Geoff Brown & Associates Ltd

TECHNICAL REVIEW OF HAY ST – MILLIGAN ST CABLE REGULATORY TEST APPLICATION

Prepared for

ECONOMIC REGULATION AUTHORITY

Final

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TABLE OF CONTENTS

SECTIONS

DISCLAIMER

This report has been prepared for the Economic Regulation Authority (Authority) to assist in its determination of whether Western Power's installation of a new 132kV cable between its Hay Street and Milligan Street CBD substations meets the requirements of the Regulatory Test. Geoff Brown and Associates Ltd accepts no responsibility to any party other than the Authority for the accuracy or completeness of the information or advice provided in this report and does not accept liability to any party if this report is used for other than its stated purpose.

In preparing this report, we have relied on information and data provided to us to assist with the review and assumed it to be accurate. We have also assumed that the data and information provided was complete and no data and information material to our review was withheld. We are therefore not responsible for conclusions or errors arising from the use of inaccurate or incomplete information.

The findings of our review are documented in this report and represent our reasonable professional judgement based on the information and data provided. Should additional information or data be relevant, our review findings could change.

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1. INTRODUCTION

Western Power is planning to construct a new 132kV underground cable between its Hay Street and Milligan Street 132/11 kV substations within the Perth central business district (CBD). This project is the first stage of a development program to upgrade the transmission substation assets serving the Perth CBD. While the electricity demand in the CBD is not forecast to increase, the upgrade is intended to maintain the reliability of the electricity supply within the CBD, as many of the existing transmission assets are in poor condition and nearing the end of their useful life.

The proposed new cable is a major augmentation as defined in the Electricity Networks Access Code 2004 (Access Code) and therefore, in accordance with clause 9.2 of the Access Code, Western Power cannot commit to the construction of the new cable until it has passed the Regulatory Test. This requires Western Power to satisfy the Economic Regulation Authority (Authority) that the new cable maximises the net benefits to those who generate, transport and consume electricity, after considering alternative options[1].

To this end Western Power has submitted a major augmentation proposal under clause 9.15 of the Access Code to the Authority, which must determine whether the installation of the new cable meets the requirements of the Regulatory Test. The Authority has engaged Geoff Brown & Associates Ltd to review the proposal and assess the extent to which it meets the Regulatory Test requirements from a technical and engineering perspective. This report documents our advice to the Authority on this matter.

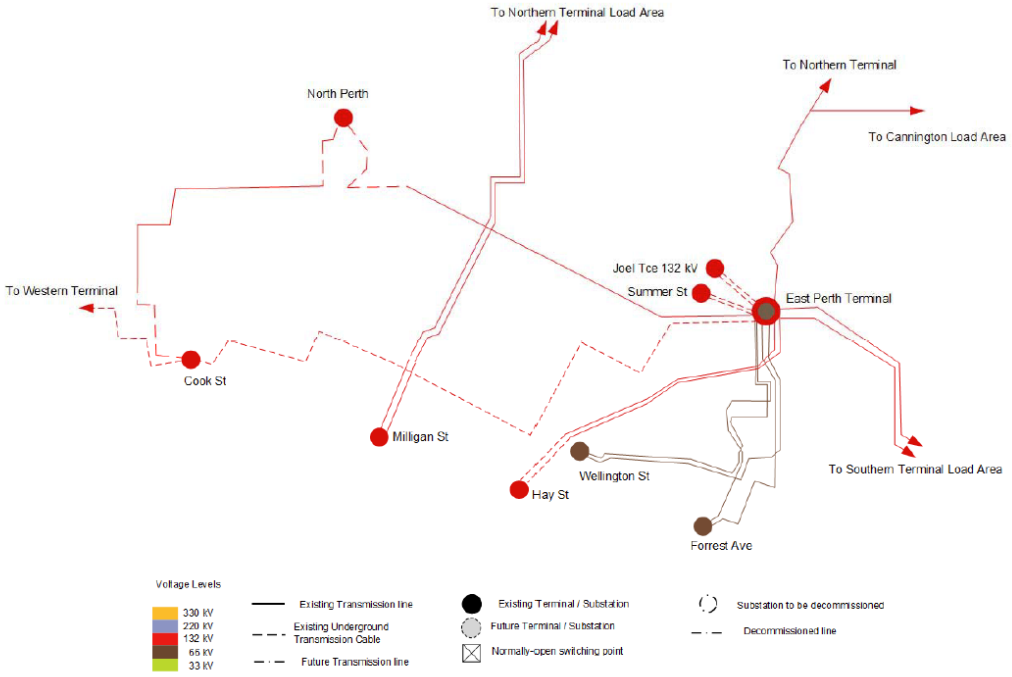
[1] Access Code, clause 9.3.

2. BACKGROUND

2.1 EXISTING TRANSMISSION SYSTEM CONFIGURATION

The existing transmission system supplying the CBD and its environs is shown in Figure 2.1.

Figure 2.1: Transmission System Serving CBD and Environs



Source: Western Power

Milligan Street (MIL) and Hay Street (HAY) substations are 132/11 kV substations serving the inner CBD area. Each substation has three transformers, with varying capacities of between 63 and 85 MVA and is supplied by two incoming 132 kV circuits, fed from the Northern and East Perth (EP) terminal stations respectively.

The area to the east and north east of the CBD, between the CBD and the Swan River, is served by 66/11 kV substations in Wellington Street (W) and Forest Ave (F). Both substations are supplied by two incoming 66kV circuits, fed from a 66kV switchyard located at the East Perth terminal station.

All substations supply 11kV feeders, which supply distribution transformers located throughout the supply area. The two ends of most feeders supplied from HAY and MIL are connected to the end of a feeder fed from a different substation. This enables the load on any such feeder to be supplied from a different substation by closing a normally open circuit breaker at the interconnection point between each feeder, but it means that, under normal operating conditions the maximum load on a feeder must be limited to 50% of the feeder's capacity. The process of transferring feeder load to another substation by opening the feeder circuit breaker at the supply end and closing the circuit breaker at the interconnection point is referred to in this report as distribution load transfer.

2.2 ISSUES TO BE ADDRESSED

The main issue that Western Power must address is the condition of many of its existing transmission assets. Section 3.2 of its Options Paper[2] lists those assets that are expected to require replacement within the next ten years. They include:

- transformers at substations, F and W);
- switchboards at F, HAY and MIL;
- 132kV cables between EP and HAY[3] and 66kV cables between EP and W; and
- 132kV and 66kV line structures. These structure replacements are not included in the different options as the work is required for all options and the cost is not material relative to the costs of other work in the redevelopment programme.

Information provided by Western Power in Section 2.2 of its Options Paper, indicates that there has been no growth in electricity demand since about 2011 although growth prior to that had been significant. Its load forecasts prior to 2017 suggested that the current trend of flat or declining growth would only last until around 2022 after which demand would start growing again, albeit at a more modest rate than experienced in the first decade of this century. The 2017 forecast suggests that the trend of flat or declining load growth will continue through to the end of the 30-year forecast period. While demand growth is not a key driver of any network redevelopment, it would be prudent for any network redevelopment plan to take account of the possibility that the current forecast is unduly conservative and that there could be a requirement to provide for modest levels of electricity demand above existing requirements within the lifetime of any new assets.

The Options Paper also notes that, in order to provide the required level of redundancy (discussed in Section 2.3), while feeder loadings under normal operating conditions are limited to 50% of their total thermal capacity, installing more cables can de-rate the existing cable further, resulting in even lower utilisation of the thermal capacity of the cable. We accept that the number of distribution feeders that can be installed to evacuate power from a zone substation may be physically constrained and that these constraints could limit the total load that can be supplied through a particular substation.

2.3 SECURITY OF SUPPLY CRITERIA

As the HAY and MIL substation supply the Perth CBD the load that can be supplied from each substation is limited by the Perth CBD planning criterion defined in clause 2.5.3(b)-2.5.3(d) of Western Power's Technical Rules. These clauses state:

> *(b) Following any outage within a sub-network to which the Perth CBD criterion applies involving:*
>
> *(1) one or two transmission lines;*
>
> *(2) one or two supply transformers; or*
>
> *(3 one transmission line and one supply transformer,*
>
> *and irrespective of whether any single transmission element outage is planned or unplanned, there must be sufficient power transfer capacity in the*

[2] *Major Augmentation Proposal, Options Paper, Perth CBD: Hay/Milligan Supply Reinforcement Investment,* Western Power, 4 August 2017 (Ref EDM#42901215)

[3] While these cables are listed in the Options Paper as assets requiring replacement, the cost of this work was not included in any of the options evaluated. Western Power subsequently clarified that further condition assessment had shown that replacement in the medium term is not required. These cables are currently 40 years old whereas their economic life, as stated in Table 10.11 (p222) of Western Power's AA4 Access Arrangement Information is 55 years. On the other hand, the 66 kV cables between EP and W, which do require replacement, are now 66 years old.

transmission system to maintain supply to all Consumers within the Perth CBD without the need to reschedule generation.

(c) For an unplanned outage of a single supply transformer, there may be a supply interruption to some Consumers of up to 30 seconds to allow for the automatic transfer of the affected loads to other supply transformers within the same substation or to other substations using capacity that is kept available for this purpose.

(d) For unplanned outages of two transmission elements in accordance with clause 2.5.3(b), there may be a supply interruption to some Consumers of up to 2 hours to allow for the transfer of the affected loads to other supply transformers within the same substation or to other substations using capacity that is kept available for this purpose.

Currently this requirement is met by having two 132 kV incoming circuits and three transformers at each substation, and by limiting the load at each substation to the maximum rating of one transformer. Under these conditions, the contingency identified in clause 2.5.3(b) of the Rules that requires the most distribution load transfer capacity is the simultaneous loss of both incoming circuits, which results in a complete loss of supply to the substation. In this event, all the load on the substation must be transferred to another substation using distribution load transfer.

The installation of an interconnecting 132 kV cable between HAY and MIL will provide three incoming circuits to each substation, which means that there will still be an incoming supply to the substation in an N-2 contingency when two transmission lines are not available. This significantly increases the load that can be drawn from each substation under normal operating conditions without breaching the above planning criteria. More specifically:

- Under the existing arrangement with only two incoming circuits, the most onerous N-2 contingency is the loss of both incoming lines. In this event there will be a complete loss of supply to the substation and the total load must be supplied from adjacent substations using distribution load transfer. Hence the available distribution transfer capacity (approximately 70 MVA) limits the amount of load that can carried at each substation.

- With a third incoming circuit the loss of two incoming lines is no longer an issue, since the load on the substation can be carried by the third circuit. The only N-2 operating condition that might require distribution load transfer is the loss of two substation transformers. In this situation most of the load can be supplied by the third transformer and distribution load transfer need only accommodate any load on the substation above this.

Assuming the current situation where the load at each substation is approximately 70 MVA and the available transfer capacity is also approximately 70MVA, if there are only two incoming circuits the available distribution load transfer capacity is fully utilised when both circuits are lost, as the full load on the substation must be offloaded to other substations. With a third incoming line and three transformers at each substation, there is no N-2 situation where any distribution transfer capacity is needed, since in an N-2 contingency there will always be an incoming supply and at least one 70 MVA transformer to carry the substation load. It follows that, with a third incoming line, the substation can be loaded more heavily. If two incoming circuits are lost, the load on the substation can be supplied by the third circuit. If two transformers are lost, then only load exceeding the capacity of the third transformer need to be offloaded. For example, if the substation load was increased to 95 MVA, only 25 MVA of distribution load transfer capacity would be required to meet the N-2 security criterion and this would be available using the existing feeders. Hence, the third incoming circuit releases capacity by allowing the existing assets to be more highly utilised without breaching the planning criteria.

It is worth noting that the simultaneous outage of two incoming transmission circuits is more likely to occur than the simultaneous outage of two transformers. This is particularly true of the two circuits supplying MIL, which are overhead circuits sharing the same structures

on a double circuit line, where a common mode outage due to the loss of a support structure is a real possibility. Power transformer outages are much less common and a simultaneous outage of two transformers at the same substation is highly unlikely[4].

[4] Nevertheless, such situations do occur. The most recent example is Muja, where the two interconnecting transformers feeding the 132 kV switchyard both failed. In this case the two failures occurred 17 months apart and only escalated into an N-2 situation because of the delays that occurred after the first replacement transformer, which Western Power had ordered from a reputable manufacturer, failed its factory acceptance test.

3. OPTIONS ANALYSIS

The Options Paper identifies the following five potential development plans to address the issues identified in Section 2.2 above while at the same time meeting the security of supply criteria described in Section 2.3. All options involve the progressive installation or replacement of network assets over the period 2019-2027. Non-network options were not considered since the driver for the work is a need to replace existing assets that have reached the end of their economic life. Consideration of non-network options is therefore not relevant as there is no question that a distribution network is still required to provide an electricity supply to consumers within the CBD. Non-network options are generally only relevant when existing network assets have insufficient capacity to meet the forecast demand and this is not the case in this situation.

While not specifically identified in the individual option descriptions below, all options require the replacement of the 11kV switchboards at Hay St and Milligan St substations, as these substations must remain in service to supply their existing loads.

3.1 OPTIONS CONSIDERED

3.1.1 Option 1: Like for Like Replacement

This involves the progressive replacement of existing network assets that are reaching the end of their economic life and therefore raise safety and/or reliability concerns. Asset replacement does not require the approval of the Authority and following completion of the work there would be no change to the existing network arrangement.

While Western Power has not structured its proposal in this manner, we suggest this option should be considered the base case, against which the other options should be benchmarked. Essentially, it is a "do nothing" option in that it involves only the replacement of existing assets as needed to maintain the serviceability of the current network and does not require the installation of new assets.

3.1.2 Option 2: New CBD Substation

This involves the installation of a new 132kV substation in the CBD to replace the 66kV network shown in Figure 2.1. The load on the Forrest Ave and Wellington Street substations would be transferred to the new substation and all 66kV assets supplying the CBD would be decommissioned. The 66kV switchyard at the East Perth terminal station would also be decommissioned as this would no longer be required.

This was the option proposed by Western Power, and accepted by the Authority, in its AA3 regulatory proposal.

3.1.3 Option 3: New Hay St – Milligan Street 132kV Cable

This cable would provide a third incoming 132kV supply to both the Hay St and Milligan substations, which would allow the existing transformers at both substations to be more fully utilised without violating the security of supply criteria described in Section 2.3.

The transformer capacity released by the new cable would accommodate some of the load currently supplied by the existing 66kV network. The balance of this 66kV load would be transferred to the Joel Terrace zone substation where spare transformer capacity is available[5]. This option would therefore also allow the 66kV network, including the 66kV switchyard at the East Perth terminal station, to be decommissioned.

3.1.4 Option 4: Minor Distribution System Upgrades and Defer 132kV Cable

This is a variation on Option 3 that acknowledges that the condition of the Forrest Ave substation is worse than Wellington St and therefore requires earlier asset replacement. It

[5] Much of the load supplied by the 66kV network is in East Perth, which outside of the CBD and is subject to a less onerous N-1 security of supply criteria.

would be possible to offload Forrest Ave to neighbouring substations if the distribution system supplied from Hay Street was augmented. This approach would allow the installation of the Hay St – Milligan St cable to be deferred.

However, this deferral would only be for three years as the new cable would still be required to allow the Wellington St substation to be decommissioned after its assets reached the end of their economic life. Hence the deferral of the 132kV cable installation is at the expense of a distribution network augmentation that would not be required if the cable installation was advanced.

3.1.5 Option 5: Major Distribution System Upgrades

This option provides for the decommissioning of the 66kV network supplying Wellington St and Forrest Ave substations and at the same time avoids the need for a new 132kV cable between Hay and Milligan St. In this case the additional capacity required to accommodate the 66kV load is achieved by a more substantial upgrade (then needed for Option 4) of the distribution network supplied by the two CBD substations.

3.2 COST BENEFIT COMPARISON

A cost benefit comparison of the five options evaluated by Western Power is shown in Table 3.1. We did not consider it necessary to test in detail the costs provided by Western Power in its proposal since we considered them to be reasonable and any adjustments to project costs would not have altered the ranking of the different options. The last column in the table presents the costs in a way that reflects the benefits of each option relative to the base case. This approach, in our view, better reflects the intent of the Regulatory Rest.

Table 3.1: Cost Benefit Comparison ($ million)

Option	Description	Nominal Cost	NPC[1]	Relative Cost[2]
1	Like for like replacement (base case)	216.0	172.2	-
2	New CBD substation	250.1	244.6	72.4
3	HAY-MIL 132kV cable	138.3	128.2	(44.0)
4	Deferred HAY-MIL 132kV cable	152.5	134.4	(37.8)
5	Major distribution upgrade	153.9	144.0	(28.2)

Note 1: Net present cost
Note 2: Relative to base case NPC

We concur with the above analysis and did not identify anything to suggest that Option 3 is not the most cost-effective option and the one that delivers the most benefits to those who generate, transport and consume electricity.

3.3 OTHER BENEFITS

Section 3.6 of Western Power's Major Augmentation Proposal briefly refers to other benefits that have not been quantified for its analysis. These are discussed further below.

3.3.1 Additional Capacity

Table 2 of the Options Paper, tabulates the approximate additional capacity provided by each option. We have some reservations about whether all the claimed additional capacity is available without further augmentation if the N-2 security requirement is to be maintained at Hay and Milligan Street substations.

For example, we understand that Milligan St substation has approximately 210MVA of power transformer capacity and 140MVA of distribution feeder capacity, providing 70MVA of available distribution transfer capacity, assuming the existing maximum substation load of around 70MVA. Any additional load on the substation (above 70MVA) will utilise some of this transfer capacity until in the extreme, the substation is loaded to 140MVA and no spare transfer capacity is available. This would violate the N-2 security criterion. We think

that realistically, the third incoming circuit will increase the available substation capacity by around 35MVA without distribution network upgrades, if the N-2 security criterion is to be preserved. This is, nevertheless, a 50% increase over existing capacity.

Western Power is currently forecasting CBD electricity demand to remain around its current level over the forecast period, so this additional capacity is unlikely to be needed. However, an additional benefit of Options 2, 3, and 4 is that they are all able to accommodate significant increases in demand above current levels should Western Power's current forecast turn out to be conservative.

3.3.2 Maintenance Costs

Western Power has not quantified the impact of each option on the cost of maintaining the network, which in turn is driven by the size of the asset base. Decommissioning the 66kV network will reduce maintenance costs as the decommissioned assets will no longer need to be maintained. This cost reduction will be offset by costs incurred in maintained new assets that have been added to the network.

Option 3 will result in the greatest reduction in maintenance costs since this option replaces the existing 66kV network with a single underground cable. Options 2, 4 and 5 will also likely result in a maintenance cost reduction but in these cases the reduction will not be as great because of the larger number of replacement assets.

3.3.3 Network Resilience

Resilience is the term used to describe the ability to respond and restore supply following an emergency high impact event that is outside normal planning and design parameters. Examples of such events include a fire in a terminal station cable tunnel and the failure of an earth wire shackle causing the released earth wire to gallop uncontrollably and short out a number of transmission circuits terminated at a major terminal station. Both these events have occurred in New Zealand in recent years.

Options 3 and 4 will both increase the resilience of the transmission network because the installation of the 132kV interconnecting cable means that the Hay and Milligan Street substations can both be supplied from either the Northern or East Perth terminal stations. This means that supply to all consumers within the CBD is unlikely to be interrupted for an extended period following a high impact low probability event that disables or severely disrupts supply from either terminal station.

The new cable will complete a second 132kV transmission circuit between the Northern and East Perth terminal stations. Under normal system operating conditions this circuit is likely to be operated in a radial configuration since operation in parallel with the 330kV network creates a potential for overloads. Nevertheless, the availability of a second circuit connecting the two terminal station switchyards could increase the options available to operators in responding to power system emergencies.

3.3.4 Revenue from Land Sales

The decommissioning of the 66kV network supplied from East Perth should free up land for other uses and allow Western Power to divest these assets. Any such divestment should benefit consumers, in accordance with the regulatory framework under which Western Power operates.

3.4 OTHER ISSUES

3.4.1 Cable Route

The proposed route of the proposed new cable between Hay and Milligan Street substation is an indirect route along Roe Street and avoids more direct routes along Wellington Street, Murray Street, Hay Street or St Georges Terrace. Western Power has advised that it has considered a number of routes in conjunction with the City of Perth and other affected authorities. It is satisfied that the Roe Street route is the most economic technically feasible

alternative given the congestion of underground services along other more direct routes and the need to minimise traffic management costs.

We accept that laying a high voltage underground cable within the CBD will be highly disruptive and must be carefully planned. We also agree that finding a route that avoids other underground services can be extremely difficult, to the extent that it is very feasible that a long route that avoids extreme service and traffic congestion could well be economic. We also note that in these circumstances, the cost of cable could be a relatively minor component of the total project cost.

3.4.2 Cable Size

Western Power is planning to install a 2000mm^2 copper cable between the two substations, which is the largest cable size readily available. The rating of an underground cable is determined by its installation conditions. Western Power has considered using both 1600mm^2 and 2000mm^2 cables and determined that these two cables would have installed ratings of 166 MVA and 194 MVA respectively. It has advised that, based on its assessment of potential network contingencies, a minimum rating of 175 MVA is required, but has provided no information to support or justify this assessment.

The primary function of the cable is to provide a backup supply to the Hay St and Milligan St substations should the normal incoming supply to either substation be lost. The maximum load at each substation is currently around 70 MVA, and Western Power does not forecast any increase in demand over its 30-year forecast period. Even if Western Power's forecast turns out unduly conservative, we cannot see the load on the cable increasing above say 100 MVA under the network conditions the cable is designed to address. This would suggest the size of the cable is excessive.

However, while the cable would normally operate in a radial configuration even under its design contingencies it forms part of a 132 kV interconnection between the East Perth and Northern terminal stations and could potentially be required to carry a high load should an unlikely high impact contingency arise that the network is not designed to withstand. Western Power likely considers it prudent to take a very conservative approach to sizing the cable to mitigate any reputational risk that could arise should an undersized cable constrain its response to a very high impact contingency.

3.4.3 Comment

While these are issues that affect the cost of Western Power's preferred alternative, this would not change our assessment of Western Power's ranking of the regulatory test alternatives. Therefore, we have not considered these matters further. These issues may need to be considered further when determining whether the project design meets the requirements of the first leg of the new facilities investment test (NFIT)[6], but this assessment is outside the scope of this review.

[6] NFIT is a test required by Clause 6.52 of the Access Code to determine the project cost to be included in the opening regulatory asset base for the AA5 regulatory period. The first leg of the test requires that the project design exhibits economies of scope and scale and the increments in which capacity can be added.

4. CONCLUSION AND RECOMMENDATION

We consider the alternatives considered by Western Power are reasonable and have not identified any additional alternatives that should have been included in the regulatory test assessment. We agree with Western Power that, as the main driver for the project is a need to replace existing network assets that have reached the end of their economic life, consideration of non-network alternatives would not be appropriate.

We agree with Western Power that, of the alternatives considered, Option 3 is the one that maximises the net benefits to those who generate, transport and consume electricity, after considering alternative options. It is also the option that maximises the quantified benefits to consumers when benchmarked against the base case alternative. Furthermore, we consider that the benefits that have not been quantified are likely to be higher for this option than for any of the other alternatives considered.

We therefore recommend that the Authority determine that the immediate installation of a 132kV underground cable between the Hay Street and Milligan Street CBD substations satisfies the requirements of the Regulatory Test.