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11 October 2010

Mr Lyndon Rowe
Chairman
Economic Regulation Authority
Level 6, 197 St Georges Terrace
Perth WA 6000

Dear Lyndon

SUBMISSION OF PROPOSED CAPITAL PROJECT FOR NFIT PRE-APPROVAL

In accordance with s6.71(b) of the Electricity Networks Access Code 2004, I am pleased to submit Western Power's request for the Authority to determine that the attached proposed transmission network augmentation meets the requirements of the *new facilities investment test*.

The augmentation establishes an electricity supply to the Water Corporation's Binningup desalination plant via a new 132kV feeder emanating from Kemerton terminal substation. The estimated cost of this project is approximately $54M overall, of which Western Power submits that $31.3M satisfies the *new facilities investment test*.

These and other similar submissions will provide Western Power with confidence about the quality of its project justification in advance of the Authority's future assessment of the efficiency of actual capital expenditure during the current regulatory period.

This formal submission comprises this covering letter and the attached detailed submission documents. Electronic versions are also enclosed, for publication by the Authority.

I look forward to receiving the Authority's determination on this submission.

Yours sincerely,

PHIL SOUTHWELL
GENERAL MANAGER REGULATION & SUSTAINABILITY

DM# 7538279

Submission to the Economic Regulation Authority

APPROVAL OF NEW FACILITIES INVESTMENT

Installation of a second 330/132 kV transformer at Kemerton Terminal and construction of a 132 kV transmission line to supply Binningup Desalination Plant.

DATE: *1 October 2010*

DOCUMENT PREPARED BY:
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safe reliable efficient

Contents

1 Summary

Western Power is undertaking works at the Kemerton Terminal to provide connection for the Water Corporation's Desalination Plant at Binningup. The works include installation of a second 330/132 kV transformer and construction of a 132 kV switchyard at Kemerton Terminal, and construction of 10 km of 132 kV transmission line to connect to the Desalination Plant.

The dedicated works which include the Western Power owned equipment at the Water Corporation site, the 132 kV transmission line and the dedicated 132 kV circuit at Kemerton Terminal (deemed to be dedicated due to the meshed arrangement) meet the requirements of section 6.52 (a), but not section 6.52 (b) of the Code[1], and consequently do not meet the requirements of the New Facilities Investment Test (NFIT). These assets are to be fully funded by the customer through a capital contribution. The remaining works, including the new transformer and 132 kV switchyard, are considered to fully meet the requirements of the NFIT.

Western Power is seeking pre-approval under section 6.71 (b) of the Code that the part of the new facilities investment described in this submission, that is not fully funded by the customer by way of a capital contribution, meets the requirements of the NFIT.

Table 1 summarises the works in question and the amount that meets the requirements of the NFIT.

Table 1 Summary of works

Element of Works	Comment	Value that meets NFIT
Binningup 132 kV substation works	Fully funded by customer.	$0M
Binningup substation to Kemerton Terminal 132 kV transmission line	Fully funded by customer.	$0M
Kemerton Terminal connection of the 132 kV transmission line	Fully funded by customer.	$0M
Kemerton Terminal works (NFIT assessment summarised below)	The NFIT assessment is based on a brought forward cost of $6.0M offset by "incremental revenue", and the remaining value of $25.3M covered under the "safety and reliability" test.	$31.3M
Total value of works that meets NFIT		$31.3M

1 Western Australian Government, November 2004, Electricity Networks Access Code 2004

2 Background

Water Corporation proposes to install a second desalination plant at Taranto Road, Binningup, approximately 50 km north of Bunbury. The Water Corporation submitted a Network Access Application on 25 June 2007 requesting Western Power to provide a power supply to the plant. They originally requested a supply of 25 MW but recently updated that to a supply of 30 MW with an in service date of September 2010, with the potential as yet unconfirmed to go to 55 MW in 2017.

Western Power, in partnership with the Water Corporation, has investigated various options to address the forecast load requirements of the Binningup desalination plant. To meet the demand the most appropriate option is the construction of approximately 10 km of 132 kV transmission line from Kemerton Terminal to Binningup and the installation of a second 330/132 kV transformer and associated works at Kemerton Terminal. The proposed major augmentation is estimated to cost $52.63 million.

Kemerton Terminal is located in the Bunbury load area within which there are three different voltage systems; 66 kV, 132 kV and 330 kV. Most of the existing lines were built in the 1960's and were designed to supply relatively small loads distributed over a large geographical area. The network has limited capacity for transferring large amounts of power due to thermal and voltage limitations influenced mainly by the capability of the 132 kV network.

Western Power submitted an application for a Regulatory Test Waiver on 7 October 2009, which covered the works to connect the desalination plant. This was subsequently approved by the Economic Regulation Authority on 4 January 2010.

Western Power is seeking pre-approval under section 6.71 (b) of the Code that that part of the new facilities investment described in this submission, that is not fully funded by the customer by way of a capital contribution, meets the requirements of the NFIT.

3 Proposed Augmentation

The proposed augmentation consists of several separate components of work. Three of the four components are connection assets required for the connection of the desalination plant at Binningup. Table 2 identifies the particular components of the proposed major augmentation.

Table 2 Components of the major augmentation

Section name	Cost of component of augmentation
Binningup 132 kV substation works	$3.3M
Binningup substation to Kemerton Terminal 132 kV transmission line	$16.53M
Kemerton Terminal connection of the 132 kV transmission line	$1.5M
Kemerton Terminal works including installation of a second 330/132 kV transformer and construction of a 132 kV switchyard	$31.3M
Total cost of augmentation	$52.63M

The first three components of the augmentation are connection assets. Connection assets are dedicated assets required only for the connection of the desalination plant. These will be fully funded by the customer through a capital contribution and will not result in any net increase in cost to other network users. The fourth component of the works is considered to be a shared asset. The shared assets are required for the Binningup desalination connection but are not dedicated for use by any single customer.

The pre-approval of the NFIT submission fundamentally only applies to the augmentation of the Kemerton Terminal, although for completeness the whole of the augmentation (connection and shared assets) is addressed in this submission.

3.1 Kemerton Terminal works

Western Power has undertaken analysis of the future load growth requirements in the area of Kemerton Terminal Station with and without the Water Corporation connection. Excluding the Water Corporation connection, the analysis identified a need to augment the network in the Kemerton area in 2013 with the installation of a second 330/132 kV transformer and construction of a 132 kV switchyard. The second transformer would serve the long term needs of the Binningup desalination plant along with the needs of the local area.

The analysis has determined that considering the near time needs of the Water Corporation and the longer term needs of the area, the most cost effective solution is to bring forward the Kemerton Terminal works from 2013/14 to 2010/11.

Binningup desalination plant is scheduled to take supply from September 2010, and will ramp up to the full load of 30 MW over a few months. The earliest achievable date of commissioning a second transformer at Kemerton Terminal Station will be approximately September 2011. To maintain an N-1 security standard for existing customers, the Water Corporation has agreed to the Binningup desalination plant having a curtailable supply for the interim period from completion of the connection in 2010 until commissioning of the second Kemerton transformer in 2011. However, it should be noted that they are not willing to accept this lower standard of supply beyond this interim period.

To establish the additional incurred cost of bringing the installation forward, Western Power has undertaken an economic analysis of two scenarios. Namely:

1. Installing the second transformer and undertaking the associated works in 2011.
2. Installing the second transformer and undertaking the associated works as planned in 2013.

The results of the NPC evaluation are given in Table 3 below.

Table 3: NPC evaluation of advancing the installation of a second transformer at Kemerton

NPC evaluation	NPC (million)
Scenario 1: Advancement of the second transformer associated works from 2013 to 2011	31.3
Scenario 2: Install the second transformer and associated works in 2013.	25.3
Cost of advancing the installation of the second transformer	**6.0**

The option of bringing forward the installation of the second transformer and associated works is a direct result of load requirements of Binningup desalination plant and as such the brought forward costs will be apportioned to the Water Corporation through capital contributions and access charges in accordance with Western Power's Contributions Policy. Note that the capital contribution for these works is actually zero based on the forecast access charges.

4 Options Analysis

In its planning report (Attachment 1) Western Power identified 4 major reinforcement options to address the emerging shortfall of power supply capacity in the Bunbury region. The options were:

Option 1: Minimum infrastructure build which provided the Water Corporation with a curtailable supply. This option does not meet the requirements of the Technical Rules, or the standard of supply required by the Water Corporation.

Option 2: On-site generation. This option was forecast to be more expensive than the chosen option 4 and also not acceptable to the Water Corporation.

Option 3: Installation of a 90 MVAr capacitor bank at Kemerton Terminal and rebuilding existing lines. This option met the requirements of the Technical Rules and the customer but was estimated to be a more expensive solution than the chosen option 4.

Option 4: Install a second 330/132 kV transformer at Kemerton Terminal and construct a 132 kV switchyard. This is the preferred option.

An additional option was considered in the planning report that was effectively option 3 without installation of the 90 MVAr capacitor bank. However, this option has been discounted because it does not provide a supply that meets the Technical Rules.

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5 Access Code Considerations

5.1 New facilities investment test requirements

Prior to new facility investments being added to the capital base, several requirements under section 6.52 of the Code must first be met. Section 6.52 is reproduced below.

6.52 *New facilities investment* satisfies the *new facilities investment test* if:

(a) the *new facilities investment* does not exceed the amount that would be invested by a *service provider efficiently minimising costs*, having regard, without limitation, to:

(i) whether the *new facility* exhibits economies of scale or scope and the increments in which capacity can be added; and

(ii) whether the lowest sustainable cost of providing the *covered services* forecast to be sold over a reasonable period may require the installation of a *new facility* with capacity sufficient to meet the forecast sales;

and

(b) one or more of the following conditions is satisfied:

(i) either:

A. the *anticipated incremental revenue* for the *new facility* is expected to at least recover the *new facilities investment*; or

B. if a *modified test* has been approved under section 6.53 and the *new facilities investment* is below the *test application threshold* – the *modified test* is satisfied;

or

(ii) the *new facility* provides a *net benefit* in the *covered network* over a reasonable period of time that justifies the approval of higher *reference tariffs*; or

(iii) the *new facility* is necessary to maintain the safety or reliability of the *covered network* or its ability to provide contracted *covered services*.

The new facilities investment test elements are referred to as the 'efficiency test' (section 6.52(a)), 'incremental revenue test' (section 6.52(b)(i)), 'net benefits test' (section 6.52(b)(ii)) and 'safety and reliability test' (section 6.52(b)(iii)).

In order for the new facility investment to satisfy the requirements of the Code, the efficiency test and at least one of the other remaining tests must be satisfied.

5.2 Assessment with respect to section 6.52 (a) of the Code

Section 6.52(a) of the Code requires that any new facilities investment to be added to the capital base does not exceed the amount that would be invested by a service provider efficiently minimising costs. The new facility should exhibit economies of scale having consideration of system growth and load forecasts.

To demonstrate compliance with this section of the Code, Western Power submits that it must:

- ensure the most appropriate option has been selected to meet the requirements associated with reasonable forecasts of growth of covered services,
- demonstrate that the design and design standards are appropriate, and
- demonstrate that the delivery cost of the new facility be efficient.

Choice of network option

The choice of network option is closely analogous to the requirements of the regulatory test under the Code. The regulatory test is an assessment of whether a proposed major augmentation maximises the net benefit after considering all reasonable alternative options. Under section 9.14 of the Code the regulatory test is met if the Regulator is satisfied it has been applied:

- using reasonable market development scenarios which incorporate varying levels of demand growth at relevant places; and
- using reasonable timings, and testing alternative timings, for project commissioning dates and construction timetables for the major augmentation and for alternative options.

If the regulatory test has been satisfied, then the best option has already been determined having regard to all reasonable alternative options.

However, for this project the regulatory test has been waived. In its decision dated 7 January 2010 the Authority stated on page 2:

> *The Authority has considered the information in Western Power's application, as well as further information that was provided on request, and is satisfied that the proposed major augmentation meets the requirements of section 9.23(d) of the Access Code for the following reasons.*
>
> - *Western Power, in partnership with the Water Corporation, investigated various alternative options to address the forecast load requirements of the Binningup desalination plant. The alternative options included demand-side management, on-site generation and network augmentation. All options assessed included works for the establishment of a 132 kV switchyard at Kemerton Terminal, as this is required to connect the Binningup desalination plant. The preferred and recommended solution (that is, the option being assessed under this determination) is considered to be the best technical and economic solution in this particular instance.*
>
> - *The Water Corporation has confirmed its understanding of the augmentation works required to supply power to the Binningup desalination plant and acknowledges that a capital contribution will be required for this work. Specifically, the Water Corporation has acknowledged that the capital contribution will consist of both connection costs and shared network costs, with the shared network costs based on the advancement ("brought forward") cost of the shared infrastructure at Kemerton Terminal. An Interconnection Works Contract between Western Power and the Water Corporation has been completed detailing these costs and the contribution payment.*

- *Western Power has confirmed that it undertakes network planning over a 20 year planning horizon. The network plans that are developed incorporate both natural load growth and also take into account potential larger developments, with low, central and high load forecasts used in the evaluations. Western Power's load studies indicate that under natural load growth and with the capacity of the existing network, works at Kemerton Terminal will need to be completed in the summer of 2013/2014 (that is, forecast load is expected to exceed supply capacity by summer 2013/14). Under natural load growth, with the addition of the Binningup desalination plant (assuming Stage 1 of the desalination plant only at 25 MW), works at Kemerton Terminal will be needed in the summer of 2011/2012 to meet supply capacity.*

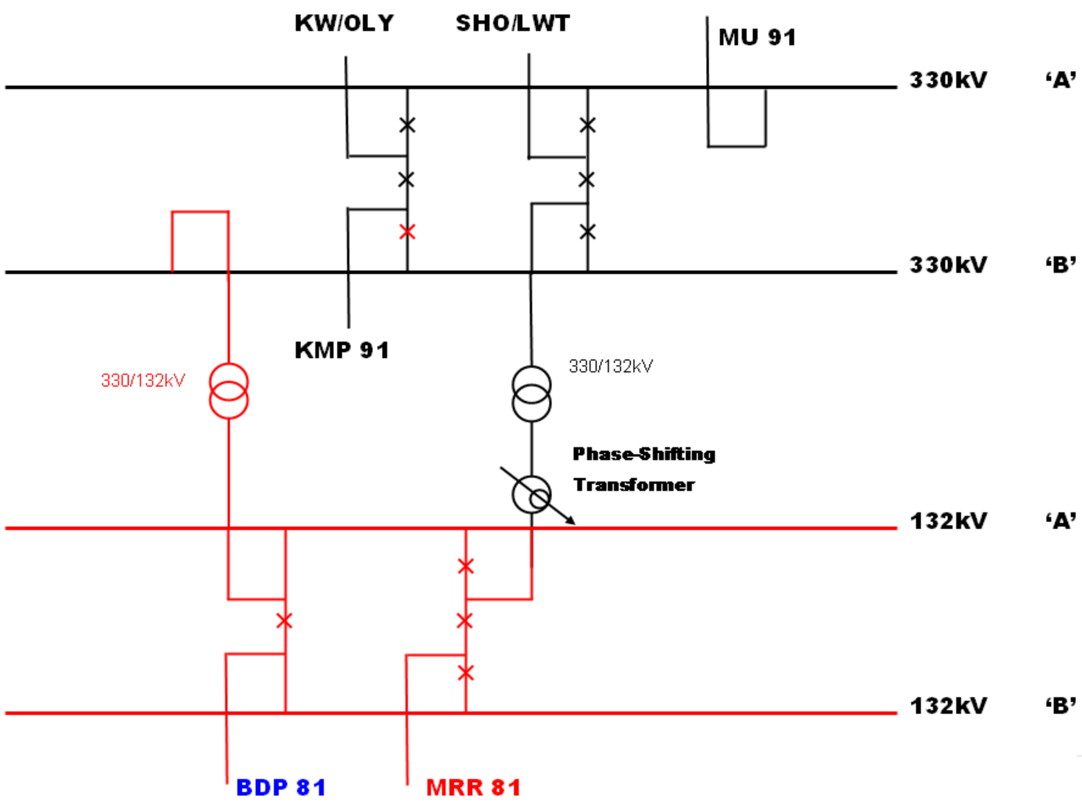
On the basis of the work undertaken for the regulatory test waiver submission, Western Power submits that the chosen network option is demonstrated to be the most efficient solution and to that extent satisfies the requirements of section 6.52 (a) of the Code.

Design standards

The second requirement with respect to section 6.52 (a) of the Code is to demonstrate that the selected network option's design and design standards will be efficient.

The existing configuration and new works at Kemerton constructed as part of the Binningup desalination plant project are shown in Figure 1.

Figure 1 Kemerton Terminal single line diagram showing existing works (black) and new works (red).



There are two key documents that relate to the design and design standards for this project (copies of each of these documents are attached for reference):

- Binningup Desalination Design Report (DM# 5539496), and
- Western Power Transmission Design Standard. Part 2 Functional Specification (DM# 619979).

The works at Kemerton Terminal have been designed in accordance with Western Power's standard for 330/132 kV terminal stations. It is worth noting that these standards have been peer-reviewed by Hydro Tasmania Consulting and deemed to align with current industry practice. This review is contained in the following document (copy attached).

- Hydro Tasmania Consulting - Western Power Substation Design Standard Review (DM# 7442038).

With respect to the design standards, further comments regarding the LV bus configuration and the choice of transformer rating are provided as additional information.

The Kemerton 132 kV switchyard is a breaker and a half configuration, consistent with Western Power's design standard. Although set up for the ultimate breaker and a half configuration, at this stage only four circuit breakers have been installed as part of this project. This is one circuit breaker per circuit which effectively operates as a four switch mesh. The breaker and a half configuration will allow for future expansion, some of which is currently being considered in relation to other projects.

With respect to the choice of transformer rating the following comments are made. Kemerton terminal station is the closest 330/132 kV injection point into the Bunbury load area. Prior to the construction of this terminal station, the power for this area was supplied by 132 kV lines directly and indirectly from Muja, and the (now decommissioned) Bunbury Power Station. Those existing 132 kV lines are reaching their capacity and technical/economic life limits. The most cost effective way to meet increased demand in the region is through expansion of the capacity at Kemerton and with the expected decreasing reliance on the 132 kV network, Kemerton will become the primary injection point for the supply to this area. .

The rating of the transformer to be installed at Kemerton terminal is 490 MVA. All of Western Power's 330 kV terminal stations have 490 MVA transformers, with the exception of the existing transformer at Kemerton. The existing Kemerton transformer (some 30 years of age) is a non standard transformer (225 MVA) that was sourced as a second hand unit from the Muja Power Station. It has not been specifically designed for Kemerton's long term forecast load requirements.

The following analysis is based on load forecasts for the Bunbury load area[2] which have been established for the next 20 year horizon and then extrapolated for the period beyond that out to 2060. This coincides with the lifespan of a transformer which is 50 years. The low load forecast incorporates natural load growth and only one block load which is the desalination plant. The medium and high load forecasts include a probability of other currently known block loads being connected. There is no allowance for any block loads beyond that known position.

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[2] The forecast for the Bunbury area is derived from "Summer Load Trends Report 2009-2028" (DM#: 5360882) and customer block load information in DM#: 6406824. The forecast trend was extrapolated from 2029. It should be noted that in the future, block loads from new developments (which Western Power has no current knowledge) may eventuate. These block loads would increase the load in the area and have not been included, even in the high case forecast.

Figure 2[3] below illustrates the low, medium and high load forecasts and the capacity limits with installation of 250, 350, and 490 MVA transformers.

The installation of a 490 MVA transformer will cover the central forecast case until 2058. Installation of smaller transformers (250 or 350 MVA transformer) will require replacement with a 490 MVA unit within the life of those transformers for all load forecast scenarios.

A net present cost analysis specifically for this site suggests that it may be a lower long run cost to install a 250 MVA or 350 MVA transformer. However that analysis demonstrates that the cost difference is less than 10% between the options, which does not provide sufficient justification to introduce a different size transformer from the standard 490 MVA unit that is in service in all other terminal stations.

Western Power's strategy is to not carry a spare transformer for terminal substations but instead to rely on full inter-changeability of units to cover the risk of catastrophic failure. (The carrying cost of a spare 330kV transformer is in the order of $1.5M per annum. There is also some commercial advantage in carrying operational spares for only one standard type of transformer.)

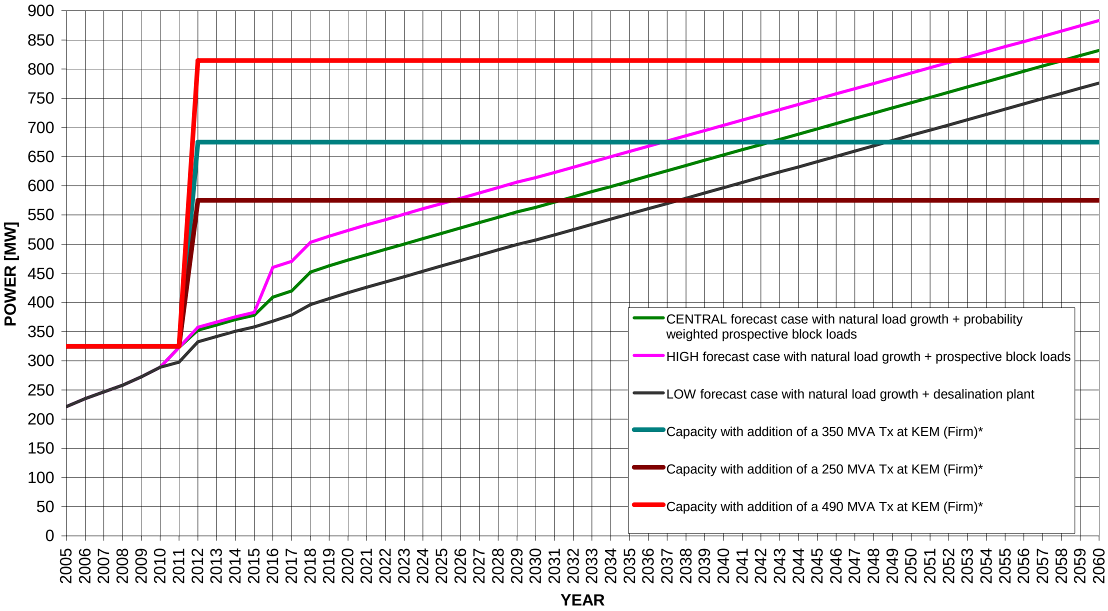
There is an economic value associated with the planning flexibility provided by the additional transformer capacity. This is particularly the case if the load forecasts prove to be conservative.

System studies have identified substantial power flows through the existing 132 kV meshed Bunbury system creating risk of thermal overloads under contingency conditions at summer peak load demand. Some of the 132kV transmission lines are reaching their thermal capacity while the 330 kV bulk network has capacity available to meet the future load growth. Strategically, it has been decided that the future power supply to the area will rely on Kemerton 330/132 kV terminal rather than the 132 kV transmission lines from Muja terminal. Therefore, a 490 MVA rated transformer is better suited to this strategy, rather than a lower rated transformer.

330kV transformers have an ordering/delivery lead time of at least 2 years. The transformer for this project was pre-ordered to meet the customer's project timelines and was sized to suit both the immediate and longer term area load forecasts, as assessed at the time.

[3] Figure 2 shows the capacity for Bunbury Load Area with the existing 330/132 kV transformer at Kemerton out of service. Approximately, 325 MW is the capacity of the existing network and the additional capacity provided by different rated transformers is shown. To fully utilize this capacity, additional reinforcements may need to occur.

Figure 2 Bunbury load area forecast



Cost of delivery

The third matter for Western Power to demonstrate is that the project has been delivered efficiently. Western Power uses a suite of approaches in its project delivery portfolio to ensure, on an ongoing basis, an efficient cost is achieved. Appendix 1 contains a detailed break down of the components of the work and the delivery mechanism employed. This approach is summarised in Table 4. For completeness the whole of the augmentation works have been included in Table 4.

Table 4 Delivery portfolio

Delivery mechanism	Value	Percent of Works
Competitive tender	$13.96M	27%
WP internal resource	$10.93M	21%
Alliance delivery	$7.7M	15%
Preferred supplier	$15.42M	29%
Offsets and easements	$2.61M	5%
Re-use of materials	$2.0M	4%
Total	$52.63M	

5.3 Assessment with respect to section 6.52 (b)(ii) of the Code (Net Benefits Test)

Section 6.52(b)(ii) requires the new facility to provide a net benefit that justifies the approval of higher reference tariffs within a reasonable period of time. The net benefit classified in the code is a net benefit to those who generate, transport or consume electricity. This new facility is not considered to provide any quantifiable net benefit to network users because the works are being undertaken at this point in time to provide connection to a single customer, and are not required at this stage without that connection.

Consequently the net benefits test will not be taken into consideration as part of this new facilities investment test submission.

5.4 Assessment with respect to section 6.52 (b)(iii) of the Code (Safety and Reliability Test)

Section 6.52(b)(iii) is satisfied when the covered network requires the new facility in order to maintain the safety and reliability of the covered network, or its ability to provide a contracted covered service.

As indicated in the attached Planning Report, Western Power considers that installation of the second transformer and associated 132 kV switchyard is required to meet the 2013/14 summer peak load. At that point in time the works are proposed to meet this leg of NFIT in order to provide contracted covered services. The proposed value of this investment that meets this leg of the NFIT is the current value of these works which is $25.3M.

5.5 Assessment with respect to section 6.52 (b)(i) of the Code (Incremental Revenue Test)

Section 6.52(b)(i) requires the new facility investment to be recovered via the anticipated incremental revenue in section 6.52(b)(i)A. A new facility investment will pass the incremental revenue test if the incremental revenue from the new investment is greater than the cost of the facility. This analysis is undertaken by comparing the net present value of the anticipated additional revenue to Western Power from Water Corporation less the net present value of the costs associated with servicing the new facility.

As the major augmentation is specifically proposed in order to allow Water Corporation to connect to the shared network, the incremental revenue test will be used as the second requirement to be satisfied as part of the new facilities investment test.

In this instance the cost to bring forward the works associated with the second transformer and 132 kV switchyard has been allocated to the Water Corporation; the amount being $6.0M. Western Power has used a tariff of $890,000 per annum, being an estimate of the likely revenue for a 30 MW CMD, has assumed flat real network access prices from the date of commissioning, and has used a real discount rate of 7.98% which is the current approved WACC for Western Power's access arrangement. There is sufficient incremental revenue to cover this cost over a period of 15 years and consequently this leg of the NFIT is adequately satisfied and this cost meets the NFIT.

Details of this assessment are included in Appendix 2.

6 Conclusion

From the above information, Western Power asserts that the value of the proposed augmentation that meets the NFIT is $31.3M. The remaining cost of works comprises the assets dedicated to the Water Corporation connection and are fully funded by the customer, and as such do not meet the requirements of the NFIT.

Table 5 summarises the components of the works and the value that meets NFIT.

Table 5 Value of new facilities that meets NFIT

Element of Works	Comment	Cost of works	Value that meets NFIT
Binningup 132 kV substation works	Fully funded by customer.	$3.3M	$0M
Binningup substation to Kemerton Terminal 132 kV transmission line	Fully funded by customer.	$16.53M	$0M
Kemerton Terminal connection of the 132 kV transmission line	Fully funded by customer.	$1.5M	$0M
Brought forward costs of the Kemerton Terminal works	The brought forward costs are apportioned to the customer – meets “incremental revenue test” of the NFIT.	$6.0M	$6.0M
Kemerton Terminal works	NPC of the works if undertaken in 2013/14 – meets the “safety and reliability test” of the NFIT.	$25.3M	$25.3M
Total value of works that meets NFIT			$31.3M

Appendix 1 – Procurement Strategy & Delivery Assessment

Tables 6 to 9 below provide detail as to the delivery strategy put in place for the total project. All of the works have been included to demonstrate that the whole works have been delivered as a single project.

Table 6 Binningup Substation – Costs and Delivery Mechanism

Project Work Package	Cost AU$M	Delivery Mechanism	Justification
Binningup Substation			
Design	0.45	Internal	Design cost is a small part of the project total. Many aspects of design and drafting require WP specific software and systems and a close liaison with the customer design team, hence it is neither efficient nor effective to outsource at this time
Procurement	0.64	Preferred Supplier Contract	Standard 132kV plant has been utilised for the majority of the yard. WP has negotiated preferred suppliers via an extensive competitive tender process.
Substation Construction	0.43	Internal	Western Power's internal construction workforce will undertake these works as part of Western Power's portfolio of construction.
Communication Cable	1.50	Competitive Tender	Purchase and installation of underground fibre cable will be subject to competitive tender process.
Other	0.28	Internal	Project Administration required to be performed by specialist Western Power resources such as Project Management, contract administration and monitoring, outage planning etc.
Section Total	**3.30**		

Table 7 Kemerton to Binningup 132 kV Line– Costs and Delivery Mechanism

Project Work Package	Cost AU$M	Delivery Mechanism	Justification
Kemerton to Binningup 132kV Power Line			
Design and Management	0.70	Internal	Design and contract management cost is less than 5% of line total. Many aspects of design and drafting require WP specific software and systems hence it is neither efficient nor effective to outsource at this time
Steel Structures	2.00	Re-use of Available Materials	The steel structures for this line have been manufactured using surplus steel remaining form the cancelled BSN-MR81 line project, producing costs benefits form utilising materials previously purchased by Western Power.
Overhead Line Material Purchase	0.50	Competitive Tender	A number of materials purchase packages have been subjected to competitive tender process to ensure the best possible value for money is obtained.
Overhead Line Construction	5.90	Alliance Allocation	This work package has been allocated to the Transfield Alliance. This follows Western Power's Alliancing strategy, to spread the capital works programme across a portfolio of service delivery mechanisms. All major contract items within these works are subject to competitive tender.
Underground Cable Materials Purchase	3.90	Competitive Tender	This substantial work package was subjected to competitive tender .
Underground Cable Installation	2.00	Competitive Tender	This substantial work package was subjected to competitive tender process.
Distribution Works (undergrounding of existing lines)	0.35	Internal	This work package is for minor distribution works along the Transmission Line corridor. It has been undertaken via Western Power’s normal Customer Funded distribution balanced portfolio of design and construction works.
Environmental costs	1.18	See table 9	
Section Total	**16.53**		

Table 8 Kemerton Terminal – Costs and Delivery Mechanism

Project Work Package	Cost AU$M	Delivery Mechanism	Justification
Kemerton 132kV Terminal and 2nd transformer			
Design	1.52	Internal	Design cost is less than 6% of project total. Many aspects of design and drafting require WP specific software and systems hence it is neither efficient nor effective to outsource. Standard 132kV and 330kV terminal designs were utilised to minimise unnecessary additional work.
Procurement	14.78	Preferred Supplier Contract	Standard 132kV and 330kV plant has been utilised for the majority of the yard. WP has negotiated preferred suppliers via an extensive competitive tender process.
Civil Works	4.91	Competitive Tender	This substantial work package was subjected to competitive tender process.
Steel Structures	1.15	Competitive Tender	This substantial work package was subjected to competitive tender.
Electrical Construction	4.21	Internal	Western Power's internal construction workforce is undertaking these works as part of Western Power's portfolio of construction.
Commissioning	0.62	Internal	Commissioning represents less than 3% of project total. Many aspects of commissioning requires specific knowledge and experience with WP systems hence it is neither efficient nor effective to outsource at this time
Line Cut-ins	1.80	Alliance	This work package has been allocated to the Transfield Alliance. This follows Western Power's Alliancing strategy, to spread the capital works programme across a portfolio of service delivery mechanisms. A Significant package of line materials has been sourced from Western Power stock materials
Environmental costs	2.6		See note below
Other	1.20	Internal	Various tasks associated with the project such as Project Management, contract administration and monitoring, outage planning etc.
Section Total	**32.80**	See table 9	
Total Cost	**52.63**		

Table 9 Environmental Works – Costs and Delivery Mechanism

Project Work Package	Cost AU$M	Delivery Mechanism	Justification
Environmental Costs			
Environmental Land Management Branch - Note, ELMB is $2.6m line, $1.18 terminal	1.17	Internal	Environmental and Land Management internal costs for ELMB compliance is performed by specialist Western Power or external resources. Outsourced contracts are either competitively tendered, or by sole source if specific technical expertise is required.
ELMB	2.61	Offsets and Easements	These costs relate to prescriptive legislative costs. Easement costs are by negotiation with landowners based on valuations. Environmental offset package costs are negotiated with Federal and State Environmental agencies, after undertaking least-cost comparison of options.

The above table describes all of the environmental works that were undertaken on both the line and the terminal station, together with the method of delivery for those works. Tables 7 and 8 have allocated those costs to the line and the terminal station.

Appendix 2 Incremental Revenue Determination

To determine the incremental revenue to be used to determine the portion of costs that meet the “incremental revenue test” in the NFIT Western Power uses standard spreadsheets which are updated as required to reflect the current approved tariffs and discount rates.

Tariff calculation

The following information is taken from the tariff calculation spreadsheet (DM#7040460). The annual amount of $890,454 (refer to Figure 3) is used as the forecast annual incremental revenue for the year 2010/11 to determine the amount that meets the requirements of section 6.52 (b)(i)A of the Code.

There is currently no published price for the Binningup connection and so the price at Marriot Road (local) has been used which is the closest transmission node for which a price currently exists. This is consistent with the approach taken by Western Power where no published price is available (as described in the “Price List Information” in the Access Arrangement).

It should be noted that average real price rises have been approved in the current access arrangement. The actual price changes expected in this period are yet to be determined although annual price side constraints provide for up to 13% real increases in July 2010 and July 2011. For purposes of the incremental revenue assessment it has been assumed that there will be real price maintenance over the longer term which is considered a conservative but reasonable assumption.

Figure 3 Tariff calculation

TRT1 - Transmission Exit

Tariff Inputs

Forecasted Maximum Demand (kW)	30000
Zone substation	Marriott Road (Local)
Transmission Node Identifier	WLMR
Value of Connection Assets	0
Economic life of Connection Assets	50
O&M expenses on the Connection Assets	0.0246
WACC	7.98%
# of Metering Installations	1

Updated: 27 January 2010 - 1 March 2010 Price List (Approved)
20/04/2010 9:40

Note: Set to zero if full cap con received for connection assets

Note: Always confirm the User Specific Charge with Regulation, Pricing and Access Development.

Tariff Calculation

		Daily & GST Exclusive			GST Inclusive		
	Units	Rate	Charge	GST	Daily	Monthly	Annual
User Specific Charge		0.01	0.00	0.00	0.00	-	0.03
Variable Use of System Charge	30000	3.15	943.80	94.38	1,038.18	-	378,935.70
Variable Common Service Charge	30000	4.99	1,495.80	149.58	1,645.38	-	600,563.70
Variable Control System Service Charge	30000	1.16	347.70	34.77	382.47	-	139,601.55
Fixed Metering Charge	1	3,713.28	37.13	3.71	40.85	-	14,908.81
Total Charge			**2,824.43**	**282.44**	**3,106.88**	**0.00**	**1,134,009.79**

For use in the Capital Contribution Calculator Only - Tariff Calculation (excludes GST)

Revenue for Capital Contribution Calculations	**890,454.00**

Determination of brought forward cost

Western Power has used the brought forward cost of the Kemerton Terminal works as the amount that should be funded by the Water Corporation with respect to the shared network costs. In this determination a standard spreadsheet is employed and a copy of the output is provided in Figure 4 below.

Figure 4 Determination of brought forward cost

Western Power Revised Access Arrangement Capital Contribution Model

Ref	2	3	6	8	9	10	11	12	13	14	15
Model Inputs											
Applicant Details											
5	**Applicant Details**										
6		Applicant Name				**Southern Seawater Desalination Plant**					
7											
Economic Parameters											
9	**Regulated WACC**										
10		WACC (real pre-tax)				7.98%					
11		WACC (nominal pre-tax)				10.65%					
12		RBA Indicator Rate				11.10%	RBA Large Business Indicator Rate				
13											
Asset Parameters											
15	**Capital Costs for Project under consideration**										
16		Construction Complete in Year Ending 30 June				**2011**					
17				**Year Ending 30 June**		**2011**	**2012**	**2013**	**2014**	**2015**	**TOTAL**
18		Capital Cost of Shared Assets [$ of today]				**31,300,000**					31,300,000
19											
20	**Original Planned Capital Costs**										
21		Original Construction Complete in Year Ending 30 June				**2014**					
22				**Year Ending 30 June**		**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**
23		Capital Cost of Shared Assets [$ of today]				31,300,000		0	0	0	31,300,000
24											
Model Outputs											
Bought Forward Cost					**Bought Forward Cost (ex-GST)**						
27	**Calculated Capital Contribution**										
28		Bought Forward Cost for Shared Assets				5,963,365					

Incremental revenue determination

Western Power has used its standard capital contribution calculation spreadsheet to determine the incremental revenue offset for the brought forward cost of the Kemerton Terminal works. A copy of the output is provided in figure 5 below. There was sufficient incremental revenue within a 15 year period to cover the brought forward cost as demonstrated by this calculation. Consequently no further determination of incremental revenue has been undertaken.

Figure 5 Incremental revenue determination

Western Power Revised Access Arrangement Capital Contribution Model

Ref	2 / 3 / 8 / 9	10	11	12	13	14	15	
Model Inputs								
Applicant Details								
5	**Applicant Details**							
6	Applicant Name	**Southern Seawater Desalination Plant**						
7								
Economic Parameters								
9	**Regulated WACC**							
10	WACC (real pre-tax)	**7.98%**						
11	WACC (nominal pre-tax)	**10.65%**						
12	RBA Indicator Rate	**11.10%**	RBA Large Business Indicator Rate					
13								
Asset Parameters								
15	**Capital Costs**							
16	Construction Commences in Year Ending 30 June	**2010**						
17	**Year Ending 30 June**	**2010**	**2011**	**2012**	**2013**	**2014**	**TOTAL**	
18	Capital Cost of Shared Assets [$ Nominal]	**5,963,365**					5,963,365	external co
19	Capital Cost of Connection Assets [$ Nominal]	**21,330,000**					21,330,000	external co
20	Total Costs [$ Nominal]	27,293,365	0	0	0	0	27,293,365	
21								
22	**Operating Costs**							
23	O&M Costs of Shared Assets	**146,699**	3% dist/2.46% trans internal cost - in today's dollars					
24	O&M annual escalation (real)	**0.00%**	assume 0% unless advised by Regulation, Pricing & Access Development					
25								
Applicant Parameters								
27	**Covered Service Revenue**							
28	Applicant Revenue Commences in Year Ending 30 June	**2011**						
29								
30	Applicant Tariff Revenue	**890,454**	first year (exclude GST) - in today's dollars					
31	Applicant Tariff Revenue annual escalation (real)	**0.00%**	assume 0% unless advised by Regulation, Pricing & Access Development					
32								
Model Parameters								
34	**Model**							
35	Discounted Cashflow Period	**15**	years (no longer than 15)					
36								
Periodic Payments								
38	**Payment Options**							
39	Periodic Payment Period	**0**	years (no longer than 5)					
40	Credit Risk	**Security in p**	assume "Security in place (full amount)" unless advised by Treasury					
41								
Model Outputs								
Capital Contribution		**Capital Contribution (ex-GST)**		**GST**		**Total (inc-GST)**		
44	**Calculated Capital Contribution**							
45	Capital Contribution for Shared Assets	0		0		**0**		
46	Capital Contribution for Connection Assets	21,330,000		2,133,000		**23,463,000**		
47	Total Capital Contribution	21,330,000		2,133,000		**23,463,000**		
48		Capital contribution valid if full payment is received within 60 days of 29/04/2010						
49	IRR over Discounted Cashflow Period	9.09%						
50	**Check**	**OK**						
51								

Attachment 1 Binningup Desalination Plant Planning Report (DM 6254223)

At the time the attached report was produced and submitted to the Economic Regulation Authority in 2009, the Water Corporation's application to Western Power was for a 25 MW load for the Binningup desalination plant. In December 2009, the Water Corporation requested an additional 5 MW, to bring the total load of the desalination plant to 30 MW.

This latest information will not affect the conclusions of the Planning Report.

Binningup Desalination Plant Planning Report

DATE:
26 October 2009

PREPARED BY:
Western Power
GPO Box L921, Perth WA 6842
ABN 18 540 492 861

westernpower

Statement regarding the increase of the Binningup desalination plant load to 30 MW

At the time this report was produced and submitted to the Economic Regulation Authority in 2009, the Water Corporation's application to Western Power was for a 25 MW load for the Binningup desalination plant. In December 2009, the Water Corporation requested an additional 5 MW, to bring the total load of this desalination plant to 30 MW.

This latest information would not affect the conclusions of this report.

Executive Summary

Western Power has been requested by the Water Corporation to provide a 132 kV supply to the desalination plant at Binningup, about 50 km north of Bunbury, which will have a Stage 1 demand of 25 MW. It is anticipated that there would be an initial load of approximately 10.5 MW in 2010, ramping up to 25 MW by 2011. The resultant increase in summer peak power demand will cause the existing network capacity to be exceeded by summer 2011/2012.

The major augmentation that is proposed is the installation of a second 330/132 kV transformer and associated circuits, a new 132 kV switchyard at Kemerton Terminal, and about 10 km of new 132 kV line from Kemerton to the Binningup desalination plant.

1 Introduction

The Water Corporation proposes to install a second desalination plant at Taranto Road, Binningup, about 50 km north of Bunbury. Western Power has been requested to provide a power supply to the desalination plant.

To supply the Binningup desalination plant will require Western Power to undertake a major augmentation. The nearest connection point is at Kemerton Terminal, about 10 km from Binningup. Table 1 shows the expected demand and the estimated service date.

Table 1: Forecast demand requirements of the Desalination Plant

Stage	Estimated service date	Demand increase	Total demand requirements
1	2010-2011	25 MW*	25 MW
2	2017	30 MW	55 MW

* It is anticipated that there would be an initial load of approximately 10.5 MW during 2010, with the remainder of the 25 MW load occurring by 2011.

Western Power in partnership with the Water Corporation has investigated various options to address the forecast load requirements of the Binningup desalination plant. To meet the demand the recommended option is the construction of approximately 10 km of 132 kV transmission line from Kemerton Terminal to Binningup and the installation of a new 330/132 kV transformer and associated works at Kemerton Terminal.

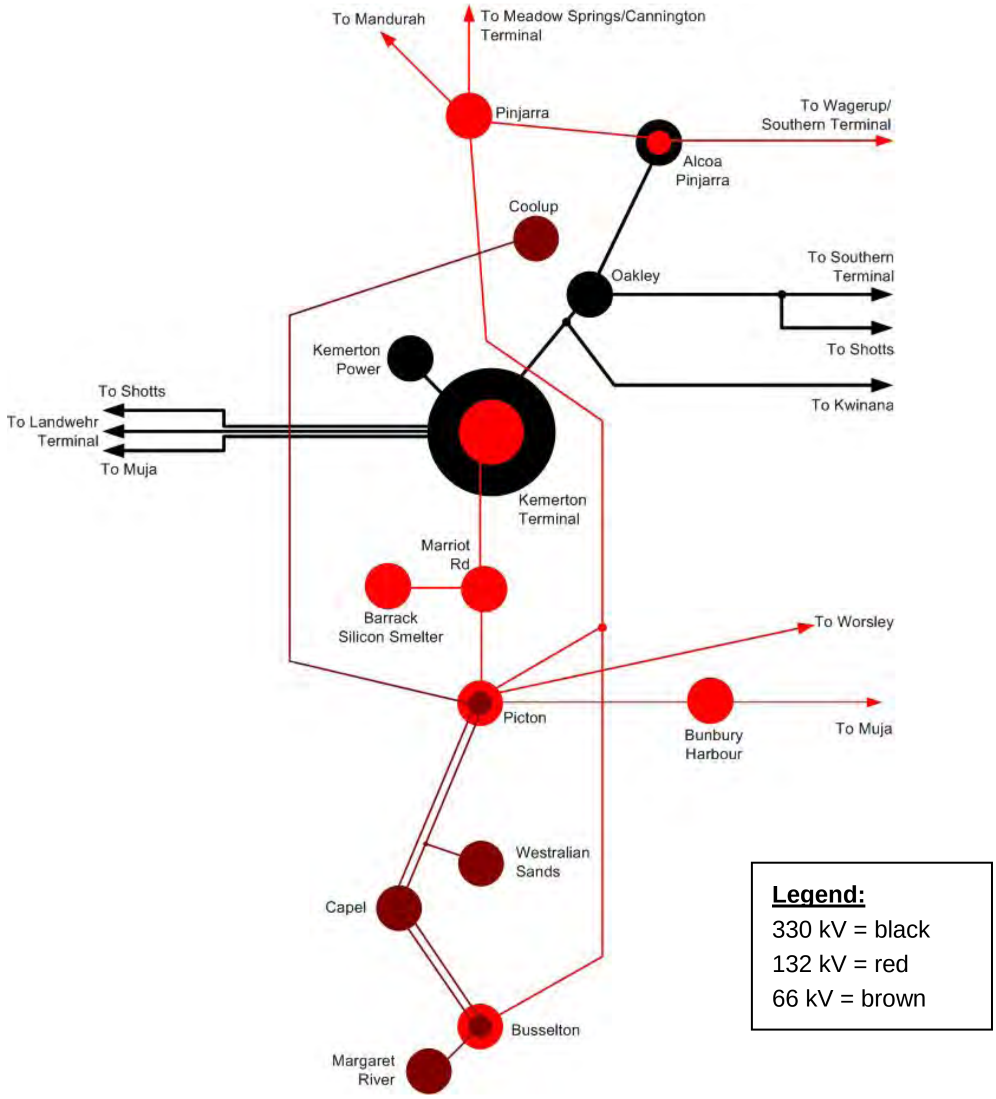
Background

The Bunbury Load Area contains three transmission voltage systems; 66 kV, 132 kV and 330 kV. Western Power's transmission network in the Bunbury area extends from Pinjarra in the north to Margaret River in the south and almost to Muja in the east (Figure 1). It includes a number of 132 kV transmission lines and a single 330/132 kV transformer with quad-booster (with a Long Term Emergency Rating of 248 MVA) located at Kemerton Terminal. This transformer which is non-standard was moved from Muja to Kemerton when a higher rated transformer was required at Muja.

There are two main in-feeds to the Bunbury area, those being through Kemerton Terminal and the Kemerton to Marriot Road 132 kV line, and the Muja-to-Bunbury Harbour 132 kV line.

The existing 132 kV transmission system is approaching its operating limits.

Figure 1. Simplified network configuration of the transmission network of the Bunbury Load Area (Source: 2009 Transmission and Distribution Annual Planning Report).



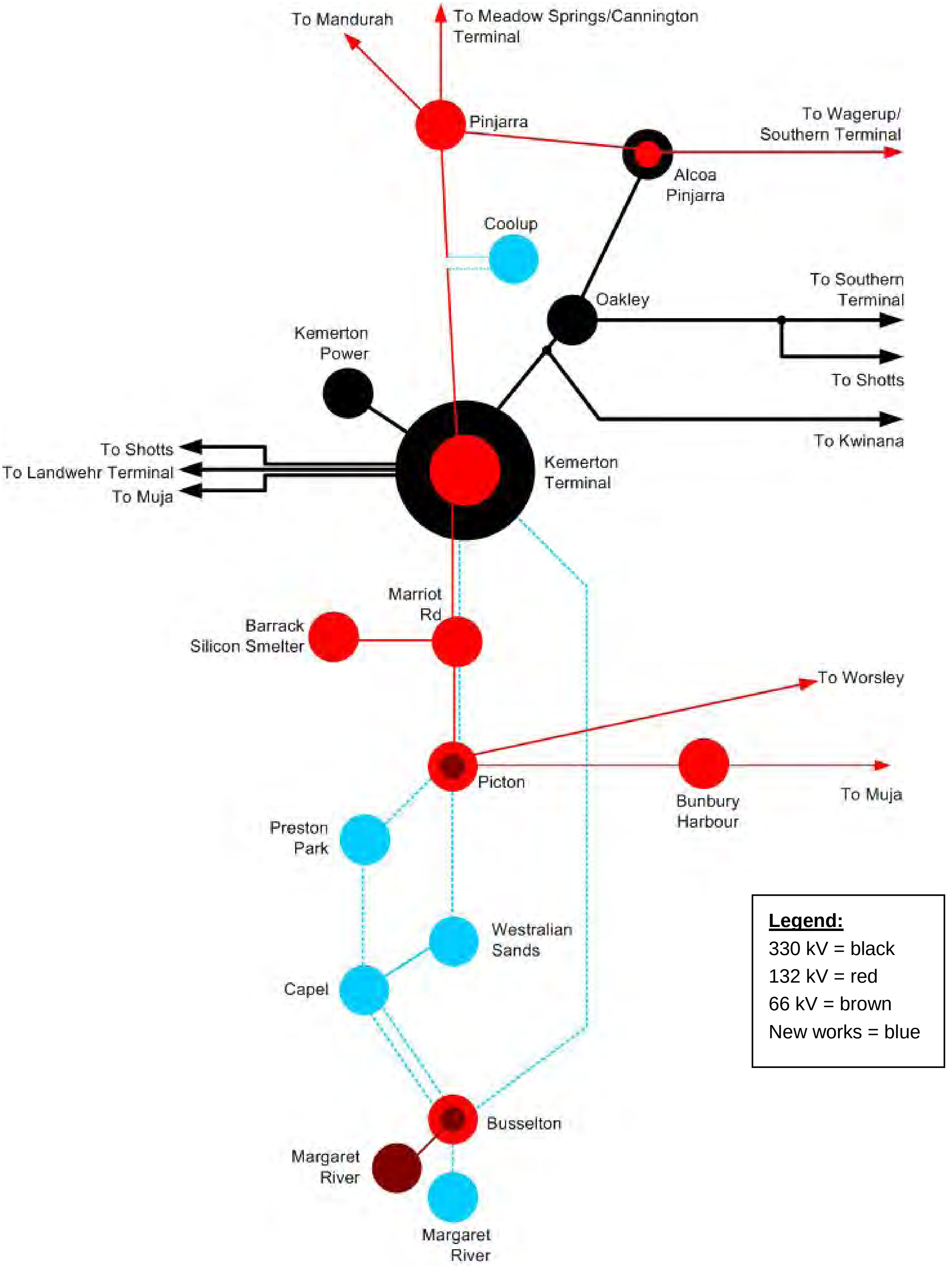
Overview of Western Power's future plans

The 2009 Annual Planning Report identifies two projects that would support the growth in load demand in the Bunbury area:

- Installation of a second 330/132 kV transformer at Kemerton;
- Converting the split-phase Kemerton-to-Marriot Road 132 kV line into a double-circuit line.

Figure 2 shows the future long-term outlook for the Bunbury load area and the developments which could occur based on central case forecasts. Mid and long-term requirements for 132 kV capacity for the Bunbury area will be met by Kemerton Terminal.

Figure 2: Overview of the future long-term transmission network in the Bunbury area (Source: 2009 Transmission and Distribution Annual Planning Report).



Load forecast

Western Power undertakes network planning for a 20 year horizon. The plans developed from this process incorporate natural load growth for an area, but also take into consideration potential larger developments. These considerations are intended to ensure that development of the network is undertaken in a strategic manner, and to ensure that investment is optimised in the long term.

Low, central and high load forecasts are used in the evaluations. To be consistent the following terminology is used:

Natural load growth forecast - based on historical load trend growth without any block loads.

Low case forecast - based on historical load trend growth plus the first stage of the Binningup desalination plant load.

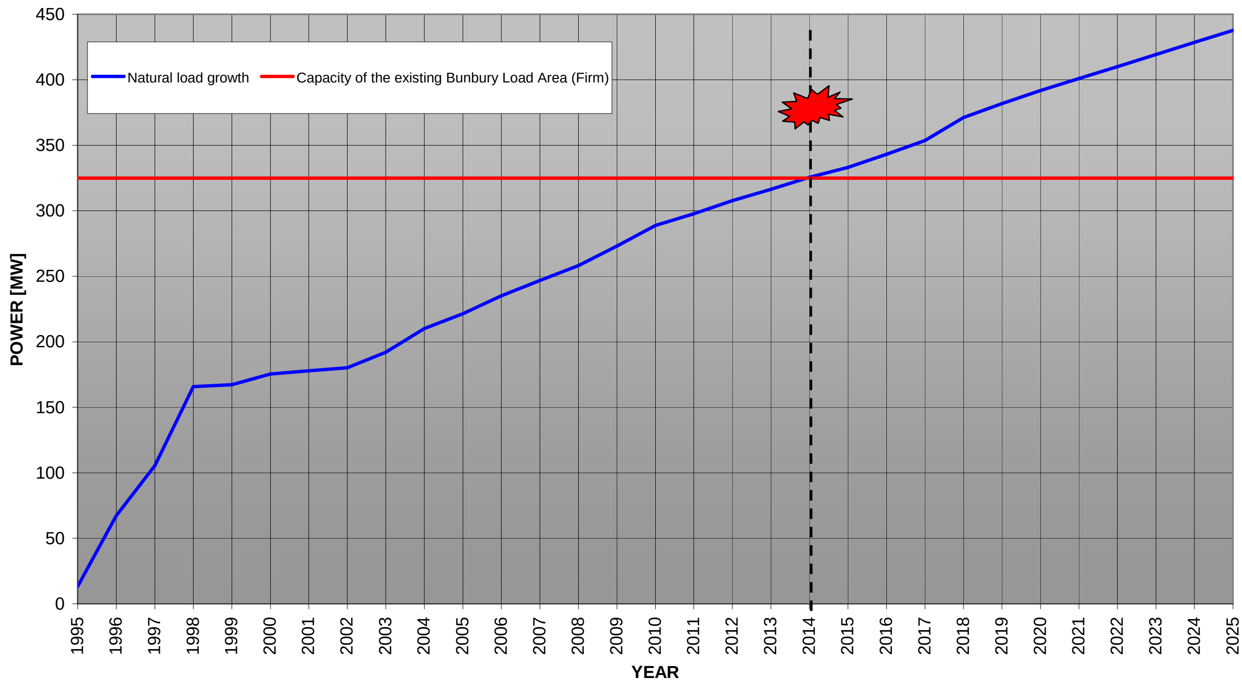
Central case forecast - based on the historical load trend growth but including prospective block loads diversified with a probability weighting.

High case forecast - based on the historical load trend growth but including prospective block loads without any diversification.

A Central case forecast is normally used for planning purposes as it provides for a balanced approach between risk and expenditure. Expansion of the network is undertaken once actual load development becomes more certain.

Natural load growth trend and capacity of the existing network

Figure 3: Demand based on natural load growth and capacity of the existing network

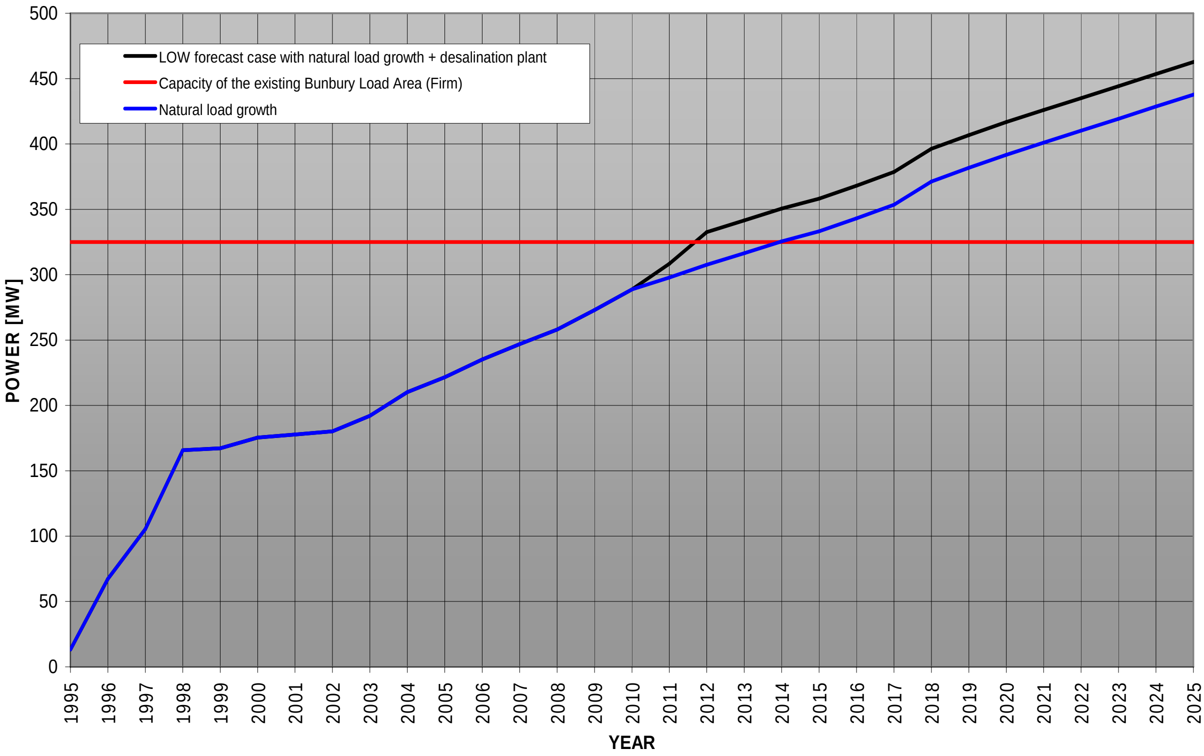


DMS#: 6254223

Western Power has reviewed the load forecast and adequacy of the existing 132 kV transmission network that supplies the Bunbury area. In figure 3, the year 2014 refers to the summer from late 2013 to early 2014. Forecast load is expected to exceed supply capacity by summer 2013/14. This is based on load flow simulations in PSS/E (Case saved in */home/trans/n017916/2014_KemAdvance_7Sept09.sav).*

Low forecast

Figure 4: Low Case forecast with the Binningup desalination plant Stage 1 block load only.



Western Power has reviewed the load forecast with the addition of the desalination plant load and adequacy of the existing 132 kV transmission network that supplies the Bunbury area. Figure 4 above shows a low case demand forecast based on ‘natural’ load growth with the Binningup desalination plant Stage 1 block load (the potential increase to 55 MW in 2017 has not been included).

According to load flow studies, the low case load forecast is expected to exceed supply capacity with the full load of Stage 1.

A Summer 2011/2012 load flow scenario has been used to determine the impact of the Binningup desalination plant load on the network. If the existing Kemerton 330/132 kV transformer is out of service, the result is that the Muja-to-Bunbury Harbour 132 kV line exceeds its maximum rating and the voltage lower limit at the Kemerton LV side and at Binningup desalination plant substation would be breached. (*Case: trans/n017916/2012_BDP.sav).* This violates the Technical Rules – Section 2.2.2 (a). See Appendix 3 for the associated load flow study notes.

Central and high forecasts

Presently there are a number of other prospective industrial customers seeking to connect to the network in the Bunbury area. These loads are not 100% certain and a probability weighting has been assigned as shown in Table 2.

Table 2: Prospective industrial block loads (DM#: 6406824)

Future block loads for CENTRAL forecast	Size of CMD (MW)	Probability	Weighted Average (MW)	RIS	Forecast	Summer
Binningup Desalination Plant (Stage 1)	25	100%	25	Jun - 2010	Central	2012
Binningup Desalination Plant (Stage 2)	30	50%	15	2017	Central	2018
Simcoa 3rd Furnace (PBL1A)	25	80%	20	2011	Central	2012
Simcoa 4th Furnace (PBL1B)	25	30%	8	2015	Central	2016
Ewington CM (PBL2)	42	30%	13	2015	Central	2016
Total block loads			**80**			

Potential new demand for connection of new customers for the central case is about 80 MW (probability weighted). However, there is no spare capacity for connection of the new large industrial loads. Full utilisation of the existing transmission capacity means constraints for connection of new industrial block loads in the Bunbury region until major transmission reinforcement is constructed.

Figure 5: All forecasts with prospective new loads in the Bunbury area

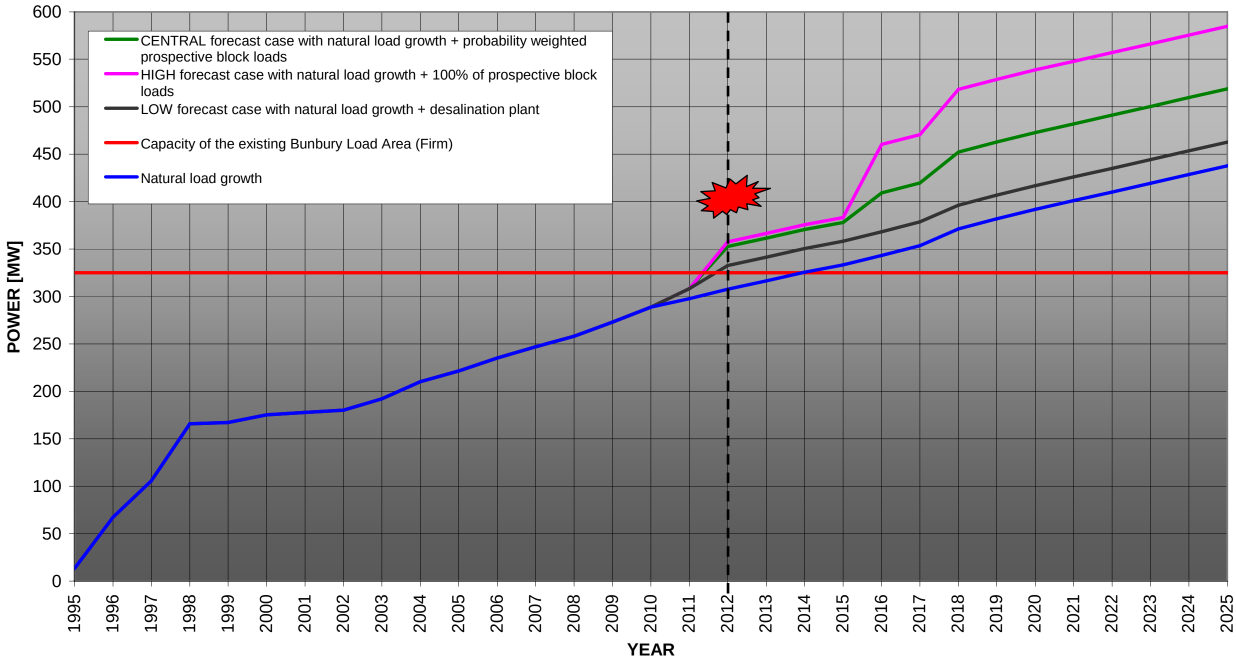


Figure 4 above shows “natural”, low, central and high case load forecasts for the Bunbury area, showing the impact from connection of the prospective block industrial loads based on a probability weighted analysis (central case) and 100% of all connections (high case).

2 Overview of Options

In assessing options and selecting a recommended option for reinforcing the electricity network, Western Power has sought to identify the solution that best meets the immediate forecast needs of the region, while providing opportunity for further expansion in the future at the lowest sustainable cost.

Western Power has identified 4 major reinforcement options to address the connection of the Binningup desalination plant and the emerging shortfall of power supply capacity in the Bunbury region. These are:

Option 1: Minimum infrastructure build (curtailable load at Binningup)

Option 2: On Site Generation (at Binningup)

Option 3: Installation of a 90 MVAr capacitor bank at Kemerton Terminal and rebuilding of existing lines

Option 4: Installation of a second 330/132 kV transformer at Kemerton Terminal.

Discussion

Note that all options include the establishing of the 132 kV switchyard at Kemerton Terminal as this is required to connect Binninngup.

Option 1 - the "Minimum infrastructure build" option involves establishing a 132 kV switchyard at Kemerton and building the line to Binningup, but not installing the second 330/132 kV transformer at Kemerton. The load forecast in Figure 4 shows that Stage 1 of the desalination plant will cause the existing network capacity to be exceeded in summer 2011/12.

This option provides a curtailable supply to the customer (in the event of a failure of the existing Kemerton 330/132 kV transformer) and does not meet the requirements of the Technical Rules with respect to provision of an N-1 supply. The customer has accepted a curtailable supply until reinforcements as per Option 4 can be delivered. Note that option 1 is not acceptable to the customer in the longer term.

Option 2 – the "On site generation" solution includes the installation of two 25 MW generating units. The use of on-site generation is more expensive than the transmission reinforcement options (see Appendix 2).

Option 3 – the "Installation of a 90 MVAr capacitor bank at the Kemerton Terminal 132 kV busbar and rebuilding of existing lines" scenario involves:

- installation of a 90 MVAr capacitor bank to address the issue of low voltages caused by an outage of the existing Kemerton 330/132 kV transformer,
- up-rating the Muja-to-Western Collieries and the Muja-to-Bunbury Harbour 132 kV lines. The Muja-to-Bunbury Harbour 132 kV line is already 44 years old. If this line is rebuilt it will only deliver an additional 40 MW increase in capacity (as per SIL and PV curve studies). The net present cost of this option exceeds the net present cost of the preferred/recommended Option 4.

Option 4 – the "Installation of the second 330/132 kV transformer" option will provide Binningup with an N-1 supply which meets all of the requirements of the Technical Rules. It will also significantly increase existing capacity to the area. The existing Kemerton-to-Marriot Road 132 kV line is a split-phase line and can be converted to a double-circuit line with minimal expense.

To provide significant N-1 capacity this would need to occur and this reinforcement has been included in the NPV analysis[1]. These two reinforcements will remove the need to up-rate the Muja-to-Bunbury Harbour 132 kV line, and will delay the need to up-rate the Muja-to-Western Collieries 132 kV line. This is the best solution in technical and economic terms. This option is preferred and is the recommended solution.

Table 3 ranks each of the options. Option 1 will not meet the requirements of the customer and violates the Technical Rules. A preliminary financial analysis of Option 2, the "On site generation" option, presented in Appendix 2, shows that this option is not likely to be financially competitive. The net present cost (NPC) of options 2, 3 and 4 are shown below:

Options	**NPC in $M**
Option 2: Install on-site generation (excluding gas connection cost and fuel). Note: See Appendix 2 for explanatory notes and assumptions.	79.6
Option 3: Install a 90 MVAr capacitor bank at Kemerton and rebuild existing lines	43.5
Option 4: Install the second 330/132kV transformer at Kemerton	32.9

In the economic analysis of Option 3, it is assumed that up-rating the lines will require these lines to be rebuilt. The Muja to Bunbury Harbour line is 44 years and is 66 kms long. The Muja to Western Collieries line is 24 years old but is only 7 kms long. A sensitivity analysis has been conducted on these costs in Table 10 (Appendix 1) to assess the impact of this assumption. The sensitivity analysis indicates that if the line costs associated with the re-build are halved (that is some savings could be achieved by not re-building the whole lines), the ranking of the options remains un-changed.

Results of evaluation and ranking, as shown in Table 3, indicate that Option 4 with installation of second 330/132 kV transformer at Kemerton Terminal is the superior solution.

Detailed analysis is contained in Appendix 1.

[1] The conversion of the Kemerton-to-Marriot Road 132 kV line from a split-phase to a double circuit line is not part of the works associated with the Binningup desalination plant. The Binningup desalination plant load does not affect the power flow in the Bunbury area during an outage of this line. The Binningup desalination plant load will only affect the power flow in the Bunbury area with an outage of the existing Kemerton transformer.

Table 3: Ranking of the options

OPTION	Ranking					
	Economic (see Appendix)	**Technical (N-1 issues)**	**Capacity increase (MW) [See note]**	**Risk of load shedding**	**Capacity provision to supply new block loads**	**Overall ranking**
1/ Minimum infrastructure build. *(Not acceptable as it does not meet customer requirements and the Technical Rules.)*	*N/A: Customer requirements not met*	*2 (line overloads, low voltages)*	*N/A*	*2*	*4*	*4 Not acceptable*
2/ On-site Generation	*3*	*1*	*3*	*1 (removed)*	*3*	*3*
3/ Install a 90 MVAr capacitor bank at Kemerton 132 kV busbar and rebuilding of existing lines.	*2*	*1*	*2 (may be approximately 40 MW provided by MU-BUH 81 rebuild)*	*1 (removed)*	*2*	*2*
4/ Install a second 330/132 kV transformer.	*1*	*1*	*1 (240 MW provided at Kemerton)*	*1 (removed)*	*1*	***1 Preferred***

Note: Comparison of the capacity increase provided for loads in the area is not as straightforward as it appears in the table. For example, to fully utilise the additional 240 MW provided at Kemerton would require additional reinforcements to deliver power to the location of the load. These further reinforcements would only be undertaken as required.

3 Kemerton Terminal works

Due to natural load growth Western Power would install the second 330/132 kV transformer at Kemerton Terminal by Summer 2013/2014 without the Binningup desalination plant connection. The 132 kV switchyard required for Kemerton in 2013/2014 (excluding Binningup) would include a 4 switch mesh arrangement to cater for the two step-down transformers and the conversion of the existing split phase line to Marriot Road to a double circuit line. This would be required as load flow studies indicate that due to natural load growth either the outage of the existing Kemerton transformer or the KEM-MRR 81 line would result in an overload in the Muja-to-Bunbury Harbour 132 kV line.

Using the low case forecast, which includes Stage 1 of the Binningup desalination plant, but no other block loads, the installation date for the second 330/132 kV transformer at Kemerton is Summer 2011/2012.

Currently there is no 132 kV switchyard at Kemerton (KEM), only a 132 kV circuit breaker. The following diagram in Figure 6 shows a 4 switch mesh 132 kV switchyard which is required as part of the works to supply the Binningup desalination plant.

Figure 6. Proposed Kemerton 132 kV switchyard works

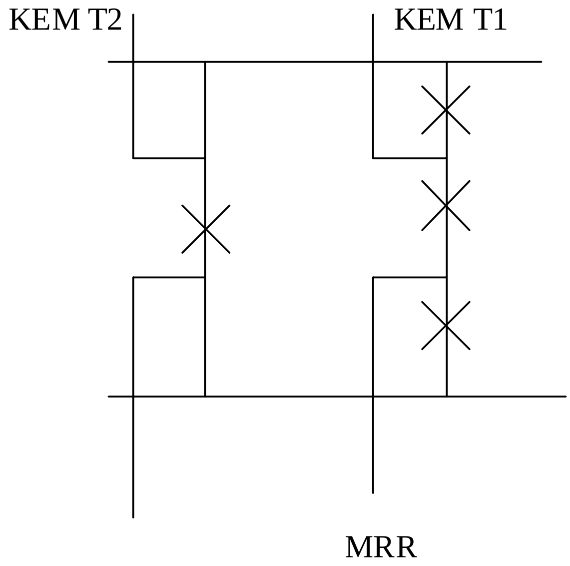
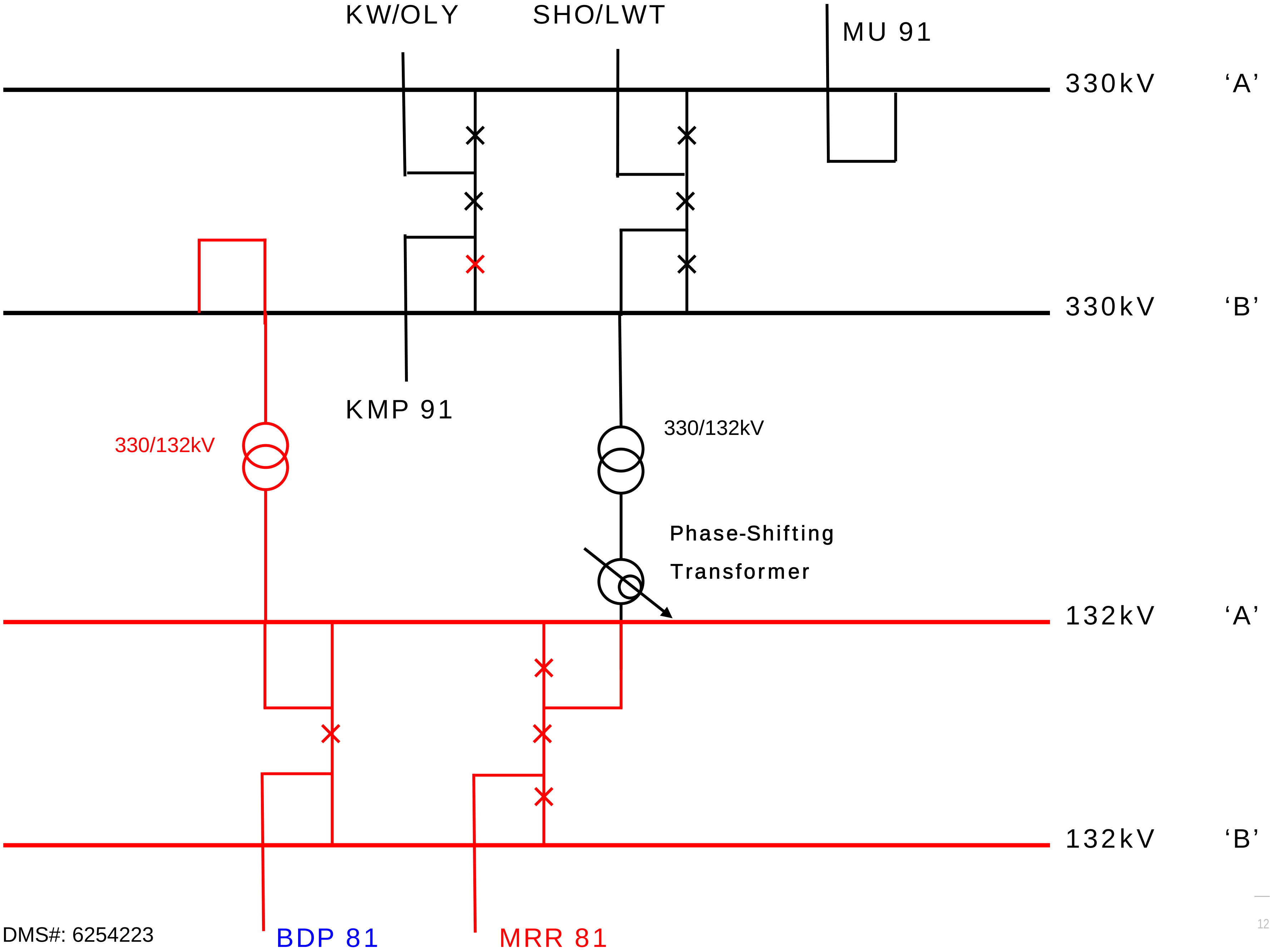


Figure 7 (next page) shows the Kemerton Terminal single line diagram with existing and new works.

Figure 7. Kemerton Terminal single line diagram showing existing works (black) and new works (red).



4 Conclusion

Based on the analysis in this report Option 4 is the recommended option. This includes installation of second 330/132 kV transformer at Kemerton Terminal and establishing the 132 kV switchyard to facilitate connection of the Binningup desalination plant.

Appendix 1: Detailed NPC analysis of options

Table 9. NPC analysis for Options 3 and 4.

Pretax-nominal with cost escalation and discount rate of 10.05%		CENTRAL FORECAST										
NPC Analysis for reinforcement in Bunbury Load Area		Hurdle Rate:		10.05%								
YEAR ending June:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Option 3: Install a 90 MVAr capacitor bank at Kemerton and rebuild existing lines												
90 MVAr Capacitor Bank (Capital Cost $1.8m)	0.2	1.4	0.3									
Kemerton 132 kV substation (including circuits for existing transformer, Marriot Rd, Binningup and capacitor bank) (Capital Cost $13.0m)	9.8	3.3										
Rebuild of MU – BUH 81 line (Capital Cost for 66km line $19.8m)		2.0	14.9	3.0								
Rebuild of MU – WCL 81 line (Capital Cost for 7km line $2.1m)	0.2	1.6	0.3									
Extension of 330 kV substation and new 330/132 kV transformer (Capital Cost $17.5m)										1.8	13.1	2.6
Conversion of KEM-MRR 81 line from split phase to double circuit (Capital Cost $2.5m)										0.3	1.9	0.4
Sub-total ($M)	10.1	8.2	15.4	3.0						2.0	15.0	3.0
Inflation rate WA (%) (as per Access economics April 2009)		2.3%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Inflation rate multiplier	1.00	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.34
Escalated Total ($M)	10.1	8.3	16.2	3.2						2.5	19.5	4.0
Discount rate for capital cost	1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35
Present Base Cost ($M)	10.1	7.6	13.4	2.4						1.1	7.5	1.4
Net Present Cost ($M)	**43.5**											
YEAR ending June:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Option 4: Install the second 330/132kV transformer at Kemerton												
Extension of 330 kV substation and new 330/132 kV transformer (Capital Cost $17.5m)	1.8	13.1	2.6									
Kemerton 132 kV substation (including circuits for new and existing transformers, and line circuits for Marriot Rd and Binningup) (Capital Cost $13.0m)	9.8	3.3										
Conversion of KEM-MRR 81 line from split phase to double circuit (Capital Cost $2.5m)	0.3	1.9	0.4									
Rebuild of MU – WCL 81 line (Capital Cost for 7km line $2.1m)				0.2	1.6	0.3						
Sub-total ($M)	11.8	18.3	3.0	0.2	1.6	0.3						
Inflation rate WA (%) (as per Access economics April 2009)		2.3%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Inflation rate multiplier	1.00	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.34
Escalated Total ($M)	11.8	18.7	3.2	0.2	1.7	0.4						
Discount rate for capital cost	1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35
Present Base Cost ($M)	11.8	17.0	2.6	0.2	1.2	0.2						
Net Present Cost ($M)	**32.9**											

Note: Water Corporation works and Western Power works at Binningup are excluded

In the analysis in Table 9, it has been assumed that up-rating the MU-BUH 81 and MU-WCL 81 lines will require a complete rebuild. A sensitivity analysis has been conducted on the costs in Table 9 for these line up-rates to determine the impact of this assumption. In Table 10, these costs have been reduced by 50%. As it is shown, the costs are of similar order although Option 4 remains the preferred option.

Table 10. NPC analysis for Options 3 and 4 showing a sensitivity analysis conducted for line uprate costs used in Table 9

Pretax-nominal with cost escalation and discount rate of 10.05%		CENTRAL FORECAST										
NPC Analysis for reinforcement in Bunbury Load Area		Hurdle Rate:		10.05%								
YEAR ending June:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Option 3: Install a 90 MVAr capacitor bank at Kemerton and rebuild existing lines												
90 MVAr Capacitor Bank (Capital Cost $1.8m)	0.2	1.4	0.3									
Kemerton 132 kV substation (including circuits for existing transformer, Marriot Rd, Binningup and capacitor bank) (Capital Cost $13.0m)	9.8	3.3										
Rebuild of MU – BUH 81 line (Capital Cost for 66km line $9.9m)		1.0	7.4	1.5								
Rebuild of MU – WCL 81 line (Capital Cost for 7km line $1.1m)	0.1	0.8	0.2									
Extension of 330 kV substation and new 330/132 kV transformer (Capital Cost $17.5m)										1.8	13.1	2.6
Conversion of KEM-MRR 81 line from split phase to double circuit (Capital Cost $2.5m)										0.3	1.9	0.4
Sub-total ($M)	10.0	6.4	7.9	1.5						2.0	15.0	3.0
Inflation rate WA (%) (as per Access economics April 2009)		2.3%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Inflation rate multiplier	1.00	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.34
Escalated Total ($M)	10.0	6.5	8.3	1.6						2.5	19.5	4.0
Discount rate for capital cost	1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35
Present Base Cost ($M)	10.0	5.9	6.8	1.2						1.1	7.5	1.4
Net Present Cost ($M)	**34.0**											
YEAR ending June:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Option 4: Install the second 330/132kV transformer at Kemerton												
Extension of 330 kV substation and new 330/132 kV transformer (Capital Cost $17.5m)	1.8	13.1	2.6									
Kemerton 132 kV substation (including circuits for new and existing transformers, and line circuits for Marriot Rd and Binningup) (Capital Cost $13.0m)	9.8	3.3										
Conversion of KEM-MRR 81 line from split phase to double circuit (Capital Cost $2.5m)	0.3	1.9	0.4									
Rebuild of MU – WCL 81 line (Capital Cost for 7km line $1.1m)				0.1	0.8	0.2						
Sub-total ($M)	11.8	18.3	3.0	0.1	0.8	0.2						
Inflation rate WA (%) (as per Access economics April 2009)		2.3%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Inflation rate multiplier	1.00	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.34
Escalated Total ($M)	11.8	18.7	3.2	0.1	0.9	0.2						
Discount rate for capital cost	1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35
Present Base Cost ($M)	11.8	17.0	2.6	0.1	0.6	0.1						
Net Present Cost ($M)	**32.1**											

Appendix 2: Option 2 Generation option analysis

To provide sufficient generation firm capacity for the first stage of the Binningup plant, it has been assumed a minimum of two 25 MW generating units would be required. With the forecast load increase in 2017 to 55 MW, additional generation capacity would be required at that time.

Western Power has recently commissioned an independent study that included current costs for various on-site generation options. The particular capital costs for generation were given as $900 per kW for open cycle gas turbines and $1,400 per kW for combined cycle gas turbines.

Based on $900 per kW for open cycle gas turbines a conservatively low cost for this option would be in the order of $45M for the generator cost (50 MW installed capacity). The cost of generation would increase should the expansion planned for 2017 go ahead. Based on 55 MW demand, the installed capacity would need to be doubled.

Additional to that is the cost of establishing a gas lateral to connect to the gas network. That cost has not been established but would clearly be significant.

Operations and maintenance costs (non-fuel) would also be additional to the capital costs and are estimated as being $11,000 per MW per annum (fixed cost), and $10.29 per MWh (variable cost).

This information is summarised below, and excludes any cost of connection to the Western Power network (assumes no network connection).

Cost component	Cost
Generators for first stage	$45M
Generators for second stage	$45M
Gas lateral connection	Unknown
Operating costs (non fuel)	$11,000 per MW and $10.29 per MWh
Fuel cost	Unknown

Based on the above costs the net present cost to install and maintain the 4 generators would be $79.6M excluding the cost of connection to the gas network and the cost of gas.

The NPC of this option is not strictly comparable to the NPCs of options 3 and 4 (discussed in the main report). Options 3 and 4 have not included the cost of connection to Western Power's network which is $19.9M. However the NPC for this generation option does not include the cost for the gas connection which is unknown but would be substantial. Consequently even with these factors in mind there is still a considerable margin between this option and the NPCs for options 3 and 4.

Table 11. NPC for Option 2

Pretax-nominal with cost escalation and discount rate of 10.05%												
NPC Analysis for reinforcement in Bunbury Load Area		Hurdle Rate:		10.05%								
YEAR ending June:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Option 2: Install local generation at Binningup												
Two 25 MW gas units for Stage 1 (Capital Cost $45m)		45.0										
Two 25 MW gas units for Stage 2 (Capital Cost $45m)									45.0			
Operating costs (non-fuel) ($11,000 per MW and $10.29 per MWh)		1.2	1.2	1.2	1.2	1.2	1.2	1.2	2.6	2.6	2.6	2.6
Sub-total ($M)		46.2	1.2	1.2	1.2	1.2	1.2	1.2	47.6	2.6	2.6	2.6
Inflation rate WA (%) (as per Access economics April 2009)		2.3%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
Inflation rate multiplier	1.00	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.27	1.30	1.34
Escalated Total ($M)		47.3	1.3	1.3	1.4	1.4	1.4	1.5	58.7	3.3	3.4	3.5
Discount rate for capital cost	1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.46	0.42	0.38	0.35
Present Base Cost ($M)		43.0	1.1	1.0	0.9	0.9	0.8	0.8	27.3	1.4	1.3	1.2
Net Present Cost ($M)	**79.6**											

Appendix 3: Load flow study notes

In this document, PSS/E studies were carried out using the PSS/E cases released in December 2007 and load forecasts released December 2008 (DMS#: 5360882).

Previous studies documented in the report “Binningup Desalination Plant – System Study (Addendum)” (DMS#: 4140312), which also include the Ewington block load, have recommended the installation of a second 330/132 kV transformer at Kemerton.

<u>Generation conditions</u>

It should be noted that the results will be significantly impacted by the generation conditions used. The Technical Rules states that “For sub-networks designed to the N-1 Criterion… supply must be maintained and load shedding avoided at any load level and for any generation schedule following the outage of any single transmission element” (DMS#: 3605551, see excerpt below):

2.5.2.2 N-1 Criterion

(a) Any sub-network of the *transmission system* that is not identified within this clause 2.5.2 as being designed to another criterion must be designed to the N-1 planning criterion.

(b) For sub-networks designed to the N-1 criterion (excluding a *zone substation* designed to the 1% risk or NCR criteria in accordance with clause 2.5.3.2), *supply* must be maintained and *load shedding* avoided at any *load* level and for any *generation* schedule following an outage of any single *transmission element*.

(c) Following the loss of the *transmission element*, the *power system* must continue to operate in accordance with the *power system* performance standards specified in clause 2.2.

The MU-BUH 81 line is of significance as it will require up-rating in the near future. Generation of significance for this line includes Worsley units, which are normally on under peak conditions.

In the load flow studies used to gauge the impact of the Binningup desalination plant, the Worsley gas turbine is out of service, and Worsley Alumina is utilizing its full contract maximum demand of 45 MW.

Similar generation conditions at Worsley were utilised in the earlier study report justifying the installation of the second 330/132 kV transformer at Kemerton (see “Binningup Desalination Plant – System Study (Addendum)” in DMS#: 4140312).

Attachment 2 Binningup Desalination Design Report (DM# 5539496)

Transmission Design Report

Binningup Desalination Plant Project

Original Issue: 28 April 2009
Prepared by: Transmission Primary Engineering & Construction

ABN 18540492861

Document Control

Endorsement Approvals

	Name	Title	Signature
Endorsed by	Al Edgar	Acting Branch Manager – Transmission Primary Engineering & Construction	
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Approved by	Mehdi Toufan	Group Manager – Transmission Delivery	

Record of Revisions

Revision number	Date	DMS version	Revised by	Description

Documents Referenced In This Document

DMS#	Title of Document
DMS and other document reference in this document are indicated in blue underlined text.	

Stakeholders (people to be consulted when document is updated)

Position / Title
Branch Manager – Transmission Program Management
Branch Manager – Transmission Primary Engineering & Construction
Branch Manager – Secondary Systems Engineering
Group Manager – Transmission Delivery

Notification List (people to be consulted when document is updated)

TABLE OF CONTENTS

1 DESIGN REPORT PURPOSE

This document describes the design inputs, methodology and key outputs for the main components of the Binningup Desalination Plant (BDP) Project, namely the extension of the 330kV Yard at Kemerton (with a 490 MVA Tx), the introduction of a 132kV Terminal Yard at Kemerton and a 132kV single circuit Kemerton - Binningup line and cable..

The purpose of this Design Report is to describe for these major BDP assets:
The What: Outline the design solution.
The Why: Provide an explanation of the reasons for the design. This includes outlining the design inputs (environmental conditions, standards, etc) underpinning the design and the design methodology used in developing the design.
The Assumptions: Provide a description on the key assumptions made and the impact of these.
The Risks: Outline the key design risks and how these are being mitigated.

Whilst achieving this purpose, the report structure provides a logical flow on how the design was developed and addresses the above items where relevant.

The report provides a central point to capture the BDP design and will be used for future Asset Management and Design reference, including network augmentation.

2 DESIGN REPORT SUMMARY

2.1 DESIGN REPORT SUMMARY OVERVIEW

This section of the report provides a summary of the critical design inputs, methodology and key design outputs for the three main components of the BDP project, namely the Kemerton 330 kV Yard extension, the introduction of a 132kV Terminal Yard at Kemerton Terminal and the 132kV single circuit Kemerton - Binningup line / cable. Further information is contained in the remainder of the report.

2.2 330 kV / 132 kV KEMERTON TERMINAL

The Kemerton 330 kV Terminal is being expanded to accommodate a new 490 MVA power transformer to meet the load criteria of the BDP project. As part of this expansion, the existing Bay 965 will be populated to enable KEM 330 kV to operate as a 6 point mesh. Once the Kemerton 330 kV site develops beyond 6 x 330 kV circuits it will need to be converted to operate as a breaker and a half switchyard.

A new 132kV terminal is required to connect into the Bunbury Load Area 132 kV network.

The ultimate arrangement for the KEM 132 kV yard includes eighteen line circuits, three transformer circuits and three capacitor banks over twelve bays in breaker and a half configuration.

For the initial development of the 132 kV yard, four line circuits and two transformer circuits will be required and arranged in a six point mesh over 3 bays, thus only part of bay 3 will be populated.

2.2.1 Terminal Design Inputs

The extension of the 330kV terminal and the new 132kV terminal will allow the connection of the increased supply capacity into the Bunbury area. The following is a summary of the key aspects:

Network Requirements (Minimum):		
Factor		
Network nominal voltage	330 kV	132 kV
Normal operating range	±10%	±10%
Equipment highest voltage	362 kV	145 kV
Rated 1 minute power frequency withstand	520 kV	275 kV
Rated lightning impulse withstand	1175 kVp	650 kVp
Continuous rating	2500 A / 3150 A (busbar)	2500 A / 3150 A (busbar)
Substation one second short time current rating	50 kA	50 kA
Design life	50 years	
Reliability	High	
Rated Physical Environment:		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	0 ^{o}C	+45 ^{o}C
Solar radiation (horizontal surface)	Nil	1,000 W/m2
Wind speed	Nil	60 m/s
Relative humidity – outdoor	30%	90%
Pollution level	Severe/High	
Altitude	Less than 1000 metres above sea level	
Keraunic level (thunder days per year – DMS#5534120)	10	

2.2.2 Design Methodology

In developing the Kemerton terminal designs, Western Power has:

Complied with relevant industry standards (particularly AS2067: Substations and high voltage installations exceeding 1 kV a.c.);
Complied with relevant Western Power standards; and
Followed proven Western Power guidelines and practices.

Designs have been undertaken by Western Power engineers and drafts-people except for some non-core areas (eg geotech) which has been outsourced to 3rd party consultancies with works overseen by Western Power.

2.2.3 Terminal Design Outputs

The following table provides a summary of the key design decisions and outputs for the Kemerton Terminal:

Network Requirements (Minimum):		
Factor		
Network nominal voltage	330 kV	132 kV
Normal operating range	±10%	±10%
Equipment highest voltage	362 kV	145 kV
Rated 1 minute power frequency withstand	520 kV	275 kV
Rated lightning impulse withstand	1175 kVp	650 kVp
Continuous rating	2500 A / 3150 A (busbar)	2500 A / 3150 A (busbar)
Substation one second short time current rating	50 kA	50 kA
Design life	50 years	
Reliability	High	
Rated Physical Environment:		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	0 °C	+45 °C
Solar radiation (horizontal surface)	Nil	1,000 W/m2
Wind speed	Nil	60 m/s
Relative humidity – outdoor	30%	90%
Pollution level	Severe/High	
Altitude	Less than 1000 metres above sea level	
Keraunic level (thunder days per year – DMS#5534120)	10	

2.3 132 kV KEMERTON – BINNINGUP TRANSMISSION LINE

2.3.1 Line Design Inputs

The overhead transmission line is to be 7 km long and single circuit with a continuous summer rating of 132 MVA. The following is a summary of the key design inputs:

Network Requirements (Minimum):		
Factor		
Network nominal voltage	132 kV	
Normal operating range	±10%	
Equipment highest voltage	145 kV	
Minimum required lightning/surge impulse withstand	650 kVp	
Line continuous rating (Summer)	132 MVA	
Short time withstand current for line overhead earth-wires and phase conductors	50 kA	
Short time withstand for overhead earth-wires	310 msec	
Short time withstand for phase conductors	400 msec	
Design life	50 years	
Electrical Reliability	High	
Rated Physical Environment:		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	-1 ^{o}C	+40 ^{o}C
Solar radiation (horizontal surface)	Nil	1,000 W/m2
Wind speed	1 m/s (Conductor rating)	43 m/s (structure rating))
Relative humidity – outdoor	10%	90%
Pollution level	Heavy	
Altitude	Less than 1000 metres above sea level	

The line is to be built in the South-West region of Western Australia over a greenfield line route (determined with substantial stakeholder input).

The wind region is Wind Region A (Synoptic Wind).

2.3.2 Line Design Methodology

In developing the BDP project designs, Western Power has:

- Complied with relevant industry standards (particularly ENA C(b)1-2006);
- Complied with relevant Western Power standards; and
- Followed proven Western Power guidelines and practices.

Designs have been undertaken by Western Power designers.

2.3.3 Line Design Outputs

The following table provides a summary of the key design decisions and outputs for the BDP project:

Line Item	Output/Decision	Comment
Conductor selection	Golf	Meets line's continuous and fault rating requirements.
Span length	*Section 1-230 m *Section 2- 350m	Western Power's standard for steel poles taking into account maintenance, visual impact and easement restriction.
Operating temperature	65 °C	Achieves line rating with Golf conductor
Insulation level	25 mm/kV	Line about 4km from the coast.
Conductor attachment height	Section 1- 12.9m Section 2 - 18.5 m	Allows for conductor sag at max operating temperature and ENA C(b)1 ground clearance requirement.
Tower earthing	10 Ohm	Economically achievable resistance to provide satisfactory lighting performance
Wind loading terrain category	2.0	AS1170.2: Structural Design actions: Wind Actions and line topography.
Wind average recurrence interval (ARI)	200 years	ENA C(b)1-2006, WP standard practice and line reliability requirements.
Failure containment	0.25 x wind pressure or 0.24 kPa	Based on ENA C(b)1-2006.
Maintenance load	10 m/s wind; simultaneous work on phase and OHEW	Based on ENA C(b)1-2006. The Maximum Wind load condition has the overriding impact on the structure design.

*Section 1- First 3km of line section of proposed KEM-BDP 81.
*Section 2 – Second 4km of line section of proposed KEM-BDP 81.

2.4 132 kV KEMERTON – BINNINGUP TRANSMISSION LINE (CABLE SECTION)

The cable section of the Kemerton – Binningup circuit starts from the aerial-cable transition pole on the eastern side of Old Coast Road and ends at the cable termination inside Binningup Desalination Plant Substation. It consists:

1000 mm^2 single phase, copper conductor, XLPE insulated, corrugated copper sheath, and HDPE outersheath.

2.4.1 Cable Design Inputs

Due to environmental reasons, there will be a 1.8 km underground cable section between the eastern side of Old Coast Road and the Binningup Desalination Plant Substation. Standard 132 kV cable type construction adopted by Western Power is used in the design.

The following is a summary of the design inputs for this cable section:

Design factor	Value
Electrical parameters	
Network nominal voltage	132 kV
Maximum operating voltage (110% of nominal voltage)	145 KV
Minimum impulse withstand voltage	650 kV
Cable continuous rating (summer)	132 MVA (577A)
Fault current rating of conductor (minimum)	50 kA (1 second)
Fault current rating of metallic sheath (minimum)	50 kA (1 second)
Design life	50 years
Cable configuration parameters	
Nominal cable depth (direct buried section)	1 m
Nominal cable depth (directional drilling across Old Coast Road)	5 m
Nominal cable depth (Substation cable entry)	7 m
Cable section	3
Cable formation (direct buried section)	Trefoil, no transposition
Cable formation (directional drilling section; cable duct section)	Flat, no transposition
Cable formation (substation entry; cable duct section)	Flat, no transposition
Cable sheath bonding	Cross bonding
Environmental parameters	
Soil thermal resistivity range	2 to 4 ^{o}C-m/W
Soil thermal resistivity (nominal for buried section)	4 ^{o}C -m/W
Thermal resistivity for special backfill used	1 ^{o}C -m/W

Soil temperature (1 m deep)	30 ^{o}C
Air temperature (maximum in summer)	46 ^{o}C

2.4.2 Cable Design Methodology

In developing the project designs, Western Power has:

- Complied with relevant industry standards
- Complied with relevant Western Power standards; and
- Followed proven Western Power guidelines and practices.

Designs have been undertaken by Western Power designers.

2.4.3 Cable Design Output

The design output for the underground cable section of the circuit is summarised as follow:

Items	Selection
Cable type	Single phase, copper conductor, XLPE insulation, corrugated copper sheath, HDPE outer sheath
Cable size	1000 mm^2
Cable section	3 (each of 600 m)
Cable formation	Trefoil, without transposition for direct buried section Flat, without transposition for other sections (including the substation cable entry)
Sheath bonding	Cross bonding; WP end (cable terminations) directly to earth; SVL installed for cable joints
Cable depth	1 m nominal for direct buried section; Maximum 5 m under Old Coast Road; Maximum 7 m under the berm outside substation
Special backfill	Installed for the direct buried section and underneath the berm area
Cable continuous rating (summer)	132 MVA (577A)

3 GENERAL REQUIREMENTS

3.1 PROJECT SCOPE

The scope for the Binningup Desalination Plant project includes the following from the BDP Project Planning Definition (DMS#4235291)

Expanding the existing Kemerton 330 kV Terminal to include a 490MVA Tx and to operate as a 6 point mesh.
Establishing a new 132 kV 'Kemerton' (KEM132) Terminal located 80m south of the 330 kV Terminal;
Building a new 7km single circuit 132kV steel pole line Kemerton – Binningup. Install a 132kV UG cable for the last 1.8km's of this supply.
Cutting one existing 132 kV line into KEM, namely MRR;
Interconnecting the 330/132kV Tx1 and Tx2 transformers to the new 132kV Terminal Yard;
Reconfiguring lines at various substations to suit the final arrangements; and
Installation of a communications system to enable satisfactory protection operation and to provide SCADA information transfer and telephone services.

3.2 PLANNING CONCEPT

The designs for the Binningup Desalination Plant (BDP) project comply with the Technical Rules (DMS#3605551) and the plant and equipment ratings given in the appendices of Western Power's Transmission Planning Criteria (DMS#1195855). The main body of the Planning Criteria document has been superseded by the Technical Rules (DMS#3605551).

3.3 REGULATORY REQUIREMENTS

The designs for the BDP project comply with the following regulatory requirements:

Western Powers Technical Rules (Approved by the ERA);
Electricity Act 1945;
Energy Coordination Act 1994;
WA Occupation Safety and Health Act 1984 and Regulations 1996;
Electricity (Supply Standards and System Safety) Regulations 2001;
Electricity Industry Act 2004;
Electricity Corporations Act 2005 (WA);
Electricity Industry (Network Quality and Reliability of Supply) code 2005;
Energy Safety Act 2006;
Environmental Protection Act 1986;
Environmental Protection (Noise) Regulations 1997;
Environmental Protection and Biodiversity Conservation Act 1999;
Australian and relevant international standards;
Building Code of Australia;
ESAA guidelines;
Contaminated Site Act 2003; and
Contaminated Site Regulations 2006.

For further details refer to the Transmission Standard Design Policy requirements and design guidelines, DMS#3377089.

3.4 RELIABILITY REQUIREMENTS

As per the BDP System Study – Internal Report (DMS#4145759), for a load of 25MW at Binningup in Jun 2010, system reinforcement is required under the new generation schedule.

The second Kemerton 330/132kV Tx reinforcement option has also been found to be required in 2013 to cater for load growth if there is no load at Binningup.

The Technical Rules (DMS#3605551) require, at a minimum, the project to meet N-1 criterion.

4 330/132 kV KEMERTON TERMINAL

The Kemerton Terminal (KEM) designs are based on Western Powers Standard 330/132 kV Terminal designs (refer DMS#3619983/3619979) – these have been peer reviewed (Hydro Tasmania) and deemed to be “industry standard”.

Since KEM is located within the Wind Region A area, the standard terminal structures and foundations will be utilized to their full extent, with an average recurrence interval of 1000 years to achieve the reliability required for a Terminal.

Construction standard and quality will be based on previously executed works (e.g. Neerabup Terminal 330/132 kV general requirements for Construction and Commissioning.

4.1 TERMINAL OVERVIEW

Kemerton Terminal is currently required (in addition to switching) to step down the 330 kV via the Tx1 transformer and connect into the existing Bunbury area 132 kV Network.

The ultimate arrangement for the KEM 330 kV yard includes six lines and three transformers over five bays in breaker and a half configuration. The ultimate arrangement for the new KEM 132 kV yard includes eighteen line circuits, three transformer circuits and three capacitor banks over twelve bays in breaker and a half configuration.

In the 132 kV yard, initially four line circuits and two transformer circuits will be required and arranged in six point mesh arrangement over 3 bays, thus only part of bay 3 will be populated.

4.2 TERMINAL DESIGN INPUTS

4.2.1 Network Conditions

The expected network conditions for equipment installed in the terminal are as follows:

Network Withstand Environment - As per DMS#3619979: Transmission Standard Design - Part 2		
Factor		
Network nominal voltage	330 kV	132 kV
Normal operating range	±10%	Controlled
Equipment highest voltage	362 kV	145 kV
Rated 1 minute power frequency withstand	520 kV	275kV
Rated lightning impulse withstand	1175 kV_p	650 kV_p
One second short time current rating and CB interrupting capacity	50 kA	50 kA

4.2.2 Environmental Criteria

Terminal designs have been based on the following physical environmental conditions: (As per Australian and IEC standards)

Rated Physical Environment		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	0 ^oC	+45 ^oC
24h average shaded air temperature (no solar radiation)		+35 ^oC
Unshaded outdoor cubicles – internal temperature		+70 ^oC
Solar radiation (horizontal surface)	Nil	1,000 W/m^2
Wind speed	Nil	60 m/s
Monthly rain fall	Nil	100 mm
Relative humidity	30%	90%
Dust levels: a) Normal b) Under wind conditions	0.1– 0.5 mg/m^3 10 – 20 mg/m^3	
Altitude	Less than 1000 metres above sea level	

4.2.3 Maintenance / Access Requirements

The KEM 132 kV yard is designed to provide full and ready access to all its major plant and equipment for planned and unplanned maintenance without the need for customer outage or load curtailment.

The annualised maintenance costs for the complete terminal yard should not exceed a target of 1% of the establishment cost. The design of the terminal yard allows for online condition monitoring of the plant and equipment.

The area enclosed within the terminal yard security fence will have sufficient area and clearance from high voltage equipment to allow light cranes and vertically extendable work platforms to access all HV plant.

The terminal is designed to operate automatically and will generally be unmanned. There will be requirements for certified personnel to work within the terminal yard premises, either in the switchyard or within the terminal buildings for operational or maintenance purposes.

4.2.4 Future Expansion

The designs allow for future extension of both terminal yards (330 kV and 132 kV). This ensures that construction crews have the required access to the site without the need for customer outage or load curtailment.

4.2.5 132 kV Terminal Site Selection

The criteria considered for the terminal site selection were:

- That it should be as close to the existing 330 kV site as possible, as well as close to the existing 132 kV line that supplies the Marriot Road region;
- Community and environmental considerations (Wetlands, Declared Rare Flora etc);
- Minimal cut and fill site works;
- Minimise line crossovers;
- Future expansions;
- Enable lines (current and future) to exit from all bays;
- Transmission line costs (new and existing)' and
- Site access.

The need to connect new 330kV circuits between Kemerton and the metropolitan area, together with the potential line corridor located east of the terminal station dictates that any new load connections at Kemerton should be located at the western end of the switchyard. This leaves space available on the eastern end of the switchyard to accommodate the new circuits required to connect northwards.

Utilising the above criteria, a site approximately 80m south of Kemerton 330kV Terminal was selected for the new 132kV Terminal.

Appendix C, Figure E3 provides a layout of the determinations made.

4.3 RATINGS

4.3.1 Continuous Ratings

Ratings of 330 kV and 132 kV circuits and plant are specified in the Western Power Planning Criteria (DMS#1195855). 330 kV plant will have a rated voltage of 362 kV, and a current rating of 2500 A or 3150 A (3150 A required for busbar and associated plant). 132 kV plant will have a rated voltage of 145 kV, a current rating of 2500 A or 3150 A (3150 A required for busbar and associated plant).

Terminal yard transformers may experience temporary overloading during N-1 contingent events up to 1.3 times their name plate ratings. This level of overloading can only occur for a short term (less than half an hour) before excessive internal temperature is experienced. The 1.3 factor is used for the maximum ratings for other switchgear and power cables within each transformer bay.

4.3.2 Fault Levels

Terminal sites are designed for a 50 kA fault level as per Western Power Planning Criteria (DMS#1195855). Therefore all 330 kV and 132 kV plant must be rated for a short time withstand of 50 kA for 1 second.

4.4 SITE UTILISATION

The outdoor 330 kV and 132 kV yards were designed to provide a medium level of visual impact, a high level of community safety and low maintenance requirements. The six point mesh arrangement of these yards provides a cost effective and highly reliable supply.

4.4.1 Ultimate Yard Arrangements

The ultimate arrangement for the Kemerton (KEM) 330 kV yard includes six lines and three transformers over five bays in breaker and a half configuration.

The ultimate arrangement for the KEM 132 kV yard includes eighteen line circuits, three transformer circuits and three capacitor banks over twelve bays in breaker and a half configuration.

4.4.2 132 kV Initial Yard arrangement

The initial arrangement of KEM132 is designed to meet the criteria detailed in the Project Planning Definition Report (DMS#4235291).

In the 132 kV yard, initially four line circuits and two transformer circuits will be required. The positioning of the line and transformer circuits is such that only the maximum 3 bays are populated. To meet security and reliability requirements for the six 132 kV circuits, a six point mesh configuration is adopted as per Western Power standard planning practice. This arrangement requires six circuit breakers and associated equipment. Refer to Appendix C Figure E.2 for the 132 kV Single Line Diagram.

Appendix C Figure E.3 contains an overall orientation layout of the Terminals, followed by the electrical layouts of both the 330 kV and 132 kV yards.

4.5 INSULATION COORDINATION

The system highest voltage is the highest r.m.s. line-to-line voltage which can be sustained under normal operating conditions at any time and at any point on the system. It excludes temporary voltage variations due to fault conditions and/or sudden disconnection of large loads. The system highest voltages for 330 kV and 132 kV are 362 kV and 145 kV respectively. The table below is taken from the Western Power Planning Criteria (DMS#1195855) and shows the rated voltage, the power frequency withstand voltage and the lightning impulse withstand voltage for the system voltage of 330 kV and 132 kV.

System Voltage	330 kV	132 kV
Rated Voltage (kV rms)	362	145
1 Minute Power Frequency Withstand Voltage (kV rms)	520	275
Lighting Impulse Withstand Voltage across open switching device (kV Peak)	1175	650
Switching Impulse Withstand Voltage (kV, Peak)	950	-

Surge arrestors will be installed on the line side of all 132 kV line entries and on the 330 kV and 132 kV winding terminals of the 330/132 kV transformer as per Western Powers Insulation Co-ordination Standard (DMS#1325182) and the AS1824: Insulation Co-ordination. Refer to section 4.6.3 for more details on surge arrestors.

4.6 SITE LAYOUT

4.6.1 Clearances

The Terminal is being designed in accordance with the safety and electrical clearances stated in AS2067. The required clearances are summarised below:

Rated Physical Environment		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	0 °C	+45 °C
24h average shaded air temperature (no solar radiation)		+35 °C
Unshaded outdoor cubicles – internal temperature		+70 °C
Solar radiation (horizontal surface)	Nil	1,000 W/m^2
Wind speed	Nil	60 m/s
Monthly rain fall	Nil	100 mm
Relative humidity	30%	90%
Dust levels: b) Normal b) Under wind conditions	0.1– 0.5 mg/m^3 10 – 20 mg/m^3	
Altitude	Less than 1000 metres above sea level	

** Rounded off distances.

Rated Physical Environment		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	0 °C	+45 °C
24h average shaded air temperature (no solar radiation)		+35 °C
Unshaded outdoor cubicles – internal temperature		+70 °C
Solar radiation (horizontal surface)	Nil	1,000 W/m^2
Wind speed	Nil	60 m/s
Monthly rain fall	Nil	100 mm
Relative humidity	30%	90%
Dust levels: c) Normal b) Under wind conditions	0.1– 0.5 mg/m^3 10 – 20 mg/m^3	
Altitude	Less than 1000 metres above sea level	

The design of the 330 kV and 132 kV yards also incorporates the following features:

- The placement of the 330/132/22 kV power transformer adjacent to a dedicated internal access road to allow the transportation and lifting of transformers with minimal restrictions on the system 132 kV overhead lines;
- The location of the 132 kV relay room to minimise the length and crossings of secondary cabling.

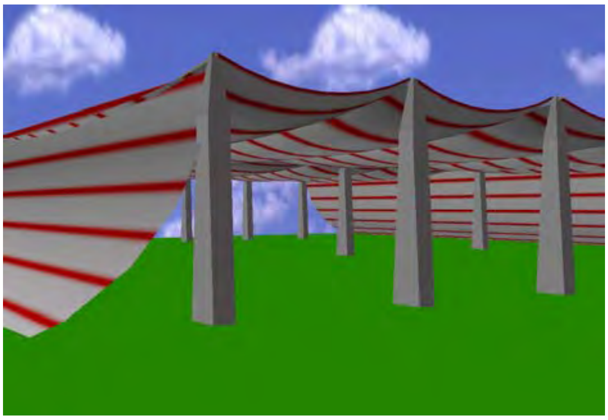
4.6.2 Lightning Protection

The lightning protection systems will be designed in accordance with AS1768: Lightning Protection. For the 330/132 kV Terminal Yards standard design lightning shielding of the outdoor switchyard will be provided by a combination of lightning rods on the line termination towers, earth wire strung between gantries and lightning poles within the switchyard area.

Strategically placed lightning masts, directly connected to the terminal yards earth grid and positioned so that they do not obstruct maintenance access to other equipment in the switchyard, are to be located in the switchyard to cover the initial and final location of equipment. The masts may also be used to mount light fittings for yard lighting.

Earth wires will be strung between the gantries. These earth wires will form part of the lightning protection scheme and will be considered during the lightning design.

An example of a lightning design for a Terminal Yard using the rolling sphere method is included below:



In calculating the shielded area, the "Rolling Sphere" method as described in AS1768: Lightning Protection is to be used. The Australian Standard states that a sphere of radius between 20 and 60m can be used, depending on the protection level required.

The Western Power standard Lightning Protection of Substations (DMS#3089633) states that a radius of 24m shall be used. The 24m radius is the outcome of an iterative process of calculating the risk due to lightning strikes and comparing this with the tolerable value of risk. This value is widely used in the power industry.

The height of the masts is to be 15 metres. The distribution of lightning masts is to provide sufficient cover to protect the future bays. The masts will be based on Western Power's standard design.

4.6.3 Plant

The plant listed below to be used at KEM is sourced from Western Powers preferred plant lists and standing contracts with suppliers:

330 kV Yard General:

- 330/132/22 kV, 550/490/60 MVA Transformer;
- Earthing Compensator;
- 362 kV 3150 A, HSSPAR Circuit Breaker;
- 362 kV 3150 A, Current Transformers;
- 362 kV Capacitive Voltage Transformers;
- 362 kV Disconnectors with 1 Earth switch;
- 362 kV Disconnectors with 2 Earth switches;
- 362 kV Surge Arrestors;
- 362 kV Station Post Insulators;

132 kV Yard

- 145 kV, 3150 A Circuit Breakers
- 145 kV, 3150 A Current Transformers
- 145 kV, 2500 A Disconnectors with 1 Earth switch
- 145 kV, 2500 A Disconnectors
- 145 kV Surge Arrestors
- 145 kV Voltage Transformers
- 145 kV Station Post Insulators
- 110 V Batteries and Chargers
- 50 V Batteries and Chargers

All items of plant to be installed at the terminals will meet the insulation coordination requirements as detailed in Section 4.5 and 5.7.

<u>Power Transformer:</u>
The 330/132/22 kV power transformer will be oil filled, have three windings complete with on-load tap changer and will comply with AS2374: Power Transformers. The transformer will have outdoor bushings and surge arrestors will be installed on both the 330 kV and 132 kV sides adjacent to the transformer. The power transformer will be mounted on anti-vibration pads and the transformer weight will be sufficient so that no holding down bolts will be required. Associated protection, control and indication equipment will be installed as outlined in Section 4.7.

<u>Circuit Breakers:</u>
The 362 and 145 kV circuit breakers will be outdoor SF6 live-tank, three pole type with a motor-charged spring operating mechanism. The circuit breaker will comply with AS2650: Common specification for High-Voltage switchgear.

Disconnectors and Earth Switches:

Disconnectors are required for off-load live operation and will be capable of switching the charging current of open busbars or currents from parallel circuits. 362 kV disconnectors will be the 3 pole double break type, and will comply with AS62271: High-Voltage switchgear and control gear. The disconnector will be motorised and have a manual earth switch. 145 kV bay disconnectors will be manually operated. Line disconnectors will be motorized and will have an earth switch on the line side.

Voltage Transformer:

Voltage transformers shall comply with AS60044: Instrument Transformers. The secondary terminals of VTs shall be cabled via a CT/VT marshalling box. Facilities shall be provided for short-circuiting and grounding VT secondary's. Current transformers shall comply with AS60044: Instrument Transformers. The secondary terminals of CTs will also be cabled via a CT/VT marshalling box. The CTs shall have up to 6 cores to be used for various protection functions.

Surge Arrestors:

Surge arrestors will be of the metal-oxide gapless type and comply with AS1307: Surge Arresters, with a nominal discharge current of 10 kA. As mentioned previously, surge arrestors will be connected on the line side of all 132 kV lines and as close as possible to the transformer HV and LV bushings.

Auxiliary Supply Systems:

There will be two separate AC supplies connected to an AC changeover board and distribution board. The AC supply for the yard and control room will be reticulated via the AC distribution board. 110 V and 50 V battery banks and associated chargers will be used to provide a DC supply to the control protection and SCADA equipment, telephone isolation equipment and emergency lighting. The battery system will consist of the following equipment:
2 x 110 V DC Battery Bank and Charger;
1 x 110 V DC Paralleling Board;
1 x 50 V DC Battery Bank and Charger; and
1 x 50 V DC Paralleling Board.

The battery will be capable of supplying the standard and emergency load for a minimum period of 24 hours, as per the Western Power DC Battery Standard (DMS#455368).

A separate 48 V DC battery supply is required for communications DC power in each control room. The battery will be capable of supporting the communications load for a minimum of 48 hours. Design practice is outlined in Communications DC Power Practice (DMS#2478157) and further details in Section 5.7.

4.6.4 Conductors and Cables

As per Western Power Standard Designs (refer DMS#3619983) and to meet Terminal rating requirements, overhead conductors shall be twin triton in the 132 kV bays and twin venus on the transformer interconnector. In the 330 kV yard, twin venus will be used throughout.

4.6.5 Earthing

The earthing system will be designed to manage the transfer of fault energy in such a manner as to limit the risk to people, equipment and system operations. This is achieved by providing a reliable low impedance path to the general earth mass for system faults and to provide an earth connection point for the lightning protection system.

The optimum earthing system design will be determined by site specific features like soil resistivity and system fault levels as per Western Powers Earthing Design Procedure (DMS#4467894). Third party assets (like water, gas and telecommunication services) will also be considered in the detailed design of the earthing system. This is necessary to minimise possible EPR mitigation costs. The earthing system will be designed to meet the following:

AS2067: Substations and high voltage installations exceeding 1 kV a.c.
IEEE80: Guide for safety in AC Substation Grounding;
IEEE81: Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Ground System;
ESAA Guidelines for Terminal Yard Earthing ;
ENA EG1: Substation Earthing Guide; and
ENA Earthing Guide – Risk based Design.

Ultimately, the Terminal Yard Earthing System is project specific because it depends upon the electrical resistivity and other characteristics of the soil at the particular Terminal Yard site and the fault levels. However, the design approach, components and installation procedures are standardised and the Kemerton specific design uses these standards. A detailed design has to be undertaken for every site-specific project to ensure full compliance to standards, statutory regulations and personnel safety requirements.

For the conceptual designs of typical 330 kV / 132 kV Terminal Yards and in order to achieve the required safe step and touch voltage levels, the earthing conductors are arranged at spacings up to approximately 15m to facilitate the connections to the equipment. A layer of crushed rock shall also cover the ground surface inside the Terminal Yard. Site earth resistivity test results are required for the detailed design phase at KEM.

Once earth resistivity measurements have been completed at KEM, Western Powers earthing software package AVC (Analytical Voltage calculator) will be used to determine a safe, accurate and cost effective design for the terminal yard.

4.6.6 Lighting

The lighting system will provide light for safe access and operation in the terminal site with minimal disturbance to the surrounding area, as per Western Power

Substation Lighting Standard (DMS#741783) and Western Power Lighting Procedure (DMS#4479054). The lighting systems secondary function is security, as stipulated by the IEEE. The lighting is designed in compliance to:

AS4282: Control of the obtrusive effects of outdoor lighting;
IEEE1127: Guide for the Design, Construction and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility; and
AS60598: Luminaries – General requirements and tests.

Interior building lighting is required to allow the safe movement of personnel and the safe operation of equipment. Emergency lighting will also be fitted within buildings in accordance with AS2293: Emergency escape lighting and exit signs for buildings and the Building Code of Australia (BCA).

Outdoor lighting will be as per the figures listed in Table 1 of the CIE Publication No. 68 'Guide to the lighting of exterior work areas'. Halogen type lamps are required and will be mounted on lightning protection masts or dedicated light poles with a minimum height of 6m above ground level.

4.7 COMMUNICATIONS

Communications bearers and multiplexing equipment will be provided to cater for Protection, SCADA and operations requirements including telephony. Communications bearers will be designed to meet the Western Power Technical Rules Clause 2.9 (DMS#3605551) requirements for fully independent protection schemes on 132 kV lines and align with the Maunsell Report Recommendations (DMS#3045692 - report, DMS#3045698 appendix) for diverse bearers.

The scope of the communications design will include the following:

An OPGW (Optical Power Ground Wire) on the new KEM-BDP 132 kV line construction,
An underground optical fibre from Overhead to Underground Transition Joint location on the KEM – BDP 132 kV line to Binningup Desalination Plant,
A second separate underground optical fibre between Binningup Desalination Plant and Kemerton Terminal.
Utilising existing fibre and microwave bearers to provide duplicated communications path for Protection and SCADA.

The OPGW takes the place of the OHEW (Over Head Earth Wire) on the KEM-BDP line build and contains fibre optic cores for communications circuits. Installation of OPGW on new line construction is standard electric utility practice in Australia and around the world. It is the least cost method of providing optical fibre connectivity between substations, representing only a nominal increase in cost over ordinary OHEW.

4.8 SCADA

A Remote Monitoring Equipment (RME) will be installed at BDP to meet the requirements in Clause 3.4.10 of the Technical Rules. This RME will enable System Management to monitor the customer connected load.

A new SCADA facility will be installed at the new Kemerton 132 kV terminal yard. This SCADA facility will communicate with the XA21 Master Station in East Perth Control Centre (EPCC) to enable System Management to remotely monitor and control the terminal yard.

This project impacts the existing SCADA facility at Kemerton 330kV terminal yard. SCADA equipment will be installed to bring new real time data in this terminal yard back to the XA21 Master Station.

The SCADA facilities including the RME will be designed in accordance with Western Power's Transmission Design Standards for Terminals and Zone Substations (DMS references 3619979, 3619983, 3470476 and 3493930).

4.9 PROTECTION SYSTEMS

The protection system will be provided for the primary plant according to the system planning requirements outlined in the BDP Project Planning Definition report (DMS#4235291). The protection requirements for duplication, speed and sensitivity are designed according to the Technical Rules (DMS#3605551) and Western Power's standard protection design and settings. The following protection will be installed for the different BDP components:

The new 132 kV line between Binningup and new Kemerton 132 kV Switchyard (KEM-BDP) consists of distance blocking and digital differential schemes schemes. Both protections will meet the Total Fault Clearance Times of 115 ms (local fault) and 160 ms (remote fault) as required by Table 2.11 of the Technical Rules. Two high speed protections are used to cater for discrimination between the distance protections on the long lines terminated in Kemerton 132 kV, and this line (KEM-BDP) which is relatively short. Special cases like this one are covered under the Technical Rules, Clause 2.9.1 (a), (b)

One of the existing three lines terminated in Kemerton 132 kV switchyard is three-ended line (KEM-PIC-BSN). It will be protected by duplicate distance blocking schemes. These schemes have been selected at Kemerton end to match the existing protection at the other ends of the line. Both protections will meet the Total Fault Clearance Times of 115 ms (local fault) and 160 ms (remote fault) as required by Table 2.11 of the Technical Rules*.

Two-ended line (KEM-PNJ) will be protected by duplicate distance blocking schemes. These schemes have been selected at Kemerton end to match the existing protection at the other end of the line. Both protections will meet the Total Fault Clearance Times of 115 ms (local fault) and 160 ms (remote fault) as required by Table 2.11 of the Technical Rules.

Two-ended line (KEM-MRR) will be protected by distance blocking and digital differential schemes. Both protections will meet the Total Fault Clearance Times of 115 ms (local fault) and 160 ms (remote fault) as required by Table 2.11 of the Technical Rules.
One of 330 kV Circuit Breakers at Kemerton 330 kV Switchyard will be installed as part of this project. This Circuit Breaker will be protected by duplicate Circuit Breaker Failure protection with a synchronising check. Both protections will meet the “CB Fail” Total Fault Clearance Times of 270 ms (local fault) and 315 ms (remote fault) as required by Table 2.11 of the Technical Rules.
All 132 kV Circuit Breakers at Kemerton new 132 kV Switchyard will be protected by duplicate Circuit Breaker Failure protection with a synchronising check. Both protections will meet the “CB Fail” Total Fault Clearance Times of 310 ms (local fault) and 355 ms (remote fault) as required by Table 2.11 of the Technical Rules.
330/132 kV Transformer at KEM will be protected by biased differential (P1) and high impedance differential (P2) protections as well as a number of pressure, temperature and Buchholtz mechanical protections.
The circuit connecting the transformer with the 132 kV Kemerton switchyard will be protected with duplicated transformer interzone high impedance differential protection. Both protections will meet the Total Fault Clearance Times of 115 ms as required by Table 2.11 of the Technical Rules.
The 330 kV circuit connecting the transformer and bay will be protected with duplicated transformer interzone high impedance differential protection. Both protections will meet the Total Fault Clearance Times of 100 ms as required by Table 2.11 of the Technical Rules.
132 kV Busbars at KEM 132 kV Switchyard will be protected by the virtue of overlapping lines and transformer interzone protection which will meet Total Fault Clearance Times of 115ms as required by Table 2.11 of the Technical Rules.

Notes:
** Limitation: communications bearers on KEM-BSN 132 kV line do not have diverse paths. It is a legacy arrangement. Hence, in case of communications bearer failure, both protection schemes will be affected. This will result in accelerated tripping thus coordination may be lost.*

These protection requirements have also been described in the Protection Planning Report (DMS#5549622).

4.10 SITE CONDITIONS

The selected Kemerton 132 kV site is approximately 110m x 100m and is situated in an undulating topography, dropping 26m from the north to 18m in the south east. The nearest vehicle access is from the existing limestone track which connected to Rhodes Road which is over 2 km to the south of the site. The expansion of the existing 330 kV yards is approximately 36m x 210m on the western side to the terminal. Both sites are vegetated with long grass and some trees.

4.10.1 Earthworks

As the soil for this site is sandy in nature, a flat finished surface level of the yards has been designated for the 132 kV yard with balanced cut & fill, requiring careful selection of the finished levels. The cut and fill has been balanced to accommodate the next expansion phase of Bay 4 (importing fill at a later stage will be prohibitively expensive). An estimated 17,000m3 of cut will be generated and used as fill to create the finished levels. The 330 kV yard extension needs to match the existing finished surface level. The estimated excess volume of 62,000m3 of cut will be deposited to the eastern side of the terminal yard for future expansion.

The following civil issues were considered in deciding where to position the pad on the large site:

- Flood inundation levels
- Wet lands, Declared Rare Flora
- Road access
- Stormwater design and disposal
- Geotechnical conditions
- Topographical conditions

4.10.2 Road Works

A 30m access road is required to connect the site to the existing limestone track leading to the existing 330 kV yard. The road has been designed to the following standards:

Surface with 40mm asphalts to provide an all weather 20 year, low maintenance design life.
6m width to ensure two way access for industrial vehicles and guarantee access in the event that a vehicles breaks.

4.11 Geology

Geological maps indicate that the proposed alignment is underlain by:

sand derived from Tamala limestone – close to Old Coast Road (about 500 m) and from about the change of direction at Wellesley Road to close to Kemerton Substation (about 3 km);
swamp deposit comprising Peaty Sand - the central part of the alignment where the line runs parallel to Old Coast Road (about 3 km) and..
Bassendean Sand – close to Kemerton Substation (about 500 m).

A preliminary geotechnical study has been completed in the substation area for preliminary design purposes. A detailed investigation is in the process of completion (delayed due to EPA Approvals) to verify the findings of the preliminary investigation.

The purpose of the geotechnical investigation for the Kemerton Terminal yards is as per the following:

Assess subsurface soil and groundwater conditions,
assess the presence of expansive or collapsing soils,
determination of 100 year flood level for the site,
provide geotechnical design parameters for design of shallow foundations,
provide geotechnical design parameters for design and analysis of deep foundations (pole foundations),
provide geotechnical design parameters for pavement design,
provide information on construction issues and the influence of groundwater on foundation construction and
comment on excavation on site and suitability of excavated materials for fill.

The Acid Sulphate Soil (ASS) risk maps indicate that the alignment is within the following areas:

high to moderate risk of ASS - from Old Coast Road to about the change of direction at Wellesley Road (about 4 km),
no known risk of ASS – from about the change of direction at Wellesley Road to close to Kemerton terminal (about 2.5 km); and
moderate to low risk of ASS – close to Kemerton Substation.

Geotechnical investigation is combined with Acid Sulphate Soils (ASS) assessment in order to have an economic and cost effective multi-purpose schedule that can address both issues in one report.

The objectives of the geotechnical investigation for the alignment are to:

assess subsurface soil and groundwater conditions along the alignment;

provide geotechnical design parameters pertinent to the design and analysis of pole foundations; and
assess the occurrence of Acid Sulphate Soils (ASS) along the alignment.

Findings of the study will be used in design of foundations as well as preparation of ASS management plan, if required.

4.12 FOOTINGS

4.12.1 General

Footing design will be guided by Australian Standard AS2870 & AS3600.

4.12.2 Cable Trenches

A main trench will lead from outside the Control Room in the centre of the yard to service the switchyard outdoor equipment. Final cable runs to individual equipment from the main trench will be buried in PVC conduit.

The main trench will be constructed from inverted precast concrete box culverts with steel covers. Where the trench crosses a Terminal Yard road, the cable trenches and covers will have sufficient strength to withstand the load of heavy vehicles.

The trenches will be set into the ground and finished level with the aggregate surface. The trenches will be drained to the storm water drainage system by gravity.

A cable duct will run between the 330 kV and 132 kV yards with lockable access pits spaced over the distance.

4.12.3 Oil Containment

A reinforced concrete bund and slab will be used to contain leakage of oil from the power transformer. The design will ensure that all of the oil is contained in the bund in the event of any major spill.

A valve will be installed between the bund and an oil separator in the valve pit. This valve will close automatically in response to low transformer oil level alarms. A gravity oil separator will be used for separation of oil and water. The oil separator is designed to collect and contain the oil and ensure that only clear water is discharged to the environment. This system shall conform to local council requirements.

4.12.4 Structures

All structural steel will be designed in accordance with AS4100: Steel Structures for the load combinations required by AS1170: Structural design actions.

4.13 BUILDING DESIGN

The Western Power standard designs will be used for the 132 kV Terminal Yard building. The building will be site constructed using precast concrete hinged wall panels, resting on concrete edge beams and supported by structural steel portal frames.

The building will be divided into four segregated areas to accommodate:

- Relay/Control room buildings will contain Protection Relay Racks, SCADA RTU cubicles, SCADA supervisory termination racks, communication equipment, 415V AC distribution boards, 110V and 50V DC paralleling boards, batteries and chargers
- 110 and 50 volt batteries
- A washroom and W.C. facilities (Water closet).
- A store room

A lockable internal door shall provide access between the Relay and Battery rooms. The buildings will be equipped with air-conditioning units, an AC lighting and small power system, emergency lighting, battery room eyewash equipment, battery room ventilation, fire extinguishers and a Vesda smoke detection system.

The building will comply with relevant Australian Standards including:

- AS3850 Titlt-up concrete construction;
- AS1170 Parts 0, 1, 2, 4 (loading): Structural design actions;
- AS4100 Steel Structures;
- AS3600 Concrete Code; and
- AS3000 Wiring Rules.

4.14 WATER

As there is no reticulated water service in the vicinity of the Terminal Yard, a storage tank will be provided to collect roof runoff from the building for the use of the 132 kV Terminal Yard facilities.

4.15 SITE DRAINAGE / STORM WATERS

Runoff from upslope of the site will be intercepted and diverted away form the yards to minimize runoff over the cut batters. The finished surface level of the yards should be graded with falls to minimise the incidence of water pounding due to the presence of clayey material on site. Subsoil drains and pipes will be provided at sufficient grade for self cleansing velocities. Guideline from Manual of Urban Drainage Design and Australian Rainfall and Runoff VI is being used for the design of yards and site runoff and to the requirements of the local authority.

4.16 SEWERAGE

As there is no sewer line available adjacent to the site, a domestic septic tank will be installed in accordance with the requirements of the local Council.

4.17 FENCES AND GATES

The Western Power standard for substation fencing is a weld mesh type fence, detailed in the standard titled 'Weld mesh fences and gates" (DMS#4175749). This standard conforms to the “National Guidelines for Prevention of unauthorised Access to Electricity Infrastructure” (ENA DOC 015 – 2006). Typical design of the security fence and gates shall conform to AS1170.2: Structural design actions. There will be a clearance zone of 2m outside the fence which will be maintained clear of vegetation or other objects that could aid the scaling of the fence.

The fence at Kemerton will use galvanised structural components and galvanised (or zinc/aluminium coated) welded mesh. It can be expected to have a life of at least 25 years, and little maintenance should be required except for any repair of accidental or deliberate damage. Since KEM is located in Wind Region A, the fence will be designed to withstand the required wind loading for this region.

An anti-tunnelling slab (700mm wide by 150mm thick) will be installed below the fence. The overall fence will be 3m high, from the top of the anti-tunnelling slab to the top of a 700mm diameter flat barbed wire looped tape attached to wires between fence posts above the weld mesh panels.

The main substation gate shall provide a clear 6m wide access to the substation, and the gate must be able to open through 180 degrees. A personnel gate will also be installed adjacent to the vehicle access gate. The 330 kV and 132 kV yards will have separate gates, to allow personnel to access only the yard they need to visit.

4.18 FIRE PROTECTION

As per Western Power standard designs (refer DMS#3619983/3619979), the Relay Room will be equipped with a smoke detection and alarm system. Extinguishers will be provided externally and within the Terminal Yard buildings.

The standard building design has been produced by external consultants and architects in compliance with the latest building codes and fire requirements.

5 132 KV LINE FROM KEMERTON TO BINNINGUP

5.1 LINE DESIGN INPUTS

5.1.1 Network Conditions

The network conditions quoted below underpinned the designs for the proposed line (refer Project Planning Definition report DMS#4235291, Technical Rules DMS#3605551 and Transmission Planning Criteria DMS#1195855):

Network Withstand Environment (Minimum):	
Factor	
Network nominal voltage	132 kV
Normal operating range	±10%
Equipment highest voltage	145 kV
Minimum required lightning/surge impulse withstand	650 kV_p
Continuous rating (Summer)	132 MVA
Short time withstand current for overhead earth-wires and phase conductors	50 kA
Short time withstand for overhead earth-wires	310 msec
Short time withstand for phase conductors	400 msec
Design life	50 years
Electrical Reliability	High

5.1.2 Environmental Conditions

Line designs have been based on the following physical environmental conditions (as per relevant Australian and IEC standards):

Rated Physical Environment:		
Factor	**Minimum**	**Maximum**
Shaded air temperature (no solar radiation)	-1 ^{o}C	+40 ^{o}C
Solar radiation (horizontal surface)	Nil	1,000 W/m^2
Wind speed	1 m/s (conductor rating)	43 m/s (structures rating)
Relative humidity – outdoor	10%	90%
Pollution level	Heavy	
Altitude	Less than 1000 metres above sea level	

5.1.3 Maintenance requirements

As per standard Western Power practice, the line is designed to provide full and ready access to all its equipment for planned and unplanned maintenance without the need for customer outage or load curtailment. This is to meet the reliability performance criteria stated in section 3.4.

5.1.4 Design Life

Western Power is aligned with good industry practice by using an intended design life of 50 years for the line (and all components) as per ENA C(b)1-2006. The durability of materials is consistent with achieving the service life nominated. The performance of the line will be maintained throughout the design life of the line.

5.1.5 Line Route

Appendix B contains a description of the line route selection process for the BDP 132 kV line. Key aspects are:

Land traversed: line is about 7km long and covers areas including conservation areas, grazing and cropping country.

Structure Types: Where absolutely necessary, pole sections (to minimise visual impact).

Whilst design requirements were considered in the line route selection, once the line route was defined, the line route became an input into the line design.

5.1.6 Optical Ground Wire

An Optical Ground Wire (OPGW) is to be installed on the 132 kV BDP line for communication purposes.

5.2 CONDUCTOR SELECTION

5.2.1 Conductor Rating Requirement

As per the Project Planning Definition report DMS#4235291, the required capacity/ rating for the BDP 132 kV line is 132 MVA / 577 A with a 50 kA fault rating.

5.2.2 Conductor Type Selection

To minimise the height of the structures, a steel reinforced conductor was selected because of its strength and thereby its sag.
Due to the line's proximity to the coast, an aluminium clad steel core is required for satisfactory corrosion performance.

In light of the above, the type of conductor was ACSR/AC.

5.3 MAXIMUM CONDUCTOR OPERATING TEMPERATURE

The line was profiled to operate at a maximum temperature of 65°C.

This provides for the required rating of 577A and achieving the ground clearance requirements of ENA C(b)1-2006.

5.4 CONDUCTOR TENSION

The conductor tension selected was 21% to minimise the load on the many strain structures along the route and also providing satisfactory vibration performance.

5.5 SPAN LENGTH

Considering maintenance, easement requirements and visual impact, two sections with different span lengths were selected:

Section 1- 230m span (minimise easement because of forest clearing)
Section 2- 350m span (maintenance and visual impact)

Section 1- First 3km of line section of proposed KEM-BDP 81
Section 2 – Second 4km of line section of proposed KEM-BDP 81.

5.6 LINE PROFILING

The PLSCADD program was used to profile the line based on the span lengths and pole heights selected.

5.7 INSULATION SELECTION AND COORDINATION

The impulse level of the insulators is 650 kVp and is in accordance with WP standard design.

5.8 POLE GEOMETRY

5.8.1 Cross-arm Length

Section 1:
Steel poles are design without cross arms (Running Post)
Section 2 :
The cross arm length will be designed by the contractor to comply with the insulator swing angles at low and maximum wind specified in the technical requirements of the specification.

Clearances required for determining the length of the cross-arms:

Factor	Value	Comment
Power frequency clearance (high wind)	0.5 m	As per ENA C(b)1-2006
Lightning/switching impulse clearance (low wind)	1.3 m	As per ENA C(b)1-2006

5.8.2 Lightning Protection and Shielding Angle

Section 1:
The shielding angle of 33 deg was determined in accordance with Western Power's Transmission Lines Design Guidelines. This provides for a shielding failure every 20 years.

Section 2:
The shielding angle of 27 deg was determined in accordance with Western Power's Transmission Lines Design Guidelines. This provides for a shielding failure every 20 years.

5.8.3 Height Above Ground at Conductor Attachment Point

Section 1:

Conductor sag at 65^0C	5.5 m	- 230m span
Ground clearance	6.7 m	- As per ENA C(b)1-2006
Tolerance	0.7 m	-AS per WP Guidelines (DMS#1788481)
Total	**12.9 m**	

Section 2:

Conductor sag at 65^0C	10.6 m	- 350m span
Ground clearance	6.7 m	- As per ENA C(b)1-2006
Tolerance	1.2 m	- AS per WP Guidelines (DMS#1788481)
Total	**18.5 m**	

5.9 EARTHING

A footing earth of 10 ohm will be aimed for as per Western Power's Transmission Lines Design Guidelines (DMS#1788481). Historically, this earthing figure;

- can be achieved reasonably economically;
- is an industry standard and,
- has achieved good lightning back flashover performance on existing Western Power lines.

Where a 10 ohm figure cannot be achieved, further studies will be undertaken on a case by case basis.

5.10 LINE TRANSPOSITION

Not required for short lines.

5.11 FERRANTI EFFECT

No compensation is required for Ferranti Effect on short lines.

5.12 LINE FITTINGS

The line fittings will be in accordance with standard industry practice and will include armour grip suspension units, vibration dampers, etc.

5.13 STRUCTURE AND FOUNDATION REQUIREMENTS

5.13.1 Basis of Design

The structures will be designed to withstand the minimum loading requirements as per ENA C(b)1-2006 and corresponding Australian Standards. Western Power will provided conductor mounting point loads and support wind speeds in the calculated loading diagrams. These loading diagrams will consider numerous factors including pole geometry, wind, conductor weight/size/tension, line deviations, maintenance loads and failure containment loads.

5.13.2 Structural Reliability

As per ENA C(b)1-2006, Western Power practice and the specific reliability requirements for the KEM-BDP 81 line, the following criteria were selected:

The reliability level adopted (LR=3) is one step greater than the minimum transmission level (LR=2) nominated in ENA C(B)1-2006.

The regional wind speed (Vr) is based on an average recurrence interval (ARI) of 200 years with a probability of 22% that a more severe event may occur over 50 years of design life of structures.

5.13.3 Design Actions

5.13.3.1 Wind Loading

The wind load is based on ENA C(b)1-2006 and AS1170.2: Structural Design Actions: Wind Actions.

Wind Region	A1
Regional wind speed	VR=43m/s
Terrain category	2.0
Assessed Topographic multiplier Mt	1.0 (in general) 1.07 on conductors and 1.12 on structure (the identified part of the line)

In accordance with ENA C(b)1-2006 the structures will be designed to withstand the wind combinations as follows:

Transversal wind;
Oblique wind 22.5° inclination to transverse axis;
Oblique wind 45.0° inclination to transverse axis;
Oblique wind 67.5° inclination to transverse axis;
Longitudinal wind; and
Tornado wind.

5.13.3.2 Failure Containment Loads

The Failure Containment Loads are based on ENA C(b)1-2006. As such, the structures will be designed to withstand unbalanced longitudinal conductor tension due to failure of adjacent structure by considering the equivalent longitudinal loads resulting from not less than any one third of all phase conductors on the structure being broken with a nominal coincident wind velocity of 0.25 times the ultimate wind pressure or based on a minimum pressure of 0.24 kPa, whichever produces more adverse effect.

5.13.3.3 Maintenance and Construction Loads

The Maintenance and Construction Loads are based on ENA C(b)1-2006. As a minimum, Western Power requires the maintenance loads to be considered for each complete phase or overhead earth-wire being worked on in turn. In addition, the design is required to make further allowance should the particular construction method and/or equipment loads to be used be more severe than that specified.

The conditions are based on the worst weather conditions under which maintenance will be carried out. The limiting wind velocity for maintenance work was taken as 10m/s (industry work practice).

5.13.3.4 Loading Trees

Loading trees are contained in the Technical Requirements of the specification.

5.13.3.5 Structure Selection

The initial analysis of electrical, environmental and civil requirements identified the need for the following structure types:

Light suspension pole,
45° Strain pole,
90° Strain pole,
Terminal pole, and
Standard Transition pole.

5.13.4 Detailed Pole Design

The detailed pole design complying with the loading trees will be submitted by the contractor. Western Power will review and approve the design before construction commences.

5.13.5 Material Selection

The poles will be manufactured in China due to competitive pricing, using locally available materials aligned to Chinese standard GB/T 1591-94 (Available standard). The compliancy of the Chinese material to requirements of Australian Standards has been evaluated previously by SKM (for other projects) and also checked by Western Power personnel. As a result, it was found that the Chinese steel mostly equals and sometimes exceeds the mechanical requirements of the corresponding Australian Standard.

5.13.6 Pole Acceptance Testing

Each type of pole will be full scale prototyped and may then be load tested prior to full production to demonstrate that the developed designs meet the quality requirements of Western Powers Technical Requirements.

All load tests will generally be in accordance with IEC 60652 with agreed test procedures to simulate design conditions as closely as practicable.

Western Power will witness these tests to ensure they meet design requirements.

5.13.7 Foundation Selection

Based on Western Powers experience on previous lines, concrete caisson foundation of different diameters shall be specified in Western Power's Technical Requirements.

The geotechnical parameters shall be based on geotechnical studies along the line route.

The detailed foundation design complying to the Technical Requirements specification will be submitted by the contractor. Western Power will review and approve the foundation design before construction commences.

5.14 CABLE SECTION

5.14.1 Thermal resistivity along Taranto Road

Thermal resistivity of the native soil along the cable route (Taranto Road) is an essential parameter in designing the cable size and the configuration to deliver the required current rating.

Measurement of thermal resistivity of native soil is carried out at three locations along Taranto Road. The thermal resistivity value ranges from 2 to 4 ^{o}C -m/W. A nominal value of 4 ^{o}C -m/W is used to calculate the required cable size and configuration.

Consultant for Water Corporation advises that there will be a berm built with beach sand outside the Desalination Plant (visual requirement). As the actual composition and compaction details of the berm are not known, a figure of 5 ^{o}C -m/W for beach sand is assumed.

5.14.2 Choosing of cable type and size

Western Power adopts a standard construction type for its new 132 kV underground cable taking into considering general environmental, spare part stocking, maintenance, rating requirement and availability of jointing skills factors. The standard cable is 2000 mm^2 single phase copper conductor, with XLPE insulation, corrugated copper sheath and HDPE outer sheath.

The cable supplying Binningup Desalination Plant is a radial feeder and is equivalent to a transformer feeder. As Binningup Desalination Plant is owned and built by Water Corporation, the chance to utilise the cable as an interconnector between Western Power's substations is quite remote.

The cable rating required, hence, is relatively much smaller than the standard cable rating required on Western Power's network. Cable with smaller cross section area than the standard 2000 mm^2 can be selected.

1000 mm^2 cable size is selected, taking into account the buried depth required and the high thermal resistivity values.

5.14.3 Cable configuration

The cable route length can be divided into three equal sections, making it suitable to choose a trefoil cable formation and cross bonding the cable sheath to achieve minimum electromagnetic field generated, while delivering the required cable rating. In additional, a trefoil formation requires narrower trench width than a flat formation.

The dimension and weight of cable drum for a cable section of 600 m can be handled quite easily. Moreover, the sheath induced voltage by normal and fault currents for a 600 m cable section is manageable.

The design to divide the cable route into two cable sections to reduce the cable joints material and installation cost is not feasible. Because the length of the cable section will be around 900 m which is very difficult to handle and the sheath induced voltage will be much higher.

5.14.4 Cable rating capacity

Given the design inputs especially the thermal resistivity values measured and assumed for beach sand near the substation entry, achievable cable rating for various section is simulated using software CYMCAP.

Simulations indicate that the cable size selected can just deliver the required capacity of 132 MVA (577 A)

APPENDIX A ABBREVIATIONS

In this document the follow abbreviations refer to:

Abbreviation	Description	Comment
AS	Australia Standard	
AVC	Analytical Voltage Calculator	
BCA	Building Code of Australia	
BDP	Binningup Desalination Plant Substation	
CASA	Civil Aviation Safety Authority	
DEC	Department of Environment and Conservation's	
DMS	Document Management System	
ELMB	Environmental and Land Management Branch	Documents available on request.
ENA	Energy Networks Australia	
EPA	Environmental Protection Authority	
GPS	Global Position System	
IEC	International Electrotechnical Commission	
ESAA	Electricity Supply Association of Australia	
HDPE	High Density Polyethylene	
HMI	Human Machine Interface	
HSSPAR	High Speed Single Pole Auto reclosing	
KEM	Kemerton Terminal	
MRR	Marriott Road Substation	
NENS	National Electricity Network Safety Code	
OHEW	Over Head Earth Wire	
OPGW	Optical Power Ground Wire	
PLSCADD	Power Line System Computer Aided Design and Drafting	
RAAF	Royal Australian Airforce	
RTU	Remote Terminal Unit	
SCADA	System Control and Data Acquisition	
SOE	Sequence of events	
SSWA	Southern Seawater Alliance	
TBL	Triple Bottom Line	
WC	Water Closet	
WP	Western Power	
XLPE	Cross Linked polyethylene	

APPENDIX B LINE ROUTE SELECTION

132 kV Line to Binningup Desalination Plant - Public Consultation Process

In March 2008 initial meetings were held with the Water Corporation regarding the public consultation process to be undertaken. The Water Corporation provided their stakeholder lists to Western Power along with other resources and advice to support Western Power's efforts. Key stakeholders identified by the Water Corporation included:

- Binningup Desalination Action Group (BDAG)
- Shire of Harvey
- Residents of Harvey
- Local and state media
- Government agencies
- Indigenous and environmental groups
- Industry

In April 2008 the Western Power project team attended a community meeting to engage with the local residents and key stakeholders. Due to the Water Corporation facing considerable community push-back on the project, Western Power endeavoured to work with the community as much as possible to develop a positive working relationship from the beginning in order to mitigate the communities concerns about the line route project.

Over the following months, Western Power held a number of community information sessions to detail the approvals process and to discuss the community's concern regarding the perceived community and environmental impact of the transmission line.

After extensive research and one-on-one meetings with potentially affected landowners and stakeholders carried out by the project team, Western Power presented the community with 12 potential line routes within a 5km corridor from Kemerton Terminal to the Binningup site, highlighting the desire to reduce the clearing footprint where possible.

In June 2008 Western Power engaged with community representatives to participate in the line route impact assessment. Each of the 12 line routes were weighted against a set of criteria using a matched pair analysis to evaluate the alternatives to minimise the overall impact of the line.

The criteria, set by the community, included:

- Non negotiable land constraints (Controlled Access Roads, Conservation wetlands, EPP Wetlands, Rare Flora)
- Houses (Avoid where possible)
- Visual impact (Minimise / mitigate)
- Impact to land use (Reduce impacts)
- Land owners affected (Minimise)
- Clearing required (Minimise / avoid)

The selected line route was chosen by the community as it was as identified as the least overall impact option, as weighted by the community. The line route is approximately 9.5km long including 7.6km of overhead line located 1.2km east of Old Coast road, and 1.9km of underground cable along Taranto road. The Water Corporation offered to underground the first section of the line along Taranto road, up to Old Coast road, however Western Power requested that it continue under Old Coast road for 100m to mitigate the visual impact for the community.

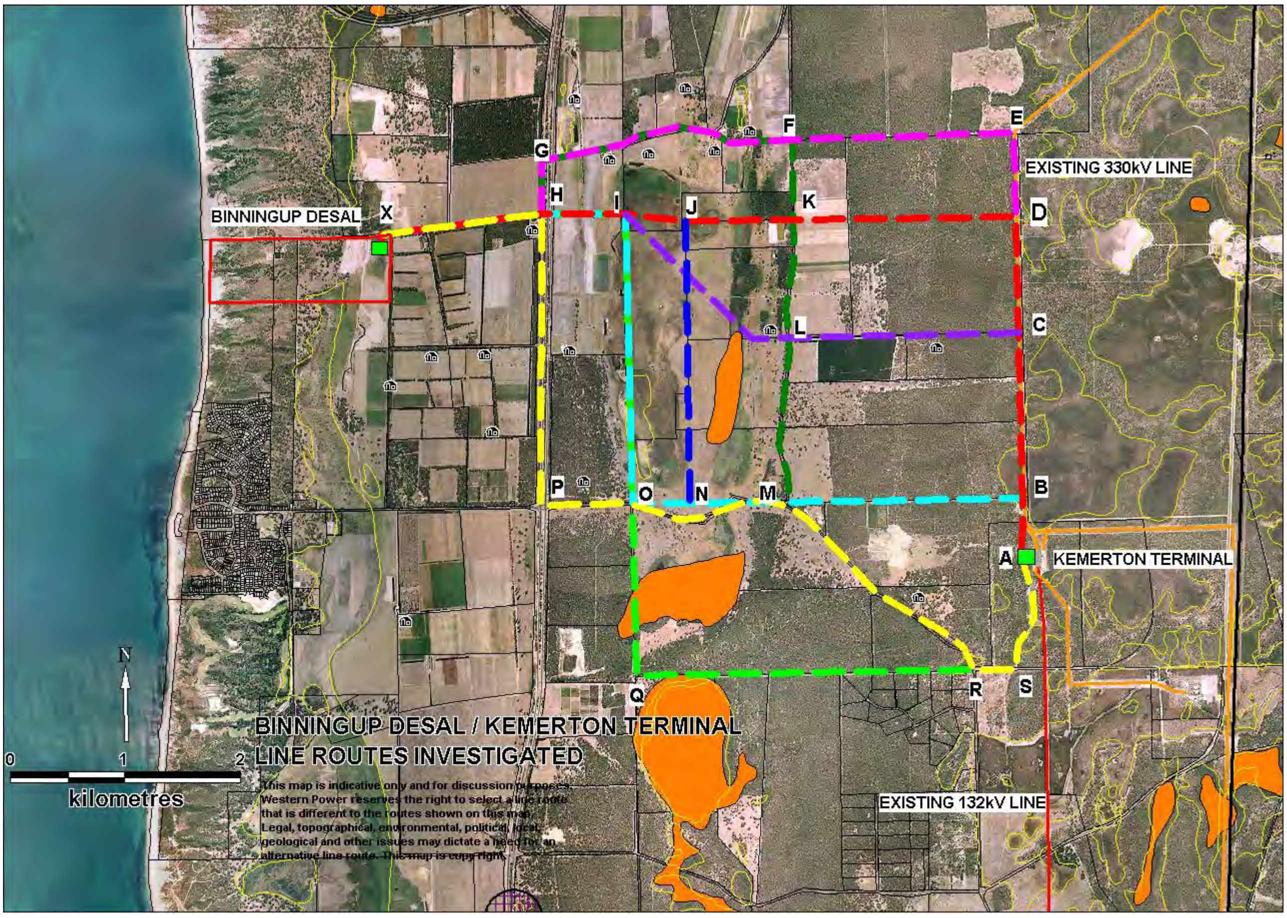


Figure D1: Potential line route options investigated.

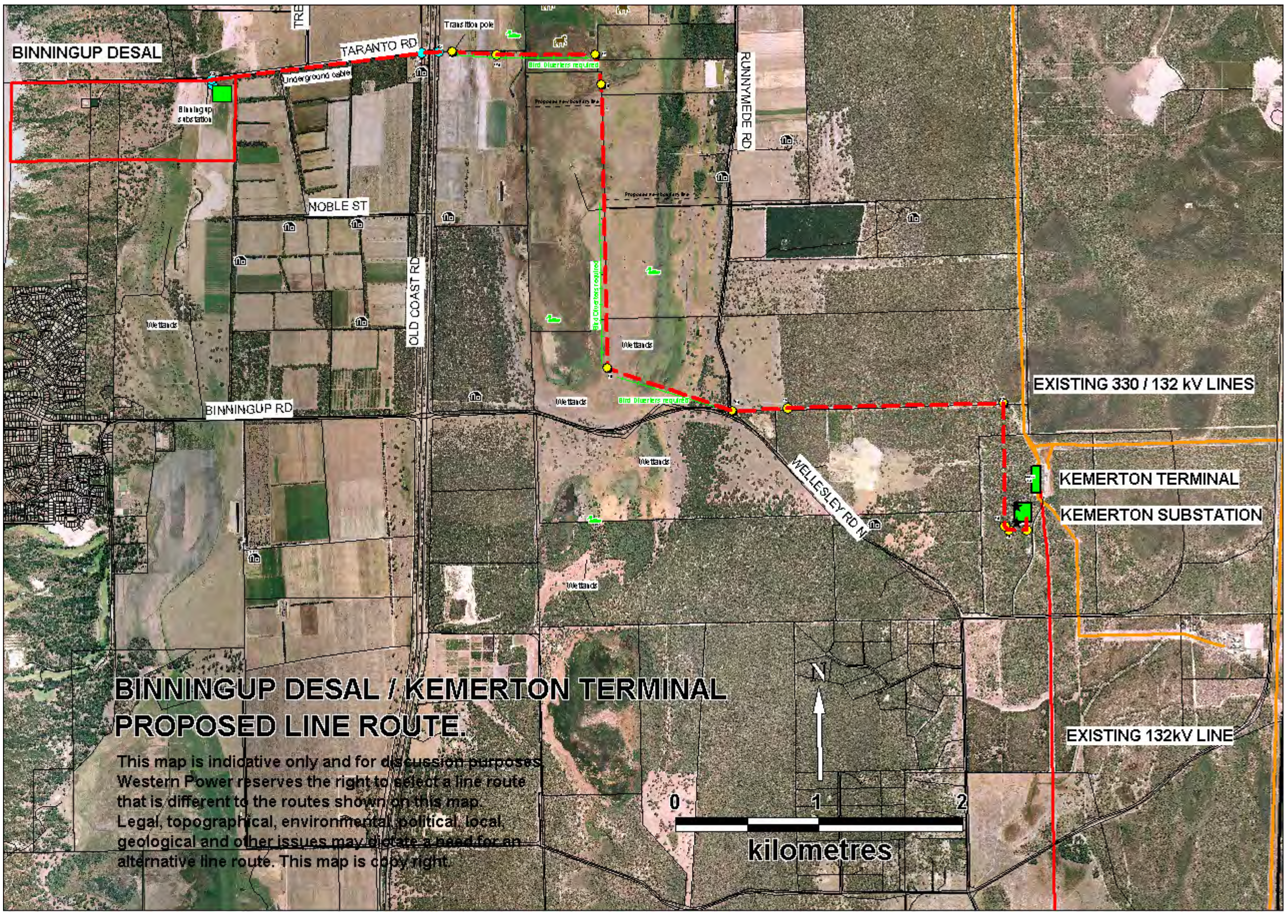


Figure D2: Selected Kemerton to Binningup line route

All of the potentially affected landowners on the selected line route have been personally contacted by Western Power to determine the exact location of the line route through private property. Through consultation with the landowners the line route impact has been minimised where possible by traversing property boundaries.

In early February 2009 Western Power attended a meeting in Binningup held by the Water Corporation's Community Reference Group. Western Power presented the group with an update on the approvals process including the selected line route and selection process; environmental aspects of the project; the community consultation program and the visual impact of the line route.

At this current time, the community has expressed appreciation at the inclusive manner by which Western Power has conducted the consultation process. Western Power will continue to consult with the community throughout the approvals and construction period.

APPENDIX C TERMINAL SINGLE LINE DIAGRAM AND SITE LAYOUTS

Figure E.1 Kemerton KEM 330 kV Single Line Diagram

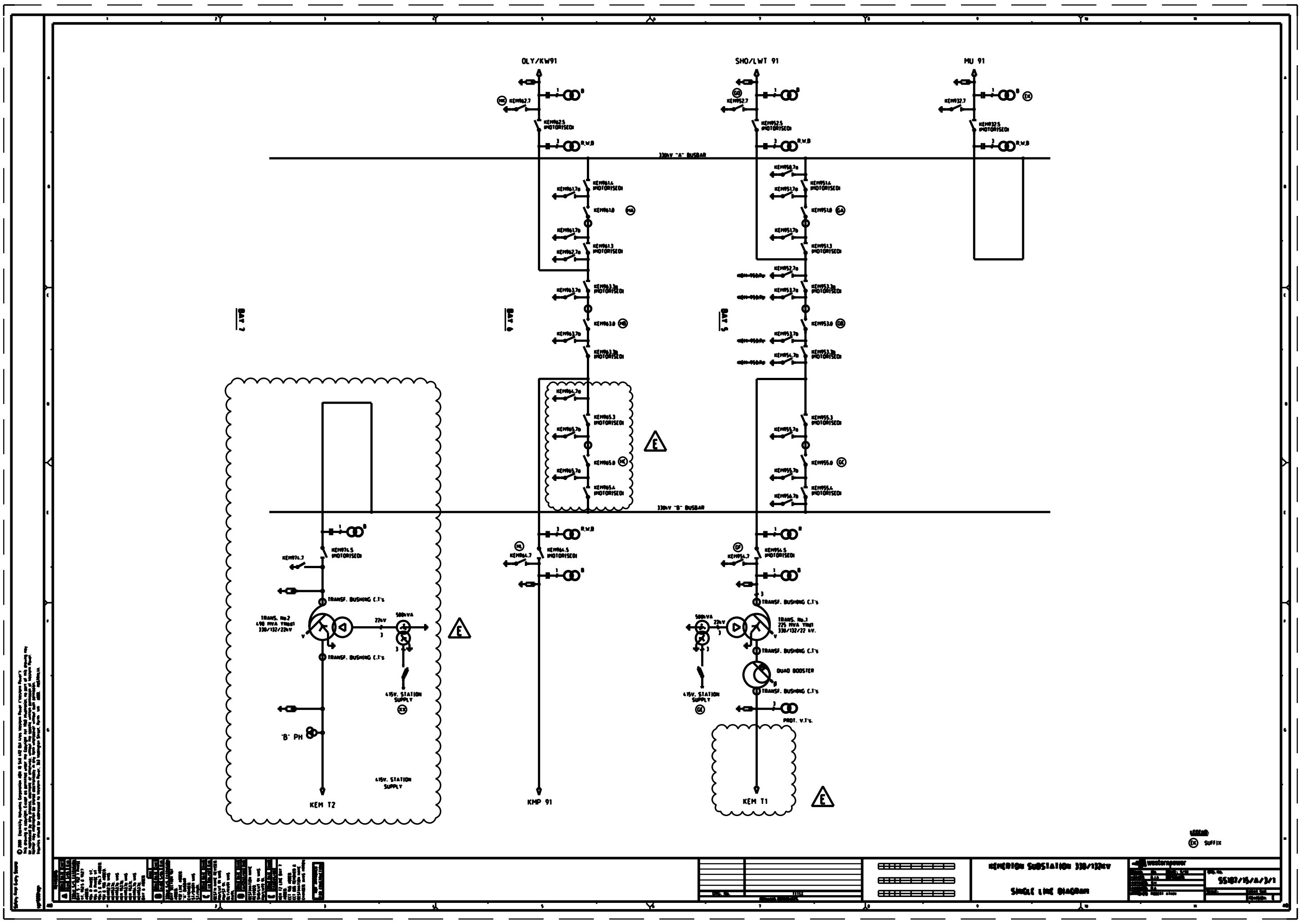


Figure E.2 Kemerton KEM 132 kV Single Line Diagram

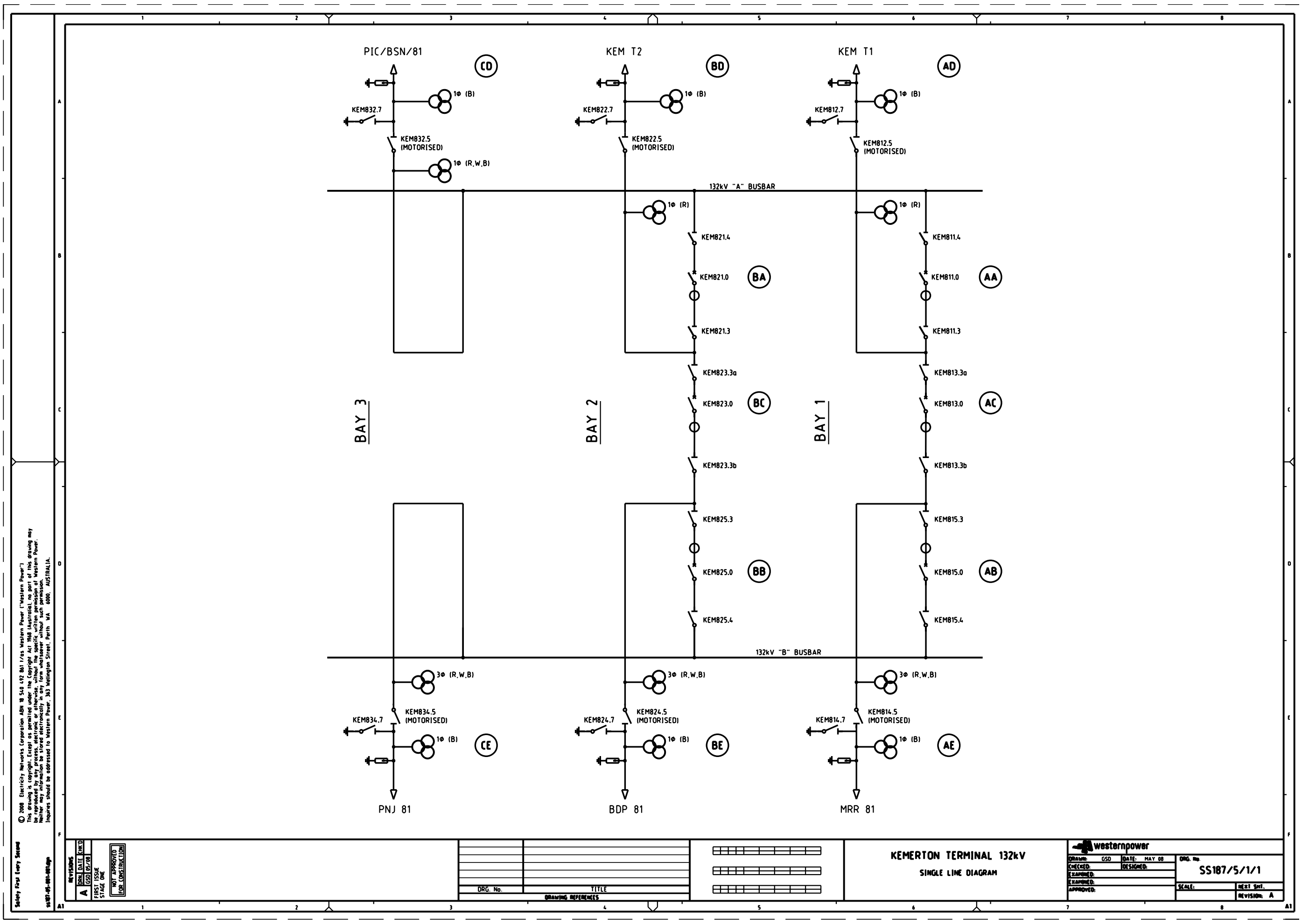


Figure E.3 Kemerton Terminal Site Orientation

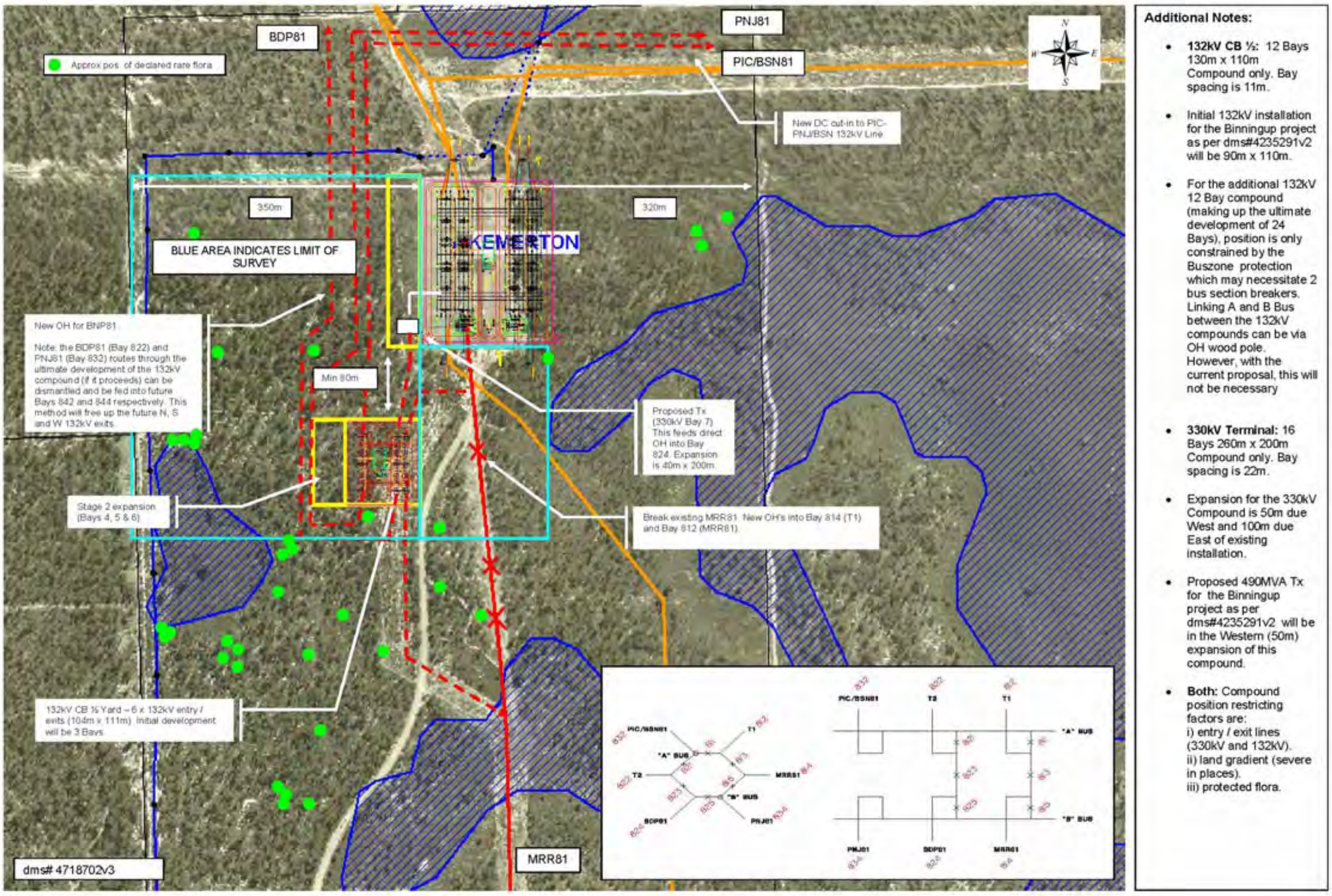


Figure E.4 Kemerton Terminal KEM 330 kV Civils Site Layout

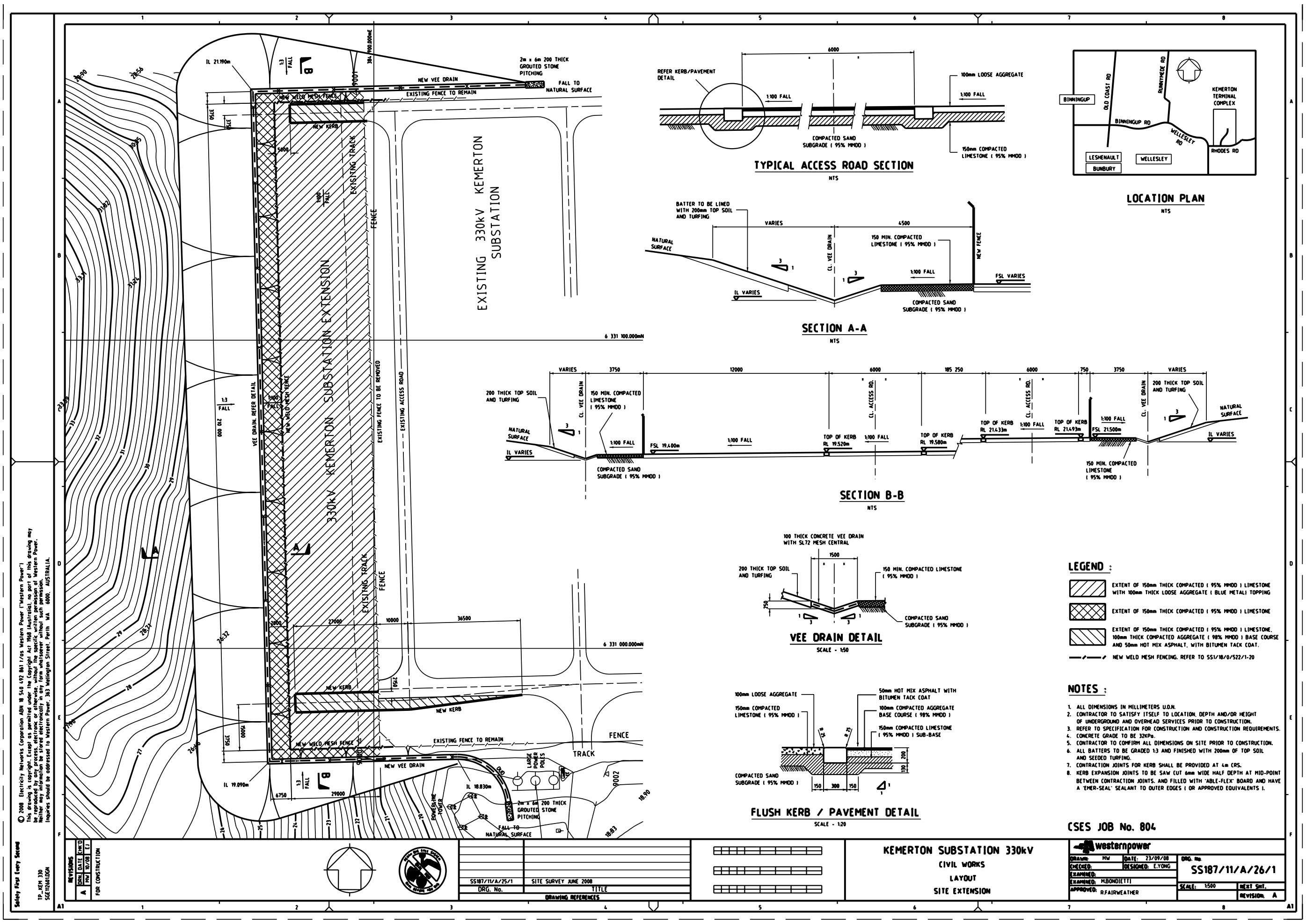


Figure E.5 Kemerton Terminal KEM 132 kV Civils Site Layout

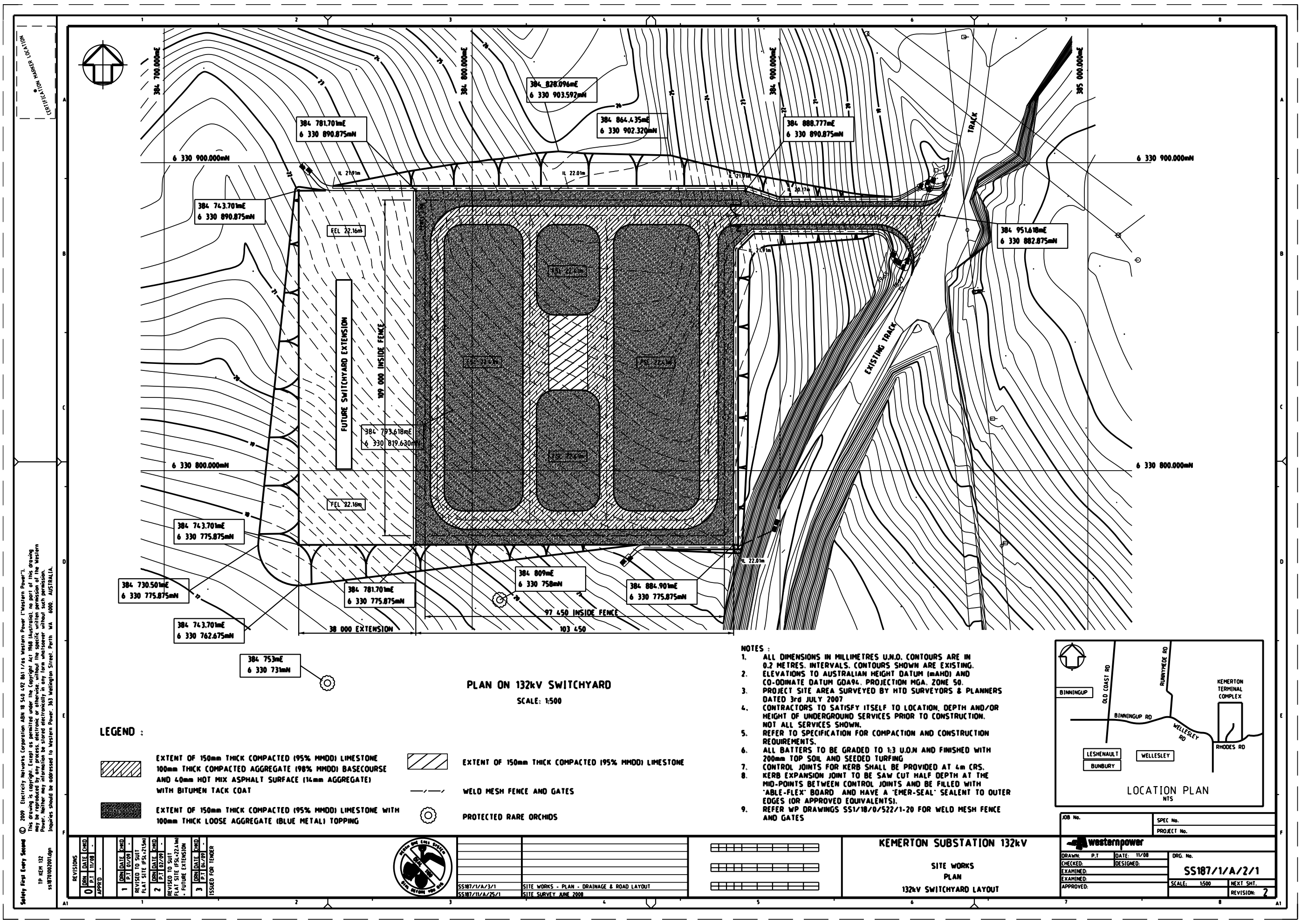
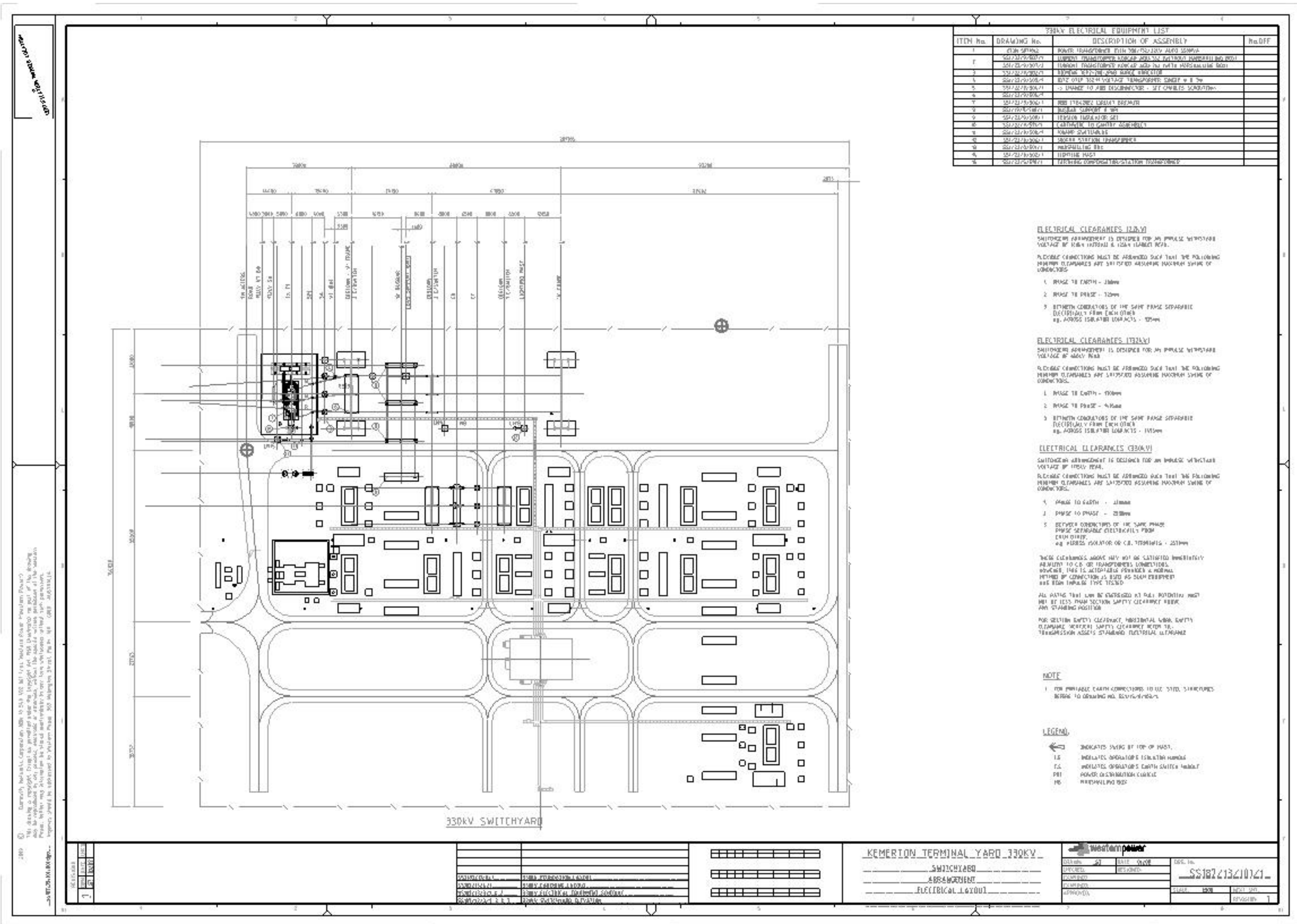
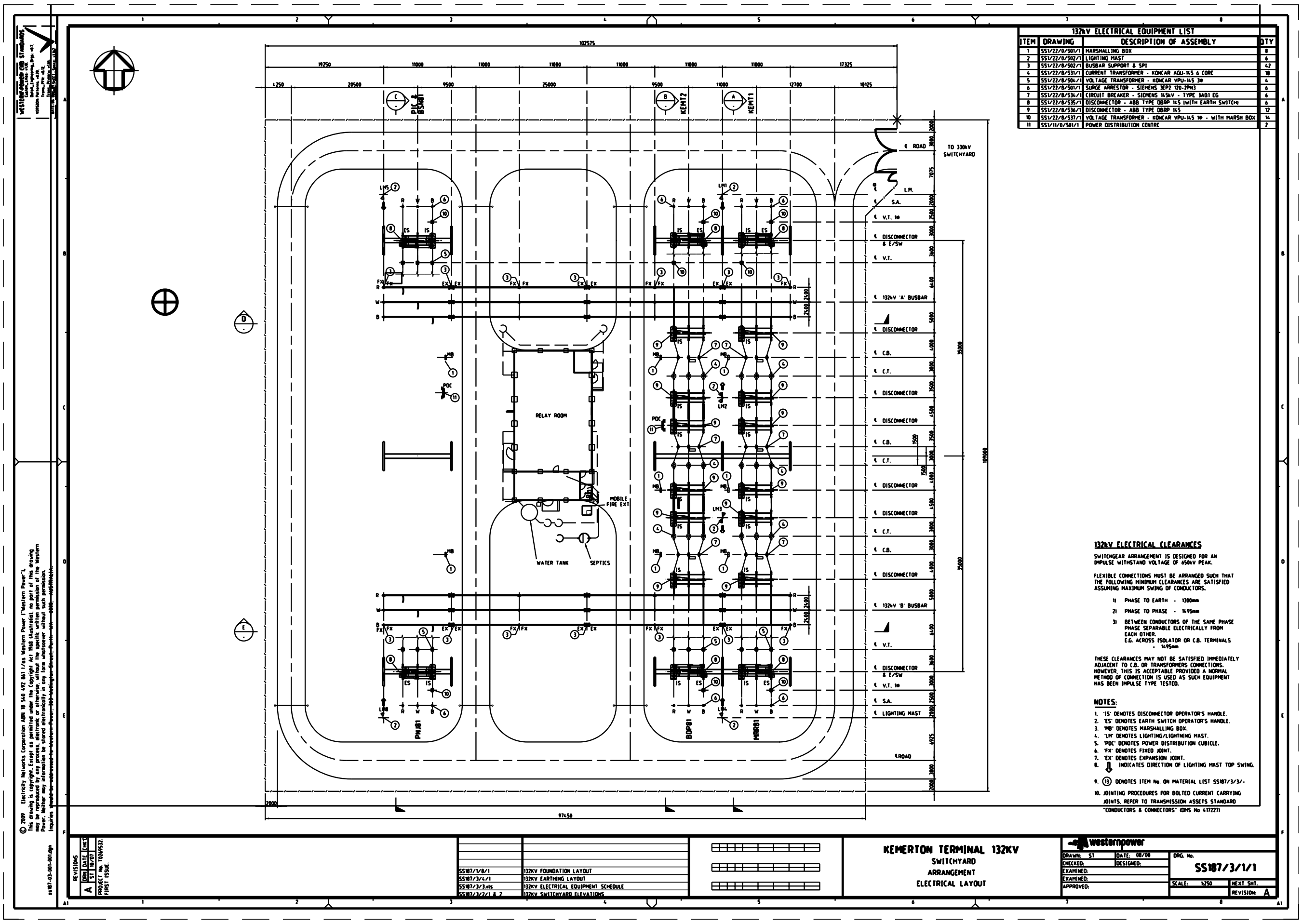


Figure E.6 Kemerton Terminal 330 and 132 kV Site Layouts





132kV ELECTRICAL EQUIPMENT LIST

ITEM	DRAWING	DESCRIPTION OF ASSEMBLY	QTY
1	SS1/22/0/501/1	MARSHALLING BOX	8
2	SS1/22/0/502/1	LIGHTING MAST	6
3	SS1/22/B/502/1	BUSBAR SUPPORT & SPI	42
4	SS1/22/B/531/1	CURRENT TRANSFORMER - KONCAR AGU-145 6 CORE	18
5	SS1/22/B/504/1	VOLTAGE TRANSFORMER - KONCAR VPU-145 3Φ	4
6	SS1/22/B/501/1	SURGE ARRESTOR - SIEMENS 3EP2 120-2PN3	6
7	SS1/22/B/534/1	CIRCUIT BREAKER - SIEMENS 145kV - TYPE 3AQ1 EG	6
8	SS1/22/B/535/1	DISCONNECTOR - ABB TYPE DBRP 145 (WITH EARTH SWITCH)	6
9	SS1/22/B/536/1	DISCONNECTOR - ABB TYPE DBRP 145	12
10	SS1/22/B/537/1	VOLTAGE TRANSFORMER - KONCAR VPU-145 1Φ - WITH MARSH BOX	14
11	SS1/11/0/501/1	POWER DISTRIBUTION CENTRE	2

Attachment 3 Western Power Transmission Design Standard. Part 2 Functional Specification (DM# 3619979).

Tranmission Standard Design

PART 2 – FUNCTIONAL SPECIFICATION
330/132 kV TERMINAL YARD

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Prepared by: Transmission Primary Engineering Services

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Document Control

Endorsement Approvals

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Approved by	Mehdi Toufan	Group Manager – Transmission Delivery	

Record of Revisions

Revision number	Date	DM version	Revised by	Description

Documents Referenced In This Document

DM#	Title of Document
DM and other document reference in this document are indicated in blue underlined text. Also indicated in Appendix	

Stakeholders (people to be consulted when document is updated)

Position / Title
Transmission Substations Engineering Manager
Transmission Standards & Policy
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Asset Performance Manager

This document must not be made available to personnel outside Western Power without the prior written approval of Western Power.

Contents

1 Purpose

This document describes the Functional Specification of the 330/132 kV Terminal Yards in Western Power's Networks.

In general a Terminal Yard comprises of plant, equipment, buildings and structures that are assembled to deliver the Terminal yard's intended services and functions at a desired performance quality. The Functional Specification describes Western Power's need for a standard 330/132 kV Terminal Yard including:

- Switchyards required services and functionality;
- Desired features that a fully built switchyard will include;
- Performance criteria for the intended services and functions; and
- Key design parameters and service conditions that the switchyard shall withstand

The Functional Specification presents Terminal yard features as a "combined asset" and does not provide details relating to the switchyard components and their assembly plans. These are provided in Parts 3, 4 and 5 of this Manual.

2 Policies and Design Philosophies

The following Functional Specification has been developed in compliance with Western Power's policies and design philosophies relating to the life cycle management and operation of Terminal yard assets. These policies and design philosophies are described in Part 1 (DM# 3377089) of this Manual.

3 References

The design and construction standards presented in this Manual shall comply with applicable Standards, Regulations and Acts including, without limitation, the following:

Electricity Act 1945
Australian and relevant international standards
Building Code of Australia
Contaminated Site Act 2003
Contaminated Site Regulations 2006
Electricity (Supply Standards and System Safety) Regulations 2001
Electricity Corporations Act 2005 (WA)
Electricity Industry (Network Quality and Reliability of Supply) code 2005
Electricity Industry Act 2004
Energy Coordination Act 1994
Energy Safety Act 2006
Environmental Protection (Noise) Regulations 1997
Environmental Protection Act 1986
Environmental Protection and Biodiversity Conservation Act 1999
ESAA guidelines
WA Occupation Safety and Health Act 1984 and Regulations 1996
Western Power Technical Rules
Western Power's corporate policies
Western Power's environmental guidelines
Western Power's Oil Containment and Environmental Management Policy
Western Power's Planning Criteria and Security Criteria
Western Power's Substation Design Standards
Western Power's Substation Standards Purchasing Specifications

4 Definitions

Terminal Yard: A secure site that containing equipment to provide control and voltage transformation between the Transmission 330 kV Network and the 132 kV Transmission Networks.

Transmission Network: An interconnected high voltage transmission system, that interconnects generation and terminal stations, consists mainly of transmission lines, transformers, busbars, switchgear and other circuit components. Terminal Yards are included in the transmission network.

Outage: The state of a component when it is not available to perform its intended function due to some event directly associated with that component. Depending on system configuration, an outage may or may not cause an interruption of service to customers.

Forced Outage: A Forced Outage is an outage that results from emergency conditions directly associated with a component, requiring that component be taken out of service immediately, either automatically or as soon as switching operations can be performed or outage caused by improper operation of equipment or human error.

Planned or scheduled Outage: When a component is deliberately taken out of service at a selected time, normally for the purpose of construction, maintenance or repair.

Interruption: An interruption means a loss of electricity supply for more than one minute that is due to a cause beyond the control of the customer concerned. As stated by the Electricity Industry (Network Quality and Reliability of Supply) Code 2005

Forced Interruption: An Interruption is an interruption caused by a forced outage.

Planned or scheduled Interruption: This is an interruption that is caused by a planned or scheduled outage.

Security Level: Denotes the inherent security of supply provided by major Network components as determined by the extent of duplication or redundancy of primary serial elements and their associated secondary protection and control systems.

N-1 Security: Security of supply to all connected customers in the event of failure of a single primary network element or associated secondary system.

N-1-1 security: The N-1-1 Criterion applies to those sub-networks of the transmission system where the occurrence of a credible contingency during planned maintenance of another transmission element would otherwise result in the loss of supply to a large number of Consumers.

Normal Cyclic Rating (NCR): Maximum calculated load that the transformer can supply, in accordance with IEC 354, without causing accelerated ageing. It takes into account the maximum allowable transformer hot spot temperature, and the cyclic variation in the daily load profile and daily temperature profile.

The Normal Cyclic rating of a transformer is the peak load of the daily load profile for which the transformer without exceeding the following design criteria:

- Cyclic rating at which a maximum 120°C hotspot will occur during the daily load cycle,
  OR
- Cyclic rating at which a maximum 105°C top oil temperature will occur during the daily load cycle, and
- The ageing over a 90 day summer season with max ambient peaking at 46C over a 90 day summer season not exceeding unity.

Normal Cyclic Rating Criterion: The NCR risk criterion permits the loss of a portion of power transfer capacity at a substation following the unplanned loss of a supply transformer within that substation.

Transformer Maximum Continuous Rating: Long-term transformer rated capacity (i.e. the Name Plate Rating) with all the cooling systems fully operational.

Firm Capacity: The firm capacity of a multiple-transformer Terminal yard is assessed as the Long Term Emergency cyclic load that is allowed to be carried in a contingency situation involving the sustained loss of the highest capacity transformer at the Terminal yard (i.e. a worst case transformer outage).

Long Term Emergency Cyclic Rating: The Long-Term Emergency Cyclic rating of a transformer is the peak load of the daily load profile for which the transformer uses 35 days of it's design life for each day of service (ie 17.5 years of each design life in 6 months) without exceeding the following design criteria:

- Cyclic rating at which a maximum 130°C hotspot will occur during the daily load cycle,; or
- Cyclic rating at which a maximum 115°C top oil temperature will occur during the daily load cycle.

5 Acronyms

		Comments
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency	
ARI	Average Reoccurrence Interval	
BCA	Building Code of Australia	
CB	Circuit Breaker	
DC	Direct Current	
DM	Document Management System	
DTC	Transfer Capacity	
EMF	Electric and magnetic fields	
EPA	Environment Protection Authority	
EPR	Earth Potential Rise	
ERA	Economic Regulation Authority	
EHV	Extra High voltage	i.e. 330 kV
HV	High voltage	i.e. 132 kV
LAN	Local Area Network	
LV	Low Voltage	i.e. 415 V
MV	Medium Voltage	i.e. 22 kV
NHMRC	National Health and Medical Research Council	
NCR	Normal Cyclic Rating	
RRST	Rapid Response Spare Transformer	
RTU	Remote Terminal Units	
SCADA	Supervisory Control and Data Acquisition	
SVC	Static VAR Compensator	
SWIS	South-West Interconnected System	

6 The 330/132 kV Terminal Switchyard

6.1 Introduction

The 330/132 kV Terminal Switchyard is designed to supply the 132 kV transmission networks in the South-West Interconnected System (SWIS). It is intended to be a highly reliable Terminal Switchyard with minimal impact on its local environment. The Terminal yard provides a medium level of visual impact (an outdoor 330 kV and 132 kV switchyards), a high level of community safety and low maintenance requirements.

The Terminal yard has an ultimate installed capacity of 3 x 490 MVA, with a nominal firm capacity of 1225 MVA [1] at N-1 security level. Provision is made for the Terminal yard to be initially implemented with a reduced number of 490 MVA transformers and circuits if required. However, it is a requirement of the standardised design that the upgrade path to full capacity is not compromised[2].

6.2 Terminal Yard Objectives

The **primary objective** of the Terminal Switchyard is to provide an adequate and dependable 132 kV supply into the 132 kV transmission network by transforming the 330 kV transmission network supplies, while meeting Western Power's power quality and reliability performance requirements set out in the technical code. Apart from failures of the external networks or a valid command disconnection, the Terminal shall maintain the 132 kV supply continuously under all normal operating conditions, during emergency periods and immediately following disasters as defined in section 10: Operating conditions. This performance shall be available for the Design Life of the Terminal .

A **secondary objective** of the Terminal Yard is to provide a flexible switching node in the 330 kV transmission network. The Terminal switchyard shall provide this switching function through its 330 kV busbar system and associated switchgear with the same performance standard as for the provision of the 132 kV supply.

The Terminal yard while capable of independent operation is an element in both the meshed 330 kV and meshed 132 kV networks. The above objectives shall be achieved while providing enhanced safety, aesthetic and physical security features to facilitate its application in urban and inner rural areas.

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[1] This value derived as an Ideal Firm Capacity i.e.: 2 x 490 MVA x 1.25 (emergency cyclic load).

[2] This requires a progressive installation of selected equipment with space being allowed for future sections including transformers and circuit breakers.

7 Terminal yard Electrical Specifications

The 330/132 kV Terminal Switchyard shall present the following features and Functional Specification for service conditions under “Rated Physical Environment” as defined in Section 9 of this document. De-rating and/or lesser performance shall be applied during an “Extended Service Environment” defined in Section 9 with more stringent and harsher service conditions such as ambient temperature, etc.

7.1 Configuration

The configurations described below assume the planning criterion initially requires a minimal power transfer in the 330 and 132 kV networks[3].

- **Stage 1 – Base Configuration** – The initial development will be a flexible arrangement and can only require the development of the 330 kV yard. The minimum number of three 330 kV bays in a full 1 & ½ CB arrangement will be installed making provision for the ultimate development.
- **Stage 2 - Intermediate Configuration –** The Terminal Yard Configuration will cater for four 330 kV bays in a full 1 & ½ CB arrangement with one 330/132/22 kV - 490/60 MVA auto power transformer and one relay room in the 330 kV yard. In the 132 kV yard provision will be made for six 132 kV bays in a full 1 & ½ CB arrangement with one relay room and possibly, if required, one 132 kV capacitor bank. (1 & ½ CB Bay section arrangement are indicated in SS1/30/1/3/1)
- **Stage 3 – Ultimate Configuration** [4] - The Ultimate Terminal Yard configuration will consist of up to eight 330 kV bays in a full 1&½ CB arrangement with up to three 330/132/22 kV-490/490/60 MVA auto power transformers and one relay building in the 330 kV yard. The 132 kV yard will be expandable up to twelve 132 kV bays in a full 1 & ½ CB arrangement with two relay rooms and possibly, if required three 132 kV capacitor banks.

Depending on the application requirements provision might be made for splitting the busbars into bus sections.

For a particular project, the Terminal yard shall be capable of expansion to the maximum configuration shown in the Ultimate Design drawings for the sites. **A typical Ultimate Design single line diagram is shown in Appendix A**. The initial installation can be chosen to be less than the Base Configuration depending on requirements.

The standard design of the 330/132 kV Terminal switchyard assumes that the transformers are not normally operated in parallel as stated in section 7.4.

[3] See clause 6.1
[4] The number of 330 & 132 kV circuits chosen are arbitrary only, for illustration purposes.

7.2 Neutral Earthing

The following EHV, HV and MV earthing arrangements will be used:

- The 330/132 kV Auto transformer (YNauto d) primary winding neutral is to be solidly earthed locally at the terminal yard; and
- The transformer 22 kV winding (tertiary winding) is to be effectively earthed via a 22 kV earthing transformer, as seen in figure 2.

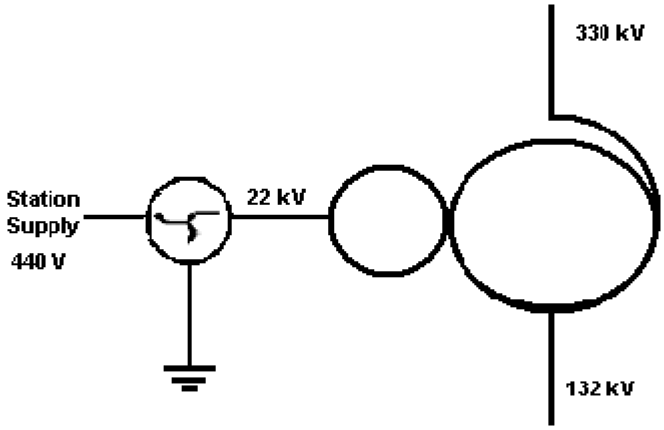

Figure 2: Transformer Earthing arrangement

7.3 Transformer Parallel Operation

Under normal operating conditions Western Power Terminal yard transformers are not normally operated in parallel due to plant rating limitations. However, the parallel operation of transformers shall be at the discretion of the operator, for use in circumstances where parallel operation will allow the operator to create a soft transfer through load sharing as a transformer is brought into or returned to service. Where transformers can be paralleled a master/slave tap changer arrangement will be installed for voltage control.

7.4 Capacity

7.4.1 Terminal yard Maximum Rated Capacity

The 330/132 kV Terminal Switchyard shall be designed to deliver a total maximum capacity of 1470 MVA into the local 132 kV transmission network while maintaining the 132 kV busbar voltage within the Output Operating Voltage Envelope specified under Voltage Regulation in Section 7.7 This is the ultimate rating of the Terminal yard and is limited by the thermal limits of major components. This level of Terminal yard loading is expected to be experienced temporarily during a major outage of an adjacent terminal yard when the Terminal yard's outgoing 132 kV transmission lines are heavily loaded to their near maximum ratings during the outage period. In these loading conditions the N-1-1 security rating of the Terminal yard will be reduced temporarily.

7.4.2 Firm Capacity

The Terminal yard shall have a Firm Capacity of 1225 MVA [5] at N-1-1 security. This is based on Western Power's Planning Criteria (DM# 3605551) that allows transformers to be loaded to their Long Term Emergency Cyclic Ratings during N-1-1 contingent events.

For 490 MVA transformers the Long Term Emergency Cyclic Rating is considered to not exceed 612.5 MVA[6]. This is 125% of the Transformer Maximum Continuous Rating.

[5] Refer to Clause 6.1

7.4.3 Temporary Overload

Terminal yard transformers may experience temporary overloading during N-1 contingent events up to 1.3 times their name plate ratings. This level of overloading can only occur for a short time (less than half an hour) before excessive internal temperature is experienced. The 1.3 factor is used for the maximum ratings for other switchgear and power cables within each transformer bay.

7.4.4 330 kV and 132 kV Busbar Rating

The 330 and 132 kV side of the Terminal station shall be capable of sourcing, sinking and transferring up to a maximum of 3125 A (including the switchyards own load) at sustainable N-1-1 security level. The 132 kV transfer capability may be by any combination of ringed or meshed 132 kV interconnections, depending on the needs of the network.

7.4.5 330 kV 1 & ½ CB Bay Rating

The rating of the 330 kV CB Bay equipment shall be 2500 A.

7.4.6 330/132 kV Transformer Bay Rating

The rating of the 330 kV CB Bay equipment shall be 2500 A.

7.4.7 330 kV Line Circuit Rating

The rating of the incoming/outgoing 330 kV line circuit equipment shall be 2000 A.

7.4.8 132 kV 1 & ½ CB Bay Rating

The rating of the 132 kV CB Bay equipment shall be 2500 A

7.4.9 132 kV Line Circuit Rating

The rating of the incoming/outgoing 132 kV line circuit equipment shall be 1600 A.

(Refer to Network Planning Criteria Reference DM# 1195855).

7.5 Normal Cyclic Rating Criterion and Security

7.5.1 General

The Normal Cyclic Rating (NCR) criterion is used to determine a terminal yard's NCR capacity. The ideal NCR capacity of the Terminal yard is calculated or defined as the sum of the normal cyclic rating of each installed terminal yard transformer. However, this Ideal NCR capacity will be reduced.

An important point to note is; at terminal yards with more than one transformer, the ideal NCR capacity must be de-rated if there is any unevenness in the loading of non-paralleled transformers. A possible solution to maximise load balance is to operate the transformers in parallel. However, this may not be feasible at high loads due to limitations of plant continuous current ratings.

7.5.2 Security

Under normal operation, the terminal yard shall operate at an N-1-1 security level. The letter "N" refers to the total number of major components in a Terminal yard. Hence N-1-1 refers to the number of terminal yard components after a single terminal yard component fails or is taken out for service.

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[6] 490 x 1.25

7.5.3 Terminal Yard Security Rating Summary

The following Terminal Yard security ratings have to be met:

TERMINAL YARD CAPACITY	RATING
Transformer Name Plate Rating (NPR)	490 MVA
Transformer Long Term Emergency Rating (LTER)	612.5 MVA
Terminal Yard Firm Capacity (FC)	1215 MVA[7]
Terminal Yard N-1 Security Rating (Ideal)	1225 MVA
Total Maximum Capacity (3 Transformer Yard – NCR)	1470 MVA

7.6 Voltage Regulation

330 kV Network Voltage - Under Normal network operation, the 330 kV supply to the Terminal yard may range between $\mathbf{0.9_{pu}U_n}$ and $\mathbf{1.1_{pu}U_n}$ where $\mathbf{U_n}$ is equal to 330 kV. The Terminal yard and its various systems shall operate reliably and effectively within this range.

132 kV Busbar Voltage - The output voltage at the Terminal yard's HV side busbar shall be maintained by an automatic voltage regulation system. The busbar voltage shall be capable of being maintained on a selected voltage-load line that is within the Output Operating Voltage Envelope. The Output Operating Voltage Envelope is defined between:

- 0.97_{pu} nominal voltage and 1.06_{pu} nominal voltage.

The above voltage regulation shall be achieved for the following loading conditions:

- zero and 2_{pu} load when both power transformers are in service; and
- zero and 1.5_{pu} load during N-1 events with only a single transformer in service

where,

1_{pu} load is the load equal to the Transformer Maximum Continuous Rating. In case of the 330/132 kV Terminal yard, 1_{pu} load = 490 MVA at the power factor ranging from 0.95 lag to unity.

The automatic voltage regulation system shall maintain the 132 kV busbar voltage within plus or minus 2.5% of the selected voltage-load line over a five-minute period.

7.7 Reliability

Standard designs will aim to meet the following reliability targets:

Targeted Forced Interruption Rate - As an essential component of Western Power's network, the Target Forced Outage Rate for the substation shall be zero over a year;

Targeted Planned Interruption Rate - As an essential component of Western Power's network, the Target Planned Outage Rate shall be zero. This requirement shall be satisfied under all maintenance conditions over a year;

Equipment Outage - The Terminal yard's Performance capability shall be maintained during and following the outage of any one major element of the Terminal yard (i.e. the outage breaches the Terminal yard's N-1-1 operational security condition); and

Design Life - The design life for this Terminal yard is 40 years. The Performance shall be maintained throughout the design life of the Terminal yard.

[7] Typical value only. assumes a 10 MVA unbalance between the 2 x490 MVA –Transformers at N-1.

7.8 Communications

Communications are necessary to ensure the safe, efficient and reliable operation of the electrical network. The communications requirements at the terminal flow from three basic areas, Protection, SCADA and Operations.

7.8.1 Protection

To enable the protection scheme to quickly identify and clear faults on two-ended lines, protection relays at opposite ends of the line are connected with one or more analogue or digital communication links. Except for very long lines, the protection systems are typically duplicated, using two completely independent systems. This physical duplication extends to the communications links at the Terminal Yard. Each Terminal Yard must be connected by at least two physically diverse bearers. Three physically diverse bearers may be required for certain protection configurations on three (or more) ended lines

7.8.2 SCADA (Supervisory Control and Data Acquisition)

SCADA Remote Terminal Unit (RTU) is installed at Terminal Yards to monitor plant status, report alarms, record current and voltage and to operate circuit breakers and other plant. RTU's are connected back to the SCADA Master Station at East Perth Control Centre and to the backup master stations at the Head Office and Southern Terminal.

Duplicated physically diverse analogue or digital circuits are required for the Terminal Yard RTU.

7.8.3 Operations

Telephones are required for safe operation of electricity sites. Remote condition monitoring and work efficiency are driving the requirement for Engineering LAN at Terminal Yards. Fault recorders that store large quantities of power quality data require LAN access for quick data retrieval. The Engineering Officers need access to email, electronic drawings and software databases while on site.

7.9 SCADA System

A Supervisory Control and Data Acquisition (SCADA) System shall be installed to collect and process real time data (alarms, indications, controls and measurements) associated with the electrical plant within the terminal. This SCADA system shall communicate with the XA21 Master Station in East Perth Control Centre (EPCC) to enable operators to remotely monitor and control the electrical plant.

The SCADA System shall consist of a programmable Remote Terminal Unit (RTU) and other auxiliary equipment that enable it to:

- Collect Input Output (I/O) data either via hardwired or serial interface;
- Provide a local Human Machine Interface (HMI) to monitor and control the terminal electrical plant;
- Provide a facility to store sequence of event (SOE) data (changes of states of alarms and indications). The SOE data store is remotely accessible by users from SCADA or Investigation sections via conventional telephone line; and
- Provide global time synchronisation of the RTU and other equipment that passes time-tagged information to the SCADA RTU. This is achieved by the use of a GPS (Global Positioning System) clock.

7.10 Automation and Control

7.10.1 Automation

The Terminal yards shall operate ***automatically*** under the control of various control and protection systems designed to meet the requirements of this functional specification. These control systems shall be integrated so as to optimise the operation of the terminal yard within the electricity network.

The Terminal yards shall operate both independently and as elements of both sub-transmission and distribution networks under the control of these protection and control systems.

7.10.2 Control

Terminal yard Control covers switchgear operation including voltage regulation. The Terminal Yard control shall be available locally at the Terminal, as well as remotely at the East Perth Control Centre. This shall be achieved via locally installed SCADA System which will be linked to the master station in the Network Control Centre.

Transformer paralleling control is to be performed by a hard-wired scheme. Use of the RTU is not acceptable[8].

Three levels of control shall be provided for the Terminal yard:

- **Station Local Control and Indication** – Control and indication facilities shall be provided at the Terminal yard for authorised network operators and authorised Terminal yard technicians.

  Trip/Close local control and indication shall be provided at the Protection Relay Cubicles and the Switchgear (see below).

  Data Display Panels shall be installed for station Local Indication.

  Local control is selected and remote control blocked by selection switches at the substation. This is to ensure safety of staff from inadvertent remote operation.

- **Switchgear Local Control** - There shall be provision for operating the switchgear in the Terminal yard at the switchgear locations. This is not a common mode of operation and shall only be used for maintenance work or emergency situations.

- **Remote Control**– The integration of the protection and control systems shall allow for remote control and data acquisition. Remote control of electrical plants is achieved via the locally installed SCADA System that will be linked to the Master Stations in East Perth Control Centre.

Refer to the latest version of Western Power's Transmission Asset Standard for Control, Indication, Alarms and Metering - DM# 347636.

7.10.3 Data Acquisition

The Terminal yard shall report plant status to the master station in the East Perth Control Centre (EPCC) via the local SCADA System. Selected maintenance data and reports shall be accessible remotely to the nominated maintenance provider.

[8] See the Transmission Asset Standard for Control, Indication, Alarms and Metering – DM# 347636.

7.11 Metering

Metering data systems shall be provided for 330 and 132 kV Line circuits, main transformers (EHV or HV side), capacitor bank circuits including load management cells and other reactive devices such as fixed reactors and SVC's, such that the feeder loads and main transformer loads can be determined (off site) with and without the impact of reactive loads. All metered values shall be available at the Terminal yard's Human Machine Interface (HMI).

Refer to the latest version of Transmission Assets Standard – Control, Indication, Alarms and Metering – DM# 347636.

7.12 Terminal yard Protection System

The Terminal yard shall be equipped with protection systems to ensure the safety of personnel, the avoidance of damage to plant and the minimum impact on the continuity and quality of power supply, as per the western Powers Technical rules published by the ERA.

Terminal yard incoming and outgoing circuits shall be equipped with adequate numerical protecting devices. All Terminal yard plant including power transformers, circuit breakers, capacitor banks, EHV/HV/LV busbars and bus sections shall also be equipped with automatic protection systems.

All protection will be designed with duplicated schemes (Protection 1 and Protection 2), which are to be fully independent on both DC and secondary AC circuits, operating in a 'one for two' arrangement. The operation of protection relays shall be designed with sufficient discrimination to minimise plant tripping and supply interruptions.

Modern multifunction protection relays shall have communication capability and sufficient electronic storage to provide post events intelligence. All the modern protective relays will have disturbance recording feature for waveform capturing during faults.

The Terminal yard protection systems shall also operate as designed during over-voltage, under-voltage, under frequency, over-current and overload conditions.

7.13 Terminal Yard Lightning and Earth Potential Rise Protection

The Terminal yard shall be equipped with suitably designed lightning protection equipment to ensure personnel safety within the Terminal yard premises, and to protect plant, control and communication systems from lightning strikes.

The configuration of the terminal yard's earthing system (stand-alone or not) will be assess during the site specific design phase. The earthing system will comply with EPR limits set in AS 3835: Earth potential rise - Protection of telecommunications network users, personnel and plant and AS 4853: Electrical hazards on metallic pipelines.

Suitable protection shall also be provided to protect galvanic communication circuits that may enter or leave the terminal yard. This shall ensure earth potential rise within the terminal yard vicinity is not transferred via communication circuits to a remote site such as the telephone exchanges, communication devices and circuits in properties that are adjacent to the terminal yard.

Where required the earth grid will extend past the security fence and where necessary include a connection to the security fence.

7.14 Terminal yard Auxiliary Supplies (AC/DC)

The Terminal yard shall have a reliable three-phase 4-wire 415 volt AC power supply. The supply shall be sourced from a terminal yard 22 kV earthing transformers 22/0.415 kV winding. A 22/0.415 kV supply shall also be obtained from a dedicated distribution transformer and associated equipment and shall be completely contained within the boundary of the terminal yard. The system shall provide for two parallel AC supply routes in order to provide higher security of supply.

The terminal yard shall be equipped with a DC supply system that complies with Transmission Assets Standard – DC Systems – DM# 455368. The DC system shall provide two highly reliable 110 Volts DC supplies for critical systems within the terminal yard such as protection schemes, emergency lighting and circuit breaker operation. Similarly a 50 Volt DC supply shall be provided within the terminal yard for SCADA, EPR Isolation equipment and indication.

The DC system shall be rated sufficiently to provide for the DC power supply requirements of the terminal yard up to 24 hours[9] during (as per AS2067: Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV) and after an emergency situation (eg Terminal yard blackout).

A separate –48 V_{DC} supply shall be provided for Communications equipment in each control room in the terminal yard. The system shall be rated sufficiently to provide for the DC power supply requirements of the communication equipment in the control room for a minimum of 48 hours to 72 hours.

[9] Refer to DM# 455368

8 Physical Specifications

8.1 Terminal yard Site

The Terminal yard site shall adequately accommodate a 330 kV and a 132 kV Terminal yards in its maximum configuration. The area shall include provision for:

- Switchyard equipment and their support structures;
- Power Transformers;
- Terminal yard Buildings;
- Incoming and outgoing feeder routes including line termination structures;
- Terminal Yard Services Transformers;
- Lightning protection;
- Cable trenches;
- Vehicle access;
- Off street/road parking; and
- Associated site buffer zones.

The site shall be protected from unauthorised access by perimeter fences. Adequate signage and safety warnings shall be installed in visible locations on the perimeter fence and terminal yard building.

The Terminal yard shall be landscaped suitably to blend with the surrounding environment. Terminal yard services such as water, sewage, telephone and radio shall also be fed to and from the site. A monitored terminal yard access system may be installed to maintain maximum security.

8.2 Terminal Yard Site Selection

The site selection criteria is beyond the scope of this document, however, due to the importance of the site location key aspects of the selection criteria are provided here as a guide for the acquisition of property. Practical site selection will need to balance risks and objectives to locate a suitable site in the required general location.

The Terminal yard site shall be in a protected location and be capable of providing a stable surface for the construction of a 330/132 kV Terminal yard and shall meet the requirements detailed below including during and after the specified disaster incidents.

8.2.1 Hazard Avoidance

The location of the Terminal yard site shall not expose the terminal yard to hazards. In particular, the following locations shall be avoided:

- Sites located close to the outside of a bend in a road – risk of vehicle impact;
- Sites located close to forests or heavy industries – risk of fire wind-blown debris and contamination from pollutants;
- Sites located close to hazardous industries such as petrol service stations, chemical plants, etc. – risk of explosion, fire and contamination from pollutants;
- Sites located close to ocean. Generally within 1 kilometre of the ocean front or 0.3 kilometre of a bay connected to the ocean – risk of accelerated corrosion and damage from tidal surges and tsunamis;
- Low lying areas or areas close to creeks and rivers – risk of flooding; and
- Sites with restricted cable or overhead line – limitation on power access and an increased risk of vehicle impact with poles.

8.2.2 Risk Minimisation

The site shall not expose the Terminal yard or Western Power to high levels of risk. The following locations shall be avoided in order to minimise risks:

- Sites located close to waterways and dams – risk of pollution from Terminal yard;
- Sites located in close proximity to underground services and to residential and commercial buildings – risk of transfer potentials electrocuting humans and animals;
- Sites located close to schools, parks and playgrounds – sensitive areas, risk to children and from vandalism and unauthorised entry;
- Sites close to heavily populated areas – prudent avoidance of electric and magnetic field (EMF) exposure.
- Sites located downwind of any heavy industry with airborne pollution that could be hazardous to Western Power personnel and impact on the design life of the Terminal yard; and
- Sites located, as far as practical, away from metallic pipes, railway lines, neighbouring conductive fences and communications cable to minimise the effect of transfer potentials.

8.2.3 Area

The Terminal yard site shall be of sufficient size (330 m x 680 m) to accommodate the complete terminal yard, access routes for extremely high voltage (330 kV) and high voltage (132 kV) feeders, access routes for various services, areas for driveway access, vehicle parking, landscaping and including a 10 metre buffer zone on sides and rear.

8.2.4 Ownership

Western Power shall own the terminal yard site. The ownership shall include the means of access to the Terminal yard at any time and under all conditions. Where the Terminal yard is dedicated to supplying a single customer, the Terminal yard site does not need to be owned by Western Power but its right of occupancy and access needs to be legally guaranteed. Appropriate title searches are to be done to ensure that public services such as freeways will not compromise the safety, accessibility and future expansion of the Terminal yard or nearby proposed public services.

8.2.5 Purchase Commitment

Prior to a commitment to purchase land for a Terminal yard site, a geo-technical survey shall be carried out. This survey shall at least include specialist reporting on soil bearing capacity, soil thermal resistivity and soil electrical resistivity. The relevant technical specialists (substations, lines and earthing) prior to purchase shall review these reports.

8.2.6 Adverse Conditions

The performance of the Terminal yard shall not be unfavourably affected by the Terminal yard site condition during adverse environmental conditions specified for the Terminal yard. This shall include secondary effects such as soil erosion and scouring during severe rain and flooding and increased earth resistance during droughts.

8.2.7 Access

Site access is to be designed to enable access by staff, equipment and vehicles required for construction, operations and maintenance and plant replacement during Terminal yard design life. This access requirement shall cover all aspects of the Terminal yard's operation and include for personnel and light and heavy vehicles. The access shall be available in all weather conditions. Access roads, feeder routes and services access through private property must be covered by a suitable registered easement.

8.2.8 Access Road Construction

Roads inside the Terminal yard boundary shall be kerbed to identify vehicle restrictions relative to live equipment. The road layout is to provide heavy vehicle access to transformers and site buildings. The roads shall be constructed in accordance with Western Power's Standards.

8.2.9 Vehicular Traffic

The site shall avoid potential adverse effects from road traffic. It shall not be located on the outside bend of a heavily trafficked or high-speed road. The site shall have at least one suitable vehicle access point from a public road. This access point shall provide safe vehicle exit and entry to the public road. Access points on blind curves, close to the crest of hills and other locations with restricted vision and acceleration areas shall be avoided. The access point shall be suitable for development as a roadway for vehicles, including low loaders and cranes (to enable heavy plant such as power transformers to be transported to and from the Terminal yard). Relevant local government or Main Roads approval shall be obtained for access.

8.2.10 Provision for Vehicles

Where practicable the site shall be provided with parking for at least two light vehicles (sedan or utility) immediately adjacent to the Terminal yard building preferably outside the Terminal yard security enclosure.

8.2.11 Landscaping

The Terminal yard construction program shall include landscaping the site. This shall be arranged in agreement with the local council and may involve community consultation. Landscaping shall incorporate aesthetic and security aspects. In some cases Western Power land may be set aside for planting of flora or positioning of an architecturally designed Terminal yard building to limit the view and noise of outdoor EHV and HV plant. On completion of the Terminal yard, the design and finish of the site shall meet local council and community expectations with respect to aesthetics.

8.2.12 Flooding

The Terminal yard site shall be 300mm minimum above the "1 in a 100 years" flood line and above the local tidal surge and tsunamis levels.

8.2.13 Cliffs

The site is to be located away from cliffs and steep rocky slopes so that the risks of damage from slides, avalanche and vandalism are reduce to an acceptable level.

8.2.14 Rock Layers

Any site rock layers shall be sufficiently deep to allow for the installation of standard Western Power foundations, stormwater drains, earthing, cables and other underground Terminal yard components.

8.2.15 Critical Infrastructure Security

The top security concerns identified in the CIGRE brochure DM# 5151924 was terrorism, theft, vandalism and sabotage. Different security measures will be applied depending on the accessibility of the site and its importance. Common security measures used are alarm systems, security lighting, signs fences with barbed wire road gates and locks. Other options available are laser ray systems, trenches, perimeter detection systems, passive protection (camouflage), steel doors, crash barriers and concrete walls to protect transformers.

8.2.16 Site Development

Prior to commitment to a particular parcel of land for a Terminal yard site, it shall be confirmed that the land can be developed as a satisfactory Terminal yard site. The development may involve civil works and landscaping, however the parcel of land must have a significant number of intrinsic features to limit the development costs and to ensure it's suitability as a Terminal yard site.

While site development is a project specific activity, development activities that could be considered include:

- Cut, fill and levelling can be used to prepare a stable surface for the construction of the Terminal yard;
- Firebreaks created to reduce the risk from grass and bushfires; and
- Terminal yard orientation and landscaping to improve the visual amenity.

8.3 Terminal Yard Internal Roads

8.3.1 Access Road Construction

Roads inside the Terminal yard shall be suitable for heavy vehicle access to transformers, site buildings. Concrete kerbs shall be used to identify vehicle restrictions relative to live equipment.

8.4 Switchyard Buildings

The switchyard shall include buildings to house secondary equipment and support Western Power's operational requirements.

The Buildings shall provide high levels of physical security and support the local landscape amenity. They shall also be designed as low maintenance buildings.

The buildings shall comply with the general requirements of the Building Code of Australia (the "BCA") and other statutory requirements, codes and standards. They are however specialised buildings and do not require disabled access or related facilities[10].

The buildings can be pre-made concrete hinged wall panels, resting on precast and site installed concrete foundations.

Buildings will serve as a Relay/Control rooms, housing protection relay cubicles, SCADA and Communications equipment, batteries/chargers and associated equipment.

Power and control cabling shall enter into the buildings from a concrete cable trench, into a sunken section of the foundation that will ultimately be covered with fire rated computer floor panels.

In general the following areas are required:

8.4.1 Entrance

A weather protected entry area with access to the Relay Room and the ablutions area.

[10] Refer to legal opinion – see DMS# 3632833.

8.4.2 Ablutions Area

An isolated area [11] containing a water closet and hand wash facilities.

8.4.3 Terminal yard Control Area

A general area to house the local operator's computer console (the Human Machine Interface (HMI)). The area is to be complete with phone and radio for external communications, corporate data port, table and chairs for plans and report preparation, limited amenities and storage for plans, records and instruction manuals. The Terminal yard Control Area shall also house various relay and control panels and switchboards.

8.4.4 Communications Area

A section of the Relay Room dedicated to communication equipment. The location of this area is to be such that it has minimal passing traffic.

8.4.5 Battery Room Area

The Battery Room area shall be an integral part of the building but segregated from the Relay/Control room building, with a single internal access door between the 2 – sections. The battery room shall be air (natural) ventilated.

8.4.6 Air Conditioning

All site buildings shall be equipped with split system wall mounted air conditioners because of the limited operating temperature of some equipment mounted in various areas and personnel comfort.

8.4.7 Storage Building

A building shall be provided for the storage of ancillary equipment, such as earthing sticks, earthing cable conductors, oil spill clean-up equipment and other associated miscellaneous items. The building shall be transportable and prefabricated off site.

[11] The term "Isolated Area" is a security term which means that this area does not have a direct means of access to another area without returning through the foyer.

9 Asset Management Specifications

Asset management features cover all aspects such as safety, maintenance, operations, risk management, environmental management and commercial features of the Terminal yard.

9.1 Safety Requirements

The Terminal yard shall meet the requirements of relevant safety codes and standards. This requirement shall be satisfied both internally, for personnel working within the Terminal yard, and externally, for personnel, general public and animals within the vicinity of the Terminal yard.

The Terminal yard incorporates equipment and materials that can be hazardous under certain conditions. The Terminal yard shall include features that preferably eliminate these hazards or at least reduce the risks associated with them to less than 1×10^{-4} Significant Incidents [12] per annum over the design lifetime of the facility. This risk quantity is a Western Power and industry accepted risk value recommended by the ENA, section 6 DM# 4497625. Risk assessment, as highlighted in AS 4360, is an overall process of risk identification, risk analysis and risk evaluation

Safety of personnel in and around the Terminal yard is a fundamental aspect to the design of the Terminal yard to ensure risks are minimised to target zero injuries.

9.2 Commercial Requirements

A series of formal cost estimates shall be prepared as part of the Terminal yard design. These cost estimates shall consist of an integrated set made up of the following estimates:

9.2.1 Establishment Cost

All the costs associated with designing, procuring, installing and commissioning the Terminal switchyard shall be estimated.

9.2.2 Operating Costs

The costs associated with ongoing operation, maintenance and support of the Terminal yard shall be estimated. The estimate shall include planned and unplanned maintenance, equipment refurbishment, replacement, disposal, compliance costs, transformer loss costs together with the annualised labour, vehicle and consumables costs involved in supporting the Terminal yard through its life.

9.2.3 Life Cycle Costs

The full life cycle cost of the Terminal yard shall be calculated from the Establishment and Operating Costs. The design shall minimise the life cycle costs while satisfying the requirements of the Functional Specification.

9.3 Risk Management

For any specific terminal yard project a risk management plan shall be prepared to document the risks associated with the establishment, operation and disposal of the terminal yard. The design shall be optimised to minimise the risks associated with the terminal yard within the constraints of ensuring the yard carries out its function. Following the completion of design, the risk management plan shall include recommendations on how the residual risks shall be managed.

9.3.1 Network Emergency

The Terminal yard's performance capability shall be maintained under all emergency service conditions external to the Terminal Yard. This shall include the loss of one high voltage 330 kV line and variations of the voltage of the remaining high voltage supply feeders in the range $\mathbf{0.9_{pu}U_n}$ and $\mathbf{1.1_{pu}U_n}$ where $\mathbf{U_n}$ = 330 kV. Under these conditions, the 132 kV busbar voltages shall remain within output voltage operating envelope defined for the Terminal Yard.

[12] A Significant Incident in this context is any loss or damage to a process or plant.

9.3.2 Disasters

The Performance capability shall be maintained during and after the disaster conditions defined for the terminal yard in section 10- Operating Environment. In the event that the Terminal yard's operating environment exceed the Defined Disaster conditions, then the switchyard's monitoring and control systems shall progressively initiate automatic actions to protect the Terminal yard and alarm the conditions and the actions to Western Power's Network Control Centre.

9.4 Maintenance and Extendibility Requirements

9.4.1 Maintenance Limitations

The Terminal yard shall be designed to provide full and ready access to all its major plant and equipment for planned and unplanned maintenance without the need for customer outage or load curtailment. The maximum guaranteed supply capacity is the Terminal yard Firm Capacity (1225 MVA).

9.4.2 Maintenance Cost Target

The annualised maintenance costs for the complete Terminal yard (i.e. including all electrical and non-electrical equipment, building structures and grounds associated with the Terminal yard site) shall not exceed a target of 1% of the Establishment Cost.

9.4.3 Maintenance Reporting

Where it can be justified on economic or reliability enhancement basis, Terminal yard plant subject to deterioration shall be monitored and its condition reported to Terminal yard asset managers.

9.4.4 Online Condition Monitoring

The design of the Terminal yard shall allow for online condition monitoring of the plant and equipment.

9.4.5 Maintenance Access

The area enclosed within the Terminal yard security fence shall have sufficient area and clearance from high voltage equipment to allow light cranes and vertically extendable work platforms ("scissor lifts") to access all EHV and HV plant.

9.4.6 Extendibility

The design shall allow future extension of the Terminal yard. Provision for the extension shall consider site access to construction crews without the need for customer outage or load curtailment.

9.5 Operational Requirements

The Terminal yard shall be designed to operate automatically and will generally be unmanned. There will be requirements for certified personnel to work within the Terminal yard premises, either the switchyard or within the Terminal buildings for operation and maintenance purposes.

The Terminal yard shall have the following facilities for operational purposes:

- Personnel access log including events log;
- Hardcopy drawings of the equipment with ease of access within the Terminal yard building;
- Provide easy access to specialised tools relating to the switchgear operations and maintenance; and
- Western Power LAN access (where possible).

9.6 Environmental Compliance

In general Greenfield Terminal yards shall be designed to have a minimum environmental footprint as well as achieving Western Power's business and commercial objectives and targets. The balance between these design objectives shall ensure that an optimised total life cycle cost of the Terminal yard will be achieved.

In particular the standard Terminal yard shall comply with the following environmental compliance requirements:

9.6.1 Oil Filled equipment

Oil, if released to the environment can lead to environmental contamination. Each Power Transformer shall be contained in a suitably bunded area in accordance with the Environmental Protection Act 1986, AS2067: Substations and High Voltage installations and Western Power's Oil Containment and Environmental Management Policy.

Oil containment tanks will be installed to capture hydrocarbon spills that result from maintenance on transformers or other electrical equipment.

9.6.2 Hazardous substances

Designers shall note the requirements and containment of any hazardous substances to be maintained on site. Compliance with AS 1940: The storage and handling of flammable and combustible liquids and any local government requirements shall be noted.

9.6.3 Terminal yard noise

Noise can cause annoyance to nearby noise sensitive receptors, particularly at night or where background noise levels are low. Tonal components (hum) can often be characteristic of Terminal yard noise. The design and specification of the Terminal yard and its equipment shall actively avoid the generation of noise. Noise levels shall be managed in compliance with the Environmental Protection (Noise) Regulations 1997, AS 2067 Substation and high Voltage installations. AS1055: Acoustics – Description and measurement of environmental noise. Consideration may need to be given to the design of a suitable acoustic enclosure for transformers and where applicable Audio Frequency Load Control equipment.

9.6.4 Dust

Dust nuisance from exposed bare earth surfaces can often be a source of nuisance to nearby premises. The design shall ensure that Terminal yard areas are sealed, grassed or covered by aggregate to minimise dust nuisance.

9.6.5 Visual amenity

The visual impact from Terminal yards needs to be considered from a local community perspective. The design shall consider the local character of the surrounding environment. The use of appropriate landscaping including native trees and shrubs shall be considered. Colours of the buildings shall be selected to promote a neutral visual impact to blend in with the surrounding environment. Maximum height of the structures within the Terminal yard boundary shall be 26m, except for communication masts that may extend to 65m.

9.6.6 Storm water

Contaminants collected by rainwater falling onto Terminal yard sites can have potential to cause environmental harm if released to the surrounding environment. The design shall allow inspection of run off/discharge areas to verify that discharge has not occurred. Stormwater associated with bunded areas shall be provided with an appropriate pollutant trap, with the ability to remove oil, prior to discharge off site.

9.6.7 Fire breaks

Terminal yards, if located in rural areas or near naturally vegetated areas or near built up areas will need to meet local government requirements for fire breaks. The design shall note any requirements of local government for firebreaks around the Terminal yard.

9.6.8 Lighting

The design shall ensure that light spillage to neighbouring premises is minimised.

Lighting shall be suitable for routine operations for accessible indoor and outdoor locations as per AS 1680: Interior and workplace lighting.

9.6.9 Security fencing

Terminal yard shall be fenced to resist unauthorised entry to the Terminal yard and subsequent contact with energised equipment, loss or damage of equipment or facilities and potential safety and environmental liabilities. Fencing style will be dependent on the site, security and visual requirements.

Fencing shall comply with AS 2067: Substation and High Voltage Installations and AS 3016: Electrical installations – Electrical Security Fences and Western Power standards –DM#4175749. Further information is available from ENA DOC 015: National guidelines for Prevention of unauthorised access to electrical infrastructure.

9.6.10 Cultural Heritage

Issues with cultural heritage, native sacred sites or sites with historical artefacts/remains are to be resolved with the Environment Protection Authority (EPA) and Department of Natural Resources & Mines.

9.6.11 Community Acceptance

Community acceptance for the Terminal yard shall be fostered. This will tend to be a community specific issue but if necessary community concerns shall be resolved with public forums and local government as early as possible.

9.6.12 EMF Compliance

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) have not finalised their standard for allowable electric and magnetic fields. To minimise electric and magnetic fields at the substation border, power transformers and reactors shall be located near the centre of the substation.

Current National Health and Medical Research Council (NHMRC) guidelines requires that the magnetic field levels at the Terminal yard boundary shall not exceed 4 milligauss for continuous (24 hours) exposure for members of the public. Within the Terminal yard boundary, the maximum EMF exposure level for personnel shall not exceed 10 kV/metre for electric fields and 5,000 milligauss for magnetic fields.

9.7 Terminal yard Interface Outline and Demarcations

The following interfaces and demarcations are defined for the Terminal yard:

9.7.1 330 kV and 132 kV Network Interfaces

These interfaces are at the Line Termination point of the Switchyards “A-Frame” structure insulators for overhead line applications and at the 132 kV Cable Support structure busbar connection where buried cables are used.

9.7.2 Services and Auxiliaries Interfaces

The following services and auxiliaries shall be provided:

- 22 kV Distribution Cables – at the 22 kV services transformer cable terminals;
- 415V Power Cables – at the appropriate Auxiliaries Power Distribution Panel terminals in the Relay Room;
- Communication Cables – at the appropriate communication points in the Relay Room;
- Water – at the Water Authorities terminal point on boundary of the site; and
- Sewage – where applicable at the boundary of the site.

The design must ensure that Step and Touch potential rises, electromagnetic fields, etc are managed on site and are not transferred off-site.

Interfaces require particular consideration to ensure the requirements and capacities on both sides of the interface are compatible.

10 Operating Environment

The Terminal yard shall operate satisfactorily within Western Power's electricity supply network and the Western Australia environment.

For convenience, the Operating Environment is considered as a combination of the Network and the Physical Environment. The Network Environment covers the electrical aspects of the operating environment and the Physical Environment covers the non-electrical aspects.

10.1 Network Environment

The Terminal yard shall be designed to operate and withstand the following electrical operating environment:

Table 2.1 - Network Withstand Environment

Factor		EHV	HV
Network Nominal Voltage		330 kV	132 kV
Normal Operating Range		±10%	Controlled
Equipment Highest Voltage		362 kV	145 kV
Rated 1 minute Power Frequency Withstand		520 kV	275kV
Rated Lightning Impulse Withstand		1175 kV_p	650 kV_p
One Second Short Time Current Rating and CB Interrupting Capacity		50 kA	50 kA
One Second Short Time Current Rating		50 kA	50 kA
Minimum Creepage Distance for air exposed insulation per kV of the line to ground voltage			
	Outdoor		40 mm/kV
	Indoor		25 mm/kV

10.2 Network Physical Environment

The physical environment in which these standard Terminal yards are required to operate will vary from project to project. For the standard design of the Terminal yard an operating environment must be defined. For these standard designs, the operating environment has been defined as the Rated Physical Environment. It has been based on the service conditions used in various high voltage equipment specifications produced by Standards Australia.

10.2.1 Rated Physical Environment

The design ratings of the Terminal yard shall be based on the following operating environment. This environment is classified as the "Physical Rated Environment" and is derived from the service conditions used in the various high voltage equipment specifications produced by Standards Australia and by the International Electro-technical Commission (IEC).

Temperatures and wind speeds in the following Table are extracted from Transmission Standard – Plant Common Requirements – DM# 885524 and AS 2650: Common specification for high-voltage switchgear and controlgear standards. Other data has been quoted from Western Power's Specifications.

Table 2.2 - Rated Physical Environment		
Factor	**Minimum**	**Maximum**
Shaded Air Temperature (no solar radiation)	-5 °C	+50 °C
24h Average Shaded Air Temperature (no solar radiation)		+35 °C
Unshaded outdoor cubicles – internal temperature		+70 °C
Solar Radiation (horizontal surface)	Nil	1,000 W/m^2
Wind Speed (Wind Region C – DM# 885524&AS 1170: Structural Design actions –Wind Action)	Nil	50 m/s
Monthly Rain Fall	Nil	100 mm
Rain Fall Intensity 5 MIN— Average recurrence interval (ARI) 20 YEARS	120 mm/h	300 mm/h
Relative Humidity - Indoor - Outdoor	30%	95% 98%
Atmosphere 3.5 km inland from the coast	Coastal/Salty	
Dust Levels: a) Normal b) Under Wind Conditions	 0.1– 0.5 mg/m³ 10 – 20 mg/m³	
Altitude	Less than 1000 metres above sea level	
Ambient ground temperature at 800/900 mm depth (Refer to DM# 4195534)	+30.2 °C	
Soil Thermal Resistivity (Yellow builder's sand) (Refer to DM# 4195534)	~1.0 °C. m/W	1.25 °C. m/W

10.2.2 Extended Physical Environment

The Terminal yard and all of its equipment shall operate satisfactorily and carry out all functions fully while operating in the following more onerous operating environment. This environment is classified as the "Extended Physical Environment. Limited variations to the Terminal yard's design ratings are acceptable. These variations will be mainly associated with the thermal performance of the Terminal yard and the structural strength of the buildings. The variations to the Terminal yard's rated performance shall be accurately predicted with the use of equipment manufacturer's advice, models, environmental data, etc.

Table 2.3 - Extended Physical Environment		
Factor	**Minimum**	**Maximum**
Air Temperature Extremes (no solar radiation)	-5.0 ^{o}C	+50 ^{o}C
Maximum 24 hour Average		+40 ^{o}C
Solar Radiation (horizontal surface)	Nil	1,200 W/m^2
Wind Speed - Maximum	Nil	60 m/s [13]
Maximum Rain Fall - 50 Years - 100 Years	110 mm/h 160 mm/h	320 mm/h 400 mm/h
Rain Fall Intensity 5 MIN - ARI 20 YEARS - ARI 100 YEARS	110 mm/h 160 mm/h	320 mm/h 400 mm/h
Relative Humidity - Outdoor	20%	98%
Ambient ground temperature at 800/900 mm depth	+35 ^{o}C	
Soil Thermal Resistivity (Soil unknown) (Refer to DM# 4195534)	1.0 oC. m/W	2.5 ^{o}C. m/W

10.2.3 Physical Withstand Environment

The Terminal yard shall withstand the stresses imposed by the electricity network and the physical environment in which it operates. To a significant extent these stresses are random, both in nature and magnitude and thus are difficult to predict.

The establishment of performance standards for a standardized design must take into account criteria that may or may not be applicable to a specific site, and as such a combination of required standards shall all be considered.

The following is a summary of the minimum design criteria required, not withstanding the requirements of the relevant design codes and legislation, such as the Building Code of Australia, and relevant Australian Standards.

[13] See Transmission Standard – Plant Common Requirements (Ref DM# 885524).

10.2.4 Minimum Design Criteria for Civil Works

Shelter / Floor Loads	
Imposed Load	3 kPa imposed load + Equipment Load (Floor shall accommodate the manual shifting of equipment via the use of rolling platforms)
Dead Load	All present loads including the self weight of all elements and finishes.
Shelter Loads	Provision shall be made to lift the shelter from 4 lifting points. (Allowance shall be made for the shelter to be fully loaded at the time of lifting).
Wind Loads	The shelter shall be designed in Wind load in accordance with AS 1170.2: Structural design actions-Wind action, for the following criteria: Annual probability of exceeding 1:2000 Region C Terrain Category 2, Shielding Multiplier 1.0 Topographical Multiplier 1.0 Minimum internal pressure coefficient 0.7 Importance Level 1.1 Strength limit state design pressures for overhead fixed and strung bus and overhead earth-wires shall equal or exceed 2.5kPa.
Earthquake	The shelter shall be designed for Earthquake in accordance with AS 1170.4: Structural Design Actions Earthquake actions in Australia for the following criteria: Structure Type: III A = 0.16 (Acceleration Coefficient) S = 1.25 (Site Factor) I = 1.25 (Importance Factor) Rf = 2.8 (Structural Response Factor)
Rainfall	For buildings, the following rainfall shall be used Return Period = 50 years Duration = 5 minutes For civil earthworks and drainage (Site Works) Rainfall and design shall be in accordance with Australian Standard. Rainfall and Runoff to suit the geographical location.
Hail	N/A
Flood	The Terminal yard shall be located 300 mm minimum above the 1:100 Year flood level.
Local Flooding	Not withstanding the flooding criteria, the Terminal yard shall be located in areas not affected by local flooding.
Tsunami	Whilst designing for the effects of a tsunami is not practical, the Terminal yard, where possible, shall be located away from the low lying coastal areas.
Fire	Site selection and ground clearing shall take into account the effects of bushfire, etc. Non combustible materials shall be used for the building envelope.
Site Access	The site access to the site shall be determined by the site designer, but may consist of a combination of direct road access, and private access requirements.

10.2.5 Building Service Conditions

The building shall be designed to operate within the following environment:

Air Temperature	- 5°C to + 50° C
Solar Radiation	Up to 1000 W/m2
Humidity	15% to 95%

The internal operating conditions of the building shall be:

10.2.6 Temperature:

Switchgear Room	25°C to 28° C
Control and relay room	25°C to 28° C
Humidity	20% to 95%

Air conditioning (AC) shall be provided in the Terminal yard building. The AC system shall provide automatic and manual temperature control for various areas of the building depending on the type of equipment installed and their operating temperature range.

The Air conditioning system shall have manual override capability during Terminal yard occupancy times with automatic reset feature when evacuated.

Appendix A – Single Line Diagrams

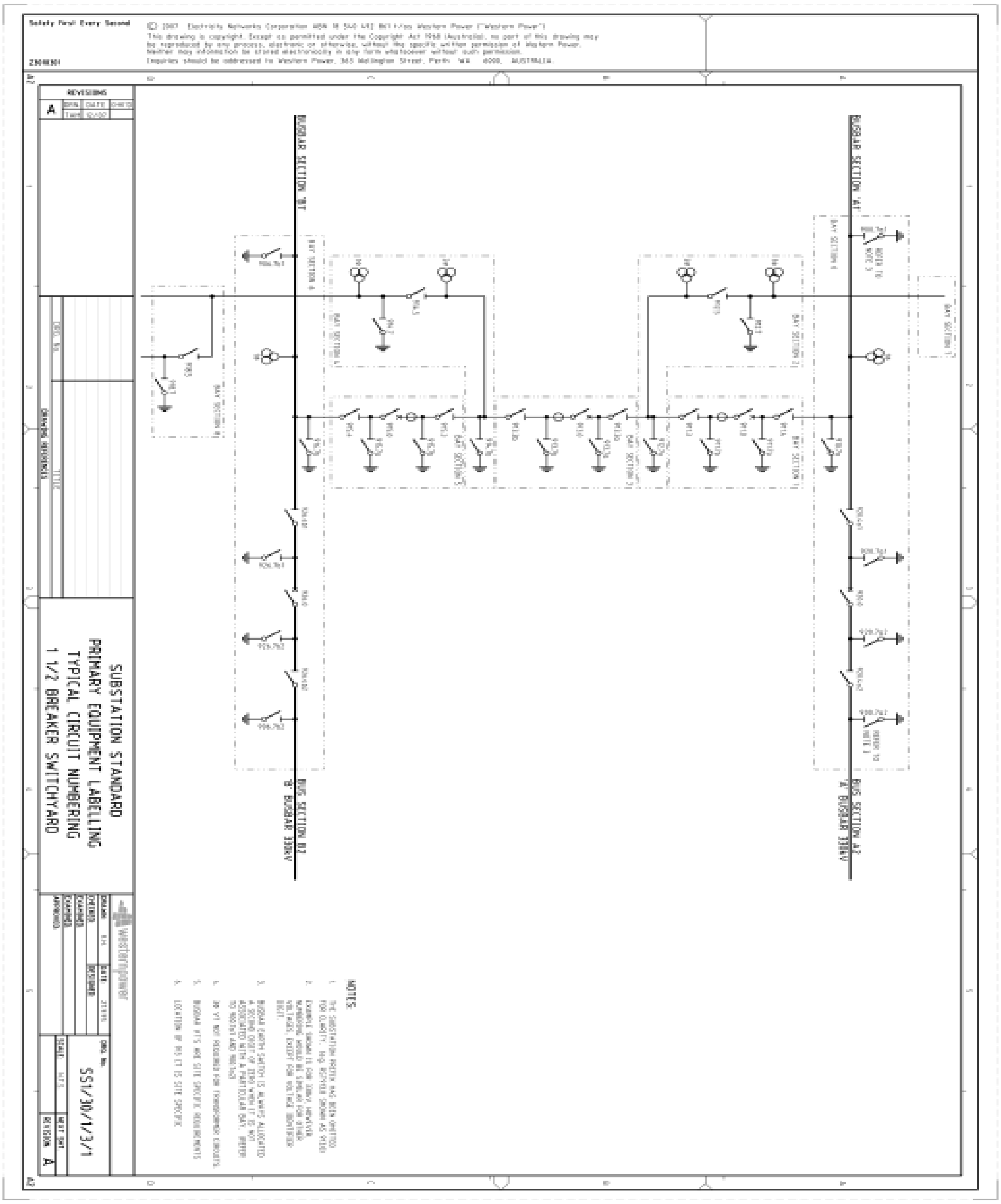


Diagram A1: A Typical 1 & ½ breaker arrangement

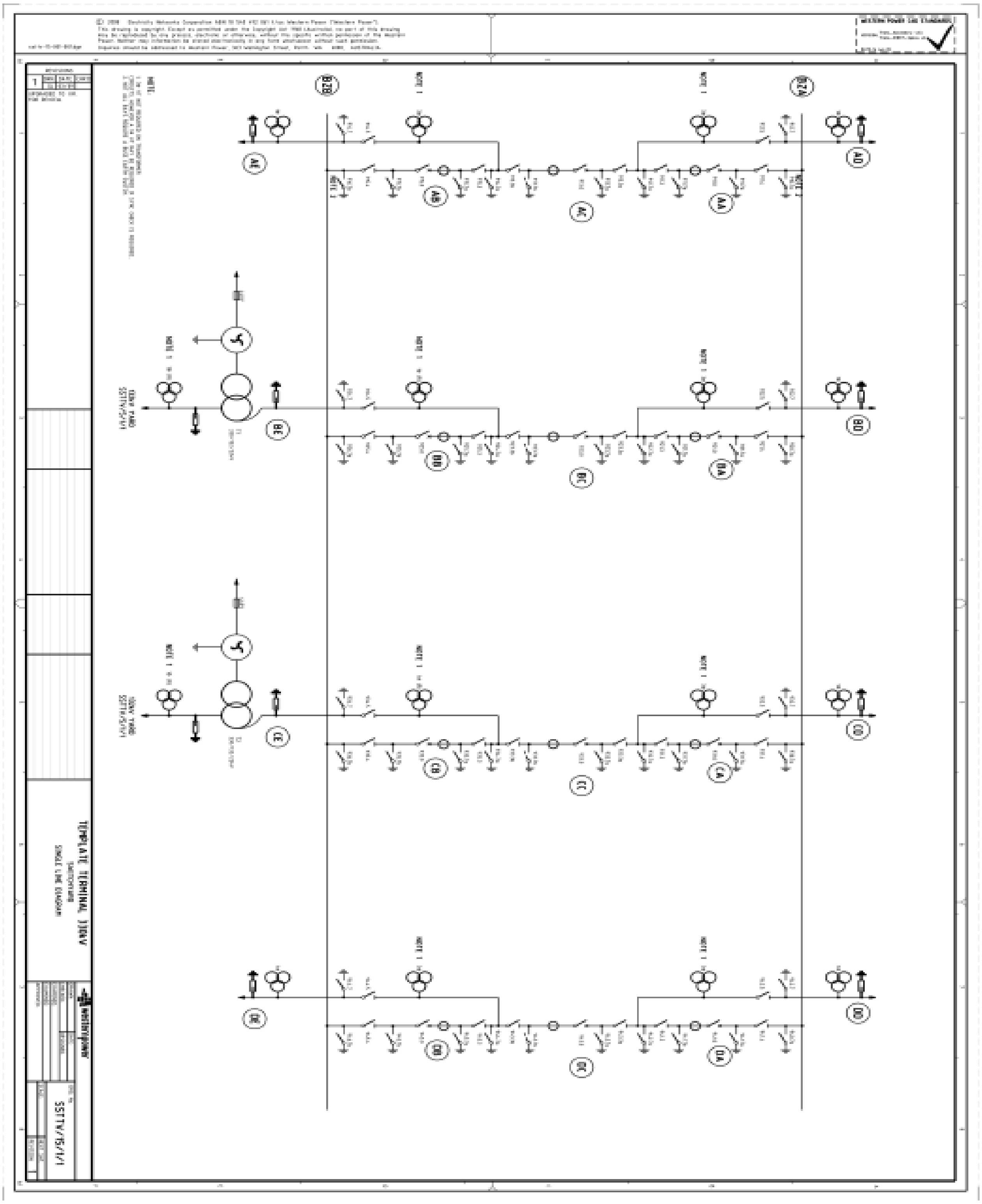


Diagram A2: Single Line Diagram for the 330 kV Yard

The transformer bays can be moved to any location.

Only half the ultimate terminal yard development has been indicated on the single line diagram.

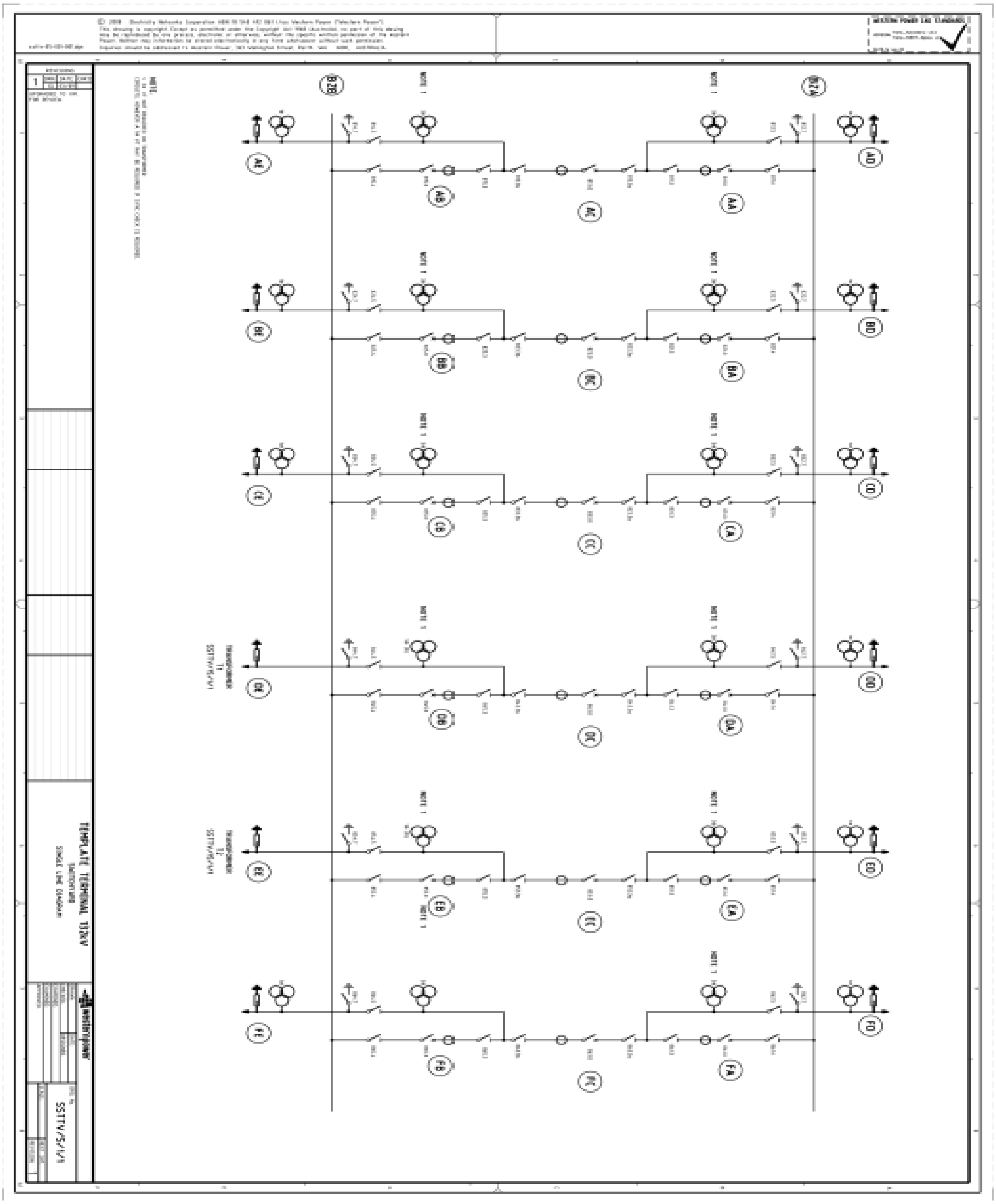
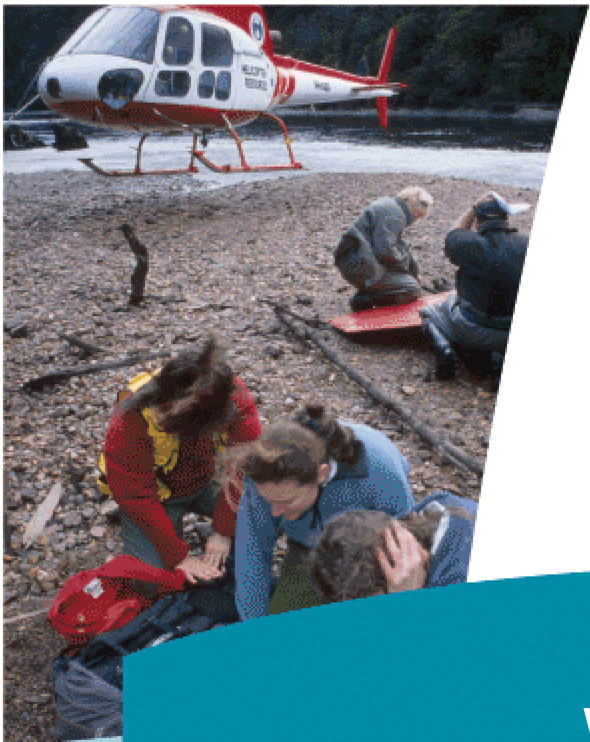


Diagram A3: Single Line Diagram for the 132 kV Yard

The transformer bays can be moved to any location.

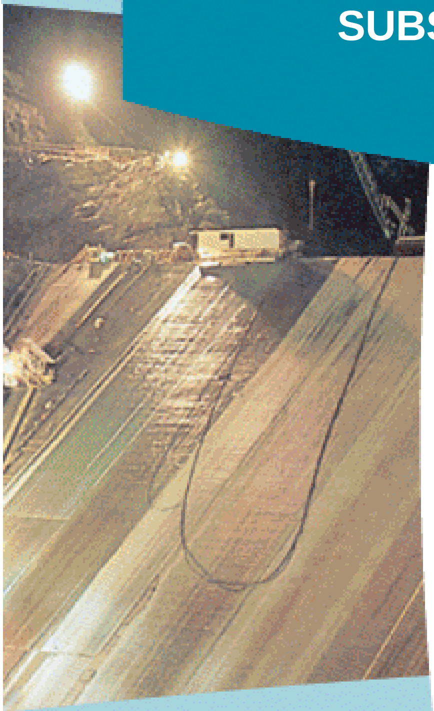
Only half the ultimate terminal yard development has been indicated on the single line diagram.

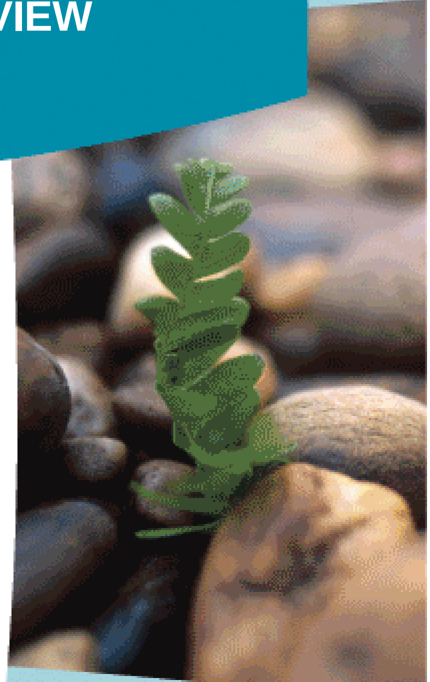
Attachment 4 Hydro Tasmania Consulting - Western Power Substation Design Standard Review (DM# 7442038).



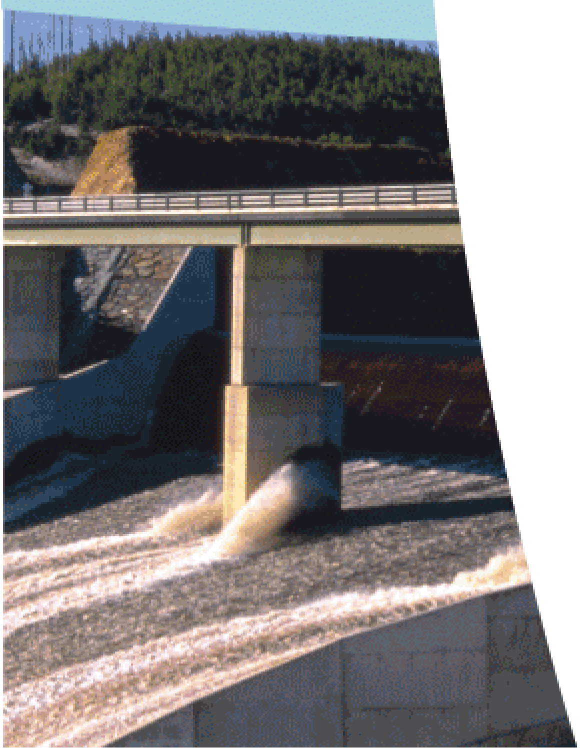
Hydro Tasmania Consulting

WESTERN POWER SUBSTATION DESIGN STANDARD REVIEW





30 September 2008



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EXECUTIVE SUMMARY

Hydro Tasmania Consulting was engaged by Western Power to undertake a high-level review of a set of documents that it had prepared to standardise and document its current approach to substation design. The documents cover:

- Western Power's Transmission Standard Designs Policies,
- Functional and conceptual requirements for 132/22 kV Zone Substations and 330/132 kV Terminal Yards,
- 132 kV Underground Cable Circuits

The review covered three key areas; Primary, Secondary and Civil design. Comments on detailed aspects for each of these disciplines are included in Section 3 of this report. These comments are intended to improve document readability and cross-referencing, and amend minor errors.

In general the review found that Western Power's approach is considered, well documented, and based on philosophies, design parameters and methodologies consistent with, and currently being implemented by other utilities in Australia.

It was noted, however, that the documentation provided does not include the underlying technical reasoning behind some of the requirements or methodology in the documentation. As this documentation is intended to be a knowledge capture, it is recommended that the design reasoning also be documented as an aid to those undertaking future design revisions. A good example of such a document is Western Power's "HV Extruded Cables Design and Installation Guide".

It is understood that Western Power is currently undertaking a project to review its future substation requirements. These documents provide an excellent starting point for such a review, which can include consideration of alternative technologies to Air Insulated Substations (AIS) such as Gas Insulated Switchgear (GIS) and Mixed Technology Switchgear (MTS).

The review process was necessarily at a high level but Hydro Tasmania Consulting is able to provide additional assistance in specific areas, including consideration of future technologies, if this is required.

CONTENTS

1. INTRODUCTION

Western Power has completed a review project to standardise its current designs to address inefficiencies and inconsistencies across the design function. Hydro Tasmania Consulting was engaged by Western Power to review these standards for the following three key areas:

- Electrical Primary Design
- Substation Electrical Secondary Design
- Civil Structural Design

2. PROJECT SCOPE

The scope for the project was:

- To obtain all documentation and drawings to facilitate an initial review and identify opportunities for potential improvement or clarifications, along with any suggested fine detail modifications

- For the three discipline leaders from Hydro Tasmania Consulting to meet with Western Power Representatives to discuss the output from the first stage and any other broader issues that require resolution

- To complete the review report and dispatch this at least two weeks ahead of a presentation at Western Power.

Hydro Tasmania Consulting was advised at the meeting held at Western Power that the documents to be reviewed were prepared as a knowledge capture exercise. The purpose was to document the basis of design and the designer's intent that had been involved in preparation of the standard:

- 132/22 kV Zone Substation design;

- 330/132 kV Zone Substation design; and

- Cable Installation design.

The documents have been reviewed on this basis.

3. DOCUMENT REVIEW

The documentation supplied has been reviewed for consistency and technical content. The functional and scope documents for the zone and terminal substations and cable design has been edited using Microsoft Word's Track Changes feature to simplify the capture of editorial changes.

The review has been carried out taking into account Western Power's draft Transmission Standard Designs Part 1 - Policies.

Each of the document parts were reviewed for clarity and from a high technical overview perspective. The following is commentary on the three disciplines to be addressed: Primary, Secondary, and Civil Design.

3.1 Primary Design

3.1.1 General

Review of the supplied documentation reveals that Western Power has adopted a specific approach in designing its 330 kV and 132 kV networks and that the standard designs provided have been developed to facilitate this approach.

The documents provide a good overview of Western Power's approach for the substations but, from a newcomer's perspective, an explanation and examples of how they fit into the system would assist in understanding how the substations enable the system development philosophy.

The following are general comments for improving the documents:

- There is an inconsistency in the use of the words "shall", "should", "will", and "would". This should be reviewed to ensure those items that are mandatory are clearly and consistently identified.

- In a number of places generic or non-specific terms are used that to convey the idea that best performance is required but do not define what that ultimate is, eg use of the terms "optimum impact", "optimise the operation of the substation", "minimum impact", greater than, etc. This may be acceptable for internal use of the documents but would nevertheless aid interpretation if these concepts were clarified.

- In numerous places references are made to other documentation, such as "DMS Reference No. 347636v2". It is recommended that that the version number be removed so that it reads "DMS Reference No. 347636" because the document will need to be updated every time the referenced document is altered. This additional step is likely to be omitted in practice and could cause confusion or serious error. A general statement should be included indicating that "the latest version of referenced documents shall be used". The referenced documents should also include a cross-reference advising the editor to review other documents to ensure any changes are properly captured and addressed.

- Consideration should be given to standardising the introduction to each document part. This could be achieved by having the first four sections the same, or combined under one main heading with sub headings.

- Abbreviations used in the document should be clearly stated at the beginning of each document part. In some cases within the document there is a mixture of abbreviations with the full description.

3.1.2 Electrical Clearances

The electrical clearances adopted by Western Power are in accordance with the current AS 2067 but should be reviewed when the new edition of AS 2067 – High Voltage Substations is released (third quarter of 2008).

It is noted that the table supplied does not require provision for additional phase-earth and phase-phase clearance for birds and vermin at voltages up to 22 kV, as is typical for some authorities.

Some authorities specify minimum clearances that vary from those in AS 2067. For example, one authority has adopted the following values:

Voltage (kV)	Phase-Earth Clearance (mm)	Phase-Phase Clearance (mm)
22	280	450
66	690	800
220	2,300	2,650
330	2,850	3,300

3.1.3 Electromagnetic Fields

As a general comment it should be noted that the ARPANSA recommendations for allowable electric and magnetic field exposure have not yet been finalised. However, it is strongly recommended that EMFs are minimised at the substation boundary as far as is practical. Recently a local council stipulated that the maximum level they would accept is 2 mG, a level that is extremely difficult to achieve in practice. For this reason, power transformers and reactors should be located near the centre of the substation to minimise the boundary magnetic field.

3.1.4 Critical Infrastructure

Authorities in some states are reviewing security at their critical infrastructure such as substations and are applying differing security measures, depending on the accessibility of the site and its importance.

The documentation provided indicates that varying standards of security are applied, but does not refer to risks of terrorist attack. There are simple security measures that can be adopted, such as introducing a tight bend in access roads near the substation so that vehicle speed is controlled to minimise the risk of "ram-raids" being successful.

Cigré Technical Brochure 253, "Substation Physical Security Trends", was released in 2004 following an international survey and provides data on security strategies adopted by authorities in different countries.

3.1.5 Functional Specifications 132/22 kV Zone Substations

An edited electronic version of the supplied document is included with this report. The following comments relate to key issues identified in the document:

Section 4. Definitions

- The definition for *Transformer Maximum Continuous Rating* should identify that it is applicable "in the Rated Physical Environment".

Section 6. Substation Electrical Specifications

- The reference to "*Extended Service Environment*" should refer to "*Extended Physical Environment*".

Section 6.3, Figure 1: Zone Substation Single Line Diagram

- Surge arresters are not shown on the 132 kV line entrances (they are shown on drawing SS1/30/5/500/1).

Section 6.5.1 General

- NCR is referenced here – it should be defined as Normal Cyclic Rating at its first occurrence.

Section 6.7 Reliability

- The term "Outage Rate" should be defined at the beginning of this section.

Section 6.12 Substation Lightning and Earth Potential Rise Protection

Should include statements re:

- Whether or not the earthing system is to be a stand-alone system – ie whether or not it must meet the required performance without assistance from external earthing via cable screens, overhead earth wires, etc.

- The limits of surface voltage rise outside the substation during an earth fault – eg it may be a requirement to contain the 1000 V surface voltage contour within the substation site security fence.

- Whether or not the earth grid is permitted to extend beneath and/or include connection to the security fence.

Section 7.1 Substation Site

- Reference should be made to whether or not provision is to be made for crane access, lighting, and fencing (both perimeter and security).

Section 7.2 Substation Site Selection

- **Adverse Conditions** – "*resistance*" should be "*resistivity*"

- **Vehicular traffic** – Comment could be added re prevention of ram-raids and whether or not vehicle barriers, etc are required or permitted within the substation.

- **Landscaping** – it may not be practical to meet community expectations: eg there may be a requirement to build it underground so that it is not visible. This wording may require further definition.

Section 7.4 Substation Building

- The BCA does not specifically cover substation buildings and this should be addressed in this section.

Section 7.4.1 Switchrooms and Relay/Control Room

- Footnote 14 should be corrected to read "… does not have any direct means of access to another area".

Section 8.2 c) Life Cycle Costs

- This could include reference to selecting MV/EHV power cable cross-sectional area such that the capitalised value of losses and the cable cost are minimised over the cable life (the capitalised value of transformer load loss can be used to establish this).

Section 8.6 Environmental Compliance

- **Dust** – add to end of first sentence "… and contamination to substation insulation."

- **Services and Auxiliaries Interfaces** – ensuring that step and touch potential rises and electromagnetic fields, etc are managed on site and not transferred off-site is not practical. Limits of EMF and the allowable surface and transfer voltages at the substation boundary during faults should be nominated. Reference may be made to ARPANSA requirements for EMFs when these are finalised (currently under consideration).

3.1.6 Functional Specifications 330/132 kV Terminal Yards

Similar comments to those made in the previous section also relate to the Functional Specifications 330/132 kV Terminal Yards document.

3.1.7 Functional Specifications 132 kV UG Cable Circuits

This document covers the requirements for a cable installation in a clear and concise manner. A few comments are included below:

Section 6.2.5 Communications and cable Monitoring Facilities

- Requirements for the distributed temperature system monitoring equipment are not identified.

Section 8.6 Environmental Compliance

- The adoption of 4 mG as the upper limit of magnetic field is consistent with the levels being adopted internationally (refer comment in Section 3.1.3 above).

3.1.8 HV Extruded Cable Design & Installation Guide

The document provides a good and comprehensive overview of the principles that underlie a cable installation design. The reasons behind preferred installation methods, such as flat spacing vs trefoil arrangements, are documented and provide a solid background for future design modifications.

3.1.9 Concept Design 132/22 kV Zone Substations

An edited electronic version of the supplied document is included with this report. The following comments relate to key issues identified in the document:

Section 4 References and Standards.

- If the concept design document is issued to external parties for implementation then it is recommended that a statement be included to the effect that a proposed list of alternative standards be submitted to Western Power for acceptance/approval.

Section 5.1 Introduction.

- **Substation Buildings** – There is no reference to the required Earth Stick Building
- **Site Works –** It is recommended that a distinction be made between the site security fence and the site perimeter fence (assuming one is required). The R&M building is not defined.

Section 5.2.2 Standard Dimensions and Minimum Electrical Clearances

- The Standard Dimensions table refers to “height above foundation”. It is unclear if this is intended to refer to “height above switchyard finished level (ie surface level)” as this may be more appropriate.
- It is suggested that Appendix 3A be reserved for the Single Line Diagram as this is the key drawing for the substation and that Appendices 3B and 3C be for the Switchyard Layout Drawings.

Section 6.1.1 General Description

- Some sections of AS 2374 are now replaced by AS 60076.1 and AS 60067.4

Section 6.1.2 Size and Ratings

- In the second sentence the phasing and connections when viewed from the transformer HV side should be reviewed.

Section 6.1.3 Design Basis

- The table of transformer dimensions does not clearly state whether or not the dimensions include the coolers.
- If the document is issued to others, permission should first be sought from Wilson and EBG for the data to be circulated.

Section 6.4 Combined CT/VTs

- Some authorities refer to these as CVCTs (Combined Voltage and Current Transformers).

Section 6.6.2 Size and Ratings

- "The surge arresters will be of the metal-oxide gapless type and comply with AS 1307.2, with a nominal discharge current of 10kA and line discharge Class 3. Further detail are contained in the table below:" should be replaced with "The surge arresters will be of the metal-oxide gapless type and comply with AS 1307.2 and the table below:" to eliminate duplication of data.

Section 6.7.2 Design Basis (Lightning Protection)

- It is noted that lightning masts may be used to mount light fittings. Is there any evidence of lightning strikes to masts causing damage to lighting cabling?

Section 6.9.3 Design Basis (Busbars and Connections)

- The sentence below the table refers to "The above maximum span" but there is no other reference to this span.

Section 6.12.1 General Description (22 kV Capacitor Bank Feeders)

- Some of the data provided is repeated in Section 6.12.2.

Section 6.14.1 General Description (Substation Services Transformers)

- Reference to "off load" tap changer should be "off circuit".

Section 6.17 Substation Earthing System

- Drawing SSTTT/3/4/1 shows an internal and external grading ring at the security fence. It is possible that the internal grading ring may not be required and comment should be made that this should be reviewed. Note that, to reduce the risk of inadvertent voltage transfer, in some jurisdictions it is not permissible to connect the security fence to the earth grid. In this case the grid must lie totally within and no closer than 2 metres from the security fence.

- The document could note that the forthcoming ENA Earthing Guide, which provides for a probabilistic earthing design approach, is due to be released in the near future. The document should state whether a probabilistic approach is acceptable.

- It should be stated whether or not the resistivity of the surface layer (eg crushed rock) is permitted to be taken into account when calculating allowable step and touch voltage levels. This is allowed for in the ENA Earthing Guide but is not permitted by some authorities. The minimum, thickness and resistivity of this layer should be specified (eg 100 mm, 3,000 Ωm).

- It should be stated that it is mandatory for the earth grid to be tested by the current injection method (it is not clear if this is a requirement in Section 6.17.3, which refers to standard DMS No. 1326076.

- In Section 6.17.4 it is not clear if the portable earthing systems have been tested. It is recommended that each assembly be tested as they are safety devices. A note should be included to ensure that, if the standard design is modified, the revised assembly must be re-tested for the design fault level.

3.1.10 Concept Design 330/132 kV Terminal Yards

Similar comments to those made in the previous section also relate to the Concept Design for the 330/132 kV Terminal Yards document.

3.2 Secondary Design

3.2.1 General

It was noted that inconsistent terms are used throughout the document; it is recommended that standard terms be adopted.

The report uses expressions such as "sufficient electronic storage", "serial communication capability", "etc". These types of statements should be avoided or reference should be made to a current standard document which contains Western Power's current equipment requirements.

To provide better clarity of Western Power's methods, additional information could be included in certain areas. References to DMS documents where more information is available may be sufficient. Because DMS documents were not provided, as they were not part of this scope, it is not clear what information is contained in these documents and how these documents complement the reviewed documents.

It may be useful to the reader if the DMS documents listed in the appendix are grouped in their respective disciplines.

As the document is intended to capture knowledge, there would be benefit in adding historical information on why certain methodology is adopted within Western Power's network. This would help young engineers and new engineers gain a better understanding of how and why Western Power has taken this approach.

Microprocessor relays currently on the market need to be configured; there is no mention in the Functional Specification or Concept Design documents on Western Power's requirements for standardisation, e.g. inputs, outputs, etc.

Reference is made to "local SCADA System"; for clarity and less confusion, the term Substation Control System (SCS) is recommended.

It is recommended that the term "modern" be deleted.

3.2.2 Functional Specification 330 / 132kV Terminal Yards

Section 6.14 Terminal yard Auxiliary Supplies (AC/DC)

- The reference made to the 50V DC supply should state the source of the supply i.e. from the 50V battery bank.

- The DC battery capacity in hours stated for the terminal yard when loss of AC supply occurs seems high. Microprocessor protective relays consume much more power than the earlier protective relays; therefore higher DC battery capacity would require a larger DC battery bank. Generally, battery banks are rated for 12 hours. If Western Power has remote terminal yards that are not accessible within 12 hours then a higher capacity battery would be required. Additionally this section should indicate the battery capacity necessary to operate equipment for a specified time that meets Western Power requirements.

3.2.3 Concept Design - 330 / 132kV Terminal Yards

Section 5.2.4 Building Design Features

- -48V DC communication batteries are not mentioned and it is assumed they will be located in the communication hut.

Section 6.11.3 Design Basis

- This text needs to be corrected to meet requirements for the 132kV system. The current text makes reference to 22kV.

Section 7.1 Protection system

- The term “duplicate” is used with reference to protection under option (a) Protection 1 - Interlocked Current Differential and Protection 2 – interlocked Distance / IDMT Earth Fault schemes. This is not a duplicated scheme.

- The statement “The design shall be modular and flexible allowing easy testing and isolation facilities.” should include more information on how Western Power lays out their cubicles, or refer to a template (or DMS). Each power utility has a defined panel layout based on their testing and isolation methods.

- The statement "if mounted in the same cubicle, be separated vertically by a suitable insulating material" should be accompanied with stated minimum requirements for insulation between Protection 1 and Protection 2, or refer to a reference document.

- The statement "Separate supervision relays shall be used when relays with self-diagnostic features are not used" does not make clear what supervision is required, for example "trip circuit supervision, loss of DC supply, etc.

Section 7.1.1 330kV Line protection

- The term "speed requirements" is an undefined term, it would be better to use the term "fault clearance time requirement".

Section 7.1.4 330 kV/132 kV Transformer Protection

- The table shown below the statement "The complete scheme will consist of duplicated fully independent and discriminative protections." lists Protection 1 and Protection 2 required protection functions. The protection functions are not duplicated; however there is redundancy between the two sets of protection.

Section 7.1.5 132 kV Capacitor bank Protection

- The protection function listed does not provide protection from overvoltage across the capacitors. It is recommended that a protection relay designed for capacitor banks be considered.

Section 7.1.6 22/0.415 kV Station Transformer Protection

- This section should be reviewed by Western Power for clarity.

Section 7.1.12 Metering Information & Indication

- No mention of CT or VT requirements for revenue metering. Meters for revenue metering are placed on separate CT cores that meet the required CT class for revenue metering.

Section 7.1.13 Fault Recorder

- The term "*investigation section*" is used and it is not clear if this is a Western Power group or comes under Protection and Control. If there are standards available on determining where fault recorders are placed, then reference should be made to this document.

Section 7.2.1 Communication Requirements – Protection

- The Statement "Duplicated digital differential protection on a three-ended line may require a third physically diverse bearer path between two of the three sites." should include reference to the section that determines if a third bearer path is required or reference to a Western Power standard for guidance.

Section 7.3 SCADA System

- Reference is made to 48V DC; this should be changed to 50V DC to maintain consistency throughout the document.

Section 7.3.1 Remote Terminal Unit (RTU)

- This section should refer to a standard document where Western Power outlines its current RTU requirements e.g. number of spare DI, DO & AI that is required and what communication protocols are required on the RTU.

Section 7.3.7 Human Machine Interface (HMI)

- The HMI supply is referred to as 48V DC and should be changed to 50V DC to maintain consistency.

Section 7.3.8 Power Supply

- The RTU supply is referred to as 48V DC and should be changed to 50V DC to maintain consistency.

Section 8.2 DC Auxiliary Power Supply System

- Refer to comment under Section 6.14 regarding battery capacity.

3.2.4 Functional Specification 132 / 22kV Zone Substations

Section 6.13 Substation Auxiliary Supplies (AC/DC)

- Additional information should be added to indicate what needs to be operated at the specified time after loss of AC supply.

Section 6.9.2 Control

- Little information is given on the philosophy of how Western Power parallels its transformers. If a DMS document for this is available then reference to it should be included.

3.2.5 Concept Design - 132 / 22kV Zone Substations

Section 7.1 Protection system

- The term “duplicate” is used with reference to protection, under option (a) Protection 1 - Interlocked Current Differential and Protection 2 – interlocked Distance / IDMT Earth Fault schemes. This is not a duplicated scheme.

- The statement “The design shall be modular and flexible allowing easy testing and isolation facilities.” should include more information on how Western Power lays out their cubicles, or refer to a template (or DMS). Each power utility has a defined panel layout based on its testing and isolation methods.

- The statement “if mounted in the same cubicle, be separated vertically by a suitable insulating material” Should be accompanied with stated minimum requirements for insulation between Protection 1 and Protection 2 or refer to a reference document.

- The statement “Separate supervision relays shall be used when relays with self-diagnostic features are not used” does not make clear what supervision is required e.g. “trip circuit supervision, loss of DC supply, etc.

Section 7.1.1 132kV Line protection

- The term “speed requirements” is an undefined term, it would be better to use the term “fault clearance time requirement”.

Section 7.1.2 132 kV / 22 kV Transformer Protection

- The table shown below the statement “The complete scheme will consist of duplicated fully independent and discriminative protections.” lists Protection 1 and Protection 2 required protection functions. The protection functions are not duplicated; however there is redundancy between the two sets of protection.

Section 7.1.3 under Voltage Load Shedding

- Resetting of lockout trip relays remotely should be avoided. Lockout trip relays are reset once the faulted equipment has been inspected and cleared for service.

Section 7.1.4 22 kV Circuit Protection - General

- The statement "The transformer LV overcurrent and LV earth fault protection shall provide backup protection" does not make clear what it is backing up .e.g. feeder protection.

- The statement "When the transformer protection cannot provide adequate sensitivity, a low impedance bus zone relay capable of measuring individual circuit currents shall provide backup protection:" does not make clear if it is referring to the 22kV switchgear busbar protection.

Section 7.1.6 22 kV Capacitor bank Protection

- The protection function listed does not provide protection from overvoltage across the capacitors. It is recommended that a protection relay designed for capacitor banks be considered.

Section 7.1.12 Metering Information & Indication

- Meters for revenue metering are placed on separate CT cores.

Section 7.1.13 Fault Recorder

- The term "*investigation section*" is used and it is not clear if this is a Western Power group or comes under Protection and Control. If there are standards available on determining where fault recorders are placed, then reference should be made to this document.

Section 7.3 SCADA System

- Reference is made to 48V DC; this should be changed to 50V DC to maintain consistency throughout the document.

- This section should refer to a standard document where Western Power outlines its current RTU requirements e.g. number of spare DI, DO & AI that is required and what communication protocols are required on the RTU.

Template Drawings

Drawings submitted for review were examined and the following observations are made:

Drawing numbers: SSYYY/5/80201/1B, SSYYY/5/80201/1C, SSYYY/5/80201/1D, SSYYY/5/80202/1, SSYYY/5/80202/1A, SSYYY/5/80202/1B, SSYYY/5/80202/1 were examined and the following noted:

- Wire number labels for the supply rails are not logical. The wire number labels are shown on some connection branches and not on others.
- The power supply connection should be placed at the end of each supply loop; this will give better supervision of the supply rail in the event a loop connection is broken after the cubicle fuse.
- On the same sheet, connections are shown as a wired schematic and as a general schematic.

3.3 Civil Design

3.3.1 General

The supplied Functional Specifications, Concept Design documents and template and standard drawings generally indicate that Western Power is pursuing a product and service level that is consistent with best practice nationally. Minor suggestions or additions are highlighted in the supplied documents that align the Civil Design content with current practice nationally.

Currently the 1993 version of AS 1170.4 Earthquake actions in Australia, adopted by Western Power in the documentation (which is linked to the current version of the Building Code of Australia), is under revision. When it is reissued as a joint Australian/New Zealand standard it should be reviewed to see if it is still relevant for Western Power's design purposes. An alternative is for Western Power to specify design criteria from the latest version of AS 1170.4.

3.3.2 Infrastructure

3.3.2.1 General

The following observations on the basic guidelines for firewalls, noise abatement walls and durable concrete structures are suggestions based on industry practice in Australia. The comments include references to the Building Code of Australia where the terminal yard and substation are to be constructed in potentially 'built up' areas.

3.3.2.2 Fire Rating of Walls

Transformers shall be separated by a minimum three-hour fire rated wall(s) between transformers when the separation distance is less than a set dimension which is dependent on the MVA rating of the transformers concerned. The separation distance can vary between 25 metres reducing to 15 metres for lesser rated transformers. Refer to the Building of Australia (BCA) Part C2 for the requirements when the substation is sited in a built up area. The cooling requirements of the transformers shall be addressed when designing the separating fire walls.

3.3.2.3 Noise Control

Based on noise level design calculations referenced to the substation boundaries and as required, on site noise measurements there may be a requirement for constructing noise abatement walls around the transformer bunds. Consideration should be given to taking into account the future additional installation of transformers on the level off noise produced. The level of noise attenuation required for each site will partially depend on the ambient noise and development of residential areas. The cooling requirements of the transformers and access to the transformers shall be addressed when designing the noise abatement walls.

For built up areas Part F5 of the Building Code of Australian should be referred to when considering noise abatement measures.

3.3.2.4 Durability

Generally to address durability issues of substation reinforced concrete structures reference is made to AS 3600.

In areas of reactive soils it is generally not economical to remove the soil therefore the structures are designed to AS 3600. Installation of external membrane coatings is considered when countering extreme conditions.

3.3.3 Functional Specifications – 330/132kV Terminal Yards

Section 8.6 Environmental Compliance

- **Oil Filled Equipment**: Addition of subsurface agricultural drains draining to sumps or an oil containment tank especially in high water table areas can be installed to supplement the bunded areas to capture hydrocarbon spills that result from maintenance on the transformers or other electrical equipment.

Section 9.2.3 Physical Withstand Environment

- Referencing **Minimum Design Criteria for Civil Works** a heading and paragraph should present a general statement which states that the following load conditions applies to all civil works including earthworks and structures within the Terminal Yards where applicable, (not specifically only applicable to the 'shelter').

- Referencing the listed design criteria for wind loads Western Power's coverage zone apply to Wind Regions A1, A4 and B, not the cyclonic region C. In turn the Average Recurrence Interval (ARI) of 1 in 1000 years is nominated as an acceptable wind design criteria. The Importance Level is to be revised with reference to the current issue of the Building Code of Australia (BCA), Part B1, Table B1.2a.

- Referencing the listed design criteria for earthquakes from AS 1170.4. 1993, AS 1170.0 2002 Appendix D has been provided to link the requirements of AS 1170.4. 1993 with the new requirements in Part B1 of the Building Code of Australia (BCA) which include policy criteria in the form of importance levels and the associated annual probabilities of exceedance. The importance factor (I) has been replaced by the variation of annual probability of exceedance. The Structure Type is replaced by importance level. The Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 specifies the values to be considered at each substation site.

- Currently the 1993 version of AS 1170.4 is under revision. When it is reissued as a joint Australian/New Zealand standard it should be reviewed to see if it is still relevant for Western Power's design purposes. An alternative is to specify design criteria from the latest version of AS 1170.4, currently 2007 (where the Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 are replaced by Hazard Factor (Z) for Western Australian Figures 3.2(C) and (D)).

3.3.4 Concept Design – 330/132kV Terminal Yards

Section 9.1 Site

- Specify the site development to include a balanced cut and fill method to construct the platform for terminal yard sites where suitable foundation material exists. The disturbed foundation material shall be compacted with a minimum of four passes of a vibrating 10 tonne roller.

- This section should specify the maximum cut/fill batter angles when constructing the terminal yard platform, for example 1 on 3 for sand.

- The maximum slope of the terminal yard platform for drainage purposes is to be 1 in 40. Where sites are flat the minimum slope shall be 1 in 100.

- The maximum slope of the access ramp(s) from the main road to the platform is 6% to allow the placement of the RSST unit within the terminal yard. The minimum road width on the platform should be 5 metres with corners to suit size of transformer delivery equipment, for example 15 to 20 metre radii.

Section 9.3 Footings

- Typical footing templates should be indicated for sand foundation material, sandy gravel foundation material and gravelly clay foundation material in Appendix 3 D. These footing templates may consist of a typical thick slab or typical pier footing to cover various foundation materials from predominately sand through clay to rock.

- Additionally typical dimensioned footing templates, both slab and pier can be specified to apply to Wind Regions A1, A4 and B covered by Western Power. The templates are to be placed in Appendix 3 D.

Section 9.4 Structures

- Specify the respective Wind Regions, either A1, A4 and B and provide corresponding typical electrical equipment structural steel support templates to suit each region assuming say Terrain Category 2, Shielding Multiplier 1.0 and Topographical Multiplier 1.0.

Section 9.5 Outdoor Cable Trenches

- Reference the required maximum traffic loading (as axle loading or wheel loading) on the types of reinforced concrete box culverts and concrete lids in this clause or list the relevant template design drawings that state the maximum loadings.

- Specify, if relative levels allow, installing subsoil drains from the cable trench outfalls draining to the oil containment system or dedicated sump or pit collecting stormwater drainage prior to discharging off the site.

Section 9.6 Oil Containment

- Referring to the general description and issued drawings of Western Power's oil containment system the outflow would struggle to comply with a limit of a maximum of 15 parts per million of hydrocarbons released into the environment if the bund Oil Stop isolation valve failed during a transformer failure especially during a storm event where the resultant oil/water mix would form an emulsion as it passed through the series of holding tanks prior to discharging into the soak-well.

- An alternative, especially applicable in a high water table area, is to provide an above ground bunded area, free of gravel infill, surrounded by bund walls of 300mm minimum height with the Transformer supported on a 150mm to 300mm high raised plinth. The leaking oil is drained quickly through a pipe system that comprises flame traps and sediment traps into a containment tank. The tank is sufficiently sized to capture oil between internal baffles and use the time emulsified oil takes to flow through the tank to separate the oil from the emulsion and reduce the parts per million released into the environment. For smaller sites the oil containment tank can be reduced in size and coalescing plate separators installed downstream of the tank to separate the emulsified oil prior to discharging.

- For the oil containment arrangement above including the bunded catchment area feeding into the oil containment tank, the system shall be designed for a site rainfall of a 1 in 20 year event occurring simultaneously with a transformer failure.

- Install subsoil drains to surround electrical equipment that contain small volumes of oil or areas where oil may be spilt and drain to the oil containment system or a sump where stormwater drainage can be monitored prior to discharging from the site.

Section 9.11 Stormwater

- To assist in draining areas that trap water, for example where raised tops of cable ducts form barriers, an option is to install subsoil drains that discharge into drainage pits acting as a sediment trap prior to discharging off the site.

Section 9.13 Roads, Vehicle Access and Car Parking

- **Access Road Construction -** Where generally a 25mm Hot-mix layer is currently specified for internal road surfacing, a 40mm Hot-mix minimum thickness layer is suggested for the apron roads over which the transformers are transported.

  Similarly where cable ducts cross these apron roads specify the maximum load ratings for the ducts and the trafficable cable trench covers or list the design drawings on which the maximum load ratings are specified.

3.3.5 Drawing Template - Terminal Yard – 330kV

Drawing SSTTT/11/10/1 - Cable Trenches Layout

- Refer to the listed culvert load ratings including drawing number in the relevant Transmission Standard Designs documentation.

Drawing SSTTT/11/10/2 - Cable Trenches Detail

Referring to “Typical section through insitu trench” - increase mesh reinforcement to a minimum size of SL92 to increase control over cracking.

Referring to drawing Notes:

- Modify note 1. to include ‘with a compaction method of a minimum of 6 passes of a vibrating plate compactor.’ and delete ‘to 8 blows/300mmof a standard penetrometer.’

- Modify note 6. to include ‘surround blue metal in (Section B) drain detail with geotextile to ensure surrounding foundation material does not contaminate the blue metal.’

Drawing SSTTT/11/9/1 - Foundations Detail

- Bund Plan General Comment: Specify sufficient reinforcement to provide good control over concrete cracking as per AS 3600.

Site Preparation (Notes – Footings)

- Modify note 1. to include 'with a compaction method of a minimum of 8 passes of a vibrating plate compactor.' and delete 'to 8 blows/300mm of a standard penetrometer.'

- An alternative to note 2.for localised areas is to delete 'to a minimum of 95%maximum M.D.D. in accordance with AS 1289 Clause 5.2.1' and replace with 'with a compaction method of 6 passes of a vibrating plate compactor.' Specify also a compacted 150mm minimum deep layer of fine crushed rock (FCR) or a 100mm minimum deep layer of 20 MPa concrete to be used as levelling fill over the cohesive soil and gravel subgrade.

- Modify note 6. to include 'with 6 passes of a vibrating plate compactor' and delete 'to its original state'.

Concrete (Notes – Footings)

- Modify note 5. to remove the second reference to 'steel trowel' and insert 'wood float' to provide a non-skid finish.

Formwork (Notes – Footings)

- Modify note 2. to specify surface finishes to AS 3610 as indicated on drawing SSTTT/11/10/2.

Drawing SSTTT/11/9/2 - Foundations Detail and SSTTT/11/9/3 Foundations Detail

- The above drawings apply to sand foundations. For non sand foundation areas or areas with high water tables change the layout of the transformer bund by replacing the deep bund and included aggregate with an 'above ground' shallow bund where water or discharged oil is quickly drained via flame traps to an oil containment tank eliminating the need for aggregate infill. Bund reinforcement detail is to provide good control over cracking. The bund valve and pit is optional. The included flame traps and oil containment tank are to comply with relevant environmental standards.

3.3.6 Functional Specifications –132/22kV Zone Substation

Section 8.6 Environmental Compliance

- **Oil Filled Equipment** - Addition of subsurface agricultural drains draining to sumps or an oil containment tank especially in high water table areas can be installed to supplement the bunded areas to capture hydrocarbon spills that result from maintenance on the transformers or other electrical equipment.

Section 9.2.3 Physical Withstand Environment

- Referencing **Minimum Design Criteria for Civil Works** a heading and paragraph should present a general statement which states that the following load conditions applies to all civil works including earthworks and structures within the Terminal Yards where applicable, (not specifically only applicable to the 'shelter').

- Referencing the listed design criteria for wind loads Western Power's coverage zone apply to Wind Regions A1, A4 and B, not the cyclonic region C. In turn the Average Recurrence Interval (ARI) of 1 in 1000 years is nominated as an acceptable wind design criteria. The Importance Level is to be revised with reference to the current issue of the Building Code of Australia (BCA), Part B1, Table B1.2a.

- Referencing the listed design criteria for earthquakes from AS 1170.4. 1993, AS 1170.0 2002 Appendix D has been provided to link the requirements of AS 1170.4. 1993 with the new requirements in Part B1 of the Building Code of Australia (BCA) which include policy criteria in the form of importance levels and the associated annual probabilities of exceedance. The importance factor (I) has been replaced by the variation of annual probability of exceedance. The Structure Type is replaced by importance level. The Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 specifies the values to be considered at each substation site.

- Currently the 1993 version of AS 1170.4 is under revision. When it is reissued as a joint Australian/New Zealand standard it should be reviewed to see if it is still relevant for Western Power's design purposes. An alternative is to specify design criteria from the latest version of AS 1170.4, currently 2007 (where the Acceleration Coefficient maps of Western Australian Figures 2.3(d) and (e), AS 1170.4. 1993 are replaced by Hazard Factor (Z) for Western Australian Figures 3.2(C) and (D)).

- Referencing the design criteria for rainfall, specify an Average Recurrence Interval (ARI) for the substation of 1 in 20 year rainfall with the duration being site specific.

3.3.7 Concept Design – 132/22kV Zone Substations

Section 6.10.1 General (RRST Installation)

- Specify design wheel or axle loads for the RRST concrete apron in the standard or specify the drawings that list the design loads.

Section 9.1 Site (Civil and Structural)

- Specify the site development to include a balanced cut and fill method to construct the platform for terminal yard sites where suitable foundation material exists. The disturbed foundation material shall be compacted with a minimum of four passes of a vibrating 10 tonne roller.

- This section should specify the maximum cut/fill batter angles when constructing the terminal yard platform, for example 1 on 3 for sand.

- Specify the maximum slope of the terminal yard platform for drainage purposes is to be 1 in 40. Where sites are flat the minimum slope shall be 1 in 100.

- Specify the maximum slope of the access ramp(s) from the main road to the platform is 6% to allow the placement of the RSST unit within the terminal yard. The minimum road width on the platform should be 5 metres with corners to suit size of transformer delivery equipment, for example 15 to 20 metre radii.

Section 9.3 Footings

- Typical footing templates should be indicated for sand foundation material, sandy gravel foundation material and gravelly clay foundation material in Appendix 3 D. These footing templates may consist of a typical thick slab or typical pier footing to cover various foundation materials from predominately sand through clay to rock.

- Additionally typical, dimensioned footing templates, both slab and pier can be specified to apply to Wind Regions A1, A4 and B covered by Western Power. The templates are to be placed in Appendix 3 D.

Section 9.4 Structures

- Specify the respective Wind Regions, either A1, A4 and B and provide corresponding typical electrical equipment structural steel support templates to suit each region assuming say Terrain Category 2, Shielding Multiplier 1.0 and Topographical Multiplier 1.0.

Section 9.5 Outdoor Cable Trenches

- Reference the required maximum traffic loading (as axle loading or wheel loading) on the types of reinforced concrete box culverts and concrete lids in this clause or list the relevant template design drawings that state the maximum loadings.

- Specify, if relative levels allow, installing subsoil drains from the cable trench outfalls draining to the oil containment system or dedicated sump or pit collecting stormwater drainage prior to discharging off the site.

Section 9.6 Oil Containment

- Referring to the general description and issued drawings of Western Power's oil containment system the outflow would struggle to comply with a limit of a maximum of 15 parts per million of hydrocarbons released into the environment if the bund Oil Stop isolation valve failed during a transformer failure especially during a storm event where the resultant oil/water mix would form an emulsion as it passed through the series of holding tanks prior to discharging into the soak-well.

- An alternative, especially applicable in a high water table area, is to provide an above ground bunded area, free of gravel infill, surrounded by bund walls of 300mm minimum height with the Transformer supported on a 150mm to 300mm high raised plinth. The leaking oil is drained quickly through a pipe system that comprises flame traps and sediment traps into a containment tank. The tank is sufficiently sized to capture oil between internal baffles and use the time emulsified oil takes to flow through the tank to separate the oil from the emulsion and reduce the parts per million released into the environment. For smaller sites the oil containment tank can be reduced in size and coalescing plate separators installed downstream of the tank to separate the emulsified oil prior to discharging.

- For the oil containment arrangement above including the bunded catchment area feeding into the oil containment tank, the system shall be designed for a site rainfall of a 1 in 20 year event occurring simultaneously with a transformer failure.

- Install subsoil drains to surround electrical equipment that contain small volumes of oil or areas where oil may be spilt and drain to the oil containment system or a sump where stormwater drainage can be monitored prior to discharging from the site.

Section 9.11 Stormwater

- To assist in draining areas that trap water, for example where raised tops of cable ducts form barriers, an option is to install subsoil drains that discharge into drainage pits acting as a sediment trap prior to discharging off the site.

Section 9.13 Roads, Vehicle Access and Car Parking

Access Road Construction

- Where "25mm Hot-mix surface" is currently specified, suggest insert a minimum 40mm Hot-mix surface for transformer apron roads.

RRST Parking Area Construction

- Where a "170mm thick slab reinforced with SL92 mesh" is currently specified, suggest the RRST designated parking area is to be constructed of 170 thick concrete with a minimum of one layer of SL81 mesh reinforcement to provide a higher degree of crack control within the parking area slab to improve durability.

Provision for RRST Access

- Similarly referencing "Trafficable covers" where cable ducts cut across these RRST apron roads specify the maximum load ratings for the cable ducts and duct covers or list the design drawings on which the maximum load ratings are specified.

3.3.8 Drawing Template - Substation – 132/22 kV

Drawing SSYYY/1/10/1 - Cable Trenches Layout

- Refer to listed culvert load ratings including drawing number in the relevant Transmission Standard Designs documentation.

- Surround the blue metal in 'Typical Culvert Drain Detail' with geotextile to ensure surrounding foundation material does not contaminate the blue metal.

- Referring to drawing Notes: Modify note 5. to include 'with 6 passes of a vibrating plate compactor' and delete 'to its original state'.

Drawing SSYYY/1/10/2 - Cable Trenches Detail

Referring to drawing Notes:

- Modify note 1. to include 'with a compaction method of a minimum of 6 passes of a vibrating plate compactor.' and delete 'to 8 blows/300mmof a standard penetrometer.'

- Modify note 2. to increase concrete strength to Grade N32 minimum for coastal region sites.

Referring to 'Typical Insitu Trench Section', increase mesh reinforcement to a minimum size of SL92 to increase control over cracking and improve durability.

Referring to the 'Culvert Drain Detail' surround the blue metal with geotextile to ensure surrounding foundation material does not contaminate the blue metal.

Drawing SSYYY/1/8/1 - Foundations Layout

Referring to drawing Notes:

- Modify note 1. to include 'with a compaction method of a minimum of 6 passes of a vibrating plate compactor.' and delete 'to 8 blows/300mmof a standard penetrometer.'

- Modify note 5. to include 'with 6 passes of a vibrating plate compactor' and delete 'to its original state'.

3.3.9 Concept Design for 132kV Urban Wood Pole Lines

Section 5.3 Phase Conductor Insulators (Line Components/Performance)

- Referring to 5.3.1 should read 25.4mm/kV.

- Similarly, under 5.3.2 Line Post, should read 25.2mm/kV.

General Notes:

- All conventional bolted-type suspension clamps used on suspension structures shall be equipped with armour rods to protect the conductor from fatigue caused by Aeolian vibration. Further protection may be achieved by installing Stockbridge vibration damper (*Western Power reported that dampers are not required*).

- OHEW shall be connected to ground wire using 2 x 2 bolt parallel groove clamp (*Western Power reported that current clamps are oversized so 2 are not required*).

3.3.10 Drawing Template Standard 132kV Urban Wood Poles

Drawing T5000/6/3/1 - Suspension Polymer Firtree

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction procedure to be 8 passes of vibrating rammer or plate.

Horizontal post insulator (trunnion type) may not be practicable when used in large angles because it will be very difficult to sit the conductor on the clamp during stringing. (*Robert Fairweather from Western Power has reported that there have not been any problems with 15º so this is not seen as a problem*).

Horizontal post insulator (drop-tongue type) with suspension clamp may be used.

Drawing T5000/6/5/1 - Suspension Polymer Running Post

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction procedure to be 8 passes of vibrating rammer or plate

Drawing T5000/6/7/1 - Suspension Polymer Cruciform

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction

- procedure to be 8 passes of vibrating rammer or plate

Drawing T5000/6/9/1 - Terminal Polymer

Referring to drawing Notes:

- Modify Note 3. to state backfill around pole to be in 300mm layers and state compaction procedure to be 8 passes of vibrating rammer or plate

In the typical section showing the strain insulator assembly, the eyebolt used was identified as item 3. This should be item 5

Drawing T5001/6/8/1/1 - Steel Terminal Transition Pole Type TS0/13

- Under Design Notes Table; for the Venus Conductor under MWT, 18% should be 26%.

Drawing T5001/6/8/2/4 - Structure Details Steel Terminal Transition Pole Type TS0/13

- Bending radius of a 2000mm² XLPE with an outside diameter of 138mm **±**5% shall be no less than 4.103 m based on the formula 20(d+D) **±** 5%.

Drawing T5001/6/8/2/3 - Structure Details Steel Terminal Transition Pole Type TS0/13

- Continuous magnetic path around single phase cable leading to potential for inductive heating. Need to break loop, e.g. aluminium or stainless steel cover.

4. SUMMARY

The documentation supplied is generally consistent with standard practices adopted within Australia, taking into account specific requirements that apply in the various States. It demonstrates a solid, consistent, and appropriate approach to meeting the needs of an expanding network.

The reasoning behind the adopted approach, loading conditions, etc should be documented for future reference as this is not provided in the reviewed documents. This is essential as it becomes more difficult to modify the designs if the fundamental technical details underpinning the design are not understood or available. The "HV Extruded Cables Design and Installation Guide" is a good example of such knowledge capture.

The comments made in the evaluation are for general improvement or correction where there is an obvious error. However, as this has been a high-level review, it should not be assumed that all errors have been identified.

For future substation optimisation considerations it should be noted that, amongst others, Cigré Working Groups are currently preparing Technical Brochures on:

- "Circuit Configuration Optimisation";
- "Cost Reduction of Air Insulated Substations" (Publication end August 2008); and
- "Turnkey Substations".