AusNet Transmission Group Pty Ltd

Transmission Revenue Review 2017-2022

Support Document: Planning Report Springvale Terminal Station (Public)

Submitted: 30 October 2015

AMS – Electricity Transmission Network

Planning Report Project XB61
Springvale Terminal Station Redevelopment

CONFIDENTIAL

Document number	AMS 10-301
Issue number	3
Status	Final
Approver	J Bridge
Date of approval	17/08/2015

ISSUE/AMENDMENT STATUS

Issue Number	Date	Description	Author	Approved by
1	28/11/2012	Initial Draft	A Thomaidis	D Postlethwaite
2	31/01/2013	Final. Added Figure 5	A Thomaidis	D Postlethwaite
3	17/08/2015	Revised planning report based on latest demand forecast, VCR rate and asset condition information	H De Beer	J Bridge

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 the Asset Management Division of AusNet Services. Please contact the indicated owner of the document with any inquiries.

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

Table of Contents

1 Executive Summary

1.1 Responsibility

AusNet Transmission Group (AusNet Services) as a Transmission Network Service Provider (TNSP) in the state of Victoria has the ownership, operation and maintenance responsibility for Springvale Terminal Station (SVTS). TNSP obligations include maintaining a safe working environment for staff and contractors, maintaining the quality, reliability and security of customer supplies, and preventing operating and maintenance costs from escalating to inefficient levels.

1.2 Emerging Constraints

SVTS was developed in the 1960's. The majority of the electricity assets at SVTS are 48 years old and condition assessments indicate that several assets are approaching the end of their technical lives. The emerging service constraints are:

- Health and safety risks presented by a possible explosive failure of instrument transformers, 220 kV circuit breaker bushings, 66 kV bulk oil circuit breakers or transformer bushings;
- Security of supply risks presented by a failure of the 220/66 kV transformers, 220 kV circuit breakers or 66 kV circuit breakers;
- Operational and security of supply risks from the existing 220 kV switching arrangement;
- Collateral plant damage risks presented by an explosive failure of a transformer bushing, instrument transformer or bulk oil circuit breaker bushing;
- Environmental risks associated with insulating oil spill or fire.

1.3 Economic Option

This planning study considers credible options to address the service constraints and to meet the long term planning requirements for SVTS outlined in the Victorian Annual Planning Report. The options that have been assessed are:

- Business as usual to define the baseline risk;
- Non network option of embedded generation and/or demand side response;
- Run to failure and replace assets upon failure;
- Integrated redevelopment with Air Insulated Switchgear (AIS);
- Staged redevelopment;
- Redevelopment with Gas Insulated Switchgear (GIS)

The most economic option to address the emerging constraints at SVTS is an integrated redevelopment with AIS that replaces all deteriorating assets and addresses all emerging risks. This option has the lowest present value cost ($73.3M) and is consistent with the future development plans for SVTS. The economic timing for project completion is 2019/20 with an estimated total capital cost of $77.2 M ($68.6 M direct $2015).

2 Purpose

This planning report outlines asset condition, asset failure risks and network development plans relevant to SVTS for the planning period from 2015/16 to 2024/25. It provides an analysis of viable options to address the identified risks and maintain the efficient delivery of electrical energy from SVTS consistent with the National Electricity Rules (NER) and stakeholder's requirements. It also summarizes the scope, delivery schedule and expenditures associated with the most economical solution to emerging constraints.

3 Regulatory Obligations and Customer Requirements

This planning report acknowledges AusNet Services' obligations as a TNSP under the National Electricity Rules with particular emphasis on:

Clause 6A.6.7 of the National Electricity Rules requires AusNet Services to propose capital expenditures necessary to:

(1) meet or manage the expected demand for prescribed transmission services over that period;

(2) comply with all applicable regulatory obligations or requirements associated with the provision of prescribed transmission services;

(3) to the extent that there is no applicable regulatory obligation or requirement in relation to:

(i) the quality, reliability or security of supply of prescribed transmission services; or

(ii) the reliability or security of the transmission system through the supply of prescribed transmission services,

to the relevant extent:

(iii) maintain the quality, reliability and security of supply of prescribed transmission services; and

(iv) maintain the reliability and security of the transmission system through the supply of prescribed transmission services; and

(4) maintain the safety of the transmission system through the supply of prescribed transmission services.

The Electricity Safety Act (section 98(a)) requires AusNet Services to "design, construct, operate, maintain and decommission its supply network to minimise the hazards and risks, so far as is practicable, to the safety of any person arising from the supply network; having regard to the:

a) severity of the hazard or risk in question; and

b) state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and

c) availability and suitability of ways to remove or mitigate the hazard or risk; and

d) cost of removing or mitigating the hazard or risk".

4 Background

SVTS is located approximately 27 km south-east of Melbourne's CBD (Melway map reference 79 J3) and supplies the eastern Melbourne zone substations of Clarinda, East Burwood, Glen Waverley, Notting Hill, Noble Park, Oakleigh East, Riversdale, and three zone substations in Springvale via 66 kV feeders.

SVTS is supplied via two incoming 220 kV lines from Rowville Terminal Station (ROTS) and radially feeds Heatherton Terminal Station (HTS) via two outgoing 220 kV lines as shown in Figure 1, below. Both sets of 220 kV lines are arranged on double-circuit towers.

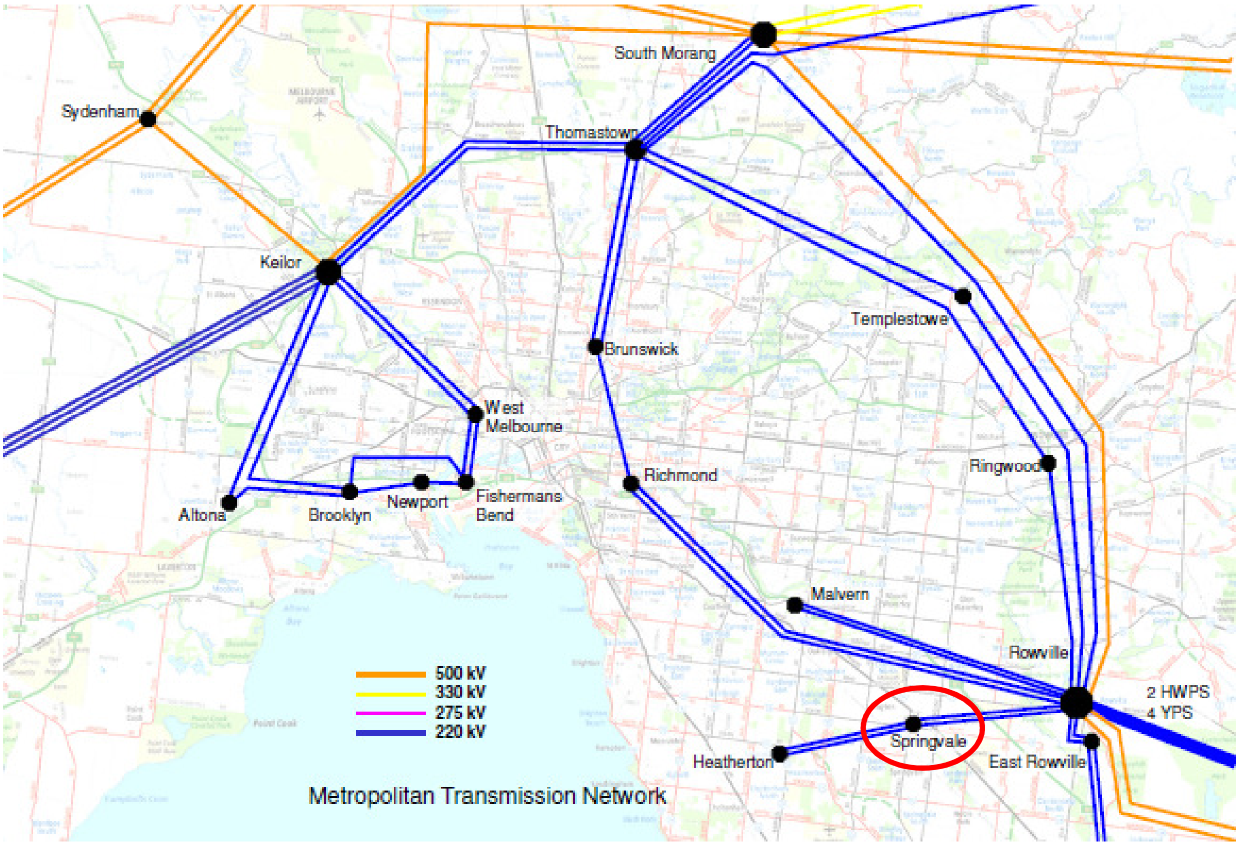

Figure 1 – Metropolitan Melbourne Transmission Network

The 220 kV switchyard consists of two incoming lines from ROTS, four busbars, four minimum oil circuit breakers (two bus-ties and two line circuit breakers) and one SF6 bus-tie circuit breaker in an open-ring bus arrangement. Transformation at SVTS comprises of four 150 MVA 220/66 kV transformers that provide transmission connection services to two distribution network service providers, United Energy and CitiPower.

The 66 kV switchyard includes ten feeders, six buses, five bus-ties and three 50 MVAr capacitor banks. Seventeen of the twenty two 66 kV circuit breakers are bulk oil circuit breakers manufactured prior to 1973. Figure 2, below shows the present configuration at SVTS.

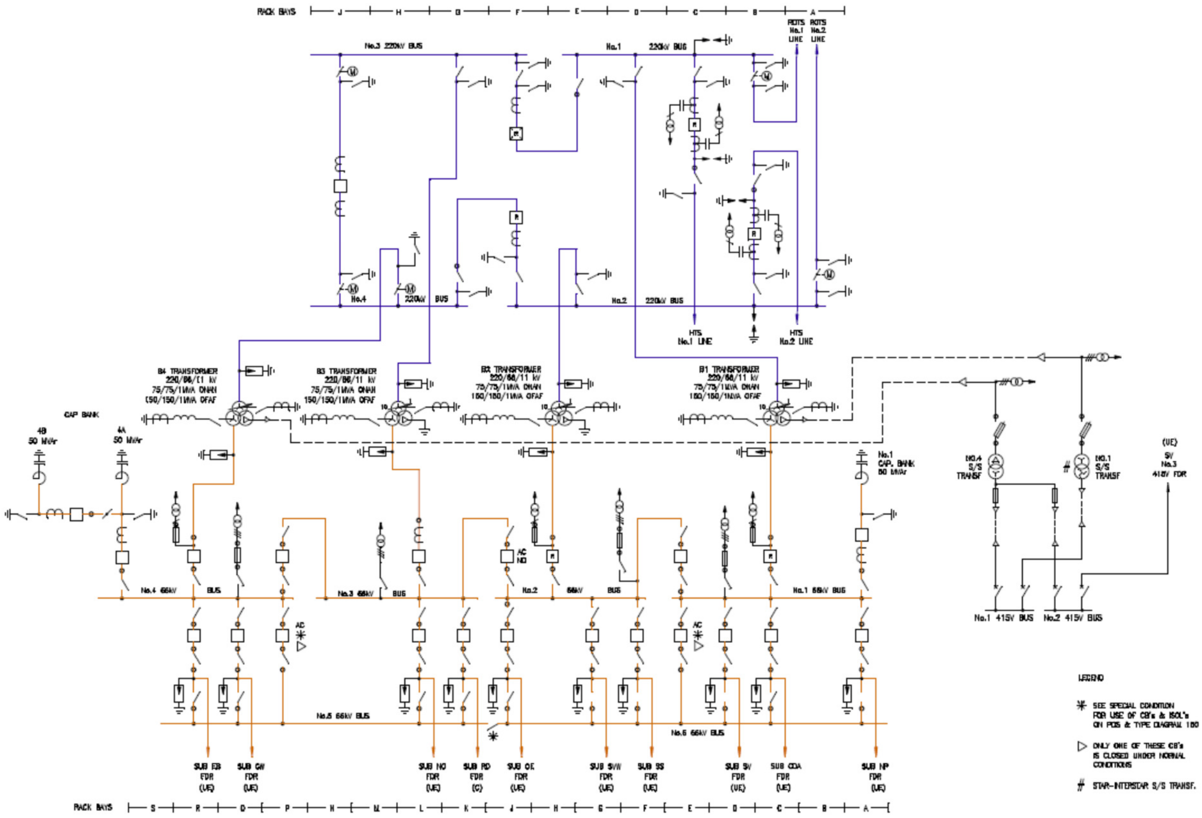

Figure 2 – Single Line Diagram of SVTS

Many of the primary and secondary assets installed at the time that SVTS was established have deteriorated and are reaching the end of their technical lives. The risks associated with plant failure are increasing and these assets are becoming more difficult and expensive to maintain due to a lack of manufacturer support and a scarcity of spare parts.

5 Planning Considerations

5.1 Planning Responsibilities

The augmentation responsibility for SVTS lays with the Australian Energy Market Operator (AEMO) for the shared transmission network and with the distributors, United Energy and CitiPower, for the transmission connection assets.

5.2 Demand

SVTS 66 kV is a summer peaking station with an all-time peak demand of 490.7 MVA recorded in the summer of 2009. Figure 3 below shows the forecast demand for Summer POE10 and POE50, and Winter POE50 conditions. Demand is forecast to grow at an average annual rate of 2.3% and 2.1% for the POE10 and POE forecasts respectively.

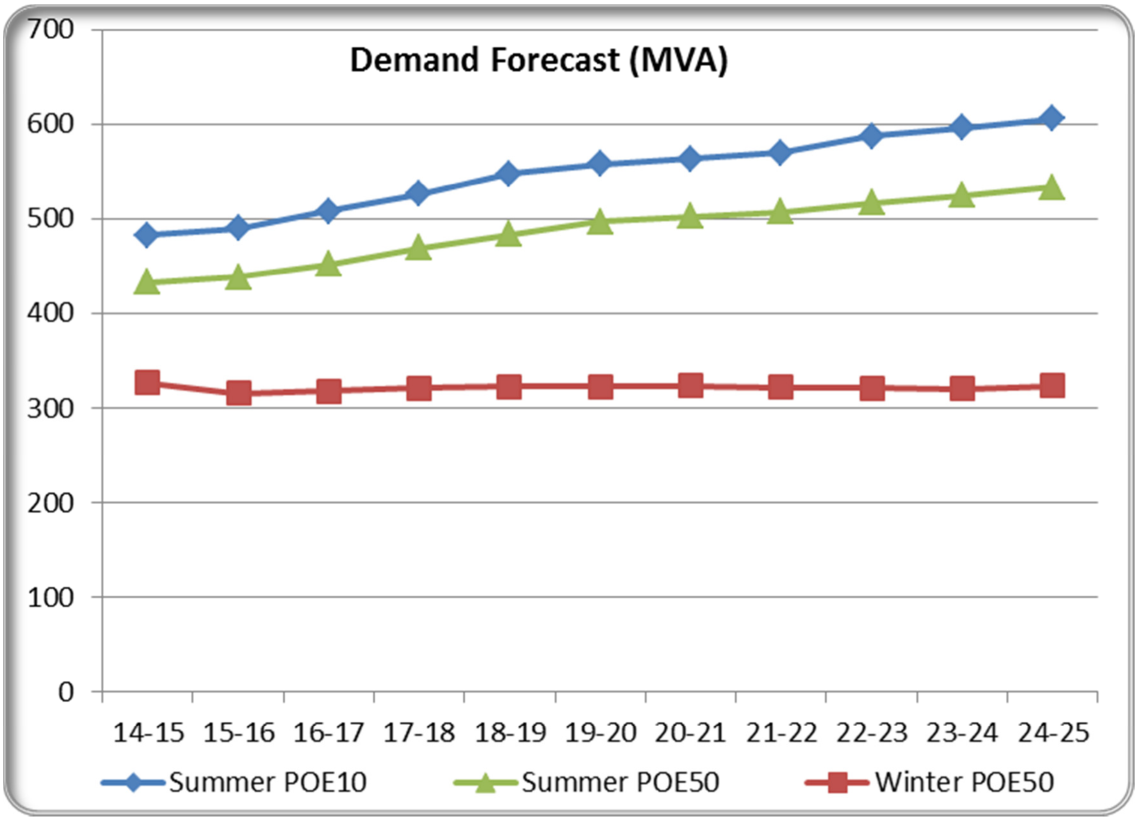

Figure 3 –Demand Forecast for SVTS

5.3 Future Planning Requirements

AEMO's 2014 Victorian Annual Planning Report (VAPR) describes the following shared network constraints for SVTS and HTS:

- Under peak demand conditions in summer and following an outage of one of the Rowville–Springvale 220 kV lines, the remaining Rowville–Springvale 220 kV line is forecast to be loaded over its short-term (15-minute and 5-minute) rating from 2014–15. The loads at Springvale and Heatherton may be curtailed pre-contingent to ensure the post-contingent loading remains within the thermal capability of the Rowville–Springvale 220 kV line.
- Similarly, following the loss of one of the Springvale-Heatherton 220 kV lines, the remaining Springvale–Heatherton 220 kV line is forecast to be loaded over its short-term (15-minute) rating from 2014–15.
- In addition, an outage of either of these double-circuit lines will result in total loss of supply to the relevant terminal station or terminal stations. A Rowville–Springvale line tower failure can result in a loss of over 900 MW of load for an extended period of time. However, a portion of load may be supplied from nearby terminal stations via emergency distribution network rearrangements taking anywhere from minutes to hours to implement.

Demand growth in the Springvale and Heatherton areas will lead to increased loading of both the Rowville–Springvale and Springvale–Heatherton 220 kV lines. AEMO is considering a number of options to enhance the security of supply to SVTS and HTS, including options to improve the switching configurations at these two terminal stations with the following switching limitations being identified in the 2014 VAPR[1]:

- A loss of one of the Rowville–Springvale 220 kV lines leads to the loss of the Rowville–Springvale–Heatherton 220 kV line and one 220/66 kV transformer at SVTS.
- A loss of one of the Springvale–Heatherton 220 kV lines will lead to the loss of one 220/66 kV transformer at HTS.

Any significant asset replacements at SVTS must consider the longer term shared network and connection network development plans of other parties to ensure individual decisions will not compromise security of supply or impede economic future capacity augmentation. AusNet Services' redevelopment project accommodates AEMO's and the distributors' future plans for SVTS, which include the following:

- Five 150 MVA 220/66 kV transformers;
- Fourteen 66 kV feeders;
- Four 50 MVAr 66 kV shunt capacitor banks;
- Possible reconductoring of both ROTS-SVTS circuits and both SVTS-HTS circuits and/or third ROTS-SVTS 220 kV line;
- One 200 MVAr 220 kV capacitor bank.

1 AEMO Victorian Annual Planning Report (VAPR) 2014.

6 Asset Condition

AMS 10-13 Condition Monitoring describes AusNet Services' strategy and approach to monitoring the condition of assets as summarised in this section. Asset condition is measured with reference to an asset health index, on a scale of C1 to C5. The C1 to C5 condition range is consistent across asset types and relates to the remaining service potential. The table below provides a simple explanation of the asset condition scores.

Condition Score	Likert Scale	Condition Description	Recommended Action	Remaining Service Potential%
C1	Very Good	Initial Service Condition	No additional specific actions required, continue routine maintenance and condition monitoring	95
C2	Good	Better than normal for age or refurbished		70
C3	Average	Normal condition for age		45
C4	Poor	Advanced Deterioration	Remedial action/replacement within 2-10 years	25
C5	Very Poor	Extreme deterioration approaching end of life	Remedial action/replacement within 1-5 years	15

Table 1 – Condition Score and Remaining Service Potential

Asset condition is the main driver for this project. The condition of the key assets at SVTS is discussed in the Asset Health Reports for the key asset classes such as power transformers, instrument transformers and switchgear with information on asset condition rankings, recommended risk mitigation options and replacement timeframes.

6.1 220/66 kV Power Transformers

AMS 10-141[2] identifies a number of [C-I-C] 150 MVA 220/66 kV transformers at various terminal stations that display a high level of internal deterioration, which is predominantly due to:

- High average loading and operating temperatures during periods of high ambient temperatures;
- Ineffective operation of the insulating oil circulation and air cooling systems.

Deterioration of the winding primary insulation system is well advanced in these transformers and refurbishment of core and coils is no longer a cost effective option. Asset Health Index scores of C4 have been assigned to the core and coils of all three [C-I-C] 220/66 kV transformers at SVTS, as a result of their poor condition. They are of similar specification to those discussed in AMS 10-141 and exhibit the same deterioration characteristics. AusNet Services has outlined the objective to maintain a sustainable risk position for the next decade with respect to power transformers in AMS 10-67[3].

Table 2 shows the condition scores for each component of the four 220/66 kV transformers at SVTS. The overall condition of the three [C-I-C] transformers is assessed at C4 with a failure rate of 3.6%, whilst the [C-I-C] transformer is assessed at C2 with a failure rate of 0.04%.

2 AMS 10-141 Asset Health Review for Power Transformers in Terminal Stations .

3 AMS 10-67 Power Transformers & Oil-filled Reactors.

DESCRIPTION	MANUFACTURER	INSTALL YEAR	Asset Condition	Core & Windings	Bushings	Oil	Tap Changer	Tank /Aux
B1 220/66KV	[C-I-C]	1967	C4	C4	C4	C4	C4	C4
B2 220/66KV	[C-I-C]	1967	C4	C4	C4	C4	C4	C4
B3 220/66KV	[C-I-C]	1969	C4	C4	C3	C3	C4	C3
B4 220/66KV	[C-I-C]	2003	C2	C2	C1	C1	C1	C1

Table 2 – Transformer Condition Score

A major transformer failure as result of a winding failure, major tap changer failure or bushing failure resulting in an extended transformer outage of months for major repairs or replacement is estimated to have a probability of between 3.6% to 5.5% over the planning period until 2022.

6.2 220 kV Circuit Breakers

There are four [C-I-C] minimum oil circuit breakers in the 220 kV switchyard, which are approaching the end of their technical life. The circuit breaker strategy AMS 10-144[4] identifies this type of circuit breaker amongst the oldest in AusNet Services' 220 kV circuit breaker fleet. [C-I-C] circuit breakers are of a minimum-oil type interrupter design with a spring type mechanism. This type of circuit breakers have generally provided reliable service, however deterioration is now measurable and they are becoming less reliable as they exhibit a range of service age and duty related defects. Consequently their replacement is considered when scoping economic station redevelopment projects. Recent failures of these type of circuit breakers are shown in Table 3 below.

Incident Date	Station	kV	CB Manuf.	CB Designation	Technology	Duty	Age (years) at time of failure	Nature of Failure	Remedial Action	Incident Year
24/01/2000	HTS	220	Sprecher & Schuh	HPF514P/6A	Minimum Oil	Transf./Line/ Bus Tie	34	Partial close operation. Drive insulators fractured.	Replaced broken drive insulators. Class 2 overhaul on interrupters	2000
19/04/2002	KTS	220	Sprecher & Schuh	HPF514P/6A	Minimum Oil	Transf./Line/ Bus Tie	40	Partial close operation. Drive insulators fractured.	Replaced broken drive insulators. Class 2 overhaul on interrupters	2002
22/03/2010	BLTS	220	Sprecher & Schuh	HPF514Q/4D	Minimum Oil	Transf./Line/ Bus Tie	35	Partial close operation, external linkages seized causing drive insulators fracture.	Replace broken drive insulators. Improved maintenance regime.	2010
14/12/2010	SVTS	220	Sprecher & Schuh	HPF514P/6A	Minimum Oil	Transf./Line/ Bus Tie	44	Partial close operation. Drive insulators flange mortar crumbled.	Replaced broken drive insulators.	2010
31/08/2011	BLTS	220	Sprecher & Schuh	HPF514Q/4D	Minimum Oil	Transf./Line/ Bus Tie	36	Failure to close on one phase as mechanism seized through internal corrosion.	Replaced broken drive insulators. Class 2 overhaul on interrupters	2011

Table 3 – 220 kV Circuit Breaker Failures

Table 4 shows the condition scores of the 220 kV circuit breakers at SVTS.

CIRCUIT	INSTALL YEAR	MANUFACTURER	ASSET CONDITION
HTS NO.2 220KV LINE CB AT SVTS	1967	[C-I-C]	C5
HTS NO.1 220KV LINE CB AT SVTS	1967	[C-I-C]	C5
1-3 220KV BUS TIE CB AT SVTS	1969	[C-I-C]	C5
2-4 220KV BUS TIE CB AT SVTS	1969	[C-I-C]	C5
3-4 220KV BUS TIE CB AT SVTS	2006	[C-I-C]	C1

Table 4 – 220 kV Circuit Breaker Condition Score

4 AMS 10-144 Asset Health Review for Transmission Circuit Breaker.

6.3 220 kV Current Transformers

There are twelve [C-I-C] and three [C-I-C] 220 kV post-type current transformers installed at SVTS. As described in AMS 10-64[5], [C-I-C] current transformers of various operating voltages are demonstrating thermal and partial discharge issues in conjunction with declining dissolved gas analysis (DGA) results. They present a risk to network reliability, as well as a safety risk to personnel as some failure modes include explosion and fire.

[C-I-C] current transformers (all voltage levels) have been monitored closely in recent times due to the explosive failure nature and safety risk they present. At least two [C-I-C] current transformers have failed explosively in the Victorian transmission network over the last ten years[6]. In an effort to prevent further failures more than 200 units have been replaced in the last five years as a result of increasingly frequent monitoring, which revealed accelerated deterioration and imminent failure.

The [C-I-C] and [C-I-C] current transformers have a high and increasing cost of ownership due to regular oil sampling and analysis and the partial discharge condition monitoring necessary to manage the risk of an explosive failure.

CIRCUIT	INSTALL YEAR	MANUFACTURER	ASSET CONDITION
2-4 220KV BUS TIE CB NO.2 BUS CT R/PH	1967	[C-I-C]	**C5**
2-4 220KV BUS TIE CB NO.2 BUS CT W/PH	1967	[C-I-C]	**C5**
2-4 220KV BUS TIE CB NO.2 BUS CT B/PH	1982	[C-I-C]	**C5**
HTS NO.1 220KV LINE CB BUS CT R/PH	1983	[C-I-C]	**C2**
HTS NO.1 220KV LINE CB LINE CT R/PH	1967	[C-I-C]	**C2**
HTS NO.2 220KV LINE CB BUS CT R/PH	1967	[C-I-C]	**C2**
HTS NO.2 220KV LINE CB LINE CT R/PH	1967	[C-I-C]	**C2**
HTS NO.1 220KV LINE CB BUS CT W/PH	1990	[C-I-C]	**C2**
HTS NO.1 220KV LINE CB BUS CT B/PH	1967	[C-I-C]	**C2**
HTS NO.1 220KV LINE CB LINE CT W/PH	1967	[C-I-C]	**C2**
HTS NO.1 220KV LINE CB LINE CT B/PH	1967	[C-I-C]	**C2**
HTS NO.2 220KV LINE CB BUS CT W/PH	1967	[C-I-C]	**C2**
HTS NO.2 220KV LINE CB BUS CT B/PH	1967	[C-I-C]	**C2**
HTS NO.2 220KV LINE CB LINE CT W/PH	1967	[C-I-C]	**C2**
HTS NO.2 220KV LINE CB LINE CT B/PH	1967	[C-I-C]	**C2**
1-3 220KV BUS TIE CB NO.3 BUS CT R/PH	2009	[C-I-C]	**C1**
1-3 220KV BUS TIE CB NO.3 BUS CT W/PH	2008	[C-I-C]	**C1**
1-3 220KV BUS TIE CB NO.3 BUS CT B/PH	2008	[C-I-C]	**C1**

Table 5 – 220 kV Current Transformer Condition Score

6.4 66 kV Circuit Breakers

Seventeen of the twenty-two 66 kV circuit breakers at SVTS are of bulk-oil technology. These bulk-oil circuit breakers are amongst the oldest circuit breakers installed in the network, ranging in service age from 48 to 42

5 AMS 10-64 Instrument Transformers.

6 In 2002 and 2005 at Moorabool Terminal Station (MLTS).

years old. Asset Management Strategy AMS 10-106[7] provides a summary of the key issues of these type of bulk oil circuit breakers, which includes the following:

- Age/duty related deterioration including the erosion of arc control devices, bushing oil leakages, and wear of operating mechanisms and drive systems;
- Limited fault level capability requiring restrictive switching configurations;
- Maintenance intensive;
- Manufacturer no-longer provides technical support or spares;
- Insufficient oil bunding.

CIRCUIT	INSTALL YEAR	MANUFACTURER	ASSET CONDITION
NO.1 66KV CAPACITOR BANK CB AT SVTS	1979	[C-I-C]	C5
EB 66KV FDR CB AT SVTS	1973	[C-I-C]	C4
GW 66KV FDR CB AT SVTS	1970	[C-I-C]	C4
NO 66KV FDR CB AT SVTS	1973	[C-I-C]	C4
NP 66KV FDR CB AT SVTS	1971	[C-I-C]	C4
CDA 66KV FDR CB AT SVTS	1971	[C-I-C]	C4
OE 66KV FDR CB AT SVTS	1971	[C-I-C]	C4
RD 66KV FDR CB AT SVTS	1971	[C-I-C]	C4
SVW 66KV FDR CB AT SVTS	1970	[C-I-C]	C4
SS 66KV FDR CB AT SVTS	1971	[C-I-C]	C4
SV 66KV FDR CB AT SVTS	1967	[C-I-C]	C4
NO.1 TRANS 66KV CB AT SVTS	1967	[C-I-C]	C4
1-2 66KV BUS TIE CB AT SVTS	1967	[C-I-C]	C4
1-6 66KV BUS TIE CB AT SVTS	1967	[C-I-C]	C4
NO.2 TRANS 66KV CB AT SVTS	1967	[C-I-C]	C4
3-4 66KV BUS TIE CB AT SVTS	1969	[C-I-C]	C4
4-5 66KV BUS TIE CB AT SVTS	1969	[C-I-C]	C4
NO.4 TRANS 66KV CB AT SVTS	1969	[C-I-C]	C4
NO.4 66KV CAPACITOR BANK CB AT SVTS	1990	[C-I-C]	C4
NO.4B 66KV CAPACITOR BANK CB AT SVTS	1995	[C-I-C]	C3
NO.3 TRANS 66KV CB AT SVTS	2006	[C-I-C]	C1
2-3 66KV BUS TIE CB AT SVTS	2006	[C-I-C]	C1

Table 6 – 66 kV Circuit Breaker Condition Score

6.5 Secondary Systems

The protection and control systems at SVTS consist of varied technologies. Some of the electromechanical type relays originally installed are still in service. Over the years, protection system upgrades for specific

7 AMS 10-106 Circuit Breakers.

primary assets have been necessary, resulting in the existence of first generation digital relays as well as some newer protection equipment. These targeted protection system replacements have resulted in a hybrid protection configuration where the station's mimic panel is still partly used. A complete protection and control system Human Machine Interface (HMI) has not been implemented.

The electromechanical and first generation digital relays have mal-operated in the past and have reached the end of their technical lives. The lack of a proper HMI with Remote Telemetry Unit (RTU) makes operation and maintenance challenging and more risky in network contingency situations. Interfacing the existing equipment with new protection systems required for new primary plant will further complicate the non-standard protection system configuration at SVTS and increase the associated operation and maintenance costs and risks.

7 Emerging Constraints

The key service constraints and monetised risk identified for the aging and deteriorated assets at SVTS are described in this section.

7.1 Safety and Environmental Hazards

7.1.1 Transformers

As described in AMS 10-67 Power Transformers and oil Filled Reactors, Transformers B1, B2 and B3 at SVTS have synthetic resin bonded paper (SRBP) 220 kV bushings. These bushings are of an obsolete design. Condition assessments indicate de-lamination of the SRBP core in several bushings on these transformers resulting in oil draining from the bushing into the transformer main tank. Rigorous monitoring of oil levels to close tolerances and frequent transformer outages are required to maintain oil conservator levels and to replace the oil lost from the bushings to prevent the ingress of moisture and subsequent bushing failure.

The failure of a transformer bushing could cause a fire and some of these type of failures have resulted in the complete destruction of the transformer plus damage to other equipment. AusNet Services' network experienced 220 kV bushing failures and transformer fires in 1965 and 1987 at Dederang Terminal Station from this failure mechanism. Four recent interstate bushing failures in Queensland and New South have involved complete transformer failures. These failure modes present a safety risk to personnel working in the vicinity of the transformer due to the nature of the failure which could sometimes result in projectiles or oil fires.

AusNet Services has initiated two refurbishment projects X417[8] (Stage 1) and Project X834[9] (Stage 2) to replace this type of bushing on transformers where other key transformer components including the 'core and coils' are in sound condition and additional transformer service life is probable. The poor core and coil condition of the SVTS transformers suggests that bushing replacement is not economic.

7.1.2 Circuit Breakers

Most of the 66 kV circuit breakers at SVTS are bulk oil technology circuit breakers. As described in AMS 10-54 Circuit Breakers, bulk-oil circuit breakers have proven expensive to maintain in comparison with more modern technologies. In addition, explosive failures of bulk oil circuit breakers have occurred in the past, resulting in plant damage and fire ignition.

Due to the large volume of insulating oil within the tanks and the high voltage bushings, failures could potentially cause collateral damage to adjacent high voltage plant, cables, secondary systems and onsite personnel. Spillage of oil also poses environmental hazards and clean-up costs as bulk oil circuit breakers are not positioned within a bunded area.

7.1.3 Current Transformers

As described in AMS 10-64 Instrument Transformers, several explosive failures[10] have confirmed that deteriorated single-phase, porcelain clad, oil insulated current transformers present an unacceptable risk. This risk includes supply outages, collateral plant damage, environment damage and possible injury to personnel. A progressive replacement with toroidal current transformers incorporated within plant such as dead tank circuit breakers is part of AusNet Services' asset management strategy to address these risks.

There are 15 [C-I-C] and [C-I-C] type current transformers in the SVTS 220 kV switchyard. It has been ascertained that some of these current transformers are exhibiting thermal and partial discharge issues and declining Dissolved Gas Analysis (DGA) test results.

8 X417 220 kV Transformer Bushing Replacement – Stage 1 at Ballarat Terminal Station, Ringwood Terminal Station and West Melbourne Terminal Station, completed in 2007.

9 X837 220 kV Transformer Bushing Replacement – Stage 2 at West Melbourne Terminal Station, Richmond Terminal Station, Ballarat Terminal Station, Geelong Terminal Station, Shepparton Terminal Station and Morwell Power Station, target completion in 2014.

10 Moorabool Terminal Station 2002 & 2005, Jeeralang Terminal Station 2003, Ballarat Terminal Station 2006 and Terang Terminal Station 2006.

7.2 Safety, Plant Collateral Damage and Environmental Risk Cost

The Electricity Safety Act requires AusNet Services to design, construct, operate, maintain and decommission its supply network to minimize hazards and risks, so far as is practicable, to the safety of any person arising from the supply network.

In practice this means safety risk should be proactively managed until the cost becomes disproportionate to the benefits. With respect to the management of safety risks that may cause a single fatality amongst a crew of workers; application of the principle of "as low as reasonably practicable" indicates costs in excess of $ [C-I-C] may be disproportionate.

The following assumptions were used to calculate the monetise safety, plant collateral damage and environmental hazards presented by the plant described in Section 7.1; consistent with the methodology described in AMS 10-24 Victorian Electricity Transmission Network – Asset Renewal Planning Guideline:

- An explosive failure or oil fire could injure or kill workers on site with an economic consequence cost of $ [C-I-C];
- Plant that contains large volumes of oil poses an environmental risk with an average consequence cost of $30k per event;
- Transformer with oil that contains poly-chlorinated biphenyls (PCB) poses an environmental risk with an average consequence cost of $100k per event;
- Plant collateral damage, including consequent supply outages, is on average $1.0 Million per event.

The likelihood of the above hazards occurring at SVTS have been calculated from the major failure rates in the circuit breaker, current transformer and power transformer reliability centred maintenance (RCM) models and the CIGRE research into the probability of explosion and fire associated with major plant failures[11].

Figure 4 shows the expected safety, plant collateral damage and environmental risk cost at SVTS based on the following risks:

- Health and safety risk due to an instrument transformer, power transformer bushing or circuit breaker explosive failure;
- Environmental risk presented by insulating oil spillage;
- Collateral damage to adjacent plant due to catastrophic failure of plant.

[11] Cigre Final Report of the 2004 – 2007 International Enquiry on Reliability of High Voltage Equipment.

[C-I-C]

Figure 4 – Expected Annual Safety, Plant Collateral Damage and Environmental Risk Cost

7.3 Reliability and Security of Supply Risk

7.3.1 220 kV Switchyard

No switching is provided for the four 220/66 kV transformers and two 220 kV lines to Rowville Terminal Station (ROTS). This arrangement compromises the station security and operational flexibility and presents the following risks:

- A fault on either ROTS-SVTS line will result in an outage of one SVTS transformer and one SVTS-HTS line.
- A fault on either the B1 or B2 transformer will result in an outage of one ROTS-SVTS line and one SVTS-HTS line.
- A fault on either the No.1 or No.2 Bus will result in an outage of one ROTS-SVTS line, one SVTS-HTS line and one transformer.
- If either the 220 kV No.1-3 or 220 kV No.2-4 bus-tie circuit breakers fails to operate, an outage will result on two transformers, one of the ROTS-SVTS lines and on one of the SVTS-HTS lines.
- Risk of losing all load at SVTS and the nearby HTS if a fault (e.g. at transformer or incoming line) occurs during a bus outage for maintenance of a bus isolator, earth switch or the bus.

7.3.2 66 kV Switchyard

Most of the 66 kV circuit breakers at SVTS are bulk oil technology circuit breakers and the following supply risks for a failure of a 66 kV circuit breaker have been identified:

- A fault on any of the transformer circuit breakers will result in an outage of a transformer.
- A fault on any of the bus-tie circuit breakers could cause a short outage of two buses. All circuits may be restored after isolating the faulty circuit breaker. The result of such an event is that potentially tens of thousands of customers will experience a power outage for at least 60 minutes.

- A fault on any of the feeder circuit breakers could cause a short outage of a bus which can only be restored once the faulty circuit breaker is isolated. The result of such an event is that potentially tens of thousands of customers will experience a power outage for at least 60 minutes.

7.3.3 Expected Supply Risk

Figure 5 shows the expected supply risk cost associated with 220 kV and 66 kV switchgear failures as well as 220/66 kV transformer failures (N-1 and N-2) at SVTS.

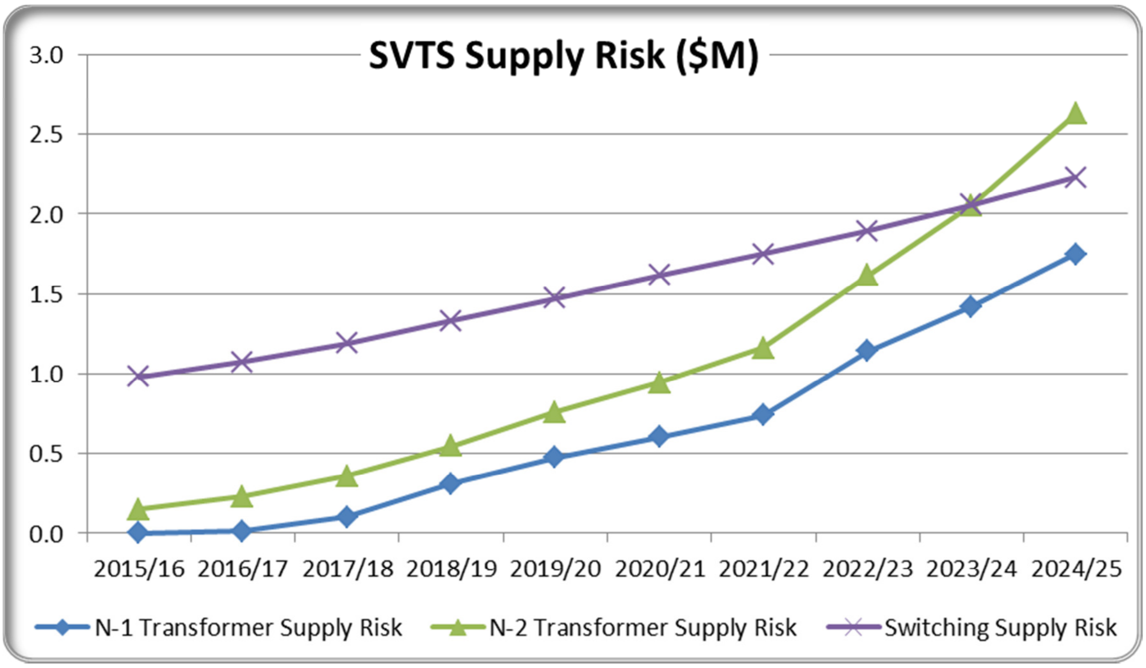

Figure 5 – Expected Supply Risk Cost for Transformer, and 220 kV and 66 kV Switchgear Failures

7.4 Baseline Risk

The baseline risk[12] for SVTS is illustrated in Figure 6. The monetised baseline risk includes safety, environmental, collateral plant damage and security of supply risks involved with both major transformer failures resulting in extended transformer outages and initial plant failures. It presents the probability weighted risk at SVTS for the key risk components as calculated in the preceding sections 7.2 and 7.3.

12 For details of the calculation of the baseline risk refer to the excel economic model of the SVTS Redevelopment.

[C-I-C]

Figure 6 – Baseline Risk

The baseline risk in Figure 6 is the probability weighted risk cost at SVTS of low probability, but high consequence events. It does not represent the actual societal cost of a fatality or injury, or loss of supply event. The societal cost of explosive plant failures that could injure or kill workers on site and/or critical plant outages that could result in a loss of supply from SVTS are much higher than the probability weighted monetised risk presented in Figure 6. It is estimated at $ [C-I-C] for a fatality, $5 M for a major transformer failure and $13 M for a circuit breaker failure. The high societal cost of plant failures, including explosive failures, suggests that options such as “Do nothing” or “Run to Failure” are not prudent asset management strategies for the asset failure risks at SVTS.

The safety and asset failure risk is forecast to progressively increase over time, predominantly due to the deteriorating condition of the transformers and switchgear. The societal cost due to plant failures at SVTS is also expected to increase as demand increases. Table 7 illustrates that significant capital investments may be economic to address the increasing base line risk at SVTS.

YEAR	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023	2023/ 2024	2024/ 2025
Annual Risk Cost ($)	3.0	3.4	3.9	4.6	5.3	6.0	6.6	7.8	8.9	10.2
Present Value Risk Cost at 7.5% Discount Rate ($M)	39.0	43.4	49.9	59.0	67.9	76.3	85.0	100.5	114.6	131.2

Table 7 – Societal Risk

8 Options to Address Risks

The following options have been assessed to address the increasing community risk at SVTS:

- Business as usual. This option is included in the option analysis to define the baseline risk and to quantify the potential benefits of options that address the baseline risk;
- Non network option of embedded generation and/or demand side response;
- Run to failure and replace assets upon failure;
- Integrated redevelopment with Air Insulated Switchgear (AIS);
- Staged redevelopment,
- Redevelopment with Gas Insulated Switchgear (GIS).

9 Evaluation of Options

An economic cost-benefit assessment is used to assess and rank the economic efficiency of the non-network and network options listed in Section 8. The option analysis considers key aspects like operating cost versus capital cost trade-offs, security of supply risk during the construction phase of the project, economic merits of an integrated versus staged replacement and the future augmentation plans for SVTS.

A "Business as usual" option (Option 1) has been included in the option analysis to presents the baseline risk. It illustrates whether deferment of asset replacement presents an economical option or whether the risk has reached a level that needs to be addressed during the 2017 to 2022 regulatory control period. Option 2 assesses the technical and economic merits of non-network options such as embedded generation and demand side management. Option 3 is a reactive asset replacement option. Options 4, 5, 6, and 7 involve proactive replacement of deteriorated and failure prone equipment based on the assessed risk of an asset failure.

The economic analysis allows comparison of the economic cost and benefits of each option, to rank the options and to determine the economic timing of the preferred option. It quantifies the capital, operation and maintenance, and risk cost for each option. The risk cost includes safety, security of supply, environmental and collateral damage risks at SVTS. The robustness of the economic evaluation is tested for three discount rates, a sensitivity analysis of the forecast plant failure rates, different demand growth scenarios and different VCR rates.

Each of the identified options for SVTS is evaluated based on the incremental benefits it delivers in the following areas:

- Reduction in health and safety risk due to plant explosive failures;
- Reduction in supply risk due to unplanned outages;
- Reduction in environmental risk due to insulating oil spillage;
- Reduction in collateral plant damage risk due to explosive plant failures;
- Reduction in operation and maintenance cost, including network losses.

9.1 Option 1: Business as Usual

The baseline risk at SVTS, as shown in Figure 6 and Table 7, defines the economic cost for the "Business as Usual" option for the period until 2024/25. It shows that the annual risk cost increases from \$3.0 M to \$10.2 M over the period from 2015/16 to 2024/25. The Present Value of the risk cost, assuming a flat risk profile after

2024/25, is more than $131 M[13]. This suggests that a "Business as Usual" approach would not be an economical option or a prudent management strategy for the assets at SVTS.

The progressive reduction in reliability of supply and increase in safety risk is inconsistent with AusNet Services' obligations under the National Electricity Rules. Recurring asset failures is furthermore inconsistent with the requirements of the Electricity Safety Act and AusNet Services' accepted Electricity Safety Management Scheme.

This option is used in the economic evaluation as a reference to measure the economic benefits of options that mitigate the identified risks at SVTS and to ascertain the economical time[14] for a particular option to proceed.

9.2 Option 2: Non network options of embedded generation and/or demand side response

SVTS does not have any N-1 energy at risk under 50% POE conditions based on the current demand forecast for the planning period until 2019/20 and only a small amount of energy at risk on extremely warm days and summer 10% POE conditions. The economic benefits of non-network options are hence limited over the planning period and insufficient to warrant further analysis of this option based on typical costs for non-network options. Non network options can furthermore not address the safety risk or meet the full supply requirement of SVTS.

9.3 Option 3: Run to failure

This option involves replacing assets upon failure, which poses a significant risk to the community. The community costs that would result from applying an asset management strategy to only replace an asset after the asset has failed is as follows:

- $5 M for a major failure of a 220/66 kV transformer.
- $13 M for a circuit breaker failure.

Some of the plant (transformer bushings, bulk oil 66 kV circuit breakers and instrument transformers) at SVTS also present a safety risk should they fail explosively. This risk cannot be managed with a "run to failure" strategy as it would involve workers replacing failed equipment in a switchyard containing other equipment known to be in a deteriorated condition with a potentially hazardous mode of failure. This type of safety risk is valued at $ [C-I-C] as a person/s could be injured or killed following an explosive failure.

Unplanned replacement of assets after a failure occurred is furthermore an inefficient asset replacement strategy for terminal stations due to the significant higher cost (project mobilisation and demobilisation) of emergency replacements.

Recurring unplanned outages associated with a series of asset failures is inconsistent with the requirements of the Electricity Safety Act, AusNet Services' accepted Electricity Safety Management Scheme and the National Electricity Rules. This option is hence only used for modelling purposes.

9.4 Option 4: Integrated Replacement

This option involves replacement of selected 220 kV and 66 kV assets with elevated failure risks and includes a reconfiguration of the 220 kV switchyard using air insulated switchgear in a single integrated project. The replacement of three of the existing four transformers in new locations facilitates the ultimate station requirement of 5 x 150 MVA 220/66 kV transformers.

This option has the highest capital cost ($77.2 M), delivers significant benefits and addresses most of the risks.

---

13 This is a conservative assumption as the risk cost is more likely to increase as a result of deteriorating plant condition and consequent failure rates, and demand growth.

14 "Do Nothing" is the default option until the year when the annual benefits (reduction in risk cost and operating cost) of the most economical option exceed the annual cost.

9.5 Option 5: Staged Replacement – 220 kV and transformers

This option assesses the economic feasibility of a staged rather than integrated replacement of the deteriorated assets at SVTS. The first stage replaces the 220 kV switchgear (condition C5), three of the four 220/66 kV transformers and critical 66 kV switchgear such as the bus tie circuit breakers and transformer incomer circuit breakers. The remainder of the plant are replaced in a second stage, five years after completion of the first stage.

This option allows deferral of some asset replacements and is estimated to cost $65.2 M. It delivers significant benefits by addressing most of the risks.

9.6 Option 6: Staged Replacement – 66 kV

This option assesses the economic feasibility of a staged rather than integrated replacement of the deteriorated assets at SVTS. The first stage replaces the 66 kV switchgear, followed by a second stage that replaces the 220 kV switchgear and three of the four 220/66 kV transformers.

This option allows deferral of some asset replacements and is estimated to cost $14.1 M. It only address some of the risks.

9.7 Option 7: Brownfield GIS Redevelopment

This option is also to Option 4, however the existing 220 kV and 66 kV air insulated switchgear (AIS) is replaced with compact gas insulated switchgear (GIS) within buildings. Some of the existing rack structures and line termination structures remain, yet many of the overhead connections and feeder exits will be placed underground in this option.

SVTS is located within a suburb characterised by a mixture of commercial and industrial developments. The nearest residential properties are more than 200 m from the SVTS site on the opposite side of a main arterial road. It is not expected that GIS equipment within buildings will be a requirement of a planning permit, as was the case with the Brunswick augmentation and Richmond redevelopment projects. However, this remains a possibility and this option may trigger contingency expenditures.

9.8 PV Analysis

The present value cost (taking into account the total project capital cost, supply risk cost, operation and maintenance cost, safety risk cost, environment cost and plant collateral damage risk costs) is calculated for all credible options and is summarised in Table 8. This allows for the options to be ranked based on their economic merits. A real discount rate of 7.5% is used for the base case.

Options Title	Assessment of Options	Capital Cost[15]	PV Cost (7.5% DCR)[16]
1. Business as usual	The baseline risk rises quickly, suggesting that a “Business as usual” approach is not sustainable.		More than $139 M
2. Non-Network Option	This is not an economic or technically feasible solution based on the magnitude of the load and the safety risk at HYTS, which cannot be addressed with a non-network option.		Uneconomic

15 Total project cost expressed in real 2015 dollars.

16 Present value cost expressed in real 2015 dollars at a 7.5% discount rate.

Options Title	Assessment of Options	Capital Cost[15]	PV Cost (7.5% DCR)[16]
3. Run to failure	This option is inconsistent with AusNet Services' accepted ESMS, the Electricity Safety Act and AusNet Services' obligations under the NER. The baseline risk has reached a level that requires a proactive asset management strategy. Uneconomic option.		
4. Integrated Replacement	Address all the identified risks in a single efficient project.	$77.2 M	$73.3 M
5. Staged Replacement – 220 kV and Transformers	Addresses most of the risks.	$65.2 M	$80.3 M
6. Staged Replacement – 66 kV	Addresses a limited number of risks.	$14.1 M	$81.2 M
7. GIS Redevelopment	High capital cost. Fully address all risks.	$160 M	$131.0 M

Table 8 – Economic Assessment of Options – Base case assumptions

The robustness of the economic assessment is tested for different discount rates[17], asset failure rates (low case at 0.75 x base case failure rate and high case at 1.25 x base case failure rate), demand growth rates (plus and minus 15% of the base case forecast) and VCR rates (low case at 0.75 x base case and high case at 1.25 x base case) as shown in Table 9 below.

17 AER Regulatory Investment Test for Transmission, June 2010. The present value calculations must use a commercial discount rate appropriate for the analysis of a private enterprise investment in the electricity sector. The discount rate used must be consistent with the cash flows being discounted. The lower boundary should be the regulated cost of capital, which is estimated at 6% (real and pre-tax).

	Discount Rate		
	6.0%	7.5%	9.0%
Option 1: Business as Usual	$157.888	$139.485	$123.579
Option 4: Integrated Replacement	$78.179	$73.291	$68.790
Option 5: Staged Replacement - Transformers and 220 kV	$86.720	$80.253	$74.425
Option 6: Staged Replacement - 66 kV	$90.291	$81.229	$73.309
Option 7: GIS	$140.082	$130.994	$122.630
Economic Option	Option 4	Option 4	Option 4

	VCR Rate		
	Low	Base	High
Option 1: Business as Usual	$119.730	$139.485	$159.240
Option 4: Integrated Replacement	$71.472	$73.291	$75.111
Option 5: Staged Replacement - Transformers and 220 kV	$78.427	$80.253	$82.079
Option 6: Staged Replacement - 66 kV	$77.386	$81.229	$85.072
Option 7: GIS	$129.175	$130.994	$132.814
Economic Option	Option 4	Option 4	Option 4

	Asset Failure Rate		
	Low	Base	High
Option 1: Business as Usual	$100.920	$139.485	$182.197
Option 4: Integrated Replacement	$68.833	$73.291	$78.008
Option 5: Staged Replacement - Transformers and 220 kV	$74.825	$80.253	$85.943
Option 6: Staged Replacement - 66 kV	$72.075	$81.229	$91.286
Option 7: GIS	$126.534	$130.994	$135.713
Economic Option	Option 4	Option 4	Option 4

	Demand Growth		
	Low	Base	High
Option 1: Business as Usual	$92.195	$139.485	$256.839
Option 4: Integrated Replacement	$69.895	$73.291	$83.133
Option 5: Staged Replacement - Transformers and 220 kV	$76.853	$80.253	$90.099
Option 6: Staged Replacement - 66 kV	$71.405	$81.229	$108.500
Option 7: GIS	$127.597	$130.994	$140.836
Economic Option	Option 4	Option 4	Option 4

Table 9 – Economic Assessment of Options – Sensitivity Study

9.9 Economic Option and Economical Timing

The integrated replacement option (Option 4) is the most economic option to address the plant failure risks at SVTS as it has the lowest PV cost for all the scenarios shown in Table 9.

The PV for Option 4 is also calculated for a series of different years to determine the economical timing for it to proceed, consistent with the RIT-T guidelines. This assessment concludes that the economic timing for project completion is 2019/20.

Project Economic Timing (PV Cost $M)	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Option 4: Integrated Replacement	74.36	73.47	73.29	73.55	74.19	75.44

Table 10 – Economic Timing

9.10 Sensitivity Studies

A sensitivity study[18] for higher (x 1.25) and lower (x 0.75) failure rates shows the economic timing of the redevelopment of SVTS may be as early as 2018/19 or as late as 2022/23. Due consideration of this sensitivity is important to avoid assets failure during the construction phase of the planned replacement project given the significant worker safety and community consequence.

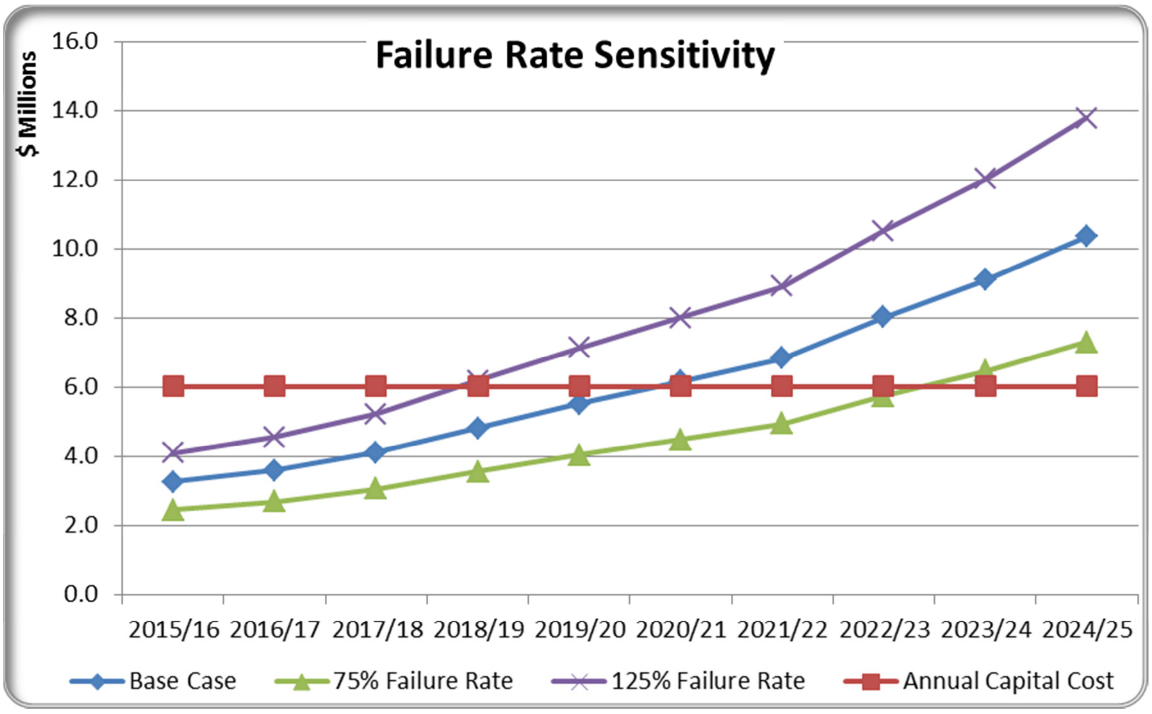

Figure 7 – Sensitivity Study – Plant failure rate higher or lower than expected

A sensitivity study for higher demand growth rates (15% above the base case) and lower demand growth rates (15% below the base case) shows that the project economic timing may be as early as 2017/18 or as late as 2023/24. Due consideration of this sensitivity is important to avoid un-necessary risk during the planned replacement project given the significant safety and community consequence.

18 The intersection of the annualized project cost plot and the incremental benefits plot shows the project timing that delivers the optimum economic outcome.

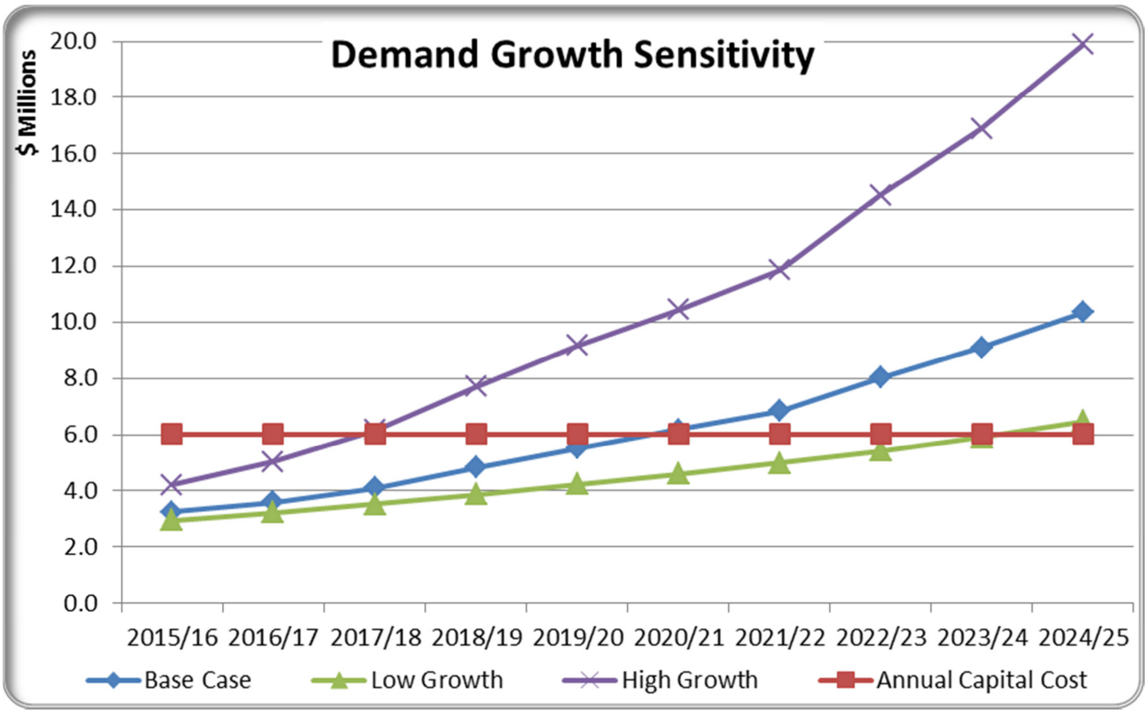

Figure 8 – Sensitivity Study – Demand growth higher or lower than expected

The economical timing of the SVTS redevelopment is also tested for different VCR rates (25% higher or lower than the base case) as shown in Figure 9. The sensitivity study shows that the project economic timing may be as early as 2019/20 or as late as 2020/21. Due consideration of this sensitivity is important to avoid unnecessary risk during the planned replacement project given the significant safety and community consequence.

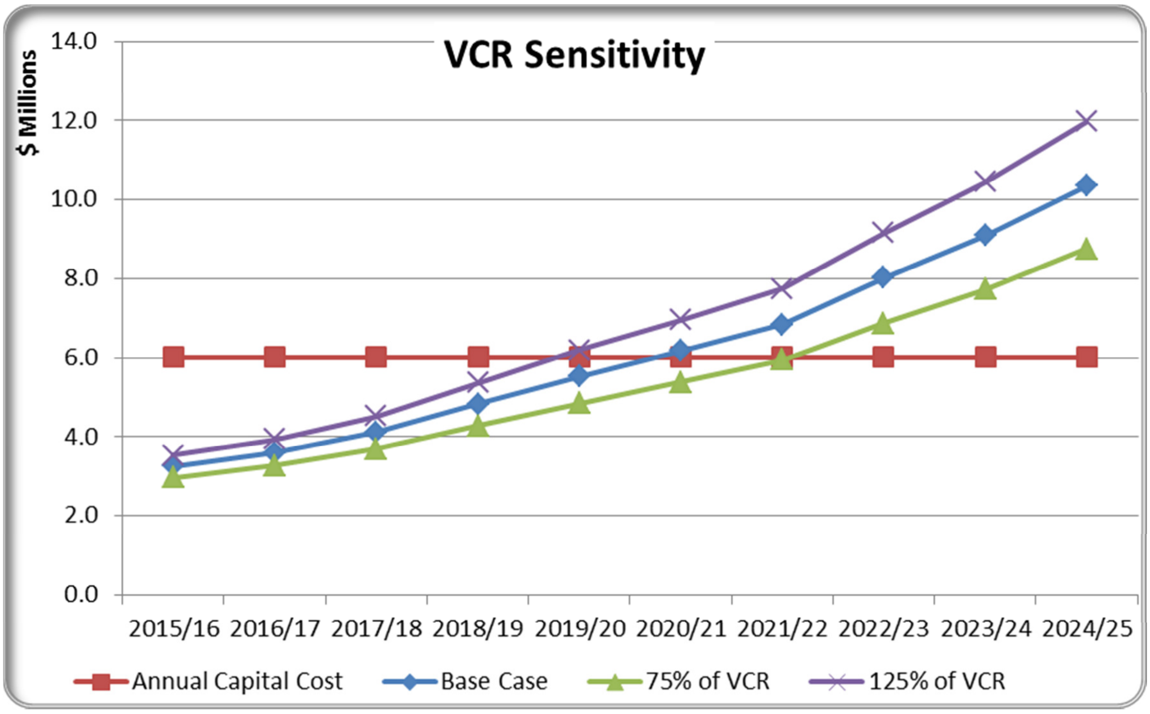

Figure 9 – Sensitivity Study – VCR Rates higher or lower than expected

Operational measures such as additional plant inspections and condition monitoring to manage the safety risk until planned replacements are completed is economical based on the safety risk assessment in Section 7.2.

10 Scope of Work

The high level scope of work for the preferred solution (Option 4) includes:

- Remove the existing 220 kV 1-2 bus tie circuit breaker, 220 kV 1-3 bus tie circuit breaker and 220 kV 2-4 bus tie circuit breaker.
- Remove the 220 kV HTS No.1 and HTS No.2 line circuit breakers.
- Remove the existing B1, B2 and B3 transformers.
- Replace the existing 220 kV buses including insulators and supports.
- Supply and install three 150 MVA 220/66 kV three phase transformers (B1, B2 and B3) including all associated primary and secondary connections.
- Supply and install six new 220 kV dead tank circuit breakers including associated remote operated isolators (ROIs), earth switches, voltage transformers, primary and secondary connections for the switching of the B1, B2, B3 and B4 transformers (B2 and B3 single switched, B1 and B4 double switched).
- Supply and install six new 220 kV dead tank circuit breakers including associated ROIs, earth switches, voltage transformers and primary and secondary connections for the switching of the incoming ROTS-SVTS lines and the SVTS-HTS outgoing lines.
- Supply and install new 66 kV dead tank circuit breakers including associated isolators and primary and secondary connections.

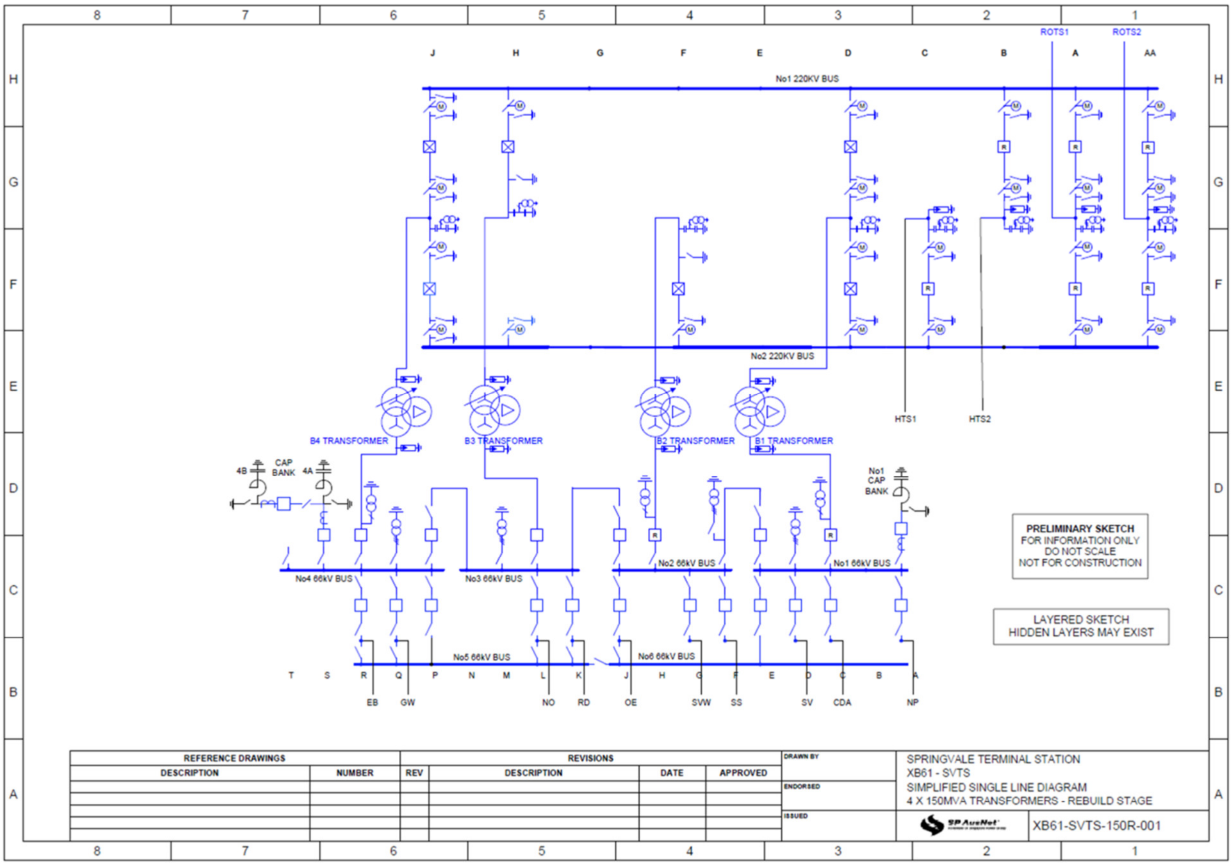

Figure 10: Proposed works at SVTS (Option 7)

The size of the SVTS site restricts 220 kV switching to double switched bays as the greater length of a breaker-and-half switch bay cannot be accommodated. This switching configuration is in line with AEMO and United Energy's augmentation plan for SVTS and both AEMO and United Energy agree with the proposal to provide switching for each transmission line and transformer. This is consistent with the "breaker-and-half" switching standard for 220 kV and higher voltage transmission networks defined in AEMO's "Guidelines for Shared Transmission Connections in Victoria"[19].

19 Guidelines for Shared Transmission Connections in Victoria, published by AEMO.

APPENDIX A: PLANNING ESTIMATE FOR PREFERRED OPTION: OPTION 4 - INTEGRATED REPLACEMENT

[C-I-C]

Note: The costs in the table above are expressed in 2015 real dollars.