Geoff Brown & Associates Ltd

TECHNICAL REVIEW OF WESTERN POWER'S SHENTON PARK ZONE SUBSTATION REGULATORY TEST APPLICATION.

Prepared for

ECONOMIC REGULATION AUTHORITY

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RECOMMENDATION

We recommend that the Authority grant regulatory test approval for the construction of the proposed new 132/11 kV substation at Shenton Park on the basis that:

- no non-network alternative has been identified, or is likely to be available, that would address emerging issues related to both the capacity and condition of the existing transmission and distribution network with the Western Terminal load area; and

- the new substation at Shenton Park is a component of all identified development options that are likely to be cost effective.

The decision should note that regulatory test approval does not imply new facilities investment test (NFIT) approval of the detailed design and project scope that formed the basis of the regulatory test application and that the Authority is not satisfied that this design and scope is the most cost effective approach available to Western Power. Therefore, any application for NFIT approval should contain further analysis comparing the design with potential alternative options including but not necessarily limited to:

- excluding the construction of new 132 kV circuits between Western Terminal and Shenton Park on the basis that these are not required at this stage and can be installed at a later date if found to be necessary; and

- installing 3x35 MVA transformers rather than the 2x75 MVA units to reduce the risk of transformer over-capacity and potential 11 kV feeder congestion.

1. INTRODUCTION

Western Power has submitted an application for regulatory test approval, in accordance with Chapter 9 of the Access Code, for the construction of a new zone substation at Shenton Park, an inner western suburb of Perth. The new substation will be constructed next to, and will eventually replace, the existing 66/6 kV 3x13 MVA Shenton Park zone substation. The work covered by this application includes:

- Establishment of a new 132/11 kV, 2x75 MVA zone substation with two incoming 132 kV line circuits and provision for a further two 132 kV outgoing circuits. The outgoing circuits would be used to supply a proposed new 132/11 kV Medical Centre substation and are outside the scope of the regulatory test application;

- Overhead line works associated with the two incoming line circuits. These include diverting the existing Western Terminal –Northern Terminal 132 kV line to form and temporary incoming supply and the later construction and connection of two new 132 kV lines between Western Terminal and Shenton Park; and

- Conversion of the distribution networks currently fed from the existing Shenton Park and Herdsman's Parade zone substations from 6.6 kV to 11 kV.

The new substation will replace not only the existing Shenton Park substation but also the Herdsman Parade substation, since the increased distribution network voltage will allow the load of this substation to be transferred to Shenton Park.

The forecast cost of the project is $39.55 million, including provisions for risk and cost escalation. This does not include the cost of decommissioning either the Herdsman's Parade or existing Shenton Park zone substations, which will be undertaken on completion of the project as non-recurring opex.

2. WESTERN TERMINAL LOAD AREA

The Western Terminal load area includes the inner western suburbs of Perth and is bounded by Kings Park to the east, the Swan River to the south, the coast to the west and Wembley Downs / City Beach to the north. The area is primarily residential and includes some of the most affluent residential suburbs in Western Australia. The two largest customers are the Sir Charles Gairdner hospital and the University of Western Australia. The only other customers supplied at distribution voltage are Hale School and the Floreat shopping centre. All remaining customers take supply at low voltage.

Electricity within the load area is supplied from the 132/66 kV Western Terminal substation, which in turn is supplied by three incoming 132 kV circuits fed from Northern Terminal, Cook Street and South Fremantle Terminal respectively. Western Terminal has three 100 MVA, 132/66 kV transformers, which supply six zone substations via two 66 kV ring circuits. The northern ring includes Shenton Park, Herdsman's Parade and the recently upgraded Wembley Downs substations while the southern ring includes the Medical Centre, University and Nedlands substations. Distribution voltage from all substations is 6.6 kV, except for Wembley Downs where the distribution voltage has been upgraded to 11 kV.

There are a number of issues within this load area that Western Power needs to address. These include:

- Demand growth The size of the transformers at most existing zone substations is small (10-15 MVA) and existing peak demands are approaching the point where under contingency operating conditions, one or more of these transformers could be overloaded;

- The condition of existing substation assets: Western Power assesses transformer condition on a scale of 1-10 where 1 represents a new asset and 10 in a poor condition requiring immediate replacement. The three power transformers at Shenton Park are all assessed as 10. There are ten other 66/6.6 kV transformers in the Western Terminal load area, of which seven are assessed as 9, two at 8 and one at 7;

- Limitations of the 6.6 kV distribution voltage: This voltage is an old industry standard, which has now been superseded by 11 kV, and even 22 kV, throughout the world. It requires zone substations to be constructed close together and limits the ability to transfer loads to other feeders or zone substations in the event of a fault. Losses are relatively high and an inability to rely on distribution load transfers to assist with the management of unplanned equipment failures can result in a need for additional power transformer capacity within a load area. A 6.6 kV supply voltage is no longer favoured by large commercial and industrial customers; we understand that both the University and the Sir Charles Gairdner hospital want to upgrade from 6.6 kV to 11 kV. We have previously reviewed this issue in respect of the Western Terminal load area[1].

- Limitations of the 66 kV transmission voltage: This is also an old industry standard, although it remains more widely used internationally for transmission or subtransmission than 6.6 kV does for distribution. Its main limitation is a lower thermal capacity – Western Power's older 66 kV distribution lines have a power transfer capacity of around 80 MVA whereas a new 132 kV line typically has a capacity of about 230 MVA.

Western Power engaged Sinclair Knight Merz (SKM) to develop a long term (25 year) strategic plan for the development of the network in the Western Terminal load area, based on the medium economic growth, 10% probability of exceedence load forecast prepared for the 2011 Annual Planning Report (APR). SKM was also required to take due account of the age and condition of the existing assets, the potential for rationalising

[1] *New Facilities Investment Test for Western Power's Medical Centre Zone Substation – Technical Review;* Geoff Brown & Associates Ltd, 3 December 2008.

existing substation sites and the impact of customer driven connection requirements. We assume that the latter criterion refers to the additional load required in the near term at both the Sir Charles Gairdner hospital and the University. The findings of the SKM report form the basis of the Shenton Park redevelopment proposal.

3. COMMENT

3.1 DEMAND FORECAST

Actual peak demand within the load area is approximately 140 MVA and the forecast POE 10 peak demand in 2013, as advised by Western Power in July 2012 is approximately 155 MVA.

The SKM study used Western Power's APR 2011 peak demand forecast, and is based on a POE 10, medium economic growth scenario. This forecast gives a demand of 170 MVA in 2013, increasing to 190 MVA in 2017 primarily due to expected new block loads at both the hospital and the university. Western Power is then forecasting a peak demand of about 265 MVA by 2036, an increase of over 4 MVA per year.

There are issues with this forecast that merit further consideration.

- The current forecast 2013 POE 10 peak demand for 2013, as provided to us by Western Power, is consistent with the actual peak demands in 2011 and 2012 once a margin for uncertainty is provided for. However this figure is 15 MVA lower than the 170 MVA 2013 demand used by SKM in its report.

- We have compared the rate of growth indicated in the SKM report with the overall rate of growth in demand for the whole of the SWIN as reported in the 2011 APR forecast. In 2013 the forecast peak demand of 170 MVA represents 3.90% of the POE 10 forecast peak demand for the total SWIN. In 2017 and 2022 (the final year of the APR 2011 forecast) these ratios are 3.91% and 3.93%. While these differences are small, they suggest that Western Power is expecting that demand within the Western Terminal load area is expected to grow at a marginally faster rate than demand across the SWIN as a whole.

  The reason for this is unclear. The SKM report comments:

  > *It is forecasted that the load growth within the Western Terminal load area over the next 25 years will be driven organically through residential and commercial customers. Developments in the area are expected to be centred on the rationalisation of existing land uses such as higher density residential and commercial buildings, with very few Greenfield developments. However, the area contains most of the affluent suburbs of Western Australia and it is experiencing a considerable infiltration of air-conditioning use, which is believed to be the cause of the area's significant load growth in the past few years. The re-zoning and re-development of parts of the Western Terminal load area has contributed significantly to the area's high load growth, with the re-zoning to high density residential of areas such as Mt Claremont resulting in extensive developments of many high electricity-consumption residences.*

  While we recognise the recent high penetration of air conditioning and the impact of this on the demand for electricity throughout Australia, we consider it probable that air conditioning load will saturate over time. In recent times this demand has been offset by rooftop PV systems where the penetration within the Western Terminal load area is also likely to be high.

  Most new electricity demand arises from greenfield development and, as noted by SKM, the potential for new greenfield development in the load area is limited because of the lack of available land. Significant demand growth would require changes in existing land use to permit more intensive development and, notwithstanding the rezoning within Mt Claremont, we are not aware of any proposals for a widespread rezoning of land within the load area. This suggests that a large component of the demand growth forecast used as the basis for the SKM report may be speculative and that the probability of the forecast rate of demand growth not being achieved is relatively high.

We think that the SKM report could have been improved if alternative network development options had been sensitivity tested against both high and low economic growth demand forecasts to demonstrate their robustness to a range of load growth outcomes. This would be more consistent with the regulatory test in the National Electricity Rules (NER), which require alternative options to be assessed for a range of "reasonable scenarios".

3.2 NON-NETWORK ALTERNATIVE OPTIONS

We do not see any likelihood of any non-network alternative options being available to address all the emerging issues identified in the SKM report. Even if non-network options were identified, they would only address the issue of increasing demand and would not be effective responses to the limitations caused by the 6.6 kV distribution network voltage or the poor condition of the zone substation transformers serving the load area. These latter issues not a result of increasing customer demand but are nevertheless key drivers for the redevelopment of the Western Power networks in the Western Terminal load area.

3.3 STRATEGIC DEVELOPMENT PLAN

As noted in Section 1 above, the upgrade of the Shenton Park substation is the first stage of the more comprehensive strategic development plan developed by SKM. This plan covered the whole of the Western Terminal load area and selected from the following four options identified by SKM. All four options provided for the upgrade of the distribution network from 6.6 kV to 11 kV. As discussed in Section 2, we support this strategy.

Option 1: Retain 66 kV and Upgrade Network Capacity

This option aims to retain the use of the existing 66 kV transmission network and involves the replacement of existing assets as required with minimal change to the existing network configuration. It includes new 66/11 kV zone substations at both Shenton Park and the Medical Centre and the retention of the existing zone substations at Herdsman's Parade and University. The option would require the installation of a 4th 132/66 kV transformer at Western Terminal during AA3 in order to meet the N-1-1 planning criteria[2]. It would also require the rebuilding of a number of existing 66 kV lines on condition grounds over the period 2025-2033, including the existing line between Shenton Park and Herdsman. This line takes a circuitous route around Cook Street and North Perth and appears to be the result of connecting together a number of old 66 kV lines that are no longer required.

This option has the advantage of minimising the capex requirement during AA3, so would have the lowest short term impact on electricity tariffs. However costs in the latter part of the study period are high and there would be little available capacity at the end of the 25 year study period, suggesting a significant network upgrade could then be required. From an environmental perspective this option is also not favoured as the total number of substations and transmission lines within the load area would be high.

Option 2: Retain 66 kV in Southern Loop and Upgrade Shenton Park to 132 kV

This option is intended to offload the existing 66 kV network by constructing the new Shenton Park substation at 132 kV. This, together with the distribution upgrade to 11 kV would allow the Herdsman's Parade substation to be decommissioned. However a disadvantage of this proposal is that the total number of transmission lines would be increased due to the overlaying of a 132 kV transmission system on the existing 66 kV network.

[2] In Section 4.1.2.1 of our 4 September 2012 Report *Technical Review Of Western Power's Comments On The Economic Regulation Authority's AA3 Draft Decision,* we argued against the construction of a fourth circuit to supply Western Terminal on the grounds that the consequence of an N-1-1 line outage was relatively low. However, without reinforcement of the existing transformer capacity, the consequences of an N-1-1 transformer outage would be much greater as each transformer is rated at only 100 MVA, compared to 132 kV transmission line ratings of more than 200 MVA.

Option 3: Convert both Medical Centre and Shenton Park to 132 kV

This option is an extension to Option 2 in that it would also construct the new Medical Centre substation at 132 kV, fed from the Shenton Park substation. The main advantage of this is that it would allow the University substation to be decommissioned in addition to Herdsman's Parade. However the option overlays the 66 kV transmission system in both the northern and southern parts of the load area with a new 132 kV system. This means that the number of transmission lines is even higher than for Option 2.

Option 4: Full 132 kV Upgrade

This option extends Option 3 by converting the whole network to 132 kV. This option is technically preferred as it would provide sufficient capacity to meet all foreseeable load requirements in the Western Terminal load area, allow the 132/66 kV transformers at Western Terminal to be removed and minimise the number of transmission lines required to supply the load since all would be at a single voltage. However, since it would require both Wembley Downs and Nedlands substations to be upgraded to 132 kV it is relatively expensive. Nedlands substation, in particular, is a problem because of space limitations and this upgrade has been costed assuming gas insulated switchgear (GIS) would be used because of its lower footprint.

At a strategic level, these options embrace all the network redevelopment alternatives available to Western Power. However, within each strategic alternative a number of sub-options or variants exist, some of which are discussed in Section 3.4 below. While the choice of sub-option can have a material impact on the cost of electricity, we think it appropriate at regulatory test stage to consider primarily the different strategic alternatives available to Western Power and to leave the more detailed consideration of the available sub-options within the preferred alternative to the NFIT.

3.4 DISCUSSION

SKM has compared the above four options using a discounted cash flow analysis, with timings determined on the basis of the demand forecast discussed in Section 3.1. The results of this analysis are shown in Table 3.1

Table 3.1: Net Present Costs of SKM Options

	NPC ($ million)
Option 1	117.7
Option 2	114.8
Option 3	112.1
Option 4	119.4

In its regulatory test application, Western Power has noted that a new 132/11 kV substation at Shenton Park is required under Options 2, 3 and 4. It has designed the substation on the basis of Option 3 proceeding, as this is the option with the lowest net present cost.

We note that the NPC of Option 4, the highest cost but technically superior option, is only $7.3 million or 6.5% higher than the preferred Option 3. Given that this cost differential is relatively small, we have looked at the cost benefit analysis more closely to consider whether all relevant factors have been taken into account and, in particular, whether the choice of option would impact the design and cost of the proposed Shenton Park development covered by this regulatory test application.

Shenton Park 132 kV Supply

All four options assume that Western Terminal will remain as a hub substation for the load area and all zone substations will be supplied from Western Terminal, irrespective of whether the supply is at 132 kV or 66 kV. However we do not see any technical reason

for 132 kV substations need to be supplied directly from Western Terminal, at least in the short term. As an interim measure Western Power is planning to divert the Northern Terminal – Western Terminal line to supply Shenton Park so the existing 66 kV circuits can remain to supply the existing Shenton Park substation before it is decommissioned after all load has been transferred. If this arrangement was made permanent it would avoid the need to construct two new 132 kV circuits between Western Terminal and Shenton Park and also to install two new 132 kV circuit breakers at Western Terminal. This would reduce the cost of the Shenton Park project.

In respect of making the initial temporary 132 kV connection permanent, Western Power commented:

> *The Shenton Park substation is proposed to be reconnected onto the Western Terminal to Shenton Park 132kV circuits (currently operating at 66kV) because the Western Terminal - Northern Terminal 132kV circuit is proposed to supply the new Osborne Park 132kV substation in 2018/19 and the 132 kV circuit overloads with both Osborne Park and Shenton Park connected. It has been recognised that sub options do exist to reconfigure the 132kV lines around Shenton Park and retain the cut in on the Western Terminal - Northern Terminal circuit, as you stated. These will be assessed in detail and taken forward in a future major augmentation proposal.*

In our view, this is no reason to include Western Power's "permanent" 132 kV network reconfiguration in this project. According to Table 3 of the SKM report the Northern Terminal – Western Terminal 132 kV circuit has a rating of 243 MVA. In 2020, when the new Osborne Park substation is currently planned to be commissioned, the peak load on Shenton Park will be about 60 MVA and the load on the Medical Centre will be under 55 MVA, based on Figure 2 of the SKM report. Assuming an initial load of 40 MVA on the Osborne Park substation, the peak demand on the line in 2020 in the event of an outage of the Shenton Park – Western Terminal line section will be 155 MVA, well within the line rating. Assuming 2% per annum load growth the peak demand on the line after a further 20 years under contingency operating conditions will only be 230 MVA, still within the rating of the line. Therefore Western Power's proposed "temporary" arrangement will meet all requirements until after 2040 and no action would be needed until then.

Connecting the Shenton Park substation to the Northern Terminal – Western Terminal circuit at this stage does not preclude a subsequent reconfiguration of the 132 kV supply to Shenton Park. However, completing this reconfiguration approximately 25 years before it is needed raises two concerns. Firstly, customers are being asked to pay for the assets prematurely, unnecessarily raising the cost of electricity. Secondly, Western Power operates in a dynamic environment and in 25 years time the two new circuits between Western Terminal and Shenton Park my no longer be an optimal solution.

Environmental Impact

The cost benefit analysis also gives no weight to the benefits of minimising the number of transmission lines running through the supply area. These benefits are:

- a reduction in the impact of the overhead transmission lines on the amenity value of the built environment to the community. The potential for removing older, low capacity overhead lines should make it easier to gain community acceptance in the consultation process;
- a reduction in maintenance costs, which are related to line length; and
- a likely reduction in losses, since a solution that minimises the impact on the community would require all lines and substations to operate at 132 kV.

Inclusion of these benefits in the analysis is likely to narrow the NPC gap between Options 3 and 4. Our analysis of Option 4 indicates that there are potential cost saving sub-options that could narrow the NPC gap even further. In particular:

- While we haven't seen the relevant load flow analysis, we do not see any technical reason why the existing 132 kV circuit between Cottesloe and Western Terminal could not be diverted to supply Nedlands. If this was done, the current proposal to upgrade the existing Cottesloe-Nedlands and Nedlands-Western Terminal lines to 132 kV would be unnecessary and these lines could be removed;

- Option 4 has been analysed on the assumption that Nedlands substation would need more expensive gas insulated switchgear for a 132 kV upgrade, although there is some suggestion that more detailed analysis may show this could be avoided. If the three existing 66 kV lines into Nedlands substation were to be removed and the incoming 132 kV diversion used underground cable, there may be sufficient room for a less costly upgrade solution. Alternatively, under these circumstances it may be possible for Western Power to get planning consent to purchase an adjacent lot to increase the size of the site.

Ultimate Shenton Park Transformer Capacity

A variant of Option 4 that provided for the eventual removal of all existing 66 kV transmission lines would also allow the removal of the 66 kV assets at Western Terminal, which would become a 132 kV switching station. However, the area vacated by the 66 kV transformers could be reserved for a future 132/11 kV zone substation, which would be strategically located to offload the Shenton Park, Nedlands and possibly some of the Medical Centre substation in the longer term. A zone substation on this site would be low cost because all required 132 kV infrastructure would already be in place.

The availability of the Western Terminal site for a future zone substation raises the issue of the optimal size transformers to be installed at Shenton Park. Western Power is proposing to install two 75 MVA transformers at Shenton Park and three 35 MVA transformers at Medical Centre. Both options give a similar N-1 firm capacity. We asked Western Power to comment on the reason for the two different approaches to transformer sizing and were advised:

> *The SKM report considered the use of 75MVA and 35MVA transformers across the Western Terminal load area. The proposal for Medical Centre in the SKM report uses 2 x 75MVA transformers in the recommended Strategy Three. Further detailed analysis at Medical Centre has investigated the practicability of using 3 x 33MVA transformers as this gives 66MVA of firm capacity (nameplate) and circa 75MVA of firm capacity in terms of transformer LTER. A detailed cost assessment of the Medical Centre options has been completed and it was found that a 3 x 33MVA option is a marginally more cost effective one with lower project risk. The principal reason for this is that a 75MVA transformer has a dual 11kV secondary winding. This, combined with a 66kV to 132kV reconfigurable primary winding makes for a non-standard design and introduces more complex manufacturing challenges which our supply chain has never previously undertaken. This increases the project costs and risks (including possible delays) at Medical Centre to such a point that a 33MVA option is preferred.*

This response does not address the question of whether or not a 33 MVA option should also be considered at Shenton Park, if it is a more cost effective option at the Medical Centre. We suspect the reason why 35 MVA transformers are not preferred for Shenton Park is the demand forecast. According to the forecasts in the SKM report, the peak demand at the Medical Centre substation will be around 60-65 MVA by 2036, the final year of the study, whereas the peak demand at Shenton Park will be around 80-85 MVA. Hence Western Power sees a possible need for a third 75 MVA transformer at Shenton Park prior to, or soon after the final year of the study period (although this transformer is not included in the analysis).

We see two issues with this analysis.

- It is based on a demand forecast that, as discussed in Section 3.1, could turn out to be high. The forecast in the SKM report suggest, assuming no changes to the current network configuration, the load at Shenton Park could increase from

40 MVA in 2015 to 65 MVA in 2036, an overall increase of almost 65%. Forecast growth in the area served by Herdsman's Parade is much more modest with the load increasing from 15 MVA in 2011 to around 18 MVA in 2036. The Shenton Park demand forecast between 2015 and 2036 is equivalent to a compound rate of growth in demand of almost 2.5%. We question whether this is sustainable over such a long period without extensive changes in land use. It would therefore be prudent to test the plan against a lower growth rate to mitigate the risk of customers being required to pay for transformer capacity that turns out not to be required.

- We also note that, under the current plan, when fully developed Shenton Park substation would have a firm capacity of 150 MVA and it is not clear whether Western Power has considered the practicality of evacuating this quantity of electricity from a single site at 11 kV. A 240mm^2, 11 kV feeder exit cable has a thermal power transfer capacity of about 5 MVA. Assuming these feeders were loaded to a maximum of 70% to allow for spare capacity to be utilised in the event of a distribution network contingency, maximum individual feeder loading would be 3.5 MVA per feeder. This suggests that around 40 separate outgoing 11 kV feeders will be needed if the available transformer capacity is to be fully utilised. Even the feeder capacities were increased through the use of larger cables, there would still be a need for 20-25 feeder cable exits. Planning a distribution network that has such a large number of feeders converging at a single point could be difficult.

  We understand that congestion of feeder exit cables is preventing the full utilisation of available transformer capacity at the Hay and Milligan St substations within the central business district. Western Power should ensure that there is no potential for these problems to be replicated at Shenton Park.

In our view, these issues provide a further argument in favour of preferring a full 132 kV transmission solution over a hybrid 132/66 kV option. As noted above, the removal of the 132/66 kV transformers from Western Terminal would provide a well located site for a future low cost, high capacity zone substation where the size of the site is unlikely to be a constraint. This would allow the use of smaller transformers at Shenton Park, alleviating potential 11 kV congestion problems. It would also allow transformer capacity to be added in increments better matched to the rate of demand growth in the area, mitigating the risk of customers being burdened with the cost of excess zone substation transformer capacity.