AMS 10-62 Gas Insulated Switchgear

2023-27 Transmission Revenue Reset

PUBLIC

Document number	AMS 10-62
Issue number	10
Status	FINAL
Approver	P. Ascione
Date of approval	07/07/2020

ISSUE/AMENDMENT STATUS

Issue Number	Date	Description	Author	Approved by
5	22/11/06	Editorial review.	G. Lukies D. Postlethwaite	G. Towns
6	16/01/07	Review and update.	G. Lukies S. Dick	G. Towns
7	17/03/07	Editorial review.	G. Lukies D. Postlethwaite	G. Towns
8	22/11/12	Revised Structure and General update.	P. Seneviratne S. Dick	D. Postlethwaite
9	14/10/15	Editorial review.	S. Sridhar T. Gowland	J. Dyer
10	7/07/20	Review and update	N Boteju	P Ascione

Disclaimer

This template is for generating internal and external document belonging to AusNet Services and may or may not contain all available information on the subject matter this document purports to address.

The information contained in this document is subject to review and AusNet Services may amend this document at any time. Amendments will be indicated in the Amendment Table, but AusNet Services does not undertake to keep this document up to date.

To the maximum extent permitted by law, AusNet Services makes no representation or warranty (express or implied) as to the accuracy, reliability, or completeness of the information contained in this document, or its suitability for any intended purpose. AusNet Services (which, for the purposes of this disclaimer, includes all of its related bodies corporate, its officers, employees, contractors, agents and consultants, and those of its related bodies corporate) shall have no liability for any loss or damage (be it direct or indirect, including liability by reason of negligence or negligent misstatement) for any statements, opinions, information or matter (expressed or implied) arising out of, contained in, or derived from, or for any omissions from, the information in this document.

Contact

This document is the responsibility of Network Management Division, AusNet Services.
Please contact the indicated owner of the document with any inquiries.

AusNet Services
Level 31, 2 Southbank Boulevard
Melbourne Victoria 3006
Ph: (03) 9695 6000

Table of Contents

1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' electricity transmission network. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of Gas Insulated Switchgear (GIS) in terminal stations.

Approximately 82.7% of the GIS equipment operate at 66kV (52%) and 220kV (29.6%) and the remainder are operating at 500kV (15.2%) and 22kV (2.1%). Disconnectors and Earth switches contribute to 41.4% of the total population of GIS assets. Circuit breakers and instrument transformers contribute to 11.3% and 16.6% respectively.

Approximately 71% of the GIS bays are in either C1, C2 or in C3 condition. The remainder 29% are in either C4 (7.6%) or in C5 (21.7%) asset condition. GIS bays that is in poor and very poor condition are located at SMTS, SYTS and NPSD.

Modelling criticality of GIS as a complete unit is complex since it is integrated with number of switchgear, such as circuit breakers, instrument transformers, disconnectors and surge arresters. It is normally evaluated during the overall network planning exercise as individual GIS bays or as a complete GIS, hence not considered under this strategy.

The most efficient program is to replace poor/very poor condition as an integral part of the major station replacement programs during 2022-27. In addition, a modest proactive operational life extension program is recommended at the indoor Newport Power Station (NPSD), which requires renovation work to reduce gas leakages.

Proactive management of Gas Insulated Switchgear including condition-based maintenance and replacement practice is required to ensure that stakeholder expectations of cost, safety, reliability and environmental performance are met. The summary of proposed asset strategies is listed below.

1.1 Asset Strategies

1.1.1 New Assets

- Continue to purchase fully type tested Gas Insulated Switchgear to the latest specification

1.1.2 Maintenance

- Continue maintaining Gas Insulated Switchgear in accordance with PGI 02-01-02.
- Continue annual PD monitoring of the older GIS
- Continue monitoring the performance of all GIS to determine the need for refurbishment or replacement

1.1.3 Spares

- Maintain strategic spares holding of Gas Insulated Switchgear as per spare holding policies
- Replace selected types technically obsolete to generate spares, where no strategic spares exist and there is no manufacturer support.

1.1.4 Replacement

- Replace SYTS very poor condition Gas Insulated Switchgear during the major station asset replacement programs during 2022-27.
- Replace or partially replace SMTS very poor condition Gas Insulated Switchgear during the major station asset replacement programs during 2022-27.

1.1.5 Refurbishment

- Complete replacement of leaking components at NPSD by 2022.
- Complete leak repair and replace sliding supports at ROTS Gas Insulated Line by 2022.

2 Introduction

2.1 Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of Gas Insulated Switchgear installed in terminal stations in AusNet Services' Victorian electricity transmission network. This document is intended to be used to inform asset management decisions and communicate the basis for activities.

In addition, this document forms part of our Asset Management System for compliance with relevant standards and regulatory requirements. It is intended to demonstrate responsible asset management practices by outlining economically justified outcomes.

2.2 Scope

This asset management strategy applies to all Gas Insulated Switchgear associated with the AusNet Services regulated asset base electricity transmission network that operate at 500kV, 220kV, 66kV and 22 kV in terminal stations.

The Circuit Breakers, Disconnectors & Earth switches, Instrument Transformers and Surge Arresters installed in Gas Insulated Switchgear assets are also covered under the other strategies:

- Circuit Breakers AMS 10-54
- Disconnectors and Earth Switches AMS 10-59
- Instrument Transformers AMS 10- 64
- Surge Arresters AMS 10-73

2.3 Asset Management Objectives

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

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

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

- Maintain top quartile benchmarking;
- Maintain reliability;
- Minimise market impact;
- Maximise network capability;
- Leverage advances in technology and data analytics;
- Minimise explosive failure risk.

3 Asset Description

3.1 Asset Function

Gas Insulated Switchgear are used at 500kV,220kV, 66 kV and 22 kV in terminal stations are used as an alternative construction technique to air insulated switchgear (AIS). It is typically used when a compact layout is required and also when preclude the use of AIS due to safety and regulation, pollution and constraints in local authority planning laws. It encloses all circuit breakers and associated instrument transformers, disconnectors and earth switches and seldom surge arresters within an SF_6 filled metal enclosure. It provides for earthing of certain equipment as required by the design to connect de-energised equipment to the general mass of earth and permit safe access for maintenance work.

3.2 Asset Population

AusNet Services has a total of 52 GIS switch bays, as reported in 2018/19 RIN installed in AusNet services terminal stations. There is also 2 sections of 500kV Gas Insulated Line (GIL) within Rowville Terminal Station.

Figure 1 below illustrates the population of GIS switchgear by Operating Voltage and Object type. Most GIS operates at 66kV. Disconnectors and Earth switches contribute to 41.4% of the total population of GIS assets. Circuit breakers and instrument transformers contribute to 11.3% and 16.6% respectively. Approximately 82.7% comprise of 66kV (52%) and 220kV (29.6%) and the remainder are operating at 500kV (15.2%) and 22kV (2.1%).

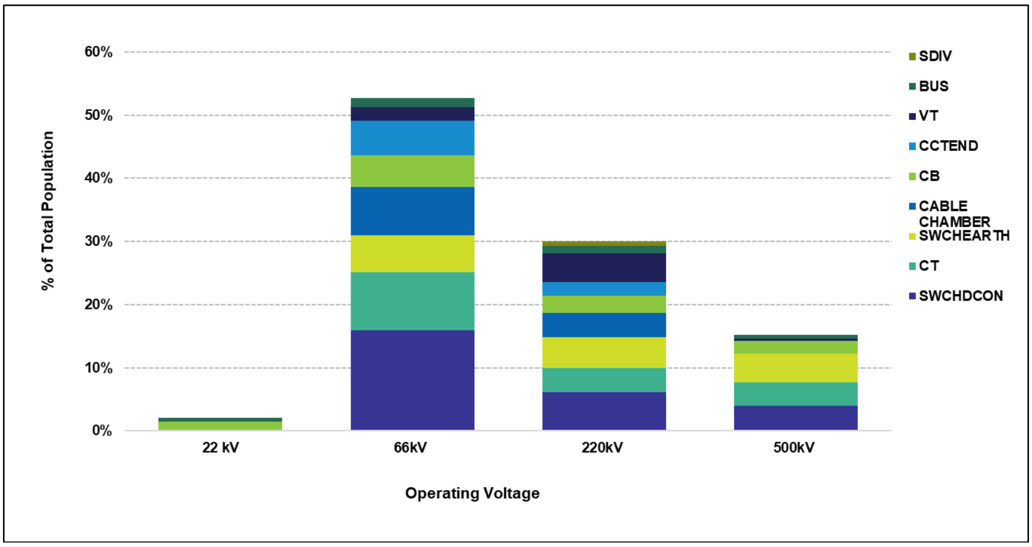

Figure 1 – Population of GIS switchgear by Operating Voltage and Object type

Figure 2 below illustrates the population of Gas Insulated Switchgear by Manufacturer in terminal substations in AusNet Services network. The most common Manufacturer -[C-I-C] at 37.8% of the GIS bus bays are 66kV [C-I-C].

[C-I-C]

Figure 2 – Population of Gas Insulated switchgear by Manufacturer -Model

Figure 3 below illustrates the population of Gas Insulated Switchgear bays by location type and operating voltage in terminal substations in AusNet Services network. Approximately 81% of the GIS bays are located indoors and 19% located outdoors. The outdoor locations are 500kV SMTS and SYTS and 500kV / 220kV ROTS Gas insulated lines (GIL).

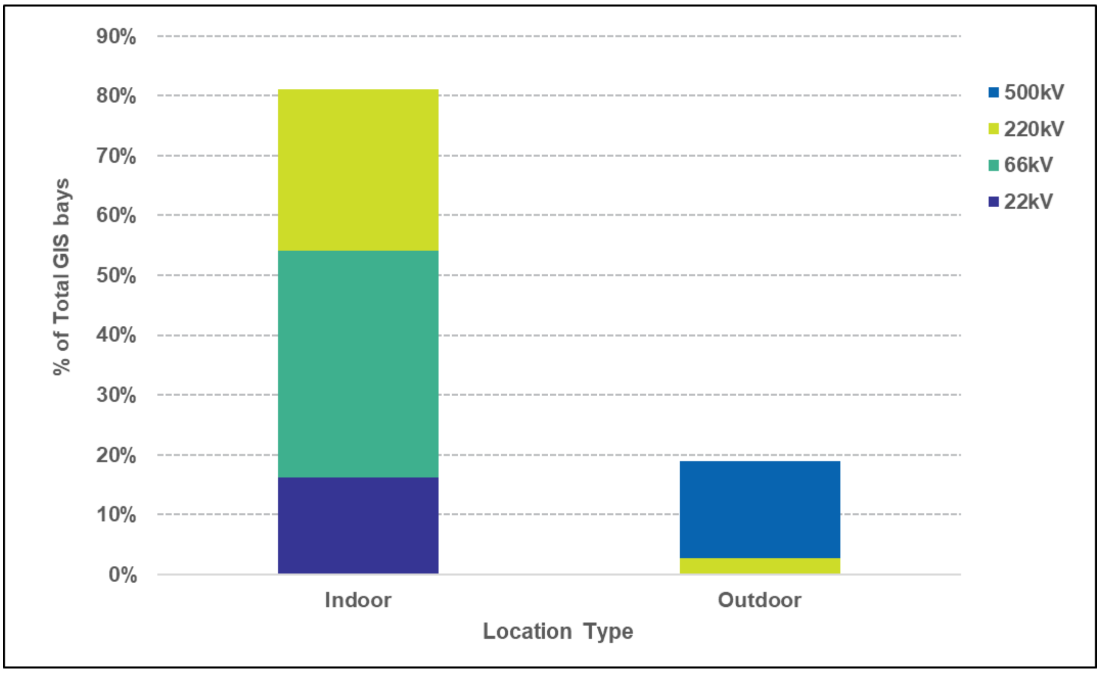

Figure 3 – Population of Gas Insulated switchgear by Location and voltage

3.3 Asset Age Profile

The service age profile of terminal station Gas Insulated Switchgear by service voltage is shown in figure 4.

About 16.2% of the total population of GIS Bays are older than 40 years operating at 220kV. Approximately 64.9% are less than 10-year-old operate at 66kV (37.8%) & and 220kV (10.8%).

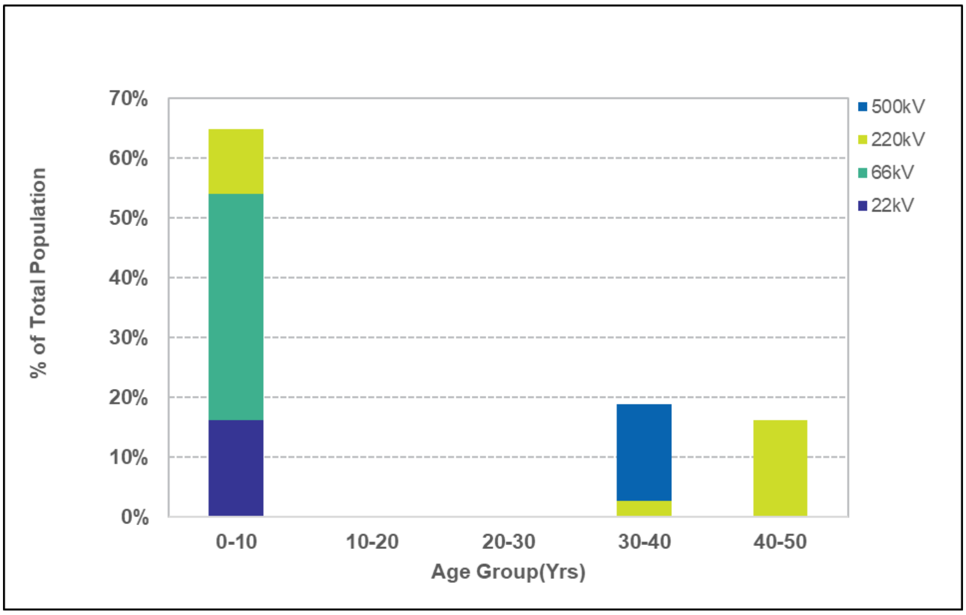

Figure 4 – Age Profile of GIS Bays in terminal stations by service voltage

3.4 Asset Condition

GIS asset condition has been derived from numerical analysis of weighted asset performance criteria. This numerical analysis technique provides an unbiased method of assessing equipment performance on data alone. However, localised phenomena are not always accounted for in generic templates and it can be necessary to affect a manual adjustment to facilitate accurate predictions. Consequently, the numerically derived condition score is verified against a logical check to test whether the new condition score follows the expected trends of previous assessments.

The condition scoring strategy for GIS was based on a theory that the condition of GIS bays should approximate to the condition identified for the GIS Circuit Breakers components of the same equipment.

While small items like seals and pressure relief devices can be replaced, the concept of GIS means that de-gassing and invasive maintenance should be avoided for as long as possible, as this has a knock-on effect on the reliability of a whole bay.

Table 1 provides the condition assessment criteria of Gas insulated switchgear in terminal stations.

Table 1: Condition Assessment Criteria

Condition Score	Condition Description	Recommended Action
C1	Very good or original condition	No additional specific actions required, continue routine maintenance and condition monitoring.
C2	Better than average for age	
C3	Average condition for age	
C4	Poor	Remedial action/replacement within 2-10 years.
C5	Very poor and approaching end of life	Remedial action/replacement within 1-5 years.

Asset Condition Profile of GIS Bays by Service Voltage is given in Figure 4. The general condition of GIS equipment is good. Approximately 71% of the GIS bays are in either C1, C2 or in C3 condition. The remainder 29% are in either C4 (7.6%) or in C5 (21.7%) asset condition. GIS bays that is in poor and very poor condition are located at SMTS, SYTS and NPSD.

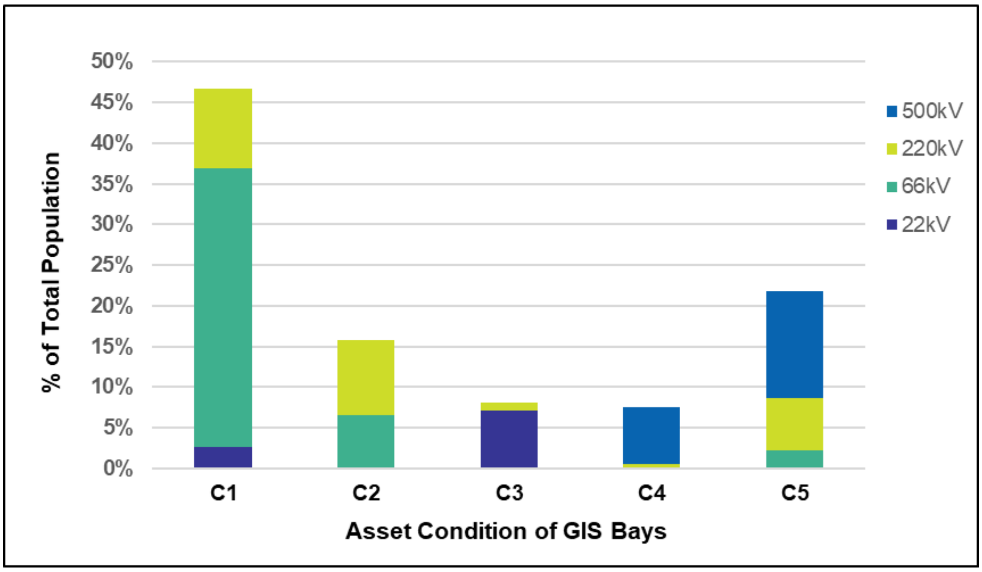

Figure 5 – Condition Profile of GIS bays by Service Voltage

3.5 Asset Criticality

GIS equipment is unlike air insulated equipment in nature as a single bay integrates several other assets and one asset failure can affect availability of other assets. Hence modelling criticality as a combined unit is complex in nature and normally evaluated during the overall network planning exercise as follows: Detail is provided in RIT-T PSCR planning reports.

- PSCR Report references (RIT-T): Maintain reliable transmission network services ant South Morang Terminal Station,
- PSCR Report references (RIT-T): Maintain reliable transmission network services at Sydenham Terminal Station)

3.6 Asset Performance

AusNet Services routinely analyses the root cause of unplanned work undertaken on GIS switchgear and investigates all major failures and tracks their effects on reliability and power quality to the customers.

3.6.1 Corrective Maintenance

All terminal station Gas Insulated Switchgear are subjected to routine maintenance in accordance with PGI 02-01-02 and relevant standard maintenance instructions (SMI).

Analysis of corrective maintenance work (ZA - condition based) carried out during 2015-2019 period is shown in Figure 6, 7 and 8.

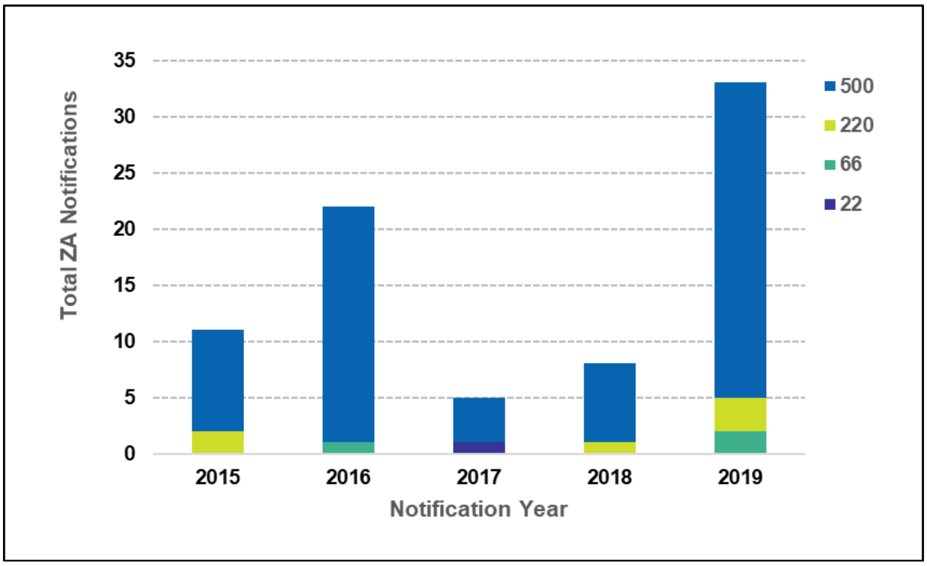

Figure 6 – ZA Notification analysis by operating voltage of GIS - 2015-2019 Period

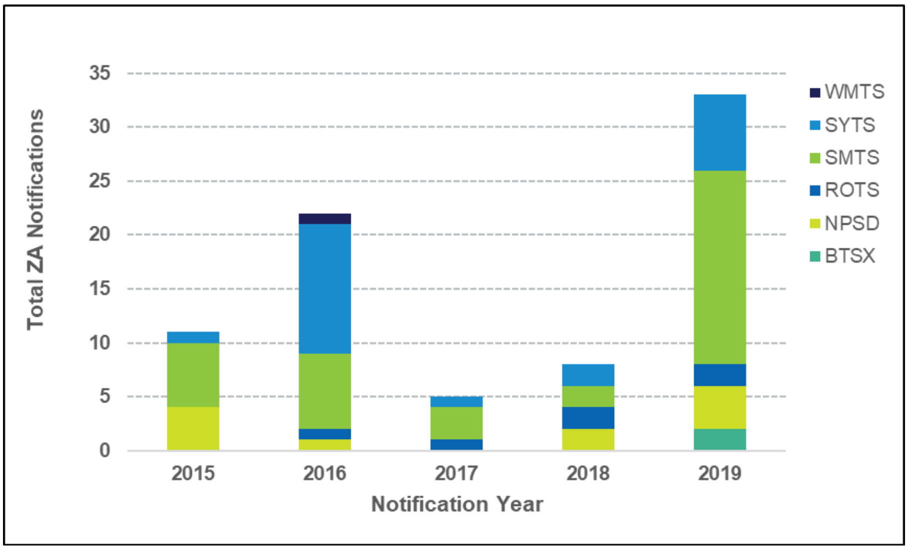

Figure 7 – ZA Notification Analysis Vs GIS Station - 2015-2019 Period

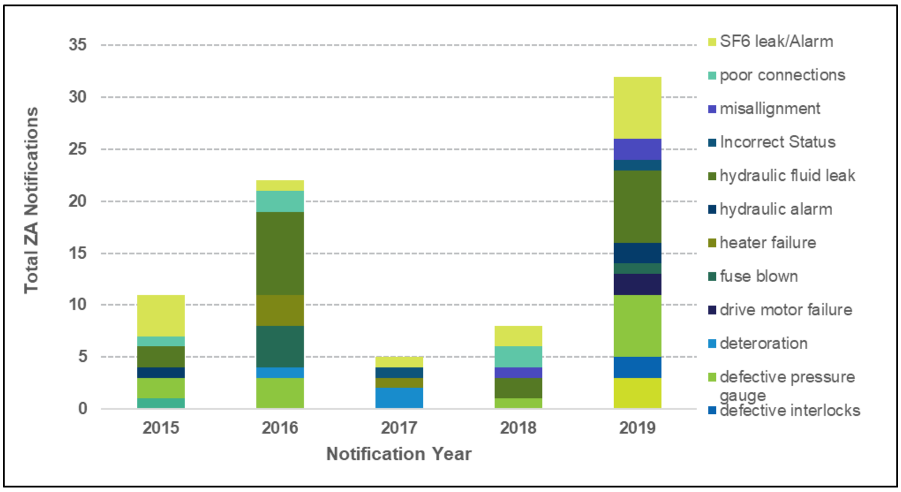

Figure 8 – ZA Notification analysis by Defect - 2015-2019 Period

Following observations were made based on figures 6,7 and 8.

1. Year 2019 recorded the highest number of ZA notifications mainly from 500kV SMTS GIS due to defective gauges.
2. Approximately 89% of the ZA notifications occurred in older 500kV GIS installations at SMTS (45.6%) SYTS (29.1%) and NPSD (13.9%) during the period 2015-2019.
3. Resolving hydraulic system problems (29%) had the highest incidents of ZA notifications followed by SF6 leaks/alarms (18%), defective pressure gauges (15%), heater related failures (7%) and other issues (31%) due to CB (10%), secondary & control system failures (21%) during the period 2015-2019.

3.6.2 SF6 Gas Leaks

Analysis of estimated SF6 gas leaks in Gas Insulated Switchgear in the 2016 -2020 regulatory reporting year is shown in figures 10 and 11. The 2020 Year values are the forecasted values based on previous year trend of gas leakages. It is estimated that approximately 60% of the fugitive SF6 gas leaks (kg) in Ausnet Services Transmission Network are associated with GIS equipment contributing to greenhouse gas effect. (The global warming potential of SF6 gas is 23500 times more than carbon dioxide.)

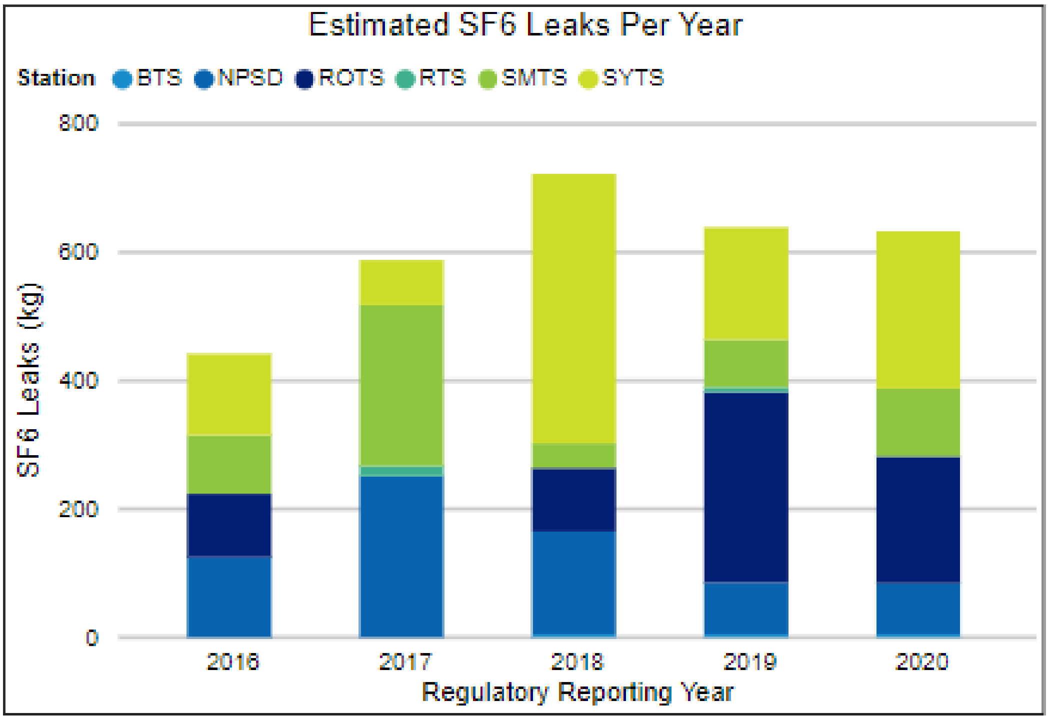

Figure 10 – SF6 Gas Estimated Leaks by GIS Location - 2016-2020 Regulatory Period

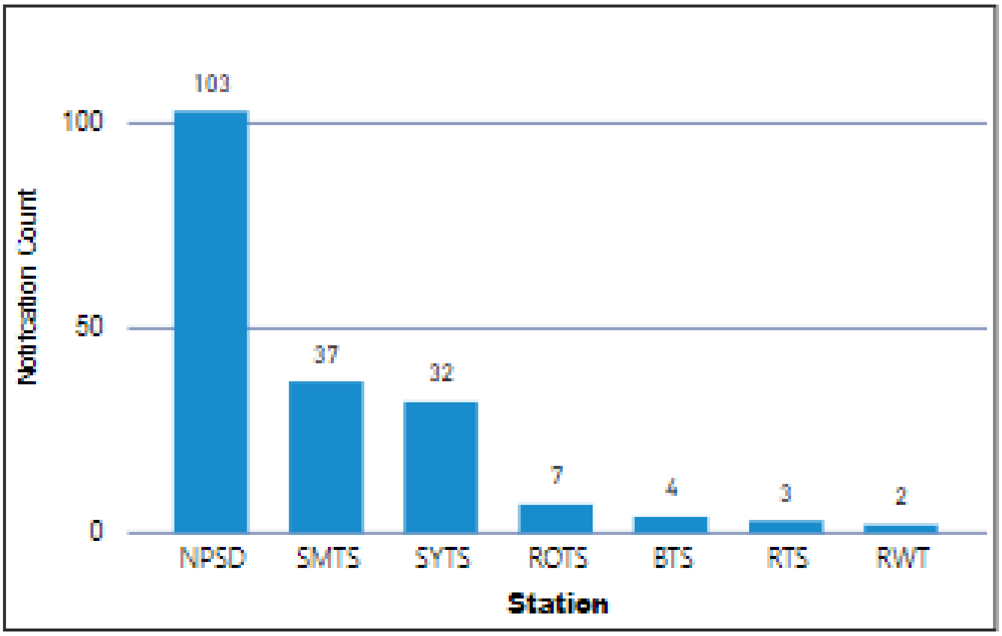

Figure 11 – SF6 Gas Leaks Notifications by GIS station - 2016-2020 Regulatory Period

It is observed that highest number of notifications associated with SF6 gas leakages occurred at NPSD followed by SMTS and SYTS during the period 2015 -2019 regulatory period. Highest amount of SF6 gas leaks (kg) was reported from SYTS (34%), followed by NPSD (23%), ROTS GIL (22%) and SMTS (18%).

There have been very significant SF6 leak repair programs implemented at the outdoor SMTS, between 2000 to 2010, and at outdoor SYTS between 2010 to 2015 to reduce leak effect although leakage is growing again. The main cause of leaks was flange corrosion and porous pressure relief discs. At the indoor NPSD, leak repairs are currently underway, predominantly requiring replacement of compartment graphite pressure relief discs.

3.6.3 Major Failures

The details of the significant incidents reported at GIS in Terminal stations are indicated in Appendix 1. They mainly occurred at NPSD, SYTS and SMTS. Repairs from these historical incidents have not had a long term impact on the reliability of the GIS, since they have stabilised and there have not been any significant major failures on the regulated GIS asset base since 2012.

Hydraulic system leaks and SF6 gas leaks are generally not considered major equipment failures, but there have been instances, where both have led to circuit trips, due to protective lockout systems on the pressures systems of either. Thus, the process of hydraulic, or SF6 gas leaks has led to significant system incidents on several occasions.

Numerous hydraulic leaks have occurred since 2012 at SYTS and SMTS. Hydraulic leaks at SYTS are most significant, in that they may be attributed to failure to achieve reliable, long term seals after the equipment was dismantled and refurbished. Improved practices and seal materials have been developed, subsequent to the investigation of post-refurbishment failures. Such that re-visited hydraulic seals repaired under the new practices should result in a return to reliability. There remains a residual risk of failure at seals which have not had a second repair, but policy is now that these locations will only be repaired as and when potential leaks become significant.

A key lesson learned from pro-active refurbishments of hydraulics at SYTS and on other AIS switchgear, is that the action of dismantling hydraulic components can result in a drop in long-term reliability and therefore repairs are conducted on SMTS hydraulic leaks, only as required.

SMTS leaks are related to deterioration with age related corrosion. By year 2000 SMTS GIS was losing almost 1000kg of SF6 per annum, and a major leak repair commenced. This program significantly reduced the leakage then but with time there are now increasing cases of leaks returning, and past the instances clearly have an impact on the assessed condition.

The most significant and repetitive cases of SF_6 gas leaks leading to system trips are at NPSD, where there are numerous gas leak locations – generally at the interface flange with Pressure Relief Devices. It is planned that these Pressure Relief Devices will be replaced with a more robust type and the increased reliability resulting from this will generate a life extension at NPSD.

4 Other Issues

4.1 Technical obsolescence and spares management

Manufacturers generally completely cease support beyond 30 years.

Although serviceability can be improved midway through asset operational life, by increasing the level of spares held in stores just before the OEM ceases manufacture stores holding will deplete to the point that salvaging components and reverse engineering become the only means of supporting a fleet. Also reused components cannot economically extend asset lives further and at this point it will become technically obsolete.

- The 500kV [C-I-C] GIS at SMTS have reached the age of 40 years are now technically obsolete and the availability of new spares is particularly difficult to maintain these fleets. Manufacturer had recently informed that there will be no maintenance support for this type of switchgear.
- Similarly, 500kV [C-I-C] GIS at SYTS had also reached the age of 40 years has become technically obsolete though some spare parts are still able to be purchased but the supply is becoming restrictive.
- 220kV [C-I-C] GIS at Newport Power Station (NPSD) is the oldest GIS in the AusNet services transmission network which is about 49 years old and no manufacturer support is not available.

- ROTS 500kV outdoor Gas insulated line (GIL), two circuits were installed in the 1980s and there is no manufacturer support available for Westinghouse CGI bus duct system from the original manufacturer, [C-I-C]. Several defects were reported in the above GIL lines since 2016 which caused significant SF6 gas leaks at several points due to corrosion of fittings and gauges in gas monitoring system and line entry bushings. It was also reported that several mechanical support stops and sliding plastic bearings were broken at the bends of both SF6 GIL lines. A project is currently underway which involves re-engineering resolve these issues with the help of a leading manufacturer.

5 Risk and Option Analysis

The drivers of this program are supply reliability, environmental and health and safety risk where reliability is the dominant driver. GIS equipment is unique in nature as a single bay integrates several other assets.

A formal economic risk assessment is undertaken at a station level and undertaken and recorded as part of a detailed planning report as mentioned in section 3.5, PSCR (RIT-T) Reports for SMTS and SYTS.

The current condition of GIS equipment indicates partial refurbishment /replacements at SYTS, NPSD and SMTS. The remaining risks presented by the GIS equipment fleet will be addressed by closely monitoring the performance of individual assets and through asset works.

It is recommended to complete the refurbishment works at ROTS GIL and NPSD.

It is recommended to replace the very poor condition GIS bays at SYTS and SMTS during TRR 2022-2027 period which enable to generate some spares for life cycle support of the remainder.

6 Asset Strategies

6.1 New Assets

- Continue to purchase fully type tested Gas Insulated Switchgear to the latest specification

6.2 Maintenance

- Continue maintaining Gas Insulated Switchgear in accordance with PGI 02-01-02.
- Continue annual PD monitoring of the older GIS
- Continue monitoring the performance of all GIS to determine the need for refurbishment or replacement

6.3 Spares

- Maintain strategic spares holding of Gas Insulated Switchgear as per spare holding policies
- Replace selected types technically obsolete to generate spares, where no strategic spares exist and there is no manufacturer support.

6.4 Replacement

- Replace SYTS very poor condition Gas Insulated Switchgear during the major station asset replacement programs during 2022-27.
- Replace or partially replace SMTS very poor condition Gas Insulated Switchgear during the major station asset replacement programs during 2022-27.

6.5 Refurbishment

- Complete replacement of leaking components at NPSD by 2022.
- Complete leak repair and replace sliding supports at ROTS Gas Insulated Line by 2022

7 Appendix 1 – Major GIS Failures (NPSD, SYTS, SMTS)

Major Failures at NPSD (installed in 1979):

Table 2: Major Failures at NPSD

Date	Compartment type	Location	Comment	Action
1997	VT	BLTS Line VT	Flashover on return to service	Replace VT
2003	VT	BLTS Line VT	Flashover on return to service	Replace VT
2012	VT	BLTS Line VT	Overheated and preesure relief disc operated	Replace VT, new switching sequence prepared

Major Failures at SYTS (installed in 1981):

Table 3: Major Failures at SYTS

Date	Compartment Type	Compartment	Phase	Comment	Action
1989	Line entry	MLTS 2L line entry	W	Flashover on energisation- suspected as particles as SF6 had been removed and compartment dried a few days prior - note this was not the first energisation since the drying process	Repaired
2002	CB	MLTS 2L 2B CB	B	No flashover, but during opening 2 out of 4 interrupters open and other 2 only partially opened due to drive rod fixing nut coming loose - discovered due to discharge noise	Replaced interrupter & repaired
2002	CB	MLTS 2L 2B CB	W	Inspection - broken CR drive casting	Repair and replace casting
2002	CB	MLTS 2L 2B CB	B	Inspection - holding pins fallen out from CR drive casting latch	Repair and replace casting
2003	CB	MLTS 1L 2B CB	R	Flashover on closure - closing resistor finger contacts loose and fell out	Replaced interrupter
2003	CB	MLTS 1L 2B CB	W	Inspection - broken CR drive casting	Repair and replace casting
2003	CB	MLTS 1L 2B CB	B	Inspection - holding pins fallen out from CR drive casting latch	Repair and replace casting
2003	CB	SMTS 1L 2B CB	R	During instrusive overhaul discover broken CR drive casting	Repair and replace casting
2004	CB	MLTS 2L 2B CB	W	X ray inspection - broken CR drive casting	Repair and replace casting
2004	CB	MLTS 2L SMTS 2L	W	X ray inspection - broken CR drive casting	Repair and replace casting
2004	CB	SMTS 1L MLTS 1L CB	R	X ray inspection - loose interrupter drive rod fixing nuts	Repair
2004	CB	MLTS 1L 2B CB	R	Flashover during open operation - arced between lower stage shield to drive rod and enclosure - cause unknown	Replace interrupter
2016	CB	MLTS1/SMTS1 CB	R	burnt trip coil & hydralic oil leak for main operating cylinder.	Replaced hydraulic mechanism
2016	CB	MLTS1/SMTS1 CB	B	Hydraulic system failure intiating alarms. hydraulic fluid leaking at high pressure from the base of the blue phase main operating cylinder.	Replaced hydraulic mechanism components

Major Failures at SMTS (installed in 1982):

Table 4: Major Failures at SMTS

Date	Compartment type	Location	Comment	Action
1983	Line Entry	TBA	flashover	Repaired
1987	CB	TBA	flashover - nozzle fractured and jammed interupter	Replaced CB pole
May-03	CT chamber	CT	External CT's dropped within housing and water entry	Secured and reskirted all CT's
Jun-03	CB	F2 Transformer No1 Bus CB white phase	nozzle fractured and jammed interrupter failure (phase open circuit , no flashover)	Replaced CB pole
Dec-03	CT chamber	Future F1 Transformer red phase	Flashover - Bay E due to RTV Silicon entry	Repaired, replaced components
Jul-04	CB	HWTS 1L 2B CB red phase	Drive tube fractured, found during X ray inspection	Replaced CB pole
Jun-05	Bus	No. 1 Bus (Bay C)	High resistance joint developed	Replaced joint
Aug-07	ROI	TBA	Loose arcing tips discovered , lack of loctite	Repaired
Jan-08	ROI	SYTS 1L 1B CB Bus side ROI white phase	During planned operation, Repetitive close/opens occurred on all phases due to simulatanous mutiple DC earth faults, eventually casuing a Flashover on white phase. All phases damaged	All ROI phases internals replaced