Jemena Electricity Networks (Vic) Ltd

BTS-NS Subtransmission

Network Development Strategy

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GLOSSARY

Amperes (A)	Refers to a unit of measurement for the current flowing through an electrical circuit. Also referred to as Amps.
Constraint	Refers to a constraint on network power transfers that affects customer service.
Continuous rating	The permissible maximum demand to which a conductor or cable may be loaded on a continuous basis.
Jemena Electricity Networks (JEN)	One of five licensed electricity distribution networks in Victoria, the JEN is 100% owned by Jemena and services over 344,000 customers via an 11,000 kilometre distribution system covering north-west greater Melbourne.
Maximum demand (MD)	The highest amount of electrical power delivered (or forecast to be delivered) for a particular season (summer and/or winter) and year.
Megavolt ampere (MVA)	Refers to a unit of measurement for the apparent power in an electrical circuit. Also million volt-amperes.
Network	Refers to the physical assets required to transfer electricity to customers.
Network augmentation	An investment that increases network capacity to prudently and efficiently manage customer service levels and power quality requirements. Augmentation usually results from growing customer demand.
Network capacity	Refers to the network's ability to transfer electricity to customers.
Probability of exceedance (POE)	The likelihood that a given level of maximum demand forecast will be met or exceeded in any given year:
Reliability of supply	The measure of the ability of the distribution system to provide supply to customers.
System normal	The condition where no network assets are under maintenance or forced outage, and the network is operating according to normal daily network operation practices.
10% POE condition (summer)	Refers to an average daily ambient temperature of 32.9ºC derived by NIEIR and adopted by JEN, with a typical maximum ambient temperature of 42ºC and an overnight ambient temperature of 23.8ºC.
50% POE condition (summer)	Refers to an average daily ambient temperature of 29.4ºC derived by NIEIR and adopted by JEN, with a typical maximum ambient temperature of 38.0ºC and an overnight ambient temperature of 20.8ºC.
50% POE and 10% POE condition (winter)	50% POE and 10% POE condition (winter) are treated the same, referring to an average daily ambient temperature of 7ºC, with a typical maximum ambient temperature of 10ºC and an overnight ambient temperature of 4ºC.

ABBREVIATIONS

AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
BTS	Brunswick Terminal Station
BK	Brunswick Zone Substation
BY	Braybrook Zone Substation
CB	Circuit Breaker
CS	Coburg South Zone Substation
ES	Essendon Zone Substation
EUE	Expected Unserved Energy
FF	Fairfield Zone Substation
JEN	Jemena Electricity Network
KTS	Keilor Terminal Station
MAT	Melbourne Airport Zone Substation
MD	Maximum Demand
MVCR	Moonee Valley Racecourse
NEM	National Electricity Market
NEO	National Electricity Objective
NER	National Electricity Rules
NPV	Net Present Value
NS	North Essendon Zone Substation
POE	Probability of Exceedance
PV	Pascoe Vale Zone Substation
TMA	Tullamarine Zone Substation
VCR	Value of Customer Reliability

OVERVIEW

Jemena North Essendon (**NS**) Zone Substation supplies 10,575 predominantly residential customers at 11 kV in Essendon, Strathmore and Moonee Ponds in the Jemena Electricity Network (**JEN**) supply area. JEN North Essendon Zone Substation is supplied by three 22 kV sub transmission lines from AusNet Services' Brunswick (**BTS**) terminal station. This paper presents the emerging constraints on the 22 kV radial sub transmission lines and the need for capacity augmentation in order to meet the forecast demand at North Essendon Zone Substation.

Identified Need

Demand at Jemena's NS Zone Substation supply area is expected to grow at 3.2% per annum during the next regulatory period 2021-2026. The expected increase in demand is mainly driven by the current proposed residential and commercial developments around Moonee Valley racecourse. The existing 22 kV sub transmission lines are currently fully utilised and will not have sufficient capacity to meet the increasing demand.

JEN currently has three radial 22 kV sub transmission lines from AusNet Services' BTS terminal station supplying JEN NS Zone Substation located at the corner of Moreland Rd and Johnson St. JEN NS Zone Substation supplies 10,575 predominantly residential customers within the JEN distribution area.

The 22 kV sub transmission lines from BTS terminal station to JEN NS Zone Substation is currently operating above its N secure rating[1]. Under single contingency condition, the loading on the sub transmission lines are above 160% utilisation which will require JEN to take customers off supply. Based on the current forecast on a single contingency event for summer 2020/21, approximately 19.4 MVA of load will be shed around Essendon, Strathmore and Moonee Ponds area to maintain system stability and operate the lines within their thermal safe loading limits. This will leave approximately 4,500 customers off supply during an outage on the sub transmission line. Besides this, two of the three sub transmission lines are sharing the same pole line increasing the likelihood of single outage taking out two of the three radial 22 kV lines. In the event of this outage condition, the whole entire load at NS Zone Substation will be shed affecting 10,575 customers.

On March 2017, Moonee Valley Racecourse (**MVRC**) released their vision and plan for the redevelopment of the entire site which includes a new grandstand, commercial centre and a new residential precincts of 2,000 new dwellings with stage 1 works has already commenced from mid-2018. Based on the initial forecast provided by the developer, [redacted] will be added to NS Zone Substation within the next 10-15 years. Table OV-1 shows the latest load demand forecast for JEN NS Zone Substation.

Table OV-1: JEN NS Zone Substation Forecast

	2021	2022	2023	2024	2025	2026
50% POE Forecast-Summer (MVA)	34.8	35.7	36.7	37.6	38.9	40.4
10% POE Forecast-Summer (MVA)	40.8	41.9	42.7	43.9	45.6	47.3

Based on the current demand forecast, the load on the NS Zone Substation is forecast to increase by 3.2% per annum during the next regulatory period 2021-26. This will leave significant risk on the sub transmission lines under the "Do Nothing" scenario.

A risk assessment was conducted to identify the potential energy at risk on the sub transmission lines. The sub transmission lines are currently operating above 90% utilisation under system normal condition and are operating

[1] JEN acceptable loading on the sub transmission line under system normal to maintain supply reliability during single contingency (N-1) condition.

well above the thermal rating under single contingency condition. Operating overhead conductors above their thermal ratings could lead to excessive sag and may cause long term damage. The substandard conductor clearance could lead to accidents, such as vehicle contacting low overhead conductors and sagged 22 kV line being in contact with its subsidiary overhead circuits.

Table OV-2 below shows the expected unserved energy at risk on the sub transmission lines under the base-case "Do Nothing" scenario from 2021-2026.

Table OV-2: Expected Unserved Energy on the BTS-NS Sub Transmission Lines

	2021	2022	2023	2024	2025	2026
Expected Unserved Energy (MWh)	69.7	92.9	116.9	155.8	220.1	300.8
Cost of Expected Unserved Energy ($M)	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43

Options Considered

In order to meet the increasing demand at North Essendon, the existing sub transmission lines needs to be upgraded. This paper looks at all credible options available to Jemena to provide a safe and reliable supply to the customers supplied from JEN NS Zone Substation.

A number of options to alleviate the emerging constraints on the BTS-NS 22 kV sub transmission lines were investigated. These include:

- Option 1: Do nothing (Base Case);
- Option 2: Upgrade one 22 kV line from BTS-NS to 690A;
- Option 3: Reconductor existing three sub transmission lines from BTS to NS to operate at 620A;
- Option 4: Upgrade all three 22 kV lines from BTS-NS to 690A;
- Option 5: Convert existing sub transmission lines from 22 kV to 66 kV lines;
- Option 6: Build new feeders from PV and ES Zone Substation to take load away from BTS-NS loop;
- Option 7: Battery Storage Solution;
- Option 8: Demand management for first two years, then Option 4;
- Option 9: Embedded Generation.

Preferred Option

A summary of the market benefits analysis assessed for each credible option is presented in Table OV-3 below. In alignment with National Electricity Objective (NEO), the preferred and recommended solution is the option that maximises the net economic market benefits whilst maintaining a safe and reliable supply to customers. Option 4, upgrade all three 22 kV lines from BTS-NS to 690A, is shown to maximise the net economic market benefit, and is therefore the preferred option for implementation.

The preferred Option 4 has a net market benefits of $42.8 million over a planning horizon of 10 years (2020 to 2029). The market benefits forecast to be delivered by the preferred solution are predominately driven by a reduction in the amount of expected unserved energy over the planning period.

1. INTRODUCTION

This section outlines the purpose of this development plan, provides an overview of North Essendon (NS) supply area, describes the general arrangement of North Essendon (NS) Zone Substation, and gives a brief overview of the network limitations in this area.

1.1 PURPOSE

The proposed development plan is consistent with JEN's long term asset management objectives which require JEN to comply with all regulatory obligations. In this case, the objective of this development strategy is to meet the needs of customer demand in Essendon, Strathmore and Moonee Ponds.

1.2 CURRENT STATE

JEN customers in North Essendon are currently being supplied by ten 11 kV feeders from North Essendon (NS) Zone Substation. The substation also supplies two CitiPower 11 kV feeders. The area is confined by 22 kV feeders of Coburg South (CS) Zone Substation in the east, CitiPower's network in the south and 11 kV feeders of Essendon (ES) and Pascoe Vale (PV) Zone Substation in the west and north respectively. Figure 1–1 shows the route map of the sub transmission lines from BTS terminal station and Figure 1–2 show the geographic supply areas of NS Zone Substation, and its surrounding ES, PV and CS Zone Substations.

Sub transmission network

Electricity supply to NS Zone Substation is provided by three radial 22 kV sub-transmission lines (BTS-NS176, BTS-NS 190 and BTS-NS 193) supplied from AusNet Services' Brunswick Terminal Station (BTS), as shown in Figure 1–1. Two of these three circuits are constructed on a single pole line from BTS to NS Zone Substation increasing the risk and probability of an N-2 outage. Under N-2 condition, the entire load at NS Zone Substation is at risk affecting all 10,575 customers.

Based on the current forecast, the existing sub transmission loop are exposed to the following risks:

- Loss of any one of the 22 kV lines from BTS will lead to an overload on the remaining two lines, well above their thermal capacity; and
- Loss of two sub-transmission lines under the following single contingency events:
  - Outage along 6,700 m long BTS-NS176 and BTS-NS193 double circuit pole line.

As part of this strategy paper, the options evaluated will consider the above sub transmission network risks.

Refer to Section 1.4 for BTS-NS sub transmission lines load forecast.

Zone Substation

NS Zone Substation currently has three 22/11-6.6 kV 12/18 MVA dual winding transformers, a 4.0 Ω neutral earthing resistor and twelve 11 kV feeder circuit breakers. Being very close to the CitiPower boundary, two 11 kV feeders from NS Zone Substation cross the boundary line and supply CitiPower customers. The remaining ten feeders supply approximately 10,575 customers in JEN distribution area.

The transformers at North Essendon Zone Substation was replaced in 2017. The substation has a N rating of 54.0 MVA and N-1 rating of 36.0 MVA and is limited by the transformer thermal capacity.

There is adequate capacity under N-1 conditions to meet the forecast maximum demand for 50% POE conditions for the forward planning period. However, the load supplied by the substation under 10% POE summer maximum demand condition already exceeds the substation N-1 rating. Based on the 10% POE summer maximum demand, outage of a 22/11 kV transformer will result in involuntary load shedding of up to 6.7 MVA in 2023. However, the substation has up to 5 MVA of emergency transfer capacity[2].

With all three transformers in service, there is adequate capacity to meet the anticipated maximum demand for the forward planning period.

Figure 1–3 presents a single line diagram of NS Zone Substation.

Refer to Section 1.5 for NS Zone Substation load forecast.

HV Feeders

The average summer 10% POE feeder utilisation across the ten NS feeder is forecast to reach 92% by summer 2025/26. Feeders NS-11, NS-12, NS-17 and NS-18 are the heaviest loaded feeders with utilisation forecast to reach 109%, 145%, 96% and 146% in 2025/26. To ensure supply security to our customers, Jemena is proposing to undertake the following feeder augmentation projects at NS in the next regulatory period (2021-2026):

- Augment feeder NS-18 by November 2023 - This project involves installation of approximately 0.8 kilometres of underground cable, thermal capacity upgrades and feeder load reconfigurations to meet forecast demand growth in the area. Without implementation of this project, up to 0.5 MVA of load reduction would be required under system normal conditions and up to 5.6 MVA under outage conditions.
- Augment feeder NS-15 by November 2026 - This project involves installation of approximately 150 metres of underground cable and reconductoring of 1.4 km of existing undersized conductor to a larger standard size conductor to meet forecast demand growth in the area. Without implementation of this project, up to 4.8 MVA of load reduction would be required under outage conditions.

The project objective and justification for the feeder upgrade projects at NS are detailed in Jemena Distribution Feeders Network Development Strategy paper and is outside the scope of this document.

Refer to Section 1.6 for NS Zone Substation HV feeders forecast.

[2] Distribution Annual Planning Report 2019.

Figure 1–1: Geographic map of the BTS-NS 22 kV sub-transmission lines

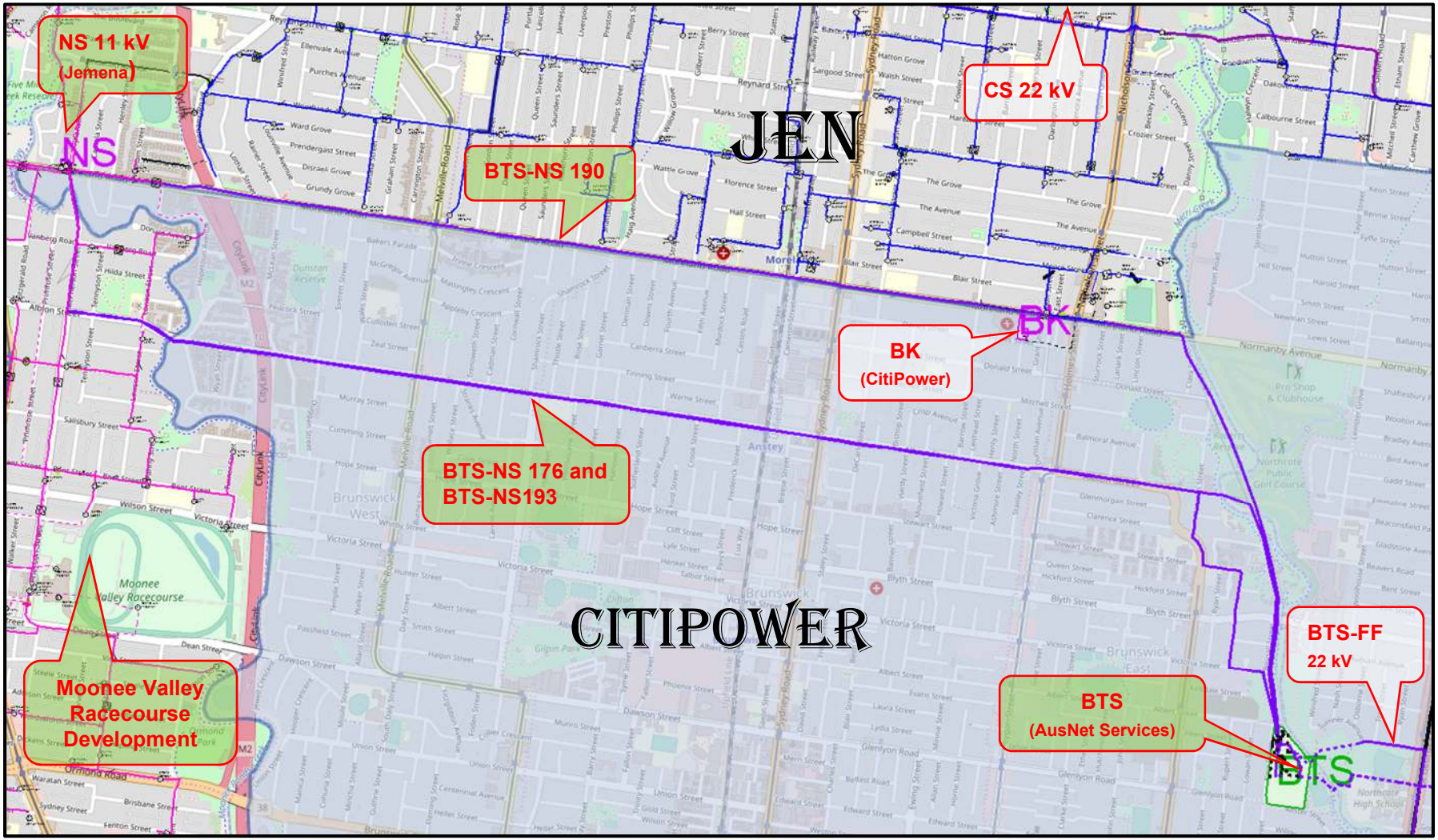


Figure 1–2: Supply areas of North Essendon Zone Substation and surrounding zone substations

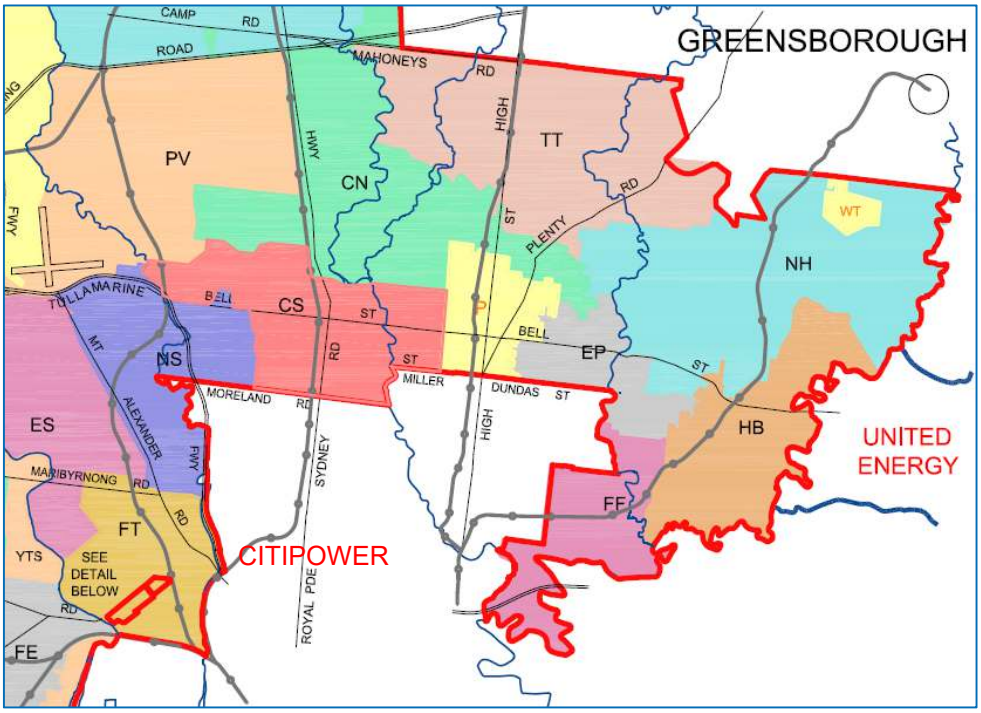
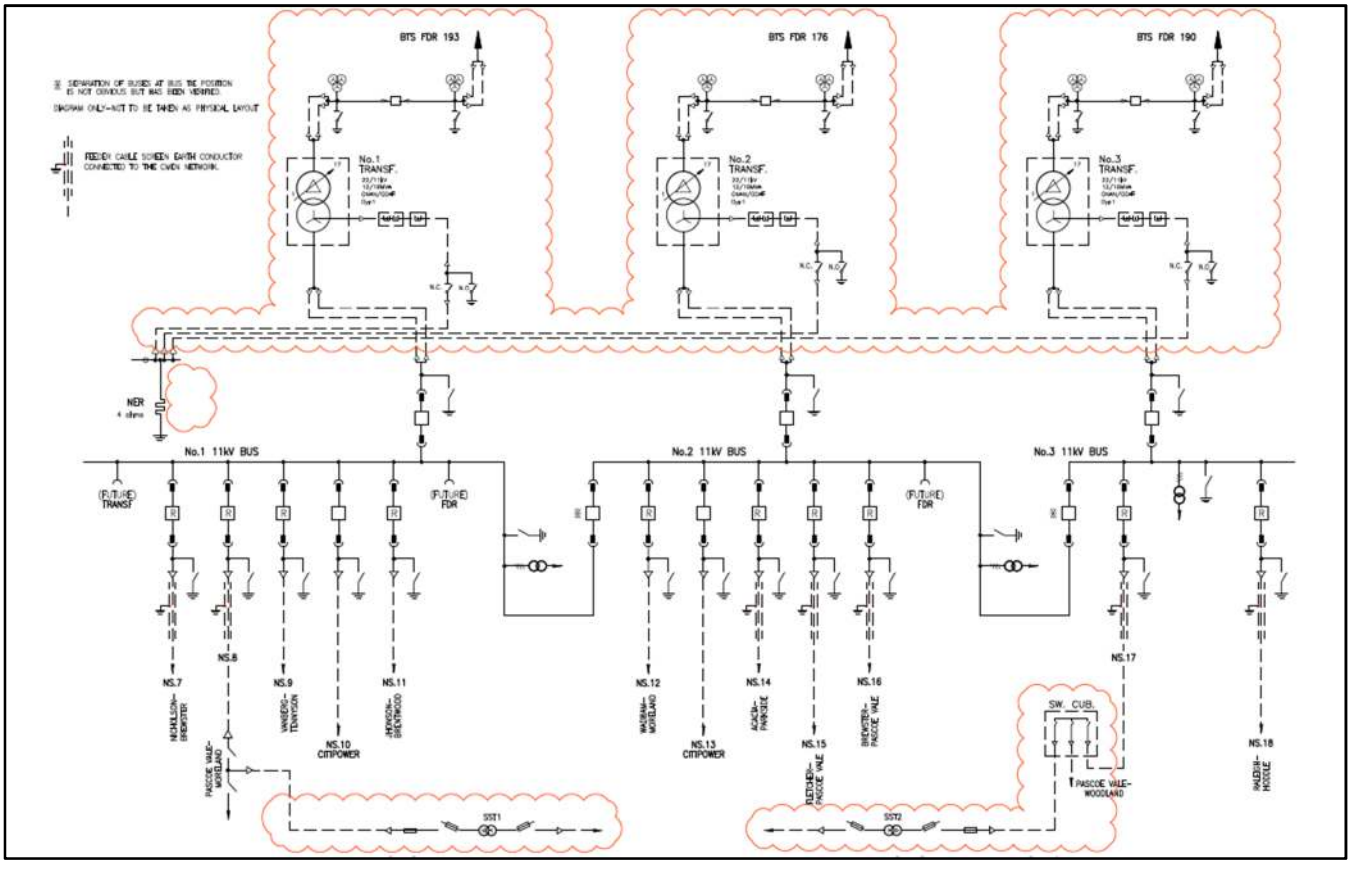


Figure 1–3: North Essendon Zone Substation single line diagram



1.3 NEW LOADS

The demand forecast is an essential input to identify the emerging network constraints and the need for reinforcement. The analyses presented in this document are based on the maximum demand forecasts prepared in 2019[3]. Based on the 2019 JEN demand forecast, maximum demand at North Essendon Zone Substation is forecast to grow by 3.2% during the next regulatory period 2021-26. This is mainly driven by the proposed development at Moonee Valley racecourse.

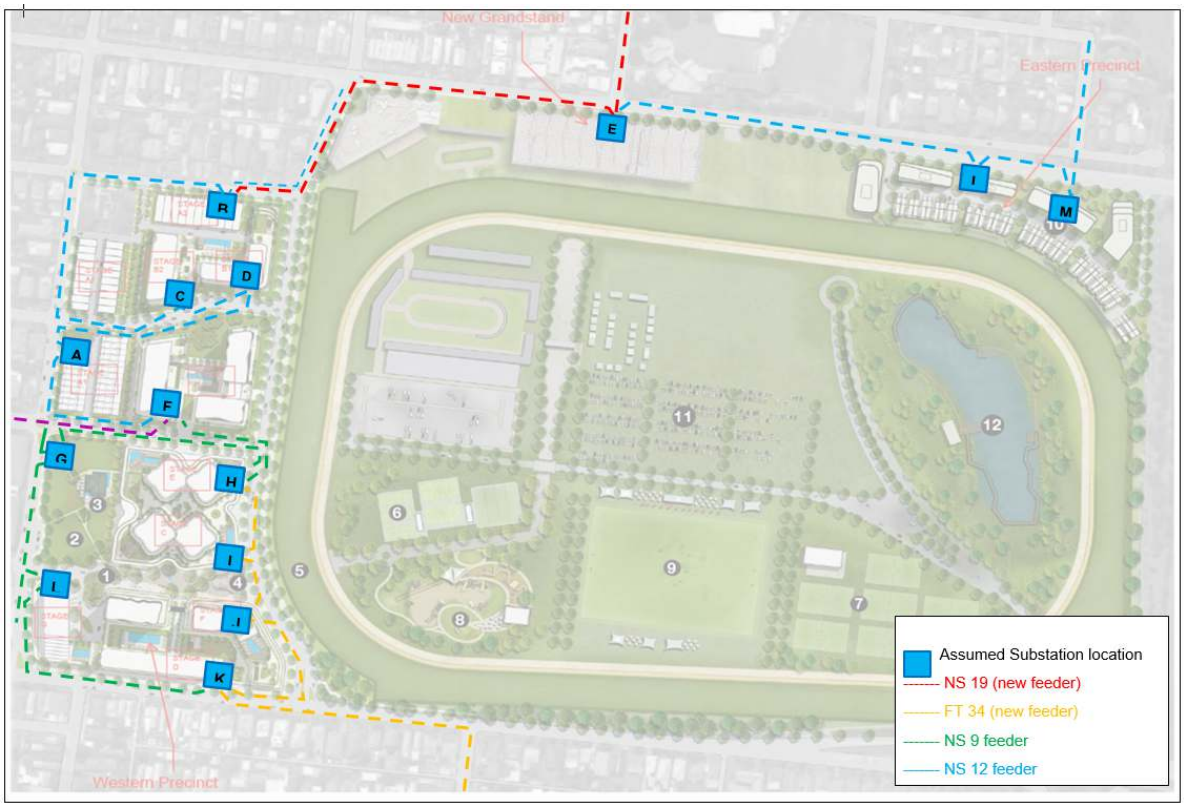
Moonee Valley Racing Club is situated within JEN distribution area and is bounded by Wilson St, McPherson St, Thomas St and Dean St in Moonee Ponds. The site is currently supplied by two 11 kV feeders, NS9 and NS12, from NS Zone Substation.

On 22 November 2017, MVRC released their vision and plan for the redevelopment of the entire site which includes:

- a new grandstand, re-oriented racetrack and redeveloped infield activated for community and major event use;
- new community, business, recreation and leisure facilities;
- an adjacent residential precinct of 2,000 dwellings.

The geographic area of the proposed development with the staging plan is depicted in Figure 1–4.

Figure 1–4: Moonee Valley Development Master Plan



[3] "*RP-NCPA-NWA-2014-170 JEN Load Demand Forecast*", September 2019.

[redacted]

[redacted]

[redacted]

[redacted] The existing 22 kV sub-transmission lines will not have sufficient capacity to support increasing demand at NS Zone Substation supply area.

The sub transmission loop is currently operating above its N-secure rating. The new load at NS will elevate the N and N-1 risk on the sub transmission lines. Jemena will not be able to provide safe and reliable supply to customers at North Essendon Zone Substation without addressing the line capacity constraints within the 2021-2026 regulatory period.

1.4 SUB-TRANSMISSION LINE UTILISATION AND FORECAST

Electricity supply to NS Zone Substation is provided by three radial 22 kV sub-transmission lines (BTS-NS 176, BTS-NS 190 and BTS-NS 193) supplied from AusNet Services' Brunswick Terminal Station (BTS). The sub transmission lines are predominantly running along CitiPower distribution area.

BTS-NS 190 and BTS-NS 193 are running on CitiPower poles for approximately 1,500m from the terminal station. These lines are sharing poles with CitiPower BTS-BK sub-transmission lines.

Table 1-2 shows the current rating of the sub-transmission lines.

Table 1-2: BTS-NS Sub-transmission line rating

	Summer (A)	Winter (A)
BTS-NS 176	445	445
BTS-NS 190	400	400
BTS-NS 193	420	445

Based on the load flow analysis carried out using PSSE software, for an outage of one of the BTS-NS 22 kV lines at a time of peak demand in summer 2021/22, the remaining BTS-NS 22 kV lines is forecast to be overloaded by up to 63% (representing up to 19.5 MVA of load at risk and equivalent to approximately 4,500 customers at risk of being load shed), and by summer 2025/26 this thermal overloaded condition is forecast to exceed 90% of the line rating (representing up to 23.1 MVA of load at risk; under this condition the entire load at NS Zone Substation is at risk under single contingency condition affecting 10,575 customers).

Overloading 22 kV lines beyond their thermal rating will also cause overhead conductors to sag excessively and will cause long term damage to assets. Excessive conductor sagging has a risk of the statutory line clearance limits being infringed. The substandard clearance could lead to accidents (such as vehicles contacting overhead conductors and sagged 22 kV lines being in contact with subsidiary 11 kV circuits). Table 1-3 and Table 1-4 show the utilisation of the 22 kV lines under N and N-1 condition for the forward planning period.

Table 1-3: Sub transmission line utilisation under system normal (N)

	2021/22	2022/23	2023/24	2024/25	2025/26
BTS-NS 176	91%	94%	97%	101%	105%
BTS-NS 190	98%	102%	105%	110%	113%
BTS-NS 193	97%	100%	102%	107%	112%

Table 1-4: Sub transmission line utilisation under outage condition (N-1)

	2021/22	2022/23	2023/24	2024/25	2025/26
BTS-NS 176	150%	155%	159%	167%	175%
BTS-NS 190	163%	167%	173%	181%	190%
BTS-NS 193	159%	164%	169%	177%	185%

Further to this risk, due to the double circuit line construction for the sub-transmission lines as shown in Figure 1–1, there is a likely chance of losing two 22 kV sub-transmission lines during a single contingency event such as vehicle accidentally running into the pole. This could potentially lead to an outage of the whole NS Zone Substation due to subsequent overload on the remaining line. This will affect approximately 10,575 customers supplied from NS Zone Substation. Besides this, NS Zone Substation has limited transfer capacity available to neighbouring ES and PV Zone Substation. Based on the current demand forecast, approximately 5.0 MVA of load can be transferred out of NS Zone Substation to ES and PV Zone Substation in summer 2019/20 under contingency condition.

1.5 ZONE SUBSTATION UTILISATION AND FORECAST

As discussed in Section 1.2, the transformers at NS Zone Substation was replaced in 2017. NS Zone Substation has three 22 kV/11-6.6 kV 12/18 MVA dual winding transformers. The station is radial fed by the sub transmission lines. There are no 22 kV bus tie CB's at NS Zone Substation.

Table 1-5 shows the rating of NS Zone Substation after the completion of the transformer replacement project.

Table 1-5: NS Zone Substation Rating

	Summer	Winter
N Rating	54.0 MVA	54.0 MVA
N-1 Rating	36.0 MVA	36.0 MVA

Table 1-6 shows the maximum demand forecast for NS Zone Substation for the forward planning period.

Table 1-6: NS Zone Substation Demand Forecast

	2021/22	2022/23	2023/24	2024/25	2025/26
Summer – 50 POE (MVA)	35.7	36.7	37.6	38.9	40.4
Summer – 10 POE (MVA)	41.9	42.7	43.9	45.6	47.3

Based on the above forecast, there is sufficient capacity at the zone substation under system normal condition to supply the area in the forward planning period. Under N-1 contingency event, there is emerging load at risk at the zone substation level. However, Jemena is not planning for any augmentation in the next regulatory period.

1.6 FEEDER UTILISATION AND FORECAST

Table 1-7 below shows the projected summer loading and utilisation of NS feeders over the regulatory period (2021 to 2026) under 10% POE forecast condition.

Table 1-7: Projected summer loading and utilisation of NS feeders under 10% POE

Feeder	Rating	2021/22	2022/23	2023/24	2024/25	2025/26
NS-007	305	61%	63%	66%	69%	72%
NS-008	345	49%	48%	48%	49%	49%
NS-009	375	58%	62%	72%	81%	85%
NS-011	375	94%	97%	101%	105%	109%
NS-012	285	73%	75%	78%	107%	145%
NS-014	375	82%	84%	86%	89%	91%
NS-015	285	89%	87%	87%	88%	88%
NS-016	305	40%	39%	39%	40%	40%
NS-017	190	93%	93%	93%	95%	96%
NS-018	305	91%	109%	120%	132%	146%

Feeder	Rating	2021/22	2022/23	2023/24	2024/25	2025/26
Average Utilisation		**73%**	**76%**	**79%**	**85%**	**92%**

Feeders NS-011, NS-012 and NS-018 are forecasted to be overloaded during the next regulatory period. Network augmentation projects have been proposed as part of the JEN Distribution Feeders Network Development Strategy paper to mitigate this risk. Hence, it will not be assessed in this document.

2. IDENTIFIED NEED

The sub transmission lines supplying North Essendon Zone Substation is currently operate above its thermal rating under single contingency condition and will not have enough capacity to supply the increasing load at NS Zone Substation. This is mainly driven by the proposed development at Moonee Valley racecourse. Major risks associated with operating assets above rating are:

- Increased risk of breaching statutory clearances (green book) on bare overhead conductors;
- Increased risk of failure of equipment (e.g. cables, joints, etc.) when equipment is pushed to operate well above its design limits; and
- Inability to restore all lost supplies in the event of a line outage.

Furthermore, two of the sub transmission lines are running along the same pole line, increasing the likelihood of an N-2 outage. Under an N-2 outage the entire load at NS Zone Substation will be at risk, affecting 10,575 customers. NS Zone Substation also has limited transfer capability to neighbouring PV and ES Zone Substation. Based on the current forecast, in 2019/20 summer NS Zone Substation only has 5.0 MVA transfer capability to PV and ES Zone Substations.

3. OPTIONS

The following options to alleviate the emerging constraints in North Essendon (NS) Zone Substation were investigated:

- Option 1: Do nothing (Base Case);
- Option 2: Upgrade one 22 kV line from BTS-NS to 690A;
- Option 3: Reconductor existing three sub transmission lines from BTS to NS to operate at 620A;
- Option 4: Upgrade all three 22 kV lines from BTS-NS to 690A;
- Option 5: Convert existing sub transmission lines from 22 kV to 66 KV lines;
- Option 6: Build new feeders from PV and ES Zone Substation to take load away from BTS-NS loop
- Option 7: Battery Storage Solution
- Option 8: Demand management for first two years, then Option 4
- Option 9: Embedded Generation.

3.1 STUDY ASSUMPTIONS

In evaluating net economic benefits, the following assumptions are used to calculate the annualised value of expected unserved energy (EUE) for all the options analysed in this paper:

- Value of Customer Reliability (VCR) of $41,331 per MWh[4];
- Average line outage rate is calculated based on Jemena historical data;
- Average supply restoration time for underground assets is 8 hours and overhead assets is 4 hours,
- Load duration curve = (MW) readings, from 1 April 2018 to 31 March 2019 inclusive, scaled to match projected sum of line peak demands.

3.2 PROJECT OBJECTIVE AND ASSESSMENT CRITERIA

Consistent with the augmentation obligations defined in the regulatory instruments, in particular the National Electricity Objective set out in the National Electricity Law and the capital expenditure objectives set out in Clause 6.5.7 (a) of the NER, JEN's distribution system planning objectives are:

- To provide safe, cost effective, efficient, reliable supply that meets target levels of performance;
- To maximise utilisation of existing assets; and
- To determine the most cost-effective means of developing the network to meet future loading requirements and customer needs.

[4] Refer Network Augmentation Planning Criteria - JEN PR 0007, for details.

A project aimed at alleviating a distribution system constraint should proceed if it minimises the net economic cost to customers, having regard to the:

- Relative costs and benefits, including any change in supply reliability, of network augmentation and non-network alternatives to the augmentation;
- Uncertainty of assumptions that must necessarily be made in the decision analysis;
- Total asset life cycle costs; and
- Need to comply with environmental and land-use planning standards, health and safety standards, and applicable technical standards.

As per JEN PR 0007 Network Augmentation Planning Criteria, for the sub-transmission network, a probabilistic planning methodology is adopted.

3.3 OPTION 1: DO NOTHING (BASE CASE)

The "Do Nothing" option presents the forecast energy at risk assuming none of the identified network augmentation options are implemented. It is used as a reference or the "Base Case", against which all of the credible options are compared and shows the comparative benefits of each credible option.

The risks associated with the "Do Nothing" option, as highlighted earlier, are:

- Increased risk of breaching statutory clearances (green book) on bare overhead conductors;
- Increased risk of failure of equipment (e.g., cables, joints, etc.) when equipment is pushed to operate well above its design limits;
- Inability to restore all lost supplies in the event of loss of a NS sub-transmission line during peak demand period;
- Deterioration of supply reliability due to capacity shortfall; and
- Intangible costs to Jemena arising from negative publicity generated due to longer than expected supply restoration time.

Table 3-1 summarises the annualised value of the expected unserved energy (EUE) for the BTS-NS sub-transmission lines for the base case over the next ten years (2020-2029).

The value of expected unserved energy (EUE) is calculated based on the assumptions listed in Section 3.1.

Table 3-1: Value of Expected Unserved Energy (EUE) – Do Nothing

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	116.9	155.8	220.1	300.8	326.0	363.4	408.7

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89

3.4 OPTION 2: UPGRADE ONE OF THREE 22 KV SUB TRANSMISSION LINE TO 690A

This option looks at upgrading one of the 22 kV lines to 690A. The existing BTS-NS 176 and BTS-NS 193 running along the same pole line will be paralleled to be a single circuit. Table 3-2 below shows the new rating of the sub transmission lines on completion of this scope.

Table 3-2: Sub Transmission Line Rating on completion of Option 2

	Summer	Winter
BTS-NS Circuit 1 (Old BTS-NS 176 & 193)	690 A	690 A
BTS-NS Circuit 2 (Old BTS-NS 190)	455 A	455 A
BTS-NS Circuit 3 (New Circuit)	535 A	535 A

3.4.1 BTS-NS SUB TRANSMISSION LINES WORK

This option will parallel the existing BTS-NS 176 and BTS-NS 193 lines running along the same pole line from Albion St to NS Zone Substation to form a single line. The existing feeder backbone of BTS-NS 176 will be uprated to increase the rating of this circuit to 690A.

On completion of the above work, the existing BTS-NS 193 feeder backbone from BTS terminal station to Albion St will be out of service. This feeder exit from BTS terminal station will be used to run a new line to NS Zone Substation. The new line will be limited by the section of overhead conductors that are currently running on CitiPower poles.

Refer to Appendix A for the proposed route of the new 22 kV sub transmission lines on completion of this scope.

The primary scope of this option includes:

- Replace approximately 100m of feeder exit cables from AusNet Brunswick terminal station with new 2x300mm^2 Cu cable.
- Thermally uprate 1250m of existing BTS-NS 176 overhead conductor from BTS terminal station to Albion St to achieve a maximum rating of 690A.
- Use existing feeder backbone of BTS-NS 193 to run the new line. Run approximately 1400m of new 2x3C 300mm^2 Cu cable from Albion St to a new cable head pole at Moreland Rd.

  Note: At Albion St the existing line BTS-NS 193 will be paralleled with BTS-NS 176 to form a single circuit.

- Replace sub transmission cable at NS from the cable head to circuit breaker and from circuit breaker to the transformer to achieve a maximum rating of 690A.
- Run approximately 5,500m 37/3.75AAC conductor along existing pole line from Moreland Rd to North Essendon Zone Substation. The existing 22 kV pole line needs to be redesigned to accommodate two 22 kV lines.

Note: From Moreland Rd, the new 22 kV sub transmission line will share pole with existing 22 kV Coburg South (CS) feeders.

- The new line will be undergrounded across existing rail crossing and along the Tullamarine freeway. The cable should maintain a minimum rating of 690A across the crossings.

The total cost of this option is estimated to be $8,706k in 2019 dollars. Table 3-3 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-3: Value of EUE and Market Benefits – Option 2

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	2.4	6.4	14.9	27.7	31.6	38.3	46.9
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	$0.10	$0.27	$0.62	$1.14	$1.30	$1.58	$1.94
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	-	-	-	$4.7	$6.2	$8.5	$11.3	$12.2	$13.4	$15.0

This option will mitigate the N-1 risk on the lines for the short term. However, there will be residual risks on the lines as detailed below.

This option will eliminate the existing N-2 risk on the sub transmission lines by having independent route for all the three lines from BTS to NS Zone Substation. However, two of the three sub transmission lines will be sharing the same pole line with CitiPower sub transmission lines to Brunswick (BK) Zone Substation.

3.4.2 RESIDUAL RISK

This option will not fully eliminate the expected unserved energy at risk under the sub transmission lines. The below identified risk will remain in the lines after the completion of this option:

- This option will not eliminate the risk on the sub transmission lines. This risk will increase over time and is expected to be approximately $1.14M by summer 2025/26.
- Under this option the sub transmission lines will still have significant N risk from summer 2024/25. Based on the analysis approximately 14.9MWh energy is at risk during summer 2024/25.
- Under this option Jemena will still share poles with CitiPower to run two circuits from BTS terminal station. Running assets on other Distribution Business assets will increase the complexity of future upgrade requirement. Due to technical requirements, Jemena will have to over invest and upgrade CitiPower lines as well if more capacity is required at NS in the future.

3.4.3 DELIVERABILITY RISK

The identified issues that can impact the deliverability of this proposed option include:

- The proposed route for the new BTS to NS sub transmission involves multiple tramway crossing, a rail and a major freeway crossing. No field assessment has been completed along the route. Crossing tramway, railway and major freeway could add significant risk to the project cost and delivery timeframe
- The underground section of the new feeder from Albion St to Moreland Rd is within CitiPower distribution area. JEN has limited information about assets around that area.
- The proposed work is along well established residential area, hence extensive community consultation will be required to manage stakeholder expectations.
- Work along major roads such as Moreland Rd, Albion Rd and Tullamarine Freeway might require crews to work outside normal business hours and might require extensive traffic management.

3.4.4 OPTION 2 - ECONOMIC ANALYSIS

The total project cost of upgrading one sub transmission line to 690A and to run a new line from BTS-NS is estimated to be $8.71M (real $2019 with overheads). Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-4 shows that this option has positive net present value and is economically viable.

Table 3-4: Economic analysis of Option 2

	Total
Present Value of Costs	$7.2M
Present Value of Benefits	$47.9M
Net Present Value (NPV)	$40.7M

3.5 OPTION 3: RECONDUCTOR EXISTING THREE SUB TRANSMISSION LINES FROM BTS TO NS TO OPERATE AT 620A

This option looks at reconductoring and thermally uprating sections of the three radial 22 kV lines from BTS terminal station to have a minimum rating of 620A. This scope involves upgrading section of the lines running on CitiPower poles. This work will require Jemena to upgrade CitiPower lines which are on the same pole line with Jemena.

Table 3-5 below shows the new rating of the sub transmission lines on completion of this scope.

Table 3-5: Sub Transmission Line Rating on completion of Option 3

	Summer	Winter
BTS-NS Circuit 1 (BTS-NS 176)	620 A	620 A
BTS-NS Circuit 2 (BTS-NS 190)	620 A	620 A
BTS-NS Circuit 3 (BTS-NS 193)	620 A	620 A

3.5.1 BTS-NS SUB TRANSMISSION LINES WORK

This option looks at thermally uprating and reconductoring section of the three sub transmission lines to achieve a minimum rating of 620A.

The primary scope of this option includes upgrading:

BTS-NS 176

- Replace existing sub transmission line exit cables from BTS terminals with new 2x300mm^2 Cu cable.
- Thermally upgrade approximately 1,800m of overhead conductor to 100 degree Celsius and maximum temperature rise of 75 degree Celsius.
- Reconductor approximately 610m of the sub transmission overhead conductor with new 19/4.75AAC conductor designed to 100 degree Celsius and maximum temperature rise of 75 degree Celsius.
- Replace approximately 50m of sub-transmission underground cable with new 2x3C 300mm2 Cu cable from cable head pole to the NS Transformer No.2.

BTS-NS 190

- Replace existing sub transmission line exit cables from BTS terminals with new 2x300mm^2 Cu cable.
- Reconductor approximately 1,725m of the sub transmission overhead conductor with new 19/4.75AAC conductor designed to 100 degree Celsius and maximum temperature rise of 75 degree Celsius.
- Thermally upgrade approximately 625m of overhead conductor to 100 degree Celsius and maximum temperature rise of 75 degree Celsius.
- Replace approximately 50m of sub-transmission underground cable with new 2x3C 300mm^2 Cu cable from cable head pole to the NS Transformer No.3.

BTS-NS 193

- Replace existing sub transmission line exit cables from BTS terminals with new 2x300mm^2 Cu cable.
- Reconductor approximately 3,800m of the sub transmission overhead conductor with new 19/4.75AAC conductor designed to 100 degree Celsius and maximum temperature rise of 75 degree Celsius.
- Thermally upgrade approximately 1,800m of overhead conductor to 100 degree Celsius and maximum temperature rise of 75 degree Celsius.
- Replace approximately 150m of sub-transmission underground cable with new 2x3C 300mm^2 Cu conductor from cable head pole to the NS Transformer No.1.

Refer to Appendix B for the proposed section of the lines to be upgraded.

The total cost of upgrading the existing sub transmission line from BTS to NS is estimated to be $10,174k in real 2019 dollars with overheads. Table 3-6 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-6: Value of EUE and Market Benefits – Option 3

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	7.3	8.3	10.1	12.3	12.8	13.4	13.9
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	$0.30	$0.34	$0.42	$0.51	$0.53	$0.55	$0.58
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	$-	$-	$-	$4.5	$6.1	$8.7	$11.9	$12.9	$14.5	$16.3

On completion of project, there will be sufficient capacity on the sub transmission lines under system normal condition.

3.5.2 RESIDUAL RISK

This option will not fully eliminate the expected unserved energy at risk under an outage condition of the sub transmission lines. The below identified risk will remain in the lines after the completion of this option:

- This option will not eliminate the existing N-2 risk on the sub transmission lines. Sub transmission lines BTS-NS 176 and BTS-NS 193 are running along the same pole line for the majority of the route. This increases the risk of an N-2 outage on the lines. Under N-2 condition, the entire load at NS Zone Substation is at risk, affecting approximately 10,575 Jemena customers.
- Under this option, Jemena will still share poles with CitiPower to run BTS-NS 190 and BTS-NS 193 from BTS terminal station. Running assets on other Distribution Business assets will increase the complexity of future upgrade for both JEN and CitiPower. Due to technical requirements, Jemena will have to over invest and upgrade CitiPower lines as well if more capacity is required at NS in the future.

3.5.3 DELIVERABILITY RISK

The identified issues that can impact the deliverability of this proposed option include:

- Jemena will have to engage CitiPower to upgrade the two sub transmission lines, BTS-NS 190 and BTS-NS 193, which are running on CitiPower poles. The sub transmission corridor is shared with three other CitiPower sub transmission lines. Upgrading Jemena lines along the corridor will require CitiPower to take outage on all five lines. This is a major risk in delivering the project on time and within budget. Majority of the work will be conducted during night under light load condition. This option requires CitiPower to install costly backup generators at Brunswick (BK) Zone Substation to ensure supply can be maintained during the duration of the construction works.
- The sub transmission lines, BTS-NS 176 and BTS-NS 193, which are on the same pole line from Albion St are running along CitiPower distribution area. Sections of these lines have CitiPower LV assets along it. Jemena will have to coordinate with CitiPower to identify and redesign the LV along the pole line. This will add further risk in delivering the project to within budget.

- The proposed work is along well established residential area, hence extensive community consultation will be required to manage stakeholder expectations.

3.5.4 OPTION 3 - ECONOMIC ANALYSIS

The total project cost of upgrading all three sub transmission line from BTS to NS to 620A is estimated to be $10.17M (real $2019 with overheads). Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-7 shows that this option has positive net present value and is economically viable.

Table 3-7: Economic analysis of Option 3

	Total
Present Value of Costs	$8.5M
Present Value of Benefits	$50.2M
Net Present Value (NPV)	$41.7M

3.6 OPTION 4: UPGRADE ALL THREE 22 KV SUB TRANSMISSION LINE TO 690A

This option looks at upgrading all three 22 kV sub transmission lines from BTS to NS to 690A rating. This option will parallel existing lines BTS-NS 176 and BTS-NS 193 running along same pole line from Albion St. The existing overhead conductors on CitiPower poles will be retired and replaced with new underground cables from BTS terminal station rated to 690A.

Table 3-8 below shows the new rating of the sub transmission lines on completion of this scope.

Table 3-8: Sub Transmission Line Rating on completion of Option 4

	Summer	Winter
BTS-NS Circuit 1 (Old BTS-NS 176 & 193)	690 A	690 A
BTS-NS Circuit 2 (Old BTS-NS 190)	690 A	690 A
BTS-NS Circuit 3 (New Circuit)	690 A	690 A

3.6.1 BTS-NS SUB TRANSMISSION LINES WORK

On completion of this option, there will be three radial 22 kV sub transmission line from BTS which will follow independent route to JEN NS Zone Substation. The sub transmission lines running on the same pole line (BTS-NS 176 and BTS-NS 193) will be paralleled to form a single circuit out of BTS terminal station. This option will eliminate the existing N-2 risk on the lines caused by a single outage due to the sub-standard double circuit pole line construction.

The primary scope of works for this option includes:

- Replace approximately 100m of exit cables of BTS-NS 176 feeder from AusNet Services' BTS terminal station with new 2x300mm^2 Cu cable to achieve minimum rating of 690A.
- Thermally uprate 1,250m of existing BTS-NS 176 overhead conductor from BTS terminal station to Albion St to achieve a maximum rating of 690A.
- From Albion St, parallel the exiting BTS-NS 193 and BTS-NS 176 to form a single circuit.

- Run approximately 2,500m of new 2x300mm^2 Cu cable from BTS terminal station to a new cable head pole in Moreland road. This will be a new circuit from BTS terminal station, however will use the existing BTS-NS 193 breaker.
- The new feeder will run overhead from Moreland Rd and will share pole with existing 22 kV Coburg South (CS) feeders.
- Run approximately 5500m 37/3.75AAC conductor along existing pole line from Moreland Rd to North Essendon Zone Substation. The existing 22 kV pole line needs to redesigned to accommodate two 22 kV lines.
- The new feeder will be undergrounded across existing rail crossing and along the Tullamarine freeway. The cable should maintain a minimum rating of 690A across the crossings.
- Replace existing feeder exit of BTS-NS 190 cable from BTS terminal station by running approximately 2,500m of 2x3C 300mm^2 Cu cable to existing pole at Moreland St. Open existing line by removing conductor between pole A066784 and A066785.
- Retire existing feeder backbone (existing line BTS-NS 190 and BTS-NS 193) running on CitiPower lines.
- Replace sub transmission cable at NS for all three lines, from the cable head to circuit breaker and from circuit breaker to the transformer to achieve a maximum rating of 690A.

Refer to Appendix C for the proposed route for this option.

The total cost of upgrading the existing sub transmission lines from BTS to NS is estimated to be $11,524k in real 2019 dollars with overheads. Table 3-9 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-9: Value of EUE and Market Benefits – Option 4

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	0	0	0	0	0	0	0
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	0	0	0	0	0	0	0
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	$-	$-	$-	$4.8	$6.4	$9.1	$12.4	$13.5	$15.0	$16.9

On completion of the project, there will be sufficient capacity on the sub transmission lines under system normal and single contingency conditions.

3.6.2 RESIDUAL RISK

There will be almost zero residual risk on the sub transmission lines on completion of this project for the next 10 years. With this option, all three sub transmission lines will be following independent routes. The chance of a N-2 failure due to a single contingency event will be eliminated under this option.

3.6.3 DELIVERABILITY RISK

The identified issues that can impact the deliverability of this proposed option include:

- The proposed route for the new BTS to NS sub transmission involves multiple tramway crossing, a rail and a major freeway crossing. No field assessment has been completed along the route. Crossing tramway, railway and major freeway could add significant risk to the project cost and delivery timeframe
- The underground section of the new feeder from BTS terminal station to Moreland Rd is within CitiPower distribution area. JEN has limited information about assets around that area.
- The proposed work is along well established residential area, hence extensive community consultation will be required to manage stakeholder expectations. The new feeder will be overhead for majority of the route. However, it will be installed along areas that already have 22 kV lines (JEN CS 22 kV feeders).

3.6.4 OPTION 4 - ECONOMIC ANALYSIS

The total project cost of upgrading three sub transmission lines to 690A is estimated to be $11.5M (real $2019 with overheads). Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-10 shows that this option has a net present value and is economically viable.

Table 3-10: Economic analysis of Option 4

	Total
Present Value of Costs	$9.6M
Present Value of Benefits	$52.4M
NPV – Net market benefit	$42.8M

3.7 OPTION 5: CONVERT EXISTING SUB TRANSMISSION LINES TO 66 KV LINES AND RUN 2 X 66 KV SUB TRANSMISSION LINES FROM BTS TO NS

This option looks at converting the existing 22/11 kV NS Zone Substation to 66/11 kV station. This will then allow two new 66 kV lines to be installed running from AusNet Services' BTS 220/66 kV switchyard to NS upgraded 66/11 kV station. The new 66 kV lines will be fully rated to 1025A. On completion of this work, there will be sufficient capacity on the sub transmission loop for the foreseeable future.

Table 3-11 below shows the new rating of the sub transmission lines on completion of this scope.

Table 3-11: Sub Transmission Line Rating on completion of Option 5

	Summer	Winter
BTS-NS 66 kV Circuit 1	1025 A	1105 A
BTS-NS 66 kV Circuit 2	1025 A	1105 A

3.7.1 BTS-NS SUB TRANSMISSION LINES WORK

This option require extensive work at BTS terminal station and at Jemena's NS Zone Substation to convert the existing station from 22/11 kV to 66/11 kV Zone Substation.

The primary scope of works for this option includes:

BTS 66kV and BTS 22kV Terminal Stations

- Retire existing three 22 kV circuit breaker at the 22 kV bus at BTS terminal station. Retire the existing 22 kV feeder exit cable from BTS terminal station.
- Secure two new 66 kV breakers at BTS 66 kV bus. The new breakers should be from different buses at BTS.

BTS-NS 66 kV Circuit 1

The new 66 kV BTS-NS circuit 1 will follow the same pole line as the existing BTS-NS 176 which is currently owned by Jemena. Hence, this circuit will be fully overhead from the terminal station to NS Zone Substation.

- Retire existing 22 kV conductors (BTS-NS 176 and BTS-NS 193[5]) running along the 22 kV pole line from BTS terminal station to NS Zone Substation.
- Replace existing poles along the route to accommodate the new 66 kV lines. This route will run along CitiPower distribution area. Sections of the existing 22 kV poles has CitiPower LV assets. Jemena will have to coordinate with CitiPower to identify and redesign the LV along the pole line.
- Run approximately 4,500m of new 37/3.75 AAC conductors from BTS terminal station to NS Zone Substation to have minimum cyclic rating of 1,025A.

BTS-NS 66 kV Circuit 2

The new BTS-NS circuit 2 will follow the same pole line as the existing BTS-NS 190 circuit. However, sections of the line from BTS terminal station to Moreland Rd are on CitiPower poles. Hence, the new circuit will be undergrounded from BTS to Moreland Rd.

- Run approximately 1,500m of new 66 kV 3x 1200mm² AL XLPE underground cable from BTS terminal station to a new cable head pole in Moreland Rd.
- From Moreland Rd the new circuit will follow the existing circuit BTS-NS 190 pole line. Replace existing poles along the route to accommodate the new 66 kV lines.
- Run approximately 3,500m of new 37/3.75 AAC conductor from BTS terminal station to NS Zone Substation to have a minimum rating of 1,025A.

[5] BTS-NS 193 is sharing pole with the current BTS-NS 176 from Albion St to NS Zone Substation.

NS Zone Substation Works

At NS Zone Substation all upstream equipment including the Zone Substation transformer needs to be replaced to convert the station to 66/11 kV.

- Replace existing 3 x 12/18MVA, 22/11 kV transformer with new 2 x 20/33MVA, 66/11 kV transformers. The No.1 transformer will connect to existing Bus No.1 and the No.2 transformer to Bus No.3.
- Install 2 new 66 kV buses at NS Zone Substation. The new 66 kV buses to have line CBs for circuit 1 and 2 and a bus-tie CB.
- Replace 22 kV isolators and disconnectors with new 66 kV isolators and disconnectors.
- Replace existing 22 kV incoming feeder cables to new 66 kV cables.

The total cost of converting the sub transmission lines to 66 kV and to convert the station from a 22/11 kV station to 66/11 kV is estimated at $27,900k in 2019 dollars. Table 3-12 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-12: Value of EUE and Market Benefits – Option 5

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	0	0	0	0	0	0	0
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	0	0	0	0	0	0	0
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	$-	$-	$-	$4.8	$6.4	$9.1	$12.4	$13.5	$15.0	$16.9

3.7.2 RESIDUAL RISK

There will be no residual risk on the sub transmission lines on completion of this project. There will be sufficient spare capacity available on the loop for the foreseeable future.

3.7.3 DELIVERABILITY RISK

The identified issues that can impact the deliverability of this proposed option include:

- Majority of the works for the new circuits will be completed in CitiPower distribution area. Jemena has limited information about the current assets around the area (both underground and overhead assets). This could have an impact on the cost and timely delivery of the project.

- Jemena NS Zone Substation is located in a well-established area and has limited space for future expansion. The feasibility of upgrading the 22 kV bus work to new 66 kV bus needs further investigation as space constraint could prevent this option from implementation, and as such, this option may be considered as non-credible. Due to the site limitation, even if it is constructible, this could affect the deliverability of this option.
- The proposed plan to run overhead 66 kV line along well established residential area will require extensive community consultation. This could add significant cost to the project and can affect the timely delivery of the option.
- There is a risk of not having spare breakers at BTS terminal station at the time of project initiation. The spare CBs need to come from separate bus. In this case, further work will be required at BTS terminal station to extend the 66 kV bus to create new feeder CBs. This will add more cost to the project. However, this risk is considered to be low as BTS terminal station was recently upgraded.

3.7.4 OPTION 3 - ECONOMIC ANALYSIS

The total project cost of converting existing sub transmission line from 22 kV to 66 kV lines and to upgrade NS Zone Substation from 22/11 kV to 66/11 kV is estimated to be $27.9M in 2019 dollar. Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-13 shows that this option has a positive net present value and is economically viable.

Table 3-13: Economic analysis of Option 5

	Total
Present Value of Costs	$23.3M
Present Value of Benefits	$52.4M
NPV – Net market benefit	$29.1M

3.8 OPTION 6: BUILD NEW FEEDER FROM PV AND ES ZONE SUBSTATION TO TAKE LOAD AWAY FROM BTS-NS LOOP

This option looks at transferring load away from NS Zone Substation to neighbouring Essendon (ES) and Pascoe Vale (PV) Zone Substation. Currently, there is limited transfer capability between the adjacent zone substations. Hence, transfer point needs to be built to take load away from NS Zone Substation which would involve establishing new feeders from adjacent 11 kV zone substations. Section 3.8.1 and Section 3.8.2 looks at the existing capacity at the zone substations and sub transmission loop to accommodate the new load from NS.

This option will result in the NS Zone Substation being underutilised due to existing sub transmission lines constraint.

3.8.1 SUB TRANSMISSION LOOP CAPACITY

3.8.1.1 KTS-MAT-AW-PV-KTS

The KTS-MAT-AW-PV-KTS 66 KV sub transmission loop supplies the Melbourne Airport Zone Substation (MAT), Airport West Zone Substation (AW), Pascoe Vale Zone Substation (PV) and Tullamarine Zone Substation (TMA). The transmission supply point for the loop Keilor Terminal station (KTS).

Jemena has a committed augmentation project to address the identified thermal capacity constraint for this loop. This project involves splitting of the existing KTS-MAT-AW-PV-KTS sub-transmission loop into a KTS-AW-PV-

KTS, and a KTS-TMA-MAT sub-transmission loop by constructing a new KTS-AW 66 kV line, and a new KTS-MAT 66 kV line. The project is due for completion by summer 2020/21. Table 3-14 shows the rating of the line post the augmentation work.

Table 3-14: Sub Transmission Line Rating – KTS-TMA-MAT-AW-PV

	Summer	Winter
KTS-TMA rating	101.7 MVA	105.7 MVA
KTS-AW1 rating	117 MVA	126 MVA
KTS-AW2 rating	117 MVA	126 MVA
KTS-CUST1 rating	117 MVA	126 MVA
KTS-PV rating	101.7 MVA	105.7 MVA

There is sufficient capacity on the loop to accommodate additional load from BTS-NS sub transmission lines.

3.8.1.2 KTS-BY-ES-KTS

The KTS-BY-ES-KTS 66 kV sub-transmission loop supplies Braybrook Zone Substation (BY) and Essendon Zone Substation (ES). The transmission supply point for this loop is Keilor Terminal Station (KTS).

Jemena has project proposed to upgrade the existing sub transmission loop. The project will be completed by summer 2020/21. Table 3-15 shows the rating of the sub transmission line post the augmentation work.

Table 3-15: Sub Transmission Line Rating – KTS-TMA-MAT-AW-PV

	Summer	Winter
KTS-BY rating	101.7 MVA	105.7 MVA
KTS-ES rating	117.0 MVA	126.0 MVA

There is sufficient capacity on the loop to accommodate additional load from NS zone substation.

3.8.2 ZONE SUBSTATION CAPACITY

3.8.2.1 ES Zone Substation

Essendon Zone Substation (ES) comprises two 66/11 kV 20/27 MVA transformers and two 11 kV buses supplying eleven 11 kV feeder lines. ES supplies areas of Essendon, Moonee Ponds, Ascot Vale and Niddrie. Table 3-16 shows the forecast load on the ES Zone Substation for the forward planning period.

Table 3-16: ES Zone Substation Forecast

	N Rating	N-1 Rating	2021/22	2022/23	2023/24	2024/25	2025/26
Summer 10POE (MVA)	54.0	36.0	45.2	45.0	45.2	45.5	45.6
Winter 10POE (MVA)	54.0	37.3	28.8	28.8	28.7	28.7	28.7

Although the substation has a N nameplate rating of 54 MVA, the station is currently limited by 66/11 kV transformer circuit breakers i.e. to maintain secure operation, the total station load should not exceed each of the transformer circuit breakers. The ES transformer circuit breakers is rated to 47.6 MVA therefore it limits the station to an N secure rating of 47.6 MVA. However as part of the ES transformer replacement project that is currently in the delivery phase, the station will not have any load at risk over the next 5 years once this project is completed in 2020.

3.8.2.2 PV Zone Substation

Pascoe Vale Zone Substation (PV) comprises two 66/11 kV 20/33 MVA transformers, one 66/11 kV 10 MVA and three 11 kV buses supplying nine 11 kV feeder lines. PV supplies areas of Pascoe Vale, Glenroy, Strathmore and Oak Park.

The substation has a N rating of 64.0MVA. Table 3-17 shows the forecast load on the PV Zone Substation for the forward planning period.

Table 3-17: PV Zone Substation Forecast

	N Rating	N-1 Rating	2021/22	2022/23	2023/24	2024/25	2025/26
Summer 10POE (MVA)	64.0	45.6	41.9	41.2	41.0	40.9	40.8
Winter 10POE (MVA)	64.0	45.6	27.9	27.5	27.1	26.9	26.7

There is no risk under the Zone Substation under system normal and single contingency conditions.

3.8.3 NEW FEEDER WORKS

The scope of this option looks at running new feeders from ES and PV Zone Substations to take load away NS Zone Substation, hence reducing the risk on the 22 kV BTS-NS sub transmission lines. This option will run two new feeders rated at 375A to take 10MVA load away from NS Zone Substation.

The primary scope of works for this option includes:

New Feeder from PV

- Use the existing spare CB (PV-025) to run the new feeder to create a new tie with NS Zone Substation.
- Run approximately 2,200m of new 240mm^2 AL XLPE cable from PV Zone Substation to a new cable head pole located at Napier St. The new feeder will have a minimum rating of 375A. The proposed route will have to cross the railway near Gaffney St.
- Reconductor approximately 700m of overhead conductor with new 19/3.25 AAC conductor.
- Install new manual gas switch on pole A090386 and leave it as normally open.

New Feeder from ES

Currently there are no spare circuit breaker at JEN ES Zone Substation. As part of the ES transformer replacement project, a new No.3 bus will be installed which will have spare circuit breakers.

- Run approximately 2,500m of new 240mm^2 AL XLPE cable from ES Zone Substation to a new cable head pole located at Leake St. The new feeder will have a minimum rating of 375A.

- The new feeder will take load away from NS-08 and NS-017.
- Install two new manual gas switches and leave it as normally open.

The total cost of running two new feeders from ES and PV is estimated at $7,999k in real 2019 dollars. Table 3-18 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-18: Value of EUE and Market Benefits – Option 6

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	11.2	12.8	18.0	28.1	31.2	36.0	42.3
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	$0.46	$0.53	$0.74	$1.16	$1.29	$1.49	$1.75
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	$-	$-	$-	$4.4	$5.9	$8.4	$11.3	$12.2	$13.5	$15.1

3.8.4 RESIDUAL RISK

This option will not fully eliminate the expected unserved energy at risk under the sub transmission lines. The below identified risk will remain in the lines after the completion of this option:

- This option will not eliminate the risk on the sub transmission lines. This risk will increase over time and is expected to be approximately $1.16M by summer 2025/26. This may require further work in the regulatory period 2026-31 to manage and mitigate the risk.
- Under this option, the sub transmission lines will have significant risk from summer 2025/26. Based on the analysis approximately 28.1MWh energy is at risk during summer 2025/26.

In addition to this, the project will increase the residual risk on existing network assets:

- The sub transmission line KTS-BY-ES will be operating close to capacity under system contingency condition after the proposed transfer from NS. Adding more load on the loop will increase the chance of a more expensive sub transmission loop augmentation project in the future, which is not factored in this documented.
- Transferring more load onto ES and PV Zone Substations will place both stations with supply risks under N-1 condition.

3.8.5 DELIVERABILITY RISK

The identified issues that can impact the deliverability of this proposed option include:

- The proposed new feeders from ES and PV has multiple railway and tram crossing. No field assessment has been completed along the route. Crossing tramway and railway could add significant risk to the project cost and delivery timeframe.
- The project is dependent on the successful completion of multiple network projects (KTS-MAT-AW-PV-KTS loop project, KTS-BY-ES sub transmission project). If any of the project deliverable date changes it could affect the deliverability of this option.
- The new feeders will run along well established Essendon and Pascoe Vale area. The proposed feeder from ES will run along busy Buckley St. This might require excessive traffic management and could result in more night works. This will impact the cost and timely deliverability of the project.
- ES Zone Substation does not have any spare breaker to run the new feeder. However, as part of the ES transformer replacement project, Jemena is adding a new No.3 bus at ES Zone Substation. The proposed scope is depended upon the successful completion of the ES transformer replacement project.

3.8.6 OPTION 6 - ECONOMIC ANALYSIS

The total project cost for running two new feeders from ES and PV to transfer load away from NS is estimated at $8.0M in 2019 dollar. This project will relieve the risk on the sub transmission lines for the short term. However, the residual risk will be significant from summer 2025/26 that would likely to require JEN to initiate another project during the regulatory period 2026-31, which has not been taken into account as part of this economic assessment. Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-19 shows that this project has a positive net present value and is economically viable.

Table 3-19: Economic analysis of Option 6

	Total
Present Value of Costs	$6.7M
Present Value of Benefits	$47.5M
NPV – Net market benefit	$40.8M

3.9 OPTION 7: INSTALL NEW ENERGY STORAGE SYSTEM

This option looks at installing grid scale batteries to mitigate the existing risk on the sub transmission lines. The battery system will be used to mitigate the system normal risk on the sub transmission lines.

In order to analyse this option, it is assumed that the grid battery will be installed at NS Zone Substation or close to NS Zone Substation and will be connected to the 11 kV bus using a new feeder. Table 3-20 shows the MW/MWh required to mitigate the system normal risk at NS sub transmission lines.

Table 3-20: Load at Risk BTS-NS Sub Transmission Line Under System Normal

Battery	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
MW	7.1	7.5	8.7	9.5	10.8	12.7	14.6	15.0	15.7	16.4
MWh	33.1	36.1	47.3	55.0	67.1	85.5	103.9	108.6	115.9	123.5

Based on the analysis, a 16MW/120MWh battery will be required at NS to mitigate the system normal risk on the BTS-NS 22 kV sub transmission lines for the next 10 years. The current NS Zone Substation does not have space

to install the battery. Jemena will have to procure new land close to NS Zone Substation to install this new battery system.

Based on an average cost of $1,930 per kW and $480 per kWh[6] the total cost of installing the new energy storage system at NS Zone Substation is estimated at $92,000k[7] in 2019 dollars. Table 3-21 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-21: Value of EUE and Market Benefits – Option 7

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	31.9	34.3	38.1	42.0	42.9	44.0	45.2
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	$1.32	$1.42	$1.57	$1.73	$1.77	$1.82	$1.87
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	$-	$-	$-	$3.5	$5.0	$7.5	$10.7	$11.7	$13.2	$15.0

3.9.1 RESIDUAL RISK

This option will not fully eliminate the expected unserved energy at risk under the sub transmission lines. The below identified risk will remain in the lines after the completion of this option:

- This option will not mitigate the N-1 risk on the sub transmission lines. Under single contingency condition, load will be shed from NS Zone Substation under this option.
- This option will not mitigate the existing N-2 risk on the sub transmission lines. Both BTS-NS 176 and BTS-NS 193 lines will still be running along the same pole line and an outage on both circuits (e.g. vehicle impact on the common pole line) could result in the loss of the entire supply at NS Zone Substation.
- The proposed energy storage system will only mitigate the system normal risk on the sub transmission lines for the next ten years. If maximum demand continues to increase at NS Zone Substation, then additional batteries may be required to address the system normal risk.

3.9.2 DELIVERABILITY RISK

The deliverability risk for this option is high due to the following constraints:

- North Essendon being a well-developed suburb, it will be extremely difficult to find a suitable real estate to install the grid scale battery systems which requires a large footprint.

6 National Renewable Energy Lab, US, https://www.nrel.gov/docs/fy19osti/71714.pdf

7 This report used a conversion rate of $1.45 AUD for $1.00 USD

- Compared to other utility assets like kiosk and pole top transformers, grid scale batteries are fairly new technology. The safety concerns of installing large grid scale battery systems next to residential houses needs to be assessed. This could lead to additional cost to account for risk mitigation methods.
- NS Zone Substation does not have any spare 11 kV breaker to connect the energy storage system. The 11 kV bus will have to be extended to add new circuit breakers. No field assessment has been conducted to identify the feasibility of extending the bus at NS. The lack of space to extend the bus at NS could result in significant increase in the cost of the project. Note this cost has not been taken into account in the economic assessment.

3.9.3 OPTION 7 - ECONOMIC ANALYSIS

The total project cost of installing a new grid scale 16MW/120MWh battery is estimated at $92.0M in 2019 dollars. Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-22 shows that this option does not have a positive net present value and is not economically viable.

Table 3-22: Economic analysis of Option 7

	Total
Present Value of Costs	$76.8M
Present Value of Benefits	$44.5M
NPV – Net market benefit	-$32.3M

3.10 OPTION 8: DEMAND MANAGEMENT IN FIRST TWO YEARS, THEN OPTION 4

This option looks at demand management for the first two years, followed with the implementation of Option 4 as outlined in Section 3.6 above. Effectively, this option is looking at deferring the capital expenditure in Option 4 by two years using demand management.

Demand management schemes have the potential to reduce peak demand on the electricity network and thereby defer the requirement for network augmentation. This is achieved by customers shifting their usage to off-peak or reducing their overall consumption by using energy efficient appliances and reducing energy wastage.

Demand management schemes could include interruptible loads offered in return for a reduced electricity price, innovative tariffs that will encourage customers to reduce their usage during peak periods.

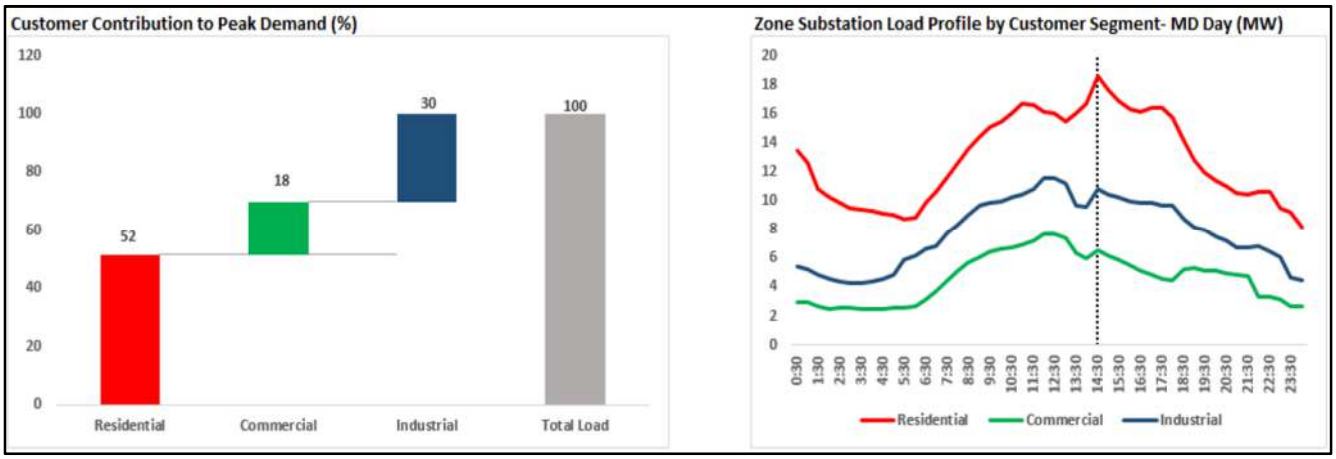
NS Zone Substation area supplies approximately 10,525 JEN customers. The zone substation is mainly supplying residential customers. Table 3-23 shows the customer segments under NS Zone Substation.

Table 3-23: Customer Number NS Zone Substation

Customer Segment	Number
Residential	9,620
Commercial	879
Industrial	26

Figure 3–1 below shows the customer contribution to peak demand at NS Zone Substation. Commercial and Industrial customers account for approximately 15 MW load during peak demand.

Figure 3–1: NS Customer Contribution to Peak Demand



At the time of preparation of this development plan there were no known proponents for demand management on the JEN network in the NS supply area. Proponents for demand management are encouraged to express their interest to JEN at any time.

Based on an average set up fee of $60,000 MW[8] and a dispatch fee of $5,000 per MWh[9] the total cost of initiating the demand management programme for two year is estimated at $1,389k in 2019 dollars. This option will defer the network project from 2023 to 2025. Following this, Jemena will need invest $11.5M ($2019) in 2025 to mitigate the risk on the sub transmission lines. Table 3-24 summarises the annualised value of the expected unserved energy (EUE) and market benefit for this option over the next ten years (2020-2029).

Table 3-24: Value of EUE and Market Benefits – Option 8

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
50PoE Summer Forecast (MVA)	34.4	34.8	35.7	36.7	37.6	38.9	40.4	40.8	41.3	42.0
10PoE Summer Forecast (MVA)	40.5	40.8	41.9	42.7	43.9	45.6	47.3	47.7	48.3	49.0
Weighted average EUSE (MWh)	64.0	69.7	92.9	31.9	34.3	0	0	0	0	0
Weighted average EUSE ($M)	$2.65	$2.88	$3.84	$1.32	$1.42	0	0	0	0	0
EUSE-Base Case ($M)	$2.65	$2.88	$3.84	$4.83	$6.44	$9.10	$12.43	$13.47	$15.02	$16.89
Market Benefits ($M)	$-	$-	$-	$3.5	$5.0	$9.1	$12.4	$13.5	$15.0	$16.9

8 The setup fee is annual fee spend to reserve capacity to reduce demand.

9 The dispatch fee is paid per event for the amount of energy reduced

3.10.1 RESIDUAL RISK

Demand Management will not eliminate the risk on the sub transmission lines. The below identified risk will remain on the loop during the two years when demand management will be implemented:

- This option will not mitigate the N-1 risk on the sub transmission lines. Under single contingency condition, load will be shed from NS Zone Substation.
- The N-2 risk on the sub transmission lines will remain with demand management. The chance of a double circuit outage of BTS-NS 176 and BTS-NS 193 will remain under demand management. This places the whole load at NS Zone Substation at risk.

On completion of the network project, there will be almost zero residual risk on the sub transmission lines for the next 10 years.

3.10.2 DELIVERABILITY RISK

The deliverability risk of managing load by demand management is considered high due to the following identified issues:

- North Essendon Zone Substation is mainly supplying residential customers, there aren't many large customers in this area. Hence, it will be harder to find commercial and industrial demand management customers to participate in the demand management programme; and
- Based on Jemena's experience with residential demand management, the customer sign up for the programme has been low.

3.10.3 OPTION 8 - ECONOMIC ANALYSIS

The total project cost of demand management for two years followed by Option 4 in 2025 is estimated at $13.7M in 2019 dollars. Based on an annual discount rate of 6.20% and a planning horizon of 10 years, Table 3-25 shows that this option does has a positive net present value and is economically viable.

Table 3-25: Economic analysis of Option 8

	Total
Present Value of Costs	$10.3M
Present Value of Benefits	$50.2M
NPV – Net market benefit	$39.9M

3.11 OPTION 9: EMBEDDED GENERATION

Embedded generation can be an alternative for the alleviation of network inadequacies and constraints, thereby deferring the need for major reinforcement projects. In order to defer any network augmentation projects, the embedded generation would need to be connected to, and supply into, the 11 kV distribution network where constraints exist.

At the time of writing this strategy paper, there were no known proponents for connection of embedded generation to the JEN network in the NS supply area. Proponents for embedded generation are encouraged to apply or express their interest to JEN at any time.

4. ANALYSIS OF OPTIONS

Table 4-1 presents a summary of the overall economic analysis of credible options considered in this report.

Table 4-1 Summary of economic analysis results

Option	Option name	Project cost (real $2019)	NPV of Net Market Benefits	Ranking
1	Do Nothing (base-case)	-	-$61.2M	8
2	Upgrade one 22 kV line from BTS-NS to 690A	$8.71M	$40.7M	4
3	Reconductor existing three sub transmission lines from BTS-NS to operate at 620A	$10.17M	$41.7M	2
4	Upgrade all three 22 kV lines from BTS-NS to 690A	$11.5M	$42.8M	1
5	Convert existing sub transmission line from 22 kV to 66 kV	$27.9M	$29.1M	6
6	Build new feeder from PV and ES Zone Substation to take load away from BTS-NS line	$8.0M	$40.8M	3
7	Battery Storage Solution	$92.0M	-$32.3M	7
8	Demand Management for first two years, then Option 4	$13.7M	$39.9M	5

Option 4, upgrading all three lines to 690A from BTS to NS, is the option that maximises the net market benefits compared to all considered options, and is therefore the preferred credible option.

5. RECOMMENDATIONS AND CONCLUSIONS

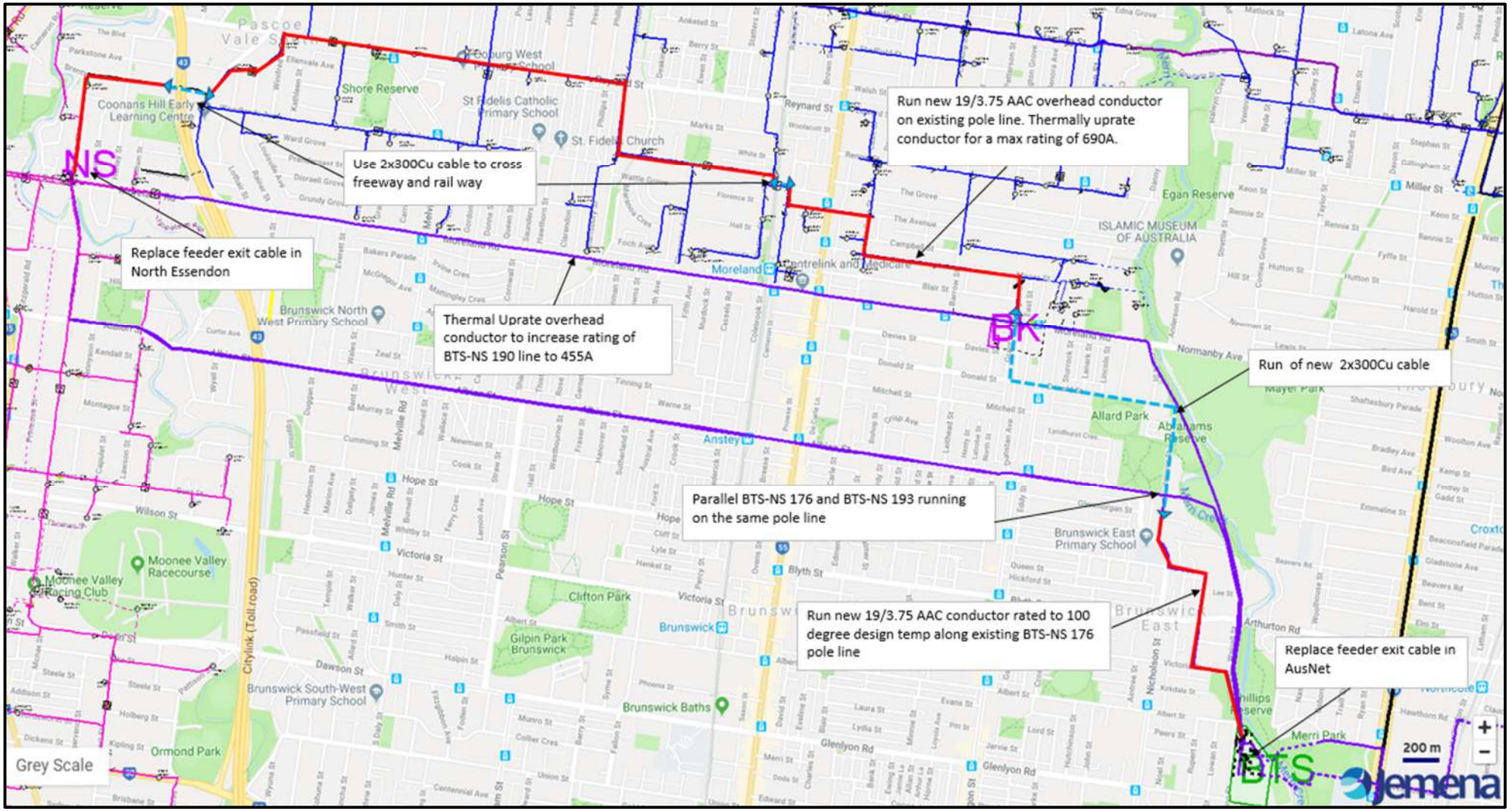
The BTS-NS 22 kV sub transmission lines are currently highly utilised and does not have capacity to meet the projected increase in demand at NS Zone Substation. The sub transmission lines are currently operating above 90% utilisation under system normal condition. The load at NS Zone Substation is expected to grow by 3.2% per annum during the next regulatory period 2021-2026.

A number of options to alleviate the emerging constraints were considered:

- Option 1: Do nothing (Base Case);
- Option 2: Upgrade one 22 kV line from BTS-NS to 690A;
- Option 3: Reconductor existing three sub transmission lines from BTS to NS to operate at 620A;
- Option 4: Upgrade all three 22 kV lines from BTS-NS to 690A;
- Option 5: Convert existing sub transmission lines from 22 kV to 66 KV lines;
- Option 6: Build new feeder from PV and ES Zone Substation to take load away from BTS-NS line;
- Option 7: Battery Storage Solution;
- Option 8: Demand management for first two years, then Option 4; and
- Option 9: Embedded Generation.

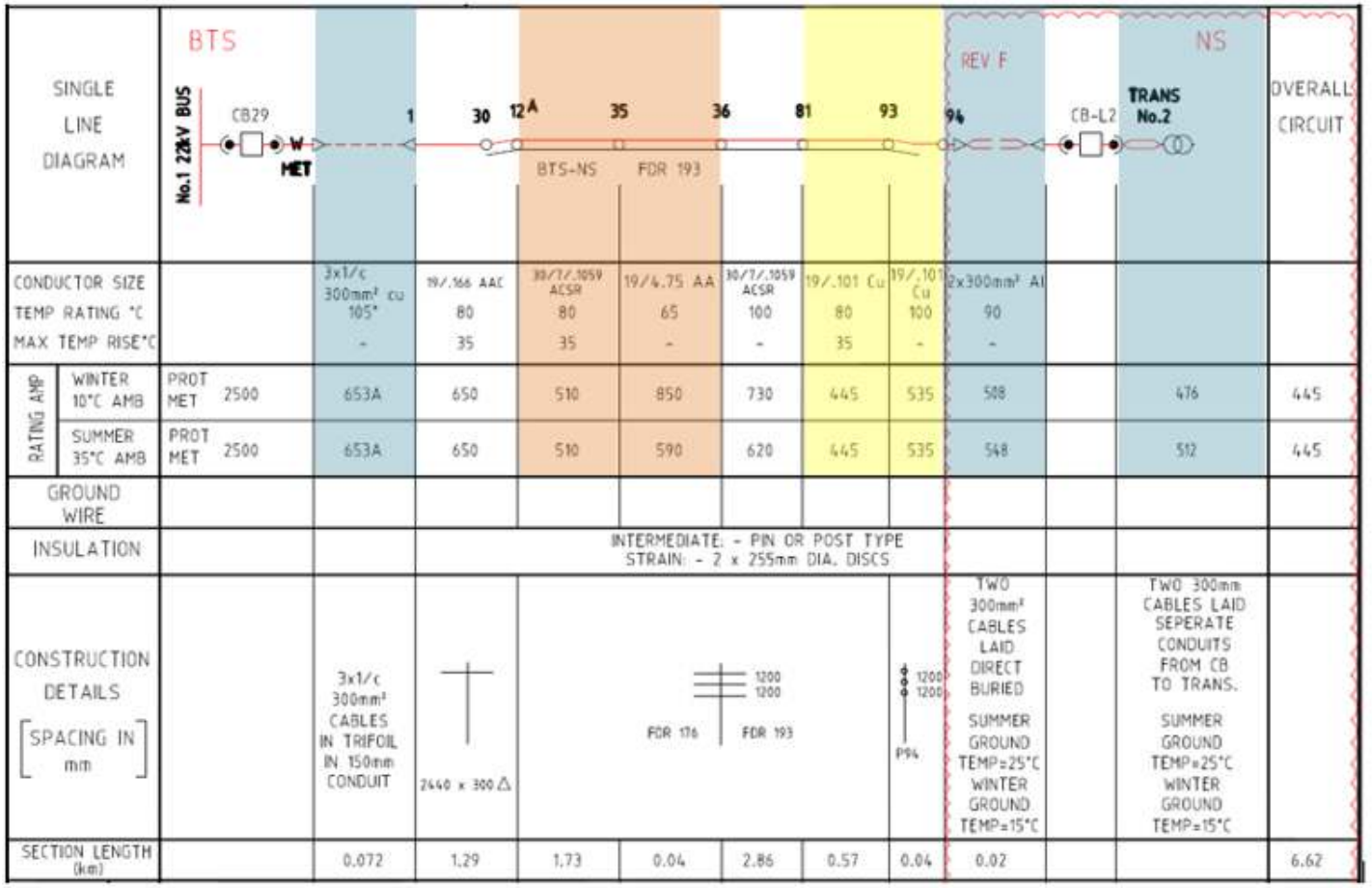
Option 4, upgrading all three BTS-NS 22 kV sub transmission lines to 690A with a total estimated expenditure of $11.5M (in real 2019 dollars), is the option that maximises the net market benefits to customers and is the preferred option. On completion of the project, there will be sufficient capacity on the sub transmission lines under system normal and single contingency condition for the next 10 years. This option has the highest net market benefits and provides the maximum benefit to JEN customers.

6. APPENDIX A: PROPOSED CONFIGURATION OPTION 2

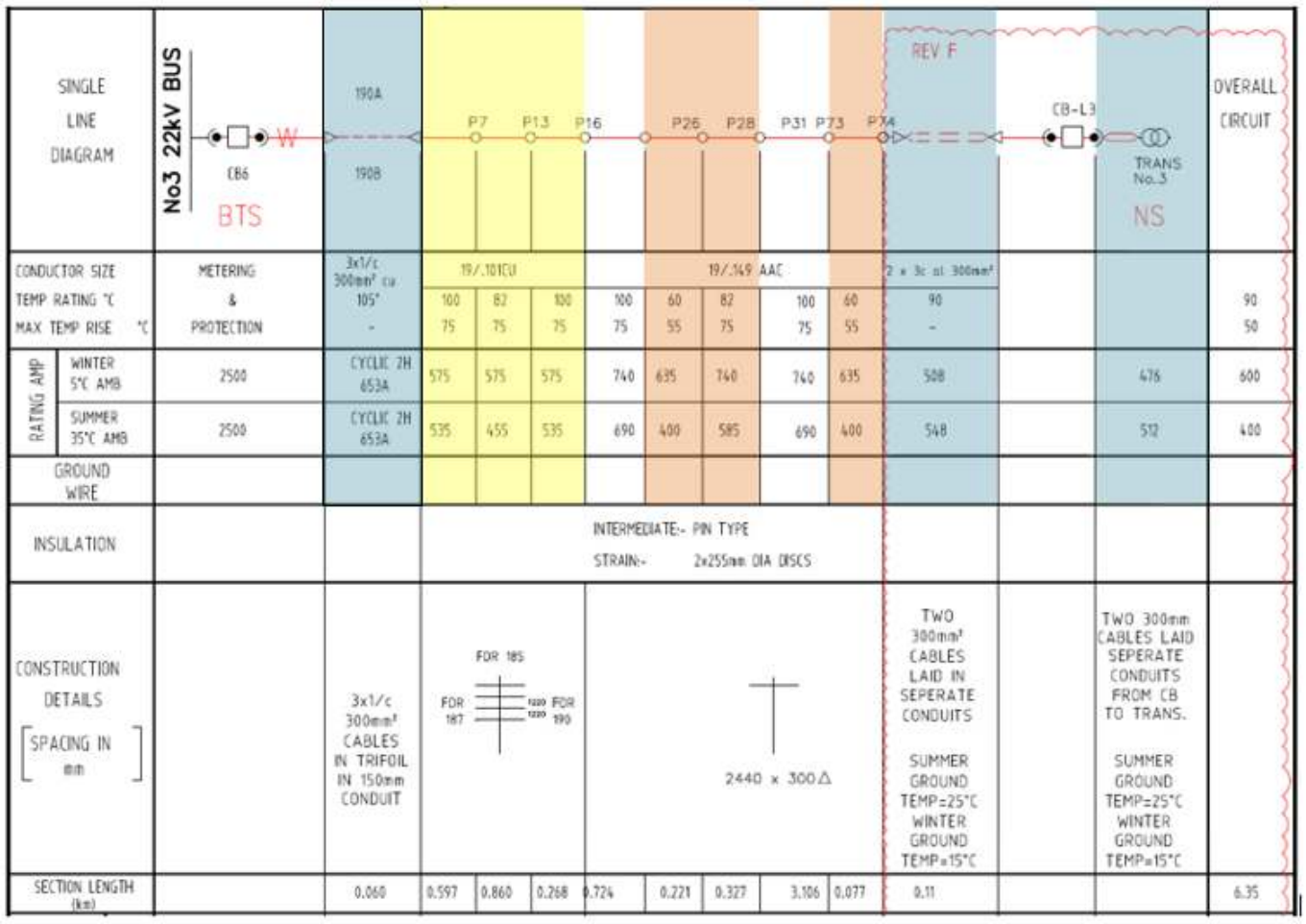


7. APPENDIX B: PROPOSED CONFIGURATION OPTION 3

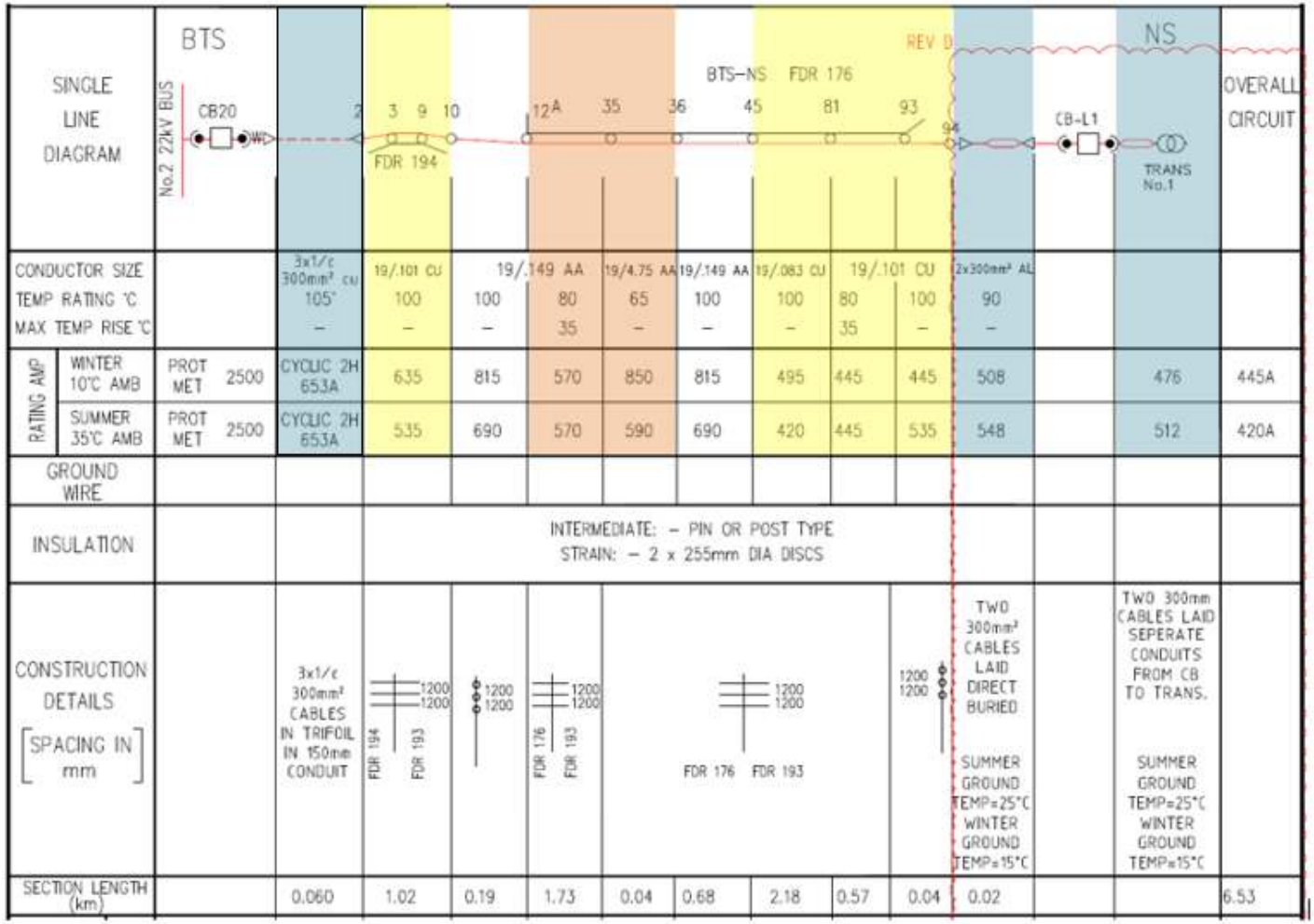
A1. BTS-NS 176



A2. BTS-NS 190


SINGLE LINE DIAGRAM
No3 22kV BUS
CB6
BTS
190A
190B
P7
P13
P16
P26
P28
P31
P73
P74
REV F
CB-L3
TRANS No.3
NS
OVERALL CIRCUIT
CONDUCTOR SIZE
TEMP RATING °C
MAX TEMP RISE °C
METERING & PROTECTION
3x1/c 300mm² cu
105°
-
19/.101CU
19/.149 AAC
2 x 3c cl 300mm²
100 82 100 100 60 82 100 60
75 75 75 75 55 75 75 55
90
-
90
50
RATING AMP
WINTER 5°C AMB
SUMMER 35°C AMB
2500
2500
CYCLIC 2H 653A
CYCLIC 2H 653A
575 575 575 740 635 740 740 635
535 455 535 690 400 585 690 400
508
548
476
512
600
400
GROUND WIRE
INSULATION
INTERMEDIATE:- PIN TYPE
STRAIN:- 2x255mm DIA DISCS
CONSTRUCTION DETAILS
SPACING IN mm
3x1/c 300mm² CABLES IN TRIFOIL IN 150mm CONDUIT
FOR 185
FOR 187
FOR 190
2440 x 300Δ
TWO 300mm² CABLES LAID IN SEPERATE CONDUITS
SUMMER GROUND TEMP=25°C WINTER GROUND TEMP=15°C
TWO 300mm CABLES LAID SEPERATE CONDUITS FROM CB TO TRANS.
SUMMER GROUND TEMP=25°C WINTER GROUND TEMP=15°C
SECTION LENGTH (km)
0.060
0.597 0.860 0.268 0.724 0.221 0.327 3.106 0.077
0.11
6.35
Thermally Uprate
Reconductor
Replace underground cable

A3. BTS-NS 193



8. APPENDIX C: PROPOSED CONFIGURATION OPTION 4