AMS 10-71 Static VAR Compensators

2023-27 Transmission Revenue Reset

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Disclaimer

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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 Terminal station Static VAR Compensators (SVC).

The strategy covers the 4 regulated Static VAR Compensators located in Terminal stations at HOTS, KGTS and ROTS.

Overall, the asset condition of SVC fleet is acceptable (C2 & C3 condition) except HOTS SVC which is in poor condition (C4). An SVC is comprised of number of integrated components where appropriate weighting factors are assigned to obtain the overall condition score. Overall C4 condition score of HOTS SVC is mainly due to poor condition (C4) of cooling system and primary equipment and very poor condition (C5) of [C-I-C] valves, SVC controller and the secondary system.

It is recommended to replace poor condition HOTS SVC during the TRR 2022 -2027 period.

Proactive management of terminal station SVCs condition-based maintenance and replacement practice is required to ensure that stakeholder expectations of cost, reliability, safety 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 SVC or components to the latest specification with modern controlled systems using [C-I-C]-controlled reactor (TCR) and [C-I-C] switched capacitor(TSC)

1.1.2 Inspection / maintenance / condition monitoring

- Continue maintaining SVCs in accordance with PGI 02-01-02.
- Introduce regular PD testing on the [C-I-C] and their controls at HOTS SVCs for the years leading to their upgrades
- Continue with annual thermo-vision scans of all SVCs (as part of station scan as per SMI 67-20-01.

1.1.3 Spares Holding

- Maintain strategic spares holding of key SVC components as per spare holding policies
- Review spares holding for KGTS and salvage key primary components removed from HOTS

1.1.4 Replacement

- Replace HOTS SVC during the period 2022-2027

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 SVC's installed in terminal stations in AusNet Services' Victorian regulated 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 the regulated asset base SVC's located in terminal stations.

The key components of the SVC's covered by this strategy are filter banks, TSC, TCR and their cooling system, step down power transformer and the associated other primary, secondary and control systems.

The associated instrument transformers and protection and control systems, are also covered under other strategies;

- AMS 10-67 Power Transformers
- AMS 10-64 Instrument Transformers;
- AMS 10-68 Secondary Systems

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

SVCs provide reactive support for the Victorian electricity transmission network and they are located at Kerang (KGTS), Horsham (HOTS) and Rowville (ROTS) terminal stations.

The SVC serves to regulate network voltages by using the TCR to consume VARs from the network under capacitive loading conditions. Conversely, under inductive loading conditions the SVC uses the TSC to add VARs to the network. The use of the SVC enables continuous voltage stability enabling the network to withstand unplanned outage events such as the loss of a line following lightning strike.

SVCs at HOTS and KGTS are required to provide reactive support to the 220kV loop in regional Victoria. Availability of the KGTS and HOTS SVCs is critical for supporting load in the outer grid, and in particular supply to Broken Hill in New South Wales (NSW). ROTS form a critical junction for 220 kV circuits from the Latrobe Valley. There are two SVCs situated at ROTS which primarily provide reactive support for the 220kV network in the Central and Latrobe Valley regions.

3.2 Asset Population

AusNet Services has a total of 4 SVC's in service installed in AusNet services in the electricity transmission network as reported in the 2019 RIN.

SVCs are fed by special purpose, 220 kV / 4.5 kV step down power transformers at KGTS and HOTS and two units of 220 kV / 10.5 kV step down transformers at ROTS. SVC components fit three main asset classifications including reactive plant, protection and control systems.

The main reactive plant components include capacitor canisters and dry type reactors which are situated in the open air within wire meshed fences. Air conditioning units provide cooling for protection systems in SVC control rooms. Pumped water cooling systems are used to regulate [C-I-C] valve temperature; these cooling systems include externally mounted heat exchangers and water deionisers. The [C-I-C] stacks and their cooling systems are situated within brick buildings and comprise the main components of the control system.

Protection for the capacitors and reactors is by individual overcurrent, overvoltage and differential relays, comprising up to 20 individual relays. Each [C-I-C] is monitored so that failure of one [C-I-C] is detected and the SVC turned off to prevent overvoltage failure on the remaining [C-I-C] in the series circuit. There are also protection circuits to detect failure of the water cooling systems for the [C-I-C].

SVCs situated at ROTS are sometimes referred to as Controlled Static Compensators (CSCs).

Table 1 provides the output ratings of the SVCs.

Table 1: SVC Ratings

Station	Volts (kV)	Output (MVar)	
HOTS	4.5	+25	-50
KGTS	4.5	+25	-50
ROTS No 1	10.5	+60	-100
ROTS No 2	10.5	+60	-100

Table 2 below provides the manufacturer details of the SVCs and their key components at the four locations.

Table 2: SVC Manufacturer details

Description of Plant	ROTS-SVC1	ROTS-SVC2	KGTS-SVC	HOTS-SVC
Manufacturer of Primary Plant	[C-I-C]	[C-I-C]	[C-I-C]	[C-I-C]
[C-I-C] and Controls	[C-I-C]	[C-I-C]	[C-I-C]	[C-I-C]
Cooling Systems	[C-I-C]	[C-I-C]	[C-I-C]	[C-I-C]

3.3 Asset Age Profile

The majority of SVC components have provided approximately 34 years of service. Table 3 displays the service age profile of the SVCs.

Table 3: SVC Service Age Profile

Station	[C-I-C] and Control Systems		Primary Plant	
	Service Age (Years)	Manufacturer	Service Age (Years)	Manufacturer
HOTS	34	[C-I-C]	34	[C-I-C]
KGTS	6	[C-I-C]	33	[C-I-C]
ROTS No 1	3	[C-I-C]	1	[C-I-C]
ROTS No 2	2	[C-I-C]	1	[C-I-C]

Most components of the SVCs have an economic life between 30 and 45 years depending on duty. However, key issues such as the obsolescence of control equipment, lack of specific spares and corrosion of the [C-I-C] / heat-sink interface may shorten the economic life of SVC components. Risk associated with control system failures causing network outages prompted the replacement of the SVC's controls and [C-I-C] at ROTS No.1 and ROTS No.2 in 2017 and 2019. Additional work relating to the replacement of 10.5kV plant (including all reactors, capacitor cans, current transformers (CTs) and voltage transformer (VTs), connections and busbar insulators for the SVC No.1 and No. 2 are in progress and expected to be completed in 2020.

3.4 Asset Condition

Table 4 provides the condition assessment criteria of Static VAR Compensators in terminal stations.

Table 4: Condition Assessment Criteria

Condition Scorecard			
Condition Score	**Condition Description**	**Summary of details of condition score**	**Remaining Service Potential**
C1	Very good	This SVC or the components are less than 10 years old and in good operating condition with no past history of defects or failures. Manufacturer support and spares are readily available. Routine maintenance and condition monitoring is recommended.	95%
C2	Good	SVC's and components in this category are in a better than average condition for their service age and technology type. They may not have developed actual faults but developing minor issues. They do not require intervention between scheduled maintenance nor do they show any trends of serious deterioration in condition or performance. Manufacturer support and spares are available. Routine maintenance and condition monitoring recommended where applicable.	70%
C3	Average	This category includes SVC's and or components which are with an average condition for their respective service age and technology type. Spares are available. Some may have minor defects like paint peeling off reactors and or minor corrosion. Ongoing maintenance and condition monitoring is recommended.	45%
C4	Poor	This category includes SVC's or components that have aged or developed faults quicker than anticipated. The technology is outdated, and components are not repairable. Spares are limited. More frequent maintenance and increased condition monitoring is recommended.	25%
C5	Very Poor	This category includes SVC's and or components which are typically at the end of their lifecycle and the technology may be outdated. These units are at increased risk of unexpected failure. Replacement strategies are recommended.	15%

SVC comprise of number of key integrated primary components such as: Cooling system, Batteries & inverter, [C-I-C], Capacitors, Busbars & Insulators, Reactors, Wall Bushings, current and voltage transformers and Filter system. Overall condition score is derived using a weighted factor method taking into consideration of asset condition of individual key items. Overall SVC asset condition is given in Table 5.

Table 5: Condition Assessment Criteria

Station	Overall Asset condition	Comments
HOTS	C4	Original equipment is in service. No other components replaced
KGTS	C3	Except new [C-I-C], control systems and cooling system, original primary equipment is in service.
ROTS No 1	C2	Except new control systems and [C-I-C], original equipment is in service. Current project to replace all primary equipment
ROTS No 2	C3	Except new control systems and [C-I-C] s, original equipment is in service. Current project to replace all primary equipment

3.5 Asset Criticality

The most common type of SVC failure is the [C-I-C] valve cooling system failure due to ageing and wear out of pumps and fans. This causes secondary failures to [C-I-C] valves due to thermal runaway. Filter Capacitor unbalance, poor primary connections due to corrosion are other causes for SVC failures. During critical component failures, SVC protection system operates, and the voltage support provided by a SVC would not be available.

SVC system criticality is determined by Network Planners, and often re-assessed as part of detailed system studies and normally evaluated during the overall network planning exercise and evaluated for HOTS SVC under: PSCR Report references (RIT-T): Voltage control in North West Victoria.

3.6 Asset Performance

AusNet Services routinely analyses the root cause of unplanned work undertaken on Static VAR Compensators 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 capacitor banks are subjected to routine maintenance in accordance with PGI 02-01-02 and relevant standard maintenance instructions (SMI).

Figure 6 provides the Number of ZA Notifications per SVC by key Object types, mainly All issues other than [C-I-C] (SVCCOMP) and [C-I-C] valves (VALVETHY) during the period 2015 – 2019. It is observed approximately 77% of the total ZA notifications had been raised on SVC issues other than [C-I-C] valves and it had increased in 2019, came from HOTS SVC (83%) and KGTS SVC (17%). Figure 7 provides the ZA notifications by station per SVC by Location.

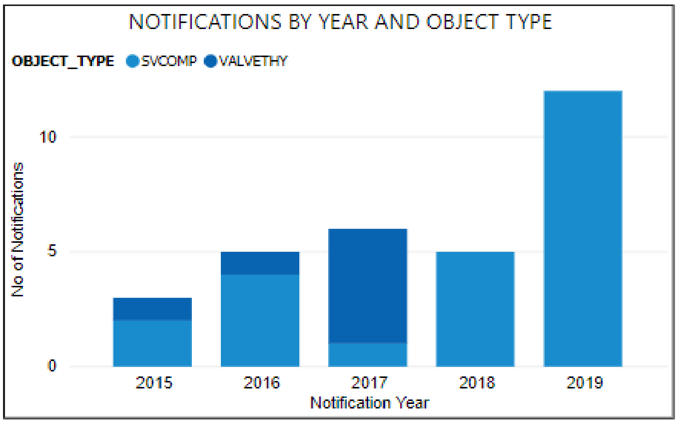

Figure 6 – Number of ZA Notifications per SVC by key Object Types 2015 – 2019

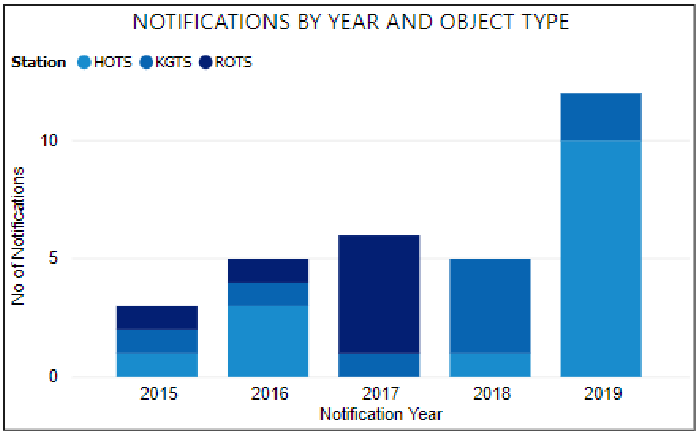

Figure 7 – Number of ZA Notifications per SVC by Station 2015 – 2019

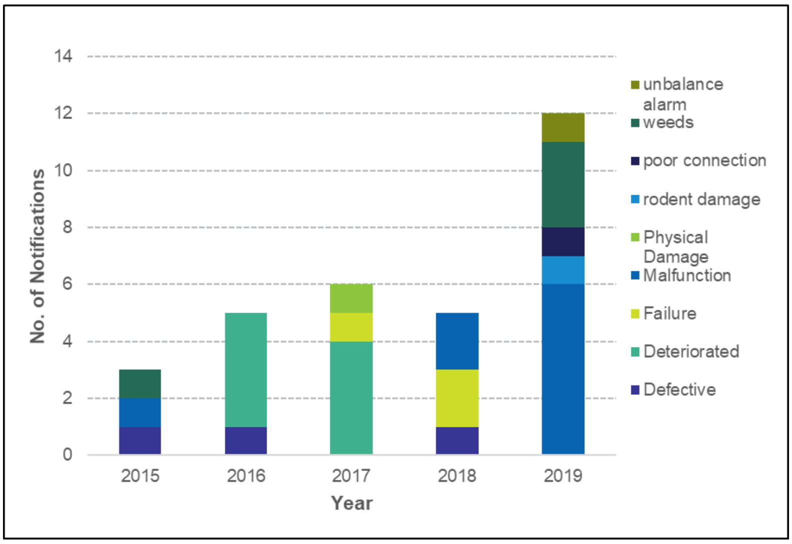

Figure 8 – Number of ZA Notifications per SVC by Defect 2015 – 2019

[C-I-C]

Figure 9 – Number of ZA Notifications per SVC by Object Part 2015 – 2019

Following observations have been made:

1. HOTS SVC is the worst performing SVC of the four SVCs in service now with all equipment are OEM installed which are now technically obsolete. Fans, motors, pump failures and oil indicator failures in cooling system were the key object parts that needed attention during the period 2015 -2019 due to wear out and ageing and note an increasing trend. There was one incident reported of a [C-I-C] failure. [C-I-C] failures could result in cooling system failures when the control system also is in a poor condition and result in cascaded failures.

2. KGTS SVC is the second worst performing SVC in service. [C-I-C] valves and control systems were upgraded in 2014 at KGTS but most of the primary equipment including cooling system in service are original equipment. Fans and pump failures in cooling system are the key object parts that needed frequent intervention due to wear out and ageing. There were no issues with [C-I-C] reported during the period 2015-2019.

3. ROTS SVC 1 & 2 needed least intervention during the period 2015 -2019. The key object part that needed intervention was [C-I-C] valves in ROTS SVC1 until [C-I-C] valves and controls were replaced in later 2017 and afterwards. Under this project, cooling systems and most primary equipment have been targeted for replacement. This work is expected to complete during the year 2020.

3.6.2 Major Failures

- In 2008, the SVC at KGTS tripped from [C-I-C] overvoltage protection and continued to do so each time an attempt was made to return the unit to service. The network constraints caused by the outage led to increases in the market price of electricity. Root cause of the failure was suspected due to the presence of Partial discharges (PD) in [C-I-C].
- In April 2016 – [C-I-C] valve failed catastrophically in ROTS SVC 2 causing damage to adjacent valves, trigger wiring.
- In 2018 a major SVC cooling system failure at KGTS, resulted in a 3-month outage and depleted our SVC spares holding. The incident highlighted the obsolescence/limited manufacturer support of the SVC, the difficulty in sourcing parts for repair, as well as highlighting other failure modes, not covered by spare holding.
- In 2019 – [C-I-C] valve failed at ROTS SVC 1.

4 Other Issues

4.1 Monitoring Capacitor Cans

Capacitor cans deteriorate with utilisation and voltage surges. This causes random out-of-balance alarms and, in some cases, tripping of the SVC. In either event, individual faulty cans are replaced and measurement of capacitance and some rebalancing between phases is required.

A number of cans have shown sign of bulging due to electrical stress and aging effects. In some cases, the cans fail catastrophically and then they rupture, bulge and or break the terminals. Cans are not repairable and have to be replaced in such cases.

Although these events are not frequent, corrective action is needed when SVCs trip on unbalance (normally due to the failure of packets within cans). Corrective work is sometimes needed due to flashovers caused by birds or small animals.

4.2 Technical obsolescence of Key Components

SVCs with older primary equipment such as 4.5 kV filter circuit breakers, bushing current transformers, series reactors are becoming technically obsolete. Replacements sometimes can have dimensional differences to OEM equipment some structure modifications when retrofitting to accommodate the newer types.

Some secondary and [C-I-C] control systems are technically obsolete with solid state cards which are more than 30 years old and no equivalents are available from other suppliers. Failure of these cards would potentially put the SVC out of service for a lengthy period. They have now been replaced at KGTS, and ROTS SVCs and HOTS SVC is the only SVC which has old [C-I-C] valves and control systems.

4.3 Series Reactors

Series reactors are typically dry type reactor with a multiple layer winding each embedded inn epoxy insulation. There is very limited testing or ability to truly condition assess a dry type reactor.

Although reactors failures had not been experienced so far, poor condition has been observed at ROTS No 1 & 2 SVCs and they are currently under replacement. Reactors at HOTS and KGTS are in very poor condition. Failure of a reactor can result in reportable fires and cause costly damage to adjacent SVC primary and secondary equipment and very long restoration time.

4.4 [C-I-C] Cooling Systems

There are two parts of SVC cooling system. Pumps, de-Mineralisers, filters and gravity feed and [C-I-C] PLCs form part of indoor cooling system. Two heat exchangers and fan groups form part of the outdoor installation. Our experience on cooling systems on other SVCs in service indicate that they do not last long as the life of other primary equipment and result in frequent breakdowns after midlife of fans, motors and other related items. [C-I-C] failures could result due to cooling system failures result in costly cascaded failures. HOTS and KGTS SVCs have the original cooling systems more than 30 years old while others have been replaced now.

4.5 Integrated matching items

SVC equipment comprised of integrated several other assets: key primary equipment such as step-down transformer, [C-I-C] valves & associated cooling systems, main and filter capacitor banks, secondary and control systems. One asset component failure can affect availability of the complete SVC due to its complex integral design. Some items such as [C-I-C] and controllers are uniquely matched to the SVC and with different design lives making it more complicated when replacing only specific components in poor condition.

5 Risk and Option Analysis

The drivers of this program are network performance, network stability and health and safety risk where network performance and stability are the key drivers.

Four SVC equipment are unique in nature and they are located in strategic locations of the Victorian transmission network. A formal economic risk assessment is undertaken and recorded as part of a detailed planning report as mentioned in section 3.5, PSCR (RIT-T) Report for Voltage control in North West Victoria.

ROTS No 1 & No 2 are now in good condition due to the planned current asset replacements.

The following work is proposed to be undertaken.

- Replace HOTS SVC during the period 2022-2027

For the remaining units, the most economic option is to continue to monitor, and hold adequate spares to attend to failures. Key primary components from the HOTS SVC which are still in good condition can be used as strategic spares.

6 Asset Strategies

6.1 New Assets

- Continue to purchase SVC or components to the latest specification with modern controlled systems using [C-I-C]-controlled reactor(TCR) and [C-I-C] switched capacitor(TSC).

6.2 Inspection / maintenance / condition monitoring

- Continue maintaining SVCs in accordance with PGI 02-01-02.
- Introduce regular PD testing on the [C-I-C] and their controls at HOTS SVCs for the years leading to their upgrades
- Continue with annual thermo-vision scans of all SVCs (as part of station scan as per SMI 67-20-01.

6.3 Spares Holding

- Maintain strategic spares holding of key SVC components as per spare holding policies
- Review spares holding for KGTS and salvage key primary components removed from HOTS

6.4 Replacement

- Replace HOTS SVC during the period 2022-2027