# Mid West Energy Project

# (southern section)

## Planning Considerations

Date: August 2011

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# Contents

# Glossary

The following table shows a list of abbreviations and acronyms used throughout this document.

**Table 1: Abbreviations and Acronyms**

| Abbreviation / Acronym | Definition |
|---|---|
| the Code | *Electricity Networks Access Code 2004* |
| DTF | Department of Treasury and Finance |
| ERA | Economic Regulation Authority |
| MWEP | Mid West Energy Project |
| NFIT | New Facilities Investment Test |
| SWIS | South West Interconnected System |
| TST | Three Springs Terminal |
| UWA | University of Western Australia |
| WPN | Western Power Network |
| | |

# 1 Introduction

As part of the Mid West Energy Project (MWEP) (southern section) reinforcement, a number of detailed design considerations which had a significant impact on the project cost and performance were investigated. The key detailed design considerations identified are as follows:

1. Three Springs Terminal (TST) Design;
2. Provision of reactors for voltage control;
3. TST transformer sizing;
4. 330 kV conductor selection;
5. Connection of additional generation with the MWEP (southern section) installed;
6. Connection between TST and Three Springs Substation.

This report will assess different options available for each of the above key detailed design considerations with a recommendation provided.

The recommended options and other options evaluated are for the purposes of demonstrating that Western Power is efficiently minimising costs in relation to the MWEP (southern section) reinforcement and providing the lowest sustainable cost over a reasonable period of time to demonstrate compliance with NFIT.

# 2 Three Springs Terminal Design

## 2.1 Introduction

As part of the MWEP (southern section) reinforcement project the development of Three Springs 330kV Terminal (TST) is proposed to supply a new mining load at Karara and reinforce the existing 132kV network. To comply with section 2.5.2.3 of the Technical Rules 330kV substations are required to be designed to be capable of meeting the N-1-1 security standard. To achieve this requires either a breaker and a half or mesh arrangement.

This design report will consider the ultimate layout of TST and the implications of the costs, reliability, protection, automation and primary design upgrades moving from stage to stage of either a breaker and a half or mesh arrangement to achieve the final configuration.

## 2.2 Mesh (Ring) Configuration

The mesh arrangement is a single busbar substation in which the busbar is formed as a closed loop with only the disconnectors in series within the loop. The arrangement for the maximum six feeders is shown below in Figure 1.

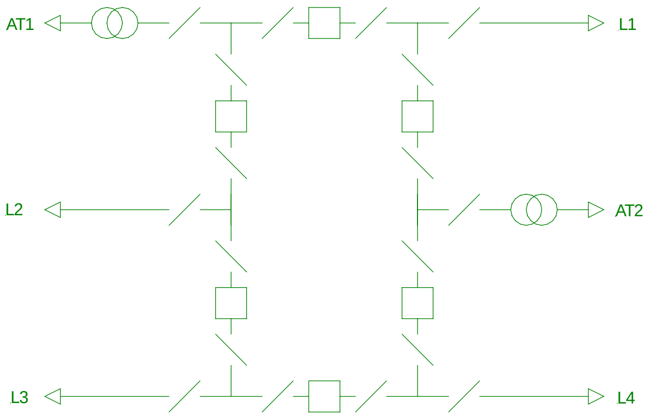

**Figure 1 Mesh (ring) arrangement.**

Where the total number of circuits exceeds six, the breaker and a half arrangement is preferable. This is due to the negative impact on reliability for the mesh as future expansion becomes difficult while maintaining sufficient security to the existing network circuits. Breaker and a half arrangements do not have the same negative reliability impact by increasing the number of circuits as the expansion does not limited by the initial layout and maintaining sufficient security to the existing network circuits.

Changing a mesh to a breaker and a half arrangement is not possible unless the yard is initially laid out as a breaker and a half. Laying the yard out as a breaker and a half can be more expensive than a mesh arrangement even though the breaker and a half is only configured as a mesh.

Using an initial mesh arrangement and layout will limit the possibility to expand the substation beyond six circuits. To achieve the mesh layout for six circuits the mesh has to be initially laid out for this number of circuits.

## 2.3 Breaker and a Half Arrangement

The breaker and a half arrangement is a double busbar substation where, for two circuits, three circuit breakers are connected in series between the two busbars, the circuits being connected on each side of the central circuit breaker. The arrangement for six feeders is shown in Figure 2 below;

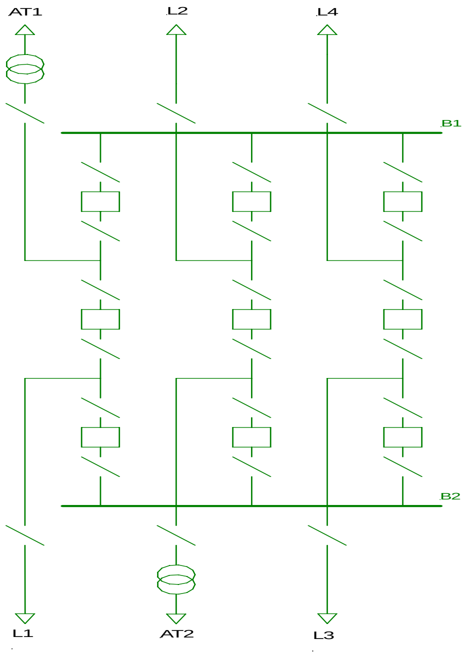

**Figure 2 Breaker and a half arrangement**

During the initial staged development of the breaker and half arrangement it will be possible to reduce the number of circuit breakers by directly connecting to the busbar. Also to limit the development of the breaker and a half arrangement during the initial stages it is possible to layout the busbar arrangement in a breaker and a half layout but configure it as a mesh.

Using the breaker and a half arrangement, additional circuits can be readily accommodated by expanding the busbar and associated primary plant, protection and automation.

## 2.4 Ultimate Layout for Three Springs Terminal

The ultimate development for TST considers up to 8 line circuits and two transformer circuits which leads to a requirement for a breaker and a half layout as shown in Figure 3.

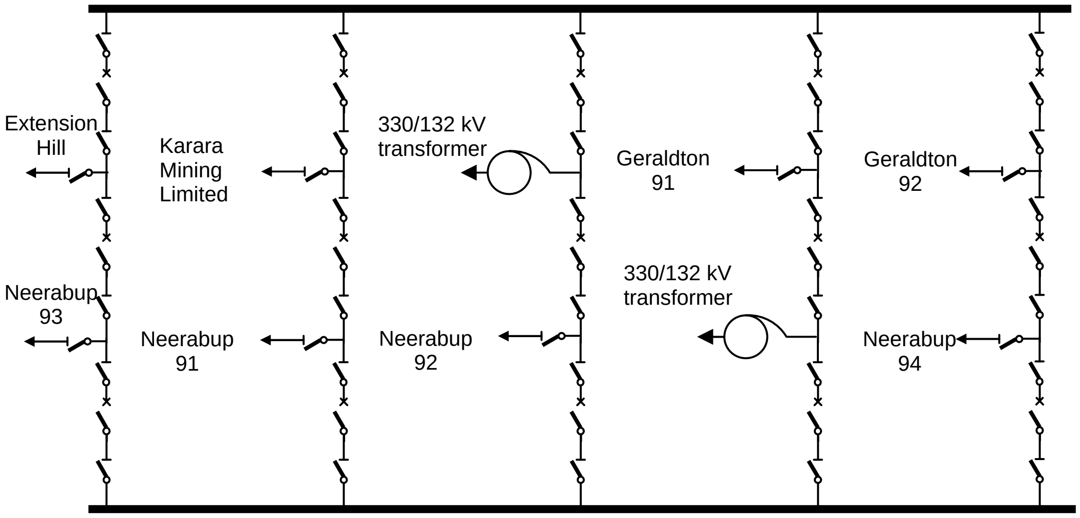

Figure 3 Ultimate arrangement of TST

Considering the final arrangement to supply Karara is shown in Figure 4. The connection to Karara and the 330/132kV transformer are shown connected to the same 330kV busbar to facilitate the interim supply arrangement supplied initially at 132kV from Eneabba. The 330kV line connected 50 Mvar reactor is shunt connected to the incoming Neerabup circuit and is switched through a 330kV circuit breaker. (not shown in the layout below).

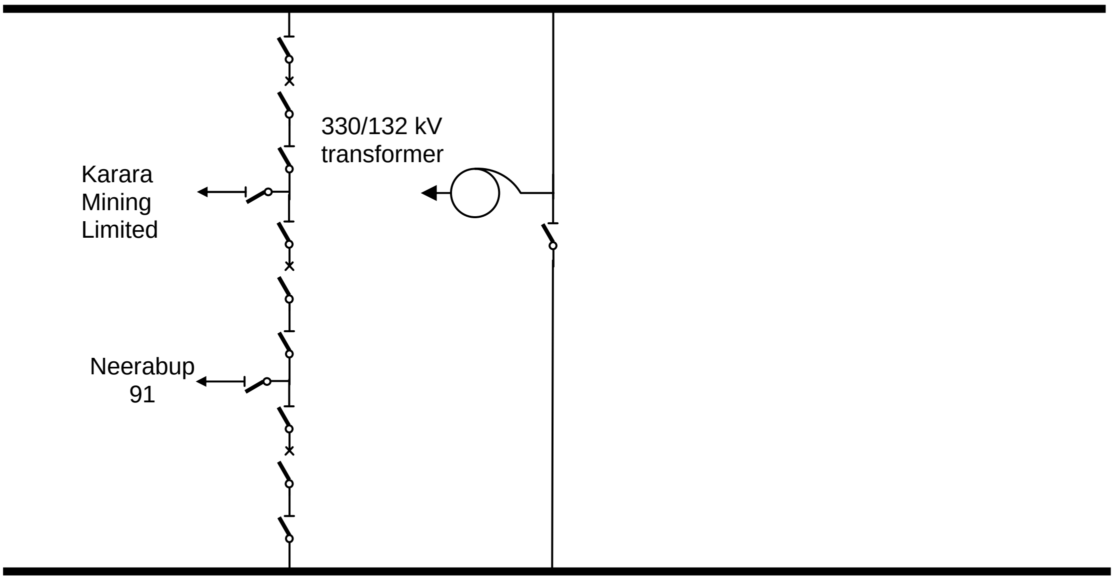

Figure 4: Final arrangement – Connection of Karara Mining Load

A review of costs to establish the terminal in the above manner, laid out as a breaker and a half but configured in a mesh layout, shows that the initial costs will be similar to establishing a mesh arrangement. The outline of cost differentials for the development of the breaker and a half and a mesh arrangement are shown in Attachment 1.

## 2.5 Future Development of Three Springs Terminal

TST shall be designed to minimise the impact of future development of the terminal on Karara and other customers. The initial layout must be capable of expansion to the ultimate layout at some time in the future. For this reason it is recommended that the Karara line circuit should be part of a fully completed bay. Consideration will be given to the transmission lines exiting the substation site to try and minimise future cross-overs.

Also under outages of the Neerabup to TST 330kV supply there is a desire from Karara to maintain a limited supply (10MW) supplied through the 132/330kV system. Studies have been completed to work through the capability to supply such a load in the future but nevertheless the capability should be present in the design.

It is also proposed that as the switchyard is developed that the combined 132 and 330kV earth grid shall also be developed incrementally to ultimately achieve the desired design rating. For the final supply to Karara it is proposed that a minimum earth grid rating of 15kA should be achieved which as the earth mat is expanded can be increased to the full 50kA. The fault level carrying capacity of the earth grid equipment should be rated at 50kA.

## 2.6 Conclusion

It is recommended that TST shall be constructed in a breaker and a half arrangement as opposed to a mesh arrangement to allow for a staged development of TST without impacting on the reliability of existing customers. As the proposed ultimate arrangement for TST will exceed six 330 kV circuits (as shown in Figure 3), a mesh arrangement is not preferable. Establishing a breaker and a half arrangement will preserve future development options to connect future loads in the Mid West and preserve a platform to reinforce to Geraldton.

As shown in Attachment 1, laying out TST for a breaker and a half arrangement but initially configured as a mesh, as opposed to laying out TST for a mesh arrangement, has a lower upfront capital cost.

# 3 Provision of reactors for voltage control.

## 3.1 Introduction

The effect of the 330kV circuit from Neerabup to TST during initial energisation and low load periods will cause voltage rise due to the 'Ferranti' effect on long transmission lines. System studies indicate that to minimise the impact of energisation of the 330kV line a total of 100Mvar of reactors would be required.

## 3.2 Summary of Previous Studies

The initial North Country Region project reinforcement to Geraldton suggested that using tertiary reactors on the 330/132kV transformer to control voltage on the transmission lines. The tertiary winding of the transformer has a continuous rating of 60MVA.

A review of this proposal suggested that this could put undue stress on the 330/132kV transformer during initial energisation and energisation after faults. A CIGRE paper[1] has documented the risks of energisation of long transmission lines and transformers. Using tertiary reactors would only allow energisation of the line and transformer together and this would put undue stress on the transformer.

A recommendation was made to consider the use of a 330 kV line shunt reactor to manage the voltage rise during energisation of the Neerabup to TST 330kV line. The approach to use shunt reactors is consistent with the methods to use voltage control elsewhere in Australia, eg Powerlink, Queensland.

## 3.3 Reactor Sizing for MWEP (southern section)

Studies have been carried out to determine the optimal size of the line shunt reactor. Studies have indicated a size of 50Mvar (330kV) would be needed to manage the voltage rise during energisation and limit step voltages to within 4%. The 330 kV reactor has been sized to manage the voltage to within acceptable levels. The 330kV reactor will require to be neutral earthed to facilitate high speed single phase auto reclose (HSSPAR).

It is proposed that once the 330kV line is energised then steady state voltage control will be managed through the provision of reactors connected to the 22kV tertiary windings of the TST 330/132kV transformer. The tertiary winding is rated at 60MVA and it is proposed that 2 x 25Mvar reactors will be connected to the transformer through circuit breakers to assist with connection of the reactor banks. Karara are considering 3 x 20Mvar 33kV busbar connected reactors to manage steady state voltages at their mining site. These reactors are embedded in the Karara network and will be used to manage voltages on site once the supply is energised.

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[1] Cigre (2006) A2-305 Transformer Internal Over-Voltages caused by remote energisation

## 3.4 Operation of 330kV line for MWEP (southern section)

To facilitate energisation (initial and after faults/outages), it is recommended that a single line reactor should be connected to the incoming Neerabup 330kV line at TST. The reactor should be shunt connected to the line through a 330kV circuit breaker and will have the ability to be switched independently of the 330kV line.

During an outage of the 330kV supply from Neerabup, the Karara load will be immediately reduced down to 10MW. The 330kV reactor will allow the re-connection of the Neerabup to TST 330kV line without the complete disconnection of the Karara load which could be supplied a minimal load through the existing Three Springs 132kV network.

When the Karara load is connected and the network is loaded up it is proposed to use the Karara reactors to maintain the voltage within statutory limits on site. Liaison between Western Power and Karara will be required to ensure the switching of reactors are coordinated.

The estimated plant purchase cost of the 50Mvar 330kV reactor is $4.6M and each 22kV 25Mvar reactor is $440k (excluding the cost of the switchgear).

# 4 Three Springs Terminal - Transformer Sizing

## 4.1 Introduction

Western Power will use a 490MVA 330/132kV transformer at Three Springs. The transformer has been sized based on a number of factors. The transformer has a 60Mvar 22kV tertiary winding which will be used for connecting 2 x 25Mvar reactors for voltage control.

## 4.2 Load Forecasts

A number of prospective loads are due to connect in the Mid West (northern section) over the next 20 years. The projected Geraldton peak load forecast is shown below;

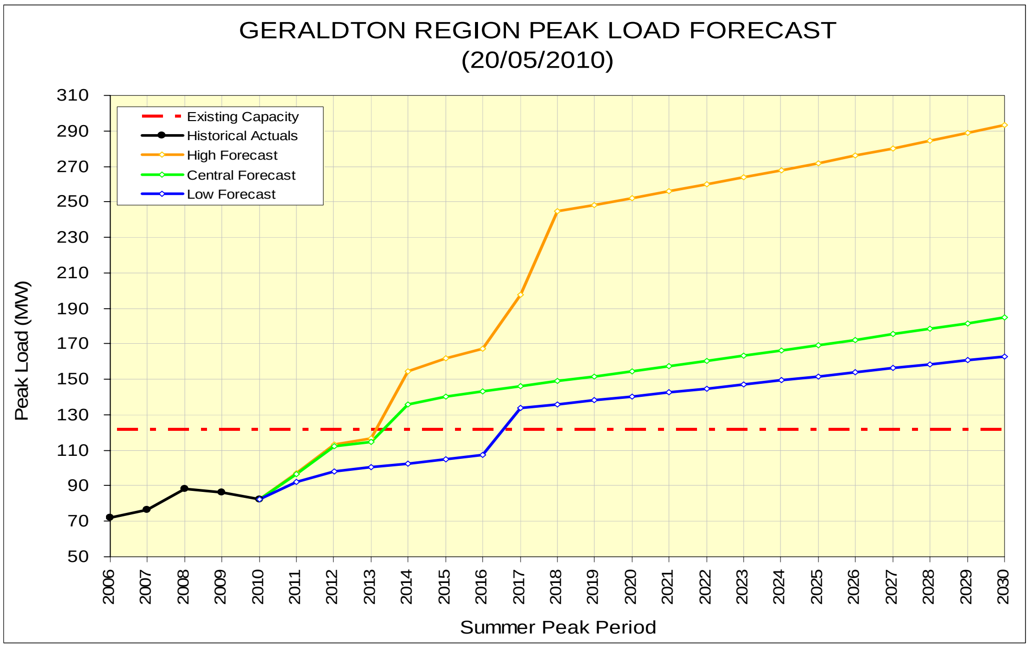

**Figure 5 Geraldton Peak Load Forecast (Region North of Three Springs)**

Note: The Geraldton region network limit indicated above (122MW) is due to the thermal limit of the existing transmission lines between Mungarra and Geraldton, net of N-1 line losses.

The projected loading under the high forecast ranges from 2012 – 122 MW in 2012 and up to 248 MW for 2020.

The use of the 490MVA transformer allows a staged approach to the MWEP (northern section). The MWEP (northern section) was originally proposed as a 330kV double circuit line from Eneabba to Geraldton and the establishment of a 330/132kV terminal near to Geraldton.

The establishment of TST with the MWEP (southern section) will allow a lower cost MWEP (northern section) alternative by extending from Three Springs to Geraldton using a 330kV constructed line operating at 132kV voltage until the voltage upgrade is required. This connection will offer:

- 330kV construction with 132kV operation;
- The loading on the 330kV line operating at 132kV will exceed the capacity of a smaller transformer (250MVA) unit by 2017 using the 60Mvar capacity of the tertiary reactors. A second 330/132kV transformer will be required in 2015/16 to provide (N-1) capability at TST;
- A larger transformer will allow continual operation at 132kV for a longer period and will defer the establishment of a future 330kV terminal at Geraldton, preserving future options;
- Allow an optimised solution to be implemented for the MWEP (northern section) which will also consider the replacement of the existing Three Springs - Geraldton 132kV lines which are approaching 35 years old;
- A smaller transformer, eg 250MVA with tertiary winding would require an earlier line upgrade to 330kV as the capacity of the smaller transformer would be exceeded. A cost benefit analysis undertaken shows the deferral of the Northern Terminal in Geraldton by one year exceeds the additional cost of the larger transformer[2];
- Western Power is processing a 200MW access application for Crosslands Resources (Jack Hills) to connect a large mining load (560km NE of Geraldton). It will require a 200MW connection at Three Springs (132kV) to connect into a proposed HVDC link to its mine site (560km) NE of Geraldton.

- Crosslands Resources has confirmed a preference for a 132kV connection at TST into their proposed HVDC convertor as a lower cost connection option from Three Springs Terminal. The proposed connection would require the 2nd stage of the MWEP (southern section) to be uprated to 330kV operation. The upgrade would require a 2nd 330/132kV transformer at Three Springs Terminal.
- Crosslands has indicated that it is also planning for a second 200MW connection that would support expansion of its processing operation. This connection would require the additional capacity afforded by the 490 MVA transformer units.

The use of a 490MVA transformer with a 60Mvar reactor allows the MWEP(northern section) 330kV option to be staged and defer future expenditure.

## 4.3 Use of 22kV Reactors for Steady State Voltage Control

The 60MVA tertiary winding allows the connection of lower voltage reactors (2x25Mvar at 22kV), these reactor loads are considered in the transformer rating. A

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[2] See DM 8493616 – Investment Evaluation Model for Geraldton Terminal

tertiary winding is necessary for stabilisation with the auto-transformer. Western Power uses a 330/132kV transformer specification that has a 60Mvar tertiary winding. The tertiary winding allows the connection of smaller tertiary connected reactors which is a lower cost alternative to a further 330kV reactor.

## 4.4 Financial Analysis

Under the high forecast for the Mid West which is the most likely scenario, the MWEP (southern section) would require upgrade by 2015/16 as reported in the approved Regulatory Test for the MWEP (southern section). This will require the 2nd 330/132kV transformer to be installed at TST by 2015/16. With lower rated 330/132kV transformer units (250MVA) a further transformer unit will be required as early as 2017 to meet the emerging load in the Geraldton region.

A financial analysis was completed for options using 250 and 490MVA units at Three Springs[3]. The analysis shows that with 490MVA transformer units only two transformers are ultimately required, however using the lower rated 250MVA units a third transformer is required as early as 2017 under the high load forecast (without Jack Hills connected at Three Springs 132kV).

A new 330/132kV transformer installation at TST will be advanced (2014) to coincide with the Crosslands Resources (Jack Hills) connection application onto the 132kV busbar at TST with lower rated 330/132kV transformer units (250MVA). This scenario was excluded from the financial analysis.

A summary of the financial analysis has been included in Attachment 2 which shows that there is a $8.6M saving using the proposed 490MVA transformer units, rather than 250MVA units. The 490MVA units will be sufficient to cover for all load scenarios and provide sufficient capacity for the proposed connection of Crosslands Resources (Jack Hills) mining load.

## 4.5 Conclusion

The 490 MVA transformer rating was selected for Three Springs due to the following reasons:

- It provides the ability to supply the Geraldton region load forecast under all of the low, central and high scenario's. A second 330/132kV transformer will be required in 2015/16 under the high load growth scenarios to provide (N-1) capability; and
- It allows a lower cost augmentation options for supplying the Geraldton region by deferring the need for 330kV operation of new transmission line to Geraldton. A 490MVA transformer allows proposed new lines constructed for 330kV to be initially operated at 132kV deferring the establishment of a 330kV terminal at Moonyoonooka.

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[3] See DM 8452685 - Investment Evaluation Model for TST

Estimated savings associated with this choice over a 250 MVA transformer is \$8.6M[4] based on the high load forecast.

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[4] DM8452685 Investment Evaluation Model for TST

# 5 Conductor Selection for 330kV Double Circuit line

## 5.1 Introduction

The conductor selection process was undertaken with the main objective of choosing the optimised conductor for the transmission lines by maximising the design life and capacity, also reducing the losses over the transmission lines design life.

The proposed Pinjar to Eneabba transmission lines will be built close in proximity to the ocean with prevailing winds. An ACSR (Aluminium Conductor Steel Reinforced) conductor with an aluminium clad steel core was chosen to minimise the risk of steel corrosion.

Within the ACSR/AC range of conductors, several size conductors were analysed for their suitability. Western Power carried out Net Present Value analysis to find the most economical size conductor by comparing the losses over the transmission lines life.

## 5.2 Load Forecast

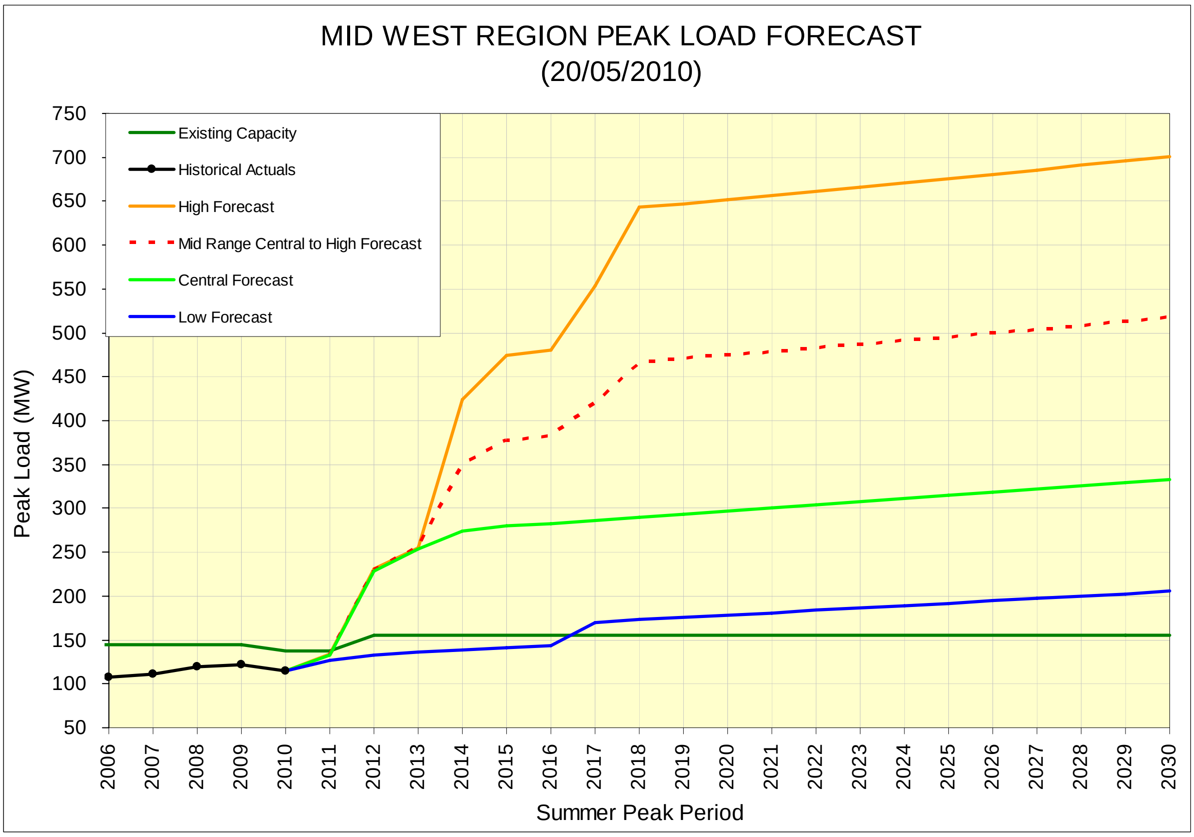

**Figure 6 Mid West Region Peak Load Forecast**

Western Power’s load forecast indicated a significant increase over the next 20 year period. The low forecast was based on the natural load growth, while the central and high forecast included the connection of mines in the Mid West region.

The central load forecast included Karara mine stage 1 connection, while the high forecast in addition includes both Karara stage 2 and Extension Hill mine connections.

The net present value calculation used the central and high forecast to ensure prudency, as both Karara and Extension Hill are likely to establish their application for new connection within the next 5 year period. [5]

## 5.3 Cost of Losses

There are two main contributing factors to conductor losses, corona and conductor resistance. In order to optimise the conductor chosen for the transmission lines, it is imperative that the cost of losses are minimised.

1. **Corona Losses**
   The design of the transmission line must cater for a satisfactory corona performance to reduce the effects of corona discharge, one of which is corona losses. Conductor configuration and multiple conductors per phase would lower the corona onset gradient. In addition, the conductor surface state coefficient would affect the result of the corona losses calculation significantly.

2. **Joule Losses**
   The losses contributed from the conductor’s resistance are inevitable. However, depending on the load and the conductor selected, the resistive losses could be minimised.

The cost of losses was determined from 1 June 2008 to 15 April 2011 statistical Short Term Energy Market (STEM) data, the weighted average rate was calculated to be $36/MWhr.[6]

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[5] In addition, sensitivity analysis for the central/high load forecast was used and this load case is comparable with Karara stage 1 and 2 or Karara stage 1 and Extension Hill stage 1.

[6] The statistical data can be found in DM#8213588

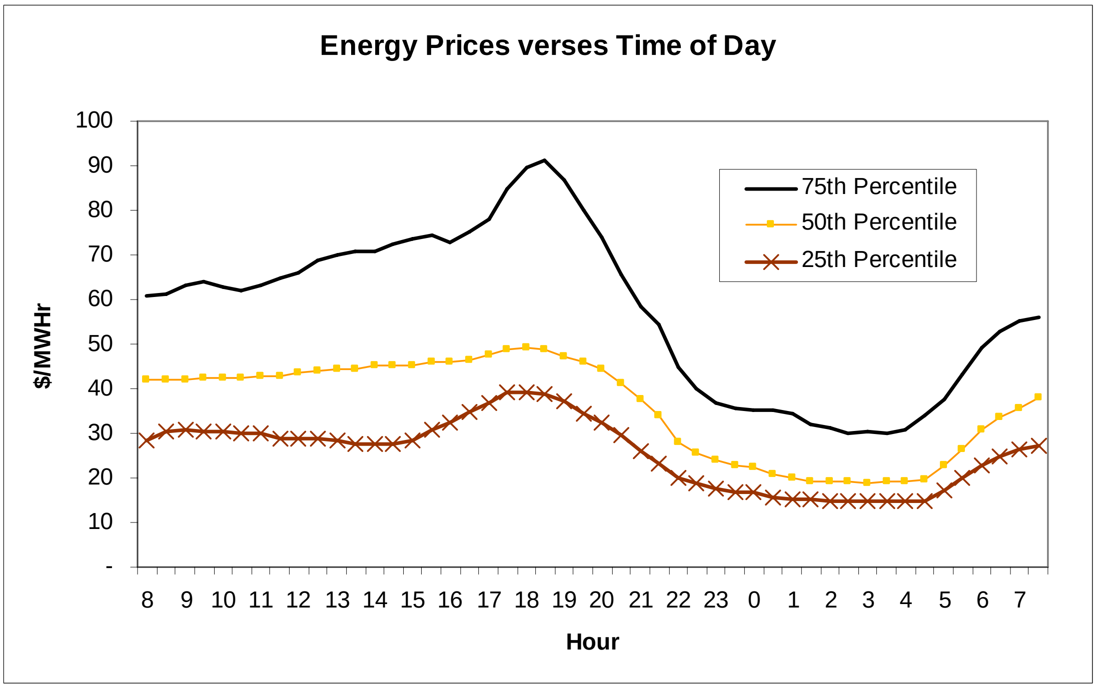

**Figure 7 Energy prices versus time of day**

# 5.4 Financial Analysis

## 5.4.1 Capital Cost

To calculate the Net Present Value, an estimated capital cost must be established. The capital cost was based on twin bundle configuration. As expected, the capital cost is proportional with the size of the conductor. Although the capital cost of the conductor itself is small in comparison to the overall capital cost, the conductor selected will determine the load of the structures, and subsequently the foundation design.

Table 2 below shows the incremental capital cost for the three conductor candidates using Gymnastics as the (lowest) base value for comparison:

**Table 2 Incremental Costs for Selected Conductors**

| Conductor | Diameter (mm) | Additional Capital Cost ($ million) |
|---|---|---|
| Gymnastics | 29.3 | 0 |
| Hurdles | 31.5 | 2.76 |
| Lacrosse | 33.8 | 6.04 |

### 5.4.2 Joule Losses

To determine the line losses, a 40 year load forecast was used as this represent the economic life of the line. As no forecast data was available after 20 years, it was assumed that the load beyond 2030 is constant.

The formula below was used to calculate the joule losses:

$$Current = \frac{Load}{\sqrt{3} \cdot x \cdot Voltage \cdot x \cdot PowerFactor}$$

*Losses = Current*$^2$ *x Conductor Resistance x 3 x Load Loss Factor x Line Length*

*Load Loss Factor = 0.8 Load Factor*$^2$ *+ 0.2 Load Factor*

As shown in the graph below, Lacrosse conductor generates the lowest resistive losses (Joule losses). The graph below shows the central load forecast with load factor of 0.7.

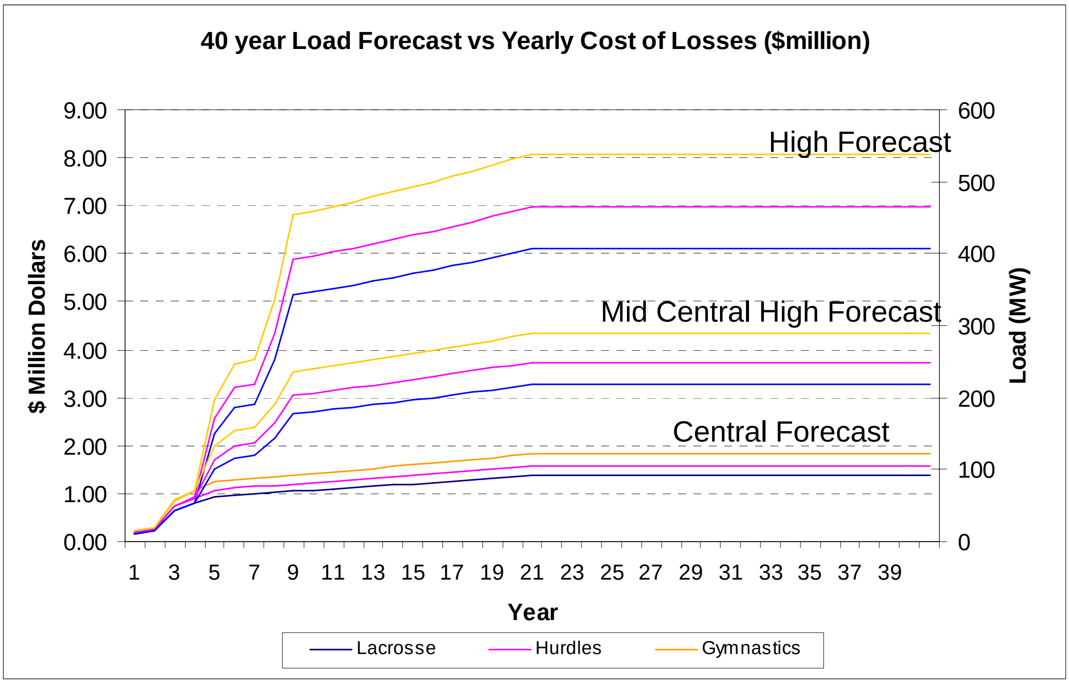

**Figure 8 Yearly Cost of Losses versus 40 year Forecast**

Western Power undertook a study which shows that approximately 75% of the load in the Mid West region will be carried by the 330kV line with the remaining 25% carried by the 132kV network.[7]

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[7] A range of studies have been completed which showed the 330kV line carry between 72% to 82% of the system load in the mid west region DM#8154715.

### 5.4.3 Corona Losses

The losses based on corona discharge vary in accordance with the conductor surface state coefficient. Western Power commissioned University of Western Australia (UWA) to undertake a study to investigate the effect (sensitivity) of the conductor surface state coefficient on corona losses for 3 ACSR/AC conductors (Lacrosse, Hurdles and Gymnastics). UWA study shows that for a conductor surface state coefficient of 0.56 or greater, Lacrosse conductor in twin bundle configuration shows no corona losses.

**Table 3 Conductor State Coefficient for Selected Conductors**

| Conductor Surface State Coefficient | Corona Power Loss (kW/km) | | |
|---|---|---|---|
| | Gymnastics | Hurdles | Lacrosse |
| 0.54 | 67.99 | 34.87 | 11.23 |
| 0.56 | 47.16 | 13.61 | 0 |
| 0.58 | 24.67 | 0.91 | 0 |
| 0.60 | 8.98 | 0 | 0 |

### 5.4.4 Net Present Value

As the corona power losses for Gymnastics were significantly higher than Hurdles and Lacrosse, further net present cost sensitivity studies were undertaken for the latter two conductors to determine the optimum conductor. Positive values indicate where Lacrosse is more cost efficient than Hurdles.

The results of this sensitivity analysis can be found below:

**Table 4 Conductor State Coefficient Sensitivity Analysis**

| Conductor Surface State Coefficient | Load Forecast | Load Factor | | | | |
|---|---|---|---|---|---|---|
| | | 0.6 | 0.65 | 0.7 | 0.75 | 0.8 |
| | | NPC of Losses ($million's) – (40 years) | | | | |
| 0.6 | Central | -1.82 | -1.63 | -1.42 | -1.21 | -0.98 |
| | Mid Central High | -0.09 | 0.35 | 0.82 | 1.32 | 1.86 |
| | High | 2.34 | 3.15 | 4.01 | 4.92 | 8.14 |
| | | | | | | |
| 0.58 | Central | -0.97 | -0.78 | -0.57 | -0.36 | -0.13 |
| | Mid Central High | 0.76 | 1.2 | 1.67 | 2.17 | 2.71 |
| | High | 3.19 | 4 | 4.86 | 5.77 | 8.99 |
| | | | | | | |
| 0.56* | Central | 10.99 | 11.18 | 11.39 | 11.6 | 11.83 |
| | Mid Central High | 12.72 | 13.16 | 13.63 | 14.13 | 14.67 |
| | High | 15.15 | 15.96 | 16.82 | 17.73 | 20.95 |
| | | | | | | |
| 0.54 | Central | 17.59 | 17.78 | 17.99 | 18.2 | 18.43 |
| | Mid Central High | 19.32 | 19.76 | 20.23 | 20.73 | 21.27 |
| | High | 21.75 | 22.56 | 23.42 | 24.33 | 27.55 |

*0.56 is the likely conductor surface state coefficient

Sensitivity analysis shows that Lacrosse is the conductor of choice over Hurdles for 49 cases out of 60 and for that reason has been chosen for the MWEP (Southern Section).

## 5.5 Conclusion

It is recommended that the conductor selected for the Pinjar to Eneabba 330kV double circuit lines to be Lacrosse ACSR/AC conductors based on the following:

- Geographical location of the lines, aluminium clad steel should be used to reduce the risk of corrosion;
- The total capital cost difference between Lacrosse and Hurdles is in the order of $3 million dollars, however the cost of losses by choosing Lacrosse conductor can be substantially reduced;
- Twin Lacrosse generates less corona losses compared to Hurdles at conductor surface state coefficient below 0.6, which is likely to be the case due to the environment the line will tranverse;
- Lacrosse is the more cost efficient option for load forecast higher than central forecast;
- Lowest conductor resistance which will provide higher capacity over the life of the transmission lines for connection of prospective load and generation;
- Even though extra capacity provided by Lacrosse conductor is not a main driver for the conductor selection, the additional capacity gives flexibility for the future planning of the region;
- Reduction in corona and line losses (joule) provided to the network makes it prudent choice for the MWEP (southern section)

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# 6 Connection of additional generation as a result of the MWEP (Southern Section)

## 6.1 Introduction

The connection of additional generation is a key consideration to the net benefits analysis presented in the MWEP (southern section) NFIT proposal. The ability to consider the connection of future generation is the result of increased circuit capacity and the connection of future loads in the Mid West which the generation will net off.

## 6.2 Load Forecast

As shown in section 5.2 (see Figure 6), Western Power's load forecast indicated a significant increase over the next 20 year period. The low forecast was based on the natural load growth, while the central and high forecast included the mine connection in the Mid West region.

The central load forecast included Karara mine stage 1 connection, while the high forecast in addition includes both Karara stage 2 and Extension Hill mine connections.

The studies considered the central and high forecast to ensure prudency, as both Karara and Extension Hill are likely to establish their application for new connection within the next 5 year period.
The forecast suggests the projected increase in load for 2014 is as follows;

- Central forecast – 125MW
- Mid range Central – High forecast – 200MW
- High forecast – 375MW

The bulk of this new load is base load mining load or activities associated with the mining industry.

## 6.3 System Studies

Western Power studies undertaken show that the MWEP (southern section) installation results in an additional 155MW of wind generation capacity becoming available without the Karara load or any other new mining loads connected. The addition of overnight load will further increase the generation capacity that can be accommodated. The Karara load is expected to be initially at 85 MW at steady state operation[8] which would increase the available generation capacity to at least 240 MW excluding additional load growth in the Mid West.

ACIL Tasman was engaged by Western Power to undertake a series of electricity market projections to assist in estimating the market net benefits with the MWEP

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[8] See DM 8238564

(southern section) reinforcement[9]. ACIL Tasman assumed that 230 MW of wind generation could be accommodated with the MWEP (southern section) installation and found that development of this generation is likely to be economic.

## 6.4 Ability of the Western Power Network to Accept Further Windfarm Generation

Western Power has produced a report on the impact of connecting more windfarm generation to the Western Power Network (WPN)[10] This report covers many of the issues that the network faces with increased levels of windfarm penetration. These include some of the following issues;

- Increased load following requirement by Open Cycle Gas Turbine (OCGT) Technology;
- Emergence of overnight issues due to limited turn down capability of base load plant; and
- Difficulty in achieving scheduling balancing in the market.

ROAM consulting has also produced a public report[11] which considers the impact on the WPN of connecting increased levels of intermittent renewable generation and the impact on the requirement for Frequency Control Services (FCS).

## 6.5 Impact on System Stability

The impact on system stability will be modelled with each connection application. These studies will identify any stability issues which will need to be resolved before connection can proceed. System Stability issues are minimised with the use of modern windfarm technology. These include the use of invertor and statcom technologies.

The impact of system stability is not expected to be a limiting issue for windfarms once the MWEP (southern section) has been constructed.

## 6.6 Conclusion

The ability to connect an additional 230MW of windfarm generation onto the WPN network as a result of the MWEP (southern section) Stage 1 can be justified by the net increase in load and the capacity increase offered by the MWEP (southern section) network reinforcement.

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[9] DM 7254479 - Net market benefits of Mid West transmission link

[10] DM 6504853 – Effects of increased penetration of intermittent generation in the SWIS.

[11] DM 7187911 – ROAM Assessment of Frequency Control Services

# 7 Connection of 132kV circuit from Three Springs Terminal (final arrangement)

## 7.1 Introduction

Consideration was given to the future connection of the 132kV circuit from TST to the existing Three Springs Substation.

The existing 132kV busbar is limited in capacity to 600A (120MW at 0.9pf) with the initial limitation being the 132kV disconnectors in the substation. Stranded copper conductor is used as the busbar 37/2.36mm (37/0.093 inch) which is rated at 644A.

There are two options for the future connection of the 132kV circuit.

1. Connection to the west side of the 132kV busbar adjacent to the Mungarra circuits or connection to the east side of the 132kV busbar adjacent to the Golden Grove 132kV circuit;
2. Connection to the east side is shown in Figure 9 below.

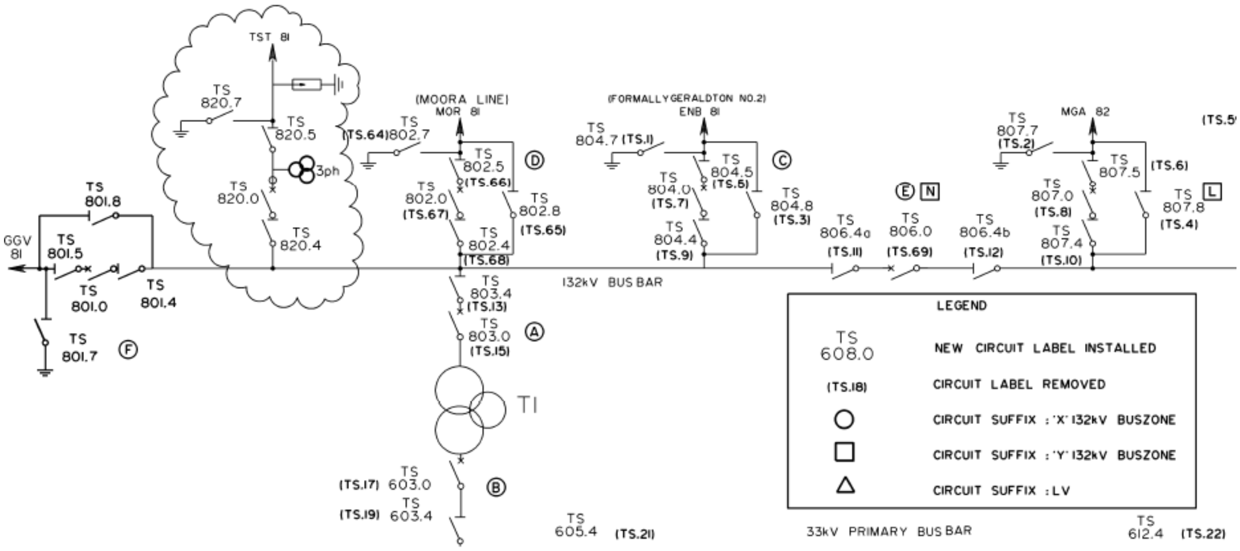


**Figure 9 Three Springs Substation Layout**

Connection to the east side would limit load (north of Three Springs) and generation (flowing south of Three Springs) to 120MW.

Advantages of connection of new 132kV circuit from TST to the west 132kV busbar:

- Ability to transfer more MW transfer from generation in the Mid West area in the near future (approximately 20MW).

Disadvantages of connection of new 132kV circuit from TST to the west 132kV busbar:

- Cost of additional line works (6 poles) crossings and bus – section extension;
- Cost of protection upgrades (Mungarra check synchronisation and black start capabilities, Protection setting of Pole slip relay);
- No additional MW flow north as the Three Springs to Mungarra circuits are voltage constrained below the 120MW capacity of the Three Spings busbar; and
- Above advantage will only last until the Mid West Energy Project Stage 2, when new 132kV circuits (assuming a staged approach) will have to come from either the new 132kV switchyard at TST or the section of busbar at Three Springs linked to the 330/132kV transformer infeed.

It is estimated that there will be an additional cost of $0.7 to $0.9M extra cost in line works and protection in achieving a connection to the west busbar as compared to the east.

## 7.2 Recommendation

It is recommended the additional circuit from TST through the 330/132kV transformer be connected to the east 132kV busbar at Three Springs to deliver future capacity to the Mid West and minimise expenditure.

# Attachment 1 – Three Springs Terminal Cost Comparison (Mesh and Breaker and a half arrangements)

## INTRODUCTION

This is a high level cost comparison between establishing:

- a breaker and a half layout initially configured as a mesh; and
- a mesh layout.

A specific design scenario has been selected as a basis for the comparison. The breaker and a half layout initially configured as a mesh is estimated based on the layout shown in Figure 10 whereas the mesh layout is estimated based on the layout shown in Figure 11.

## ASSUMPTIONS

1. Costs are based on metropolitan area typical construction costs (as per Western Power Estimating templates) as a basis for the comparison. Note that country locations can be 10% to 30% higher, depending on exact location;

2. Tubular busbar supply and installation costs and overhead strung busbar/conductor costs have been considered equivalent.

3. The following costs were assumed to be the same for both comparison cases:
    a) Secondary design and construction costs;
    b) Civil/structural and primary electrical design and drafting costs;
    c) Planning, Project Management and Environment, Community Engagement and Approval costs; and
    d) Lightning masts costs.

## COST COMPARISON

The following construction costs of gantry structures in breaker and a half layout (foundation & structure) have been allowed for:

**Table 5 Cost Comparison**

| Item | Cost |
|---|---|
| First gantry (2 legs & 1 beam) | [redacted] |
| Second gantry (1 leg & 1 beam) | [redacted] |
| Combined structure (pair) | [redacted] |
| Cost of Mesh substation gantry | [redacted] |

The following rates have been allowed for in the cost comparison for a mesh layout and a breaker and a half layout:

**Table 6 Rates for Comparison**

| Item | Rate |
|---|---|
| Fencing | [redacted] |
| Site preparation | [redacted] |
| Site surfacing | [redacted] |
| Internal Roads | [redacted] |
| Busbar support structure | [redacted] |

## COST DIFFERENCES - MESH COSTS EXCEEDING BREAKER AND A HALF

Using the mesh layout as a basis, the cost difference between:

a) A mesh layout as shown in Figure 11; and
b) A breaker and a half layout initially configured as a mesh as shown in Figure 10

for the MWEP (southern section) Stage 1 is shown as follows:

**Table 7 Cost Difference between Mesh and Breaker and a half**

| Item | Approx Difference |
|---|---|
| Mesh site preparation | +245k |
| Mesh surfacing | +253k |
| Mesh fencing | + 77k |
| Mesh internal roads | - 48k |
| Mesh gantries | - 975k |
| Mesh supports | +690k |

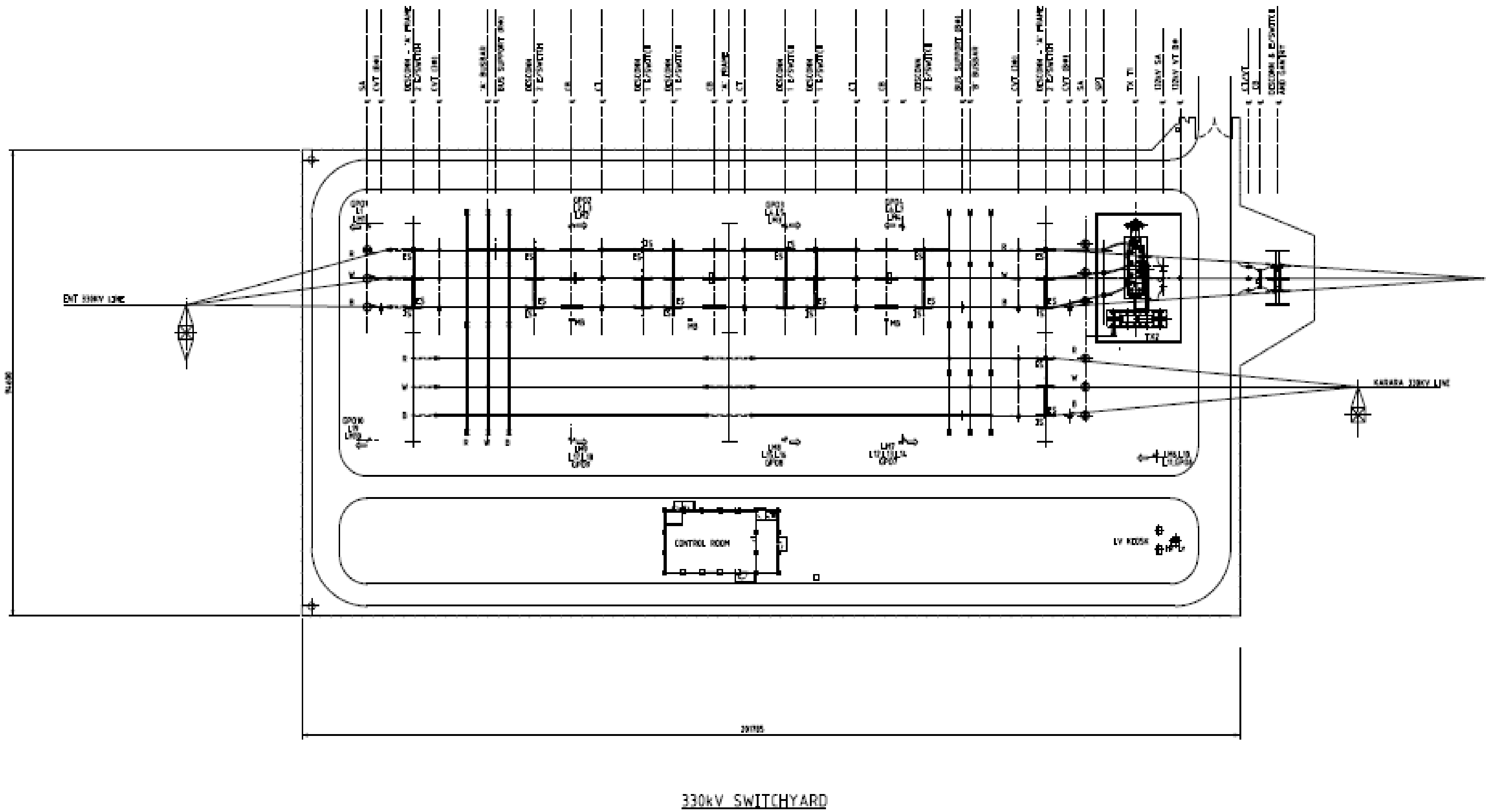
**Overall Increase +242k (say $240k)**

Therefore, based on the above estimate and assumptions used, a breaker and a half layout initially configured as a mesh is $240k cheaper than developing the initial layout as a Mesh.

## SUMMARY

The above high level comparison shows the initial development as a breaker and a half layout configured as a mesh has a lower upfront capital cost of approximately $240k. Proceeding with this arrangement will also preserve future development options to connect future loads in the Mid West and preserve a platform to reinforce to Geraldton.

## Figure 10 TST Breaker and a half arrangement - configured initially as a mesh



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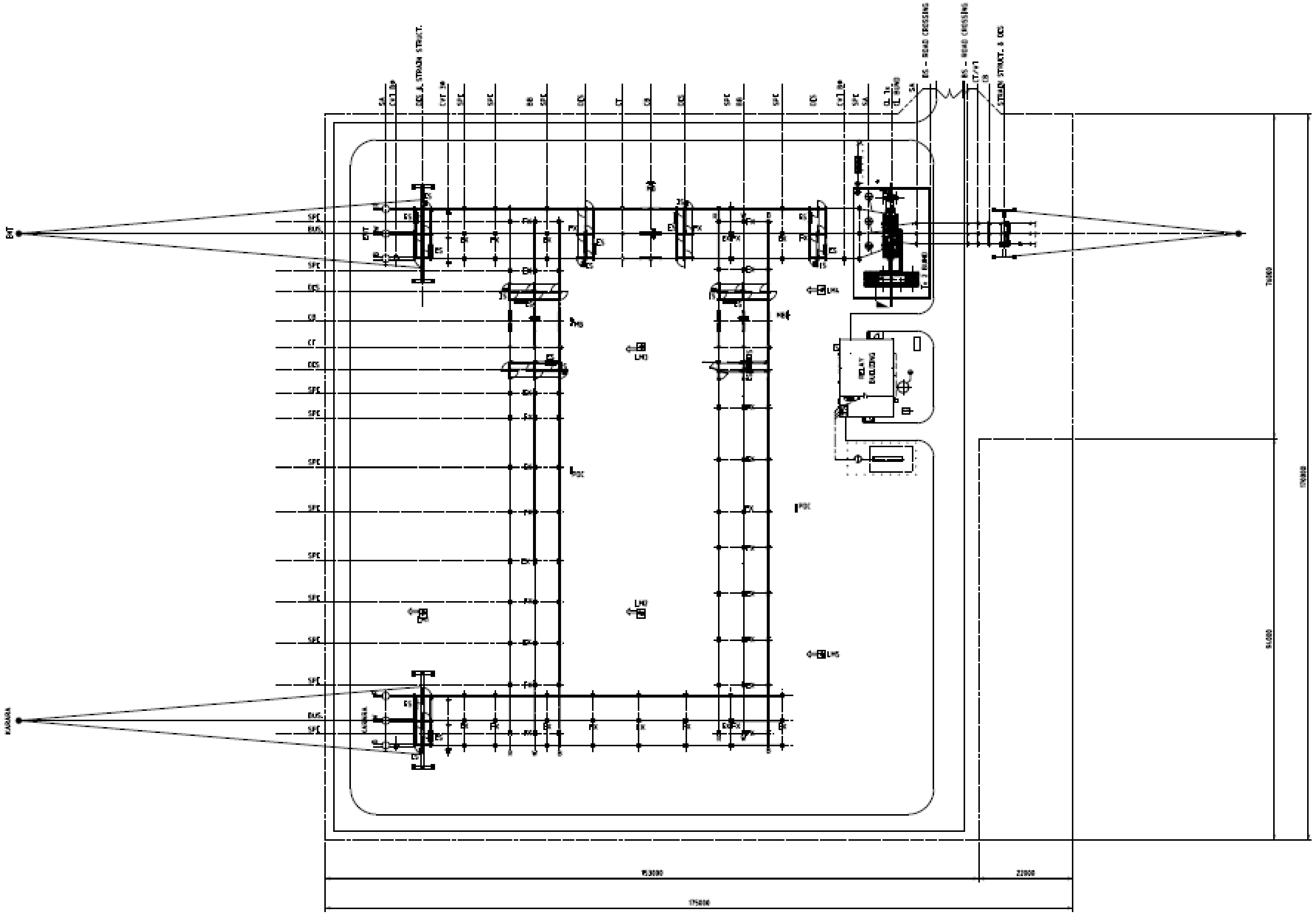
## Figure 11 TST mesh arrangement



# Attachment 2 –Three Springs Terminal Transformer Sizing Financial Analysis

## 1. Using 490 MVA transformers – two units required in 2013 and 2016

**Output NPV = $34.55M**

## 2. Using 250MVA transformers – three units required in 2013, 2016 and 2017

**Output NPV = $43.12M**

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