AMS – Victorian Electricity Transmission Network

Gas Insulated Switchgear

(PUBLIC VERSION)

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1 Executive Summary

This document defines the asset management strategies for AusNet Services' electricity transmission network's population of Gas Insulated Switchgear (GIS). AusNet Services has a total of 56 GIS equipment installed in the Victorian electricity transmission network. A summary of GIS population is provided below in Table 1.

Voltage Class	GIS Equipment
500 kV	31
220 kV	1
66 kV	6
22 kV	18
Total	**56**

Table 1 – Gas Insulated Switchgear by operating voltage

New GIS installations are planned for Brunswick and Richmond terminal stations by the end of 2016 and 2022 respectively. Additionally, one 66 kV GIS bus at WMTS is planned to be replaced with a GIS bus.

The service age of GIS assets vary from one to 34 years with approximately 40% of the GIS equipment population in C1 (Very good) condition. Approximately 27% of the population are in condition C4 (Poor) and there are 11% in condition C5 (Very Poor).

The current condition of GIS equipment indicates replacements at RTS and WMTS, and refurbishment activities at SYTS are expected before 2020. The remaining risks presented by the GIS equipment fleet will be addressed by closely monitoring the performance of individual assets and through planned maintenance and refurbishment works.

1.1 Strategies

Key asset management strategies for GIS include:

- Continue monitoring the performance of all GIS to determine the need for refurbishment or replacement;
- Complete refurbishment of SYTS GIS – including reducing SF_6 gas leakage;
- Audit SMTS GIS equipment and investigate if mid-life refurbishment is required; and
- Review long lead time spares holdings and contingency planning.

2 Introduction

2.1 Purpose

The purpose of this document is to define the asset management strategies for AusNet Services' electricity transmission network's population of GIS.

2.2 Scope

This asset management strategy applies to all GIS that are rated for 500 kV, 220 kV, 66 kV or 22 kV associated with AusNet Services' electricity transmission network.

The strategies in this document are limited to maintaining installed capability in terms of equipment performance and rating. Improvements in quality or capacity of supply are not included in the scope of this document.

2.3 Objectives

The objectives of this asset management strategy are to:

- present an overview of the GIS population;
- manage business and network risks presented by GIS efficiently and within acceptable limits;
- achieve supply reliability targets taking account of risk, costs and customer expectations;
- ensure that asset management activities relating to GIS are effective and consistent throughout its life-cycle; and
- demonstrate that GIS is managed prudently and economically throughout its life-cycle.

2.4 References

This asset management strategy forms part of a suite of documentation that supports the management of AusNet Services' assets, which include the following:

AMS 01-01	Asset Management System – Overview
AMS 10-01	Asset Management Strategy – Transmission Network
AMS 10-19	Plant and Equipment Maintenance

3 Asset Summary

Gas Insulated Switchgear (GIS) is an alternative construction technique to Air Insulated Switchgear (AIS). It encloses all live parts within an SF_6 filled metal enclosure. It is typically used when a compact layout is required as shown below in Figure 1. The use of GIS is limited as the cost of GIS is significantly higher compared to AIS.

Figure 1 – GIS Equipment at SYTS

3.1 Population

AusNet Services has a total of 56 GIS equipment installed in the Victorian electricity transmission network. The population by voltage class and equipment type is shown in Table 2 below.

Voltage Class	Bus	Circuit Breaker
500 kV	11	20
220 kV	-	1
66 kV	2	4
22 kV	6	12
Total	**19**	**37**

Table 2 – Gas Insulated Equipment

The 500 kV GIS equipment is located outdoor at South Morang Terminal Station (SMTS), Sydenham Terminal Station (SYTS) and Rowville Terminal Station (ROTS). The 220 kV and 66 kV GIS equipment is located at West Melbourne Terminal Station (WMTS). The 22 kV GIS equipment is located at Heywood Terminal Station (HYTS) and Ringwood Terminal Station (RWTS).

New GIS installations are planned for Brunswick and Richmond terminal stations by the end of 2016 and 2022 respectively. Additionally, one 66 kV GIS bus at WMTS is planned to be replaced with a GIS bus as explained below.

- Brunswick is a connection augmentation project which will add new 220 kV and 66 kV GIS by the end of 2016.
- Richmond is an asset replacement project which will result in replacement of all 220 kV, 66 kV and 22 kV AIS equipment with GIS.
- West Melbourne is an asset replacement project which will result in replacement of the 220 kV AIS equipment with AIS equipment, three 66 kV AIS buses with AIS and a single 66 kV GIS bus with GIS. The 22 kV indoor switchboard at WMTS will be retired.

AusNet Services has GIS equipment manufactured by several manufacturers. Figure 2 below shows the population by manufacturer.

[C.I.C]

Figure 2 – GIS Equipment Population by Manufacturer

3.2 Age Profile

The GIS equipment population falls into two distinctive categories as shown by the age profile in Figure 3. The majority of GIS equipment operates at 500 kV with a service age between 31 to 40 years. The second age category consists of 22 kV and 500 kV GIS equipment that has a service age between one to ten years.

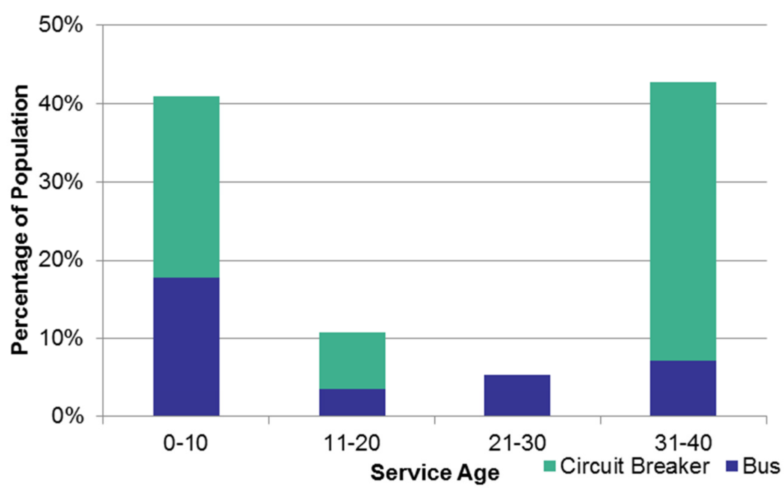

Figure 3 – Age Distribution of GIS Equipment

3.3 Condition

The general condition of GIS equipment is good. The condition was assessed adhering to the criteria described in the Table 3. This Table provides a definition of the various condition scores and recommendations.

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.

Table 3 – Condition score definition and recommended action

A condition score of C1 to C3 corresponds to an acceptable condition where no additional action (apart from continued routine maintenance and condition monitoring) is proposed. However, a condition score of C4 or C5 corresponds to GIS with high to very high failure risk requiring remedial action in a relatively short timeframe. Figure 4 shows the condition of the GIS equipment in the transmission network.

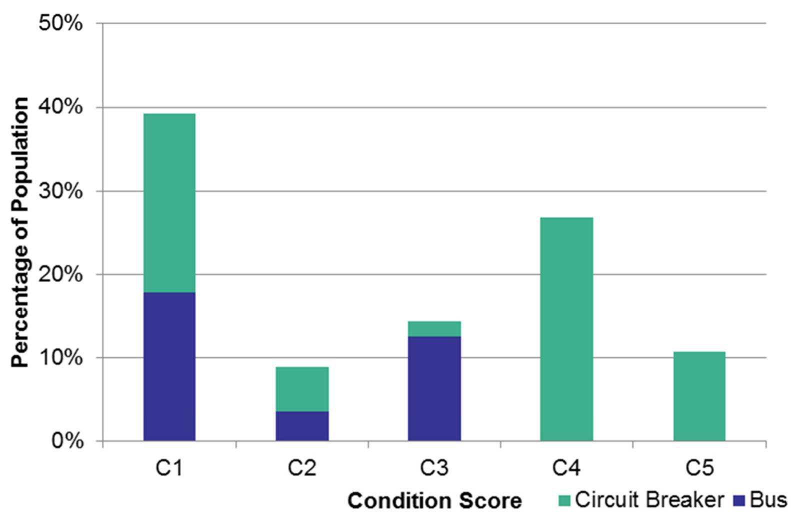

Figure 4 – Condition of GIS Equipment

The condition of approximately 40% of the GIS equipment population is C1 (Very good). Approximately 27% of the population are in condition C4 (Poor) and there are 11% in condition C5 (Very Poor).

GIS equipment that is in poor and very poor condition is located at SMTS, SYTS and WMTS. The principal issue associated with these assets are SF6 gas leaks. At SYTS, there is moisture in SF6, hydraulic leaks and loose components, however, upon completion of refurbishment works at SYTS, it is estimated the condition score will revert to C3. These issues are discussed further in Section 3.4.3.

3.4 Performance

This section provides an overview of performance issues associated with GIS equipment population and provides Failure Modes, Effects and Criticality Analysis (FMECA).

3.4.1 Defects

GIS is a technology introduced in the late 1960s. AusNet Services adopted GIS technology in the late 1970s with 220 kV switchgear, followed by 500 kV switchgear installations in early 1980s. GIS 66 kV equipment were added in 2001 and 2005 and 22 kV equipment were added in 2011.

Records are maintained for unplanned work undertaken on the GIS equipment using the asset management system. Work order analysis between 1992 and 2014 identified that the majority of the unplanned works were associated to the 500 kV GIS equipment as shown below in Figure 5.

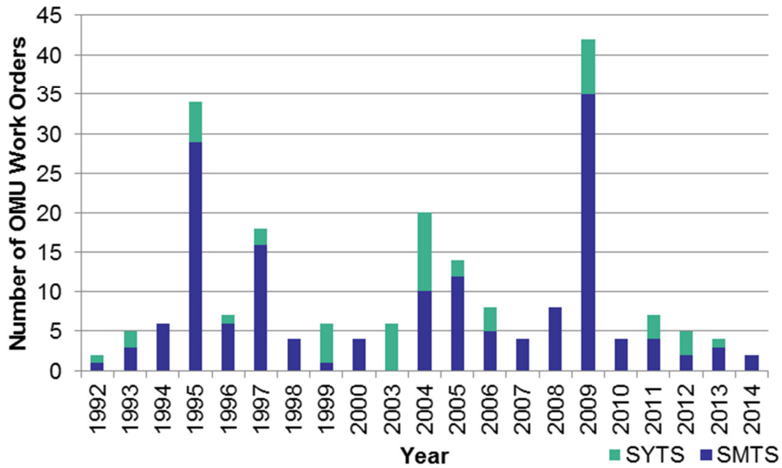

Figure 5 – 500 kV GIS Equipment unplanned work order analysis

The spike in 2009 was associated to the circuit breaker (CB) hydraulic mechanism. Since 2009, refurbishment works have been completed at SMTS and SYTS is currently under way to rectify this issue.

There were three and four unplanned works at WMTS 66 kV equipment in 2012 and 1999 respectively. There was only one unplanned work order in 2003 in RWTS.

The total number of unplanned maintenance work orders has decreased over the past five years. This reduction has been driven by major repair and refurbishment works programs initiated in the early part of the last decade at SYTS and SMTS 500kV GIS. Over the period 2000 to 2010, the entire SMTS GIS fleet was resealed for SF_6 gas leaks, cracked viewing windows were replaced and all the CB hydraulic mechanisms were refurbished. This has led to the decline in unplanned work.

Overhead bypass facilities were also designed and built for SMTS to ensure access to the GIS for maintenance and incidents. Unplanned work orders were mostly created for the 500 kV GIS equipment followed by 220 kV equipment. There have been no unplanned work orders raised for 66 kV GIS equipment since their installation in 2001 and 2005.

3.4.2 Major Failures

Table 4, Table 5 and Table 6 provide details of the GIS equipment major failures that occurred at NPDS, SYTS and SMTS since installation respectively. There have not been any significant major failures since 2012.

Major Failures at NPDS (installed in 1981)

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

Table 4 – Major Failures at NPDS

Major Failures at SYTS (installed in 1981)

Date	Compartment Type	Compartment	Comment	Action
Feb-89	Line entry	MLTS 2L line entry	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
Oct-02	CB	MLTS 2L 2B CB	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
Nov-02	CB	MLTS 2L 2B CB	Inspection - broken CR drive casting	Repair and replace casting
Nov-02	CB		Inspection - holding pins fallen out from CR drive casting latch	Repair and replace casting
Feb-03	CB	MLTS 1L 2B CB	Flashover on closure - closing resistor finger contacts loose and fell out	Replaced interrupter
Feb-03	CB	MLTS 1L 2B CB	Inspection - broken CR drive casting	Repair and replace casting
Feb-03	CB	MLTS 1L 2B CB	Inspection - holding pins fallen out from CR drive casting latch	Repair and replace casting
Sep-03	CB	SMTS 1L 2B CB	During instrusive overhaul discover broken CR drive casting	Repair and replace casting
Jul-04	CB	MLTS 2L 2B CB	X ray inspection - broken CR drive casting	Repair and replace casting
Jul-04	CB	MLTS 2L SMTS 2L	X ray inspection - broken CR drive casting	Repair and replace casting
Jul-04	CB	SMTS 1L MLTS 1L CB	X ray inspection - loose interrupter drive rod fixing nuts	Repair
Oct-04	CB	MLTS 1L 2B CB	Flashover during open operation - arced between lower stage shield to drive rod and enclosure - cause unknown	Replace interrupter

Table 5 – Major Failures at SYTS

Major Failures at SMTS (installed in 1982)

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

Table 6 – Major Failures at SMTS

3.4.3 Failure Modes

The following failure modes are being currently experienced by the GIS equipment population.

SF_6 leakage – The outdoor 500 kV GIS installations are affected by SF_6 leakages due to seal hardening and corrosion on flanges. Approximately 25% of the total network SF6 loss each year is from GIS installations. Loss rates are shown in Table 7.

Station	Installed gas (kg)	Annual Loss (kG)	Annual Leakage rate %
SMTS	29,700	<10	<0.01
SYTS	15,500	200	1.3

Table 7 – SF6 leakage in GIS stations

During the early part of the 2000s, SMTS was leaking more than 1 tonne of SF6 gas per year, a rate in excess of 5%. To mitigate against leaks, silicon was injected into the pressure vessel flanges minimising gas leaks, but the longevity of this solution is to be assessed. Since completing the SF6 sealing program from 2000 to 2009, the annual top up rate has been less than a few kg per year.

Modern equipment has a guaranteed better than 0.5% annual leakage rate so by comparison SYTS are particularly poor performers. The introduction of the carbon tax and NGERS (National Greenhouse and Energy Reporting) requirements has increased the urgency of leak repairs required for SYTS. Resealing projects have been initiated for both sites but due to difficulty in obtaining long outages, major repairs typically take a number of years.

Moisture in SF_6 – This failure mode results from an increasing level of moisture in compartments that are not fitted with drying agents or fitted with older style carbon matrix busting discs. This has been observed at SYTS and SMTS. Moisture leads to long term corrosion and dielectric withstand issues. During refurbishment activities, additional drying agent packs will be added and the bursting discs to be changed to a nickel alloy type, which is not prone to allow moisture ingress, SMTS has been retrofitted with drying agents during the gas sealing refurbishment program. SYTS is being retrofitted with drying agents as part of the current refurbishment project due for completion by 2017.

Hydraulic leaks – Internal and external hydraulic leakages in the drive mechanisms. Hydraulic seals harden with age and gradually lose the ability to hold pressure. All hydraulic mechanisms were refurbished at SMTS (except the nitrogen accumulators) over 2006 to 2010. A more cost effective refurbishment solution has been developed for the accumulators and these will be resealed to match the life of other refurbished parts over the next few years. SYTS hydraulic mechanisms are being overhauled as part of the refurbishment due for completion by 2017.

Mechanical failures – These are mechanical failures and defects including components becoming loose or fracturing. Specifically, SYTS has a number of past and ongoing mechanical problems with loose interrupter contacts, drive rod nuts and breaking closing resistor drives. These are all currently being inspected and retightened as part of the refurbishment program. Further broken closing resistor drives are being found reconfirming the need for a redesign solution.

3.4.4 Effects

SF_6 is the primary insulating and interrupting medium of GIS equipment. SF_6 gas released to the environment due to leaks is a serious environmental issue as it is a potent greenhouse gas. The effect of releasing 1kg of SF_6 is equivalent to releasing approximately 23,900 kg of CO_2 into the atmosphere. AusNet Services is committed to minimising the release of SF_6 gas. To manage the release of SF_6 gas, PGI 63-01-03 provides guide lines to the actions on SF_6 low pressure alarms, procedures for topping up, leak detection and assessment methods.

Due to the complex nature of GIS equipment and the presence of SF_6, specially trained fitters are required to undertake repairs associated with this equipment. Also, outages are longer than for equivalent repairs on AIS.

Spares are unique to the GIS design and an 18 month lead time is typically required to obtain spare parts for the older 500kV GIS equipment.

4 Risk Assessment

A formal risk assessment has not been performed on the GIS equipment population. GIS equipment is unique in nature as a single bay contains several other assets. Hence fleet modelling of risk (as undertaken for other plant assets) is of limited value.

The current condition of GIS equipment indicates replacements at RTS and WMTS, and refurbishment activities at SYTS are expected before 2020. The remaining risks presented by the GIS equipment fleet will be addressed by closely monitoring the performance of individual assets and through asset works.

5 Strategies

The strategies to address risks imposed by the GIS fleet on AusNet Services' transmission system include:

- Continue monitoring the performance of all GIS to determine the need for refurbishment or replacement;
- Complete refurbishment of SYTS GIS – including reducing SF_6 gas leakage;
- Audit SMTS GIS equipment and investigate if mid-life refurbishment is required; and
- Review long lead time spares holdings and contingency planning.