West End Switchgear Replacement and Additional Transformer

Business Case

January 2024

energex

Part of Energy Queensland

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West End zone substation (SSWED) has been identified as one of the critical substations supplying the Olympic Games 2032 infrastructure. It is anticipated the critical loads in the vicinity of SSWED would include the new International Broadcast Centre. Energex demand forecast indicates that the transformer at SSWED will be overloaded under N-1 contingency (for the loss of a 110/11kV transformer at SSWED) by 12MVA. In addition, SSWED will not meet the Safety Net regulatory obligation for an outage of one of the transformers at SSWED from 2031 onwards.

This network investment has been bought forward from 2031 to 2028 to ensure reliable supply for the 2032 Olympic Games in Brisbane.</td></tr>
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<tr><td>$m, direct 2022-23</td><td>$0.53m</td><td>$0.533m</td><td>$4.338m</td><td>$6.447m</td><td>$4.297m</td><td>$16.145m</td></tr>
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<tr><td>Benefits</td><td>In addition to achieving Safety Net compliance, the proposed work will also provide increased supply reliability for the surrounding areas during the 2032 Olympics games.</td></tr>
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2. BACKGROUND

2.1. Network Arrangement

West End Zone Substation (SSWED) is equipped with 2 x 60MVA 110/11kV transformers. SSWED is supplied via 110kV feeders F905 (from Powerlink's Rocklea Substation SSH16) and F830 (from Charlotte Street Zone Substation SSCST) and is equipped with 110kV indoor GIS and a 4-bus 11kV indoor switchgear.

SSWED has four 11kV buses with TR3 supplying BB13, BB16 and TR4 supplying BB14, BB15. There are automatic change over (ACO) schemes for bus section CBs between BB13, BB14 and BB15, BB16. In addition, there is a bus tie between BB14 and BB15. BB14 supplies three remote direct-connect customer substations.

SSWED has been identified as one of the critical substations supplying the Olympic Games 2032 infrastructure. It is anticipated the critical loads in the vicinity of SSWED would include the new International Broadcast Centre.

The SSWED substation customers and loads are summarised below:

- **West End zone substation (SSWED)** – is a 110/11kV zone substation which supplies the Brisbane CBD fringe suburbs of Woolloongabba, South Brisbane, West End, Dutton Park and South Bank totalling 7,789 domestic customers and 1426 business/mixed customers, supplying major customers. The maximum recorded demand was 71.2MVA in Summer 2022/23.

Figure 1 shows a schematic view for SSWED. Figure 2 shows a geographic view for SSWED.

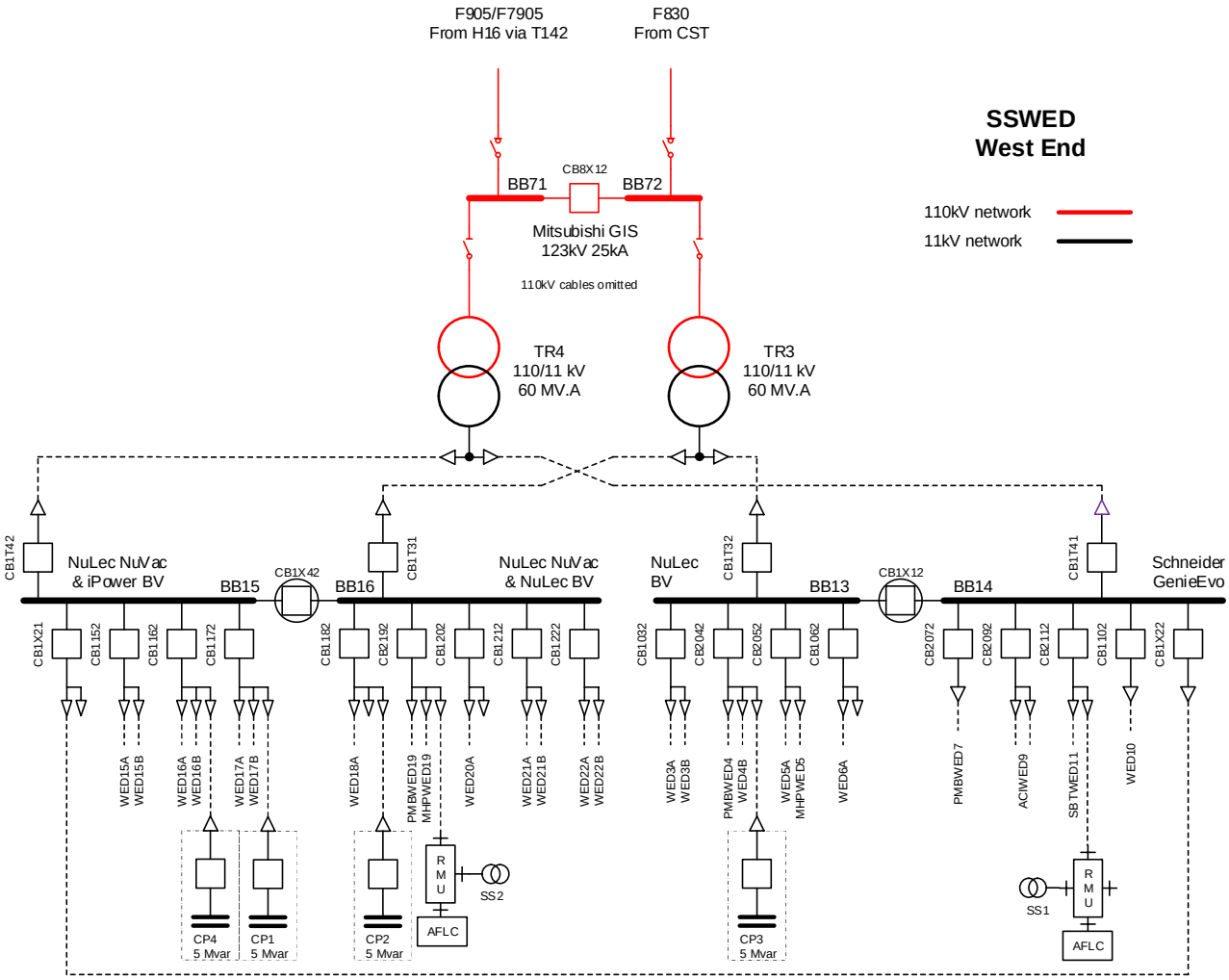

Figure 1 – Existing Arrangement of SSWED Zone Substation

Figure 2 – Geographic view of SSWED Zone Substation supply area

3. IDENTIFIED NEED

The identified need is to ensure supply in the area around the West End area remains compliant with Safety Net requirements, which is a regulatory obligation as outlined in the Distribution Authority.

The identified need for this investment is detailed in the sections below:

- SSWED has been identified as one of the critical substations supplying the Olympic Games 2032 infrastructure. It is anticipated the critical loads in the vicinity of SSWED would include the new International Broadcast Centre (IBC). There will be a breach of Safety Net at SSWED which results in substation load at risk following a N-1 contingency (for the loss of a 110/11kV transformer or supplying 110kV feeder) with the IBC connected.

3.1. Compliance

3.1.1. Sub-transmission Network

Under its Distribution Authority, Energex must adhere to the Safety Net which identifies the principles that apply to the operation of network assets under network contingency conditions. System contingency related capability is assessed against a 50% probability of exceedance (PoE) forecast load, available load transfers, emergency cyclic capacity (ECC) ratings, non-network response, mobile plant, mobile generators, and short-term ratings of plant and equipment where available. SSWED zone substation is classified as Urban, and as such, the following Safety Net criteria apply:

Urban – following an N-1 event:

- No greater than 40MVA (16,000 customers) is without supply for more than 30 minutes
- No greater than 12MVA (5,000 customers) is without supply for more than 3 hours and
- No greater than 4MVA (1,600 customers) is without supply for more than 8 hours

With the current growth in the West End area, it is forecast that SSWED will not meet Energex's Safety Net obligations in 2031.

Further to an assessment against its Safety Net obligations, in accordance with industry practice Energex also undertake an analysis of system capacity under system normal conditions such that no sub-transmission network asset should be operated above its normal cyclic capacity for a 10% probability of exceedance (PoE) load forecast.

The investment has been planned for 2028 to ensure the third transformer is available for the Olympic Games. Since transformers are known to have a high infant mortality rate[1] it is desirable to have the project completed by 2028 to allow time for the transformer to be in service for a few years before the Olympic Games in 2032.

3.1.2. Distribution network Transfer Capability

To meet our Safety Net obligations, Energex needs to maintain adequate automated and manual transfer capability of 6MVA via its 11kV feeders without exceeding their Normal Cyclic Capacities.

3.2. Sub-transmission Network Limitations

The network limitation that the proposed investment aims to address is the inability to supply all load at the West End area following the loss of a 110/11kV transformer or supplying 110kV feeder at SSWED. This is due to the lack of 110kV circuit breakers in the existing arrangement, a fault on the either of the 110kV feeders supplying SSWED will result in having one 110/11kV transformer offline.

[1] J. Marks, D. Martins, T. Saha, O. Krause, A. Alibegovic-Memisevic, G. Russell, G. Buckley, S. Chinnarajan, M. Gibson, T. MacArthur, "An Analysis of Australian Power Transformer Failure Modes, and Comparison with International Surveys", IEEE AUPEC, Australia, Sep. 2016.

3.2.1. West End (SSWED) Substation Limitations

West End Zone Substation (SSWED) is equipped with 2 x 60MVA 110/11kV transformers. SSWED is supplied via 110kV feeders F905 (from Rocklea Substation SSH16) and F830 (from Charlotte Street Zone Substation SSCST) and is equipped with 110kV indoor GIS and a 4-bus 11kV indoor switchgear. The substation capacity is limited by the 11kV transformers provides a NCC, ECC and 2HEC as below:

- Normal Cyclic Capacity (NCC) – 126 MVA
- Emergency Cyclic Capacity (ECC) – 66.8 MVA
- 2 Hour Emergency Capacity (2HEC) – 73.5 MVA

ECC and 2HEC are de-rated due to uneven load sharing on 11kV buses.

- Safety Net Constraint – 76.8 MVA

The Safety Net Constraint includes all capabilities that can be made available within the required restoration timeframe for Urban category, following the loss of a transformer at SSWED. Specifically, this comprises 66.8 MVA of ECC, 6 MVA of manual transfer and 4 MVA of mobile generation.

Figure 3 shows the 50% POE load forecast and security standard constraint for SSWED.

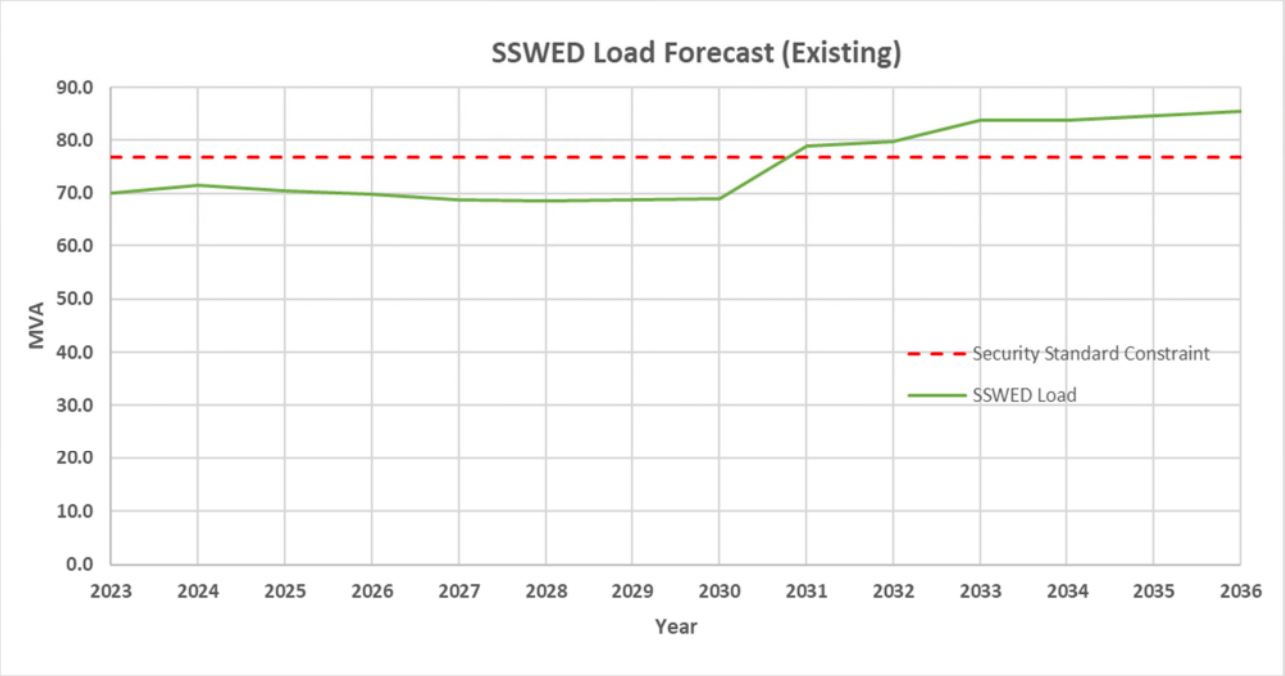

Figure 3 – SSWED Load Forecast

As shown in the above figure, based on the 50%POE load forecast, there is a breach of Safety Net at SSWED. This results in substation Load at Risk (LAR) of approximately 2 MVA in 2030/31 under N-1 conditions after including 6MVA of 11kV manual transfer available for SSWED to transfer load to neighbouring substations.

4. OPTIONS ANALYSIS

In determining the most cost-effective solution to address the identified network limitations, Energex has sought to identify a range of technically feasible, alternative options that could satisfy the network requirements in a timely and efficient manner.

Four options have been identified to address breach of Safety Net at SSWED. Identified options are:

- Option 1: Install the 3rd 110/11kV Transformer and additional 110kV & 11kV Switchgear at SSWED
- Option 2: Install a new zone substation in the South Brisbane area (1 x 60 MVA 110/11kV)
- Option 3: Load transfers between adjacent substations were considered but were subsequently rejected after investigation. Details are provided in Section 4.3.
- Option 4: 30 MW Large Scale Vanadium redox flow battery storage (4hr) for hybrid generation. Estimated cost for land acquisition, equipment and construction costs is $135M. Due to land constraints and higher capital, this option was rejected and is not considered any further.

As a result of this process, Energex has considered two options that represent a practical alternative to address the breach of Safety Net at SSWED in the required timeframe.

4.1. Option 1

This option will help in permanently providing an additional 60MVA capacity at SSWED to address the substation limitation which involves Safety Net breaches at SSWED.

This option involves:

- Construct an enclosure for an additional 60MVA 110/11/11kV transformer and two neutral earthing transformers on Energex owned land adjacent to the existing substation.
- Demolish the redundant 33/11kV transformer enclosures on the eastern side of the existing building. Construct a 110kV GIS room and an 11kV switch room in place of the redundant transformer foundations. Install protection panels to suit one feeder, one transformer, one bus tie and two bus zones. Install standard ancillaries to suit.
- Install a 110/11/11kV transformer with associated neutral earthing transformers.
- Install additional 110kV switchgear compromising of two feeder circuit breakers, one bus coupler and two transformer circuit breakers.
- Cut over existing 110kV cables F830 to new 110kV bus at SSWED.
- Install additional 11kV switchgear compromising of two transformer circuit breakers, one bus coupler and ten feeder circuit breakers.
- Cut over 6x11kV feeders from existing 11kV switchboard to new 11kV switchboard at SSWED.
- Risk cost included in the estimate: Additional land may be required to house the standard plant at the time of design and construction. Purchase of additional land project is already underway.
- Figure 4 provides the proposed network arrangement for Option 1.

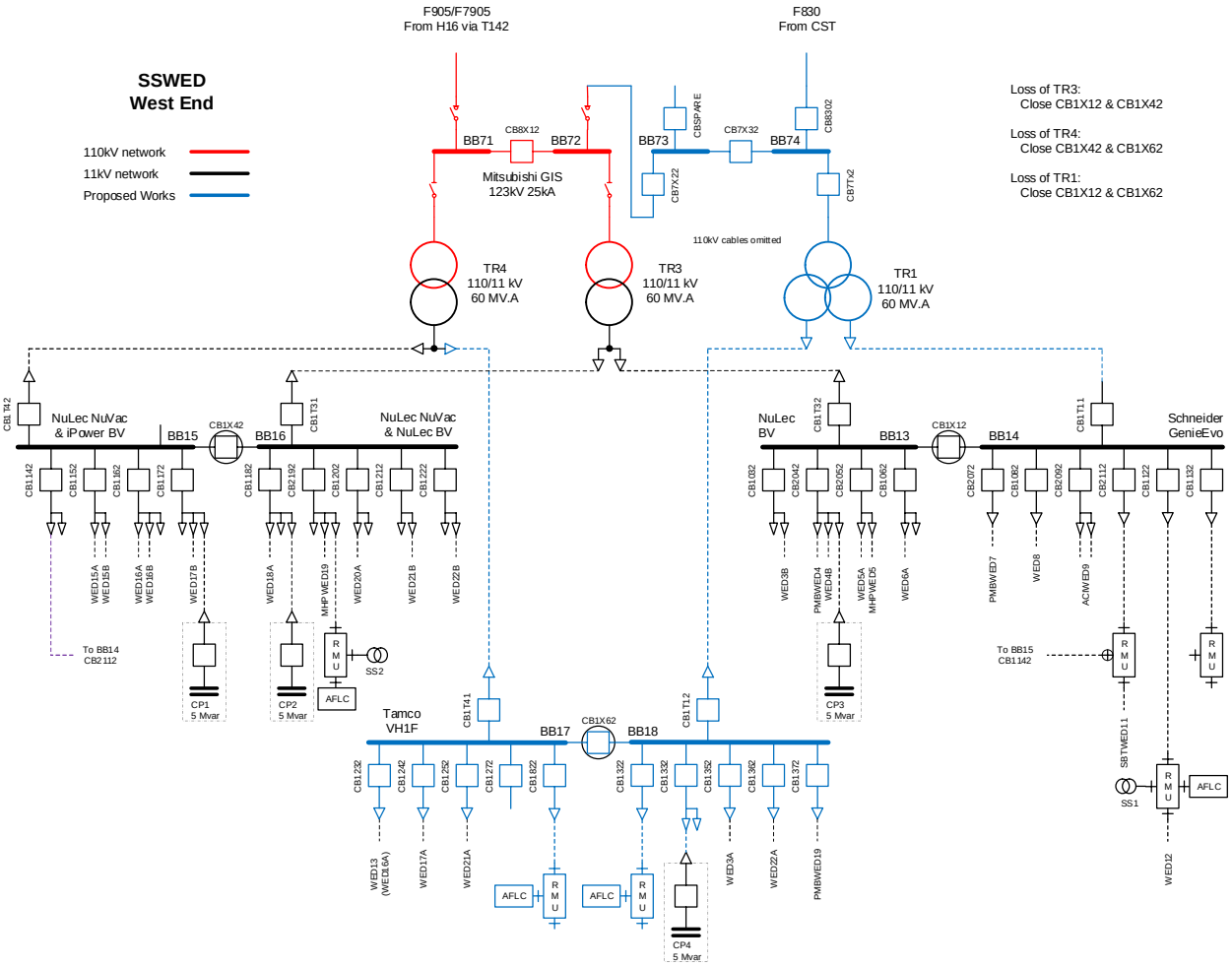

Figure 4 – Option 1 schematic diagram

4.1.1. Costs

The establishment of the third 110/11kV 60MVA transformer at SSWED and installing additional 110kV and 11kV switchgear has been estimated at $16.15m, which has been factored into the NPV as a cost in 2028.

4.2. Option 2

This option involves the establishment of new 110/11kV substation in the South Brisbane area with a single 60MVA transformer and building new 11kV feeders to take load from SSWED to address the Safety Net breaches at SSWED. It is assumed that for the loss of supply for the only transformer at the new substation, there will be a loss of all load other than 12 MVA manual transfers of load to SSWED.

Option 2 involves:

- Establishing a new 110/11kV South Brisbane zone substation (SSSBE) with a single 60MVA transformer.
- Construct new 2.2km of underground 110kV double circuit from Wellington Road (SSWRD).
- The network required date for the above work is 2028.
- The land will need to be acquired for building South Brisbane Zone substation.

Future Stages:

The future works for this option required to meet the network security standard at the new substation as it continues to supply future load in the area:

- Install the 2nd transformer at the new substation in 2047.

Figure 5 provides the proposed network arrangement for Option 2 shown in blue.

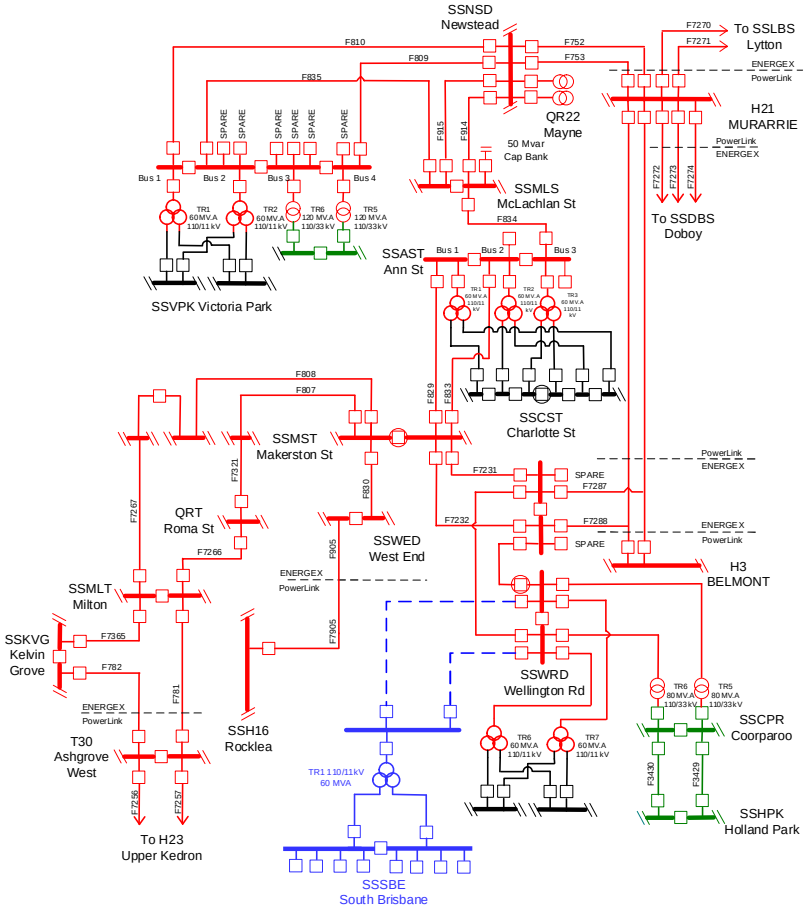

Figure 5 – Option 2 schematic diagram

4.2.1. Costs

The establishment of a new zone substation at South Brisbane with one 60 MVA 110/11kV transformer has been estimated at $35m, which has been factored into the NPV as a cost in 2028. For a future stage, establishment of a new 60 MVA 110/11kV transformer at South Brisbane zone substation has been estimated at $7m, which has been factored into the NPV as a cost in 2047.

4.3. Load transfer Options considered but rejected

Three load transfer options between adjacent substations (Figure 6) were considered but were subsequently rejected after investigation revealed the following.

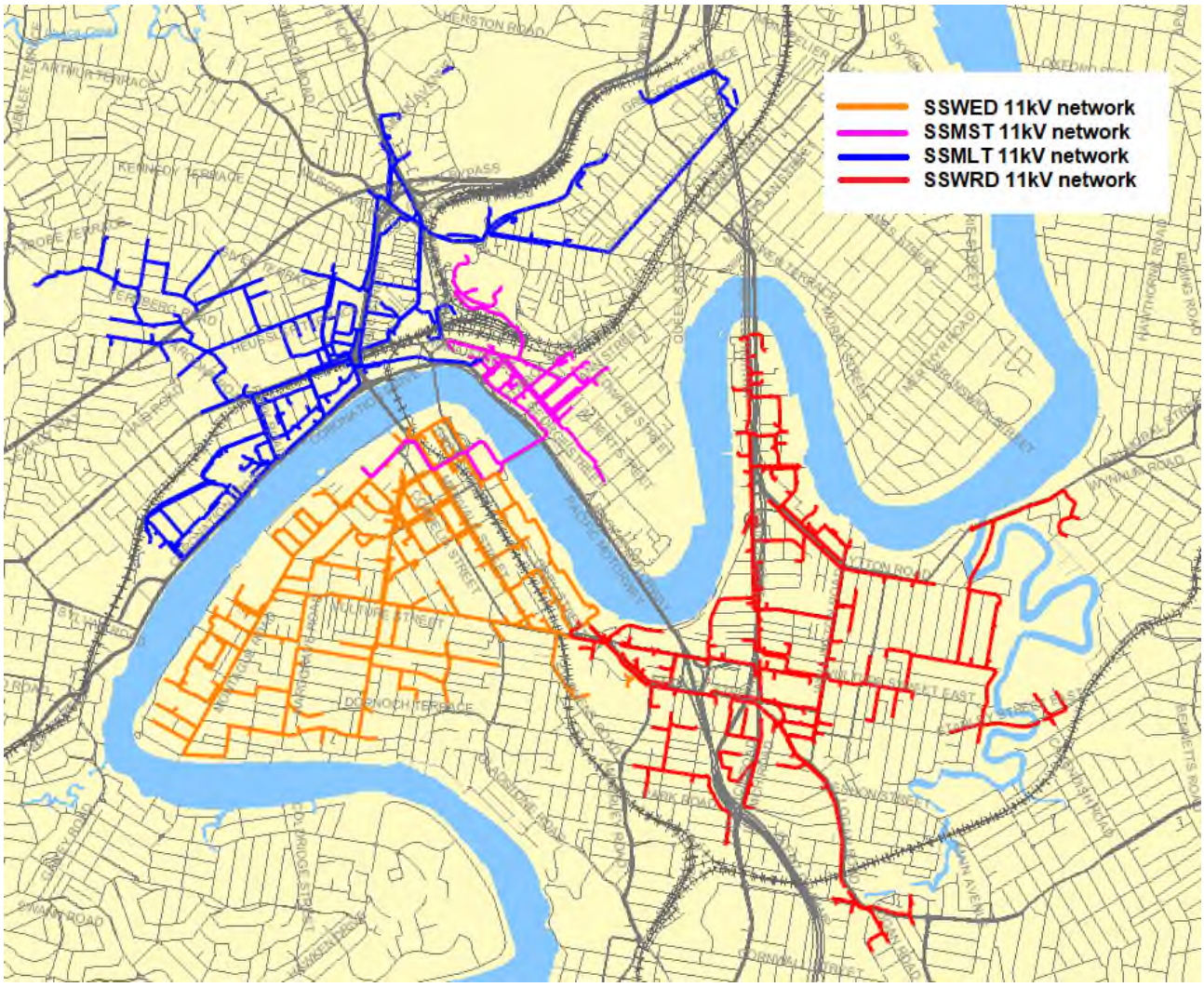

Figure 6 –11kV supply areas of nearby substations

4.3.1. Establish 11kV feeders from Milton zone substation (SSMLT) to West End

The area along the northern bank of the river opposite to West End is supplied by Milton zone substation (SSMLT) and there are three bridges in the area, the Go Between Bridge, Merivale Bridge and William Jolly Bridge that may allow the establishment of 11kV feeders across the river.

A desktop review was carried out and it was determined that there are no conduits available that can carry 11kV cables across the river from SSMLT, the routes from SSMLT to riverside are heavily congested with underground services from multiple utilities. There are also limited circuit breakers at SSMLT which means that any new feeders will have to share a breaker with another feeder, resulting in lower reliability.

4.3.2. Establish 11kV feeders from Makerston Street zone substation (SSMST) to West End

SSMST already supplies a significant amount of load in the West End and South Brisbane area, with feeders coming across the river via Victoria Bridge. There are very limited 11kV feeder positions left on the 11kV switchboard at SSMST, using up these feeder positions will result in SSMST not able to establish new connections in its local supply area.

4.3.3. Establish 11kV feeders from Wellington Road zone substation (SSWRD) to Southbank

The possibility of establishing new 11kV feeders from Wellington Road zone substation (SSWRD) to the Southbank precinct to deload SSWED has been investigated. There are limited 11kV feeder positions left on the 11kV switchboard at SSWRD, using up these feeder positions will result in SSWRD not able to establish new connections in its local supply area. The Cross River Rail, Brisbane Metro and the possible Gabba redevelopment will likely result in new developments and load growth in the area, which is not currently reflected in the forecast, therefore, adding load to SSWRD may create a new limitation.

4.4. Economic Analysis

4.4.1. Cost summary 2025-30

Option 1 to establish a new third 110/11kV 60MVA transformer with associated additional 110kV and 11kV switchgear at SSWED is the preferred option and has been estimated as $16.145m (based on 2022/23 costings). The forecast expenditure by year is shown in Table 1.

Table 1 – Cost summary 2025-30

Option	2025-26	2026-27	2027-28	2028-29	2029-30	Total 2025-30
Option 1: Install the 3rd 110/11kV Transformer and additional 110kV & 11kV Switchgear at SSWED	$0.53m	$1.533m	$4.338m	$6.447m	$4.297m	$16.145m

4.4.2. NPV analysis

From the table below, Option 1 is the lowest cost option. The NPV under the Option 1 is -$13.519m, with the Capex and Opex NPV shown in Table 2. Table 3 shows the results having changed various inputs in the financial model.

Table 2 – Base Case NPV analysis

Option	Rank	Net NPV	Capex NPV	Opex NPV
Install the 3rd 110/11kV Transformer and additional 110kV & 11kV Switchgear at SSWED	1	-$13.519m	-$13.423m	-$0.096m
Install a new zone substation at SSSBE (1 x 60 MVA 110/11kV)	2	-$32.196m	-$31.035m	-$1.161m

Table 3NPV Sensitivity Analysis

Option	Discount rate	
	2.5%	4.5%
Install the 3rd 110/11kV Transformer and additional 110kV & 11kV Switchgear at SSWED	-$14.087m	-$12.937m
Install a new zone substation at SSSBE (1 x 60 MVA 110/11kV)	-$34.068m	-$30.402m

4.4.3. Optimal Timing

Due to the Olympics infrastructure construction restrictions, Energex will be unable to undertake any major infrastructure projects between 2030 and 2033. Therefore, if Energex fails to install the third 110/11kV transformer and additional 110kV switchgear by 2028, it would be unable to be established until 2036 at the earliest. Due to the higher failure rate of transformers during the first few years of operation, optimum timing for this project is by 2028 at the latest to reduce the risk of infantile failure of the new transformer during the Olympic games.

5. RECOMMENDATION

It is recommended to establish the third 110/11kV transformer and additional 110kV and 11kV switchgear to meet the projected load growth at SSWED and enabling Energex to continue to meet the Safety Net regulatory obligation. Table 4 summarises the options under consideration.

Table 4 Options Analysis Scorecard

Criteria	Option 1 – Install the 3rd 110/11kV Transformer and additional 110kV and 11kV switchgear at SSWED	Option 2 – Install a new 1 x 60 MVA 110/11kV zone substation at SSSBE
Net Present Value	-$13.519m	-$32.196m
Delivery time	5 years	5 years
Detailed analysis – Risks	The land adjacent to the existing SSWED substation will need to be acquired to build the 3rd 60MVA 110/11kV transformer safely. Purchase of additional land project is already underway	There is no land available to build new substation at South Brisbane, which could be challenging to acquire. Also establishing a new feeder in the Brisbane CBD may provide some technical challenges.
Detailed analysis - Advantages	This option results in a secure and reliable CBD network.	This option results in a secure and reliable CBD network.

APPENDICES

Appendix 1: Alignment with the National Electricity Rules

Table 5 Recommended Option's Alignment with the National Electricity Rules

NER capital expenditure objectives	Rationale
A building block proposal must include the total forecast capital expenditure which the DNSP considers is required in order to achieve each of the following (the capital expenditure objectives):	
6.5.7 (a) (1) meet or manage the expected demand for standard control services over that period	Section 3, Section 4.1
6.5.7 (a) (2) comply with all applicable regulatory obligations or requirements associated with the provision of standard control services;	Section 3, Section 4.1
6.5.7 (a) (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 standard control services; or (ii) the reliability or security of the distribution system through the supply of standard control services, to the relevant extent: (iii) maintain the quality, reliability and security of supply of standard control services; and (iv) maintain the reliability and security of the distribution system through the supply of standard control services	Section 3, Section 4.1
6.5.7 (a) (4) maintain the safety of the distribution system through the supply of standard control services.	Section 3, Section 4.1
NER capital expenditure criteria	**Rationale**
The AER must be satisfied that the forecast capital expenditure reflects each of the following:	
6.5.7 (c) (1) (i) the efficient costs of achieving the capital expenditure objectives	Section 4.4.1 and Section 4.4.2
6.5.7 (c) (1) (ii) the costs that a prudent operator would require to achieve the capital expenditure objectives	Section 4.4.1 and Section 4.4.2

NER capital expenditure objectives	Rationale
6.5.7 (c) (1) (iii) a realistic expectation of the demand forecast and cost inputs required to achieve the capital expenditure objectives	Section 3.2, Section 4.4.1 and Section 4.4.2

Appendix 2: Reconciliation Table

Table 6 Reconciliation

Expenditure	2025-26	2026-27	2027-28	2028-29	2029-30	2025-30
Expenditure in business case $m, direct 2022-23	0.53m	0.533m	4.338m	6.447m	4.297m	**16.145m**