AMS – Victorian Electricity Transmission Network

Static VAR Compensators

(PUBLIC VERSION)

Document number	AMS 10-71
Issue number	9
Status	Approved
Approver	J. Dyer
Date of approval	02/09/2015

ISSUE/AMENDMENT STATUS

Issue Number	Date	Description	Author	Approved by
5	22/11/06	Editorial review.	G. Lukies D. Postlethwaite	G. Towns
7	17/03/07	Editorial review.	G. Lukies D. Postlethwaite	G. Towns
8	10/12/12	Editorial review.	C. Rabbitte	D. Postlethwaite
9	02/09/15	Editorial review.	T. Gowland C. Odendaal	J. Dyer

Disclaimer

This document belongs 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 the Asset Management division of AusNet Services. Please contact the indicated owner of the document with any inquiries.

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

Table of Contents

1 Executive Summary

AusNet Services has four Static VAR Compensators (SVCs) installed; two units at Rowville (ROTS) and single units at Horsham (HOTS) and Kerang (KGTS) terminal stations. SVCs are required for dynamic voltage control at critical locations on the transmission network.

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

The control systems (including thyristors) on two of the four SVCs date back to initial construction and consist of obsolete technology which is unsupported by the manufacturer [C.I.C]. Obsolescence of these control systems increases existing risks associated with failure as fault rectification works are slow and difficult resulting in extended unplanned outages.

Unplanned outages of SVCs constrain the network's energy transfer capability, increasing the cost of electricity which negatively impacts the energy market. Furthermore, failure of the SVC control system at KGTS in 2008 resulted in poor performance against the availability component of STPIS. Risk assessments reveal that replacement of the two remaining [C.I.C] control systems would be prudent.

AusNet Services' key asset management strategies for SVCs include:

- Continue with scheduled maintenance and existing inspection procedures.
- Introduce regular PD testing on the thyristors and their controls at KGTS and HOTS SVCs for the years leading to their upgrades.
- Replace the reactive plant controls of the KGTS SVC with new [C.I.C] controls and thyristors.
- Replace the reactive plant controls of the HOTS SVC with new [C.I.C] controls and thyristors.
- Hold adequate air core reactor spares for the deteriorated TCR reactors at ROTS 2 SVC.
- Replace the deteriorating 10.4 kV wall bushings at ROTS.

2 Introduction

2.1 Purpose

The purpose of this document is to define the asset management strategies for economic management of Static VAR Compensators in the Victorian electricity transmission network.

2.2 Scope

This asset management strategy applies to the four Static VAR Compensators (SVC) installed in the Victorian electricity transmission network.

SVCs provide reactive support for the Victorian electricity transmission network. SVCs are fed by special purpose step down power transformers at Kerang (KGTS), Horsham (HOTS) and Rowville (ROTS) terminal stations. Step down transformers at KGTS and HOTS are 220 kV / 4.5 kV and at ROTS are 220 kV / 10.5 kV. SVCs comprise individual Thyristor Switched Capacitors (TSC) and Thyristor Controlled Reactor (TCR) elements. The high voltage circuit thyristors are connected in series, with the combined rated thyristor voltage limit being greater than the circuit voltage.

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.

SVC components fit three main asset classifications including reactive plant, protection and control systems. The main reactive plant components include capacitor canisters and shunt reactors which are situated in the open air within wire meshed fences. The thyristor stacks and their cooling systems are situated within brick buildings and comprise the main components of the control system.

Protection[1] for the capacitors and reactors is by individual overcurrent, overvoltage and differential relays, comprising up to 20 individual relays. Each thyristor is monitored so that failure of one thyristor is detected and the SVC turned off to prevent overvoltage failure on the remaining thyristors in the series circuit. There are also protection circuits to detect failure of the water cooling systems for the thyristors. Protection systems for SVCs are discussed in more detail in a separate document[1].

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

[1] AMS 10-68 Secondary Systems.

3 Asset Summary

3.1 Population

Four SVCs are installed at critical locations in the transmission network; HOTS, KGTS, and two at ROTS. Table 1 provides the output ratings of the SVCs.

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 1 – SVC Ratings

SVCs at HOTS and KGTS are required to provide reactive support to the 220 kV 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 forms a critical junction for 220 kV circuits from the La Trobe Valley. There are two SVCs situated at ROTS which primarily provide reactive support for the 220 kV network in the Central and La Trobe Valley regions.

SVCs consist of reactive plant, protection and control systems. Air conditioning units provide cooling for protection systems in SVC control rooms. Pumped water cooling systems are used to regulate thyristor valve temperature; these cooling systems include externally mounted heat exchangers and water deionisers.

3.2 Service Age

The majority of SVC components have provided approximately 29 to 32 years of service. Table 2 displays the service age profile of the SVCs.

Station	Control Systems		Primary Plant	
	Service Age (Years)	Manufacturer	Service Age (Years)	Manufacturer
HOTS	29	[C.I.C]	29	[C.I.C]
KGTS	1	[C.I.C]	29	[C.I.C]
ROTS No 1	3	[C.I.C]	32	[C.I.C]
ROTS No 2	32	[C.I.C]	32	[C.I.C]

Table 2 – SVC Service Age Profile

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 thyristor / 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 thyristors at ROTS No.1 in 2012.

3.3 Condition

The condition of the four SVC has been assessed using a consistent condition methodology that uses the known condition details of each asset and grades that asset against the common asset condition criteria. The overall condition of the SVC is determined by weighting individual component condition assessments for each SVC.

Table 3 provides the assessment of the condition scoring for the SVC fleet. The condition of each SVC has been scored ranging from condition C1 (very good) to condition C5 (very poor) accordingly by applying the 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.	10%

Table 3 – SVC Condition Scorecard[2]

Overall, the SVC fleet is in average[3] (C3) condition with no expected full replacements but targeted component replacement will be required over the next five years. For further detailed information regarding the condition assessment framework, specific issues, conditional maintenance activities and discussions of failures, refer to AHR 10-71, Static VAR Compensators Asset Health Report.

[2] AHR 10-71 – Static VAR Compensators.

[3] Refer to AMS 10-68 Secondary Systems for Control System information.

3.4 Performance

This section describes the historic performance of the SVC fleet.

3.4.1 Suspended failures

Since 2000, the network's SVCs have experience an average of 8 suspended failures[4] annually. Suspended failures are minor in nature and have not impacted on the reliability of the electricity transmission network. The dominant failure modes are associated with the battery and inverter, cooling systems, capacitor rebalancing, and faulty thyristors as shown in Figure 1.

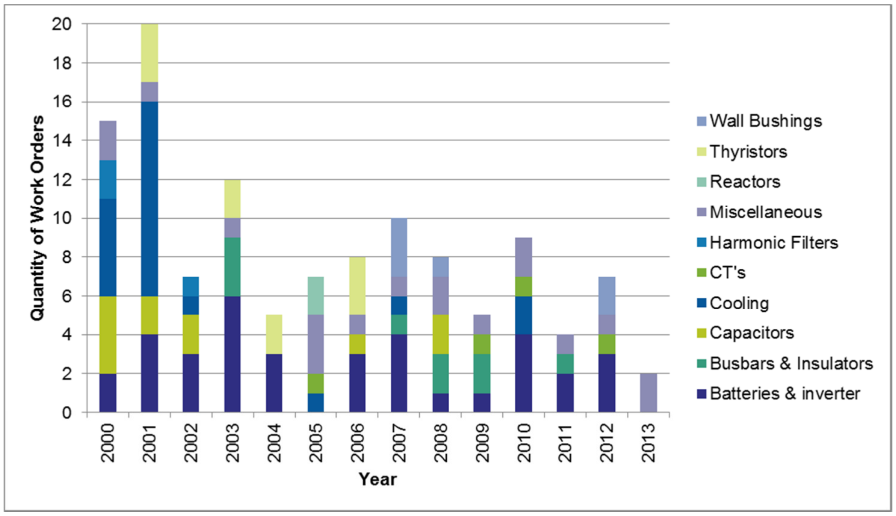

Figure 1 – SVC Suspended Failures (entire population)

3.4.2 Horsham SVC

Since 2000, there have been 34 suspended failures mainly associated to the battery and inverter system at HOTS as shown in Figure 2.

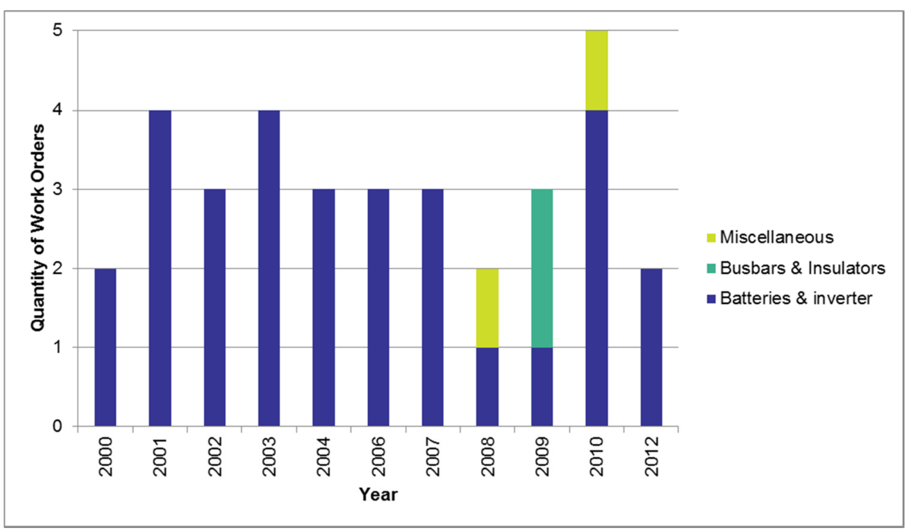

Figure 2 – HOTS SVC Suspended Failures

[4] Suspended failures include OMU (O&M Maintenance Unscheduled) and OME (O&M Maintenance Emergency) work orders.

3.4.3 Kerang SVC

Since 2000, there have been 52 suspended failures mainly associated to the cooling systems and capacitor rebalancing at KGTS as shown in Figure 3.

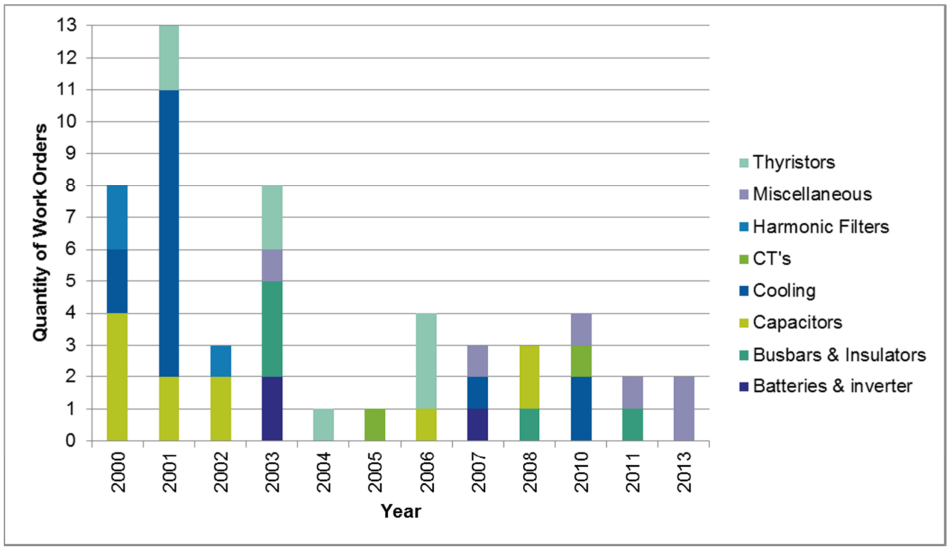

Figure 3 – KGTS SVC Suspended Failures

3.4.4 Rowville SVC No. 1

Since 2000, there have been 15 suspended failures mainly associated to the cooling systems and wall bushings at ROTS No.1 as shown in Figure 4.

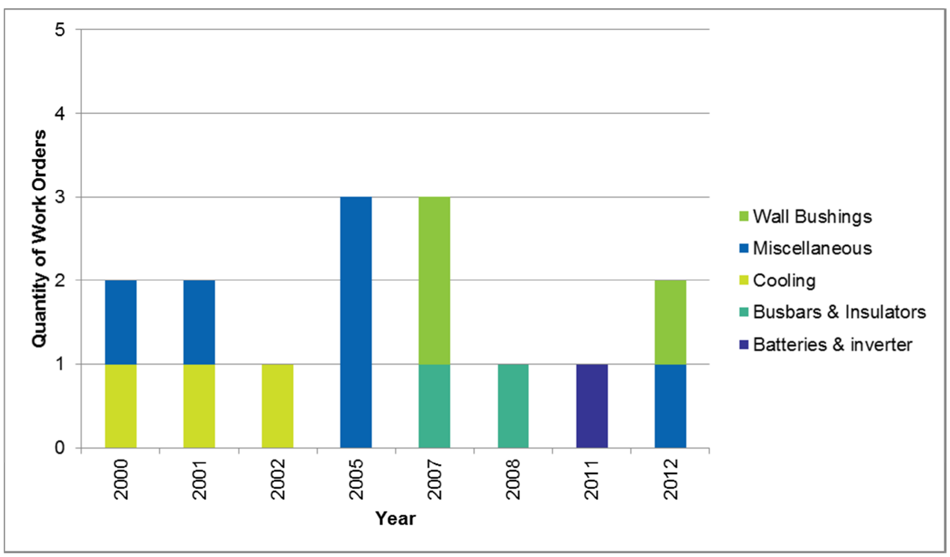

Figure 4 – ROTS No.1 SVC Suspended Failures

3.4.5 Rowville SVC No. 2

Since 2000, there have been 18 suspended failures mainly associated to the cooling systems and wall bushings at ROTS No.2 as shown in Figure 5.

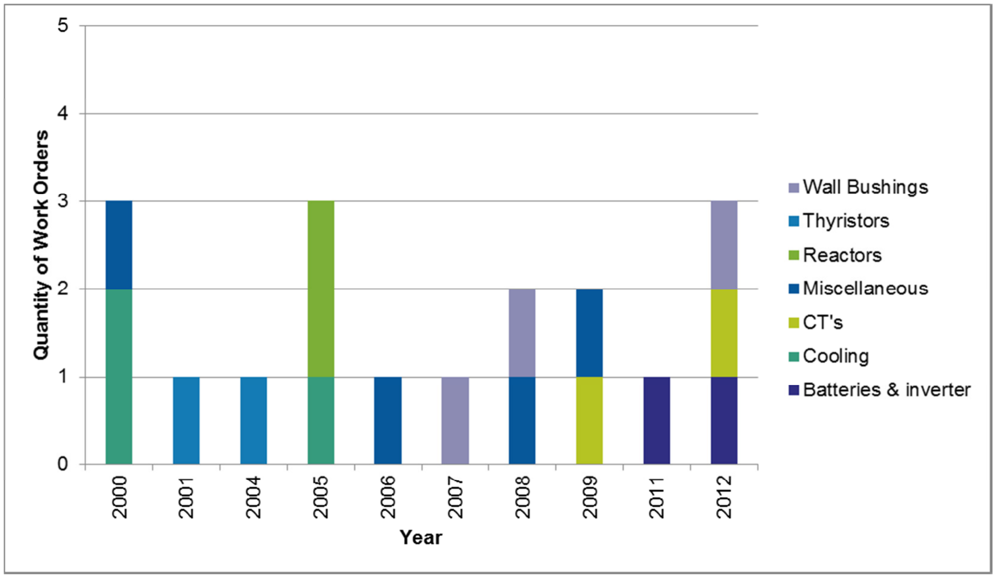

Figure 5 – ROTS No.2 SVC Suspended Failures

3.4.6 Functional failures

In 2008, the SVC at KGTS tripped from thyristor 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. Network constraints caused by the outage resulted in poor performance against the availability component of STPIS.

The root cause of the overvoltage was initially suggested to be Partial Discharge (PD). This suggestion was made by the manufacturer who reported similar issues with numerous SVCs of similar design. The manufacturer found that other instances of overvoltage protection trips were caused by the degradation of cables ties securing parts of the thyristor stack. Cable ties on the KGTS thyristor were also found to be in poor condition.

Radio Frequency (RF) scans of the SVC at KGTS were performed in 2008. These tests revealed the presence of PD on the surge arresters positioned on the input to the TCR thyristor. However the tests did not identify any PD from the thyristor units suspected to be the root cause of the failure in 2008.

Rectification of PD on the surge arresters provided a partial solution increasing the overvoltage trip time from minutes to hours. As RF testing confirmed the absence of substantial levels of PD on the thyristor, the SVC was returned to service by suppressing the over-voltage protection circuit.

In order to avoid another major failure similar to the incident at KGTS in 2008 regular tests of SVC controls are required to ensure that PD issues do not develop. The SVC’s controls at KGTS were scheduled for replacement in 2013.

Units in ROTS No.2 and HOTS, however, are not scheduled for replacement until 2018 and 2019 respectively and current business processes are to be continued.

4 Risk Assessment

Risks associated with SVCs can be assessed in terms of health and safety and performance.

4.1 Health and Safety Risk

PD issues in thyristor stacks present a risk of fire ignition[5]. The health and safety risk, associated with a fire starting in an SVC's thyristor stack, corresponds with a risk rating of III on the AusNet Services risk matrix, shown in Figure 6. This risk rating indicates that an injury requiring medical attention could be sustained as a result of fire caused by thyristor failure. The risk assessment reveals that such an incident could occur but is not anticipated, the probability of this incident taking place marginally exceeds one per cent.

Resolution of PD problems requires extensive refurbishment works which have been deferred in anticipation of scheduled replacements of SVC control systems. In the meantime adequate controls have been out in place to mitigate the risks.

VESDA (Very Early Smoke Detection Alarm) fire detection systems are installed in all terminal station buildings that house critical protection, control and communications equipment. These are single zone very sensitive systems which are alarmed to the network control centre and in most cases the local MFB (Metropolitan Fire and Emergency Services Board) or CFA (Country Fire Authority). Furthermore, all buildings also have portable fire extinguishers suitable for electrical fires.[6]

4.2 Performance Risk

Due to a lack of expertise and limited spares, a major failure of one of the three remaining obsolete SVC controls would most likely cause a lengthy outage of the SVC, reducing the overall availability of the transmission network. The Australian Energy Regulator (AER) imposes financial penalties on Transmission Network Service Providers (TNSP's) when equipment outages cause constraints on the network. Penalties are incurred via the Service Target Performance Incentive Scheme (STPIS) and increase when other assets from the same availability outage group, as defined by the scheme, are out of service simultaneously.

SVCs are in the same availability outage group as synchronous condenser. Therefore if an unplanned SVC outage occurs at the same time as a planned synchronous condenser outage, AusNet Services would incur costly[7] STPIS penalties.

The performance risk, associated with a major failure of one of the three remaining obsolete SVC controls, corresponds with a risk rating of III on the AusNet Services risk matrix, shown in Figure 6, below. This risk rating indicates that a negative financial impact in the order of [C.I.C] could be realised as a result of an SVC outage. The risk assessment reveals that such an incident could occur but is not anticipated, the probability of this incident taking place lies between one per cent and 20 per cent.

[5] This PD problem is believed to be the cause of a fire that totally destroyed a similar SVC at Nebo, Queensland.

[6] AMS 10-61 Fire Detection and Suppression, 3.1.1 Buildings.

[7] Failure of SVC at KGTS in 2008 resulted in financial penalty [C.I.C].

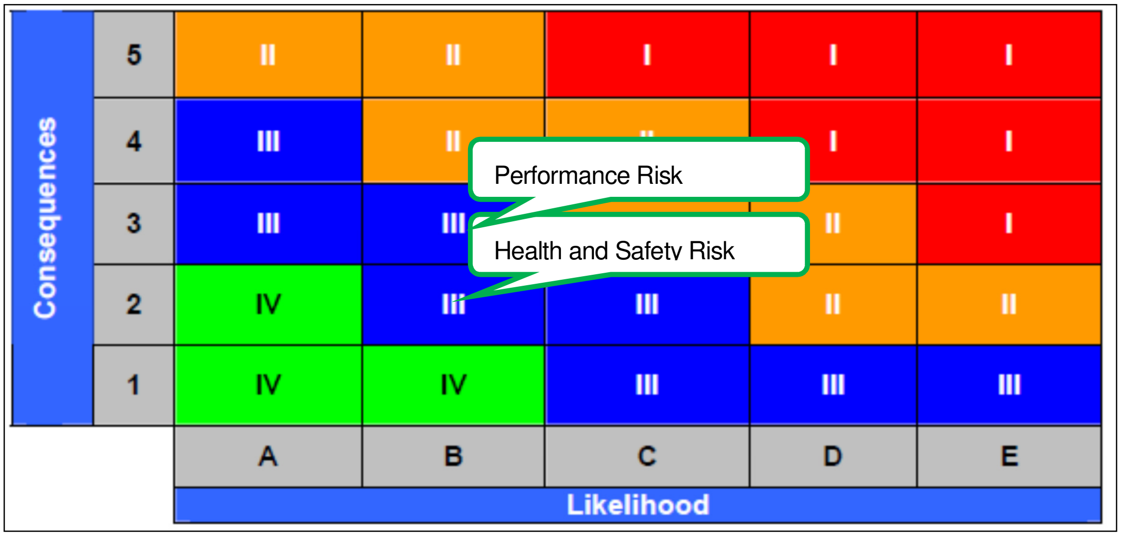

Figure 6 – AusNet Services' Risk Matrix

5 Key Issues

The key issues associated with SVCs include:

- The control systems on two of the four SVCs consist of obsolete technology with high operating costs due to scarcity of qualified service personnel, minimal or no manufacturer support or spares, limited compatibility with modern assets and limited functionality.
- An unplanned SVC outage, occurring at the same time as a planned synchronous condenser outage, can result in a significant constraint on the Victorian electricity transmission network and costly financial penalties to AusNet Services from incentive schemes.
- PD from insulating systems in a thyristor stack presents a risk of fire which may damage the SVC or present safety hazards to workers.
- Replacement of failed a thyristor is complicated by the mounting structure and leads to multiple replacements for a single failure.
- The exterior coating of some TSC reactors have deteriorated to the extent that replacement will be required.
- The wall bushings at ROTS are showing signs of deterioration.

6 Strategies

Key strategies for the continuing management of SVCs are to:

- Continue with scheduled maintenance and existing inspection procedures.
- Introduce regular PD testing on the thyristors and their controls at KGTS and HOTS SVCs for the years leading to their upgrades.
- Replace the reactive plant controls of the KGTS SVC with new [C.I.C] controls and thyristors.
- Replace the reactive plant controls of the HOTS SVC with new [C.I.C] controls and thyristors.
- Hold adequate air core reactor spares for the deteriorated TCR reactors at ROTS 2 SVC.
- Replace the deteriorating 10.4 kV wall bushings at ROTS.