AusNet Transmission Group Pty Ltd

Transmission Revenue Review 2017-2022

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AMS – Electricity Transmission Network

Planning Report Project 284A

Heywood Terminal Station Circuit Breaker Replacement

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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 Heywood Terminal Station (HYTS). 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

Some of the 500 kV circuit breakers at HYTS are in a poor condition with an increasing risk of failure. Condition assessments indicate that these 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 or circuit breakers;
- Security of supply risks presented by a failure of key 500 kV circuit breakers;
- Collateral plant damage risks presented by an explosive failure of an instrument transformer or circuit breaker bushing;
- Environmental risks associated with explosive asset failures.

1.3 Economic Option

This planning study considers credible options to address the service constraints and to meet the long term planning requirements for HYTS outlined in the Victorian Annual Planning Report (VAPR) and Transmission Connection Planning Report (TCPR). 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 replacement combined with asset refurbishment;
- Staged replacement combined with asset refurbishment;
- In situ versus reconfigured replacement

The most economic option to address the emerging constraints at HYTS is a selective (staged) replacement of critical circuit breakers in conjunction with some circuit breaker refurbishment. This option involves some network reconfiguration and addresses all emerging risks. This option has the lowest present value cost ($13.7 M) and is consistent with the future development plans for HYTS. The economic timing for project completion is before Summer 2020/21 with an estimated total capital cost of $8.1 M ($6.9 M direct $2015).

2 Purpose

This planning report outlines asset condition, asset failure risks and network development plans relevant to HYTS 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 HYTS 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

HYTS is located in south western Victoria and is the main terminal station interconnecting the Victorian 500 kV transmission back bone with the South Australian transmission network via a double circuit 275 kV line. HYTS also supplies the Portland aluminium smelter via a double circuit 500 kV line as shown in Figure 1.

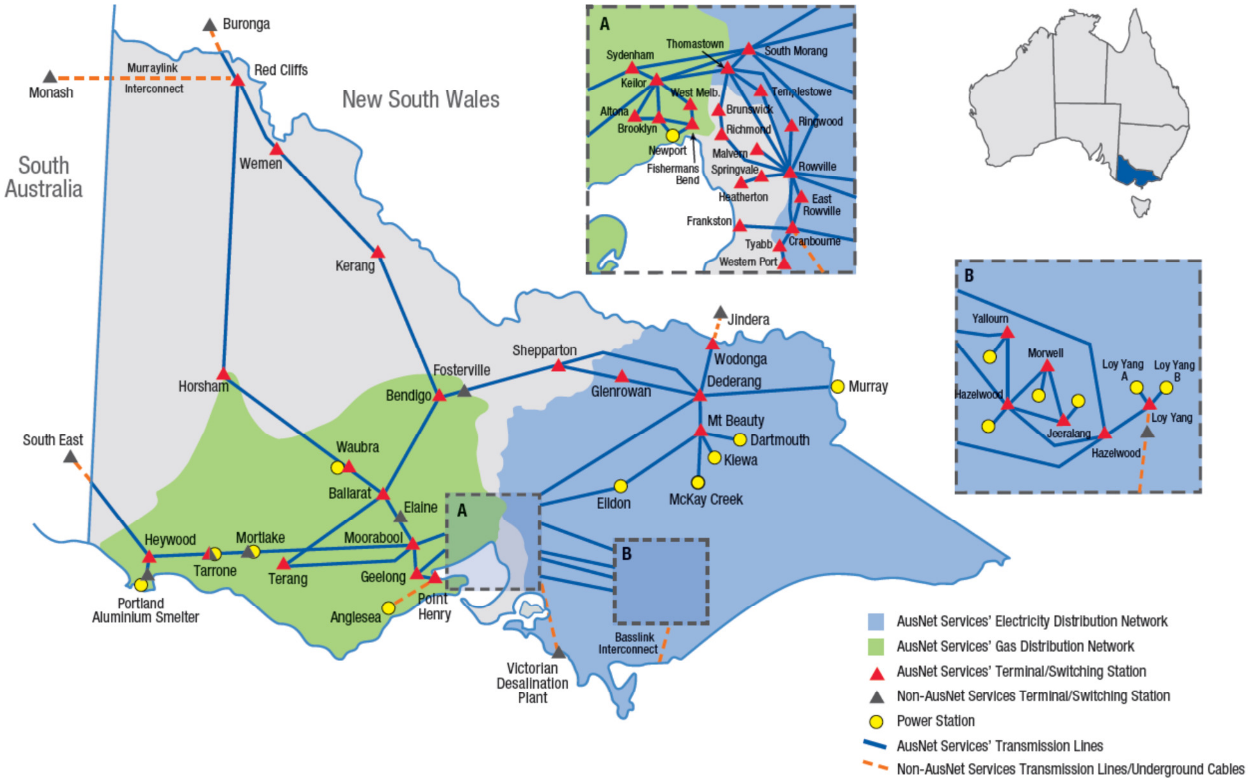

Figure 1 – Transmission Network supplying HYTS and VIC-SA Interconnector

HYTS includes a 500 kV and a 275 kV switchyard as well as two remote 500 kV circuit breakers to connect the two 500 kV lines from Tarrone Terminal Station and Mortlake Power Station as well as the two circuits of the double circuit 275 kV line to South East Substation in South Australia. HYTS also has two 370 MVA 500/275 kV transformers and a third 500/275 kV transformer is being installed as part of the Victoria-South Australia interconnector upgrade project.

The supply risks associated with some key circuit breaker failures are increasing and these assets are becoming more difficult and expensive to maintain or refurbish due to the inflexible switching arrangements at HYTS that makes it almost impossible to obtain plant outages for maintenance or refurbishment.

Figure 2, below shows the present configuration at HYTS.

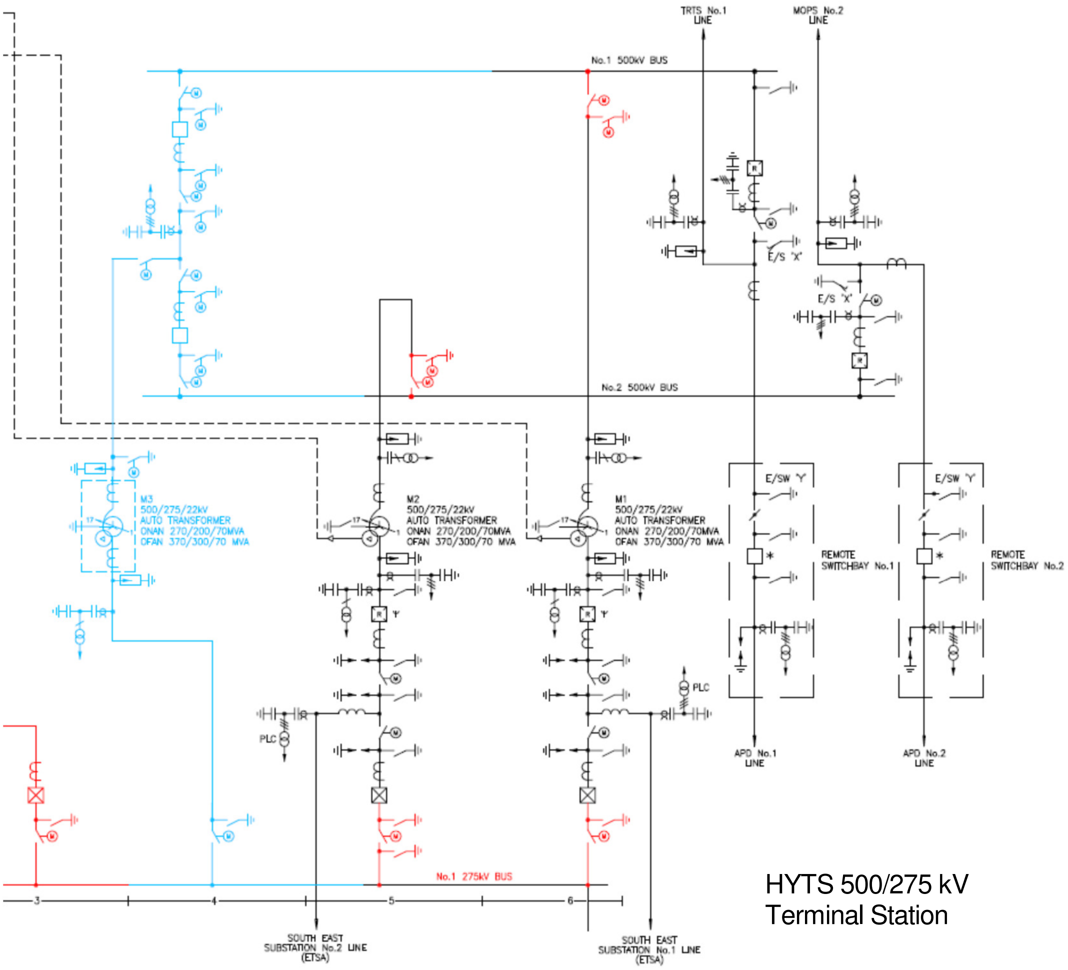

Figure 2 – Single Line Diagram of HYTS after completion of the VIC-SA Interconnector upgrade project

5 Planning Considerations

5.1 Planning Responsibilities

The augmentation responsibility for HYTS lays with the Australian Energy Market Operator (AEMO) for the shared transmission network and with the distributor, Powercor, for the transmission connection assets.

5.2 Demand Forecast

The main load supplied from HYTS is the Portland Aluminium smelter. A reliable and secure supply to the Portland Aluminium smelter is of high importance as significant cost impacts could result if the supply is interrupted.

Figure 3 shows the Distribution Businesses' forecast demand for Summer POE50 conditions. The load at the Portland Aluminium smelter is not temperature sensitive and the Summer POE10 and Winter POE50 forecasts are the same as the Summer POE50 forecast. It is not expected that demand will grow and flat growth is forecast over the planning period.

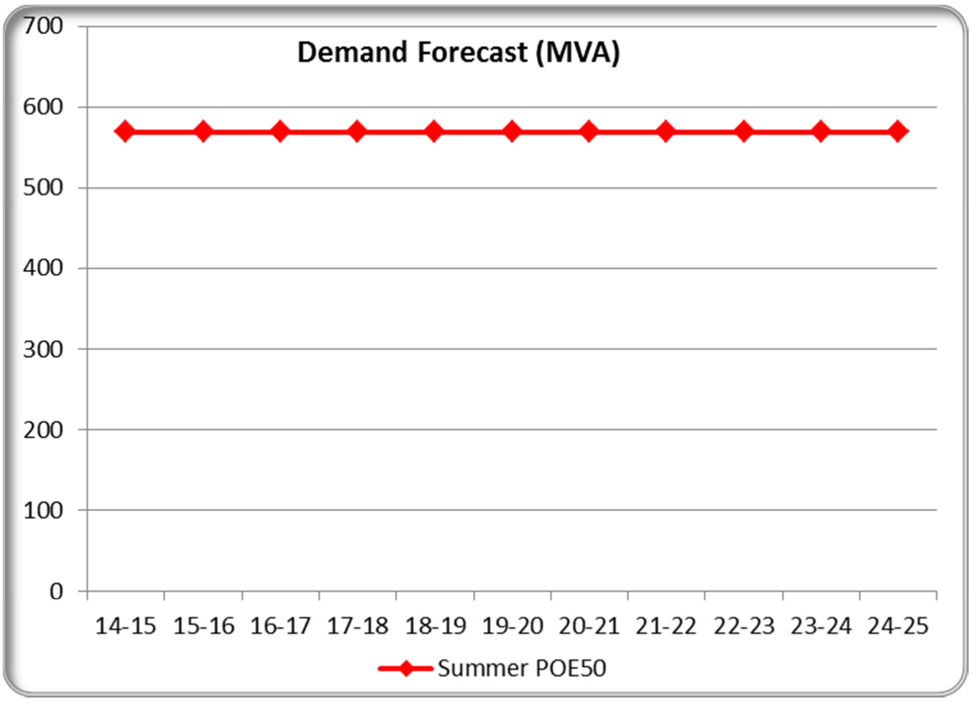

Figure 3 –Distribution Business demand Forecast for Portland Aluminium Smelter

5.3 Future Planning Requirements

Any significant asset replacements at HYTS 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 and the distributors' future plans for HYTS, which include the following:

- Six 500 kV transmission lines
- Two 275 kV transmission lines
- Two 220 kV transmission lines

- Three 370 MVA 500/275 kV transformers
- Three 750 MVA 500/220 kV transformers
- 500/66 kV transformation
- Controlled Series Compensation
- Shunt capacitor banks

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 HYTS 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 10-67 Power Transformers and Oil-Filled Reactors describes AusNet Services' asset management strategy for power transformers and oil-filled reactors. The condition of the existing 500/275 kV transformers at HYTS has been assessed according to AMS 10-67 and is shown in Table 2.

DESCRIPTION	MANUFAC TURER	INSTALL YEAR	MVA	Asset Condition	Core & Windings	Bushings	Oil	Tap Changer	Tank /Aux
M1 500/275 KV TRANSFORMER	[C-I-C]	1989	270/200/ 70	C2	C2	C3	C2	C2	C4
M2 500/275KV TRANSFORMER	[C-I-C]	1989	270/200/ 70	C2	C2	C3	C2	C2	C4

Table 2 – Transformer Condition Score

All 500/275 kV transformers at HYTS are in a good condition and no replacements are required.

6.2 500 kV Circuit Breakers

The 500 kV circuit breakers at HYTS are all in poor condition and their condition scores are shown in Table 3.

CIRCUIT	INSTALL DATE	Age	Asset Condition
MOPS NO.2 500KV LINE NO.2 BUS CB AT HYTS	30/06/1987	27	C5
TRTS NO.1 500KV LINE NO.1 BUS CB AT HYTS	30/06/1987	27	C5
APD NO.2/MOPS NO.2 LINE 500KV CB AT HYTS	31/12/1991	23	C5
APD NO.1/TRTS NO.1 LINE 500KV CB AT HYTS	31/12/1991	23	C4

Table 3 – 500 kV Circuit Breaker Condition Score

6.3 275 kV Circuit Breakers

The 275 kV circuit breakers are in average condition as indicated in Table 4.

CIRCUIT	INSTALL DATE	Age	Asset Condition
SESS NO.1 275KV LINE/M1 TRANS CB AT HYTS	30/06/1987	27	C3
SESS NO.2 275KV LINE/M2 TRANS CB AT HYTS	30/06/1987	27	C3
NO.1 275KV CAPACITOR BANK/SESS NO.1 LINE CB AT HYTS	30/06/2000	14	C3
NO.1 275KV CAPACITOR BANK/SESS NO.2 LINE CB AT HYTS	30/06/2000	14	C3

Table 4 – 275 kV Circuit Breaker Condition Score

6.4 275 kV Current Transformers

There are three [C-I-C] 275 kV post-type current transformers installed at HYTS[1]. As described in AMS 10-64[2], [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. Investigations indicate that the [C-I-C] current transformers show a design/manufacturing deficiency in the capacitive voltage grading structure of the insulation and the earth screen grounding connection. It is thought that electrical switching or lightning transient currents passing through the capacitive structure create an over-voltage condition that punctures the last few capacitive layers to earth. Partial discharge then continues to degrade the installation until cascade insulation failure occurs. The degradation of the insulation can rapidly advance causing explosive failure, resulting in human safety concerns, damage to adjacent equipment and long unplanned outages of network plant.

At least two [C-I-C] current transformers have failed in this manner on the Victorian transmission network over the last ten years[3]. [C-I-C] current transformers (all voltage levels) have been monitored closely since those failures to manage the safety risk they present. This frequent monitoring has successfully revealed accelerated deterioration and imminent failure and many units have been safely replaced as a result.

The [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. Further, ongoing DGA analysis continues to show a trend towards failure, demonstrating clearly that Tyree 330 kV, 275 kV and 220 kV

[1] The current transformers are insulated for 330 kV, but operated at 275 kV

[2] AMS 10-64 Instrument Transformers.

[3] In 2002 and 2005 at Moorabool Terminal Station (MLTS).

current transformers represent some of our highest risk types. AusNet Services' asset management strategy is therefore to completely replace the remaining fleet.

Table 5 shows the asset condition of the 275 kV [C-I-C] current transformers at HYTS.

Circuit	Install Date	Asset Condition
SESS NO.2 275KV LINE/M2 TRANS CB CT R/PH ([C-I-C])	1/01/1968	C4
SESS NO.2 275KV LINE/M2 TRANS CB CT W/PH ([C-I-C])	9/11/1971	C4
SESS NO.2 275KV LINE/M2 TRANS CB CT B/PH ([C-I-C])	30/06/1985	C4

Table 5 – 275 kV Current Transformer Condition Score

6.5 Secondary Systems

The protection and control systems at HYTS consist of varied technologies. Over the years, protection system upgrades for specific 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.

The solid state 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 serial link to HMI with a 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 HYTS and increase the associated operation and maintenance costs and risks.

Circuit breaker replacement represents an opportunity to introduce modern circuit breaker management schemes in place of the existing, ageing solid state relays and PLC based control schemes, in line with AusNet Services, secondary asset management strategies.

7 Emerging Constraints

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

7.1 Safety and Environmental Hazards

7.1.1 Current Transformers

As described in AMS 10-64 Instrument Transformers, several explosive failures[4] 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 three [C-I-C] current transformers in the HYTS 275 kV switchyard that has been assessed as being in a poor condition.

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 monetised 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 HYTS 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[5].

Figure 4 shows the expected safety, plant collateral damage and environmental risk cost at HYTS 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.

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

[5] 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

7.3.1 500 kV Switchgear

The entire Portland Aluminium smelter load will be interrupted when both remote 500 kV circuit breakers supplying APD from HYTS are unavailable for service. The probability of this occurring is very small, but the market impact will be significant. The condition of these two 500 kV circuit breakers is C4 and C5 respectively, and with increasing forecast failure rates based on their assessed condition.

The 275 kV interconnector between Victoria and South Australia will be severed when both the Tarrone Terminal Station and Mortlake Power Station 500 kV circuit breakers (C5 condition) at HYTS are unavailable for service. It is hence expected that flows on the interconnector will be limited if the loss of the interconnector is a credible contingency i.e. with one 500 kV circuit out of service.

The supply risk at HYTS is expected to rise to unacceptable levels over the planning period.

7.3.2 Expected Supply Risk

Figure 5 shows the expected supply risk cost associated with 500 kV and 275 kV switchgear failures at HYTS.

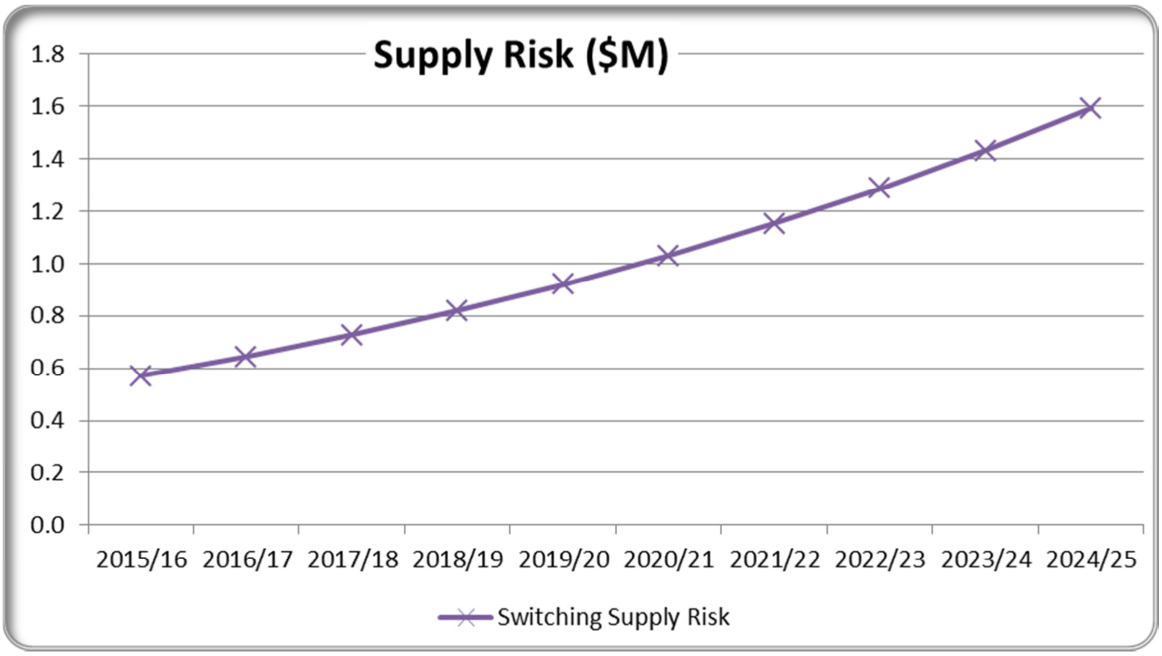

Figure 5 – Expected Supply Risk Cost for 500 kV and 275 kV kV Switchgear Failures

7.4 Baseline Risk

The baseline risk for HYTS 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 HYTS for the key risk components as calculated in the preceding sections 7.2 and 7.3.

[C-I-C]

Figure 6 – Baseline Risk

The baseline risk in Figure 6 is the probability weighted risk cost at HYTS 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 HYTS are much higher than the probability weighted monetised risk presented in Figure 6. It is estimated at $ [C-I-C] for a fatality and $10 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 HYTS.

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 HYTS is also expected to increase as demand increases. Table 6 illustrates that significant capital investments may be economic to address the increasing base line risk at HYTS.

YEAR	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Annual Risk Cost ($)	1.0	1.1	1.2	1.3	1.5	1.6	1.8	1.9	2.1
Present Value Risk Cost at 7.5% Discount Rate ($M)	12.3	13.7	15.2	16.8	18.6	20.5	22.6	24.9	27.3

Table 6 – Societal Risk

8 Options to Address Risks

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

- 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 replacement combined with asset refurbishment
- Staged replacement combined with asset refurbishment
- In situ versus reconfigured replacement.

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 HYTS.

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 HYTS. 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 HYTS 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 HYTS, as shown in Figure 6 and Table 6, 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 $1.0 M to $2.3 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 $29.9 M[6]. This suggests that a "Business as Usual" approach would not be an economical option or a prudent management strategy for the assets at HYTS.

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 HYTS and to ascertain the economical time[7] for a particular option to proceed.

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

After completion of the Victoria to South Australia interconnector upgrade project, HYTS 500/275 kV will not have any N-1 energy at risk under 50% POE conditions based on the current demand forecast for the planning period until 2024/25. 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 cannot address the safety risk or meet the full supply requirement of the Portland smelter.

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:

- $10 M for a circuit breaker failure.

Some of the plant (instrument transformers) at HYTS also presents 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: Staged and Reconfigured Replacement with Circuit Breaker Refurbishment

This option includes replacing one of the two remote 500 kV circuit breakers supplying APD and retiring the other remote 500 kV circuit breaker. Two new 500 kV circuit breakers are installed with this option to allow for the T-connection at HYTS to be double switch, which will allow essential refurbishment to be undertaken on the Tarrone and Mortlake 500 kV line circuit breakers that are in a very poor condition.

The replacement of the 275 kV circuit breakers is deferred to the end of the planning period.

6 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.

7 "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: Integrated Replacement with Circuit Breaker Refurbishment

This option allows for all the circuit breakers that are in a poor condition to be replaced in situ except the Tarrone and Mortlake 500 kV line circuit breakers at HYTS. It assumes that the market will be constrained during the time that refurbishment of these two 500 kV circuit breakers are undertaken.

9.6 Option 6: Staged Replacement of Circuit Breaker with APD lines Single Switched

This option replaces the two remote 500 kV circuit breakers that supplies APD inside the existing 500 kV switchyard so that the APD lines are single switched to the two busbars. It also provides for the Tarrone and Mortlake 500 kV line circuit breakers at HYTS to be refurbished and for the two 275 kV circuit breakers to be replaced in a second stage at the end of the planning period.

9.7 Option 7: Staged Replacement of Circuit Breaker with APD lines double Switched

This option replaces the two remote 500 kV circuit breakers that supplies APD inside the existing 500 kV switchyard so that the APD lines are double switched to the two busbars. It also provides for the Tarrone and Mortlake 500 kV line circuit breakers at HYTS to be refurbished and for the two 275 kV circuit breakers to be replaced in a second stage at the end of the planning period.

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 7. 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[8]	PV Cost (7.5% DCR)[9]
1. Business as usual	The baseline risk rises quickly, suggesting that a "Business as usual" approach is not sustainable.		More than $30 M
2. Non-Network Option	This is not an economic or technically feasible solution based on the magnitude of the load at Portland and the safety risk at HYTS, which cannot be addressed with a non-network option.		
3. Run to failure	This option is inconsistent with AusNet Services' accepted ESMS, the Electricity Safety Act and AusNet Services' obligations under the NER.		
4. Staged and Reconfigured Replacement with CB Refurbishment	Address most of the identified risks at the lowest cost. Enables refurbishment of deteriorated 500 kV circuit breakers.	$8.1 M	$13.7 M
5. Integrated Replacement with CB Refurbishment	Address most of the identified risks. Enables refurbishment of deteriorated 500 kV circuit breakers.	$10.8 M	$14.9 M
6. Staged Single Switched Replacement with CB Refurbishment	Second highest capital cost. Fully address all risks.	$12.6 M	$20.4 M

8 Total project cost expressed in real 2015 dollars and includes project overheads and finance charges.

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

Options Title	Assessment of Options	Capital Cost[8]	PV Cost (7.5% DCR)[9]
7. Staged Double Switched, Reconfigured, Replacement with CB Refurbishment	Highest capital cost. Fully address all risks.	$19.2 M	$25.1 M

Table 7 – Economic Assessment of Options – Base case assumptions

The robustness of the economic assessment is tested for different discount rates[10], VCR rates (low case at 0.75 x base case and high case at 1.25 x base case), asset failure rates (low case at 0.75 x base case failure rate and high case at 1.25 x base case failure rate) and demand growth rates (plus and minus 15% of the base case forecast) as shown in Table 8 below.

	Discount Rate		
	6.0%	7.5%	9.0%
Option 1: Business as Usual	$33.955	$30.097	$26.757
Option 4: Staged Reconfigured Replacement with CB Refurbishment	$14.724	$13.729	$12.833
Option 5: Integrated In Situ Replacement with CB Refurbishment	$15.683	$14.915	$14.197
Option 6: Staged Single Switched Replacement with CB Refurbishment	$21.783	$20.382	$19.112
Option 7: Staged Double Switched Reconfigured Replacement with CB Refurbishment	$26.771	$25.110	$23.595
Economic Option	Option 4	Option 4	Option 4

	VCR Rate		
	Low	Base	High
Option 1: Business as Usual	$25.755	$30.097	$34.438
Option 4: Staged Reconfigured Replacement with CB Refurbishment	$13.261	$13.729	$14.198
Option 5: Integrated In Situ Replacement with CB Refurbishment	$14.418	$14.915	$15.411
Option 6: Staged Single Switched Replacement with CB Refurbishment	$19.687	$20.382	$21.078
Option 7: Staged Double Switched Reconfigured Replacement with CB Refurbishment	$24.414	$25.110	$25.805
Economic Option	Option 4	Option 4	Option 4

	Asset Failure Rate		
	Low	Base	High
Option 1: Business as Usual	$19.357	$30.097	$43.007
Option 4: Staged Reconfigured Replacement with CB Refurbishment	$12.100	$13.729	$15.593
Option 5: Integrated In Situ Replacement with CB Refurbishment	$13.483	$14.915	$16.581
Option 6: Staged Single Switched Replacement with CB Refurbishment	$18.317	$20.382	$22.781
Option 7: Staged Double Switched Reconfigured Replacement with CB Refurbishment	$23.104	$25.110	$27.450
Economic Option	Option 4	Option 4	Option 4

	Demand Growth		
	Low	Base	High
Option 1: Business as Usual	$30.097	$30.097	$30.097
Option 4: Staged Reconfigured Replacement with CB Refurbishment	$13.729	$13.729	$13.729
Option 5: Integrated In Situ Replacement with CB Refurbishment	$14.915	$14.915	$14.915
Option 6: Staged Single Switched Replacement with CB Refurbishment	$20.382	$20.382	$20.382
Option 7: Staged Double Switched Reconfigured Replacement with CB Refurbishment	$25.110	$25.110	$25.110
Economic Option	Option 4	Option 4	Option 4

Table 8 – Economic Assessment of Options – Sensitivity Study

10 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).

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 HYTS as it has the lowest PV cost for all the scenarios shown in Table 8.

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 project is already economic by Summer 2015/16 where after the PV cost rise significantly.

Project Economic Timing (PV Cost $M)	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
Project PV Cost	13.44	13.73	14.08	14.48	14.94	15.45

Table 9 – Project Economic Timing

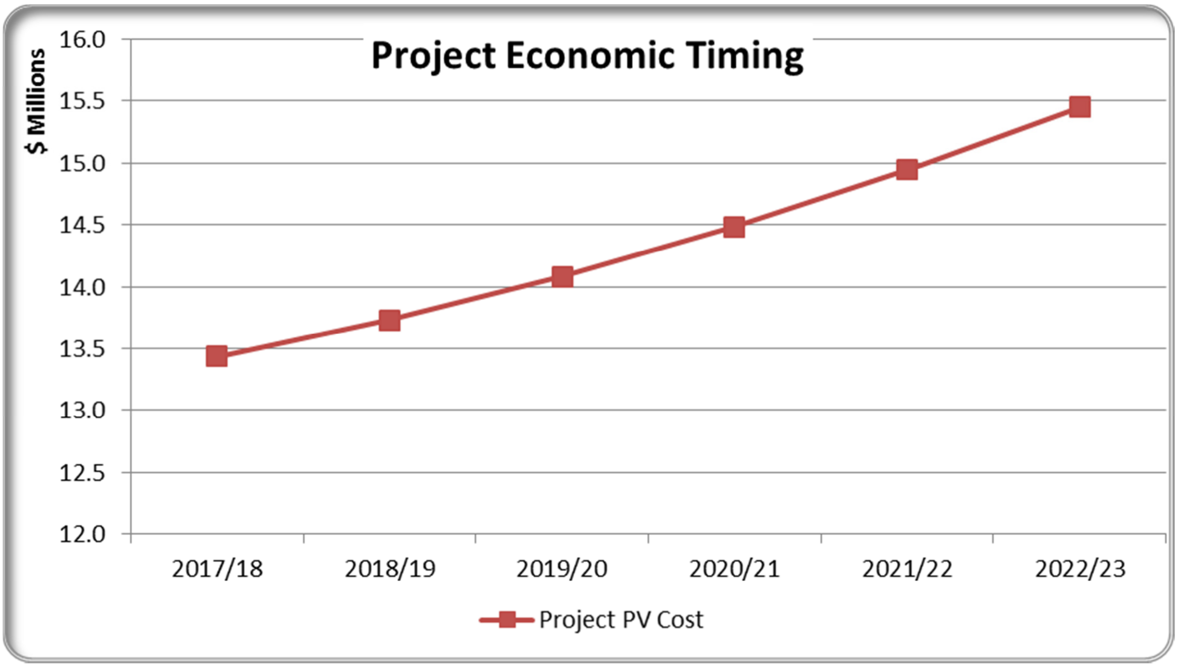

Figure 7 - Project Economic Timing

9.10 Sensitivity Studies

A sensitivity study[11] for higher (x 1.25) and lower (x 0.75) failure rates shows the economic timing of the circuit breaker replacement project at HYTS may be as early as 2015/16 or as late as 2018/19. 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.

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

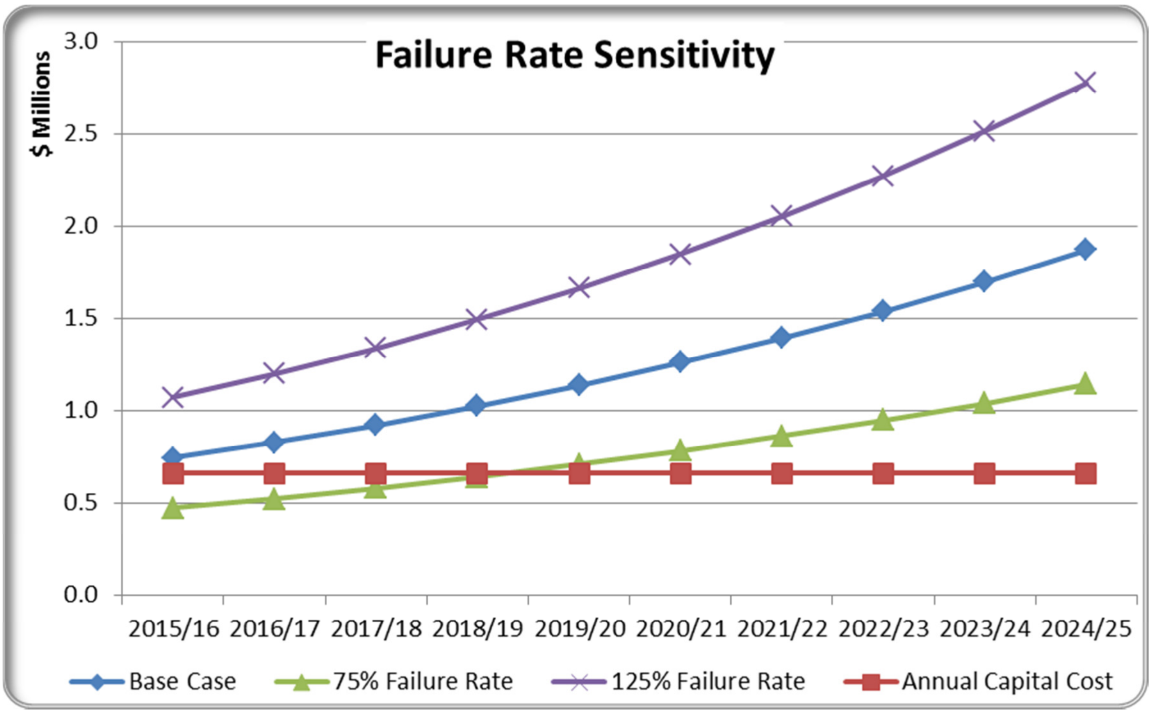

Figure 8 – Sensitivity Study – Plant failure rate higher or lower than expected

The demand at Portland is not expected to change due to the nature of the load. A sensitivity study has however being done to test the project economic timing for changes in demand. The 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 is prior to 2015/16 for both scenarios.

Due consideration of this sensitivity is important to avoid un-necessary risk during the planned replacement project given the significant safety and community consequence.

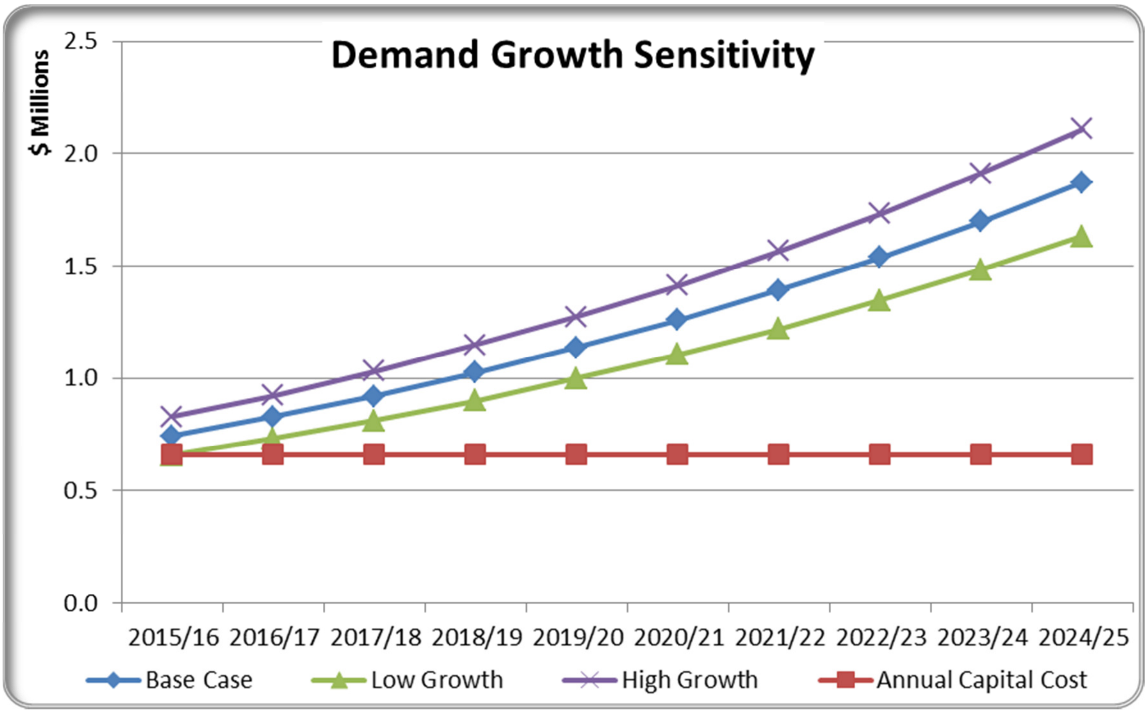

Figure 9 – Sensitivity Study – Demand growth higher or lower than expected

The economical timing of the HYTS circuit breaker replacement project is also tested for different VCR rates (25% higher or lower than the base case) as shown in Figure 10. The sensitivity study shows that the project economic timing is prior to 2015/16 for both scenarios. Due consideration of this sensitivity is important to avoid un-necessary risk during the planned replacement project given the significant safety and community consequence.

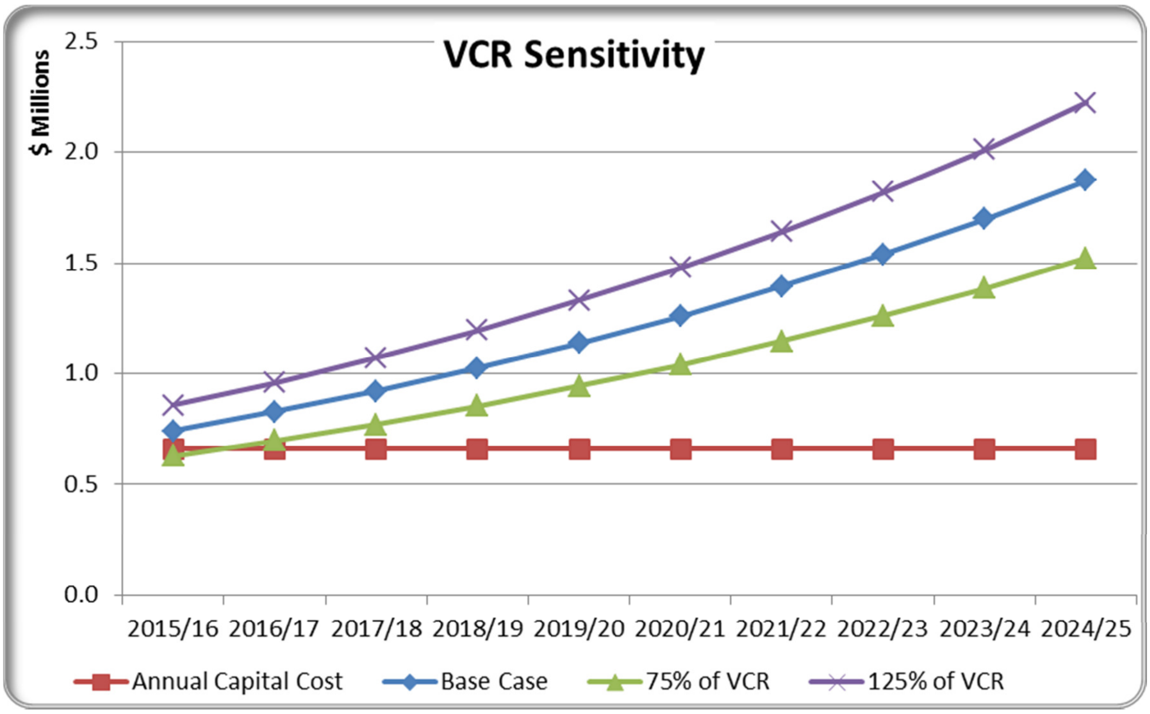

Figure 10 – Sensitivity Study – VCR Rates higher or lower than expected

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:

- Installing two new 500 kV circuit breakers at HYTS to allow the 500 kV line T-connections (Tarrone/APD and Mortlake/APD) to be double switched
- Replacing the APD No.1 line 500 kV remote circuit breaker in situ
- Retiring the APD No. 2 line 500 kV remote circuit breaker
- Refurbishing the two existing 500 kV circuit breakers that connects the 500 kV line T-connections (Tarrone/APD and Mortlake/APD) at HYTS
- Secondary replacement

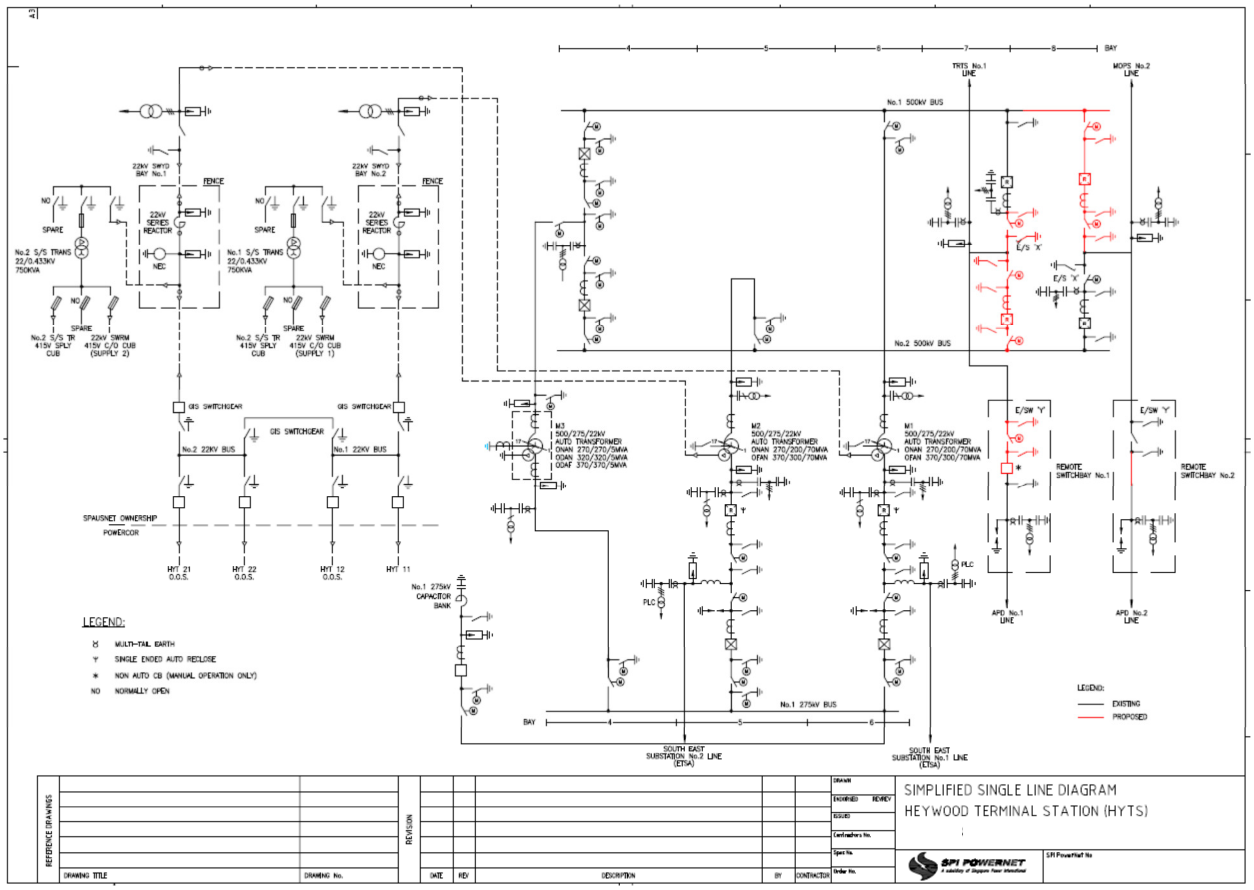

Figure 11: Proposed works at HYTS (Option 4)

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.