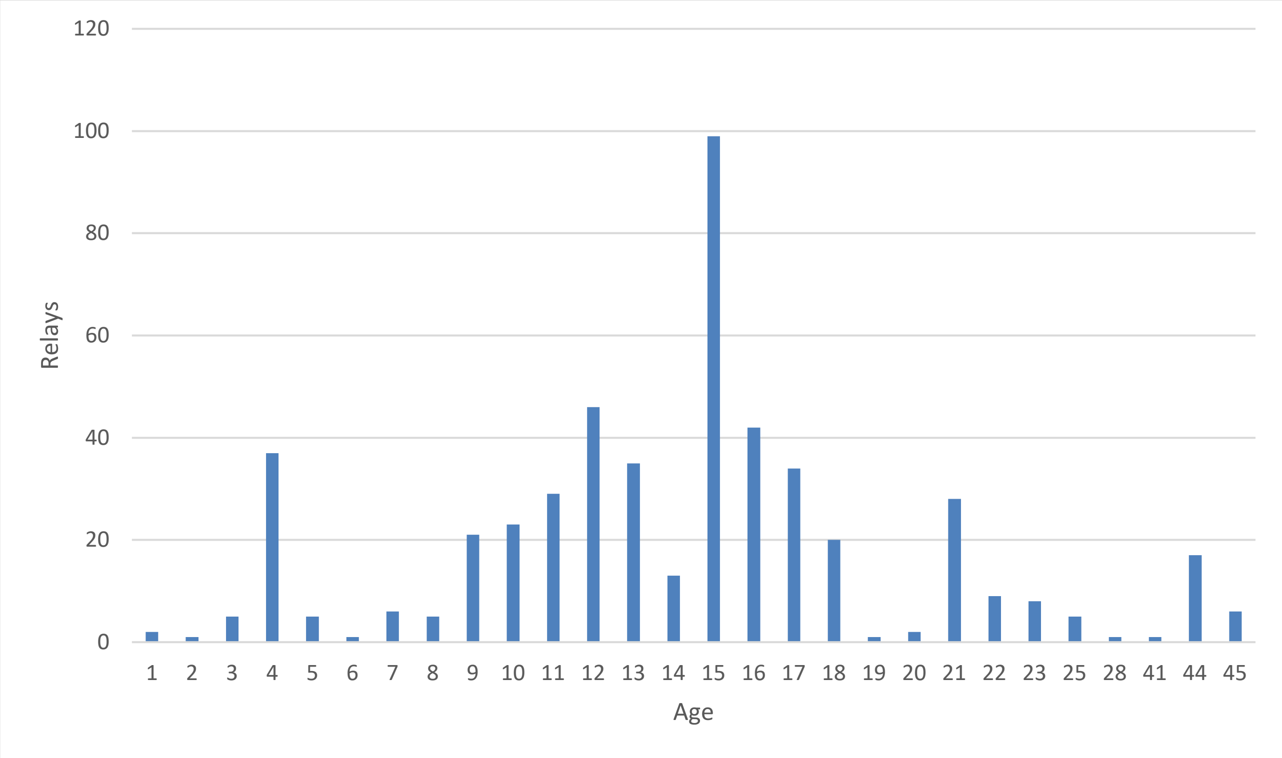
The mechanical Buchholz, tank pressure and temperature devices are generally fitted by the transformer manufacturer and maintained by the TasNetworks Substations team and, as such, will not form part of this asset management plan.

Although not really part of the transformer protection scheme, HV busbar incomer protection is applied as backup to the busbars and HV feeders, as well as transformer incomer breaker control. This single relay is installed within a new switchboard incomer breaker panel and is usually a matching relay type to the HV feeder protection relays.

Table 6: Transformer protection asset volumes

Description	Schemes	Relays
Supply Transformer	101	435
Network Transformer	17	67

Figure 6: Transformer protection age profile



4.7 Transmission line protection

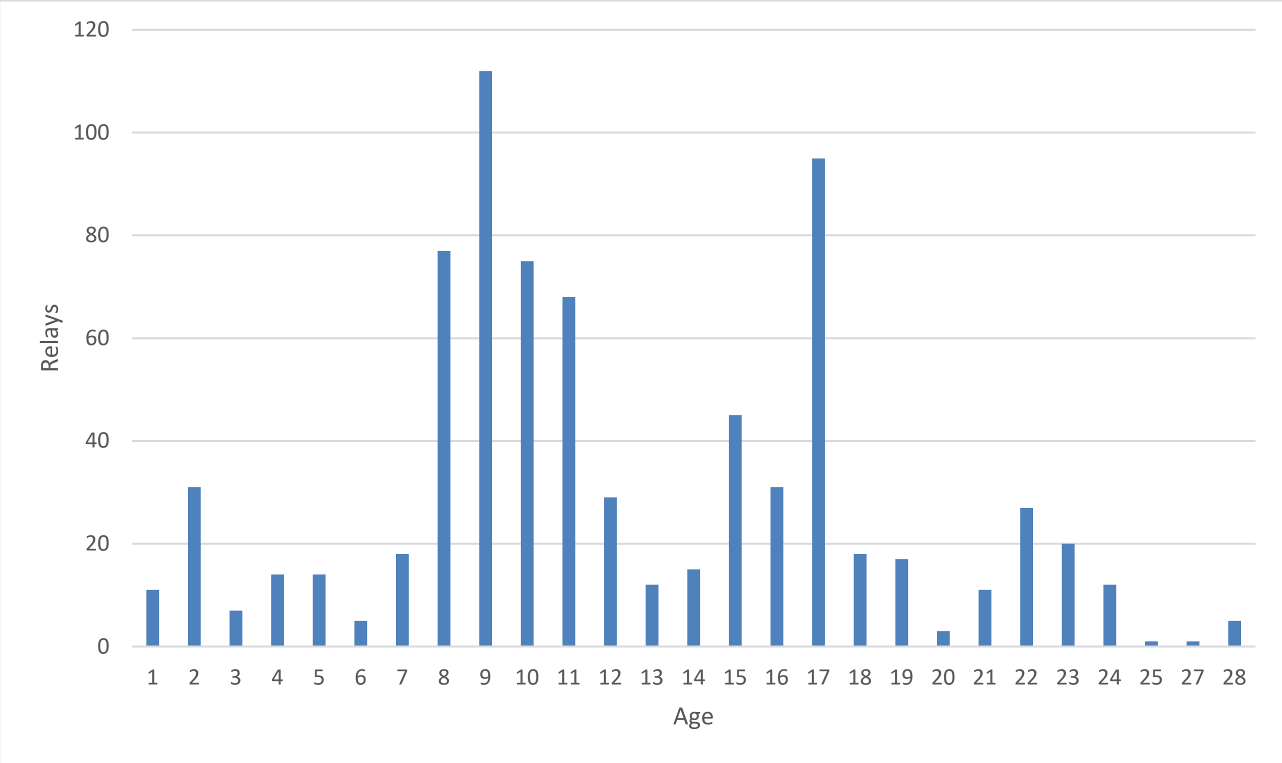
The standard 110 kV and 220 kV transmission line protection scheme includes duplicated multifunction relays to provide current differential and backup distance protection functionality. This design ensures compliance with the fault clearance requirements of the NER.

The transmission line protection scheme also includes a bay control relay, which provides the automatic breaker re-closure, synchronising check, bay interlocking and control, and operational metering, although that relay is included in the SCADA and Automation Asset Management Plan. The most recent transmission line protection scheme designs will leverage off improved relay functionality to incorporate the bay interlocking and control functions within one of the multifunction relays, similar to the design of the transformer protection schemes. This design will minimise future relay numbers and minimise ongoing installation and operational costs.

Table 7: Transmission line protection asset volumes

Description	Schemes	Relays
110 kV transmission lines	140	518
220 kV transmission lines	61	256

Figure 7: Transmission line protection age profile



5. Associated risk

5.1 Risk management framework

TasNetworks has developed a Risk Management Framework for the purposes of assessing and managing its business risks, and to ensure a consistent and structured approach to the management of risk is applied. An assessment of the risks associated with the transmission protection equipment has been undertaken in accordance with the Risk Management Framework.

TasNetworks is required to provide economic justification of renewal projects and programs based on mitigation of risk, in terms of dollars spent versus dollars saved. Due to this, the risks need to be represented in financially quantified values. The quantification of risk is provided by the Total Quantification Risk (**TQR**) tool, with the outputs of the TQR entered into the Copperleaf Asset Investment Planning & Management software. This allows individual asset renewals to be optimised against the risk assessments of each treatment option, and for the overall programs to be optimised against each other, based on the associated asset risk treatments.

5.2 Performance data

TasNetworks monitors protection performance by recording a defect notification against the equipment record in the SAP Enterprise Asset Management system. These records are able to be categorised by recording the symptom of the defect (such as non-operation or incorrect operation), the cause (such as hardware failure, incorrect settings or manufacturing deficiency) or the source of finding the defect (such as routine maintenance, corrective maintenance, or commissioning). These attributes allow reporting and Key Performance Indicators (**KPIs**) for the consequences and causes of protection asset failure, and the effectiveness of our maintenance strategies.

TasNetworks asset strategy engineers are currently working with field services technicians to improve the quality of defect data, as it often requires interpretation and more detailed investigation to ascertain the causes and consequences of protection relay failures. The end goal is to provide "dashboard" reporting for fast assessment by all stakeholders involved in the management and maintenance of the transmission protection assets.

5.3 Asset risks

5.3.1 Depletion of dedicated spares

The majority of protection relays are microprocessor based technology that will eventually fail in an unknown period. The equipment is rotable, such that when a failure occurs, a dedicated spare is used to replace the failed relay, which is sent back to the manufacturer for repair and then returned to the spares store. The consequence of a normal relay failure is low because the protection relays normally only fail in an inoperative state. Because modern protection relays provide self-supervision that alarms when the relay has failed, maintenance teams are alerted almost immediately and the protection service is mostly only depleted for up to 24 hours. Additionally, to comply with the NER, TasNetworks provides duplicate protection relays in most protection schemes and this redundancy covers any faults during the failed relay replacement.

Due to the low risk of a protection relay hardware failure, the real risk is when equipment incorrectly operates due to human error and incorrect installation. This usually occurs when the protection installation is rushed, as is the case when a failed relay does not have a direct replacement spare and has to be replaced with a different model of relay. This requires re-configuration of settings, modifications to design drawings, re-wiring of the protection panel, and re-commissioning of the protection scheme. If this work is performed under emergency conditions, the risk of introducing errors in the installation increases.

Once the rotable maintenance cycle breaks, which occurs when the equipment manufacturer ceases repair services and relay failures lead to a depletion of dedicated spares, a failure will require a different model of relay to be installed in place of the failed relay. Additionally, these re-design tasks may require a higher level of engineering skills that may not be available in the short timeframe.

The consequence of this rushed and potentially inaccurate installation is poor performance of the new protection relay that impacts the network performance and service to customers. Additionally, when higher skilled resources are required in short timeframes a cost premium may be incurred.

Table 8: Summary of asset risks

Risk Identification		Risk Analysis (Inherent)				
Asset	**Risk Description**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Treatment Plan Yes / No**
Protection Relay	Depletion of dedicated spares for protection relays leading to rushed and inaccurate restoration of failed equipment by normal maintenance personnel or requiring emergency engagement with contractors to address the resource deficiency	Safety and People	Rare	Moderate	Low	Yes
		Financial	Unlikely	Minor	Low	
		Customer	Unlikely	Minor	Low	
		Regulatory Compliance	Rare	Minor	Low	
		Network Performance	Unlikely	Minor	Low	
		Reputation	Unlikely	Minor	Low	
		Environment and Community	Rare	Major	Medium	

6. Whole of life management plan

6.1 Preventive and corrective maintenance (opex)

Since 2019, TasNetworks has taken advantage of the benefits offered by modern microprocessor based protection relays and ceased routine testing of protection relays that have self-monitoring functionality. This new strategy was implemented following a study of results from the routine testing program, which showed that relay hardware failures were not captured during routine testing, but that significant numbers of commissioning defects were being recorded, such as incorrect wiring, settings, and drawings. Given that the self-monitoring relays run self-tests and alarm failures immediately, the risk is very low of a protection relay failure being undetected. Additionally, the new strategy recommended that maintenance personnel be involved in new protection equipment commissioning where errors can be found before putting the equipment into service and issues could be rectified by the Contractors during the defects liability period.

TasNetworks currently have separate non-routine maintenance programs such as:

- CMPTC for rectification of protection relay failures;
- CMFAT for protection performance investigation and reporting following system faults; and
- PCENG for engineering support such as assisting in the review of standards.

However, it has been found that the CMFAT and PCENG work categories are quite often incorrectly applied by works planners or the support activities are applied to the CMPTC work category. Hence, starting from 2024, the CMFAT and PCENG work categories will be rolled into the single CMPTC non-routine maintenance work category. This will also better align to Regulatory Information Notice (**RIN**) category analysis reporting.

6.1.1 Substation protection routine maintenance - PMPTC

The routine maintenance program for transmission substation protection includes relay injection testing, the calibration of electromechanical relays where required, and confirmation of asset data, including drawings. This testing is only required for non-self-monitoring protection relays or for under frequency load shedding protection schemes due to NER requirements. This program is initiated from maintenance plans within the SAP Enterprise Asset Management module and the cycle for non-self-monitoring protection maintenance is three years and six years for under frequency load shedding protection schemes, with work orders created automatically two years in advance.

At present, the testing of the transmission substation protection is not finding significant numbers of failures of relays. However, as previously mentioned, most issues found during routine testing are errors introduced during the commissioning of the equipment.

6.1.2 Substation non-routine maintenance - CMPTC

The CMPTC non-routine maintenance program covers:

- corrective maintenance of transmission protection equipment, including auxiliary circuits and equipment enclosures;
- retrieval of protection operation data such as disturbance records and relay sequence of events operation for transmission system fault reporting;
- auditing and correcting compliance issues with new cyber security rules applied by the Department of Homeland Affairs;
- a 50 per cent share of the state-wide on-call emergency response availability roster allowance with the transmission SCADA non-routine maintenance program; and
- unplanned engineering tasks, such as assisting in standards and asset management plan review and review of network customer protection settings.

Based on the new “just in time” protection renewal strategy, where TasNetworks will be operating the protection assets closer to failure, it is expected that there will be an increase in corrective maintenance over time, due to increased in-service relay failures, but that this should plateau at a manageable level, based on the size of the protection relay fleet. As the routine testing program diminishes, however, commissioning errors found during the first routine test will also reduce, which should result in an initial reduction in opex.

6.1.3 Summary of opex expenditure

Table 9: Summary of opex programs and expenditure

Project/Program	Func. Area	Program Data										
		Financial year	**FY20**	**FY21**	**FY22**	**FY23**	**FY24**	**FY25**	**FY26**	**FY27**	**FY28**	**FY29**
Substation protection routine maintenance	PMPTC	Expenditure ($k)	314.7	314.7	314.7	75.0	65.0	90.0	40.0	65.0	30.0	30.0
Substation non-routine maintenance	CMPTC	Expenditure ($k)	775.4	775.4	775.4	775.4	775.4	520.0	527.5	540.0	552.5	565.0

6.2 Reliability and quality maintained (capex)

Historically, the strategy for protection renewal was to replace non-self-monitoring protection relays with self-monitoring relays. This strategy provided significant savings due to the decreased frequency of routine maintenance. However, with the majority of electromechanical protection relays in transmission substations now replaced with microprocessor technology, this strategy is no longer applicable.

The strategy applied for the 2019-2024 regulatory period was to replace older protection relays before an increase in failures. The renewal program consisted of replacement of complete protection schemes, which included new enclosures with two to three relays fitted, but this was deemed as inefficient. Hence, TasNetworks has changed the strategy for renewal of protection equipment with the intent to better support ongoing operational maintenance, given that operational maintenance is the most cost effective means for ensuring continuation of the protection services.

6.2.1 Transmission protection renewal program - RENPC

Protection relays are rotable equipment, where failures within a fleet of relays are certain to occur throughout the life of the fleet. These failures primarily drive the operational maintenance program and, as long as the maintenance teams have dedicated spares and good asset data, operationally maintaining the protection equipment is the most cost effective life-cycle management strategy. The renewal process supports the operational maintenance program by monitoring the availability of dedicated spares of obsolete relays and undertaking planned replacements of selected installations with a new model of relay to replenish spares of the obsolete model of relay. By keeping the scope of the replacement project to only a single relay replacement, this work can be undertaken by experienced maintenance technicians with the assistance of the relay’s manufacturer. This will ensure that protection relays are fully utilised and are only disposed of once they fail and cannot be repaired. The trigger for this planned replacement and retrieval of obsolete relays is driven by corrective maintenance records and spares stocks reaching a minimum holding.

Maintenance teams have already undertaken these just in time relays replacements when spares have fully depleted, and this has proven to be more cost effective than full protection scheme replacement projects.

Applying this strategy to a 40 year relay fleet aging scenario has indicated that, across the entire population of protection relays (approximately 2,500 relays), the capital cost should plateau at around $2 million per annum, with operational expenditure of around $0.6 million per annum.

6.2.2 Transmission protection augmentation

Where new protection equipment is installed in the network due to network augmentation, TasNetworks provides standard designs and standard protection relays to ensure that TasNetworks’ maintenance teams are able to manage spares and maintenance procedures. Where standard designs are not available, the last installation should be used as a template design.

Table 10: Program/project details

Project/Program description	Functional area	Document reference (IES)	Link to Copperleaf investment
Transmission protection renewal program	RENPC		Investment Details (copperleaf.cloud)

6.3 Spares management

TasNetworks’ maintenance teams are responsible for maintaining protection relay spares. The latest renewal strategy is intended to support the management of dedicated spares by replacing healthy relays of obsolete models and bringing the replaced relay back to the spares store to maintain required levels for ongoing maintenance. However, at present TasNetworks’ spares holdings are not in a satisfactory state due to years of installations without the purchase of a dedicated spare. Plus, on a lot of projects, a different version of the standard relay model is provided that doesn’t match the existing spares of that model.

Where new equipment is installed in the network, the project engineer is responsible for ensuring that spares stocks are maintained in line with TasNetworks' policy, in cooperation with the maintenance teams.

6.3.1 Spares policy

Sufficient spares are required to be maintained within the northern and southern regions of the State to enable a replacement relay to be installed within the restoration times defined in the Australian Energy Market Operator's operating procedures.

Spares are to be kept at an 8:1 in-service to spares ratio based on region (either north or south), to a maximum of three of each type per region.

Devices are to be kept as complete units, together with sufficient replacement parts to meet all credible contingencies.

If a project introduces a relay of unique design to the transmission system, or increases the quantity of a given relay type beyond the maximum 8:1 ratio, additional devices shall be purchased as a part of that project to enable the quantity of spares on hand to remain compliant with this policy.

6.4 End of life management

The latest renewal strategy is also intended to provide full utilisation of the protection relays by only disposing of a relay once it fails and cannot be repaired. Once the relay is not able to be repaired it is disposed by sending the relay to e-waste, along with TasNetworks' IT equipment.

7. Related standards and documentation

The following documents relate to the management of transmission system protection equipment:

Frequency Protection Standard (R246508)

Protection and Control of EHV Capacitor Banks Standard (R245701)

Protection and Control of HV Capacitor Banks Standard (R245703)

Protection and Control of Network Transformers Standard (R246242)

Protection and Control of Supply Transformers Standard (R245707)

Protection of EHV Busbars Standard (R246414)

Protection of HV Busbars and Feeders Standard (R246419)

Protection of Transmission Lines Standard (R246427)

Secondary Cable and Wiring Standard (R1744962)

Secondary Equipment Testing Standard (R244782)

Secondary Systems – General Requirements Standard (R246444)

Standard Transmission line Protection Panel Design Drawings (Z-809-0095-DI-001)

Standard Supply Transformer Protection Panel Design Drawings (Z-809-0083-DI-001)

Standard Network Transformer Protection Panel Design Drawings (TSD-DI-809-0080-001)