

---

PROPOSED MAJOR  
AUGMENTATION TO THE  
ELECTRICITY NETWORK

330KV TRANSMISSION LINE TO  
SUPPORT ELECTRICITY LOAD IN  
THE PERTH METROPOLITAN AREA

---



November 2008

Document release information

Client	
Project name	
Document number	5280249
Document title	PROPOSED MAJOR AUGMENTATION TO THE ELECTRICITY NETWORK - 330KV TRANSMISSION LINE TO SUPPORT ELECTRICITY LOAD IN THE PERTH METROPOLITAN AREA
Revision status	Version 4

Document prepared by:

Western Power  
ABN 18540492861

© Copyright of Western Power

Any use of this material except in accordance with a written agreement with Western Power is prohibited.

**Disclaimer:**

*While care was taken in the preparation of the information in this document, and it is provided in good faith, Western Power accepts no responsibility or liability for any loss or damage that may be incurred by any person acting in reliance on this information or assumptions drawn from it. This document has been prepared in accordance with clause 9.20 of the WA 'Electricity Networks Access Code 2004' for the purpose of the Economic Regulation Authority and interested parties regarding a proposed new large network asset. The document has been prepared with consideration of information provided by a number of third parties. It contains assumptions regarding, among other things, economic growth and load forecasts that, by their nature, may or may not prove to be correct. Western Power advises that anyone proposing to use this information should verify its reliability, accuracy and completeness before committing to any course of action. Western Power makes no warranties or representations as to its reliability, accuracy and completeness and Western Power specifically disclaims any liability or responsibility for any errors or omissions.*

## TABLE OF CONTENTS

	<b>EXECUTIVE SUMMARY</b>	<b>4</b>
1	INTRODUCTION	7
2	BACKGROUND: EXISTING ELECTRICITY SUPPLY SYSTEM	8
3	BACKGROUND	10
	3.1 Electricity Demand Forecast	10
	3.2 Load duration curves and the changing generation pattern	12
4	BACKGROUND: GENERATION DEVELOPMENTS	15
5	REASONS AUGMENTATION IS REQUIRED	17
6	OPTIONS CONSIDERED	18
	6.1 NON-NETWORK OPTIONS	18
	6.1.1 Demand Side Management	18
	6.1.2 Generation	18
	6.1.3 Reactive Support from Existing Generators	19
	6.2 NETWORK OPTIONS	19
7	OPTIONS ANALYSIS	21
	7.1 TECHNICAL COMPARISON OF NETWORK OPTIONS	21
	7.1.1 Option 1 – Establish a new 330kV transmission line from Landwehr Terminal to South-East Terminal	21
	7.1.2 Option 2 - Establish South East Terminal and reinforce Landwehr Terminal	23
	7.1.3 Option 3 – Establish South East Terminal and provide additional reactive support at Guildford Terminal	25
	7.1.4 Option 4 – Install an SVC at Northern Terminal, followed by Landwehr Terminal to South East Terminal 330kV transmission line	27
	7.1.5 Option 5 – Series compensation of 330kV bulk transmission network	29
	7.1.6 Option 6 – Establish a new 330kV transmission line from Wells Terminal to Eastern Terminal	31
	7.1.7 Option 7 – Install an SVC at Northern Terminal, followed by Wells Terminal to Eastern Terminal 330kV transmission line	33
	7.1.8 Option 8 – Establish a new 330kV transmission line from Wells Terminal to Hacketts Gully and establish South East Terminal	35
	7.1.9 Option 9 – Establish a 500kV transmission link to the metropolitan area (formerly option 8)	37
	7.2 FINANCIAL COMPARISON OF NETWORK OPTIONS	38

7.2.1	SCENARIOS CONSIDERED	39
7.2.2	Sensitivity analysis – discount rate	42
7.2.3	Sensitivity analysis – longer term outlook	43
7.3	ALTERNATIVE GENERATION DEVELOPMENTS	43
8	EVALUATION BY EXTERNAL CONSULTANTS	44
9	CONCLUSIONS	45
<b>APPENDIX A:</b>	<b>BACKGROUND TO FINANCIAL ANALYSIS</b>	<b>46</b>
	<b>RISK AND UNCERTAINTY</b>	<b>46</b>
	<b>DISCOUNT RATE</b>	<b>46</b>
	<b>APPLICATION OF THE TERMS OF REFERENCE FOR THE REGULATORY TEST</b>	<b>47</b>
	<b>ASSESSMENT METHODOLOGY</b>	<b>47</b>
<b>APPENDIX B:</b>	<b>EXTRACT FROM ELECTRICITY NETWORKS ACCESS CODE 2004 (REGULATORY TEST)</b>	<b>48</b>
<b>APPENDIX C:</b>	<b>APPLICATION OF PLANNING CRITERIA RELATING TO LONG TERM VOLTAGE STABILITY</b>	<b>50</b>
<b>APPENDIX D:</b>	<b>TRANSMISSION LINE POWER TRANSFER CAPABILITY</b>	<b>52</b>

## **EXECUTIVE SUMMARY**

### **Introduction**

This report forms the basis of Western Power's Regulatory Test application and public consultation for a proposed major augmentation to the electricity network, required to support the connection of new generating facilities in the south-west of Western Australia. These new generating facilities are required to support load growth in the Perth metropolitan area.

The proposed major augmentation addressed in this report includes a new 90km long double circuit 330kV transmission line, stringing of the second side of an existing 75km long double circuit 330kV transmission line, a 330kV switching station and two short double circuit 330kV transmission lines to interconnect the switching station with the existing 330kV transmission network.

### **Options Considered**

A total of eight network augmentation options and two non-network options were originally assessed. From these, a preferred option (a network option) was selected on the basis of financial and technical studies. A public consultation was conducted in relation to the preferred option, seeking alternative options. No alternatives were proposed following this consultation. However, it was later determined that the preferred option (to construct Eastern Terminal) could not be completed within the required timeframe.

An additional network option was subsequently developed and this is now the recommended alternative. The new option was developed to incorporate the positive technical and economic attributes of the originally preferred option, while minimising potential environmental impact. It also represents the optimal solution from a social perspective.

### ***Network Augmentation Options***

The preferred network augmentation option has been selected on the basis of economic efficiency and technical performance.

The preferred option is to establish a second 330kV transmission line between Shotts and Wells Terminal, establish a new double circuit 330kV transmission line from Wells Terminal to the Hacketts Gully area to connect to two existing transmission lines via tee connections and to establish a new 330kV switchyard at South East Terminal. South East Terminal will cut into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. A total of 75km of single circuit transmission line will be strung on existing towers and around 100km of new double circuit transmission line will be constructed under this option.

### ***Non-Network Alternatives***

This major network augmentation has been proposed in response to enquiries from generation proponents regarding the connection of new generating plant to the network, remote from the Perth metropolitan load centre. These new generator connections have been proposed in response to the system load forecast which indicates that new generating capacity will be required to meet the total electricity demand of the system. Therefore, either the connection of new generating plant in more favourable locations, or a reduction in the load forecast sufficient to prevent the need for new generator connections, would provide an alternative to the proposed network augmentation.

The connection of generation in alternative locations may prevent the need for the proposed network augmentation. However, depending on the exact proposal, other network augmentations may be required to accommodate this generation. Therefore, alternative generation scenarios need to be analysed based on specific proposals rather than in general.

Equally, for any demand side management program to be effective in alleviating the need for the proposed network augmentation, it will need to be targeted at the load within the Perth metropolitan area and to the north of Perth (as far as Geraldton) that is supplied via the 330kV lines interconnecting Perth with the main south-west generation sources. Load reduction in the eastern or southern parts of the SWIS will not assist in alleviating the need for this particular network reinforcement and may even exacerbate the existing outlook.

## 1 INTRODUCTION

This document outlines a proposed major network augmentation to support Western Power's South West Interconnected system (SWIS). The proposed augmentation comprises the construction of a new, double circuit 330kV transmission line from the South West region to Perth and the establishment of a new 330kV switching station.

The new transmission line is intended to increase the power transfer capability between generation sources located in the south-west of Western Australia and the Perth metropolitan area, which is the main load centre of Western Australia. The increased power transfer capability will allow the connection of proposed new generators that are required to meet forecast increases in system load.

There are two main options that have been considered for the route of this transmission line.

1. From Landwehr Terminal (in the Wagerup area) to a new 330kV switching station known as South East Terminal (in the Oldbury area).
2. From Shotts Terminal at Collie via Wells Terminal (adjacent to the Boddington Gold Mine) to the Hackett's Gully area.

For both options, a new 330kV switching station known as South East Terminal (in the Oldbury area) will be required.

*Of these two options, the first option involves construction of a shorter line, but as it traverses privately owned land and is located close to residences, the cost of line easements and line construction has been estimated as greater than the cost of constructing the much longer second option.*

Ultimately, load and generation growth further into the future will require further network augmentations. When such augmentation becomes necessary, it is likely that the alternative not selected here will be undertaken. That is, the construction of one of the transmission lines does not preclude the construction of the other in the future. The timing for future works is beyond 2016 and is dependent on load growth and the connection locations for new generating units.

## 2 BACKGROUND: EXISTING ELECTRICITY SUPPLY SYSTEM

The SWIS is presently characterised by a large load centre around the Perth metropolitan region that is supplied by base-load power stations located in the Collie region. The 330kV bulk transmission network transports high volumes of energy from the base-load power stations to the load. At high load times, additional electricity is generated within the Perth area at Kwinana and Pinjar.

Smaller load centres are located at:

- Geraldton - primarily supplied through the metropolitan system with some local generation support;
- Kalgoorlie – primarily supplied via local generation support and a 220kV connection to the Collie base-load power stations; and
- Bunbury, Manjimup and Albany – primarily supplied via 132kV connections to the Collie base-load power stations.

The recent development of a competitive generation market has seen new power stations established along the coastal plain in the area between Bunbury and Kwinana. These new power stations have increased the loading of the 330kV bulk transmission network between the south-west and Perth and will supply both base load and peak load.

The level of power flow in the 330kV bulk transmission network is dependent on two main factors - the total demand for electricity, and the level of generation at each of the power stations. As more electricity is demanded and more power is supplied from the southern part of the state, the bulk transmission network will become loaded close to its capability.

The capability of the 330kV bulk transmission network to transport the required power is determined by the ability to control voltage at all points within the network to within acceptable limits. Devices such as capacitor banks, static VAR compensators and synchronous compensators located at key points within the network are used with generation to help control system voltages. As more power flows through the transmission network, the management of voltage levels becomes more complex.

Historically, voltage levels in the Perth region have benefited from having substantial amounts of generation connected in the local area. In particular, these generators operate at times of high load as they are classed as peaking power plant. However, with the development of a competitive generation market, growing electricity demand, and the retirement of 400MW of generation at Kwinana, the operation of generating plant in the Perth metropolitan area is no longer certain. Generation located south of Perth is being used to supply more base load and more peak load than ever before.

This means that the management of voltage levels in the Perth region is becoming more complex. The high power flow through the 330kV bulk transmission network is reaching a point where voltage support devices such as capacitor banks and static VAR compensators are no longer adequate to support voltage levels, and if the loading levels are to continue to rise, the capacity of the transmission network will need to be improved.

Over 1,100MW of new generation capacity has been connected to the SWIS over the past 3 years and a further 1,000MW is planned to connect by the end of 2009. To accommodate these connections a number of minor network augmentations have been undertaken in recent years. The 330kV bulk transmission network is now at its transfer capacity limit and a major network augmentation is required to accommodate future new generator connections.

Table 1: Recent projects undertaken to defer the need for a major network augmentation

2005	Guildford Terminal 330/132kV transformer Metro area reactive support KEM-KW 91 330kV transmission line (string spare circuit)
2006	Pinjar synchronous compensators Kenwick Link 330/132kV transformer
2007	SHO-KEM 91 330kV transmission line (string spare circuit) Southern Terminal SVC Metro area reactive support
2008	Metro area reactive support KW-ST 92 330 kV transmission line (upgrade from 132kV line) Southern Terminal 3rd 330/132kV transformer
2009	Metro area reactive support Kwinana 330/132kV transformer

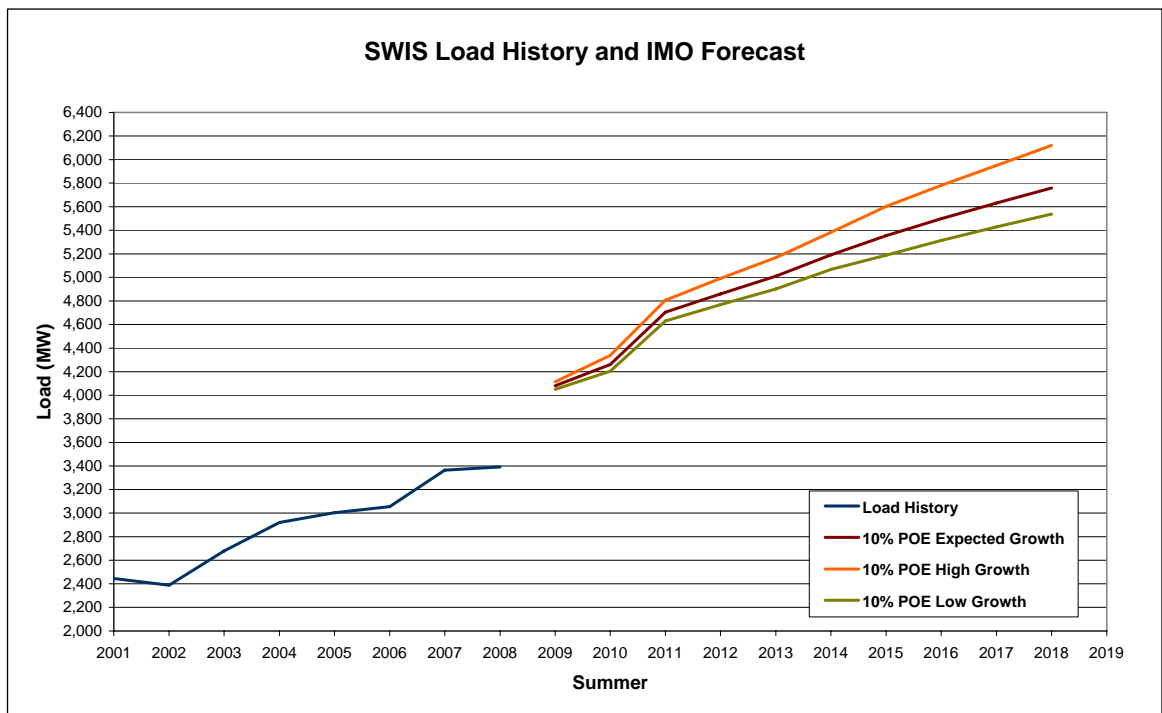
### 3 BACKGROUND

#### 3.1 Electricity Demand Forecast

An electricity demand forecast and an energy forecast are published annually in July by the Independent Market Operator (IMO). These forecasts are for entire system load for the upcoming 10 years and the demand forecast is used by the IMO to determine the minimum acceptable level of generation that must be connected to the network each year to reliably supply the forecast load.

A set of demand forecasts are published for a 10% probability of exceedence (POE), 50% POE and 90% POE for expected, high and low economic growth scenarios (9 forecasts). The 10% POE forecast for expected economic growth is used in determining required generation levels, and this forecast is also used in network simulation studies.

Figure 3.1: IMO Forecast for System Total Demand (published July 2008)



The forecasts produced by the IMO in July 2008 are given in Figure 3.1 and the energy forecast is given in Figure 3.2. These indicate that for the expected economic growth scenario over the next 10 years, peak demand is forecast to grow by 4.5% annually, while energy consumption is forecast to grow by 3.9% annually.

The fact that forecast demand growth is substantially higher than forecast energy growth indicates that the load factor of the system is forecast to deteriorate – meaning that the peak load is growing at a higher rate than the average load supplied throughout the year.

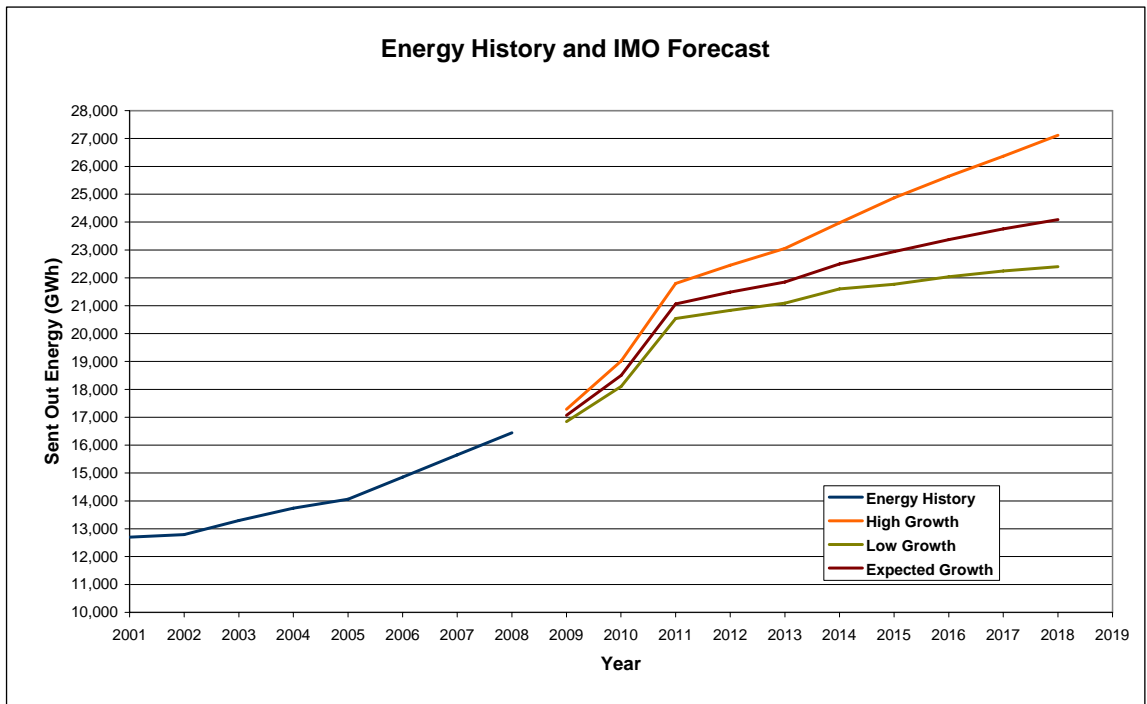


Figure 3.2: IMO Forecast for System Energy Usage (published July 2008)

### 3.2 Load duration curves and the changing generation pattern

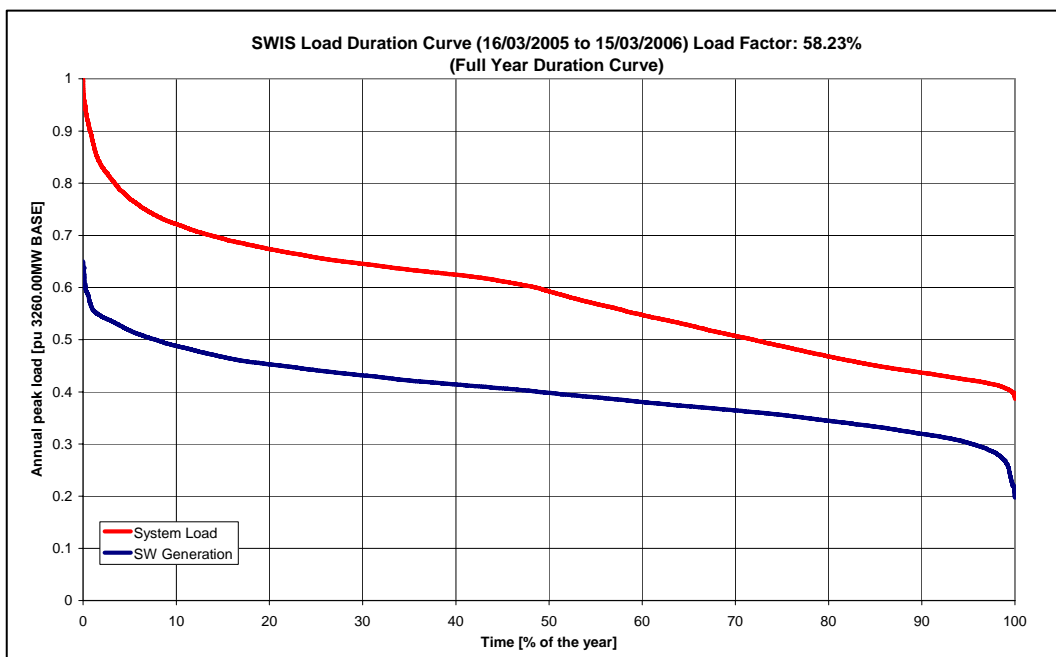
Load duration curves are used to indicate the relationship between electricity demand level and the time for which it was supplied during a 12 month period.

Referring to Figure 3.3 below as an example, the red line indicates the total electricity demand in the SWIS. At the left hand side of the chart, it can be seen that demand was 100% of peak for a very short period of time. For 10% of the time demand was in the order of 72% of peak or above and for 90% of the time demand was in the order of 45% peak or above. The minimum demand was around 38% of peak demand.

The area beneath the curve can be used to determine the total energy used throughout the year (energy = demand x time), likewise the relationship between average demand and peak demand can be used to determine a load factor (load factor = average demand / peak demand). A high load factor (>70%) indicates a high proportion of “base” or constant load whereas a low load factor (<70%) indicates that the load is “peaky” i.e. present for short durations.

Load duration curves for different generators can also be produced to determine how the load is generally supplied. The relationship between generators located in the south-west of Western Australia and the SWIS load is shown by the blue line in Figure 3.3.

Figure 3.3: Load Duration Curve for the SWIS 2005/06



The load duration curve for the system for 2005/06 (refer to Figure 3.3) indicates that the system load had a load factor of around 58% and the load factor for the south-west generators over the same period was 62%. That is, they were both of a peaky nature.

In comparison, the load duration curve for 2003/04 (Figure 3.4) shows that the system load factor was around 56%, but the load factor for the south-west generators over the same period was 74%. In this year, the load had a peaky nature but the generation located in the south-west was primarily base load.

Overall there has not been a substantial change in the load duration curve for the system. However, there is a noticeable change in the load factors for south-west

generation from 2003/04 to 2005/06. These show a substantial shift in generation patterns, indicating that more reliance is being placed upon generation located in the south-west.

The curves also illustrate that in 2003/04, about 50% of the peak load was generated outside the CBD. By 2005/06 this had increased to 65% of peak load, indicating that more generation located outside the CBD was used to meet the peak load.

It is therefore demonstrable that generators in the south-west are increasingly being used to meet peak loads as well as base load.

Figure 3.4: Load Duration Curve for the SWIS 2003/04

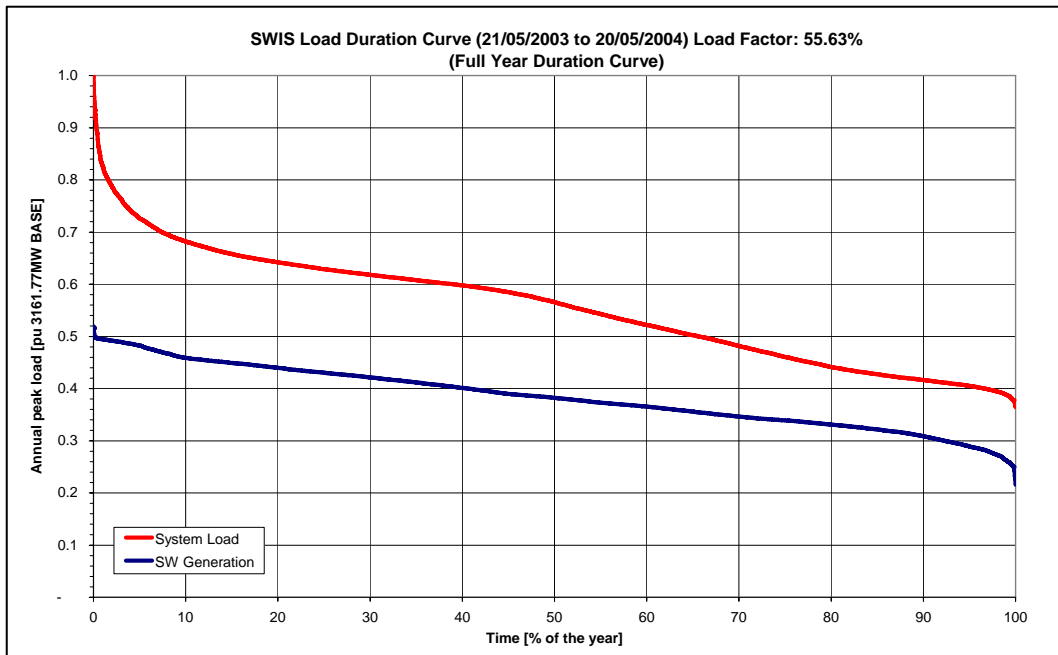
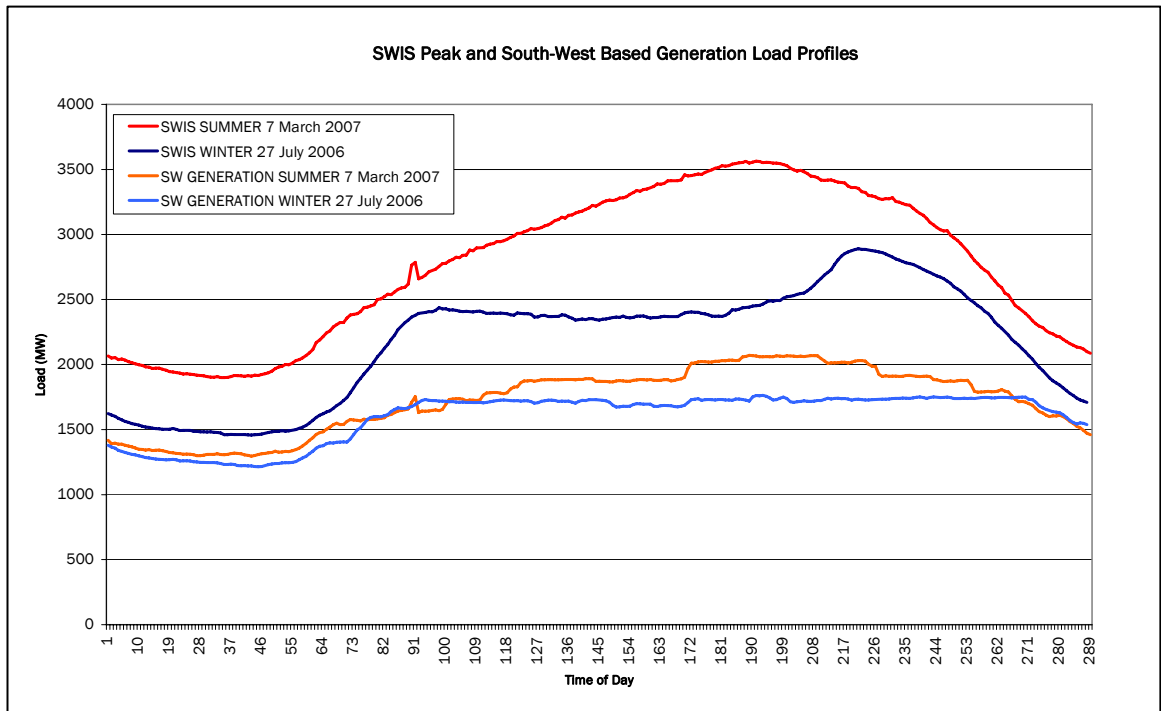


Figure 3.5 below compares the profile generation located in the south-west with the peak summer and winter load days. This chart demonstrates that the power transfer from the south-west generators is relatively high for base, shoulder and peak load periods.

The load profile and load duration data available indicates that as the competitive generation market has developed, with the present generation portfolio, more load is being transferred across the 330kV network into the Perth metropolitan region. The generation that is located within Perth is becoming relatively less utilised. The effect of this on the performance and operation of the electricity transmission network is discussed in section 5 of this report.

Figure 3.5: Daily Load Profile for Summer and Winter Peak for System Load and South West Generators 2006



## 4 BACKGROUND: GENERATION DEVELOPMENTS

The Independent Market Operator (IMO) is bound to operate according to the Wholesale Electricity Market Rules.

In accordance with these rules, the IMO annually awards capacity credits to generators to ensure that the generation capacity connected to the network is sufficient to meet the electricity demand that has been determined by the 10 year forecast. The capacity credits are awarded in August or September each year and apply to the summer 2 years following. These capacity credits are intended to ensure that sufficient generation is connected to the network to ensure that the minimum reserve margin is maintained.

As capacity credits are only awarded 2 years in advance, many generation developments are not confirmed until 2 years prior to commissioning of the generators. Therefore, in conducting planning studies for the electricity network, Western Power needs to make some assumptions regarding the likelihood of particular generation scenarios eventuating.

In order to complete long term studies of network performance, Western Power establishes prospective generation scenarios by assessing the status of current applications for access for generator connections.

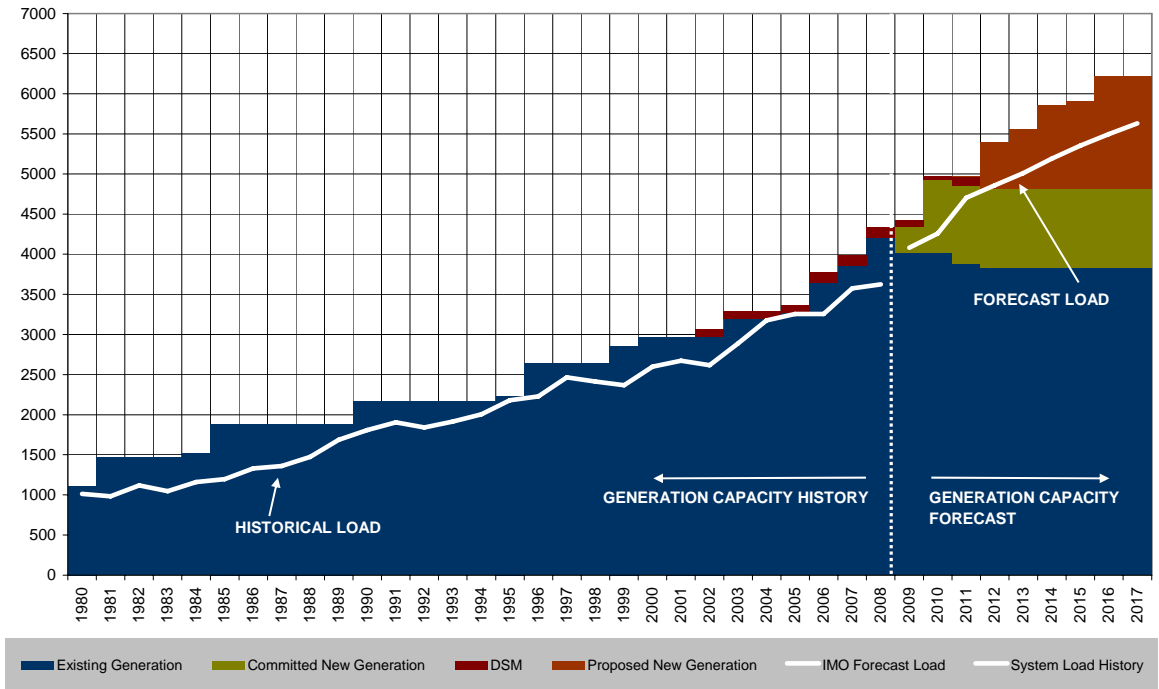
Given that many of the network augmentations required to accommodate new generators have lead times well in excess of 2 years (for example, community consultation, sustainability assessment, environmental and other approvals that are required in the identification and selection of a transmission line route before construction can occur mean that it could take 6-8 years to complete), to some extent network augmentations need to pre-empt particular generation developments.

Western Power have used the information contained within the IMO forecast (given in Figure 3.1), to develop a forecast of the additional generation capacity that will need to be connected to supply the forecast load. This generation forecast is shown in Figure 4.1 below and this has been used to develop a generation development scenario and assess its impact on the performance of the electricity network.

The Reserve Capacity cycle conducted by the IMO secures generation 2 years in advance of its commissioning date. The generation forecast shows that up until 2011/12 there is sufficient committed new generation to meet the demand forecast. However, from the end of 2011 onwards, new generation capacity will be required to meet the demand forecast.

In order to ensure that electricity demand can be met, Western Power will need to have reinforcements in place to accommodate the new generating capacity that is required to supply the additional load. To complete the works required for major system reinforcements, Western Power will need to gain regulatory approval and commence work before the new generators are awarded capacity credits.

Figure 4.1: Generation Capacity Forecast



## 5 REASONS AUGMENTATION IS REQUIRED

By the end of 2011, it is forecast that the power flow from the Collie region to Perth will reach a level where, should any one of the four 330kV transmission lines supplying the Perth metropolitan area be forced out of service, the increased power transfer on each of the lines would result in reactive power losses that are large enough to cause a deficiency of reactive power within the network (i.e. the lines become loaded well above their surge impedance loading or “natural loading”).

This means that the voltage levels at key points within the transmission network may become uncontrollable, falling to below acceptable limits and load shedding would be required to ensure the security of the electricity network.

The increase in transfer from the Collie region to Perth is attributed to the connection of new generating plant across the south-west region. A number of factors are driving the need for these new generator connections. These factors are:

- New generation is required to supply growing load across the SWIS that is primarily located within the Perth metropolitan area.
- New generation is required to replace aging generation assets that are to be retired from service, these include Muja A/B (240MW by 2008), Kwinana B (200MW by 2009) and Kwinana A (200MW by 2010).
- High efficiency generation plant is being commissioned to enter into the new competitive generation market. This new generating plant is intended to displace less efficient plant and drive cheaper energy prices for electricity consumers.

Since the commencement of development of the competitive generation market the majority of substantial new generation projects have been located outside of the Perth metropolitan area. To date, the majority of generation proposals that are in advanced stages of technical and commercial negotiations with Western Power are located in the South West region.

Many of the existing generators that will be retired (Kwinana A/B) or displaced by more efficient units (Pinjar) are located within the metropolitan area. At present, these are the units that provide the most reactive power support to the network and ensure network voltage stability. Without these units in service, the reactive power deficiency within the network will be even greater.

Therefore, the demand for reactive power support for the network will be increasing at the same time that the existing reactive power support will be removed.

In recognition of these factors, a project was recently undertaken to enable a number of the low efficiency generating units at Pinjar to be operated as synchronous compensators. This means that these units can be operated to provide reactive power support to the network without generating real power (i.e. they can support the network without burning fuel). As there are still some operating costs associated with running the units in this mode and there will be no energy output to pay the generator, a network support contract is required to operate these units.

## 6 OPTIONS CONSIDERED

### 6.1 NON-NETWORK OPTIONS

#### 6.1.1 Demand Side Management

Demand side management (DSM) could be used to reduce the amount of load that needs to be supplied through the electricity network at critical times. Various techniques may be used to achieve this, ranging through:

- employing energy efficiency measures;
- lopping of load through agreements to interrupt load at critical times;
- using alternative energy sources or co-generation sources; or
- encouraging shifting of peak load by using energy storage devices such as off-peak hot water systems or off-peak cooling for air-conditioning systems.

To be effective, a DSM solution will need to specifically target load that is located either within Perth or north of Perth (i.e. load that is supplied via the 330kV bulk transmission lines that link Perth with the south-west generators).

Usually DSM is used to reduce the total peak load of a system. To be an effective means of deferring the need for network reinforcement, in this instance the DSM would need to be available not only for high demand periods, but also for shoulder load periods where there are high power transfers from the south-west and generation within the Perth metropolitan region is low or constrained.

#### 6.1.2 Generation

Two primary alternatives are available as generation solutions.

Firstly, generation proposals to meet the forecast load growth that are located within the Perth metropolitan area may displace competing generation proposals in the south-west. Should this scenario eventuate, then the driver to augment the network in the manner proposed would be reduced and possibly even completely alleviated. Therefore, Perth based generation could defer or prevent the need for the proposed major network augmentation. However, the metropolitan based generation proposals are likely to require some form of alternative network augmentation within the metropolitan area (possibly smaller and less costly than the alternative proposed in this consultation paper). The specific location and connection arrangement of alternative generation connections would need to be studied in detail to determine the network costs of adopting such an alternative.

Secondly, there is potential that deeming certain generators located within the Perth metropolitan area as “must run” units (that is, they must be operating regardless of whether more efficient units are available for dispatch) for shoulder load periods and for particular operating scenarios will help to alleviate the driver for network augmentation. This option would defer the need for the proposed major network augmentation, but as load grows and new generation connections in the south-west increase, this alternative will reduce in effectiveness and ultimately the proposed network augmentation would be required. The generation located within Perth that would need to be scheduled on is lower efficiency plant and to re-schedule it into service will require constraining more efficient plant that is located outside the metropolitan area, therefore some additional operating costs would be associated with this alternative.

### 6.1.3 Reactive Support from Existing Generators

As noted earlier, voltage control within the Perth metropolitan area presently benefits from the operation of generators within the local area and a number of metropolitan based generators have been provided with the capability to operate as synchronous compensators.

The retirement of 400MW of generation at Kwinana, together with the operation of more efficient generating plant remote from the metropolitan area means that the reactive support from local generation is expected to diminish in the future.

A number of generators at Pinjar already operate as synchronous compensators if required i.e. they are able to provide reactive power to the network even while they are not producing real power (and using fuel). A project to provide this capability was undertaken in 2006 to defer the need for a major network augmentation at that time. This facility is very important to the voltage stability of the network.

There is a small possibility that additional generating units at Pinjar could be fitted with the capability to operate as a synchronous compensator. However, this would require substantial modifications to the generating units.

This option would defer the need for network augmentation, but as load grows and generation connected in the south-west increases, this alternative will reduce in effectiveness and ultimately the proposed network augmentation would be required.

## 6.2 NETWORK OPTIONS

There are a number of options to augment the 330kV bulk transmission network to alleviate the forecast constraints. These options are essentially variations on two main options for providing an additional transmission line tie between the generation sources and the main load centre in Perth. There are a number of alternative approaches to the timing for various components of the main reinforcement options; these are discussed in detail in sections 7.1 and 7.2.

It should be noted that adopting one option now does not preclude any of the other options from being adopted to cater for future requirements beyond 2017.

1. Establish South East Terminal and a new 330kV double circuit transmission line between Landwehr Terminal and South East Terminal.
2. Establish South East Terminal and cut the Shotts to Southern Terminal/Oakley 330kV transmission line into Landwehr Terminal. (A new double circuit transmission line will be required from Landwehr Terminal to South East Terminal 2 years later.)
3. Establish South East Terminal and install additional high voltage capacitor banks at South East Terminal and Guildford Terminal. (A new double circuit transmission line will be required from Landwehr Terminal to South East Terminal 2 years later.)
4. Install a +200/-100MVar SVC at Northern Terminal. A new double circuit transmission line will be required from Landwehr Terminal to South East Terminal 5 years later.
5. Install series compensation in the 330kV bulk transmission lines between south-west generation sources and the Perth metropolitan area. (A new double circuit transmission line will be required from Landwehr Terminal to South East Terminal 5 years later.)

6. Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line between Wells Terminal and Eastern Terminal. *This option is no longer considered viable.*
7. Install a +200/-100MVar SVC at Northern Terminal. (A new double circuit transmission line will be required from Wells Terminal to Hacketts Gully and establish South East Terminal 2 years later.) *This option is no longer considered viable.*
8. Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line from Wells Terminal, connecting to existing transmission lines in the Hacketts Gully area and establish South East Terminal.
9. Establish a 500kV transmission link to the metropolitan area (formerly option 8).

## 7 OPTIONS ANALYSIS

### 7.1 TECHNICAL COMPARISON OF NETWORK OPTIONS

Each of the proposed network augmentation options are discussed in detail below. For each augmentation option, a program of works to provide adequate network security until 2017 is outlined. Each of the augmentation options provides an equivalent technical outcome in 2017.

Beyond 2017, load growth and generation developments may require further augmentation works. Such future works could contain elements of one of the unselected options outlined below.

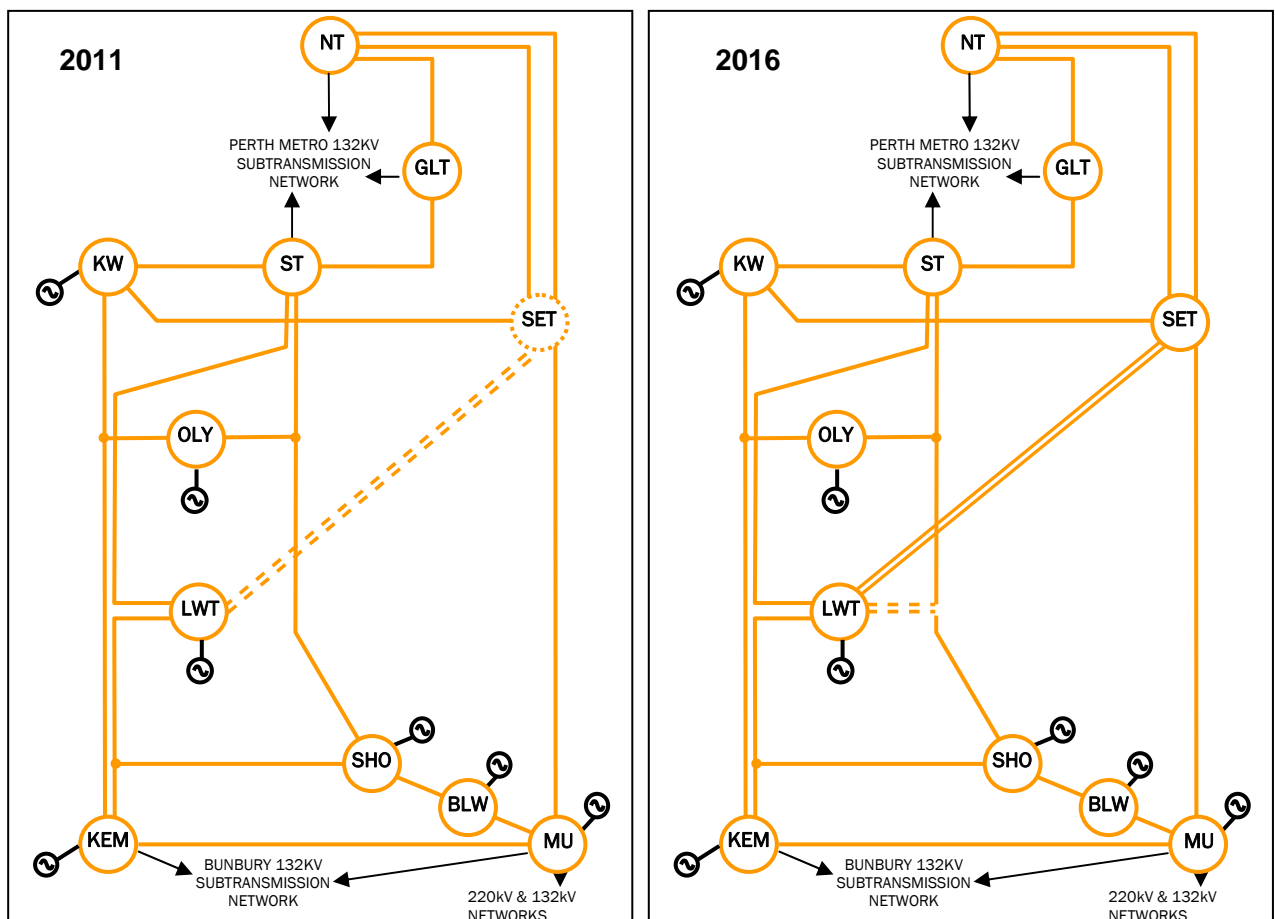
#### 7.1.1 Option 1 – Establish a new 330kV transmission line from Landwehr Terminal to South-East Terminal

This option will require the following work to be completed by the end of 2011:

- Establish a new 330kV switching station (South East Terminal) in the locality of Oldbury.
- Cut South East Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 6km of double circuit 330kV transmission line.
- Construct a new 75km long double circuit 330kV transmission line between the South East Terminal and Landwehr Terminal.

This work will provide sufficient reinforcement to meet the requirements of the Technical Rules from 2012 until 2017.

Figure 7.1: 330kV Bulk Transmission Network – Schematic Development, Option 1



By the end of 2016, the existing 330kV transmission line between Shotts, Oakley Terminal and Southern Terminal (a 3 ended tee line) will need to be cut into Landwehr Terminal. This will then form 2 new lines: Shotts to Landwehr Terminal, and Landwehr Terminal to Oakley Terminal and Southern Terminal.

This solution provides substantial reinforcement to the network, through a relatively short section of new transmission line. The new transmission line provides a direct connection between a generation source and one of the weakest points in the transmission network (the MU-NT 91 line).

The proposed route for this transmission line substantially follows a decommissioned 132kV transmission line (CT-MRR 81). This line route is over 50 years old and the proposal to rebuild a section of it has required the examination of potential environmental effects within and adjacent to the current line corridor. Based on a desktop review of available environmental databases and vegetation, flora, fauna and *Phytophthora* surveys a number of environmental issues have been identified along the relevant sections of the existing corridor. These issues identified to date will require mitigation and/or management measures at some locations along the corridor. Measures such as realignment of the line route to avoid residences, use of pile driven foundations, use of poles rather than towers, use of taller towers to limit need for clearing sensitive vegetation, strategic placement of structures to avoid habitat of endangered fauna species, and acquisition of some residences due to their proximity to the line and limited alternative alignments may be required. The social implications of this option are significant.

This option was originally the preferred option, however estimates indicated that the cost of implementing this option would be higher than originally anticipated. Reasons for this included that the proposed route for this line traverses farmland, some settlements and some environmentally sensitive areas and the mitigation measures described above, as well as the need to purchase line easements.

Technically this option performs well from the perspective of reactive reserve margin, transmission network losses and transmission voltage recovery.

7.1.2 Option 2 - Establish South East Terminal and reinforce Landwehr Terminal

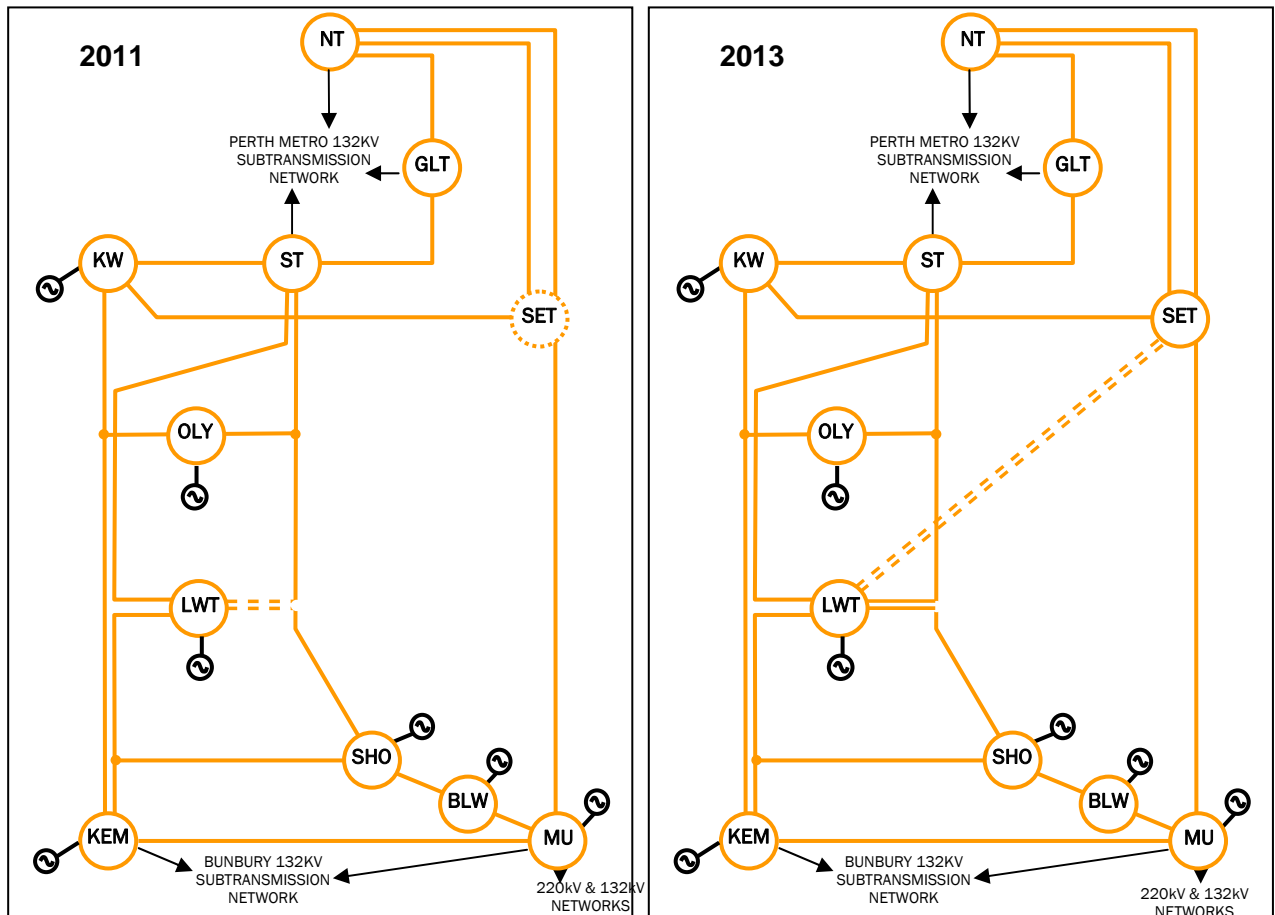
This option is a variation of option 1 that provides sufficient capacity to defer the need for the new transmission line by 2 years. The following work will need to be completed by the end of 2011:

- Establish a new 330kV switching station (South East Terminal) in the locality of Oldbury.
- Cut South East Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 6km of double circuit 330kV transmission line.
- Cut the existing Shotts to Oakley Terminal and Southern Terminal 330kV transmission line between (a 3 ended tee line) into Landwehr Terminal to form 2 new lines: Shotts to Landwehr Terminal, and Landwehr Terminal to Oakley Terminal and Southern Terminal.

This option will provide sufficient reinforcement to meet the requirements of the Technical Rules for 2012 and 2013. However, further reinforcement will be required to accommodate future demand.

By the end of 2013, the 75km long double circuit 330kV transmission line will be required between South East Terminal and Landwehr Terminal.

Figure 7.2: 330kV Bulk Transmission Network – Schematic Development, Option 2



Comments relating to the line route for option 1 apply to this option. The proposed route for this transmission line substantially follows a decommissioned 132kV transmission line

(CT-MRR 81). This line route is over 50 years old and the proposal to rebuild a section of it has required the examination of potential environmental effects within and adjacent to the current line corridor. Based on a desktop review of available environmental databases and vegetation, flora, fauna and *Phytophthora* surveys a number of environmental issues have been identified along the relevant sections of the existing corridor. These issues identified to date will require mitigation and/or management measures at some locations along the corridor. Measures such as realignment of the line route to avoid residences, use of pile driven foundations, use of poles rather than towers, use of taller towers to limit need for clearing sensitive vegetation, strategic placement of structures to avoid habitat of endangered fauna species, and acquisition of some residences due to their proximity to the line and limited alternative alignments may be required. The social implications of this option are significant.

From a technical perspective, this option performs adequately for reactive reserve, but results in greater transmission network losses for the first two years and is one of the worst performing options for voltage recovery.

7.1.3 Option 3 – Establish South East Terminal and provide additional reactive support at Guildford Terminal

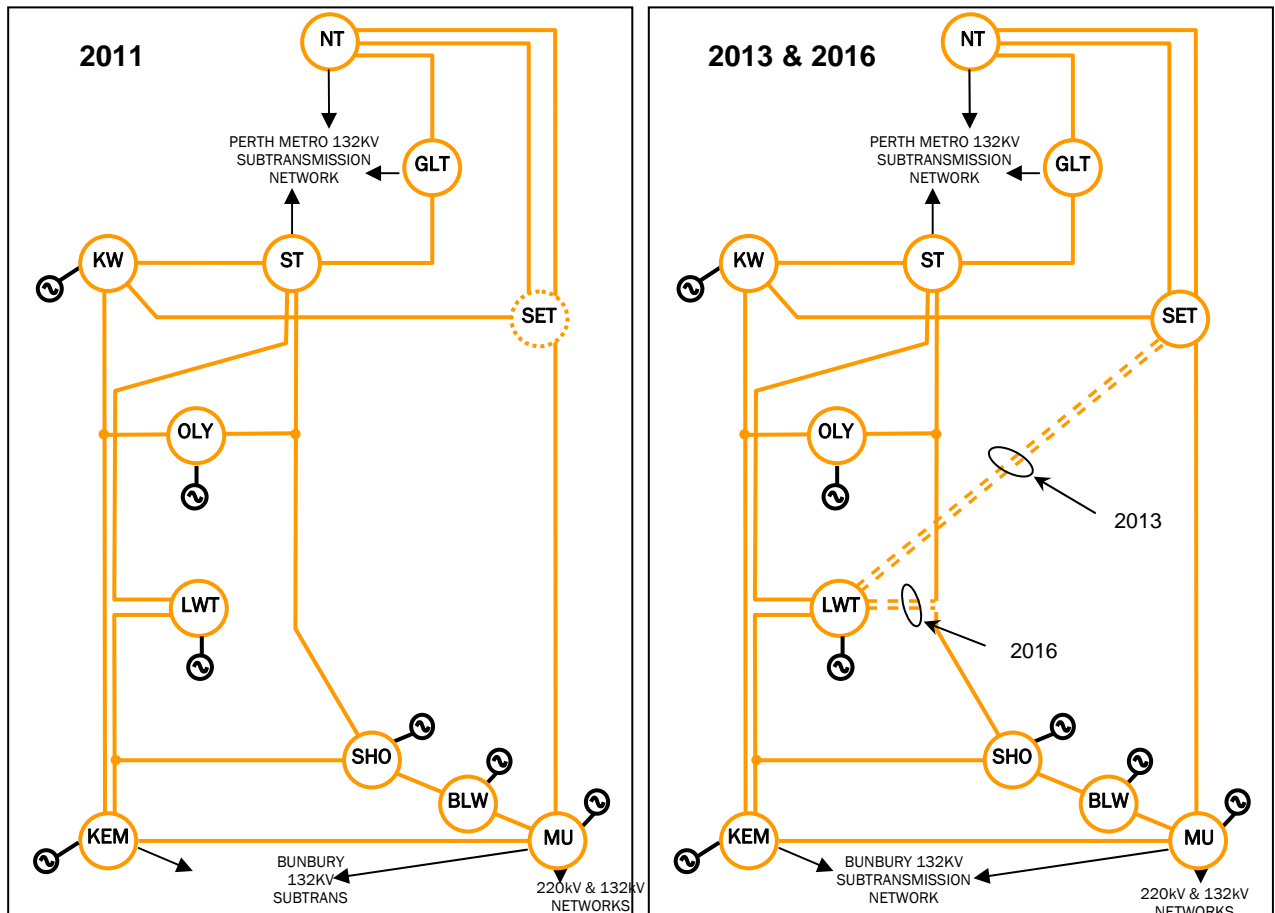
This option is a variation of option 1 that provides sufficient capacity to defer the need for the new transmission line by 2 years. The following scope of work will need to be completed by the end of 2011:

- Establish a new 330kV switching station (South East Terminal) in the locality of Oldbury.
- Cut South East Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 6km of double circuit 330kV transmission lines.
- Install a 60MVAR capacitor bank at South East Terminal connect to the 330kV busbar.
- Extend the existing 60MVAR capacitor bank at Guildford Terminal to 90MVAR.

This option will provide sufficient reinforcement to meet the requirements of the Technical Rules for 2012 and 2013. However, further reinforcement will be required in 2013 and again in 2016 to accommodate future demand. The following additional work will be required:

- Construct a new 75km long double circuit 330kV transmission line between the South East Terminal and Landwehr Terminal by the end of 2013.
- Cut the Shotts to Oakley Terminal and Southern Terminal 330kV transmission line between (a 3 ended tee line) into Landwehr Terminal to form 2 new lines: Shotts to Landwehr Terminal, and Landwehr Terminal to Oakley Terminal and Southern Terminal by the end of 2016.

Figure 7.3: 330kV Bulk Transmission Network – Schematic Development, Option 3



This option would require the construction of a new double circuit line by the end of 2013. Comments relating to the line route for option 1 apply to this option. The proposed route for this transmission line substantially follows a decommissioned 132kV transmission line (CT-MRR 81). This line route is over 50 years old and the proposal to rebuild a section of it has required the examination of potential environmental effects within and adjacent to the current line corridor. Based on a desktop review of available environmental databases and vegetation, flora, fauna and *Phytophthora* surveys a number of environmental issues have been identified along the relevant sections of the existing corridor. These issues identified to date will require mitigation and/or management measures at some locations along the corridor. Measures such as realignment of the line route to avoid residences, use of pile driven foundations, use of poles rather than towers, use of taller towers to limit need for clearing sensitive vegetation, strategic placement of structures to avoid habitat of endangered fauna species, and acquisition of some residences due to their proximity to the line and limited alternative alignments may be required. The social implications of this option are significant.

From a technical perspective, this option performs adequately for reactive reserve, but results in greater transmission network losses for the first two years and is one of the worst performing options for voltage recovery.

7.1.4 Option 4 – Install an SVC at Northern Terminal, followed by Landwehr Terminal to South East Terminal 330kV transmission line

This option is a variation of option 1 that provides sufficient capacity to defer the need for the new transmission line by 2 years. The following scope of work will need to be completed by the end of 2011:

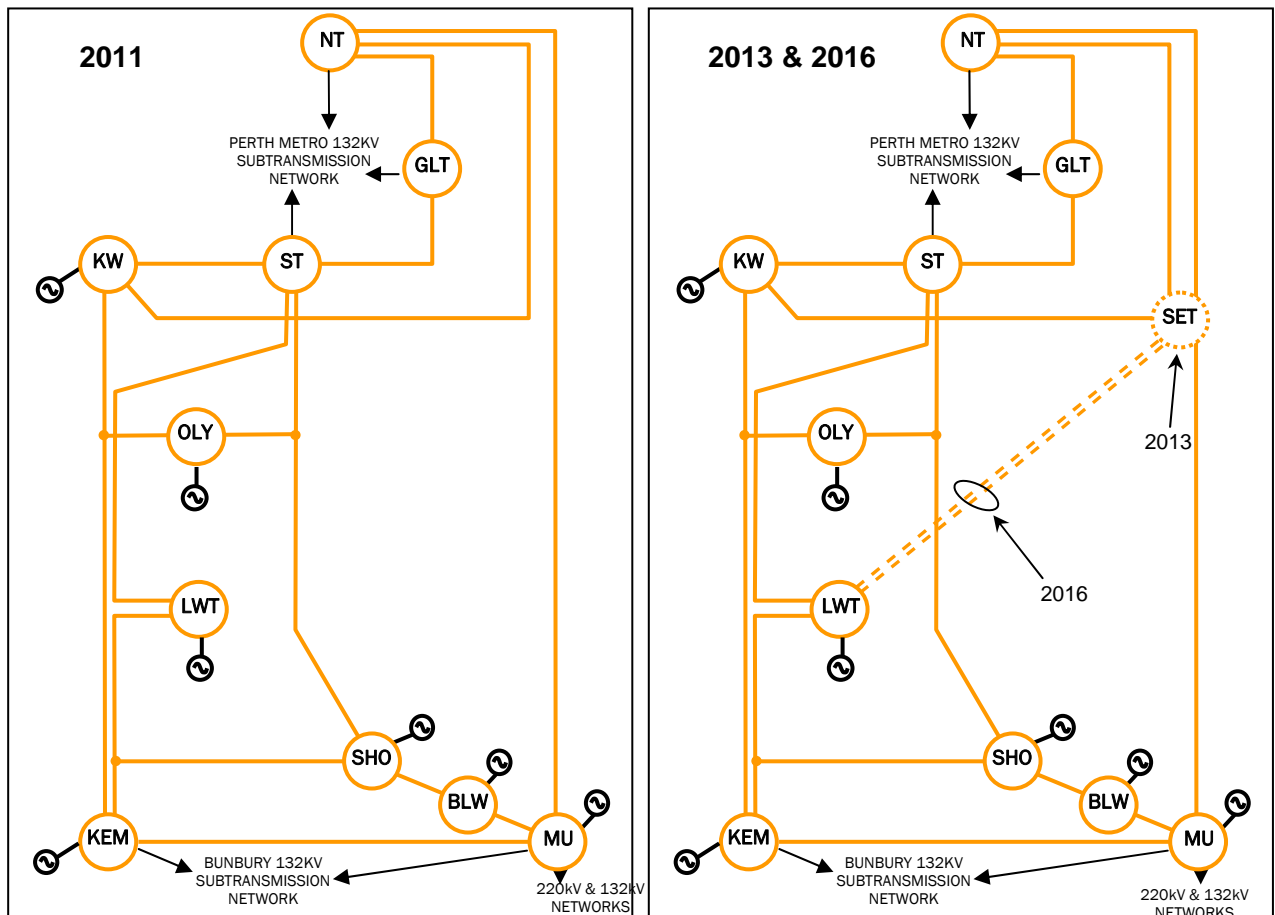
- Install a +200/-100MVar SVC at Northern Terminal. The proposed SVC will be identical to that planned to be installed at Southern Terminal and will be connected to the 132kV busbar.

This option will provide sufficient reinforcement to meet the requirements of the Technical Rules for 2012 and 2013. However, further reinforcement will be required the end of 2013 and again the end of 2016 to accommodate future demand.

The following additional work will be required:

- Establish a new 330kV switching station (South East Terminal) in the locality of Oldbury by the end of 2013.
- Cut South East Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91, this will require the construction of around 6km of double circuit 330kV transmission line, by the end of 2013.
- Construct a new 75km long double circuit 330kV transmission line between the South East Terminal and Landwehr Terminal by the end of 2016.

Figure 7.4: 330kV Bulk Transmission Network – Schematic Development, Option 4



This option requires the construction of a new double circuit line by the end of 2016. Comments relating to the line route for option 1 apply to this option. The proposed route for this transmission line substantially follows a decommissioned 132kV transmission line (CT-MRR 81). This line route is over 50 years old and the proposal to rebuild a section of it has required the examination of potential environmental effects within and adjacent to the current line corridor. Based on a desktop review of available environmental databases and vegetation, flora, fauna and *Phytophthora* surveys a number of environmental issues have been identified along the relevant sections of the existing corridor. These issues identified to date will require mitigation and/or management measures at some locations along the corridor. Measures such as realignment of the line route to avoid residences, use of pile driven foundations, use of poles rather than towers, use of taller towers to limit need for clearing sensitive vegetation, strategic placement of structures to avoid habitat of endangered fauna species, and acquisition of some residences due to their proximity to the line and limited alternative alignments may be required. The social implications of this option are significant.

This option is a variation of option 1 that provides sufficient capacity to defer the need for the new transmission line by 2 years. From a technical perspective, this option performs adequately for reactive reserve, but results in greater transmission network losses for the first five years and is one of the worst performing options for voltage recovery.



Series compensation of transmission lines has been used successfully in many parts of the world to enhance the power transmission capability of very long transmission lines. The use of series compensation has been very rare to date in Australia and it is therefore expected that the technical expertise required to successfully implement this technology would need to be sourced internationally.

The use of series compensation in Western Power's network is expected to present sub-synchronous resonance challenges due to the present system conditions. To ensure that the capacitor installations are sized appropriately to avoid system issues, extensive and complex power system analysis studies will be required. The effect of the Eastern Goldfields 220kV network and its complex saturated reactor SVC arrangements will present particular challenges for series compensation as low levels of sub-synchronous resonance are known to exist as a result of this system.

The technical risks associated with this option are therefore considered to be very high.

The series compensation of the transmission lines would be achieved through the insertion of series capacitors in the transmission lines. To accommodate these series capacitor installations, Western Power would require seven new sites for equipment installation – 2 of these sites would accommodate the capacitors for two separate lines. Four of these sites could be located adjacent or near to existing terminal stations (the feasibility of this and availability of suitable land would need to be verified), the three remaining sites would need to be located midway along existing transmission lines. A number of environmental issues would need to be addressed in identifying, acquiring and developing each of these sites.

This option requires the construction of a new double circuit line by the end of 2016. Comments relating to the line route for option 1 apply to this option. The proposed route for this transmission line substantially follows a decommissioned 132kV transmission line (CT-MRR 81). This line route is over 50 years old and the proposal to rebuild a section of it has required the examination of potential environmental effects within and adjacent to the current line corridor. Based on a desktop review of available environmental databases and vegetation, flora, fauna and *Phytophthora* surveys a number of environmental issues have been identified along the relevant sections of the existing corridor. These issues identified to date will require mitigation and/or management measures at some locations along the corridor. Measures such as realignment of the line route to avoid residences, use of pile driven foundations, use of poles rather than towers, use of taller towers to limit need for clearing sensitive vegetation, strategic placement of structures to avoid habitat of endangered fauna species, and acquisition of some residences due to their proximity to the line and limited alternative alignments may be required. The social implications of this option are significant.

This option is a variation of option 1 that provides sufficient capacity to defer the need for the new transmission line by 2 years. From a technical perspective, this option performs adequately for reactive reserve, but results in greater transmission network losses for the first five years.

7.1.6 Option 6 – Establish a new 330kV transmission line from Wells Terminal to Eastern Terminal

This option relies on the development of SHO-WLT 91 and Wells Terminal in 2009. The development of this infrastructure is driven by the Boddington gold mine expansion plans.

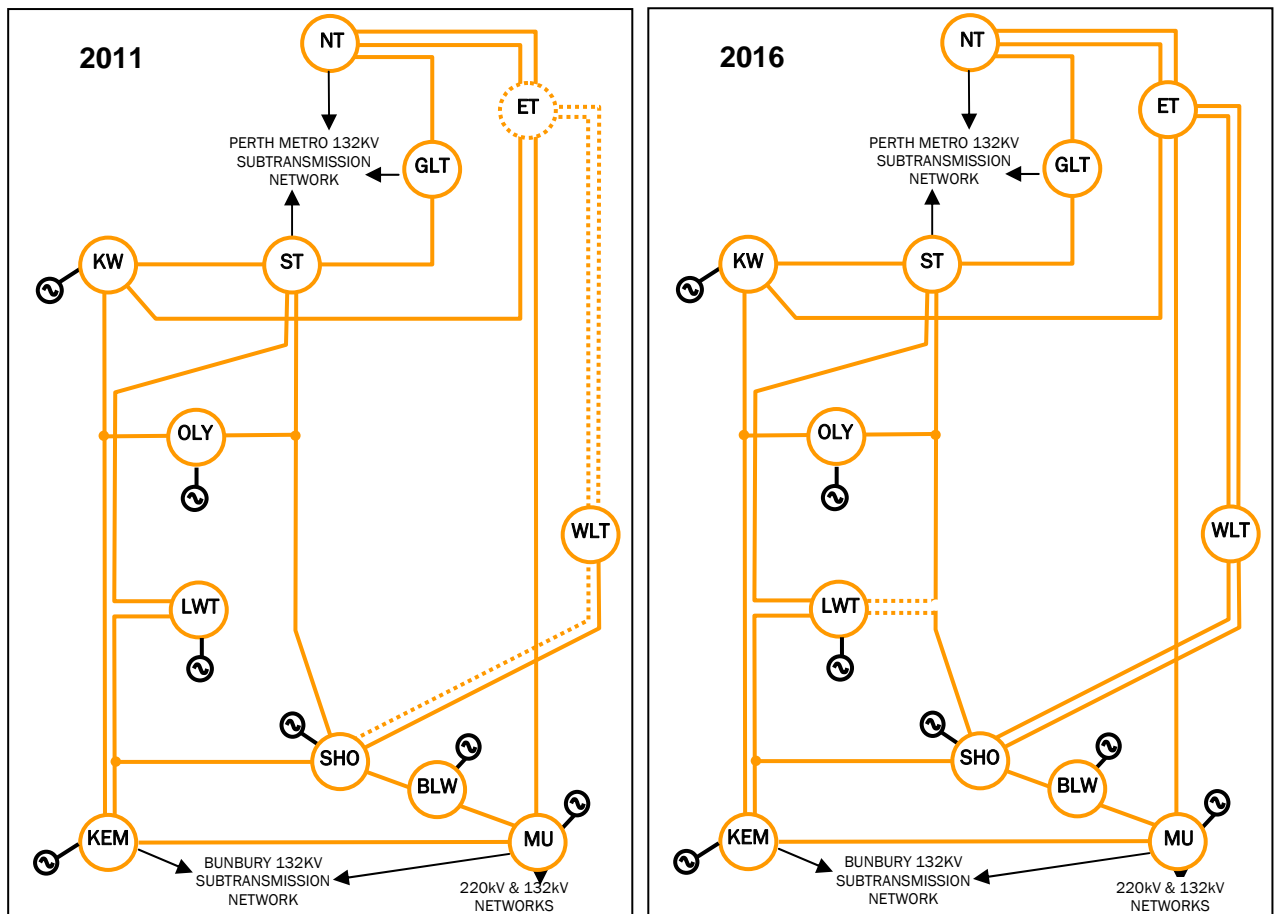
This option will require the following work to be completed by the end of 2011:

- Establish a new 330kV switching station (Eastern Terminal) in the locality of Hacketts Gully.
- Cut Eastern Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 2km of double circuit 330kV transmission line.
- String the second side of the Shotts Terminal to Wells Terminal 330kV double circuit transmission line (75km).
- Rebuild the existing 90km long 132kV transmission line from Boddington as a double circuit 330kV transmission line between Wells Terminal and Eastern Terminal.

This work will provide sufficient reinforcement to meet the requirements of the Technical Rules from 2012 until 2017.

By the end of 2016, the existing 330kV transmission line between Shotts, Oakley Terminal and Southern Terminal (a 3 ended tee line) will need to be cut into Landwehr Terminal. This will then form 2 new lines: Shotts to Landwehr Terminal, and Landwehr Terminal to Oakley Terminal and Southern Terminal.

Figure 7.6: 330kV Bulk Transmission Network – Schematic Development, Option 6



This option provides substantial reinforcement to the network, but requires the construction of an extensive section of new transmission line. The new transmission line provides the most effective new tie between the expected new generation sources and the load centre. This option was originally ruled out due to the length of line required. However estimates for this option now indicate that the cost of implementing this option is substantially lower than the alternative line between Landwehr Terminal and South East Terminal. This is related to the fact that the new transmission line follows an existing transmission line corridor and avoids developed and residential areas resulting in minimal social implications.

The proposed route for this line is an existing 132kV transmission line that will need to be dismantled prior to construction of the new line. This may involve some operating constraints on the network during the construction phase. Additionally, this option will involve the acquisition of a suitable terminal station site which is still subject to selection and negotiation.

Routing for this line along an existing 132kV transmission line corridor is viewed as advantageous as it requires minimal additional clearing to accommodate the new 330kV transmission line and avoids privately owned land. Environmental surveys have been completed to identify environmental issues along the existing corridor. These issues will require mitigation and/or management measures at some locations along the corridor. Measures such as use of poles rather than towers, strategic placement of structures to avoid sensitive flora and work practises to ensure soil hygiene have been identified.

Technically this is the preferred option – providing the highest reactive reserve margin, the lowest transmission network losses and the shortest transmission voltage recovery time for serious 330kV outages.

This option has the inherent benefit of providing a better security of supply to Wells Terminal (and therefore the Boddington Gold Mine) which is presently supplied by a single 330kV line with very limited back-up from the 132kV network.

*Note – since the original analysis was conducted, it has been determined that it would not be possible to complete the construction of Eastern Terminal within the required timeframe, if at all. Therefore this option is no longer considered a practical option. It has been included here only for completeness.*

*During 2009, Western Power will be commencing a community consultation process in relation to the location of an ultimate connection of the 330kV transmission lines from Wells Terminal to a switchyard.*

7.1.7 Option 7 – Install an SVC at Northern Terminal, followed by Wells Terminal to Eastern Terminal 330kV transmission line

This option is a variation of option 6 that provides sufficient capacity to defer the need for the new transmission line by 2 years. The following scope of work will need to be completed by the end of 2011:

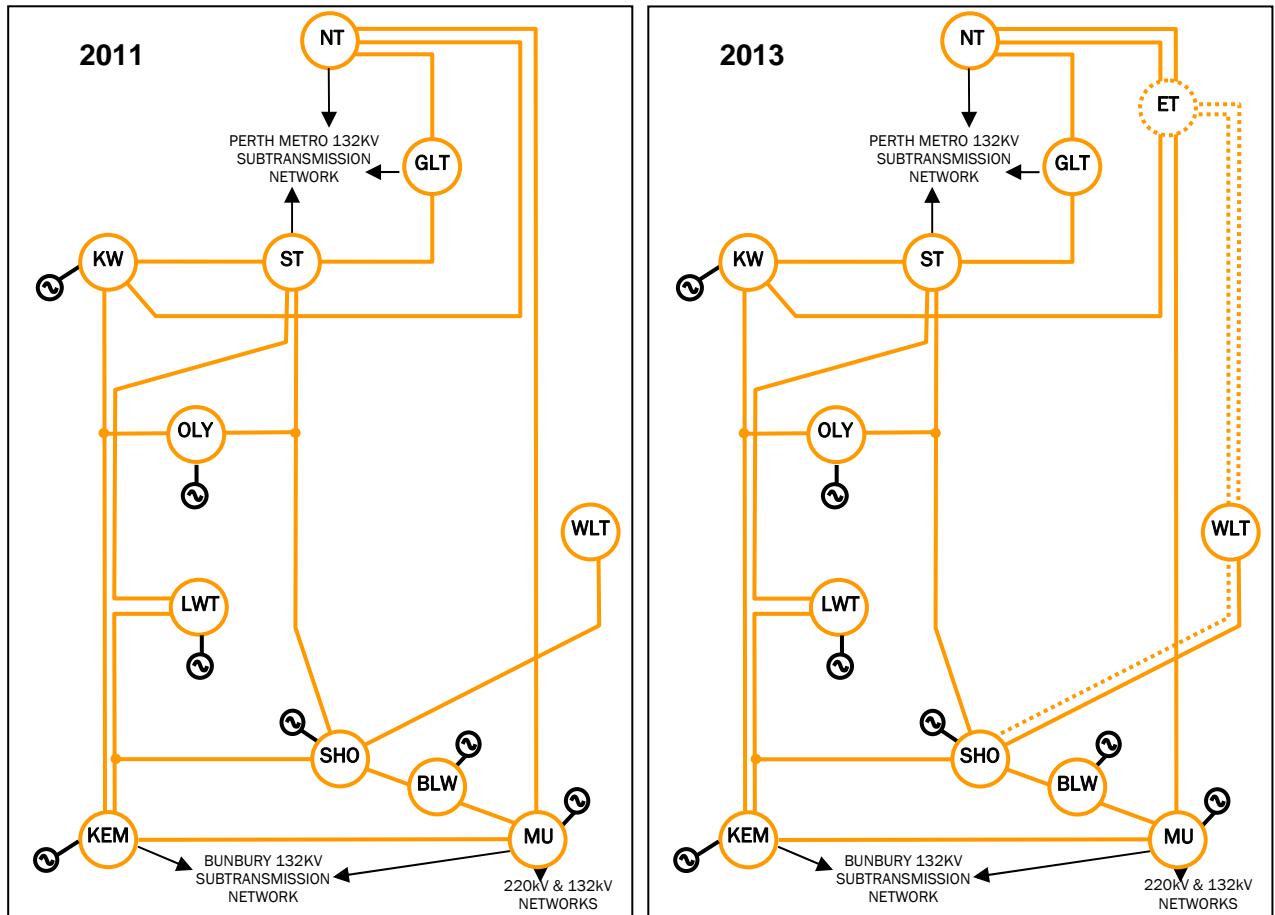
- Install a +200/-100MVar SVC at Northern Terminal. The proposed SVC will be identical to that planned to be installed at Southern Terminal and will be connected to the 132kV busbar.

This option will provide sufficient reinforcement to meet the requirements of the Technical Rules for 2012 and 2013. However, further reinforcement will be required by the end of 2013 to accommodate future demand.

The following additional work will be required by the end of 2013:

- Establish a new 330kV switching station (Eastern Terminal) in the locality of Hacketts Gully.
- Cut Eastern Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 2km of double circuit 330kV transmission line.
- String the second side of the Shotts Terminal to Wells Terminal 330kV double circuit transmission line (75km).
- Rebuild the existing 90km long 132kV transmission line from Boddington as a double circuit 330kV transmission line between Wells Terminal and Eastern Terminal.

Figure 7.7: 330kV Bulk Transmission Network – Schematic Development, Option 7



This option is a variation of option 6 that provides sufficient capacity to defer the need for the new transmission line by 2 years. Issues relating to establishing the new transmission line for option 6 apply. The proposed route for this line is an existing 132kV transmission line that will need to be dismantled prior to construction of the new line. This may involve some operating constraints on the network during the construction phase. Additionally, this option will involve the acquisition of a suitable terminal station site which is still subject to negotiation.

Routing for this line along an existing 132kV transmission line corridor is viewed as advantageous as it requires minimal additional clearing to accommodate the new 330kV transmission line and avoids privately owned land. Environmental surveys have been completed to identify environmental issues along the existing corridor. These issues will require mitigation and/or management measures at some locations along the corridor. Measures such as use of poles rather than towers, strategic placement of structures to avoid sensitive flora and work practises to ensure soil hygiene have been identified.

From a technical perspective, this option performs adequately for reactive reserve, but results in greater transmission network losses for the first two years.

*Note – since the original analysis was conducted, it has been determined that it would not be possible to complete the construction of Eastern Terminal within the required timeframe, if at all. Therefore this option is no longer considered a practical option at this stage. It has been included here only for completeness.*

*During 2009, Western Power will be commencing a community consultation process in relation to the location of an ultimate connection of the 330kV transmission lines from Wells Terminal to a switchyard.*

7.1.8 Option 8 – Establish a new 330kV transmission line from Wells Terminal to Hacketts Gully and establish South East Terminal

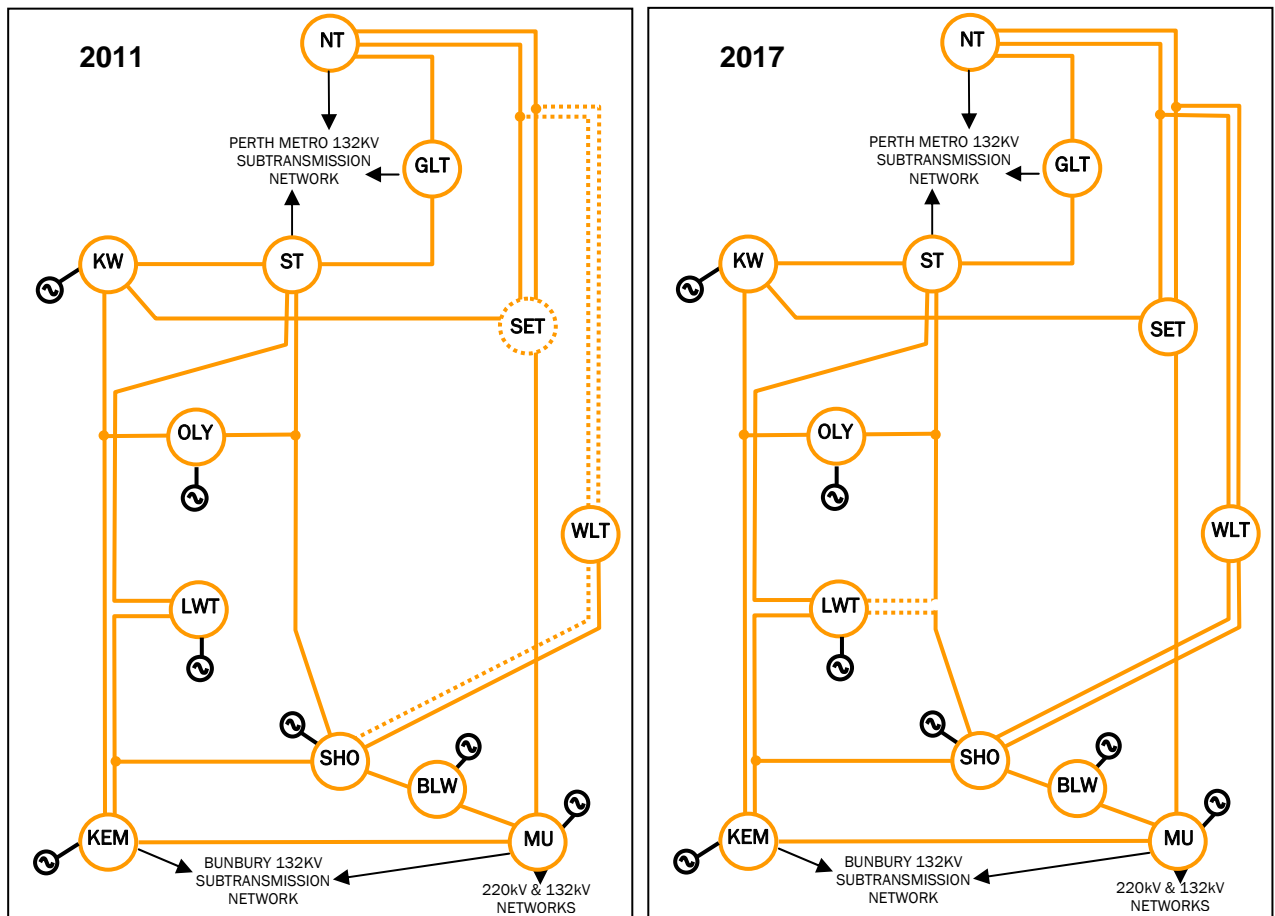
*This option has been developed after it was determined that a number of environmental and social issues in relation to the proposed Eastern Terminal would not be resolved in time to complete the project. During 2009, Western Power will be commencing a community consultation process in relation to the location of an ultimate connection of the 330kV transmission lines from Wells Terminal to a switchyard.*

This option will require the following work to be completed by the end of 2011:

- Establish a new 330kV switching station (South East Terminal) in the locality of Oldbury.
- Cut South East Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 6km of double circuit 330kV transmission lines.
- String the second side of the Shotts Terminal to Wells Terminal 330kV double circuit transmission line (75km).
- Rebuild the existing 90km long 132kV transmission line from Boddington as a double circuit 330kV transmission line between Wells Terminal and Hacketts Gully.

This work will provide sufficient reinforcement to meet the requirements of the Technical Rules from 2012 until 2017.

Figure 7.8: 330kV Bulk Transmission Network – Schematic Development, Option 6



By the end of 2016, the existing 330kV transmission line between Shotts, Oakley Terminal and Southern Terminal (a 3 ended tee line) will need to be cut into Landwehr Terminal. This will then form 2 new lines: Shotts to Landwehr Terminal, and Landwehr Terminal to Oakley Terminal and Southern Terminal.

The proposed route for this line is an existing 132kV transmission line that will need to be dismantled prior to construction of the new line. This transmission line route is viewed as advantageous as it requires minimal additional clearing to accommodate the new 330kV transmission line and avoids privately owned land. Environmental surveys have been completed to identify environmental issues along the existing corridor. These issues will require mitigation and/or management measures at some locations along the corridor. Measures such as use of poles rather than towers, strategic placement of structures to avoid sensitive flora and work practises to ensure soil hygiene have been identified.

This option provides substantial reinforcement to the network, but requires the construction of an extensive section of new transmission line. The new transmission line provides the most effective new tie between the expected new generation sources and the load centre.

*This option was developed after it was determined that option 6 could not be completed on time. This option was developed taking into consideration the technical, environmental and economic benefits and constraints of option 6 in order to provide an optimal, practical alternative.*

The proposed route for this line is an existing 132kV transmission line that will need to be dismantled prior to construction of the new line. This may involve some operating constraints on the network during the construction phase.

Technically this is the second best option (after option 6 which is no longer considered feasible).

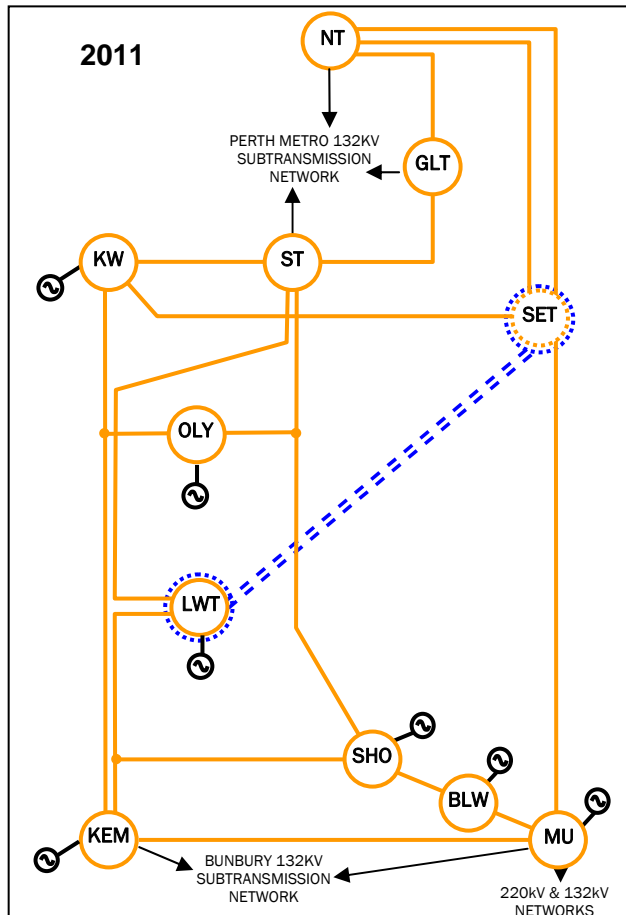
7.1.9 Option 9 – Establish a 500kV transmission link to the metropolitan area (formerly option 8)

This option will require the following scope of work to be completed by 2011:

- Establish a new 330kV switching station (South East Terminal) in the locality of Oldbury.
- Cut South East Terminal into two existing 330kV transmission lines – KW-NT 91 and MU-NT 91. This will require the construction of around 6km of double circuit 330kV transmission line.
- Construct a new 75km long double circuit 330kV transmission line between the South East Terminal and Landwehr Terminal.

This option will provide sufficient reinforcement to meet the requirements of the Technical Rules for 2012 and 2013. However, further reinforcement will be required in 2013 to accommodate future demand.

Figure 7.9: 330kV Bulk Transmission Network – Schematic Development, Option 8



Technically, this option inferior to both options 1 and 6 as it would require additional reinforcement works to be completed in 2013. This option has not been considered further as it will be considerably more expensive to implement than the other alternatives considered, and without any substantial technical advantage this additional cost cannot be justified.

## 7.2 FINANCIAL COMPARISON OF NETWORK OPTIONS

Below is a summary of the estimated Net Present Cost (NPC) for each of the network augmentation options considered.

For each augmentation option, a program of works to provide adequate network security until 2017 was outlined in section 7.1. Each of the augmentation options provides an equivalent technical outcome in 2017 and the NPC analysis includes all of the work until 2016.

Table 7.1: NPC of network reinforcement options

Option	Description	NPC	
		Initial Project	Until 2017
1	Establish a new 330kV double circuit transmission line between Landwehr Terminal and South East Terminal	143.1	153.1
2	Establish a new 330kV switchyard at South East Terminal and cut the Shotts to Southern Terminal/Oakley 330kV transmission line into Landwehr Terminal	50.8	143.0
3	Establish a new 330kV switchyard at South East Terminal and install additional high voltage capacitor banks at South East Terminal and Guildford Terminal	42.4	144.6
4	Install a +200/100MVar SVC at Northern Terminal then construct LWT-SET	32.0	137.3
5	Install series compensation in the 330kV bulk transmission lines between south-west generation sources and the Perth metropolitan area	102.3	220.1
6	Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line between Wells Terminal and Eastern Terminal	128.9	138.9
7	Install a +200/100MVar SVC at Northern Terminal then construct WLT-ET	32.0	143.2
8	Establish a new 330kV switchyard at South East Terminal, a second 330kV transmission line between Shotts Terminal and Wells Terminal and a new 330kV double circuit transmission line from Wells Terminal to Hacketts Gully	131.5	141.5

The above figures do not include losses. Option 6 was found to result in the least system losses and the additional cost of losses has been added to the total cost for the alternative options, at a rate of \$50/MWh. The overall NPC over 5 years including the cost of losses is given in Table 7.2.

Table 7.2: NPC of network reinforcement options including the cost of losses

Option	Description	NPC Over 5 years	Ranking
1	Establish a new 330kV double circuit transmission line between Landwehr Terminal and South East Terminal	161.1	7
2	Establish a new 330kV switchyard at South East Terminal and cut the Shotts to Southern Terminal/Oakley 330kV transmission line into Landwehr Terminal	154.3	4
3	Establish a new 330kV switchyard at South East Terminal and install additional high voltage capacitor banks at South East Terminal and Guildford Terminal	156.7	6
4	Install a +200/100MVA SVC at Northern Terminal then construct LWT-SET	155.2	5
5	Install series compensation in the 330kV bulk transmission lines between south-west generation sources and the Perth metropolitan area	234.2	8
6	Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line between Wells Terminal and Eastern Terminal	138.9	1
7	Install a +200/100MVA SVC at Northern Terminal then construct WLT-ET	149.7	3
8	Establish a new 330kV switchyard at South East Terminal, a second 330kV transmission line between Shotts Terminal and Wells Terminal and a new 330kV double circuit transmission line from Wells Terminal to Hacketts Gully	140.9	2

The above analyses demonstrate that except for option 5 (series compensation of 330kV transmission lines), all options are virtually equivalent (within the accuracy of the estimates) from a financial perspective.

## 7.2.1 SCENARIOS CONSIDERED

### 1. HIGH LOAD GROWTH

A high load growth scenario has been considered to understand the sensitivity of the network to variation in the load forecast and how this would affect the ranking of the network reinforcement options.

Higher than expected load growth would promote the connection of additional new generating units to the network. Equally, greater competition within the generation market could result in a scenario that is similar in effect to a high load growth scenario.

Depending on the connection location of new generating units, the need for additional reinforcement works would be advanced. The IMO's high forecast for demand growth was used as the basis for assessing this scenario. The NPC of each of the network reinforcement alternatives was recalculated for each of the options under the high growth scenario and the outcome is summarised below.

Table 7.3: NPC of Network Reinforcement Options for High Growth Scenario

Option	Description	NPC Over 5 years	Ranking	
			High	Base
1	Establish a new 330kV double circuit transmission line between Landwehr Terminal and South East Terminal	165.2	5	7
2	Establish a new 330kV switchyard at South East Terminal and cut the Shotts to Southern Terminal/Oakley 330kV transmission line into Landwehr Terminal	161.9	4	4
3	Establish a new 330kV switchyard at South East Terminal and install additional high voltage capacitor banks at South East Terminal and Guildford Terminal	165.9	6	6
4	Install a +200/100MVar SVC at Northern Terminal then construct LWT-SET	169.0	7	5
5	Install series compensation in the 330kV bulk transmission lines between south-west generation sources and the Perth metropolitan area	249.3	8	8
6	Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line between Wells Terminal and Eastern Terminal	140.5	1	1
7	Install a +200/100MVar SVC at Northern Terminal then construct WLT-ET	155.8	3	3
8	Establish a new 330kV switchyard at South East Terminal, a second 330kV transmission line between Shotts Terminal and Wells Terminal and a new 330kV double circuit transmission line from Wells Terminal to Hacketts Gully	142.5	2	2

The ranking of the first 4 most economic options did not change under the high growth scenario.

## 2. LOW LOAD GROWTH

A low load growth scenario was also considered to understand the sensitivity of the network to variation in the load forecast and how this would affect the preferred reinforcement option. Lower than expected load growth would defer the need for new generating units to the network to meet demand growth.

However, additional new generating units may still connect to the network to provide more efficient energy solutions to the competitive generation market.

The IMO's low forecast for demand growth was used as the basis for assessing this scenario and it was assumed that the minimum amount of new generation to support the forecast load would connect to the network. The NPC of each of the network reinforcement alternatives was recalculated for each of the options under the low growth scenario and the outcome is summarised below.

Table 7.4: NPC of Network Reinforcement Options for Low Growth Scenario

Option	Description	NPC Over 5 years	Ranking	
			Low	Base
1	Establish a new 330kV double circuit transmission line between Landwehr Terminal and South East Terminal	135.0	7	7
2	Establish a new 330kV switchyard at South East Terminal and cut the Shotts to Southern Terminal/Oakley 330kV transmission line into Landwehr Terminal	126.0	5	4
3	Establish a new 330kV switchyard at South East Terminal and install additional high voltage capacitor banks at South East Terminal and Guildford Terminal	127.1	6	6
4	Install a +200/100MVar SVC at Northern Terminal then construct LWT-SET	122.2	3	5
5	Install series compensation in the 330kV bulk transmission lines between south-west generation sources and the Perth metropolitan area	190.5	8	8
6	Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line between Wells Terminal and Eastern Terminal	119.3	1	1
7	Install a +200/100MVar SVC at Northern Terminal then construct WLT-ET	124.4	4	3
8	Establish a new 330kV switchyard at South East Terminal, a second 330kV transmission line between Shotts Terminal and Wells Terminal and a new 330kV double circuit transmission line from Wells Terminal to Hacketts Gully	120.9	2	2

For the low growth scenario, there was a slight change in the order the options ranked between 3 and 5, but the cost margins between the options are very small for this scenario.

Given that there is the potential for new generation to connect to provide increased competition despite the lesser load growth, it is considered that this scenario is unlikely and that a low growth scenario would produce an outcome somewhere between this analysis and the expected growth scenario.

7.2.2 Sensitivity analysis – discount rate

A sensitivity analysis of the cost of each option was completed by increasing the discount rate used (indicating a higher risk project). The results are summarised below:

Table 7.5: NPC of Network Reinforcement Options for various discount rates

Option	Discount rate					
	10%		12.5%		15%	
	NPC	Rank	NPC	Rank	NPC	Rank
1	161.1	7	145.8	7	132.4	7
2	154.3	4	136.9	5	121.8	5
3	156.7	6	138.0	6	122.1	6
4	155.2	5	132.6	4	113.9	1
5	234.2	8	204.5	8	179.4	8
6	138.9	1	126.0	1	114.6	2
7	149.7	3	132.3	3	117.2	4
8	141.5	2	128.4	2	116.8	3

The sensitivity analysis indicated that the discount rate affected the ranking of the 5 lowest cost options, the rankings of the 3 higher cost options did not vary with the discount rate. This is attributed to the fact that the costs for these options are all within the accuracy of the estimate for the base discount rate.

7.2.3 Sensitivity analysis – longer term outlook

As noted earlier, future load and generation developments will require further network augmentations in the future. A further sensitivity analysis considering the NPC of possible augmentations until 2021 for the higher ranked options has been conducted.

Table 7.6: NPC of main network reinforcement options until 2021

Option	Description	NPC (until 2021)	Ranking
1	Establish a new 330kV double circuit transmission line between Landwehr Terminal and South East Terminal	334.4	6
2	Establish a new 330kV switchyard at South East Terminal and cut the Shotts to Southern Terminal/Oakley 330kV transmission line into Landwehr Terminal	327.6	4
4	Install a +200/100MVA SVC at Northern Terminal then construct LWT-SET	329.2	5
6	Establish a second 330kV transmission line between Shotts Terminal and Wells Terminal and establish a new 330kV transmission line between Wells Terminal and Eastern Terminal	314.4	1
7	Install a +200/100MVA SVC at Northern Terminal then construct WLT-ET	326.1	3
8	Establish a new 330kV switchyard at South East Terminal, a second 330kV transmission line between Shotts Terminal and Wells Terminal and a new 330kV double circuit transmission line from Wells Terminal to Hacketts Gully	314.8	2

The results above demonstrate that with time, the economic differences between the options are reduced. There is a 6% difference in the NPC of the lowest and highest option considered.

7.3 ALTERNATIVE GENERATION DEVELOPMENTS

Alternative generation developments would substantially alter the preferred network reinforcement option only if the generation was located within or north of the Perth metropolitan area. Generation developments located further south than the scenario considered, or generation located in the eastern parts of the network would drive similar (although expanded) network reinforcement options. This is because the main power flow from/to the eastern and southern parts of the network occurs through Muja (in the Collie area). Any new generation in these areas would be delivered to Perth via the 330 kV bulk transmission network between Collie and Perth.

There is potential for new generation developments within and to the north of Perth. The potential development of a new 330kV transmission line between Perth and Geraldton will facilitate the connection of new generating plant north of Perth. However, the regulatory assessment of this transmission line only concluded recently, and at present there are no committed generation proposals for this area.

## 8 EVALUATION BY EXTERNAL CONSULTANTS

Western Power sought assistance from external consultants in evaluating the need for a new large network asset, driven by increased generation capacity connecting to the network south of the Perth metropolitan area, evaluating the various network and non-network alternatives.

Independent consultants, SKM (Sinclair Knight Merz) reviewed Western Power's discussion paper and support the conclusions drawn.

ACIL Tasman evaluated the range of network and non-network options. This evaluation incorporated a number of future scenarios including a range of generation portfolios, rates of carbon tax, and gas prices. From this analysis, ACIL Tasman concluded that the best economic outcome would be to undertake the preferred network reinforcement (Option 8), noting that option 6 was no longer viable. The network augmentation will support forecast load growth in the metropolitan area and facilitate the connection of an economically efficient mix of conventional and renewable generation. ACIL Tasman concluded that the preferred South West augmentation is likely to maximise net benefit as defined by the Regulatory Test, this is therefore the recommended option.

## 9 CONCLUSIONS

A significant number of Western Australia's power stations are located to the south of Perth and most of the power generated is supplied to the metropolitan area. The majority of the access applications received indicate that there is a strong prospect for new generators to locate in the South West region.

Studies show that from the end of 2011 onwards, the transmission network is constrained and cannot accommodate the forecast increase in generation in the South West region.

The prime driver for the proposed major augmentation is to meet forecast increases in generation in the South West region and to cater for the load growth in the Perth metropolitan area. This proposed transmission line would increase the power transfer capability between generation sources located in the South West region and the Perth metropolitan area. This will allow the connection of proposed new generators that are required to meet forecast increases in system load.

Without network augmentation, there will no longer be sufficient capacity to install significant amounts of generation in the South West region.

The proposed 330 kV transmission line from Collie to Hacketts Gully, together with South East Terminal will allow connection of conventional and renewable generation in the South West region. It will facilitate the entry of South West renewable and low carbon emission electricity generation. This greenhouse efficient generation is increasingly important to enhance network efficiency and also reduce greenhouse gas emissions.

The proposed augmentation will enhance the diversity of power generation in WA, which encourages increased competition in the Perth's energy market. Fair and open competition between all energy resources is essential to reduce the pressure on electricity costs, and to ensure the continued viability of WA industries.

Western Power, SKM and ACIL Tasman have studied the enhancement options and concluded that option 8 provides the most economical, technically acceptable solution to meet the Perth community's growing power requirements through to 2017 (based on the current load forecast).

Option 8 is required to be in service by the end of 2011.

## **Appendix A: BACKGROUND TO FINANCIAL ANALYSIS**

### **RISK AND UNCERTAINTY**

Western Power's assessment acknowledges several sources of uncertainty and risk.

The areas of risk and uncertainty include:

- the rate of growth of electricity demand and subsequently the driver for new generation connections;
- the location of new generator connections.
- the possibility that the delivered costs of a project are lower or higher than initial estimates; and
- the timeframe required to implement the selected solution is longer or shorter than initial estimates, particularly for projects requiring environmental approvals for transmission line easements or terminal station developments.

Risks relating to project estimating tend to be well known and are not specific to the particular project. Western Power's approach to such risks is to use the best available estimate, i.e. the expected values, and apply an appropriate contingency.

Risks relating to environmental and other (external) approvals are less controllable. These are generally managed by selecting strategies and alternatives that are less likely to cause community or environmental concern.

To manage the identified uncertainties, Western Power compares the load forecast produced by the IMO for the SWIS as a whole against an aggregated view of its own forecasts that are produced for each substation site located within the SWIS. Correlation between these forecasts is taken to be indicative of the integrity of the forecasts.

Uncertainty in the location of generation has been managed by undertaking an assessment of the generation proposals that are presently known to Western Power. It is anticipated that proceeding with the Public Consultation component of the Regulatory Test will enhance the certainty in relation to generation locations by encouraging the proponents of additional generation proposals that will either alleviate or exacerbate the conditions driving the need for network augmentation to clearly outline and cost their proposals.

### **DISCOUNT RATE**

The rate of return represents the return expected by investors or stakeholders for investments of a given level of risk. The rate of return is that which provides a stream of income from the investment of funds that would be sufficient to attract and retain that investment.

Normally, Western Power's economic analyses are based on returns on transmission investment that are regulated through open access arrangements. The analysis period used is 55 years.

The weighted average cost of capital (WACC) used in WP's economic evaluations is 6.5% (real pre-tax) and a discount rate of 10.05% pre-tax applies. As Western Power's WACC may vary over time, sensitivity analysis may be used to compare its impact.

## APPLICATION OF THE TERMS OF REFERENCE FOR THE REGULATORY TEST

The Terms of Reference require Western Power to conduct an assessment of a proposed major network augmentation to determine whether it maximises the net benefits after considering alternative options. The purpose of the Regulatory Test case is to assist interested parties, particularly the ERA and Government, by bringing together relevant information through a public consultation process and transparent process on the proposal.

The Regulatory Test is intended to identify the overall costs and benefits of the alternative reinforcement options and to provide information on the relevant costs, benefits and uncertainties that will assist the decision-making process.

An important distinction to draw when assessing a project is between private and public benefits. The total benefit of a project to society is called its social benefit, and is the sum of private benefits and public benefits. Private benefits are the gains to parties directly engaged in the project (*suppliers, shareholders, employees, customers, etc*), while public benefits are gained by the wider community not directly involved in the project, for example through the provision of a new supply capacity to accommodate future load growth or improvement in quality and reliability of supply to the electricity transmission network.

The fact that, for example, the provision of better quality and higher reliability of power supply to a particular region/market is defined as a private benefit rather than a public benefit does not mean that the community gains nothing from such an arrangement. Rather, it means that the members of the community who gain comprise the consumers, producers, employees, suppliers, etc who are party to the project.

**The private benefits** of this project include:

- an increase in transmission capacity to support natural load growth in the SWIS;
- an increase in transmission capacity to enable connection of customers with new loads and also connection of new generation located to the south of the Perth metropolitan area; and
- a reduction in generation cost by removing the need for uneconomic dispatch less efficient generating plant.

The **public benefits** of this project would include increased competition from higher efficiency generation plant entering into the generation market and greater fuel source diversity within the generation market.

## ASSESSMENT METHODOLOGY

The assessment should take into consideration:

- Net Present Cost evaluation of the alternative options
- evaluation of overall costs and net benefits

## Appendix B: EXTRACT FROM ELECTRICITY NETWORKS ACCESS CODE 2004 (REGULATORY TEST)

### Regulatory test not as part of access arrangement approval process

- 9.15 A *service provider* may submit a *major augmentation proposal* other than as part of the *access arrangement approval process*, in which case sections 9.16 to 9.22 apply.
- 9.16 A *major augmentation proposal* submitted under section 9.15:
- (a) must describe in detail each *major augmentation* to which the *major augmentation proposal* relates; and
  - (b) must state that, in the *service provider's* view, each *proposed major augmentation* maximises the *net benefit after considering alternative options*;  
and
  - (c) must demonstrate that the *service provider* has conducted a consultation process in respect of each *proposed major augmentation* which:
    - (i) included public consultation under Appendix 7; and
    - (ii) gave all *interested persons* a reasonable opportunity to state their views and to propose *alternative options* to the *proposed major augmentations*, and that the *service provider* had regard to those views and *alternative options*; and
    - (iii) involved the *service provider* giving reasonable consideration to any information obtained under sections 9.16(c)(i) and 9.16(c)(ii) when forming its view under section 9.16(b);
- and
- (d) must comply with the current requirements *published* under section 9.17.
  - (e) may include a request that the *Authority* give prior approval under section 6.72 in respect of the *new facilities investment* for one or more *proposed major augmentations*.
- 9.17 The *Authority* must *publish*, and may from time to time *publish* variations to, its requirements for a *major augmentation proposal* submitted under section 9.16, which requirements must be directed to ensuring that the *Authority* receives sufficient information in a suitable form to enable it to efficiently and effectively apply the test in section 9.20.
- 9.18 The *Authority* must in respect of a *major augmentation proposal* submitted under section 9.15 make and *publish* a determination whether the test in section 9.20 is satisfied or is not satisfied, and must do so:
- (a) if the *Authority* has consulted the public under section 9.19 . within 45 *business days*; and
  - (b) otherwise within 25 *business days*,
- after receiving the *major augmentation proposal*.
- 9.19 The *Authority* may consult the public under Appendix 7 before making a determination under section 9.18.
- 9.20 The test in this section 9.20 is satisfied if the *Authority* is satisfied that:
- (a) the *service provider's* statement under section 9.16(b) is defensible; and
  - (b) the *service provider* has applied the *regulatory test* properly to each *proposed major augmentation*:
    - (i) using reasonable market development scenarios which incorporate varying levels of demand growth at relevant places; and

- (ii) using reasonable timings, and testing alternative timings, for project commissioning dates and construction timetables for the *major augmentation* and for *alternative options*;

and

- (c) the consultation process conducted by the *service provider* meets the criteria in section 9.16(c).

9.21 If the *Authority* is unable to determine whether the test set out in section 9.20 is satisfied or is not satisfied because the *service provider* has not provided adequate information (despite the *Authority* having notified the *service provider* of this fact and given the *service provider* a reasonable opportunity, having regard to the time periods specified in section 9.18, to provide adequate information), then the *Authority* may determine that the test in section 9.20 is not satisfied.

9.22 If the *Authority* has not *published* a determination under section 9.18 within the time limits specified in that section, then the *Authority* is deemed to have determined that the test in section 9.20 is satisfied.

#### **Regulatory test may be expedited, otherwise modified or waived**

9.23 If the *Authority* forms the view that the application of the *regulatory test* under sections 9.10 to 9.14 or sections 9.15 to 9.22 in respect of a proposed *major augmentation* would be contrary to the *Chapter 9 objectives*, including because:

- (a) there are no, or it is unlikely that there are any, viable *alternative options* to the proposed *major augmentation*; or
- (b) the nature of the proposed *major augmentation* is such that significant advance planning is required and no *alternative options* exist; or
- (c) the nature of the proposed *major augmentation*, or part of it, is such that it should be submitted to the Independent Market Operator established under the *Electricity Industry (Independent Market Operator) Regulations 2004*, or
- (d) the nature of the funding of the *proposed major augmentation* means that the *proposed major augmentation* will not cause a net cost (measured in present value terms to the extent that it is possible to do so) to those who *generate, transport and consume* electricity in the *covered network* and any *interconnected system*, then the *Authority* may, by *publishing* a notice:
- (e) expedite or otherwise modify the application of the *regulatory test* in respect of the *major augmentation* to the extent the *Authority* considers necessary to meet the *Chapter 9 objectives*; or
- (f) waive the application of the *regulatory test* in respect of the *major augmentation* if the *Authority* considers it necessary to do so to meet the *Chapter 9 objectives*.

9.24 Without limiting the circumstances in which the *Authority* may publish a notice under section 9.23, if a person requests the *Authority* to form a view under section 9.23 in respect of a *proposed major augmentation* which is described to the *Authority* in reasonable detail then the *Authority* must as soon as practicable form a view and either:

- (a) *publish* a notice under section 9.23; or
- (b) notify the person that the *Authority* does not propose to *publish* a notice under section 9.23.

## Appendix C: APPLICATION OF PLANNING CRITERIA RELATING TO LONG TERM VOLTAGE STABILITY

Clause 2.2.11(b) of the Technical Rules dated 14 December 2006 states:

The long term *voltage stability* criterion is that the *voltage* at all locations in the *power system* must be stable and *controllable* following the most onerous post-contingent system state following the occurrence of any event specified in clauses 2.3.7.1(a) and 2.3.7.2 under all credible *load* conditions and *generation* patterns.

The credible load conditions are based on a peak load case with the load based on the IMO forecasts of a 1 in 10 year high load. The peak load case may not be the worst case. As load is scaled down generators are taken off line. Taking the generators off line can have a greater negative impact than the benefit gained from reducing the load.

Consideration is also given to the impact of the loss of large loads and the impact of standby loads, but not both. For the current network the largest impact is an outage of the proposed Boddington load, as this results in an additional 145 MW transfer from the southwest to the metropolitan area, together with a possible reduction in metropolitan area generation. However complete loss of the load is considered unlikely. The studies will be performed by reducing the Boddington load by 50 MW rather than assuming that the load is out of service.

This provides a compromise between planning the network to cater for the complete loss of the load and assuming that no load is lost. This will require System Management to manage the network if there is a complete loss of the Boddington load to ensure there is sufficient reactive support in the metropolitan area.

The credible generation patterns consider the outage of the generator that has the largest impact on reactive reserve. This is currently Cockburn 1. This outage is only considered credible if the SVC is available.

Currently a few hundred MW of load are supplied by IPPs using bilateral contracts and the Market. The remainder of the demand is supplied by Verve which balances the system generation to meet the nett load. After the Market position is determined generation is put into service and dispatched to meet the load according to the following dispatch merit order:

- Windfarms
- Verve non-liquid fired plant (Coal followed by combined and open cycle gas plant)
- IPP non-liquid plant dispatched off its resource plan
- Verve liquid plant
- IPP liquid plant dispatched off its resource plan

In accordance with the above the order in which generation is most commonly put in service and dispatched to meet the load is as follows:

- All non metro generation including wind farms
- Newgen Kwinana
- Cockburn 1
- Kwinana 5 and 6 (n.b. Kwinana A/B units expected to be retired)
- Pinjar units

The 6 frame 6 Pinjar units that are able to operate as Synchronous condensers can be left in service to improve reactive support even though they are not required to operate

as generators. It is assumed that all these units are available and that we do not have a coincident failure of the SVC and synchronous condensers.

Section 2.3.7.3(c)(1) of the Technical Rules states:

for terminal *substations* in the Perth metropolitan area, 3% of the total installed *capacitor banks* plus the reactive device that has the largest impact on the *power system* must be assumed to be out of service;

This requirement is based on historical records of capacitor bank availability. Over past years we have had at least 3% of capacitor banks unavailable as well as some of the large 132 kV connected capacitor banks. Strict interpretation of this clause would require the proposed SVC to be taken out of service in the study of reactive reserve for future years. When this is done however, it is assumed that all metropolitan generation is available and that all the Pinjar synchronous condensers are available. A coincident outage of a generator and SVC is not considered credible. Strict interpretation of the Technical Rules would require the consideration of the outage of a generator and the SVC.

The interpretation of the old Technical Code only allowed for the outage of a large capacitor bank but not the SVC. The Southern Terminal SVC has been specified to have a return to service time of 48 hours. This is the same as the return to service times of the 330 kV transmission lines. Studies consider the outage of the SVC or the outage of a generator but not both. This provides a closer alignment with the Technical Rules.

Section 2.3.7.3(c)(3)(B) of the Technical Rules states:

the *load or power transfer* to be used in the study must be assumed to be 5% higher than the expected system *peak load*, or 5% higher than the maximum expected *power transfer* into the area. (The 5% margin includes a safety margin for hot weather, data uncertainty (including line impedances) and uncertainty in the simulation). The *power system voltages* must remain within normal limits with this high *load or power transfer*,

This increased power transfer is achieved by scaling the load in the metropolitan area only.

Using the above assumptions will result in limited restrictions on generation patterns. Voltage collapse and loss of significant network load could occur, following the outage of 330 kV equipment, if the network operates outside the conditions specified in these assumptions.

.

## Appendix D: TRANSMISSION LINE POWER TRANSFER CAPABILITY

The power transfer capability of a transmission line is inversely proportional to its length. That is, the longer the transmission line, the lower its power transfer capability.

Although both the capacitive and inductive components of the transmission line increase with its length, the relationship between these components and the voltage profile and current (ampere) loading of the transmission line influence the capability of the transmission line.

Without load, a transmission line is capacitive and higher voltages enhance the apparent capacitance of a transmission line. Therefore, an unloaded transmission line will produce reactive power (MVAR) and the higher the voltage, the more reactive power that will be produced.

However as the current (ampere) loading of the transmission line increases the transmission line losses that are the result of the transmission line inductance increase also. This in turn increases the voltage drop across the transmission line leading to a reduction in the capacitance (i.e. reactive power or MVAR) produced by the line.

The loading of a transmission line can increase to a point where the absorption of reactive power by the transmission line is equal to the reactive power that would be produced if the line was unloaded. This point is known as the surge impedance loading (SIL) or “natural loading” of the line.

When the current loading of a transmission line exceeds the SIL, the transmission line will start to absorb reactive power from other parts of the network.

In summary:

- At low load times, transmission lines tend to provide reactive power support into the network. This has the advantage of propping up network voltages.
- During high load periods, transmission lines tend to absorb reactive power to facilitate real power (i.e. MW) power transfer. This has the opposite effect of pulling down network voltages.
- When the SIL of a transmission line is exceeded, reactive power support is required to facilitate higher levels of real power transfer whilst maintaining network voltages within statutory limits.