MARAYONG ZONE SUBSTATION RENEWAL

TS146 - Network Investment Options

Prepared by Asset Strategy and Planning

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Endeavour Energy

REVIEW AND APPROVAL SCHEDULE

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1.0 EXECUTIVE SUMMARY

Marayong Zone Substation is a 33kV/11kV substation located on the corner of Charles, Frederick and Raymond streets, Marayong. The substation was initially constructed during the early 1960s and supplies electricity to 6,500 customers in the suburbs of Marayong, Kings Park, Kings Langley and Lalor Park. The customer distribution is 85% residential and 15% commercial/industrial but from a demand perspective, the load on the substation is 61% industrial.

The purpose of this project is to consider redevelopment options for Marayong Zone Substation to provide for the renewal of assets which have reached the end of their effective service lives to ensure the ongoing safe and reliable operation of the substation.

The original parts of the substation are currently more than 50 years in age and a number of elements including the 11kV switchboard, the auxiliary switchboard and Transformer No. 3 have reached the end of their lives and require renewal in the short-term.

A Network Investment Options (NIO) team was established to consider the renewal options for the substation including:

- Do nothing;
- Implementing demand management strategies;
- An extension of the existing control building to accommodate a new 11kV switchboard;
- Construction of a new 11kV switchroom;
- Construction of a new indoor substation and demolition of the existing substation.

A risk and benefit assessment of the available options concluded that the most beneficial solution for the renewal of Marayong Zone Substation was to replace the substation with a compact indoor design in a single staged approach and to free up the land currently occupied by the substation for other uses.

The recommended redevelopment option provides for:

- New indoor 33kV switchgear, 11kV switchgear, protection, control and auxiliary equipment;
- Three new 33/11kV 25MVA low noise power transformers;
- Undergrounding of the 33kV feeders as they enter the substation;
- Renewal of the first sections of 11kV cables out of the substation; and
- Removal of the existing outdoor substation equipment and remediation of the site.

The cost of the project is estimated to be $19.0 million in real FY18 terms and $19.7 million in nominal terms. The contingency allowance for the project is proposed to be $2.1 million, taking the total, including contingency, to $21.8 million.

The timeframe for the works is 2017/18 – 2020/21. The PIP8.3 has a funding provision of $16.3 million for these works which will be updated as required in the next release of the PIP.

Accordingly, it is recommended that:

- A capital expenditure of $19.7 million to replace Marayong Zone Substation as detailed in this business case be approved;
- A contingency sum of $2.1 million, representing 11% of the project estimated costs to cover unforseen events be approved.

The total project estimate, including base costs and the contingency sum, totals $21.8 million.

2.0 INTRODUCTION

Marayong Zone Substation is a 33kV/11kV substation located on the corner of Charles, Frederick and Raymond streets, Marayong. The substation supplies electricity to 6,500 customers in the suburbs of Marayong, Kings Park, Kings Langley and Lalor Park. The customer distribution is 85% residential and 15% commercial/industrial in terms of number of connections. However, the peak load distribution is 61% industrial, 30% residential and 9% commercial making the substation load predominantly industrial with three high voltage customers accounting for nearly 50% of the peak demand.

The substation was initially constructed during the early 1960s by the Electricity Commission of NSW and transferred to Prospect County Council in 1960. It was augmented in 1965, 1974 and again around 1980.

The substation is normally supplied at 33kV from Blacktown Transmission Substation via 33kV Feeder 445. Alternative 33kV supplies are available from Baulkham Hills TS via Feeder 473 (Tee Kellyville ZS) and Feeder 470 (via Seven Hills ZS).

The indoor 11kV switchboard is Westinghouse HQ equipment comprised of two sections of B18 bulk-oil circuit breakers. Based on the serial numbers of the B18 circuit breakers it is estimated that 12 of the 15 breakers were manufactured in 1960 and the remaining three in 1964.

The original two 15MVA transformers were replaced by the current three Tyree 15/19/25 MVA units in 1974. There are also three Reyrolle LMT bulk oil breakers which were installed as 11kV transformer circuit breakers in an extension to the control building in 1980.

The substation includes an outdoor 33kV switchyard equipped with five Areva OX36 SF_6 circuit breakers and one Hawker Siddeley VOX 36 SF_6 breaker.

Figure 1 below shows an aerial view of Marayong Zone Substation. The area to the north of the substation is owned and maintained by Endeavour Energy but is open to the public and used as a park.

FIGURE 1 – MARAYONG ZS AERIAL VIEW

During 2008, a project was developed to rebuild Marayong Zone substation to increase its capacity and replace the 11kV switchboard. A similar augmentation was planned for the 33kV network supplying the substation. The project was finalised and endorsed by the Capital Governance Committee of the day. At that point however, the global financial crisis began to take effect and the forecasts of future load growth were significantly reduced. Subsequently, the augmentation project was cancelled.

The renewal of the substation was assessed again in 2012 based on the age and condition of the 11kV switchboard. However, it was found that the assets at that time did not present sufficient risk to warrant replacement. Five years have passed since that assessment and it is considered appropriate to consider the substation for renewal again now. In particular, the 11kV switchboard requires consideration for renewal to address the safety and reliability risks which it presents.

Accordingly, a Statement of Network Need was endorsed in November 2016 and a Network Investment Options team established to review the asset, network, operational, environmental and stakeholder needs of the substation and to develop an appropriate strategy and project for its renewal to ensure its ongoing serviceability and safety.

The Statement of Network Need for Marayong ZS, the system diagram for the 33kV network supplied by Blacktown and Baulkham Hills transmission substations and the single-line diagram and the layout for Marayong Zone Substation as it currently exists are shown in Appendix A, Appendix B, Appendix C and Appendix D respectively.

3.0 PROJECT NEED

3.1 SAFETY ISSUES

There are a number of aspects of the design of Marayong ZS which are typical of substations of this era and which create situations which are undesirable from a safety perspective. Whilst these issues are currently managed through the application of particular safe-work procedures, it is considered prudent that they be addressed when the opportunity arises, which is typically during major augmentation or renewal works.

The situations include:

- The main 11kV switchboard is bulk-oil equipment which can experience a destructive failure mode and is located in the control room building. Therefore it is desirable that the switchgear be replaced with equipment with less destructive failure modes and be located away from the operating areas in the control building;
- The 11kV auxiliary switchgear is epoxy insulated equipment which has destructive failure modes, is also not arc-fault contained and is located in the control room;
- The cable basement height under the 11kV switchboard is restricted and access is limited; and
- The protection relays are located in a tunnelboard with exposed live parts which present a hazard for protection technicians who are required to work on this equipment

3.2 ASSET AGE

Table 1 below shows the age (in 2017) of the various assets at Marayong ZS, compared with their depreciation life and their effective service life as provided to the regulator in the Regulatory Information Request (RIN) each year.

As indicated in Table 1, the age of the substation equipment is varied, ranging from new to in excess of 50 years. Further, the written down value of the substation in April 2017 was $2.42 million.

TABLE 1 – ASSET AGE

Asset category	Asset details	Asset age at 2017 (years)	Depreciation life (years)	RIN effective service life (years)
33/11kV Power Transformers	3 x Tyree 15/19/25MVA	44	50	50
33kV CBs[1]	5 x Areva OX36	13	45	45
	1 x Hawker Siddeley VOX 36	5	45	45
11kV switchgear	12 x Westinghouse BI8	57	45	51
	3 x Westinghouse B18	53	45	51
	3 x Reyrolle LMT	37	45	51
Protection relays	Various electromechanical and numerical	4 - 48	45	45
SCADA	LogicaCMG MD1000 RTU	16	15	10
Auxiliary transformer & switchgear	Magnefix MD430	54	45	45
Busbars and switchyard structures	Aluminium, copper and galvanised steel	46	45	45
Control building	Double brick. Steel roof	37-57	45	45

3.3 ASSET CONDITION

The condition indicators for the assets at Marayong ZS have been assessed in order to define the health index of particular assets in the substation and the health of the substation as a whole. The assessment has been carried out by Manager Asset Standards and Design in accordance with Substation Design Instruction SMI 161 [1]. As summary of the condition indicators and the health index ratings are shown in Table 2 below. Each asset may have a number of condition indicators which together make up the health index for the asset. These are discussed further in the following sections. Refer to SMI161 for further detail of the heath index rating system.

[1] Whilst the effective life of this equipment is currently 45 years, experience to date with Areva OX36 circuit breakers and other modern sub-transmission SF_6 and vacuum circuit breakers which contain electronic systems (such as the Hawker Siddeley VOX 36) is that both the quality of construction and the issue of support for their electronic systems will reduce their effective life to considerably less 45 years. Effective lives of between 25 and 30 years are considered to be more realistic.

TABLE 2 – HEALTH INDEX RATINGS

Item	Rating	Description
Condition Indicator	A	"As new" condition
	B	Some minor problems or evidence of aging
	C	Many minor problems or a major problem requiring attention
	D	Many major problems and the potential for major failure
	E	A major failure is imminent or there is damage that is beyond repair
Asset Health Index	100 - 85	Very good condition. Normal maintenance only required
	85 - 70	Good condition. Normal maintenance only required
	70 - 50	Fair condition. Increased diagnostic testing, possible remedial work required. Consider replacement if the asset is critical to the network
	0 - 50	Poor condition. Quantified assessment of the risk of failure and consequences with respect to safety, network reliability, response to failure and consequential damage using an approved methodology such as SA/SNZ HB 89:2013. Manager Primary Systems to develop an asset management strategy for the asset.

3.3.1 33/11KV POWER TRANSFORMERS

All three power transformers are rated at 15/19/25MVA and were manufactured by Tyree in 1973. Hence all are currently 44 years in age. Table 3 below summarises an assessment of the current condition of the power transformers. Refer to the Asset Class Condition – Power Transformers report [2] and Appendix E for further detail.

As shown in the table, the winding paper in Transformer No.3 is in poor condition placing the transformer at imminent risk of failure should it experience a close up 11kV feeder fault which is not cleared rapidly. The oil in Transformer No. 3 is also in very poor condition and requires action in the short term. Transformers No.1 and 2 also have poor oil quality and all three transformers are suffering from low insulation resistance and oil leaks with noticeable bulging of the main tank and tap-changer gaskets. Further, Transformer No. 1 has significant corrosion on its radiator fins.

Figure 2 shows a plot off all power transformer by comparing their age and health index as detailed in the Asset Class Condition – Power Transformers report [2]. All Marayong transformers lie in the "Nearing end of life" category. Transformer Nos 1 to 3 rank 28th, 24th and 11th respectively in priority for replacement due to condition out of a total of 454 units in service in the network.

Therefore the condition assessment recommends that Transformer No. 3 is replaced in the short term. It is estimated that the other transformers will remain serviceable for approximately five years. Given the age of these units it is considered that refurbishment of these units will not provide a beneficial extension of their life and therefore replacement as part of any major redevelopment works in the substation should be considered.

TRANSFORMER OIL CONTAINMENT AND FIRE PROTECTION

Each power transformer is surrounded by a concrete bund which is sealed and drained through its own pumped oil-water separator. The bunds are equipped with deflector screens to ensure any oil leaks from the transformer's tank, radiators or pipework is captured within the bund. These arrangements are functional and comply with current standards for oil containment specified by Substation Design Instruction SDI503 [3].

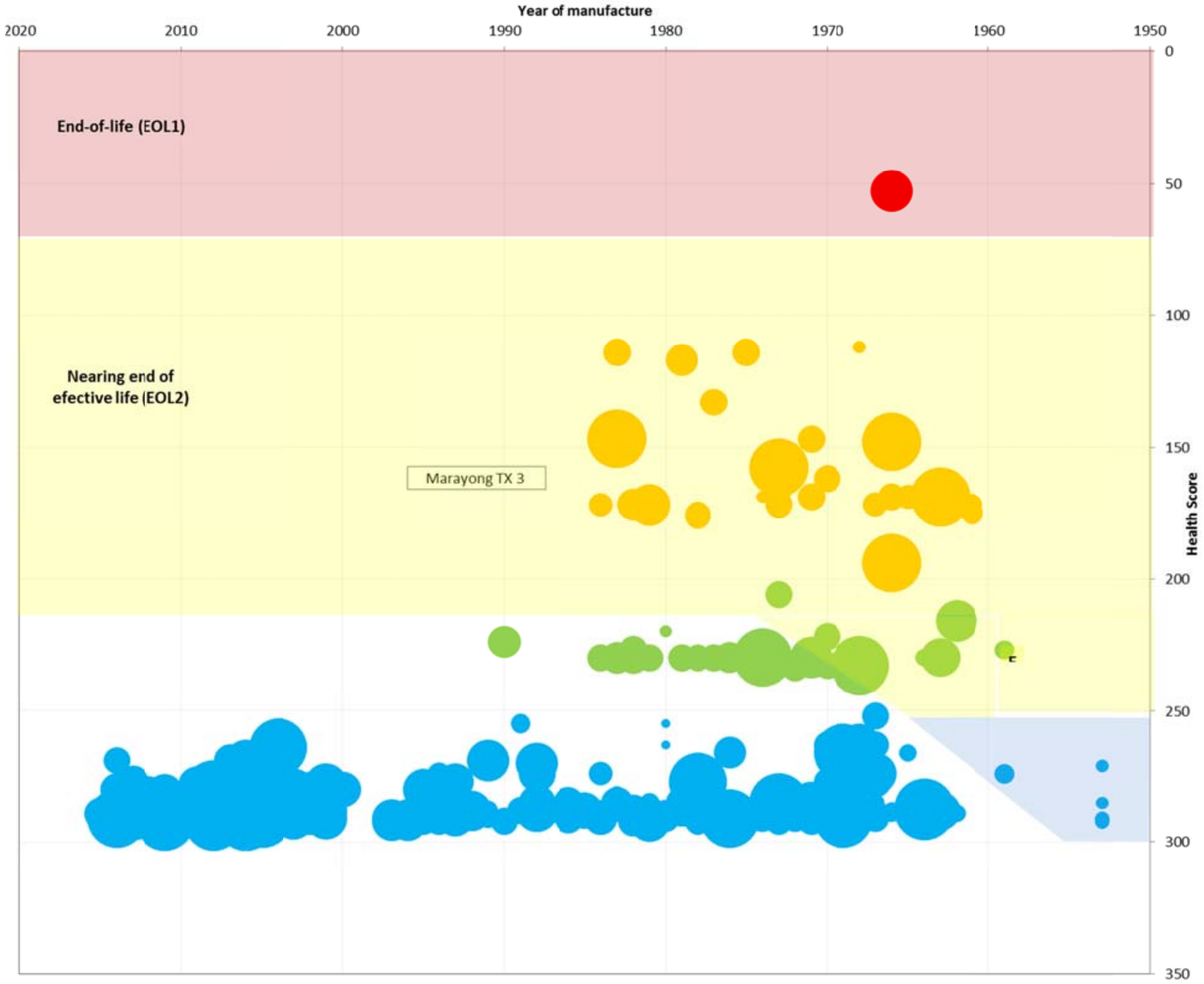
The bunds are spaced 8.5 metres apart which is adequate separation and complies with SDI503 (which specifies a separation of 7.6m for this size of transformers) from a fire–security perspective without the need for firewalls.

Accordingly, fire walls will not need to be installed between the transformers if any of the existing transformers are to be retained in service in their current bunds.

TABLE 3 - SUMMARY OF POWER TRANSFORMER CONDITION INDICATORS

Condition indicator	Values		
	Transformer No. 1	Transformer No. 2	Transformer No. 3
DP	316 – C	318 - C	243 – D
Oil Quality	Poor - D	Poor - D	Close to failure - E
DLA	4.5 mRad - A	6.95 mRad – C	6.15 mRad - B
IR-HV	1,696 MOhms – D	836 MOhms – D	606 MOhms – D
IR-LV	1,437 MOhms - D	1,40 MOhms - D	545 MOhms - D
Health Index	54	58	42

FIGURE 2 – ENDEAVOUR ENERGY TRANSFORMER HEALTH CHART



TRANSFORMER NOISE

All three transformers produce high levels of noise and the substation is located in close proximity to residential properties. Accordingly, noise levels need to be considered in any plans for the redevelopment of the substation. To this end, a noise impact assessment was carried out by consultants Day Design during June 2017. The assessment compared the noise produced by the substation (as experienced at the neighbouring property boundaries), to the limits contained within the EPA's NSW Industrial Noise Policy guidelines.

The assessment concluded that the power transformers were noisy but that the ambient noise levels around the substation were also high, due mainly to the close proximity of the substation and the surrounding residential properties to Sunnyholt Road. Despite this, there was one location in Charles Street where the substation noise levels exceeded the limits in the EPA guidelines.

The report proposed that the non-compliance be addressed by either:

1. The replacement of the existing transformers with low-noise units;
2. The installation of sound walls around two sides of each of the three transformers; or
3. The installation of a sound wall along the western boundary of the property.

CONCLUSIONS

Overall it is concluded that Transformer No. 3 is in poor condition and requires replacement in the short term. The other two power transformers are close to the end of their effective lives and therefore their replacement should be given consideration as part of the project development process.

Should any of the existing transformers be retained in service, it will be necessary to reduce their noise emissions by the installation of appropriate sound walls.

However, there is currently adequate separation between the transformers and their bunds and thus fire and blast walls will not be required to be installed.

3.3.2 33KV EQUIPMENT

CIRCUIT BREAKERS

The 33kV switch-yard is equipped with five Areva OX36 SF_6 circuit breakers which were installed circa 2004 and one Hawker Siddeley VOX 36 SF_6 breaker installed in 2012.

These circuit breakers are in good condition, however, there are some dents on the bushing turrets. It is expected these have been caused by stones thrown at them from over the substation fence as evidenced by the stones on the ground around the circuit breakers.

Whilst the circuit breakers at Marayong ZS have not had any issues with SF_6 gas leaks to date, there is a known issue with Areva OX36 SF_6 circuit breakers at other locations involving deterioration of the current transformer covers and SF_6 leaks. Refer to the Asset Class Condition – 33kV, 66kV and 132kV Circuit Breakers report [4] for further detail.

Notwithstanding this, it is assumed that these units will continue to remain serviceable for the foreseeable future providing the impact of vandalism of the circuit breakers does not escalate. If these circuit breakers are replaced before the end of their life they would make useful spares for the remaining fleet of Areva OX36 SF_6 circuit breakers in the network.

33KV BUSBARS, ISOLATORS AND SUPPORTS

The 33kV busbars are of outdoor design and constructed variously of aluminium tubing, copper tubing and stranded aluminium conductor. The 33kV busbar supports are galvanised steel. This equipment is all in good condition.

All 11 isolators in the 33kV switchyard at Marayong ZS are of the double-break rotary type manufactured by Taplin in 1972. This type of isolator is generally reliable and the equipment appears to be in good condition with nil history of failures to date.

The support structures are galvanised steel and are generally in good condition. However, there are areas of corrosion apparent, particularly on the 33kV feeder landing structures. Providing the corrosion is addressed it is assumed that the support structures will continue to remain serviceable for the foreseeable future.

33KV VOLTAGE TRANSFORMERS

The three 33kV feeder bays are equipped with three-phase ground-mounted voltage transformers. Feeder 470 and 445 VT's were manufactured by Hanson in 1964 and 1965 respectively and are greater than 50 years in age. Feeder 443 VT was manufactured by ABB in 2008. Feeder 470 VT has a cracked neutral bushing, however, electrical tests for all of these VTs are within acceptable limits in accordance with Substation Maintenance Instruction SMI153 [5].

Therefore, provided appropriate maintenance is carried out, it is assumed that the 33kV VTs will continue to remain serviceable for the short term. However, Feeder 470 and 445 VT's are expected to provide limited life beyond this period due to their age.

3.3.3 11KV SWITCHGEAR

The 11kV switchgear consists of 13 feeder circuit breakers and two bus-section breakers in a Westinghouse HQ switchboard. The switchboard is equipped with a transfer bus arrangement allowing the feeder breakers to be selectable between bus sections 1-2 and 2-3.

All of the feeder and bus-section circuit breakers are Westinghouse B18 bulk-oil types. 10 of the feeder breakers and the two bus-section breakers were manufactured in 1960. The remaining three circuit breakers were manufactured in 1964.

The three transformer circuit breakers are Reyrolle LMT bulk-oil units which were installed at Marayong ZS in 1980 when the control building was extended. These units are located in their own individual switch-rooms and are connected by cable to the Westinghouse switchboard. The ex-transformer breakers in the switchboard are now used as feeder breakers. Transformer No. 3 circuit breaker has high contact resistance, however, overall the Reyrolle LMT units are currently in satisfactory condition.

WESTINGHOUSE HQ SWITCHBOARD

Endeavour Energy has had six Westinghouse HQ switchboards in service in the past. The switchboards at Werrington, Canley Vale, South Granville and Rydalmere ZS's have all been replaced recently under major renewal projects leaving only two at Marayong and West Wollongong ZS's

These switchboards contain a compound insulated busbar. Over time the compound can leak and result in partial discharge activity inside the switchboard. However, a transient earth voltage (TEV) and acoustic test performed in 2012 found no significant partial discharge activity from within the switchboard at Marayong ZS.

CIRCUIT BREAKERS

Five of the breakers are in poor condition due to low insulation resistance and high contact resistance. A further three are considered to be close to poor condition and will likely become poor in the short term. Therefore these circuit breakers require renewal in the short term

Further, there is asbestos in the arc chutes, around the contactors and in the umbilical control cable. The control cable has been wrapped with tape to contain the asbestos.

There is a history of B18 (and J18, J22) circuit breakers in Endeavour Energy (at Port Kembla ZS) and Ausgrid (at Pymble ZS) failing to clear low level faults which result in an internal arc to the tank of the breaker. If the arc is not cleared quickly by instantaneous frame leakage or bus-bar protection, there is a risk of the breaker exploding and causing a substation fire. Marayong does not have instantaneous frame leakage or busbar protection and therefore there is an elevated risk of a circuit breaker failure and subsequent substation fire at this location.

These failures are due to the design of the circuit breaker rather than its condition and as a result, Ausgrid are either replacing all Westinghouse switchboards or retrofitting the circuit breaker trucks with vacuum units.

A similar strategy is also underway for Endeavour Energy's fleet of Westinghouse switchboards and Program TS0173 - *11kV truck replacement* has commenced retrofitting vacuum circuit breaker trucks in these switchboards that have air insulated busbars. However, the Westinghouse HQ switchboards have compound insulated busbars and it is not considered prudent to attempt to extend their life with vacuum truck replacement. Therefore, it is recommended that the 11kV switchboard at Marayong ZS be replaced in the short term.

Note that the other remaining 11kV compound filled switch board at West Wollongong ZS is planned to be replaced under project TS174 early in the next regulatory control period.

Table 4 shows a summary of the condition of the 11kV circuit breakers with a health index rating for each assessment criteria and for the breaker overall. Refer to Appendix E for further detail of the condition indicators for each circuit breaker.

TABLE 4 - 11KV CIRCUIT BREAKER CONDITION SUMMARY

Circuit breaker No.	Circuit breaker type	Feeder name	Tank & mech	Oil leaks	Control & mech	Circuit breaker wear	Timing	Contact resistance	IR	Design safety	Overall health Index
1949	Westinghouse B18	Vardys Rd	A	C	B	B	NA	B	A	E	58
1950	Westinghouse B18	Bessemer St	A	C	B	B	B	B	A	E	62
1951	Westinghouse B18	Coke 1 and Garling Rd	A	C	B	B	NA	B	D	E	40
1952	Westinghouse B18	Lalor St	A	C	B	B	C	D	A	E	53
1953	Westinghouse B18	Breakfast Creek	A	C	B	B	B	E	D	E	44
1954	Westinghouse B18	Steel St and Madagascar Dr	A	C	B	B	NA	B	A	E	58
1955	Westinghouse B18	BS 1-2	A	C	B	B	B	B	A	E	62
1956	Westinghouse B18	Forge St and Cap 1	A	C	B	B	B	C	A	E	60
1957	Westinghouse B18	Dalray St & Aux 1	A	C	B	B	B	E	D	E	44
1958	Westinghouse B18	Tattersal Rd and Aux 2	A	C	B	B	B	E	C	E	49
1959	Westinghouse B18	Sunnyholt Rd and Northcott Rd	A	C	B	B	B	C	D	E	47
1960	Westinghouse B18	James Cook Dr and Gate Rd	A	C	B	B	NA	B	A	E	58
1961	Westinghouse B18	BS 2-3	A	C	B	B	B	B	B	E	57
1962	Westinghouse B18	Jopling Cres	A	C	B	B	B	C	C	E	51
1963	Westinghouse B18	Coke 2	A	C	B	B	C	C	A	E	54
D837	Reyrolle LMT	TX 1	A	A	B	B	B	B	A	E	65
D838	Reyrolle LMT	TX 2	A	A	B	B	B	C	A	E	63
D839	Reyrolle LMT	TX 3	A	A	B	B	B	E	A	E	60

3.3.4 AUXILIARY AND ISOLATING TRANSFORMERS

Auxiliary supply is provided by a single 11kV/415V 200kVA transformer manufactured by Tyree in 1971. This transformer appears to be in reasonable condition, however, electrical test results are not available and therefore its internal condition is not known.

Back-up auxiliary supply is provided from a low voltage street feeder through a 40kVA isolating transformer which was manufactured in 1971.

3.3.5 AUXILIARY 11KV SWITCHGEAR

The auxiliary switchgear is Magnefix MD4 commissioned in 1964. There have been a number of failures of MD4 switchgear in the distribution network and in August 2015 an MD4 auxiliary switchboard failed at Prospect ZS causing damage to the control room and a prolonged outage of the substation. There is ongoing concern about the safety of MD4 equipment in the high fault level environment of a zone substation and as a result, MD4's are being progressively replaced with metal clad, arc-fault contained vacuum switchgear in zone substations under Program *TS009 Auxiliary switchgear replacement*. Marayong has been omitted from this program so that the replacement of the 11kV auxiliary switchgear can be carried out in conjunction with the redevelopment of the substation.

Therefore it is proposed that the auxiliary switchgear be replaced in the short term.

3.3.6 STATION BATTERY

There is one main station battery bank that contains sealed lead acid cells and a battery charger. The cells were replaced in 2016 in a new rack. However, the charger, which was manufactured in 2001, was not replaced. The equipment is in good condition and has no current renewal needs.

The dc supply equipment is located in the protection control room close to the protection tunnelboard. Any major redevelopement works at the substation should include relocating the battery into a separate battery room or enclosure with suitable ventilation to current standards to improve its security and to improve safety in the control room. The works should also include installling a second battery bank at the substation to provide security of the dc supply and avoid reliability risks as per the substation design instruction SDI510 [6].

3.3.7 PROTECTION SCHEMES

The 33kV and 11kV feeder protection is mainly comprised of the original electro-mechanical relays from circa 1964. Although some relays have been replaced between 1990 and 2004. This equipment is currently performing satisfactorily.

This equipment is mounted on a tunnel board which should be refurbished or replaced with standard panels when major protection replacement works are required at the site.

11KV FEEDER RELAYS

Under program *PS012 Distribution feeder safety improvement* it is proposed to replace all electromechanical relays in zone substations that protect the distribution network with fast operating numerical relays. This will reduce the severity of any arc-flash burn incidents caused by the network and will reduce the risk of initiation of a bushfire. The replacement of the 11kV feeder protection relays at Marayong ZS was omitted from program PS012 so the works could be included in this project along with the other renewal needs at Marayong ZS. If the 11kV switchgear is replaced, the new switchboard will include the required relays and therefore will satisfy this need.

33KV AND TRANSFORMER RELAYS

The protection scheme for 33kV Feeder 445 from Blacktown TS is equipped with distance protection. The scheme for 33kV Feeder 473 from Baulkham Hills TS, tee Kellyville ZS, is equipped with Translay differential unit protection operating over HARDEX copper pilots. The scheme for 33kV Feeder 470 to Baulkham Hills TS, tee Seven Hills ZS, is equipped with a numerical differential protection scheme operating over the optical fibre network. All 33kV feeder protection schemes are backed up by over-current and earth-fault protection schemes.

There is an opportunity to upgrade the protection schemes for Feeders 445 and 473 to numerical differential unit protection over the optical fibre network which will provide for more rapid clearing of faults with a subsequent reduced risk to the public and to the network assets in the event of a 33kV earth fault.

Further, the 33kV CB’s have additional CT’s available which would allow for the implementation of a high impedance busbar protection scheme, should bus-section CB(s) be installed as part of any redevelopment work.

The transformer protection schemes consist of numerical differential relays which are located on a separate panel next to the tunnelboard.

3.3.8 AUDIO-FREQUENCY INJECTION EQUIPMENT

The audio-frequency injection equipment includes a Landert Motoren 1,050hz motor-generator set with a single Zellweger injection cell. This equipment was installed circa 1980 after the control building was extended to house the 11kV transformer breakers. The equipment is rated at a nominal 44kW giving it a rating in terms of substation loading of approximately 50MVA, which is adequate for the demand on the substation.

This equipment is in satisfactory condition and has no renewal needs at present, A recent study has found that prevalence of controlled loads are in decline and further that the reliance on audio-frequency injection control (AFIC) equipment is in decline with smart meters being installed at customer premises which are able to be controlled and to in turn switch the controlled loads. A load control strategy [7] is in place to replace load control relays with smart meters. Therefore it is envisioned that the AFIC equipment at Marayong ZS will not be required in the future. However, the equipment is required at present and until such times as the smart meter strategy has been fully implemented.

3.3.9 SCADA AND COMMUNICATIONS SYSTEMS

The SCADA system includes a Megadata MD1000 RTU with distributed DIU's. The equipment was installed in the early 2000s and has reached the end of its effective life. Therefore, the SCADA system should be replaced within the short-term.

Marayong ZS is well serviced by optical fibre communications with optical fibre links to Bella Vista, Newton and Seven Hills zone substations and to Kings Park Field Service Centre.

3.3.10 11KV CAPACITOR

The substation is equipped with an 11kV ABB Abbacus capacitor bank of 5MVAr capacity which was installed in 2002. The circuit breakers and contactors within this type of capacitor bank have a history of failure due to moisture ingress and subsequent corrosion damage leading to loss of vacuum. As a result, all Abbacus capacitor banks are currently being refurbished under Program TS181. The works under this program include:

- Replacement of the VD4 CBs and contactors that fail their vacuum integrity test or otherwise have suffered corrosion damage which is likely to result in loss of vacuum before the next scheduled maintenance; and
- Installation of a kit of rain hoods, filter pads, anti-condensation heaters, dust covers a ventilation fan to eliminate the ongoing moisture ingress risk to the equipment.

The works on the capacitor bank at Marayong ZS under program TS181 are currently proposed for 2018/19 but should be coordinated with any redevelopment works proposed under this project where practicable.

3.3.11 CONTROL BUILDING

The original control building houses the 11kV switchboard, protection and control panels, AC and DC panels and auxiliary 11kV switchgear. The three 11kV transformer circuit breakers and the audio-frequency injection cell are housed in an extension to the control building which was added circa 1980.

The building is of double brick construction with a steel roof and glass windows. The cable basement height under the 11kV switchboard is low and the basement floor is rough and unmade in places. Further, the 33kV Feeder 445 overhead entry span crosses over the roof of the control building, which would complicate any works on the control building.

Notwithstanding these shortcomings, the control building is solid and in reasonable condition and is currently serviceable.

3.3.12 OVERALL SUBSTATION CONDITION

In summary, the condition of Marayong Zone Substation is varied. There are short-term needs to replace Transformer No. 3, the 11kV switchboard, the auxiliary switchgear and the SCADA equipment.

Power Transformer No. 1 and No. 2 are currently in serviceable condition but are approaching the end of their effective lives and are likely to require replacement within the timeframe of any major redevelopment project.

The 33kV switchyard, control building, protection systems, and auxiliary systems are aged but are currently in satisfactory condition and would likely be fit for continued service for the medium term. However renewal options should consider the replacement of these assets if proven to be positive in terms of risk, cost and benefits.

3.4 ENVIRONMENT

3.4.1 VISUAL IMPACT

The substation is in a moderately high profile location on the corner of two residential streets. However, it is currently reasonably well screened by mature trees and shrubs.

The land behind the substation is owned and maintained by Endeavour Energy. It is currently mown and is not fenced and is utilised by the surrounding community as a park.

Given the location of the substation in the midst of a residential area, it is preferred that any new redevelopment works undertaken are indoors, however, the existing outdoor switchyard could also remain in service provided it continues to be well screened.

3.4.2 EXCESS LAND

Consideration needs to be given to the land remaining after any redevelopment works are undertaken and the ongoing responsibility for and maintenance of that land. One approach would be to rehabilitate any excess land to public use as a park in keeping with the current use of the excess land.

However, alternative approaches which may include formal disposal of the land to Blacktown City Council or redevelopment of the land may also be considered.

3.4.3 SITE CONTAMINATION

Due to the age of the substation, there is likely to be asbestos in fibro-cement cable ducts around the site.

Although located in a residential area, the site is not far from an extensive industrial area and given that the history of the site is not known, the existing substation site and the larger lot owned by Endeavour Energy should be checked for contamination with hazardous materials in the early stages of any redevelopment proposal.

3.4.4 TRANSFORMER NOISE

As noted in 3.3.1 above, all three transformers produce high levels of noise and the noise impact assessment carried out by consultants Day Design during June 2017 concluded that the there was a non-compliance with the EPA NSW Industrial Noise Policy guidelines in Charles Street.

The report proposed that the non-compliance be addressed by either:

1. Replacing the existing transformers with low-noise units;
2. Installing sound walls around two sides of each of the three transformers; or
3. By installing a sound wall along the western boundary of the property.

No complaints of excess noise have been received to date and therefore at present there is no legal requirement for the noise levels to be reduced. However, experience has shown that while construction works are being undertaken the surrounding residents are often inconvenienced by construction noise and traffic and this can increase their sensitivity to ongoing issues such as noise emissions from the transformers. As a result there is a reasonable probability that a noise complaint will be received either during or shortly after the construction works. This risk needs to be factored into the assessment of any options which do not include noise mitigating measures.

As a precautionary measure, it is proposed that noise walls in some form will be required around the existing transformers if they are to be retained in service.

Refer Appendix F for further detail of the noise impact test.

3.4.5 SAFETY AND OTHER RISKS

Table 5 below is based on the Company’s risk assessment procedure, Board Policy 2.0.5 and assesses the principal risks presented by the assets in Marayong Zone Substation. There are many other lesser risks which are not shown.

TABLE 5 - MARAYONG ZONE SUBSTATION RISK ASSESSMENT

Asset	Event	Likeli-hood	Impact	Risk rating	Consequence and comments	Proposed treatment	Expected risk after treatment
33/11kV power transformer No. 3	Failure to operate	Likely (D)	Minor (2)	Medium (D2)	Tap-changer fault is most likely cause. Standby TX will avoid loss of supply to customers. Consequence is loss of security of supply and unscheduled F&E leading to unplanned replacement of the transformer.	The transformer is at the end of life. Replace to avoid unplanned emergency replacement.	Low (B2)

Asset	Event	Likeli-hood	Impact	Risk rating	Consequence and comments	Proposed treatment	Expected risk after treatment
	Internal failure and fire	Unlikely (B)	Major (4)	Medium (B4)	Severe internal fault which causes an oil fire and disables the entire substation for many hours with subsequent reliability impact, F&E and unplanned emergency replacement of transformer	The transformer is at the end of life - replace.	Med (A4)
	Oil leaks	Almost Certain (E)	In-significant (1)	Medium (E1)	Oil leaks are occurring. Oil is captured by bund, separated and pumped out. Ongoing maintenance requirement.	Repair oil leaks – by refurbishment or replacement. Replace radiators.	Low (B1)
11kV Westinghouse HQ switchboard	Failure to operate	Possible (C)	Moderate (3)	Medium (C3)	Fault cleared by TX CBs due to lack of busbar protection and result is loss of substation load with reliability impact until emergency response investigates and restores supply	Switchboard is at end of life - replace	Med (B3)
	Destructive failure (due to internal arc whilst clearing a feeder fault)	Possible (C)	Major (4)	**High (C4)**	Damage to control building and protection and control. Loss of supply from the substation for an extended period with reliability impact.	Switchboard is at end of life - replace	Low (B2)
	Destructive failure with personnel in vicinity	Rare (A)	Severe (5)	Medium (A5)	Fatality of personnel inside switchroom at time of failure.	Replace with vacuum and arc-fault contained switchgear	Low (A2)
11kV auxiliary switchgear	Destructive failure during operation	Unlikely (B)	Severe (5)	**High (B5)**	Explosion causing significant injury to operator.	Replace MD4 unit with vacuum and arc-fault contained equipment	Low (A2)
SCADA RTU	Failure to operate during a system emergency	Likely (D)	Minor (2)	Medium (D2)	Loss of visibility and control of the substation hampers attempts to restore supply during a system incident with reliability impact and additional maintenance requirements	The SCADA RTU is at end of life – replace	Low (B2)

This assessment confirms that the principal risks which need to be addressed at Marayong ZS are the destructive failures of 11kV switchboard and the 11kV auxiliary switchgear and the reliability impacts of Transformer No. 3.

In particular, failure of 11kV oil-filled switchgear inside the control room is of concern and is the most prominent driver for the renewal project.

Note that the other oil switchgear in the control building, the three Reyrolle LMT 11kV transformer circuit breakers present the same types of risks as the 11kV Westinghouse HQ switchboard noted in the risk assessment but with a slightly reduced likelihood of occurrence because the LMT equipment is younger and in better condition and does not have a history of failure to clear faults. However, it is still oil filled switchgear in a control building and therefore should be replaced with vacuum equipment which is preferably also arc-fault contained in line with current standards of safety.

Likewise, the other two power transformers present the same types of risks as Transformer No. 3 but with again with reduced likelihood of occurrence due to the equipment being in better condition than Transformer No. 3. Over time however, the risks presented by these assets will escalate to similar levels as that of Transformer No. 3. As noted in section 3.3.1 above, this timeframe of deterioration is likely to be around five years which is a similar timeframe to a redevelopment project and therefore the replacement of transformers 1 and 2 should be considered in a similar light as Transformer No. 3 in the assessment of options for redevelopment of the substation.

3.4.6 CONCLUSION

As a result of the risk assessment it is concluded that the minimum renewal works required at the substation in the short term include:

- Replacement of the compound filled Westinghouse HQ switchboard and B18 circuit breakers;
- Replacement of the 11kV auxiliary switchgear;

- Replacement of Transformer No 3;
- Replacement of the 11kV feeder relays and control wiring works;
- Replacement of the SCADA RTU.

However, consideration should also be given to the replacement of transformers No.1 and No. 2 and the aged control building and protection tunnel board.

3.5 NETWORK CONSTRAINTS

During 2008, a project was developed to augment Marayong Zone substation from its current firm capacity to 70MVA with augmentation of the power transformers and the 33kV network supplying the substation. At the time, the maximum demand on the substation was equal to the firm capacity and was forecast to increase significantly over the forthcoming years, due both to local industrial growth and also to the expansion of the Blacktown Central Business District. The project was finalised and endorsed. Subsequently, the effect of the global financial crisis caused a substantial reduction in the demand forecast for the area removing the need for the augmentation of the substation. The current development strategy includes the establishment of North Blacktown Zone Substation to service growth in demand in the Blacktown CBD area if and when the demand on Marayong ZS increases beyond its current firm capacity. At current growth rates, this situation is not expected to occur within the foreseeable future.

3.5.1 TRANSFORMER CAPACITY

The firm capacity of the three power transformers at Marayong ZS is currently 50MVA compared to a current summer peak demand of 40.1MVA and a winter peak of 36.3MVA.

These peak demands are forecast to remain virtually flat for the next 10 years at 39.6MVA in summer and 37.5MVA in winter (with a 50% probability of being exceeded (POE)) by the end of the forecast period.

Any significant increase in demand beyond that period is likely to come from an expansion of the Blacktown Central Business District which will be the trigger to establish the new North Blacktown Zone Substation as noted above.

As a result, the existing transformers have adequate capacity for the foreseeable future. The load forecasts for Marayong ZS (for a 50% POE) for the summer and winter peak periods are shown in Table 6 and Table 7 below.

TABLE 6 - SUMMER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
MVA	38.9	39.9	40.1	40.0	39.9	39.8	39.7	39.7	39.6	39.5	39.5	39.6	39.6

TABLE 7 - WINTER PEAK DEMAND FORECAST SUMMARY

Forecast	Actual demand			Forecast diversified demand - 50% POE and temperature corrected									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
MVA	34.8	36.0	36.3	36.2	37.5	37.4	37.4	37.3	37.3	37.3	37.3	37.3	37.5

3.5.2 33KV SUB-TRANSMISSION CAPACITY

The normal supply to Marayong ZS is via Feeder 445 from Blacktown TS. The summer rating of Feeder 445 is 45MVA.

Alternate supplies are available from Baulkham Hills TS via 33kV feeders 473 and 470 (via Seven Hills ZS). The summer ratings of feeders 473 and 470 are 32MVA and 34MVA respectively.

However, sharing load between the two transmission substations through Marayong's 11kV bus bar is not possible due to the imbalanced impedances of the two supplies which will cause circulating currents in the transmission network. Further, the 11kV busbar at Marayong ZS must be operated solid due to the substation's single AFIC arrangement and therefore, if one of the feeders from Baulkham Hills TS is lost, the maximum load that can be supplied to the substation would be 45MVA from the normal supply of Feeder 445 from Blacktown TS. In effect, this limits the substation firm capacity to 45MVA.

A second AF injection cell would allow the 11kV busbar to be split and would permit simultaneous supply from the two transmission substations. This would allow for greater utilisation of the sub-transmission network and increase the firm capacity of the substation to its firm transformer capacity of 50MVA. However the existing arrangement provides adequate capacity for the forecast demand for the foreseeable future.

3.5.3 11KV SWITCHBOARD CONSTRAINTS

Marayong ZS is currently equipped with 13 x 11kV feeder circuit breakers supplying 22 feeders. Eight of the breakers currently supply two feeders each, one supplies a feeder and capacitor bank arrangement and two supply the 11kV auxiliary switchboard as well as a feeder.

This indicates that the substation is reaching its limits in terms of 11kV feeder capacity. Further, double-cabling results in reduced reliability performance from the feeders in question and increases the impact on connected customers. In the case of Marayong ZS, whilst the current arrangement has nil capacity to accommodate additional feeders or for emergency rearrangements, reliability of the 11kV feeders is currently within the acceptable range and there is no immediate need for additional 11kV feeders.

Notwithstanding the current adequate performance, any redevelopment works on the 11kV switchboard should provide an increased number of 11kV circuit breakers to give improved flexibility during emergency switching operations and scope to accommodate additional connection of load as required.

It is recommended to provide 19 x 11kV feeder circuit breakers under any new arrangement which will include two spare breakers. It would also be beneficial to provide space for an additional two breakers to provide for future need.

4.0 RENEWAL OPTIONS

This section details the options considered to address the asset and network needs identified at Marayong Zone substation.

4.1 DO NOTHING

This option will not satisfy the renewal needs of the 11kV circuit breakers and Transformer No. 3 being in poor condition and reaching end of life. Further, the safety risk carried by the 11kV auxiliary switchboard and protections systems will need to be addressed through other programs. Therefore this option is rejected as it does not adequately address the risks posed by the substation assets.

4.2 DEMAND MANAGEMENT OPTIONS

An investigation was carried out to estimate the level of demand that may be reduced at Marayong ZS by implementing demand management strategies. The results of the investigation are summarised in Table 8 below and indicate that the maximum potential demand reduction available is 6.6MVA.

As discussed in section 3.5 the current demand on the substation is 40.1MVA. Therefore it is theoretically possible to reduce this to 33.5MVA allowing the substation to be redeveloped to a firm capacity of 35MVA. This approach would provide an estimated cost savings of $3 million compared to a redevelopment which retains the existing 50MVA firm substation capacity.

Endeavour's experience in implementing demand management programs has identified that financial incentive payments need to be sufficient to ensure adequate customer participation and that figures of around $100 per kVA per year are required.

The savings envisaged at Marayong ZS by achieving, a 5MVA reduction (which is the minimum required to justify a 35 MVA firm capacity substation) results in a financial incentive payment of only $40 per kVA per annum which is not adequate to ensure sufficient participation.

Further, the majority of initiatives implemented in other demand management programs were temporary in nature whereas for Marayong, permanent demand reduction is required. Permanent reductions can only generally be achieved with large stable industrial loads where long-term contracts can be put in place or equipment replaced with energy efficient alternatives. From Table 8, 50% of the industrial/commercial demand reduction can be considered permanent which equates to 2.5 MVA (based on Endeavour's previous industrial area program experience). However, a demand reduction of 2.5 MVA is insufficient to permanently reduce the capacity of the new Marayong ZS.

Further, although the current demand forecast for the substation is flat, development in the area may eventuate in the short term as there is much re-development occurring in the Blacktown area. Therefore, reducing the capacity of the zone substation is a high risk option as any growth in demand from re-development would require additional electrical capacity to enable supply. Upgrading the Marayong ZS would be costly after rebuilding to 35 MVA capacity as it would require a third 35 MVA transformer (to balance with the other two) and additional switchgear resulting in a much larger capacity substation than required. Increasing the capacity of Marayong ZS would require substantial augmentation of the substation. If this expenditure was undertaken within a 20 year period then the saving achieved from avoiding $3m would be negated and the demand management expenditure to achieve the demand reduction would be a sunk inefficient cost.

In conclusion, it is considered that there are insufficient savings and financial incentive to achieve sufficient participation for a demand management strategy to be successful. There is also insufficient permanent demand reduction available in the Marayong ZS supply area to meet the level required.

TABLE 8 – DEMAND MANAGEMENT STRATEGIES

Demand management strategy	Customers/loads	Take-up rate/conversion rate	Potential demand reduction (kVA)
Residential customers notified to turn of supply	5,590 customers	8% @ 1.7kVA	760
Residential-air conditioners running at half load	5,590 customers	8% @ 1.3kVA	581
Residential solar panels fitted with batteries	5,590 customers	2.8% @ 2kVA	313
Industrial / commercial	24.7 MVA	10% to 20%	up to 4.94 MVA
Total			**6,594**

4.3 NETWORK OPTIONS - RENEWAL STRATEGIES

4.3.1 TRANSFORMERS

As discussed in section 3.3.1 Transformer No. 3 requires renewal in the short term and therefore its replacement is included in all of the above options. Transformers No. 1 and 2 can currently remain in service however it is estimated that these transformers only have a further five years or so of service life remaining. Given the timeframe for major redevelopment projects, it is likely that the transformers will require replacement around the time of completion of the development works. Furthermore, to retain the existing transformers in service will require the installation of noise walls and also refurbishment works on the transformers themselves. These works will become redundant once the transformers are replaced. Given the short remaining life the transformers, this investment is not considered to be prudent. Therefore, all options considered should include the replacement of all three transformers.

4.3.2 CONTROL BUILDING

The NIO team has identified two fundamental approaches to addressing the renewal needs of the substation:

1. Minimal works and future piecemeal like-for-like replacement of assets; and
2. A strategy of redeveloping the substation to a new indoor 33/11kV substation including:
   a. A staged redevelopment approach;
   b. Redevelopment in a single stage.

The minimal works option includes sufficient works to address only the highest priority renewal needs and retains much of the original substation with a view to continuing to maintain and renew those assets in a like-for–like manner as they reach the end of their lives. This strategy will involve extensions to the existing control building to accommodate new 11kV switchgear and protection & control equipment and retention the outdoor 33kV switchyard and renewing its assets like-for-like as required.

The second approach is a strategy of redeveloping the site to a completely new indoor substation with a range of sub-options which advance the concept from the first stage which includes a new 11kV switchroom through to a completely new indoor substation. The works could either be staged by redeveloping parts of the substation when required or complete redevelopment in a single stage in the short term

4.3.3 EXTENDING THE CONTROL BUILDING

This option proposes to extend the existing control building to include a new 11kV switchroom to address the risks posed by the existing Westinghouse HQ switchboard. The current 11kV switchroom would be used to house new auxiliary switchgear.

There is enough room at the site to fit a new 11kV room with 19 feeder circuit breaker as recommended. This is shown in Figure 3 below. However, this extension encroaches council setbacks and it has been resolved that additional room for a further two circuit breakers should not be provided in this option to limit the extent of the encroachment. If there is a need for more 11kV feeders they will need to be doubled up in the future.

The 11kV transformer circuit breakers would be removed and their rooms used as battery rooms. The other equipment would remain in service with some refurbishment work to improve safety around the protection and control tunnel board.

FIGURE 3 – EXTEND CONTROL BUILDING

The 33kV switchyard will remain in service as is except that the power transformers would be replaced. There is insufficient space in the existing transformer bays for standard new 25MVA transformers and therefore the new transformers would be located outside of the existing switchyard to the north.

The landing span of 33kV Feeder 445 which currently passes over the roof of the control building would also be replaced with an underground cable to allow for the construction of the building extension in a safe and efficient manner.

However, towards the south-west corner of the site there are live 11kV feeder cables. These cables will be supported in place while the building is constructed around them. This approach presents heightened risks for crews digging and performing construction work near the live cables and managing those risks adds to the complexity and cost of the option. As a result the building works involved in this option are expected to cost about $2.3 million.

In comparison the construction of a new switchroom towards the north of the existing substation to house the new 11kV switchboard (as detailed below in section 4.3.4) is also expected to cost about $2.3 million in building works with additional cabling costs to connect the new switchroom making it only marginally more expensive. It will also provide for a larger switchroom which will provide for further circuit breakers to be installed in the future if required. As this approach will provide for the replacement of the existing 11kV switchboard at similar cost as the extending the control building but with additional benefits and reduced risks, extending the control building is rejected as not being a viable option.

4.3.4 NEW 11KV BUILDING

This option proposes to construct a new building towards the north of the existing substation to house the new 11kV switchboard. The current 11kV switchroom would be used to house new auxiliary switchgear.

The 11kV transformer circuit breakers would be removed and their rooms would be available for use as battery rooms as required. The other equipment would remain in service with some refurbishment work to improve safety around the protection and control tunnel board as per the approach detailed above in section 4.3.3. Likewise, the 33kV switchyard would remain in service and the transformers would be replaced to the north of the switchyard.

The landing span of 33kV Feeder 445 could also be placed underground to improve maintenance accessibility to the control building roof although there is no building construction works proposed in this option which would drive this work.

This approach involves construction on a vacant part of land generally clear of the live substation and will result in minimal construction complexity.

Figure 4 below shows a conceptual plan view of this option when complete.

FIGURE 4 – NEW 11KV BUILDING

Accordingly, this option is considered to be viable and will be assessed further.

4.3.5 NEW INDOOR SUBSTATION

This option proposes to replace the entire substation with a new indoor substation built on the land to the north of the existing 33kV switchyard. The existing substation would be removed and the land rehabilitated to allow it be used as a park to replace the land used for the new substation of otherwise disposed of.

Figure 5 below shows a conceptual plan view of this option when complete.

FIGURE 5 – NEW INDOOR SUBSTATION

This is an efficient "greenfield" development approach and will be assessed against the New 11kV building option.

4.4 RENEWAL OPTIONS UNDER CONSIDERATION

The two options which warrant further assessment are summarised in Table 9 below.

Option 1 is the minimal works option and involves installing a new 11kV switchroom and three new power transformers. Future works in this option may include piecemeal replacement of the 33kV assets or complete redevelopment into a new indoor substation.

Option 2 involves complete redevelopment into a new indoor substation in the short term.

TABLE 9 – MARAYONG ZS REDEVELOPMENT OPTIONS

Option	Redevelopment works
Option 1 – Staged redevelopment approach	• Underground the landing span of 33kV Feeder 445 • Construct a new 11kV building to the north of the existing switchyard • Install a new 11kV switchboard in the new building • Replace auxiliary switchboard • Refurbish the protection and control tunnel board and replace all aged relays • Install differential feeder protection over the optical fibre network for 33kV feeders 445 and 473 • Replace the SCADA RTU • Relocate the battery bank to one of the ex-11kV TX CB rooms and install a second battery bank in another of the ex-11kV TX CB rooms and provide ventilation for the battery rooms • Dispose of the Westinghouse HQ switchboard, the three 11kV transformer circuit breakers • Retain the existing 33kV switchyard • Replace the first sections of 11kV feeder cables out of the substation • Replace all three TXs • Dispose of the replaced transformers

Option	Redevelopment works
Option 2 – Complete redevelopment approach	• Build a complete new indoor 33kV substation • Replace the first sections of 11kV feeder cables out of the substation • Underground the incoming 33kV feeders • Dispose of the existing 33kV switchyard and control building and switchgear and remediate the land • Replace all TXs • Dispose of the replaced transformers

4.5 OPTION COST ESTIMATES

Estimated costs for the above options are shown in Table 10 below. As expected Option 2 has greater upfront costs, however, Option 1 has greater future cost

TABLE 10 – OPTION COST ESTIMATES

Items	Option 1	Option 2
Project management		
Project management & project definitions	618,000	1,086,000
Indoor 33kV bays		
Feeders	0	553,000
Bus sections	0	448,000
Indoor 11kV bays		
Feeders	1,555,000	1,318,000
Bus sections	201,000	170,000
Transformer bays		
Bays	662,000	847,000
Transformer costs	1,980,000	1,980,000
bunds / sound walls / blast walls / fire suppression	1,500,000	1,310,000
AFIC equipment		
SFU & Injection Cells	0	301,000
Building & switchyard		
Building/transformer runway/fencing/landscaping/building fire suppression	3,120,000	5,401,000
Ancillary equipment		
11kV aux switchboard/aux. transf./batteries & chargers/radio system/ new SCADA	216,000	550,000
Under frequency load shedding	34,000	34,000
Additional costs		
Mains	725,000	1,940,000
Distribution	1,400,000	1,400,000
Major equipment storage	83,610	122,640
Feeder changeover	200,000	100,000
Removal of existing transformers	60,000	60,000
Removal of existing equip. & fence	25,000	95,000
Demolition of existing building & switchyard	0	1,105,550
33kV cable sealing ends	60,000	
Total upfront capital costs	**12,439,000**	**18,822,000**
Estimated future capital cost (expected in 16 years time)	**10,336,000**	**0**
Total real capital expenditure	**22,775,000**	**18,822,000**

5.0 ASSESSMENT OF THE OPTIONS

In order to determine the preferred option, the identified options for addressing the renewal needs of the substation have been assessed against a number of key risk indicators and for their present cost.

5.1 TREATMENT OF RISK

The risk assessment categories include:

- Safety impact;
- Environmental impact;
- Construction risk;
- Operating and maintenance requirements;
- Reliability and supply security impact;
- Sustainability impact.

5.2 RISK RATINGS

Each of the viable options have been assessed against each other for each of the above risks as shown below. All risks are assessed based on the Company's risk assessment procedure, Board Policy 2.0.5 by assessing the likelihood and consequence of an event. Refer to Appendix G for further detail of the assessment.

5.2.1 SAFETY IMPACT

This indicator is applied to the final outcome of the project and also to the actual construction process itself. It is assumed that all equipment and procedures used by Endeavour Energy for all options will provide a safe work environment for staff and workers and will comply with the relevant safety standards. However, some options are inherently safe by design whereas others require more effort through the application of procedures and work methods to ensure safety. An option which is inherently safe will therefore achieve a lower risk score than an option which requires more effort to ensure it is safe.

Both options remove the hazards presented by the bulk-oil 11kV switchgear, the MD4 auxiliary switchgear and the cable basement.

However, *Option 1* retains the existing tunnel board in the existing control building with its poor access and also retains the existing outdoor 33kV switchyard with open air-insulated busbars and equipment, high-voltage cages and numerous trip hazards. Therefore this option scores a moderate rating for the safety impact indicator.

Option 2 however, provides a completely new indoor solution with fully enclosed and arc-fault contained switchgear and new cable to cable transformers with no exposed live parts. The design will also be compliant with the safety standards of a new installation which provides improved design of accessways, protection and control panels, basement areas, ventilation, avoidance of trip hazards etc which will provide a safer work environment than is possible with the *Option 1* which retains the legacy issues associated with the original 1960's substation design and technology.

5.2.2 ENVIRONMENTAL IMPACT

Environmental impacts apply to the finished substation as well as to the construction process. Environmental impacts may include:

- Noise impact;
- Visual impact and overshadowing;
- Effective control of oil leaks and spills and drainage off the site;
- Construction impact on neighbouring residents;
- Impact on the natural environment;
- Impact on public open spaces; and
- Traffic impacts.

Option 1 which retains the outdoor switchyard scores poorly due to its unappealing visual impact compared to the new indoor substation provided by *Option 2*. Further, this option results in the footprint of the substation increasing by a considerable margin. This will have a significant impact on "parkland" space currently being provided by the Company and may invoke an adverse response from the surrounding community.

Option 2 presents very low risks on all these accounts as it provides a compact indoor substation with virtually zero noise emissions, good visual presentation and a small footprint which will free up a significant portion of the overall site for other uses including extending the existing parkland.

5.2.3 CONSTRUCTION FEASIBILITY

Construction feasibility considers the risks to the cost and delivery schedule of the project due to issues surrounding the complexity of the construction procedures required. This will be affected by:

- Complexity of construction (number of temporary works required);
- Staging requirements for construction (number of basic construction stages);
- The extent of work in a live switchyard;
- The availability of space for construction works.

Options 1 will present a degree of risk due to works taking place in an existing live substation and extensive protection works in a live tunnel board requiring complex staging, procedures and work methods to ensure safety.

Option 2 is built entirely on a greenfield site with no connections to the existing live equipment except during change-over of the 33kV and 11kV feeders. Therefore the substation can be built in an efficient manner in a single stage and be commissioned with no effect on the existing substation. *Option 2* therefore presents a very low construction risk and considerably lesser risk than the other option.

5.2.4 OPERATING AND MAINTENANCE REQUIREMENTS

This indicator assesses the ongoing operating and maintenance requirements in terms of cost and resource demand and is influenced by issues including:

- The maintenance requirements of the equipment;
- The use of established and well understood equipment and procedures to reduce O&M risks;
- The flexibility of the substation arrangement for carrying out switching and maintenance tasks;
- The ease of access to the equipment for switching and maintenance tasks; and
- The susceptibility of the equipment to damage due to environmental or human factors such as lightning strikes, birds, storm damage and vandalism.

Option 1 retains the existing aged control building and outdoor 33kV switchyard. Further, the 33kV switchyard has been the subject of vandalism attempts which present an ongoing maintenance cost (and supply reliability) risk.

Option 1 also includes a second building for the 11kV switchboard which is separated by a significant distance from the main control building which contains auxiliary switchgear and protection and control equipment and will be inefficient from a switching and maintenance perspective and may cause confusion during emergency response situations. Accordingly, this option scores poorly for this indicator.

Option 2 removes the outdoor switchyard and replaces all of the aged assets with new equipment with minimal maintenance requirements. Further, the 33kV bus-section circuit breakers which will be included in the new switchboard will provide increased operational flexibility. Therefore this option presents a very low risk with respect to operating and maintenance costs and scores the most favourably for this indicator.

5.2.5 RELIABILITY AND SUPPLY SECURITY RISK

This indicator considers the risk posed to the reliability of the supply to customers and the security of the supply provided by the substation (at 11kV busbar level) during the development works and also by the completed asset.

Both options maintain a secure level of supply to customers and pose a reasonably low level of risk for this indicator during construction. However, *Option 1* includes works in a live 33kV switchyard and works in a live protection tunnel board and therefore carries the risk of an inadvertent trip and loss of supply during the construction period.

Further, when complete, *Option 1* retains the existing 33kV switchyard which is not equipped with 33kV bus-section circuit breakers and therefore is exposed to the risk of loss of supply from the substation in the event of storm damage, lightning strike, birds on the busbars, equipment failure or further vandalism.

Option 2, which would be constructed on site clear of the existing substation, significantly reduces the risk of an inadvertent trip of the substation during the construction period. Further, this option replaces the 33kV outdoor switchyard with inherent reliability risks and provides bus-section circuit breakers which will provide an N-1 level of supply security at 33kV bus-bar level thereby reducing even further the risk of loss of supply due to equipment failure. As a result, this option presents the lowest risk in terms of customer reliability impacts.

5.2.6 SUSTAINABILITY IMPACT

This indicator considers the energy and resource use during construction and also for the life-cycle of the asset. It also considers how well the option supports the business objective of strategically managing the network (ie to avoid future bottle necks in resource demand). This indicator includes consideration of:

- Provision for the future needs and/or further development of the substation as may be required in the future;
- Minimisation of returns to the site for additional work;
- Utilisation of assets;
- Provision for reuse of redundant equipment;
- Minimisation of usage of materials (as compact as practicable);
- Minimisation of wastage of materials and resources (temporary works); and
- Minimisation of the ongoing use of energy.

Option 1 represents an intermediate step in a strategy of redevelopment of the substation whilst *Option 2* completely renews the substation for the long-term. *Option 2* will result in the 33kV circuit breakers in the existing switchyard being prematurely decommissioned. However, the Company has a large fleet of OX36 breakers in service and no spare units available. Despite their modest age the OX36 units are developing condition issues and therefore removing the five units from Marayong and making them available as spares for the network is a valuable opportunity. Accordingly, *Option 2* presents a low risk in terms of the sustainability indicator.

5.2.7 SUMMARY OF RISKS

Based on the above analysis Table 11 below gives a visual representation of the risks presented by each of the options. It shows that Option 2 provides substantial improvements to safety, environmental impact, construction feasibility, operation and maintenance costs, customer reliability and business sustainability compared to Option 1.

TABLE 11 – MARAYONG ZS QUALITATIVE RISK ASSESSMENT

Option	Option detail	Safety	Environment	Construction	Operating & maintenance	Reliability	Sustainability
1	New 11kV building and replace all TXs						
2	New indoor substation and replace all TXs						
Code	Extreme risk	High risk	Moderate risk	Low risk			

Accordingly, Option 2, which includes the complete replacement of the substation on a clear part of the site, is the preferred redevelopment approach from a risk perspective.

5.3 NET PRESENT COST OF OPTIONS

The present cost of each option has been assessed including the initial capital costs, the present value of future capital expenditure on development works and the present value of annual maintenance costs. The assessment covers a common 45 year period including the residual value at the end of the period of capital investments made during the period.

The results of the assessment are summarised in Table 12 below. Option 2 provides a significant reduction in risk for a modest increase in present cost of $0.9 million over Option 1b. The step up in cost is primarily due to the remaining life of the 33kV circuit breakers which set the timeframe when the 33kV switchyard is replaced with an indoor 33kV switchroom which effectively transitions Option 1 into Option 2.

As noted in 3.3, whilst the effective life of 33kV circuit breakers is nominally 45 years, experience to date with modern sub-transmission SF_6 and vacuum circuit breakers is that both the quality of construction and the issue of support for their numerical control systems will reduce their effective life to considerably less than 45 years. To this end, an effective life of 30 years has been assigned to the 33kV circuit breakers at Marayong Zone Substation which in effect drives the works to replace the 33kV switchyard in 16 years' time. This significant additional capital investment in 16 years lifts the present cost of Option 1 closer to that of Option 2.

Refer to Appendix G for further detail of the present cost analysis.

TABLE 12 – NET PRESENT COST OF OPTIONS

Future work items	Cost	Year	Present cost
Option 1			
Initial redevelopment works	12.44	2018 - 2021	11.11
Replacement of 3 x 33kV VTs at end of life	0.21	2022	0.16
Replacement of 33kV switchyard with 33kV indoor switchroom at end of life of the 33kV circuit breakers	10.34	2033	4,46
Maintenance of the power transformers ($1,600 pa per new TX)			0.32
Maintenance of 33kV switchgear ($3,500 pa ramping to 7,200 pa for yard)			0.07
Maintenance of all 11kV Switchgear ($8,900 pa)			0.16
Total			**16.29**
Option 2			
Initial redevelopment works	18.82	2018 - 2021	16.82
Maintenance of the power transformers ($1,600 pa per new TX)			0.32
Maintenance of indoor 33kV switchboard ($1,700 pa for indoor 33kV switchgear)			0.03
Maintenance of 33kV switchgear ($3,500 pa ramping to 7,200 pa for yard)			0.16
Total			**17.33**

5.4 PREFERED OPTION

Whilst Option 1 provides a slightly lower present cost, Option 2 provides an efficient solution which presents significantly lower risks than Option 1 and supports the Company's strategic objectives of improving safety outcomes, reducing maintenance costs and better customer reliability.

Therefore, on the basis of alignment with the Company's desired trajectory of performance for the network asset base, Option 2 is recommended as the preferred approach to address the renewal needs at Marayong Zone Substation.

6.0 PREFERRED REDEVELOPMENT OPTION

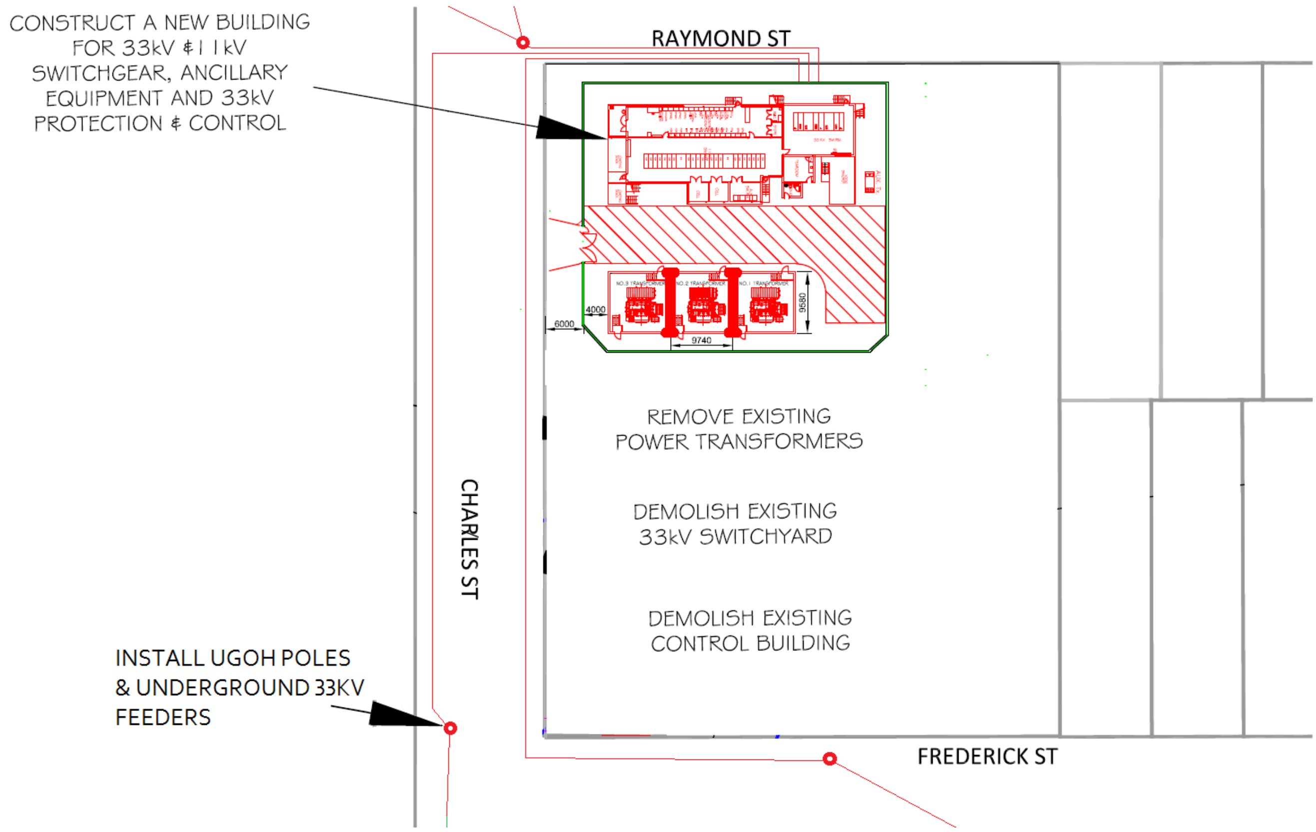
6.1 PREFERED OPTION DETAILS

This project includes replacement of the substation including:

- Construction of a new control building with new indoor 33kV and 11kV switchgear, auxiliaries and protection and control equipment;

- Installation of differential feeder protection over the optical fibre network for all the 33kV feeders;
- Installation of three new 25MVA low noise power transformers;
- Relocate the 11kV capacitor bank;
- Undergrounding of the 33kV feeders for the last span into the new substation;
- Changeover of the 11kV feeders including replacement of the first section out of the new substation;
- Removing the 33kV circuit breakers to spares;
- Decommissioning of the remaining assets in the existing substation; and
- Demolition, remediation and landscaping of the existing substation site.

FIGURE 6 – PROPOSED GENERAL ARRANGEMENT



Note that Figure 6 is a conceptual arrangement with a more tangible arrangement to be finalised during the design phase of the project to consider the most optimal arrangement in terms of construction practicality and efficiency. However, it is noted that the proposed arrangement should limit the footprint of the substation as much as practicable to the north-west corner of the site as shown in Figure 6.

7.0 PROJECT COSTS AND FUNDING

The estimated costs of the preferred option (Option 2) are summarised in Table 13 below. Refer Appendix F for further detail of the cost estimates.

TABLE 13: ESTIMATED PROJECT COST

Item	Base cost ($)
Project Management	
Project management & project definitions	1,085,722
Indoor 33kV bays	
Feeders	553,460
Bus sections	448,292
Indoor 11kV bays	
Feeders	1,318,178

Item	Base cost ($)
Bus sections	169,823
Transformer bays	
Bays	847,308
Transformer costs	1,980,000
bunds / sound walls / blast walls / fire suppression	1,310,000
AFIC equipment	
SFU & Injection Cells	301,000
Building & Switchyard	
Building/transformer runway/fencing/landscaping/building fire suppression	5,401,100
Ancillary equipment	
11kV aux switchboard/aux. transf./batteries & chargers/radio system/ new SCADA	550,303
Under frequency load shedding	33,966
Additional costs	
Mains	1,940,133
Distribution	1,400,000
Major equipment storage	122,640
Feeder changeover	100,000
Removal of existing transformers	60,000
Removal of existing equip. & fence	95,000
Demolition of existing building & switchyard	1,105,550
Total	18,822,000
Total (to nearest $0.1M) ($M)	**18.8**

7.1 CONTINGENCY

The principal risks are reflected in Table 14 against the various functional activities or work packets required to implement the project. The principle contingency sum for the works includes unforseen site constraints leading to design modifications due to soil contamination.

TABLE 14: TOTAL PROJECT COST INCLUDING CONTINGENCY PROVISIONS

Item	Contingency Provisions	
	Amount ($Real) ($M)	Detail
Project Management & PD	0.08	
Substation Design	0.06	Unexpected site requirements leading to design modifications.
Procurement/ Subcontract	0.62	Variations to equipment costs.
Civil & Building works	0.95	Unexpected site requirements leading to design modifications and additional work, soil contamination, rock conditions.
Distribution works	0.20	Possible need to replace cables pending de-rating study
Demolition works	0.19	Unforeseen site conditions in an aged substation.
Total	**2.10**	

7.2 PROJECT FUNDING

Project TS146 Marayong ZS Switchgear Replacement has a funding allocation of $16.4 million over the 2016/17 – 2020/21 years. Note that there are sunk costs of $0.2 million due to the previous investigations to develop network investment options. Future releases of the PIP will reflect the additional funds required for this project.

TABLE 15: PIP SUMMARY

PIP Element	PIP Rating
Project ID	TS146
Principal Driver	Renewal

PIP Element	PIP Rating
Percentage	88.07%

The project is estimated to cost $19.0 million in real 2017/18 terms. The estimated deliverable period is 2017/18 to 2020/21 with the expenditure spread shown in Table 16 along with the provision in the portfolio investment plan PIP8.3.

CPI has been applied at a rate of 2.5% per year. The total cost of the project in nominal terms is $19.7 million.

TABLE 16: PROJECT EXPENDITURE SPREAD

Expenditure Spread ($M)	2016/17	2017/18	2018/19	2019/20	2020/21	Total
PIP 8.3 ($ nominal)	0.1	0.5	3.6	6.8	5.4	16.4
Project cost ($ real)	0.2	2.0	7.8	7.8	1.2	19.0
Project cost ($ nominal)	0.2	2.0	8.0	8.2	1.3	19.7
Contingency	0.0	0.5	0.6	0.4	0.6	2.1
Total costs ($ nominal)						**21.8**

8.0 RECOMMENDATIONS

It is recommended that:

- A capital expenditure of $19.7 million for the construction of a new substation to replace the existing Marayong Zone Substation over the 2017/18 – 2020/21 period to be approved; and
- A contingency sum of $2.1 million to cover unforseen events be approved.

The complete project estimate, including the contingency sum totals $21.8 million.

9.0 APPENDICES

APPENDIX A - STATEMENT OF NETWORK NEED

APPENDIX B – BLACKTOWN TS SYSTEM DIAGRAM

APPENDIX C – MARAYONG ZONE SUBSTATION SINGLE LINE DIAGRAM

APPENDIX D – MARAYONG ZONE SUBSTATION GENERAL ARRANGEMENT

APPENDIX E – MARAYONG ZONE SUBSTATION CONDITION ASSESSMENT

APPENDIX F – MARAYONG ZONE SUBSTATION ENVIRONMENTAL NOISE ASSESSMENT

APPENDIX G – MARAYONG ZONE SUBSTATION QUALITATIVE RISK ASSESSMENT

APPENDIX H –TS146 COST ESIMATE

APPENDIX I – DISTRIBUTION WORKS ITEMS

APPENDIX J – MARAYONG ZONE SUBSTATION IMAGES

10.0 REFERENCES

[1] Asset Standards & Design, “SDI 161 - Condition Assessment of Assets using Health Index,” 2015.

[2] Asset Standards & Design, “Asset Class Condition - Power Transformers,” 2017.

[3] Asset Standards & Design, “SDI 503 - Transmision and Zone Substation Fire Detection, and Suppression Systems,” 2014.

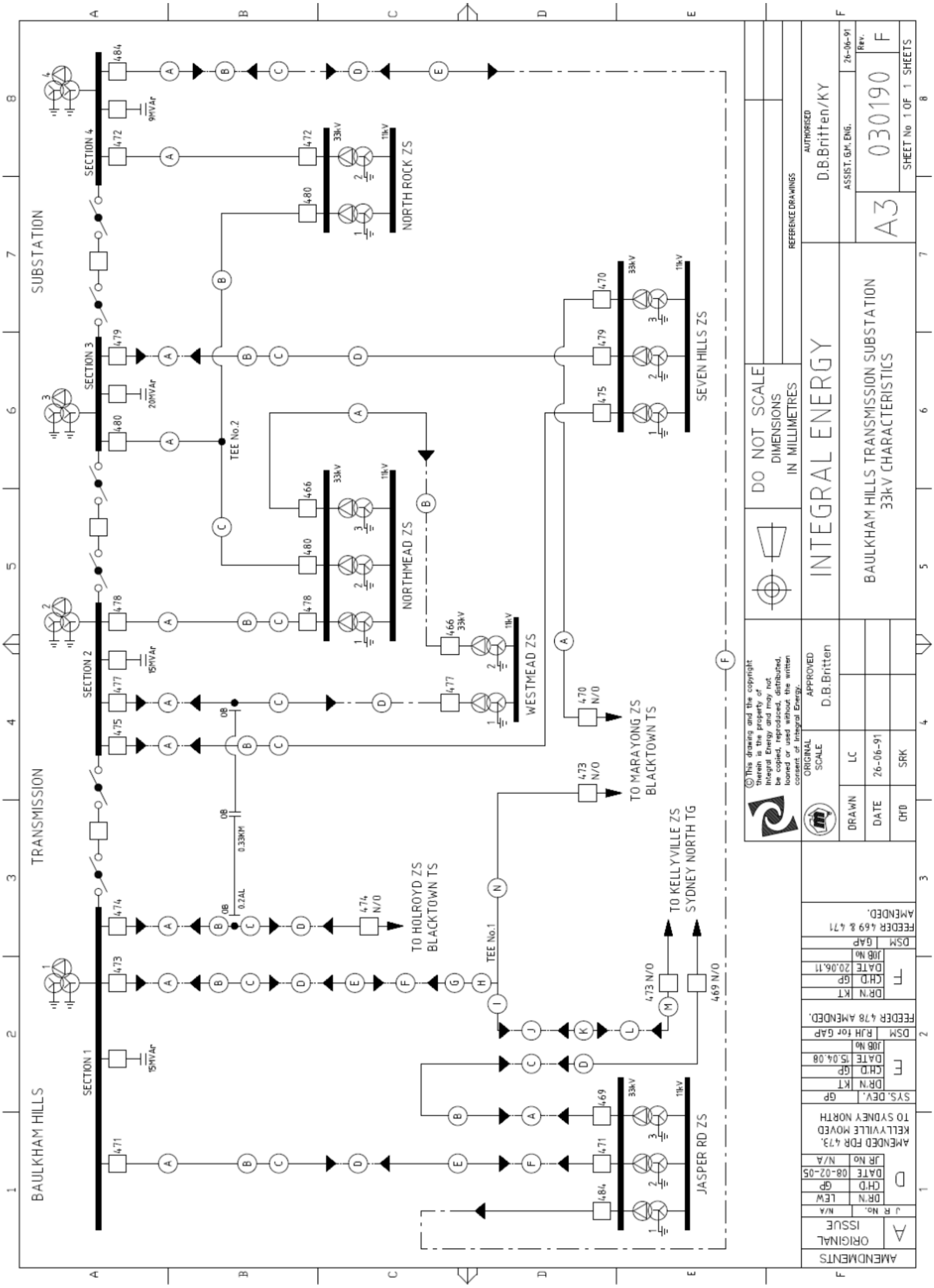
[4] Asset Standards & Design, “Asset Class Condition - 33kV, 66kV and 132kV Circuit Breakers,” 2017.

[5] Asset Standards & Design, “SMI 153 - Voltage Transfomers and Capacitor Voltage Transformers,” 2015.

[6] Asset Standards & Design, “SDI 510 - Buildings,” 2016.

[7] A. S. &. Design, “Load Control Strategy,” 2016.

Refer to the attached Appendix A – Marayong Zone Substation Statement of Network Need, November 2016.



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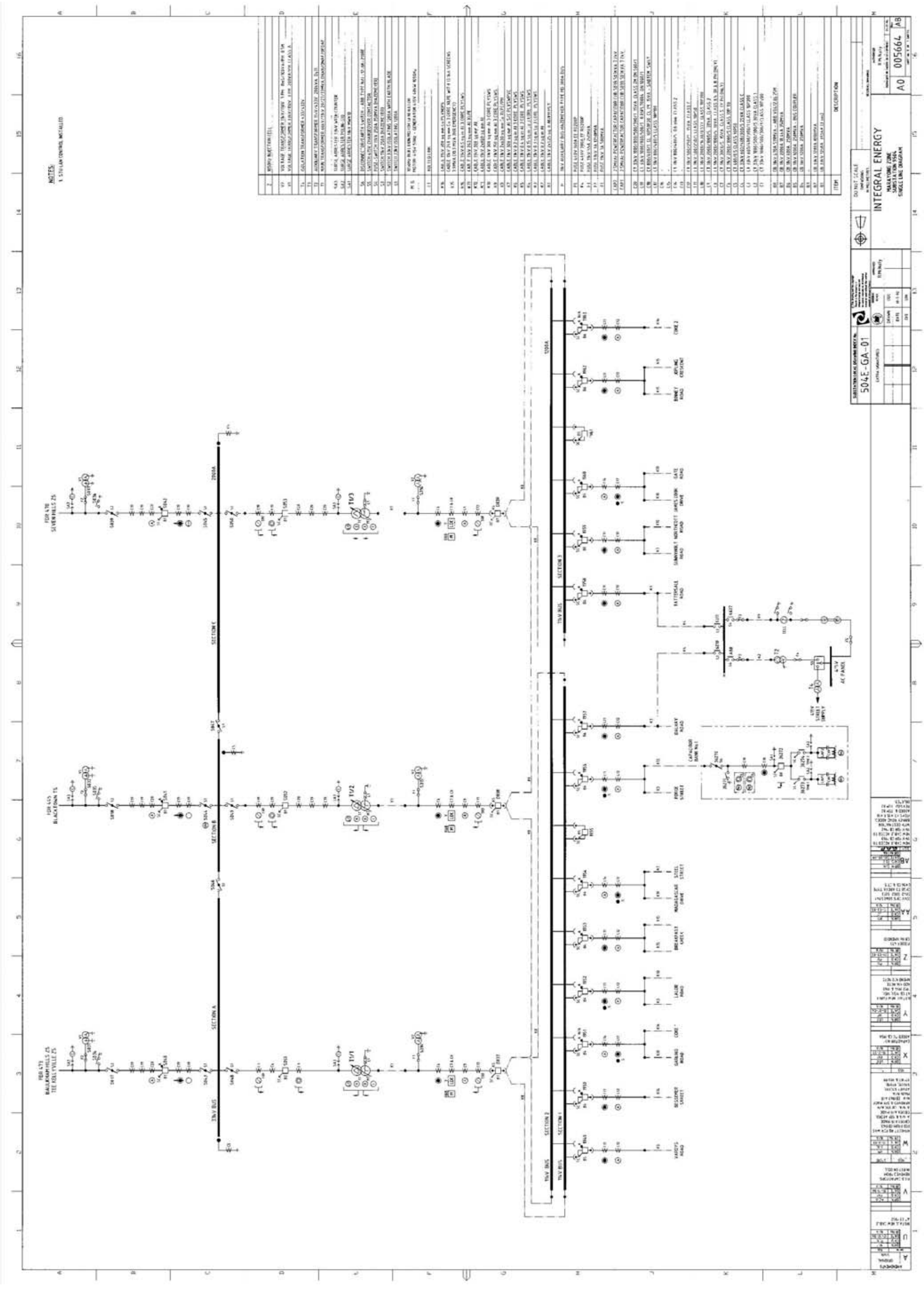
APPENDIX C – MARAYONG ZONE SUBSTATION SINGLE LINE DIAGRAM



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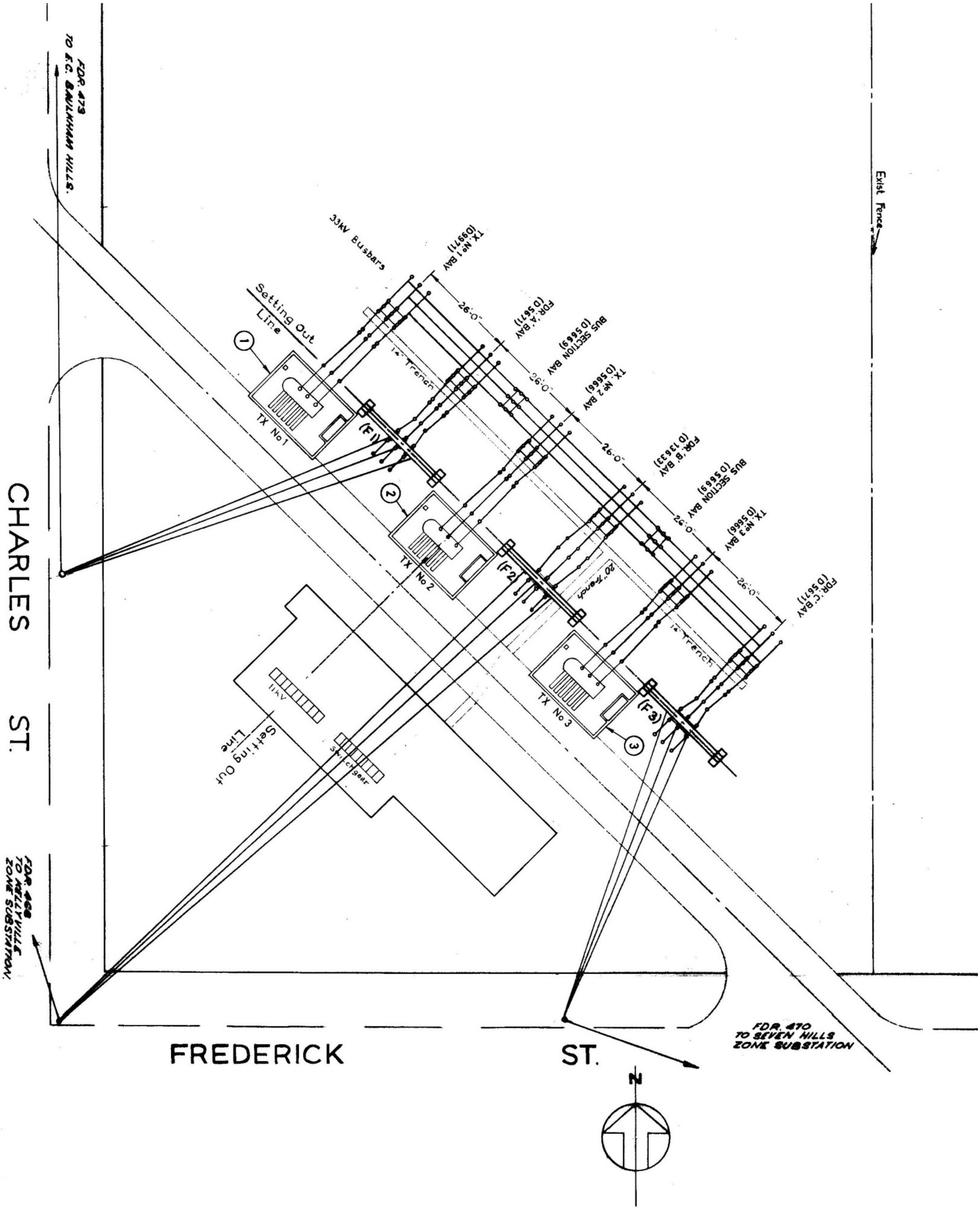

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APPENDIX E – MARAYONG ZONE SUBSTATION CONDITION ASSESSMENT

Refer to the attached Appendix E – Marayong Zone Substation Condition Assessment, February 2017.

APPENDIX F – MARAYONG ZONE SUBSTATION ENVIRONMENTAL NOISE ASSESSMENT

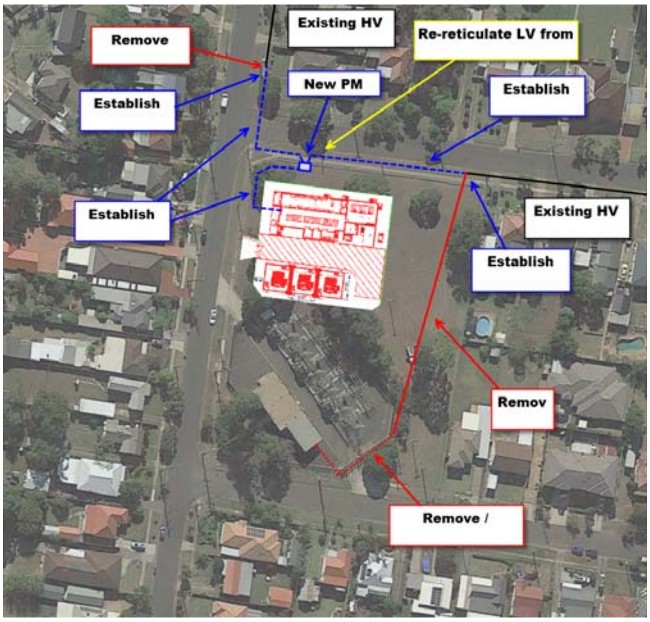
Refer to the attached Appendix F – Environmental Noise Assessment, Marayong Zone Substation 2 Raymond Street, Marayong ZSW, Report No 6260-1R, 28 July 2017

APPENDIX G – MARAYONG ZONE SUBSTATION QUALITATIVE RISK ASSESSMENT

Refer to attached spreadsheet – TS146 Marayong ZS cost and risk assessment, r9

ITEM	QTY	Labour Cost ($)	Store Costs ($)	Plant Costs ($)	Direct Charge ($)	Total Cost ($)
Outdoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Feeder Bays						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	3	$134,370	$8,629	$10,305	$400,156	$553,460
11kV	19	$507,639	$40,656	$54,077	$715,806	$1,318,178
Outdoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	0	$0	$0	$0	$0	$0
Indoor Bus Sections						
132kV	0	$0	$0	$0	$0	$0
66kV	0	$0	$0	$0	$0	$0
33kV	2	$120,169	$2,607	$4,426	$321,090	$448,292
11kV	2	$67,270	$76	$3,386	$99,090	$169,823
Joggle Chamber/Bus Ducting	0	$0	$0	$0	$0	$0
Transformer Bays						
Bays	3	$256,564	$39,307	$31,165	$520,272	$847,308
Transformer Costs	3	$0	$0	$0	$1,980,000	$1,980,000
Bunds / Sound Walls / Blast Walls / Fire Suppression		$0	$0	$0	$1,310,000	$1,310,000
AFIC Equipment						
SFU & Injection Cells		$0	$0	$0	$301,000	$301,000
Building & Switchyard						
Building/Transformer Runway/Fencing/ Landscaping/Building Fire Suppression		$0	$0	$0	$5,401,100	$5,401,100
Ancillary Equipment						
11kV Aux Switchboard/Aux. Transf./ Batteries & chargers/Radio System/ New SCADA		$91,779	$0	$276	$458,248	$550,303
Underfrequency Load Shedding	3	$3,528	$0	$333	$30,105	$33,966
Capacitor Banks	0	$0	$0	$0	$0	$0
General Arrangment Update		$0	$0	$0	$0	$0
Project Management & Project Definitions						$1,085,722
Control Panels	0	$0	$0	$0	$0	$0
Mains		$1,163,282	$134,961	$93,491	$548,399	$1,940,133
Distribution		$0	$0	$0	$1,400,000	$1,400,000
Additional Costs						
Major Equipment Storage					$122,640	$122,640
On Site Security					$0	$0
Changeover						$100,000
Removal of Exist. Transformers						$60,000
Removal of Exist. Equip. & fence						$95,000
Demolition of Exist. Bldg & Sw. Yard						$1,105,550
Sunk Costs from previous works						$200,000
0						$0
0						$0
0						$0
0						$0
SUB TOTAL:						**$ 19,022,475**
CPI:						**$ 713,343**
TOTAL (to the nearest $100k):						**$ 19,700,000**
Contingency (to the nearest $100k):						**$ 2,100,000**


Close
Existing HV
Establish
Remove HV
Existing HV
Remove /
Erect


Existing HV
Re-reticulate LV from
Remove
Establish
New PM
Establish
Establish
Existing HV
Establish
Remov
Remove /


Existing HV UG -
FDR's 1963, 1949,
Establish
Cut & STJ x
Abandon /


Existing HV UG -
FDR's 1952, 1951,
Establish
Cut & STJ x
Abandon /
Remove

Existing HV
Establish
Remove
Abandon / Remove
Bond
Cut &
Existing HV
Existing HV UG - FDR's

Establish
Replace
Abandon /
Cut & STJ x
Existing HV UG - FDR's 1960, 1953,
Existing HV

Establish
Abandon /
Establish new
Remove

View from Fredrick Street

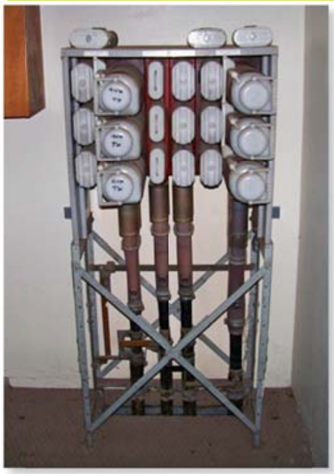
The 11kV Westinghouse HQ switchboard

1 of 3 Reyrolle LMT 11kV transformer circuit breakers in dedicated room

Protection tunnel board in control room

Inside the protection tunnel board

11kV MD4 auxiliary Switchgear



Outdoor switchyard

Power transformers with rusting radiator fins and oil leaks

1 of 5 33kV Areva OX36 SF_6 circuit breakers to be removed to spares

33kV Hawker Siddeley VOX SF_6 circuit breaker to be removed to spares

Existing control building and cable basement

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