Appendix O – Transmission Network Development Plan

September 2011

westernpower

Access Arrangement Information for the period 1 July 2012 to 30 June 2017 (AAI)

10 Year Transmission Network Development Plan (TNDP)

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Contents

1 Executive Summary

This document identifies Western Power's 2010 10 year Transmission Network Development Plan (TNDP) for the Western Power Network.

The Western Power Network covers the area from Kalbarri in the north to Albany in the south and from Kalgoorlie in the east to the metropolitan coast. The network is separated into 5 geographic regions which for the purposes of transmission planning, are further divided into 15 load areas. The load areas are defined, in general, by boundaries between major terminals and demand centres.

For each transmission load area, the TNDP provides the following information:

- The size and nature of the load area;
- Historical and forecast growth rates;
- Relationship with other load areas;
- Proximity and nature of generation;
- Current network configuration;
- Emerging transmission network constraints across the study horizon; and
- Transmission network augmentation proposals to address the emerging limitations.

The TNDP also provides a summary of the transmission planning methodology and assumptions used to prepare the TNDP, as well as an assessment of the customers at risk for various project deliverability scenarios.

As part of developing the TNDP consideration was given to a number of factors including:

- Technical Rules compliance [1];
- Load and generation forecasts [2];
- Longer term Strategic Network Objectives;
- Western Powers Network Investment Strategy [3] and Network Management Plan [4]; and
- Western Power's broader commercial objectives.

Western Power develops its transmission network in accordance with the Technical Rules, approved by the Economic Regulation Authority (ERA) in April 2007. The planning process is focused on balancing

[1] http://www.erawa.com.au/cproot/5444/2/Draft%20Technical%20Rules%2024%20March%2007.pdf
[2] ROAM Report on Generation Scenarios – DM 7968532
[3] Network Investment Strategy – DM 7314528
[4] Network Management Plan – DM 8007313.

network costs against the impact of unreliable, insufficient or poor quality power supplies on customers. Transmission Planning Guidelines [5] for the transmission network have been established by Western Power to facilitate a consistent interpretation and application of the planning criteria in the Technical Rules.

Together the Technical Rules and the Transmission Planning Guidelines provide guidance for planners in the consideration of:

- emerging limitations and associated drivers for investment in the Western Power Network;
- design of appropriate network reinforcements given their location, criticality and network risk;
- relative merits of suitable alternative development scenarios; and
- efficient use of capital.

The TNDP identifies a sequence of projects that represent least cost network investment to deliver on mandated service and supply standards over time. Project proposals within the TNDP will be subject to the normal community consultation, business case and regulatory approvals processes at the appropriate time, as part of the more detailed project development phase.

In essence, the TNDP should be seen as a works program which forms a suite of individual projects that are all considered deliverable in the timeframe specified. To achieve this the Agreed In Service (AIS) date for projects takes account of approvals and deliverability timeframes. In some cases the AIS is delayed compared to the Required In Service (RIS) date, which is the date by which the project should be delivered to meet the planning criteria in the Technical Rules. This means Western Power trends towards compliance with the Technical Rules over a number of years, rather than achieving compliance from the first year of the study horizon.

The TNDP is a document which is to be refreshed annually in recognition of changes to load forecasts, generation connections and the development of more refined project definitions as part of the project development phase.

The network development plans outlined in this report were based on relevant planning criteria specified in the ERA approved Technical Rules, with studies performed under peak demand conditions. The load and generation planning scenario adopted for these studies was chosen based on the most probable outlook regarding load growth and new entrant generation planting as identified by an independent consultant (Scenario 20 [6]). A number of alternative generation scenarios were also explored as part of the analysis. These scenarios were used to assess the robustness of the plans proposed in this document through investigation of alternative network strategies, as well as assessing the impact of different generation planning schedules on the proposals in this TNDP.

[5] Transmission Planning Guidelines – DM 8494654.
[6] ROAM Report on Generation Scenarios – DM 7968532

As part of the TNDP a total cost of transmission capital expansion projects as well as operating expenditure associated with network control services can be estimated across the study horizon. Table 1 provides a summary of these costs across the period from 2011/12 to 2019/20. Total costs have been identified, as well as the break down across the 5 Western Power Network regions.

Table 1 –Transmission capital expansion estimated costs 2011/12-2019/20

	Estimated Total Costs 2011/12 to 2019/20*	
Region	**Capital Expansion ($m)**	**Operating Expenditure ($m)**
Metro	931	1
North Country	409	8
South Country	234	31
East Country	0	0
Goldfields	0	12
Total Cost	$ 1,575	52

* $Real 2010/11, unescalated, no risk or cost driver allowance

2 Introduction

2.1 Purpose of this document

This document identifies Western Power's 2010 10 year Transmission Network Development Plan (TNDP). It provides a summary of:

- planning methodology and assumptions used to prepare the TNDP;
- emerging network constraints across the study horizon; and
- transmission network augmentation proposals to address the emerging limitations.

Since transmission assets typically have an economic life longer than the period of time considered by the timeframe of the 10 year transmission development plan, it is appropriate to consider the 10 year plan's alignment with the longer term strategic intent in order to understand the long-run efficiency of the discreet projects and of the broader strategic plan.

Western Power is currently developing longer term (25+ year) network plans that align with the strategic intent for network development across this horizon. Whilst these plans are not yet prepared this 10 year TNDP has considered the strategic intent and adopted planning philosophies and option analysis that align with its objectives.

2.2 Interaction with Western Power's other investment strategies

2.2.1 Network Investment Strategy (NIS)

The NIS [7] is one of the key strategic documents that supports and gives effect to Western Power's corporate vision and objectives. It articulates the long term vision for the network, the objectives associated with this vision and the nature of investments that need to be made to achieve these. The NIS contains Western Power's guiding principles for network investment decision making, based on both traditional and emerging non-traditional (non-network) solutions. It complements and is supported by a range of other internal processes, systems, policies and documents, including the 10 year TNDP. It is designed to be explicit and transparent to facilitate understanding and provide confidence that Western Power's investment decisions are made prudently and commercially, with appropriate consideration of risk and return on investment.

2.2.2 Network Management Plan (NMP)

The NMP [8] is the key document in Western Power's asset management system. It provides the technical overview, strategies

[7] Network Investment Strategy – DM 7314528

[8] Network Management Plan – DM 8007313

and plans for the network in order to meet Western Power's corporate objectives and external obligations from an asset management perspective.

The primary outcome of the NMP is the presentation of the six-year capital and operating investment program required to optimise the lifecycle management of the network assets. This program is aimed towards meeting known business objectives derived from Western Power's understanding of customer, stakeholder and regulatory requirements, knowledge of the existing and projected network assets and associated risks, the measured and expected condition of the assets, and the required and expected asset performance requirements. The plan is co-ordinated with other corporate mechanisms including the NIS and the TNDP to ensure asset management investment is optimised across the business.

2.3 Interaction with Western Power's AA3 submission

Western Power's AA3 submission contains a representation of the expenditure required to efficiently and effectively manage Western Power's transmission network.

Each of the individual transmission projects included in the AA3 submission is aligned with the preferred projects identified in the 10 year TNDP, which is, in turn, aligned with Western Power's vision for the long term strategic development of the State's transmission infrastructure (see Section 2.2 - Network Investment Strategy).

This document provides the context required to understand the prudency of the AA3 transmission investment proposals.

2.4 The role of the Network Planning and Development Branch

Western Power is responsible for the planning, development and management of the Western Power Network.

Network Planning and Development provides short and long term network investment planning for the transmission and distribution networks to address long term growth requirements and imminent customer connection requirements. Responsibilities include:

- identifying the needs of customers, budgeting, scoping, and obtaining approval for investments in network capacity;
- provision of efficient solutions and support for major WA customer connections;
- establishment of enhancement plans to optimise network capacity and network performance and make prudent network investments while meeting all legal, regulatory and budgetary requirements;
- management of Network System Load Forecasts to ensure the network is planned according to realistic projections;

- working with internal stakeholders to promote a safe environment that ensures the safety of employees and the general public; and
- sponsoring projects from planning through to commissioning.

3 Transmission Network Development

3.1 Transmission network planning standards

Western Power develops its transmission network in accordance with the Technical Rules, approved by the Economic Regulation Authority in April 2007.

The Technical Rules contain network planning criteria which are the deterministic standards to be applied when planning the network (eg n, n-1, NCR or n-1-1 criteria defining the required triggers for additional capacity.) Chapter 12 of the Access Code defines the objectives for the Technical Rules and stipulates the requirement for the ERA to approve the Technical Rules and for Western Power and network users to comply with the Technical Rules.

Given the prescriptive role the planning criteria play in shaping the planning of the Network, Western Power ensures the planning criteria are consistently interpreted and applied.

Transmission Network Planning Guidelines are maintained to drive a consistent interpretation of the planning criteria in the Technical Rules.

Western Power's planning process is focused on balancing network costs against the impact of unreliable, insufficient or poor quality power supplies on customers.

Together the Technical Rules and the Transmission Planning Guidelines provide direction for planners in the consideration of:

- emerging limitations and associated drivers for investment in the Western Power Network;
- design of appropriate network reinforcements given their location, criticality and network risk;
- relative merits of suitable alternative development scenarios; and
- efficient use of capital.

The transmission system is broadly divided into the bulk transmission network with a sub-transmission network providing supply to various substations. This TNDP provides a 10 year proposal to address emerging constraints on the bulk transmission network and sub-transmission network, as well as constraints that arise from a substation capacity perspective.

3.1.1 Bulk transmission network

The bulk transmission network operates at 330 kV and 132 kV. It consists of the power station switchyards, major terminal switchyards and the interconnecting transmission lines.

The bulk transmission network is designed to withstand a single unplanned outage without the loss of load. It is also designed to withstand one forced outage and one planned outage at 80% of forecast peak load (assuming generation rescheduling after the first outage). [9]

The bulk transmission network is planned to a higher security standard than other areas of the network in recognition of the significant amount of load it services.

3.1.2 Sub-transmission network

The sub-transmission network operates at 132 kV and 66 kV, with a small number of 33 kV sections. It comprises zone substations and the interconnecting transmission lines between these sites and the bulk transmission network.

The sub-transmission network is generally designed to withstand a single unplanned outage of any component without the loss of load.

In the event of multiple outages, there may be insufficient capacity to meet all demand.

This description broadly applies to the network supplying urban areas of Perth and major regional centres that are not supplied via the bulk transmission system. These parts of the network tend to be characterised by relatively high load densities and shorter transmission lines.

The Perth CBD has a higher level of security, enabling continuous supply in the event of two concurrent unplanned outages of elements of the transmission system. This level of redundancy reflects the importance of power supply reliability in the central business district.

3.1.3 Radial networks

Bulk transmission and sub-transmission networks may be radial in nature.

Radial networks generally supply regional towns where the construction of a meshed network is not economic given the distance of the load from the generation source and the relative sparsity of the demand between substation sites.

It is often uneconomic to provide full redundancy on radial networks due to the length of transmission lines, the dispersed nature of load, and the typically smaller load compared to regional centres or the metropolitan area.

3.1.4 Terminals and substations

Terminals provide for a common connection point for multiple transmission circuits and in most cases also provide bulk transformation capacity between various voltage levels on the transmission and sub-transmission systems.

[9] Some sections of the bulk transmission network designed and constructed prior to the development of the Technical Rules may not achieve this standard. Furthermore some new network may not achieve this criteria where compliance is particularly costly and risk may be minimal. This obligation may be waived through agreement with the Regulator.

Substations connect the sub-transmission network with the distribution network. Each substation is designed according to appropriate planning criteria, which varies based on the substations location and the type and size of load served.

Substations within the defined Central Business District (CBD) are designed to withstand the failure of any two items of plant, within or supplying the substation, with only a temporary interruption to supply.

The majority of substations in the metropolitan area are designed to the NCR Criteria, which permits the loss of up to 75% of the smallest transformers capacity for up to 12 hours. In practice the amount of load lost is minimised through use of operational switching arrangements and the arrival of mobile transformer facilities within the 12 hour period.

Most regional substations are designed to withstand the failure of a single item of plant without any sustained loss of load. A small number of regional substations are designed to withstand the failure of a single item of plant with a small risk to up to 10% of the load needing to be shed (1% Risk Criteria).

A small number of substations are not able to continue to supply following the failure of a single element of plant. These substations have typically been designed for the use of a single customer who has accepted the risk to supply or, in accordance with the Technical Rules, where the load at the substation is less than 10 MVA. Most substations in the Perth metropolitan area are designed to withstand the failure of a single item of plant recognising that some proportion of load may be shed, on a rotational basis, for up to 12 hours.

3.2 Transmission planning methodology and assumptions

3.2.1 Planning methodology

Western Power maintains a Transmission Network Development Plan (TNDP) for the Western Power Network, incorporating the impacts of possible future generation and demand growth scenarios.

The TNDP significantly improves transparency of decision-making both within the organisation and externally, and substantially mitigates risk of imprudent or inefficient expenditure. It also ensures alignment of projects with longer term strategic objectives.

The TNDP is developed through consideration of a number of factors including:

- Technical Rules compliance;
- Load and generation forecasts;
- Asset management plans;
- Longer term strategic network development objectives [10] (see also Section 3.3); and

[10] Network Investment Strategy – DM 7314528

- Western Power's broader commercial objectives.

A TNDP is a sequence of projects that represent least cost network investment to deliver on mandated service and supply standards over time.

Each of the projects within a TNDP can be clearly associated with particular drivers (such as new load or generation connection), triggers for augmentation (e.g. insufficient thermal capacity on transmission lines following new load or generation connection) and timing.

A TNDP demonstrates initiatives to address both current and forecast limitations on the transmission network, whilst also delivering (incrementally) improvements to more global network issues which may not present immediate threats to the reliability of supply.

These issues include better utilisation of the 330 kV network, improved load sharing among assets, minimisation of network loss, operational flexibility and enhanced system security.

A TNDP highlights how Western Power's augmentation options are consistent with the strategic intent of long term development 10 (see Section 3.3). This increases clarity and transparency, reduces ambiguity and improves the prospect of clear auditing within the regulatory arena.

The development of a TNDP seeks to address the requirements of the Technical Rules assuming there are no constraints on attaining the necessary funding for augmentations where drivers can be clearly demonstrated and solutions are shown to be prudent. The TNDP recognises deliverability constraints for various projects, based on internal and external resourcing requirements as well as project staging needs.

Sensitivities to this assumption can be considered to provide an indication of the risk of non-supply to customers should funding be restricted. These sensitivities will include:

- reducing Western Power's capital expenditure program at the expense of network compliance; and
- reducing Western Power's capital expenditure program through installation of cheaper project solutions in the shorter term, which may ultimately lead to higher cost solution overall (incremental/short run planning rather than long run/least cost).

Further justification on any of the projects included in this document, including particular project drivers such as overloaded elements (and the magnitude of the overload), alternative augmentation options analysis and benefit assessments are also available. [11]

The TNDP forms a strategic part of Western Power's transmission planning methodology and will be reviewed each year as forecasts are updated to ensure relevancy and accuracy are maintained.

[11] Project On A Page (POAP) Summary – DM 8561831

3.2.2 Planning assumptions

Western Power's transmission planning responds to expected growth in maximum demand and the expected connection of new generation.

The long lead times required to obtain project funding and environmental, regulatory and development approvals for new transmission lines often allows generation projects to develop more rapidly than transmission line projects.

Therefore, Western Power must plan transmission development on the basis of a rigorous assessment of the most likely generation development scenarios since waiting for generation proponents to commit to plans creates the risk of extended delays in their connection.

Periodically, Western Power refreshes published generation development scenarios to understand how different generation scenarios might drive network development. This information is used in conjunction with network access applications to help identify the long-term target networks required for different load and generation development scenarios. The long-term target network required for each scenario is then examined to determine commonality in network development.

The network development plans outlined in this report were based on relevant planning criteria, with studies performed under peak demand conditions. The load and generation planting scenario adopted for these studies was chosen based on the most probable outlook regarding load growth and new entrant generation planting as identified by an independent consultant (Scenario 20 [12]). A number of alternative generation scenarios were also explored as part of the analysis. These scenarios were used to assess the robustness of the plans proposed in this document by determining alternative network strategies, as well as assessing the impact of different generation planting schedules on the proposals in this TNDP.

Scenario 20 projects a central forecast, 15% carbon reduction trajectory; and a low level of wind ambition. The scenario suggests development of wind generation in the South West Interconnected System (SWIS) is limited by technical and cost prohibitive factors (for example, around frequency control ancillary services).

Planning assumed generation dispatch according to merit order. Using merit order as a basis for planning assumptions is a prudent planning approach since:

- this minimises generation fuel costs; and
- in most cases nearly all generation is operating at almost full capacity at peak load times meaning the ability to re-dispatch (dispatch out of merit order) at this time is minimal.

Adding to the reasonableness of this approach is Western Power's prudent system management processes with respect to outage

[12] ROAM Report on Generation Scenarios – DM 7968532

planning which mitigates risk surrounding contingencies under other dispatch conditions. [13]

Developing generation scenarios requires assumptions about the location of new generation based on an understanding of likely new generation sites, expansion plans of incumbent generators and the planning directions of Government policy making it an inexact science.

Network conditions which vary from those assumed for planning purposes may arise where different generation development and dispatch scenarios eventuate. A robust plan is one that positions the network to accommodate a range of uncertain futures with optimised investment.

Project timing and scope may change as a result of network conditions arising which render plans obsolete, inefficient or ineffective. To address this, actual network expansion is only triggered once there is sufficient certainty to justify the projects.

Further investigation is performed in a detailed project planning phase for each emerging limitation and a thorough investigation of differing generation dispatch conditions is considered.

3.2.2.1 Developing and applying electricity demand forecasts

In contrast to the Independent Market Operator's (IMO's) Statement of Opportunities (SOO), which provides forecasts at the overall system level, the transmission network development planning process requires forecasts for each substation and terminal station.

To then determine augmentation needs, Western Power assesses network capability against electricity demand forecasts using computer simulations to identify thermal, voltage stability and fault rating constraints.

Western Power's load forecasting methodology

Three levels of demand forecasting are required for detailed network planning purposes. These include:

- Peak demand forecast for the bulk transmission system, which is broadly aligned with the demand forecasts reported in the Independent Market Operator's Statement of Opportunities, allows peak network flows across the bulk transmission network to be modelled. An overall load forecast for the bulk transmission network is the sum of individual substation forecasts at the time of the expected system peak load;
- Peak demand forecasts for each load area, which allow peak power flows across the network elements in each load area to be modelled; and
- Peak demand forecasts for each substation, which are developed by extrapolating previous peaks for each substation, and which allow peak power flows across each substation element to be modelled. Western Power's forecasting methodology is based on statistical analysis of historic load

[13] This also reduces the likelihood of constraints on generation, allowing generation to operate unconstrained in accordance with the Technical Rules.

information for every substation and terminal station. Expected block loads are added to these demand forecasts, as appropriate.

In each case, the focus is on understanding the most credible onerous conditions that will affect each network element. For example, the bulk transmission network's most credible onerous power flows are normally at the time of system peak.

An individual substation may have its peak load at a different time to the remainder of the network. Simply using load forecast for the time of system peak would potentially understate the demand placed on each substation element and lead to inadequate development plans.

The most onerous operating condition for each load area is derived from an assessment of the demand at the time of both the system peak and local demand peaks, depending on the characteristics of that load area. In some cases, off-peak conditions, with minimal generation on-line, can present the most onerous operating condition.

Forecasts produced by Western Power indicate that from 2011, peak demand is forecast to grow by 158 MW / year over the next 10 years, reaching a peak of 5604 MW in 2021. This equates to an annual growth of around 3.2%. Energy consumption is forecast to grow by 2.3% annually from 2012/13 to 2016/17.

Forecasts produced by the IMO indicate that for the expected economic growth scenario over the next 10 years, peak demand is forecast to grow by 4.4% annually, while energy consumption is forecast to grow by 3.7% annually. [14]

This indicates that the peak load is growing at a higher rate than the average load supplied throughout the year.

Location of new generation

Western Power provides non-discriminatory access to the Western Power Network. Pricing signals to users and potential users of the network are intended to aid in the optimisation of the development of the system, including the location of new generation sources. However, as Western Power may not direct the location for new generation, it must make prudent assumptions regarding possible generation development scenarios in its network development planning process.

There are a range of factors that can change the feasibility, timing, size and location of such projects. Moreover, in some instances, proponents only provide details of their intentions once the projects are nearly committed, to minimise their commercial risk.

Each of these factors affects Western Power's ability to accommodate new generation proposals in a timely and economically efficient manner. Western Power's planning process must manage the high level of uncertainty associated with the timing, size and location of potential future generation sources.

The impact of this uncertainty is compounded by the time taken to complete major transmission network augmentation projects, such as the construction of 330 kV transmission lines. While the construction

[14] http://www.imowa.com.au/soo.

phase of a generation project can take as little as two years, establishing a new transmission line can take seven to ten years from concept to commissioning.

3.2.2.2 Typical drivers of load growth

In the SWIS, typical drivers of load growth include:

- new residential sub-divisions. There is rapid growth in new residential developments along the northern and southern coastal strip towards Two Rocks and Mandurah, as detailed in the Metropolitan Development Program. [15];
- in-fill growth in older metropolitan suburbs, resulting in increased housing and hence increased load density;
- larger customers such as shopping centres and particular industrial/commercial loads. There have been a number of announcements of sizeable industrial loads to come into operation over the next decade. These loads are included in the base assumptions when they can be considered as committed projects; and
- mining activity in regional areas and growth in regional centres.

3.2.3 Development of budgets

When preparing cost estimates for network reinforcement options considered as part of the 10 year TNDP Western Power used internal cost "building block" estimates derived from a mix of historical cost and current market values for various transmission components. Whilst costs are not listed in this document further information on any of the projects included in this document, including project drivers, alternative augmentation options analysis and benefit assessments is available. [16]

3.3 Transmission planning Strategic Network Objectives

The long lived nature of Transmission assets means that any augmentations to the transmission system today will influence the characteristics of the system for the next fifty years. To minimise the risk that near term plans formulated on a strictly "least cost" basis, frustrate the implementation of the future changes required to achieve longer term strategic objectives, it is important that all near term development plans, formulated to address near term constraints, are also formulated having regard to the long term strategic needs of the network. This approach allows the near term plans to become enablers, rather than frustraters of the strategic direction.

Western Power is in the process of compiling long-term (10-25 year) plans for each of its load areas.

[15] http://www.planning.wa.gov.au/641.asp

[16] Project On A Page (POAP) Summary – DM 8561831

10–25 year plans will direct the work required to address the long-term issues of each load area as they relate to strategic network objectives for transmission system development.

Whilst these plans are not yet prepared this 10 year TNDP has considered the strategic intent and adopted planning philosophies and option analysis that align with its objectives.

Issues Western Power is seeking to address through its long-term transmission development objectives (including developments across the 10 year horizon) have been broadly categorised to include the following six points:

1. **Inefficient load sharing among existing 330 kV and 132 kV assets**: Western Power will work to improve load sharing among existing 330 kV and 132 kV assets. In particular, increased utilisation of 330 kV infrastructure resulting in subsequent relief of congestion at 132 kV.
2. **Power flow controllability**: The current network is heavily meshed with multiple parallel 330 kV and 132 kV paths. This creates limitations in controlling power flow from an operational perspective, particularly under peak demand conditions. Planning will consider options to address this, such as opening key points in the network. Proposed solutions will have consideration of the need for operational flexibility under post-contingent conditions, including black start requirements.
3. **Aging 66 kV infrastructure**: Some areas of the Western Power Network contain aged 66 kV assets in excess of 60 years old. Western Power's planning considers the need for staged replacement and upgrade of these assets to 132 kV, to support load growth with minimal additional footprint. This also removes one transmission voltage level in the area resulting in improved backup supply options, fewer spares, increased flexibility for future reinforcement and avoiding the need for 66 kV transformation costs.
4. **New generation location**: Lead times associated with transmission development can often be in excess of those required for generation construction and commissioning. Planning considers the likely connection and location of future generation plant under a range of scenarios, to facilitate the timely connection of new entrants.
5. **Fault level considerations**: Numerous locations on the Western Power Network are now approaching fault level limitations and in some cases operational mitigations are already in place to avoid protection risks. These operational procedures can limit the maximum supportable demand by constraining generation, and therefore potentially impacting the least cost generation dispatch, unduly influencing market operation.
6. **Operational and market related issues**: A clear understanding of other operational and market issues that relate to the development of the network is important. Where applicable, solutions to these issues will also feature in TNDP cost benefit option analysis.

These strategic objectives have been used in developing the 10 year plan as a means of guiding the selection of alternative projects to address a particular need.

However, simple alignment with these strategic objectives is insufficient for Western Power to commit to any particular project and does not replace the detailed power system studies and economic comparison of options that takes place as part of detailed business planning.

Additionally, for any project with a value greater than $30m, Western Power is also required to demonstrate the project satisfies both the Regulatory Test and the New Facilities Investment Test (NFIT) imposed by economic regulation.

While the strategic objectives do not present an authority to proceed with a project they are an essential element of the planning and approvals process since, in order to demonstrate projects meet the Regulatory Test and NFIT, Western Power must show that they are aligned with an economically efficient strategy.

It is not possible to demonstrate the economic merit of strategic objectives such as changing from 66 kV to 132 kV or better utilisation the 330 kV network, across the 10 year planning horizon on which the TNDP is based and a much longer planning horizon must be considered (25 to 50 years.)

While long term plans (10-25 years) are still in development, the 10 year plans expressed in this document are cognisant of the longer term needs of each load area and therefore represent work plans that are consistent with the achievement of the long-term strategic objectives.

For each load area, the long-term issues may not require specific and immediate mitigation. However while these issues may not necessarily present an emerging threat to reliability of supply in the short term, existing operational inefficiencies/problems such as power quality, poor load sharing, reduced operational flexibility and increased line loss will be mitigated in a manner consistent with the achievement of the long-term strategic intent.

Through adherence to the regulatory principles of economic efficiency, network investment that only delivers on strategic objectives is unlikely to be proposed, unless benefits can be clearly quantified and are sufficient to justify the project.

As a result, option analysis will always consider strategic direction and seek to value these benefits as well as those attributed to reliability, quality and security of supply.

This approach strengthens the argument for particular network reinforcement over alternatives.

The value of strategic direction and its contribution to long-term economic efficiency cannot be overstated.

3.4 Committed or Highly Prospective works

This section describes transmission augmentation projects which are now committed, having achieved business case approval or at a sufficiently advanced stage that there is a high level of confidence that the project will proceed. In all cases these projects are partially funded under the AA2 period but which will not be concluded and commissioned until after the commencement of the AA3 period.

Table 2 provides a summary of the committed and highly prospective transmission projects.

The forecast transmission system constraints and network development scenarios outlined in the following sections are cognisant of the capacity increases provided by the augmentation projects listed below and any forecast constraint is expected to occur as a result of load or demand growth in excess of the capacity afforded by these projects.

Table 2 – Committed or highly prospective projects

Project Description	Driver
Installation of a third 132/22 kV transformer at Marriott Road Substation	Accommodate increasing demand in the area. Create additional feeder capacity to allow for load growth and additional distribution transfer capacity. **RIS [17] Quarter 4 2012**
Installation of a second 132/22 kV transformer at Joondalup Substation	Accommodate increasing demand in the area. Create additional feeder capacity to allow for load growth and additional distribution transfer capacity. **RIS Quarter 4 2012**
Installation of second 132/22 kV transformer at Henley Brook Substation	Accommodate increasing demand in the area. Create additional feeder capacity to allow for load growth and additional distribution transfer capacity. **RIS Quarter 2 2012**
Installation of a third 132/22 kV transformer at Southern River Substation	Accommodate increasing demand in the area. Create additional feeder capacity to allow for load growth and additional distribution transfer capacity. **RIS Quarter 4 2012**
Installation of a third 132/22 kV transformer at Waikiki Substation	Accommodate increasing demand in the area. Create additional feeder capacity to allow for load growth and additional distribution transfer capacity. **RIS Quarter 4 2012**
Establish new Balcatta 132/22 kV Substation	Accommodate increasing demand in the area. Create additional feeder capacity to allow for load growth and additional distribution transfer capacity. **RIS Quarter 4 2013**
Mid West Energy Project (Southern Section Stage 1)* *This project is not committed although it has satisfied the Regulatory Test and is currently undergoing NFIT Pre-approval.	Accommodate increasing demand in the North Country area, in particular mining loads east of Three Springs. Facilitates future staging of a 330kV network north of Three Springs. **RIS Quarter 1 2014**

[17] RIS – Required In Service date

4 Transmission Load Areas

The Western Power Network covers the area from Kalbarri in the north to Albany in the south and from Kalgoorlie in the east to the metropolitan coast. The network is segmented into 15 geographic load areas for the purposes of transmission planning. Figure 1 and Figure 2 provides an illustration of the geographic boundaries between load areas and the transmission/sub-transmission network within the areas, respectively.

This section outlines, for each transmission load area, the developments that are proposed over the next 10 years.

This section considers for each area:

- The size and nature of the load area;
- Historical and forecast growth rates;
- Relationship with other load areas;
- Proximity and nature of generation;
- Current network configuration;
- Emerging transmission network constraints across the study horizon; and
- Transmission network augmentation proposals to address the emerging limitations.

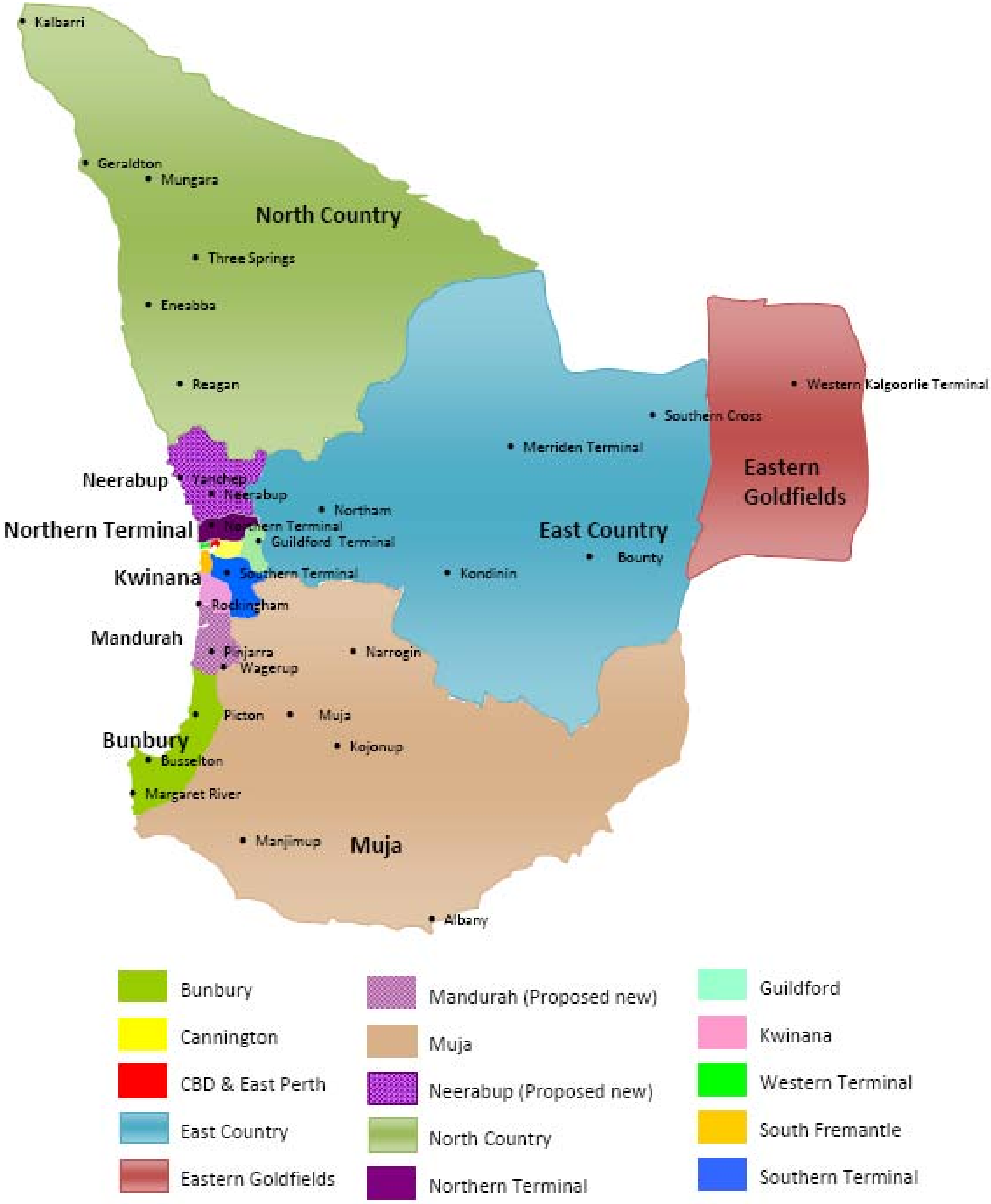

Figure 1: Western Power Network geographic load areas

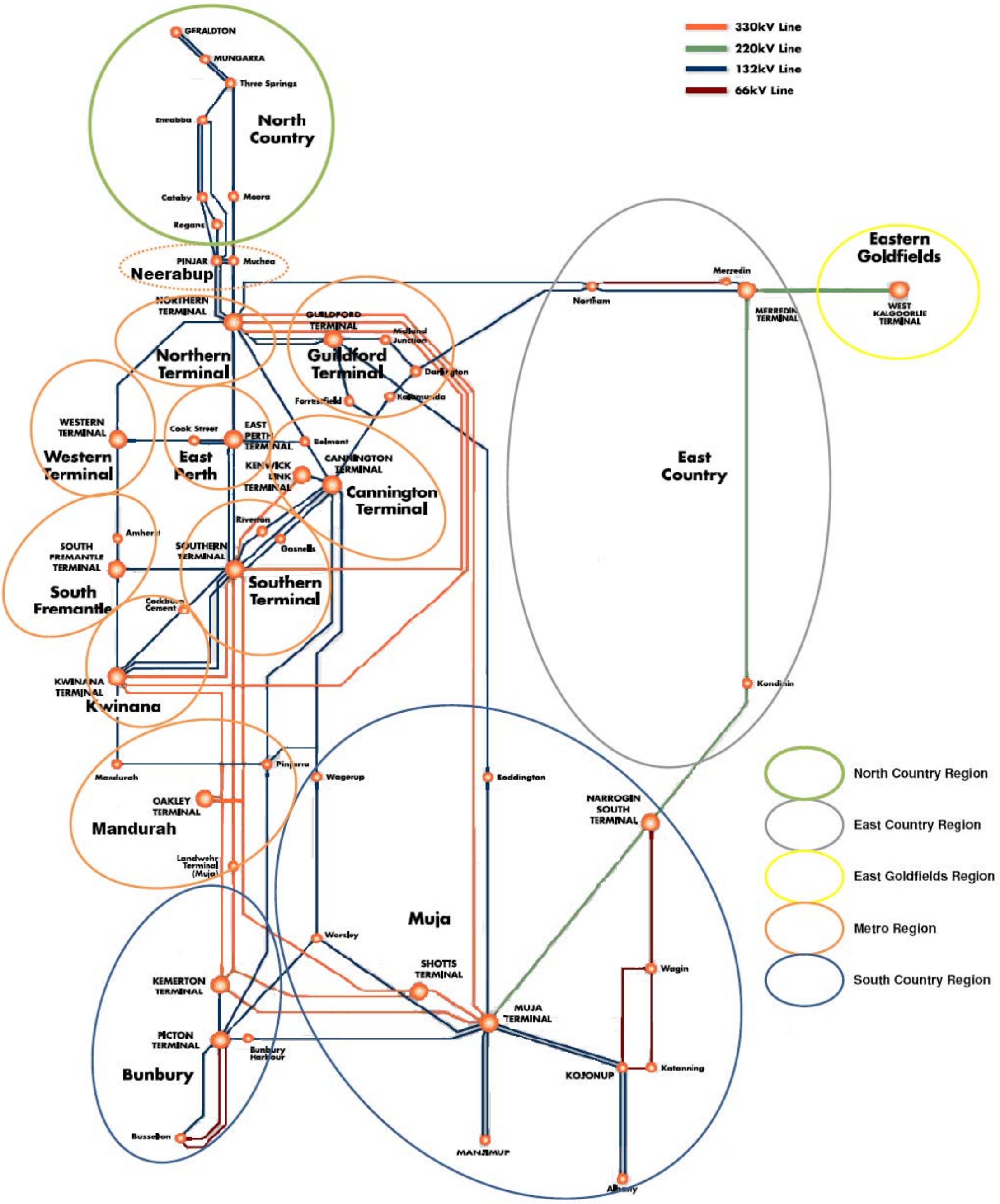

Figure 2: Transmission and sub-transmission system within Western Power Network load areas

4.1 North Country

4.1.1 Geographic load area

The North Country Load Area extends from Pinjar and Muchea at the northern edge of the Neerabup Terminal Load Area to Kalbarri at the northern extremity of the Western Power Network. The load area extends inland approximately 150 km to service the northern Wheatbelt.

4.1.1.1 Load area characteristics

The North Country Load Area is electrically connected to the Western Power Network via a number of very long 132 kV transmission lines. The network has evolved over time primarily supplying relatively small loads distributed over a large geographical area. As a result of the particularly long distances covered by this network the power transfer capability is small and governed mainly by voltage and synchronous stability limitations. Thermal issues also present constraints in some areas.

4.1.1.2 Demand

4.1.1.2.1 Historic growth rates

Since 2000 the North Country Load area has exhibited a steady growth of 4 MW / year.

4.1.1.2.2 Customers served

The approximate number of customers supplied in this load area is 30,000. Commercial customers account for more than 4,100 connections. Domestic customers make up more than 24,200 connections. Farming customers represent almost 1,500 connections and industrial connections total almost 90.

4.1.1.2.3 Projected growth rates

From 2011, the North Country Load Area is forecast to grow at 19 MW / year over the next 10 years reaching a peak demand of 360 MW in 2021.

In this 10 year period, 11 block loads have been included in the forecast. Of these 11, the following three are the most prominent. It should be noted that the predominantly block-nature of the loads contributing to growth will result in an uneven growth profile across this period.

- 2012: Gindalbie Metals Ltd. 85.5 MW
- 2013: Gindalbie Metals Ltd. 22.5 MW
- 2014: Oakajee Port and Rail Stage 1 Development. 25.2 MW

4.1.1.3 Generation

There are a number of generating units in the area and due to existing network limitations there is heavy reliance on some generators to provide network support under certain operating conditions.

Due to the availability of fuel resources, including wind and other renewable sources, there has been a strong attraction for new entrant generation to be sited in the area and Western Power continues to receive considerable interest for new developments. These interests are reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

Given the volume of connection enquiries it is anticipated that over the medium to longer term the North Country Load Area is likely to serve the purpose of a generation hub. It is therefore important to ensure sufficient transmission network capacity is available for this generation to efficiently supply major load centres for the foreseeable future.

4.1.1.4 Current network

The following figure represents the existing transmission network within the North Country Load Area.

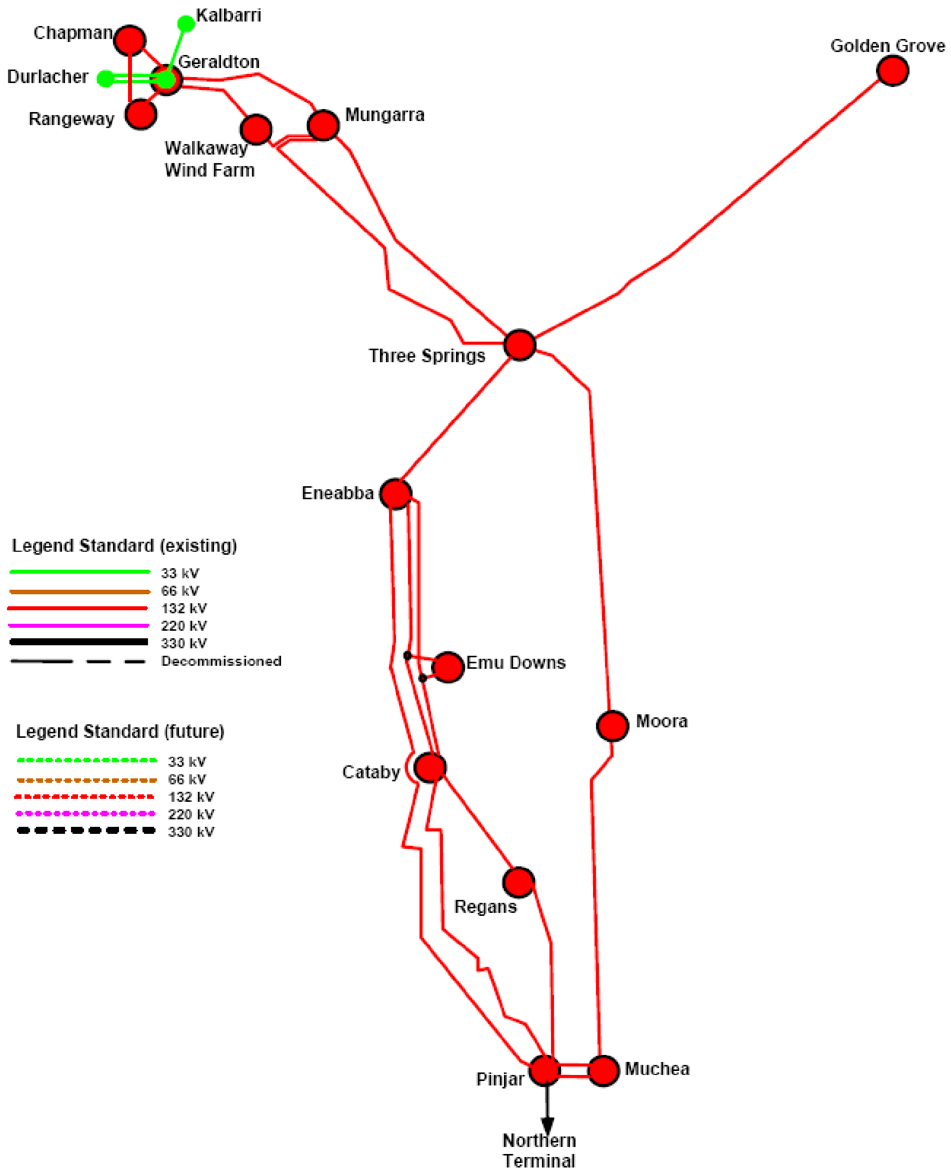

Figure 3: Transmission System – North Country Load Area

4.1.1.4.1 Purpose (Relationship with other load areas)

The North Country transmission network extends north from Perth and neighbours the Neerabup Load Area. Under nearly all operating conditions power is transferred from the south to North Country loads.

Generation connection inquiries tend to indicate the load area may be subject to considerable generation connection in the future.

Relative to the length of network, there is a small number of substations, and load is focused around the town of Geraldton.

More recently a number of new mining loads have demonstrated increased commitment to connecting into the area, including Gindalbie Metals (Kararra Mining Limited) which is a foundation customer for the new 330 kV Mid West Energy Project (Southern Section Stage 1).

4.1.1.4.2 General considerations

Western Power is currently considering numerous large mining load and generator connection enquiries. These connections are typically very responsive to the current economic climate and this, coupled with the risks associated with funding such ventures, can make these propositions somewhat volatile. This in turn presents difficult load forecasting decisions which can result in load forecasts that fluctuate considerably from year to year. This presents challenges for transmission planning as the optimum timing and size of new augmentations, as well as the risk associated with these projects can be difficult to substantiate.

The very long, weak nature of the transmission system in North Country presents operational challenges for system management. Significant reliance is placed on network support from generators in the area and large power system disturbances can cause difficulties with system stability. Furthermore, there are few transmission circuits so the risk of exposure and subsequent damage to multiple elements resulting from lightning and fire mean the infrastructure offers a marginally lower level of reliability overall.

4.1.1.4.3 Substations

There are 10 substations in the North Country Load Area of which the following nine are owned and operated by Western Power.

- Geraldton
- Chapman
- Rangeway
- Durlacher St
- Three Springs
- Eneabba
- Moora
- Cataby
- Regans

All Western Power substations in this load area are subject to peak demand conditions during the summer months.

4.1.1.4.4 Transmission lines

The existing North Country transmission system is a 132 kV network connected between Pinjar and Muchea in the south to Chapman in the north (with 33kV network extending as far north as Kalbarri). The network is approximately 450km long and is largely comprised of two single circuit 132 kV lines north of Eneabba and four 132 kV circuits to the south of Eneabba. A number of generators inject at various locations within the North Country network and provide valuable support to ongoing system security in the area.

To ensure Western Power can continue to provide reliability of supply to customers and facilitate future generation connections, it is anticipated that the North Country Load Area will be subject to considerable network development over the coming decade.

The Mid West Energy Project (Southern Section Stage 1) has recently satisfied the Regulatory Test and is expected to be complete early 2014. This development has been primarily driven by a foundation customer, Karara Mining Limited, although the development presents considerable benefits to the North Country Load Area as a whole, and facilitates future stages of work.

The transmission lines in this load area are generally designed to meet the N-1 capacity criteria.

4.1.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.1.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the North Country Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which may be employed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Geraldton (GTN)

Geraldton Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Durlacher St (DUR)

Durlacher St Substation has two transformers and operates under the N-1 criteria. Following planned distribution reinforcements between Durlacher St Substation and Rangeway Substation [18] by summer 2012/13, load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Rangeway (RAN)

Rangeway Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations with the exception of possible transfers from Durlacher St.

Chapman (CPN)

Chapman Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Three Springs (TS)

Three Springs Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations. However following release of the forecasts used for the preparation of the Network Development Plans Western Power has received numerous connection enquiries at Three Springs which will exceed capacity if a reasonable proportion materialise.

Eneabba (ENB)

Eneabba Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Moora (MOR)

Moora Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14.

Cataby (CTB)

Cataby Substation has no transformers, but provides a 132 kV supply to a customer owned substation called KMC (Kerr McGee Minerals).

[18] This is a customer driven project.

Regans (RGN)

Regans Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.1.2.2 Fault levels

There are no notable fault level issues in the North Country Load Area.

With the current level of generation connection enquiry it is anticipated that some sites may reach fault level limitations in the medium term, depending on connection location.

4.1.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on:

- 132 kV circuits between Geraldton and Mungarra for loss of parallel circuits; and
- Moora to Three Springs 132 kV following loss of the new Eneabba to Neerabup 330 kV circuit installed as part of the Mid West Energy Project (Southern Section Stage 1).

The new entrant generation schedule used as input to the power system studies features considerable new generation in the Eneabba area. Western Power has assumed the bulk of this generation would connect to a new 330 kV Terminal at Eneabba by summer 2014/15 for the purpose of power system studies. However, in recognition that some of this generation may not materialise by this date the actual Agreed In Service (AIS) date for the Terminal is planned to be around summer 2016/17 (see Section 5 for more information on Deliverability). Should this generation connect at 132 kV at Eneabba a number of additional thermal limitations will arise.

4.1.2.4 Voltage limits

With one or more Mungarra generating units offline, voltage stability limitations exist at Geraldton under peak demand conditions following a number of contingencies including:

- loss of 132 kV circuits between Mungarra and Geraldton; and
- loss of a Three Springs to Mungarra 132 kV circuit.

Post-contingent voltage recovery is particularly sensitive to the staged development of the Mid West Energy Project, including operating times of special protection schemes to facilitate connection of Karara.

Static VAr Compensation facilities at Walkaway Wind Farm mitigate these stability issues to some extent, although with increasing demand in the far north of the load area additional reinforcement is required to maintain satisfactory voltage levels.

As the Mid West Energy Project (Southern Section Stage 1) provides reinforcement to Three Springs from the south, it offers some support to the emerging issues further north of Three Springs, which are mentioned above.

It is currently anticipated that Network Control Services (NCS) north of Three Springs may be able to defer considerable investment for a number of years. Should load growth in the North Country Load Area be higher than currently projected or sufficient NCS not be available, reinforcement options between Three Springs and Mungarra and further north, will need to be brought forward.

4.1.2.5 Asset condition

The North Country transmission system contains a number of aging circuits. Of particular note are the following circuits which are now in excess of 35 years old:

- Three Springs to Moora 132 kV; and
- Moora to Muchea 132 kV.

The Durlacher Substation is also approaching the end of its economic life.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.1.3 Network development within a 10 year period

4.1.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in Section 3.1.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentations and timings have been identified below.

4.1.3.2 Preferred substation solutions

- Installation of 132 kV cable from Rangeway to the Geraldton Port Authority (energised at 11kV) to facilitate increased supply requirements of the Port by summer 2012/13 [19];
- Installation of 3rd transformer at Three Springs Substation by summer 2016/17;
- Transfer of load from Durlacher St Substation to Rangeway Substation by summer 2012/13 to defer augmentation at Durlacher St Substation to around summer 2020/21;
- Establish a new substation (Geraldton Port Authority (GPA)) by around summer 2020/21. Transmission supply to this substation is to be provided by re-energisng the 132 kV cable (which will be energised at 11kV in 2012/13 from Rangeway Substation to supply GPA load) to 132 kV and connecting this new substation to Rangeway Substation at 132 kV. Existing Geraldton Port Authority load supplied at 11kV from Rangeway Substation is to be transferred to the new substation. A

[19] This is a customer driven project.

second 132 kV cable is also to be installed from Rangeway Substation to the new substation by summer 2020/21; and

- Transfer of load from Durlacher Street Substation to Geraldton Port Authority by summer 2020/21. Move towards possible decommissioning of Durlacher Street Substation by summer 2021/22.

4.1.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network, as well as existing fault level issues. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term (10-25 years) and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes to defer more costly investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

The following aspects were key influences on the preferred network solutions in the North Country Load Area;

- Connection of major customers;
    - Karara Mining Limited (see also Gindalbie Metals Ltd - connection of 85.5 MW by summer 2011/2012 increasing to 108 MW by summer 2012/2013);
    - Oakajee Port and Rail Stage 1 (connection of 25.2 MW by summer 2013/2014); and
    - additional large block loads that were not included in the central forecasts used as input for the 2010 Network Development Plans. Whilst these loads were not used to determine the timing of emerging limitations, they were considered when sizing augmentation proposals which addressed constraints seen under the central forecast.
- Ongoing use of existing aged sub transmission assets and their role in the future strategy;
- Staging development to optimise asset utilisation;
    - It is important to ensure that network reinforcement is staged to ensure deliverability as well as optimise use of existing infrastructure. Consideration has been given to the use of special protection schemes to trip major loads following various contingencies. This may allow major augmentation to be deferred.
- Use of Network Control Services to defer investment;

  - Given the long distances involved opportunities for Network Control Services should be exhausted to defer costly augmentations.

- Ability for existing and future generation to operate unconstrained under various dispatch conditions [20];
  - Projected connection of significant new entrant generation around Eneabba area between 2015 and 2020 as part of ROAM Scenario 20; and
  - Given extensive interest for new entrant generation connections in the North Country Load Area network development strategies should consider establishment of generating hubs to facilitate connection of generation to the bulk transmission system and improve reserve sharing opportunities.

- Strategic importance of Neerabup and Northern Terminals in to longer term reinforcement needs of the North Country Load Area;
  - Northern Terminal is a particularly strong 330 kV Terminal with connections to Guildford, Kwinana and Muja, as well as Neerabup. There is considerable spare capacity on these 330 kV circuits and a number of relatively low cost options exist to expand this capacity further. As the North Country Load Area evolves and its demand on the remainder of the Western Power Network increases, there will be increased reliance on this infrastructure. Future development of the North Country Load Area should be optimised to best utilise existing network capacity to the south as well as support strategic development of bulk transmission capacity further north. This will ultimately lead to improved generation sharing opportunities and a strong bulk power transfer capacity for the length of the Western Power Network.

With consideration to the above influences on a preferred network development plan a number of options were considered. These options look to address the emerging constraints in the area, defer costly investment and work towards delivering on the Strategic Network Objectives (see section 3.3).

4.1.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

[20] Whilst studies were performed using merit order dispatch, consideration was given to sizing augmentations to allow for unconstrained operation under various dispatch conditions.

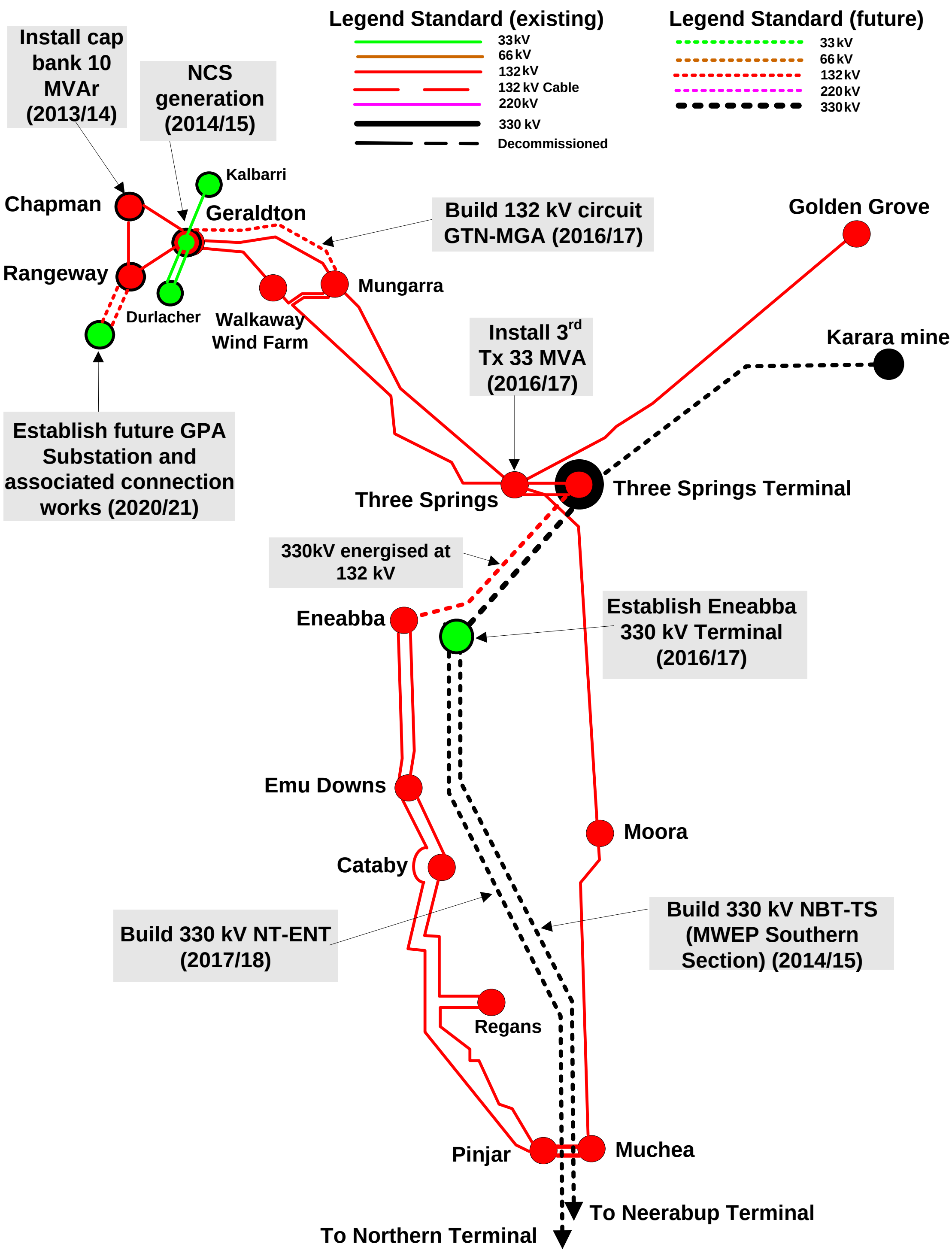

Figure 4: North Country Load Area – preferred transmission solutions

The specific projects planned for the North Country Load Area over the next 10 years include:

- Installation of a shunt capacitor bank at Chapman Substation by summer 2013/14;

- Install Mid West Energy Project Southern Section Stage 1 by summer 2014/15 [21];
- Use of Network Control Services (NCS) from around summer 2014/15 in the Geraldton area to defer more costly network reinforcements north of Three Springs;
- Customer related works associated with connection of Oakajee Port and Rail by summer 2015/16 [22];
- Establish Eneabba 330 kV terminal (ENT) cutting into the new Neerabup to Three Springs 330 kV line (which is established as part of the Mid West Energy Project (Southern Section Stage 1)) by summer 2016/17;
- Build new single circuit 132 kV line from Mungarra to Geraldton by summer 2016/17; and
- Uprate the 2nd circuit of the Northern Terminal to Eneabba Terminal 330 kV line to 330 kV (Mid West Energy Project southern section – Stage 2) by summer 2017/18.

The preferred solution offers the following benefits:

- Strengthens the North Country system particularly between the northern metropolitan area and Three Springs, providing for connection of future generation and reduced constraint on existing plant;
- Improves reactive support in the North Country Load Area, especially between Northern Terminal/Neerabup and Three Springs;
- Improves dynamic stability north of Mungarra;
- Facilitates connection of major customers including Karara and Oakajee Port and Rail;
- Provides good staging flexibility for future 330 kV expansion in the load area, ultimately facilitating a strong 330 kV system the length of the Western Power Network. This will improve reserve sharing across the network and significantly improve bulk 330 kV utilisation; and
- Provides for the decommissioning of assets in poor condition at Durlacher St Substation through establishment of a new Geraldton Port Authority Substation.

[21] Currently anticipating completion early 2014.
[22] This is a customer driven project.

4.2 Eastern Goldfields

4.2.1 Geographic load area

The Eastern Goldfields Load Area is comprised, in the main, of mining loads centred on the City of Kalgoorlie. The load area extends west of Kalgoorlie to Merredin and south of Kalgoorlie to Kambalda.

4.2.1.1 Load area characteristics

Energy demand in the region is dictated by mining activity which, in turn, is heavily dependent on commodity prices. Agricultural load in the western extent of the load area is relatively steady and paints a picture of a load area made up of two very different halves.

4.2.1.2 Demand

4.2.1.2.1 Historic growth rates

Since 2000 the Eastern Goldfields Load Area has exhibited a steady growth of 1 MW / year.

4.2.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 12,550. Commercial customers account for almost 1,400 connections and domestic customers make up more than 11,000 connections. Farming and industrial customers combined total less than 100 connections

4.2.1.2.3 Projected growth rates

From 2011, the Eastern Goldfields Load Area is forecast to grow at 3 MW / year over the next 10 years reaching a peak demand of 129 MW in 2021.

In this 10 year period, 5 block loads have been included in the forecast.

4.2.1.3 Generation

There is a significant amount of gas-fired generation installed at Kalgoorlie. The total capacity installed in the Eastern Goldfields Load Area is more than 200 MW, the bulk of which is independent power producers supporting in-house mining loads.

There are currently no committed plans for the establishment of new generating capacity in the Eastern Goldfields Load Area, however some interest has been raised for the connection of solar PV generation around Kalgoorlie. These interests are reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

4.2.1.4 Current network

The following figure represents the existing transmission network within the Eastern Goldfields Load Area.

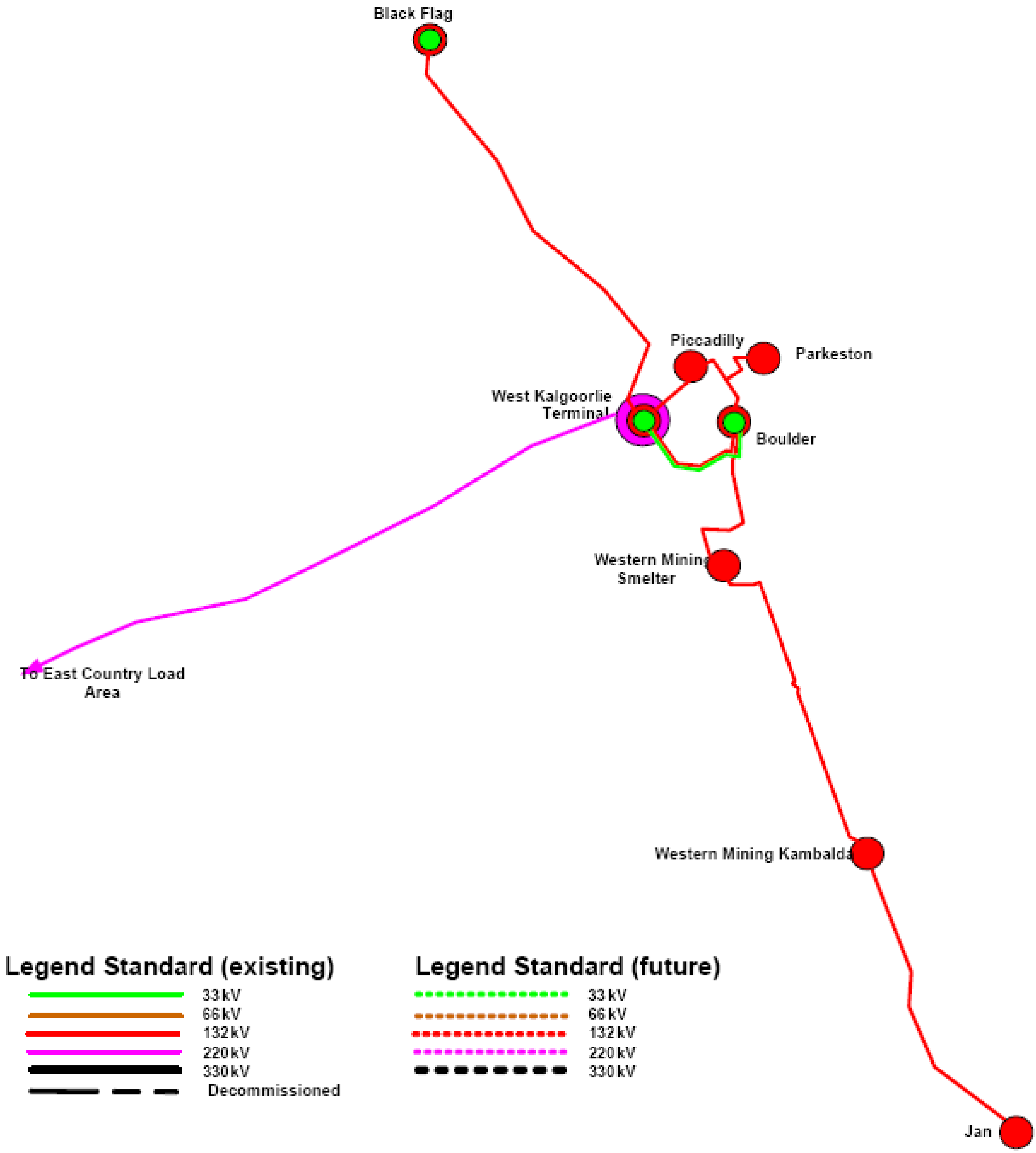

Figure 5: Transmission System – Eastern Goldfields Load Area

4.2.1.4.1 Purpose (relationship with other load areas)

The network in the Eastern Goldfields Load Area supplies residential and mining loads centred on the towns of Kalgoorlie Boulder and Coolgardie and provides a transmission link to the rest of the Western Power Network.

Eastern Goldfields Load Area is connected via a single transmission line to the neighbouring East Country Load Area through which the supply of local load is supported.

4.2.1.4.2 General considerations

As a result of its single connection to the rest of the Western Power Network, the Eastern Goldfields Load Area network is operated at N-0, which presents a reduced level of reliability to loads in the area.

It is not yet clear if Western Australian domestic gas markets will be subject to international gas price parity as a result of liquefied natural gas developments in the State. It is anticipated that gas prices are likely to rise and when coupled with a carbon tax the gas fired generators in Eastern Goldfields may reduce capacity factors. This potential reduction in generation levels in the area will bring forward the timing of required network augmentations given its impact on the balance of power flows to the Eastern Goldfields Load Area.

A complicating factor in the planning and timing of network augmentation projects is the nature of the surrounding loads. These are typically block loads required to meet mining needs, which makes them difficult to forecast due to their inherent volatility in response to market economics. This in turn creates difficulties when planning the transmission system.

Finally, the network is very long and presents considerable operational challenges surrounding stability and justification of future investment to the area on the basis of significant cost.

4.2.1.4.3 Substations

Eastern Goldfields load area consists of seven zone substations, of which five are owned operated by Western Power.

- Black Flag
- Piccadilly
- Boulder
- West Kalgoorlie 11 kV
- West Kalgoorlie 33 kV

All Western Power substations are subject to peak demand conditions during the summer months.

4.2.1.4.4 Transmission lines

The Eastern Goldfields is connected to the Western Power Network via long 220 kV single circuit from Merredin. Supply to the substations in the area is via a 132 kV sub-transmission network.

Dynamic reactive reserve is provided via saturated reactors at Merredin and West Kalgoorlie terminals in addition to local generating units.

4.2.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.2.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Eastern Goldfields Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

West Kalgoorlie Terminal 11 kV (WKT 11)

This Terminal has one transformer. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

West Kalgoorlie Terminal 33 kV (WKT 33)

This terminal has one transformer. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Black Flag (BKF)

Black Flag Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Boulder (BLD)

Boulder Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Piccadilly (PCY)

Piccadilly Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.2.2.2 Fault levels

There are no notable fault level issues forecast to develop on the Eastern Goldfields Load Area network over the next 10 years.

4.2.2.3 Thermal limits

Thermal limitations are not expected to present any issues over the next 10 years. With the introduction of a carbon tax it is anticipated that fuel costs associated with gas fired generation may make generation in this areas less competitive. This in turn will drive increase reliance on imports from neighbouring load areas. At present there are voltage stability limitations which set power transfer capability to the Eastern Goldfields Load Area, however should these voltage limits be relieved thermal limitations may then arise.

4.2.2.4 Asset condition

The majority of assets within this load area were installed around 1982 and as such have considerable remaining operating life.

4.2.2.5 Voltage limits

There are voltage and transient stability limitations in the Eastern Goldfields Load Area which are influenced by:

- the power output of from local generators in the area; and
- total power import into the Goldfields.

These stability limitations are evident following a number of contingencies both within the area and in other load areas. Transient limitations are driven, in part, by the relatively low inertia of generating units and the voltage stability limits arise due to insufficient reactive reserve. These limitations are currently managed through prudent system management dispatch processes and including special protection control schemes.

Oscillatory stability issues (small signal) have also been identified between machines in the area and other SWIS generating units.

4.2.3 Network development within a 10 year period

4.2.3.1 Substation capacity expansion

As forecasts indicate substation capacity in the Eastern Goldfields Load Area is adequate to meet demand over the next 10 years there is no substation expansion plan being proposed across this horizon.

4.2.3.2 Transmission reinforcement

While emerging limitations in the Eastern Goldfields Load Area transmission network are considerable, the cost of significant augmentation make it difficult to justify expenditure on augmentation projects. Uncertainty surrounding the impact of the Carbon Tax contributes to the reluctance to commit to major upgrades of the transmission system. Should the Carbon Tax drive considerable additional congestion in the network, or should additional block loads connect, reinforcement will have to be considered.

Voltage and transient stability limitations are currently managed through prudent system management and dispatch processes, as well as existing special protection control schemes.

Western Power currently anticipates installation of a dynamic power system monitoring tool by summer 2012/13 (Psymetrix) to allow better identification of oscillatory stability related issues to maximise utilisation of existing network and improve system security. This monitoring equipment is expected to be in service by around summer 2012/13.

It is anticipated that Network Control Services (NCS) will be required in the area from around summer 2012/13 to support load growth, as well as potential reduction in market driven gas fired generation in the area due to higher gas prices and carbon tax impacts.

4.3 East Country

4.3.1 Geographic load area

The East Country Load Area covers the Wheatbelt district of the south west and is bound by Sawyers Valley and the outer metropolitan area in the west, Southern Cross in the east, the Muja Load Area to the south and the North Country Load Area to the north.

4.3.1.1 Load area characteristics

The load area is mostly comprised of rural, water-pumping, mining and residential loads and has historically been characterised by a slow growth rate mirroring the slow economic growth of the region.

Recent developments in the mining industry have had a resurgent effect on demand growth in the area.

4.3.1.2 Demand

4.3.1.2.1 Historic growth rates

Since 2000 the East Country Load area has exhibited a steady growth of 3 MW / year.

4.3.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 26,500. Commercial customers account for almost 3,500 connections and domestic customers make up almost 21,000 connections. Farming customers represent almost 2,400 connections with almost 50 industrial connections.

4.3.1.2.3 Projected growth rates

From 2011, the East Country Load Area is forecast to grow at 2 MW / year over the next 10 years reaching a peak demand of 140 MW in 2021

In this 10 year period, 3 block loads have been included in the forecast.

4.3.1.3 Generation

Historically, the East Country Load Area has not had local generation. However, more recently, Western Power has begun to receive interest in connecting generation of both renewable and non-renewable nature to the East Country network. These interests are reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

The first of a number of potential generation connections is the Colgar Wind Farm with staged commissioning through to 2013/14.

4.3.1.4 Current network

The following figure represents the existing transmission network within the East Country Load Area.

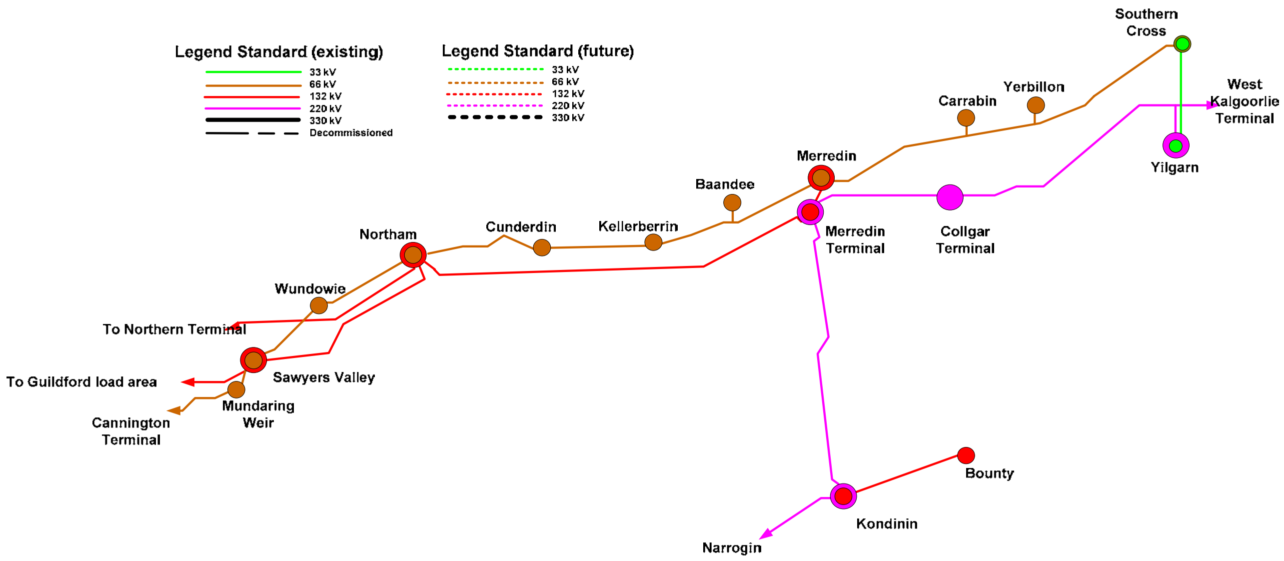

Figure 6: Transmission System – East Country Load Area

4.3.1.4.1 Purpose (Relationship with other load areas)

The purpose of the network in the area is to support local load as well as to provide a link through to the Eastern Goldfields Load Area from the neighbouring Muja and Guildford load areas.

More recently there has been increased interest in new generator connection opportunities around Merredin and as such it is anticipated the area may become a net generation exporter to the west under certain future operating conditions.

4.3.1.4.2 General considerations

There is an expectation that, with the increased penetration of local generation, particularly from wind farms, the power flow of the local network may become volatile with the fluctuations in wind farm output. Operation of the transmission network may become more difficult.

The network has developed over time, largely on the basis of being a load-based area which imports power from surrounding areas. With the advent of new generation penetration, the dynamics of this situation are likely to change placing additional stresses on the network.

Additionally, the network is very long and investment in the area is difficult to justify on an economic basis resulting in an increased reliance on NCS.

4.3.1.4.3 Substations

There are 13 substations in the East Country Load Area which are owned and operated by Western Power.

- Baandee (partially owned by a customer)
- Bounty
- Carrabin
- Cunderdin
- Kondinin
- Kellerberin
- Mundaring Weir
- Merredin 132/66
- Merredin 132/220 Terminal
- Northan
- Sawyers Valley
- Southern Cross
- Wundowie
- Yerbillon
- Yilgarn

4.3.1.4.4 Transmission lines

East Country transmission network is connected via 132 kV lines to Northern Terminal and Guildford Load Areas, as well as 220 kV lines to Muja and Eastern Goldfields Load Areas, and a 66 kV line to Cannington Load Area. The 132 kV networks are normally operated in parallel with the 220 kV interconnection.

At present Merredin Terminal has two 132/66 kV transformers which provide supply to a local 66 kV sub-transmission network that extends to Northam. This network has the capacity to be operated in parallel with the 132 kV network between Merredin and Northam, however this is rare. Under system normal conditions the 66 kV line between Cunderdin and Kellerberrin is out of service to prevent unacceptable voltage levels.

Merredin also provides supply to Southern Cross substation during the outage of the 33kV line between Southern Cross and Yilgarn substations.

The transmission lines in this load area are generally designed to meet the N-1 criteria, with some 66 kV network designed to N-0 standards.

4.3.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.3.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the East Country Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Baandee (BDE)

Baandee Substation is a customer operated substation partially owned by Western Power. It was established solely to provide supply to the Water Corporation. Baandee Substation operates under the N-0 criteria as per supply agreement between customer and Western Power. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Bounty (BNY)

Bounty Substation has one transformer and under the N-0 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Carrabin (CAR)

Carrabin Substation has one transformer and operates under the N-0 criteria. A second transformer at this substation is funded and operated by a customer. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Cunderdin (CUN)

Cunderdin Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Kondinin (KDN)

Kondinin Substation has two transformers and operates under N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Kellerberrin (KEL)

Kellerberrin Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Mundaring Weir (MW)

Mundaring Weir substation has two transformers and operates under the N-1 criteria. To accommodate a Water Corp expansion at Mundaring Weir an additional 132/22 kV transformer is proposed to be installed at Sawyers Valley by summer 2012/13 and provide supply to the customers new load [23]. This will almost entirely offload Mundaring Weir Substation deferring substation capacity constraints beyond the foreseeable future and allowing for the potential decommissioning of Mundaring Weir Substation.

Merredin (MER) 132/66 kV

Merredin Substation contains two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation will be exceeded around summer 2012/13. However, this will be addressed by relocation of two transformers from Cannington Terminal.

Northam (NOR)

Northam Substation has six transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Sawyers Valley (SV/SVY)

Sawyers Valley Substation has three transformers (2 x 66/22 kV and 1 x 132/22 kV) and operates under the NCR criteria. To accommodate a Water Corp expansion at Mundaring Weir an additional 132/22 kV transformer will be installed at this site by summer 2012/13 and provide supply to the customers new load [23]. This allows for retirement of all the 66 kV infrastructure. Following installation of this new transformer load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Southern Cross (SX)

Southern Cross Substation has two transformers and operates under N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Wundowie (WUN)

Wundowie Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Yerbillon (YER)

Yerbillon Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

[23] This is a customer driven project.

Yilgarn (YLN)

Yillgarn Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.3.2.2 Fault levels

There are no notable fault level issues within the East Country Load Area across a 10 year horizon. However with ongoing interest in the connection of new generation in the area, fault levels may constrain network capacity in future.

4.3.2.3 Thermal limits

Under peak demand conditions, thermal limitations do not present considerable congestion. However, under lighter load conditions, particularly combined with high output from the Colgar Wind Farm, thermal limitations may arise as a result of power exports from the East Country Load Area. As part of its connection requirements, Colgar Wind Farm will operate under a run back scheme to assist with managing this constraint.

4.3.2.4 Voltage limits

The completion of the conversion of the Sawyers Valley substation to 132 kV operation has off-loaded the 66 kV network between the East Country and Cannington load areas providing some relief to previous voltage stability constraints (at 66 kV level) in the area.

Unacceptable post contingent voltage levels are anticipated around Northam for a number of contingencies due to a reactive reserve deficit in the area. A 132 kV capacitor bank is proposed to be installed at the Guildford Terminal which will relieve these limitations. (See Guildford Load Area for detail.)

Under some generation dispatch scenarios voltage stability may become problematic however good system management practice, coupled with the proposed capacitor bank at Guildford (see Guildford Load Area) will mitigate this risk.

4.3.2.5 Asset Condition

The East Country sub-transmission networks contain a number of aging assets. Of particular note are the following transmission elements that are now in excess of 40 years old:

- Merredin Terminal to Merredin Substation 132kV;
- The majority of 66 kV transmission line and other plant in the area; and
- The two 132/66 kV transformers at Merredin.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.3.3 Network development within a 10 year period

4.3.3.1 Substation capacity expansion

Current forecasts indicate substation capacity is adequate to meet demand over the next 10 years, accounting for committed developments. As a result there is no significant reinforcement proposed.

4.3.3.2 Transmission reinforcement

While emerging limitations in the East Country Load Area transmission network are considerable, due to the distances involved, augmentations are costly and difficult to justify.

Western Power currently anticipates installation of a dynamic power system monitoring tool by summer 2012/13 (Psymetrix) to allow better identification of stability-related issues and maximise utilisation of the existing network. Furthermore, special protection schemes including Run-Back are proposed to facilitate new entrant generation.

There is also a proposed project to install a third transformer at Sawyers Valley to accommodate an increase in customer load by summer 2012/13.

Within the 10 year horizon it is anticipated that capital investment can be deferred through good management of planned outages and appropriate generation dispatch.

4.4 Muja

4.4.1 Geographic load area

The Muja Load Area extends from Muja Power Station to Manjimup and Beenup in the south west, Albany to the south east, Boddington to the north and Narrogin in the north east. The load area includes the agricultural areas of Wagin, Katanning and Kojonup, Mount Barker, Denmark and Albany.

4.4.1.1 Load area characteristics

Due to the extensive geographical spread of the load area, the area's substations supply peak loads at various points across the period of a year. Substations supplying mostly residential loads have a winter peak pattern with substations supplying predominantly agricultural loads having a summer peak pattern.

As a whole, the Muja load area is a winter peaking due to heating load. The city of Albany is developing in to a major regional centre and has seen significant growth in recent years. The area is also seeing increasing mining and port developments.

It is likely that, in coming years, the Muja Load Area will be split for planning purposes given the growing polarisation between the nature of the load demand in the northern and southern ends of the load area. The continuing development of Albany as a regional and industrial centre is reflected in its load characteristics whereas the north of the load area still demonstrates typical rural traits.

4.4.1.2 Demand

4.4.1.2.1 Historic growth rates

Since 2000 the Muja Load Area has exhibited a steady growth of 12 MW / year.

4.4.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 52,600.

Commercial customers account for approximately 7,000 connections and domestic customers make up more than 40,000. Farming customers represent almost 5,000 and industrial customers make up the smallest segment with just 95 connections.

4.4.1.2.3 Projected growth rates

From 2011, the Muja Load Area is forecast to grow at 6 MW / year over the next 10 years reaching a peak demand of 342 MW in 2021.

In this 10 year period, 7 block loads have been included in the forecast.

Of these 7 block loads, the prominent ones are:

- 2011 – Ramp up of Boddington Gold Mine – 28.70 MW

Southdown Joint Venture (70% Grange Resources & 30% Sojitz Resources) is developing a mine near Wellstead 90 km north east of Albany with a 180 MW demand and an 11 MW load development at Albany port. This project is not yet committed although currently planned for a March 2014 completion.

4.4.1.3 Generation

The area is home to the vast bulk of base-load generating capacity on the SWIS.

The Muja, Collie and Blue Waters power stations are each directly connected onto the 330 kV transmission network and the major 330 kV circuits connecting the Muja load area to the Perth Metropolitan area.

Due to the availability of fuel resources, particularly coal, there has been a strong attraction for generation to be sited in the area and Western Power continues to receive considerable interest for new entrant developments. These interests are reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

Albany is also the location for two wind farms, Grasmere Windfarm 13.8 MW due to be commissioned around summer 2011/12 and Albany 22 MW, both are connected at 22 kV. The wind farms present voltage control issues and bespoke control systems have been installed.

There is interest in further wind generation projects in the area principally on the coast for proximity to wind resources but also inland adjacent to transmission infrastructure proposed for mining developments where wind resources are also attractive.

4.4.1.4 Current network

The following figure represents the existing transmission network within the Muja Load Area.

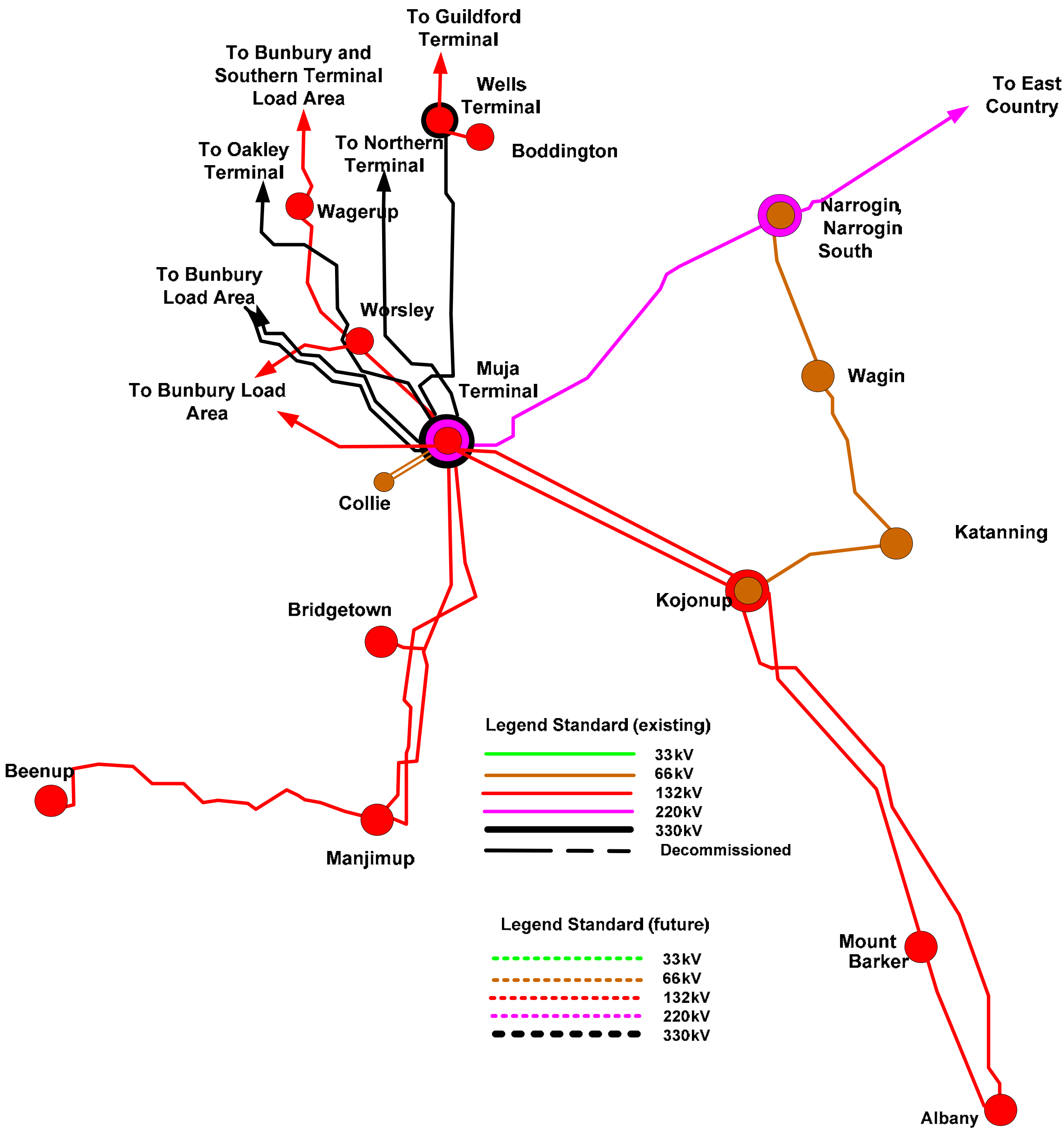

Figure 7: Transmission System – Muja Load Area

4.4.1.4.1 Purpose (Relationship with other load areas)

The Muja Load Area is connected to the Perth metropolitan area via the 330 kV transmission network. There is also a single 220 kV transmission line from Muja Power Station that supplies Narrogin South Terminal and then continues to the Eastern Goldfields. The Muja Load Area is a source of generation supply to the Bunbury Load Area via 132 kV lines.

The operation of the network in this area is vital to the ongoing reliability of supply to the Western Power Network. Generation plant has direct access to multiple 330 kV transmission lines which transfer power long distances to 330 kV terminals in the north.

4.4.1.4.2 General considerations

The bulk of the load in the Muja Load Area is connected via long weak transmission systems to Muja Terminal. With long radially configured transmission circuits, voltage limitations are often the first to be reached as load in the area grows.

This has been the case at Albany where voltage limits have triggered reactive compensation investments to improve network performance. This investment is very cost effective given the high costs of a new transmission circuit of such a length.

The load area has a number of very large mining and wind generation developments under consideration. Network reinforcement plans need to be cognisant of these developments when addressing emerging constraints.

4.4.1.4.3 Substations

There are 14 substations in the Muja Load Area which are owned and operated by Western Power.

- Katanning
- Wagin
- Narrogin
- Kojonup
- Mount Barker
- Albany
- Bridgetown
- Manjimup
- Beenup,
- Collie
- Western Collieries (customer operated)
- Worsley (customer operated)
- Wagerup
- Boddington.

The majority of the Western Power substations in the Muja Load Area are subject to peak demand conditions during the summer months apart from Albany, Katanning, Kojonup, Mount Barker and Narrogin.

The load area also features three terminal substations including Muja, Shotts and Narrogin South.

4.4.1.4.4 Transmission lines

Muja Terminal is currently one of the largest terminals in the Western Power Network and is characterised by significant generation connection and strongly meshed 330 kV and 132 kV networks with neighbouring areas.

The Muja Load Area is divided into four independent sub networks three are connected via 132 kV transmissions lines with one supplied via 66 kV transmission lines.

Most of the transmission lines in the area are of wood pole construction and are approaching the later stages of their technical lives.

Supply to the south of Kojonup, to Mount Barker and Albany is carried via 132 kV lines while areas to the north east of Kojonup including Katanning and Wagin are supplied at 66 kV.

The transmission lines in this load area are generally designed to meet the N-1 criteria. Muja Terminal is subject to the N-1-1 criteria at 80% peak load.

4.4.2 Emerging network limitations within a 10 year period

4.4.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Muja Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Katanning (KAT)

Katanning Substation has four transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Wagin (WAG)

Wagin Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Narrogin (NGN)

Narrogin Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Kojonup (KOJ)

Kojonup Substation has one transformer and operates under the N-0 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Mount Barker (MBR)

Mount Barker Substation has two transformers and operates under the N-0 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Albany (ALB)

Albany Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around winter 2013.

Bridgetown (BTN)

Bridgetown Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Manjimup (MJP)

Manjimup Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Beenup (BNP)

Beenup Substation has one transformer and operates under the N-0 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Collie (CO)

Collie Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Wagerup (WGP)

Wagerup Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Boddington (BOD)

Boddington Substation has one transformer and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.4.2.2 Fault levels

There are no notable fault level issues expected to arise in the Muja Load Area over the 10 year horizon.

4.4.2.3 Thermal limits

A number of thermal overloads are evident following various contingencies in the area. These include overloads on the 132 kV network from Muja to Kojonup and on to Albany following loss of parallel circuits in the Muja to Albany corridor.

These overloads are evident from 2011 onwards.

4.4.2.4 Voltage limits

Low voltage issues are forecast under N-1 conditions at Albany and Mount Barker substations. Reactive compensation investments have been committed in AA2. The first 21 MVAr capacitor bank is to be commissioned in July 2011 at Albany 132 kV substation with another 21 MVAr planned for the 2012 winter.[24]

4.4.2.5 Asset condition

The Muja sub-transmission networks contain a number of aging circuits. Of particular note is the following circuit that is now in excess of 40 years old:

- Muja to Kojonup 132 kV circuit

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.4.3 Network development within a 10 year period

4.4.3.1 Substation capacity expansion

The only substation capacity constraint identified in the 10 year period is Albany Substation by winter 2013.

Albany substation is remote from adjacent substations in the Muja Load Area and so load transfers to other substations are not considered economic.

To address the emerging substation capacity limitations identified in section 3.4.2.1 a number of augmentations were considered including substation capacity reinforcements and Network Control Services.

4.4.3.2 Preferred substation solutions

The following investments are proposed.

- NCS generation is forecast to connect at 132kV or 22 kV from summer 2013/14 to summer 2016/17 and could defer the need for investment until 2017/18.
- Extend the capacity of the existing Albany substation with a fourth 132/22 kV transformer in 2017/18.

[24] Business case reconfiguration of Capacitor Bank at Albany - DM# 7857635 (Stage 1) and 8133695 (Stage 2)

4.4.3.3 Transmission reinforcement

Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term (25 years) and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

The following aspects were key influences on the preferred network solutions in the Muja Load Area;

- Use of Network Control Services;
  - o Due to the large overhead line investment costs required to construct new transmission circuits over long distances it can be economically viable to invest in Network control Services to defer these costs.
  - o Network Control Services were also identified as likely to present a possible benefit for substation capacity at Albany.
- Integration with potential major customer connections;
  - o Large mining and generation proponents are developing projects in the Muja load area and this may present an opportunity to integrate the connection requirements of new connections with the wider network expansion needs. This makes best use of existing overhead line route corridors minimising environmental impact and provides overall lower cost solutions through economies of scale. The challenge of this approach is synchronising the timing of connection with broader network reinforcement needs and retaining flexibility in the investment plans to take these opportunities into account.
- Use of technology;
  - o Technology can also offer opportunities to enhance network performance and defer new long transmission circuits. This can take the form of voltage support through Static VAr Compensators or of impedance reduction through series capacitors.
- Use of higher voltages;
  - o Investments have been considered with a view of future deployment of higher voltages in the transmission network from Muja.
  - o The age of the Muja to Kojonup 132 kV circuit.

- o Given the radial nature of the network, reconfiguration opportunities are minimal.

4.4.3.4 Preferred transmission solutions

The following figure represents the preferred Transmission Network strategy for the coming 10 year horizon.

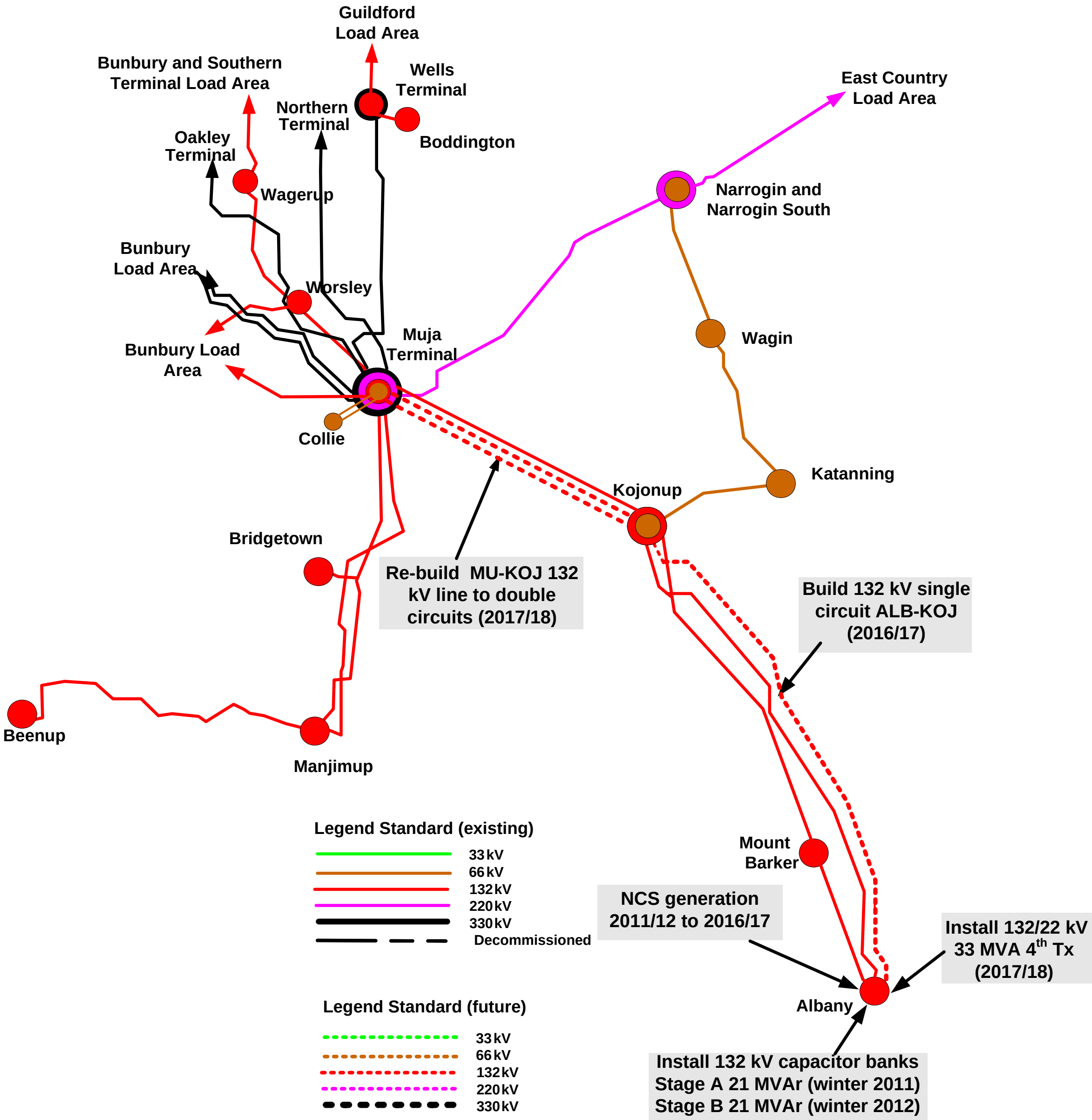

Figure 8: Muja Load Area - preferred transmission solution

The specific projects planned for the Muja Load Area over the next 10 years include:

- Installation of 21 MVAr capacitor bank at ALB by winter 2011 followed by an additional 21 MVAr by winter 2012;
- Procure NCS (generation and demand management options) from summer 2011/12 to summer 2016/17;

- Establish 157 kms of 132 kV single circuit overhead line from Albany to Kojonup by summer 2016/17; and
- Establish double circuit 132 kV line from Muja to Kojonup by summer 2017/18 and decommission existing MU-KOJ 82.

The preferred solution offers the following benefits:

- Deferral of significant transmission line reinforcement through the use of Network Control Services;
- Deferral of investment through the employment of NCS enables large customer projects to mature and retains the option for integrated transmission investments to be realised. The NCS also more closely aligns the asset condition timing requirements with network capacity expansion requirements;
- The construction of an additional 132 kV circuit from Muja to Kojonup (as part of a new double circuit overhead line) together with the additional 132 kV circuit from Kojonup to Albany will ultimately provide three high capacity 132 kV circuits from Muja to Kojonup and support demand growth in the Albany area for many years;
- The continued use of 132 kV rather than an early deployment 330 kV (operated at 132 kV) defers the significant investment required to construct 330 kV designed assets until the forecast load materialises to justify such investment.
- Should the Southdown Joint Venture project become committed, network reinforcement from Muja to Kojonup and Albany is likely to be reconsidered to achieve an economically prudent outcome and may proceed with assets constructed to 330 kV design due to the load increase that this project will drive.

4.5 Bunbury

4.5.1 Geographic load area

The Bunbury Load Area covers the south west corner of the Western Power Network stretching from Pinjarra in the north to Augusta in the south. Major demand in the regional comes from the tourism, mining and agricultural industries.

4.5.1.1 Load area characteristics

The growing concentration of urban development in the region has seen similar pressures placed on the system as in the Perth metropolitan area, where the penetration of air conditioning has had a significant impact on demand growth.

Major industrial development including the development of water desalination infrastructure and generating plant has occurred in the area in the recent past.

The growth in the load area's major centres of Bunbury and Busselton, has been underpinned by tourism, coastal lifestyle seekers, industrial and mining developments.

Proposed upgrades to the area's main roads and other infrastructure developments are expected to encourage high residential and commercial growth.

A number of residential and industrial developments are already proposed for the area over the next few years, with major industrial developments expected in and around Bunbury and Kemerton.

4.5.1.2 Demand

4.5.1.2.1 Historic growth rates

Since 2000 the Bunbury Load area has exhibited a steady growth of 8 MW / year. Forecast growth is consistent with historical patterns.

4.5.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 53,000. Commercial customers account for about 5,800 connections and domestic customers make up 46,000 connections. Farming customers represent 1200 connections and industrial customers make up about 75 customer connections.

4.5.1.2.3 Projected growth rates

From 2011, the Bunbury load area is forecast to grow at 18 MW/year over the next 10 years reaching a peak demand of 464 MW in 2021.

In this 10 year period, 8 block loads have been included in the forecast.

Of these 8 block loads, the most prominent are:

- 2011 – Southern SeaWater Desalination Plant – 15MW
- 2012 – Southern SeaWater Desalination Plant – 15 MW

- 2012 – Simcoa Expansion – 24.3 MW
- 2018 – Southern SeaWater Desalination Plant – 30 MW

4.5.1.3 Generation

The Bunbury area is supplied by local generation at Kemerton and has a heavy reliance on generation from the Muja area.

There has been an attraction for generation to be sited in the area and Western Power continues to receive interest for new entrant generation developments. These interests are reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

4.5.1.4 Current network

The following figure represents the existing transmission network within the Bunbury Load Area.

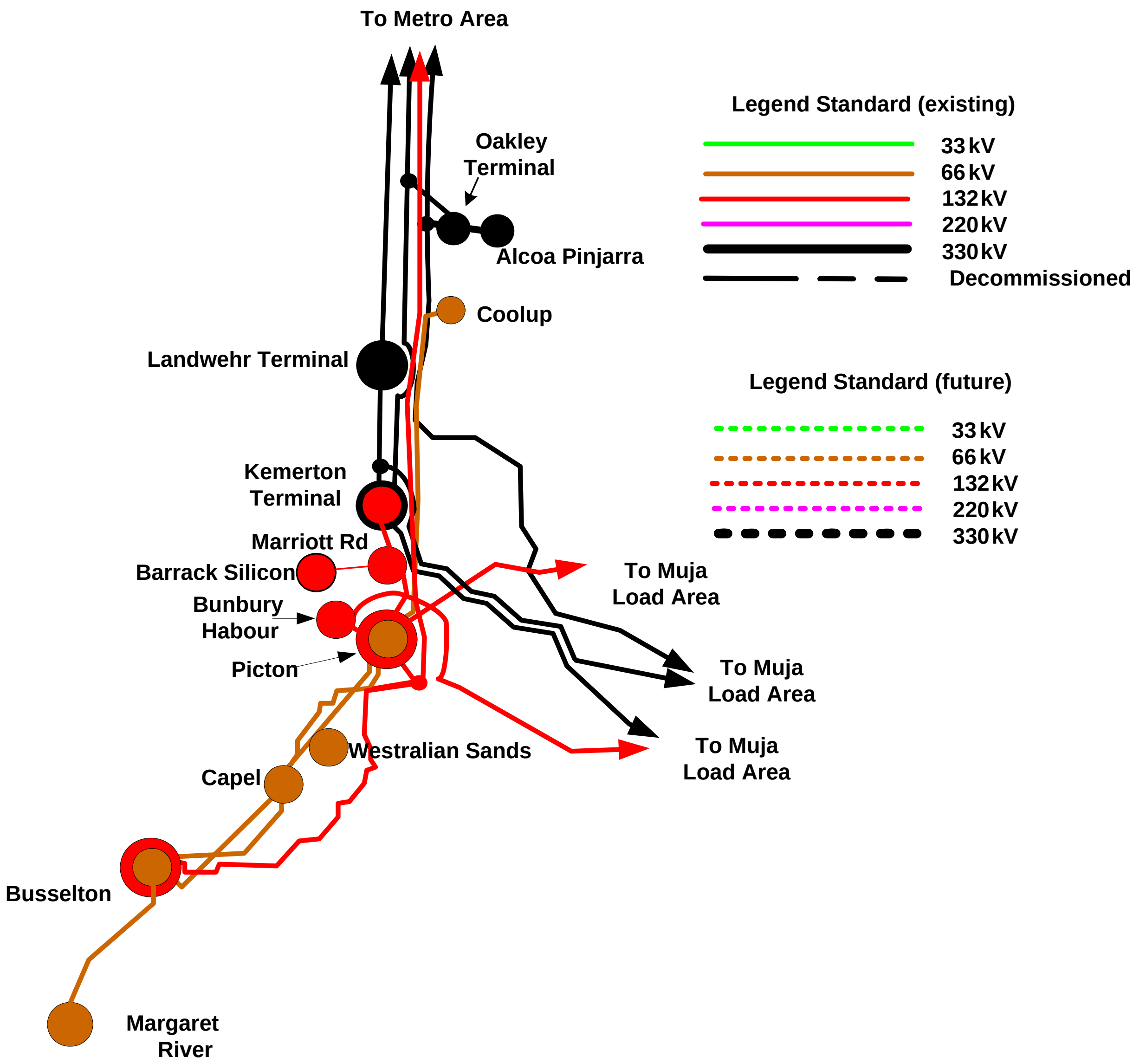

Figure 9: Transmission System - Bunbury Load Area

4.5.1.4.1 Purpose (Relationship with other load areas)

The network in the Bunbury load area serves, in the main, to supply customer demand south of Kemerton.

The network is also configured to enable the flow of power from the Muja load area and from Kemerton Terminal via 132 kV transmission lines.

There are strong 330 kV connections between Kemerton, Southern Terminal, Kwinana and Muja which enable bulk power transfer between these terminals.

4.5.1.4.2 General considerations

The individual transmission lines in the area, in particular between Muja, Picton and Bunbury Harbour are approaching the end of their useful lives.

Incremental network upgrades are not an option given the aged and heavily utilised nature of the local network requiring a more strategic response over the medium to long term. However investment is difficult to justify given the significant cost of such a development.

The load sharing on various 132 kV circuits to the Picton area from neighbouring areas is heavily influenced by generation dispatch conditions. As a result the timing of thermal overloads can vary considerably. Due to the high investment costs for network reinforcement prudent system management of dispatch conditions and outage planning plans a significant role.

Since the 330 kV network is in reasonable proximity and has sufficient capacity to support long-term load growth in the area, consideration will be given to the development of a new terminal substation in the Bunbury Load Area or potential reinforcement of the lines from Kemerton Terminal.

4.5.1.4.3 Substations

The Bunbury Load Area incorporates the Kemerton 330/132 kV, and Picton 132/66 kV Terminals.

Western Power owns and operates seven zone substations in the Bunbury load area:

- Bunbury Harbour
- Marriott Road
- Coolup
- Capel
- Busselton
- Margaret River
- Picton

In contrast to much of the Western Power Network, it is possible for some of these substations to be subject to peak demand conditions during the winter months.

4.5.1.4.4 Transmission lines

The Bunbury Load area is supplied via three 132 kV transmission lines to neighbouring load areas and several 330 kV connections from Kemerton Terminal. A 132 kV and 66 kV sub transmission system extends south from Picton to Busselton, with the 66 kV system extending as far south as Margaret River.

The transmission lines in this load area are generally designed to meet the N-1 Capacity criteria. Kemerton Terminal is subject to the N-1-1 criteria at 80% peak load.

Kemerton is a 330/132 kV terminal with strong connections to the bulk transmission network, however the connection from Kemerton to Picton via Marriott Road Substation at 132 kV level is relatively weak.

4.5.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.5.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Bunbury Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Bunbury Harbour (BUH)

Bunbury Harbour Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded by summer 2011/12.

Marriott Road (MRR)

Marriott Road Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded by summer 2011/12. Following the installation of a 3rd transformer by summer 2012/13, load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Coolup (CLP)

Coolup Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Capel (CAP)

Capel Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Busselton (BSN)

Busselton Substation has three 66/22 kV transformers, a 132/22 kV transformer and a 132/66 kV transformer. It operates under the N-1 criteria. Load forecast indicate the capacity of the substation is expected to be exceeded around summer 2015/16.

Margaret River (MR)

Margaret River Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Picton (PIC)

Picton Substation has three transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2020/21.

4.5.2.2 Fault levels

There are no notable fault level issues within the Bunbury Load Area forecast to arise over the 10 year horizon.

4.5.2.3 Thermal limits

Recent system studies have identified substantial power flows through the existing 132kV meshed Bunbury Load Area network creating risk of thermal overloads under contingency conditions.

The Alcoa Pinjarra to Pinjarra 132kV circuit and Southern River to Alcoa Pinjarra / Wagerup 132 kV circuit overload under a number of contingencies. These overloads are evident from summer 2011/12 and summer 2014/15 respectively.

Depending on dispatch conditions, a number of other 132 kV overloads appear on lines between Muja and Picton following the loss of parallel circuits.

The cost of network development to satisfy the Technical Rules for all credible generation dispatch scenarios is significantly higher than the increased operating cost associated with out-of-merit dispatch. The risk associated with not planning to meet every dispatch scenario is mitigated by Western Power's prudent system management processes with respect to outage planning. It is currently anticipated that significant reinforcement can be deferred beyond the 10 year horizon.

4.5.2.4 Voltage limits

A number of voltage limitations appear under post-contingent conditions these include:

- low voltage at Busselton and Margaret River 132 kV buses following loss of the Picton to Busselton/Pinjarra 132 kV line;

- low voltage at Busselton and Capel 66 kV buses following loss of the Busselton 132/66 kV transformer; and
- low voltage conditions at Marriott Road and Picton 132 kV buses following an outage of the 132 kV line from Kemerton terminal to Marriott Road Substation and Marriott Road Substation to Picton, respectively.

The majority of these limitations are apparent from summer 2011/12.

4.5.2.5 Asset condition

The Bunbury sub-transmission networks contain a number of aging circuits. Of particular note are the following circuits that are now in excess of 40 years old:

- Muja to Bunbury Harbour 132 kV;
- Capel to Busselton 132 kV;
- Picton to Coolup 66 kV;
- Picton to Marriott Road 132 kV; and
- Busselton to Margaret River 66 kV

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.5.3 Network development within a 10 year period

4.5.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in Section 3.5.2.1 a number of augmentations are required including substation capacity reinforcements, coupled with load transfers. The proposed augmentation and timings have been identified below.

4.5.3.2 Preferred substation solutions

- Transfer of load from Bunbury Harbour Substation to Picton Substation by summer 2011/12 [25].
- Transfer of load from Capel Substation to Picton Substation by summer 2011/12 [25].
- Install an additional 33MVA transformer at Marriott Road Substation by summer 2012/13 [26];
- Replace existing transformers at Capel Substation with higher capacity transformers by summer 2014/15;
- Rebulid Busselton Substation with higher capacity transformers by summer 2015/16; and

25 This brings forward the timing of a shortfall in capacity at Picton from summer 2020/21 to around summer 2016/17.

26 This is a committed project that will commence during the AA2 period and be concluded/commissioned during the AA3 period; as such funding has been budgeted in both Access Arrangements.

- Establish a new substation (Dalyellup) by around summer 2018/19. Load to be transferred from Bunbury Harbour and Picton Substations to the new site.

4.5.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Across a 10 year horizon these limitations are primarily related to reactive reserve deficits. Thermal overloads that appear north of Picton are considered manageable across this timeframe through use of lower cost control schemes and prudent system management.

In recognition of the longer term reactive reserve requirements in the area consideration was given to voltage stability limitations associated with excess shunt compensation. In particular, studies indicated too much shunt compensation leads to brittle voltage performance and degradation in system security margins. As a result options were considered which optimise investment across a broader horizon and seek to maintain system security safety margins. Another key influence on the preferred solution was existing 132 kV infrastructure currently energised at 66 kV. Options include:

- Installation of shunt capacitor banks to provide additional reactive reserve;
- Installation of Static VAr Compensators. Even though this provides a superior form of reactive support, the cost of this option, given future 132 kV line reinforcement to the area may prove to be imprudent;
- Installation of new 132 kV circuits between Picton and Busselton, upgrade of existing 66 kV assets to 132 kV as well as re-energising 132 kV assets built to 132 kV standard from 66 kV to 132 kV;
- Installation of special protection schemes and demand management solutions; and
- A combination of the above, including staging opportunities.

4.5.3.4 Preferred transmission solutions

The following figure represents the preferred Transmission Network strategy for the coming 10 year horizon.

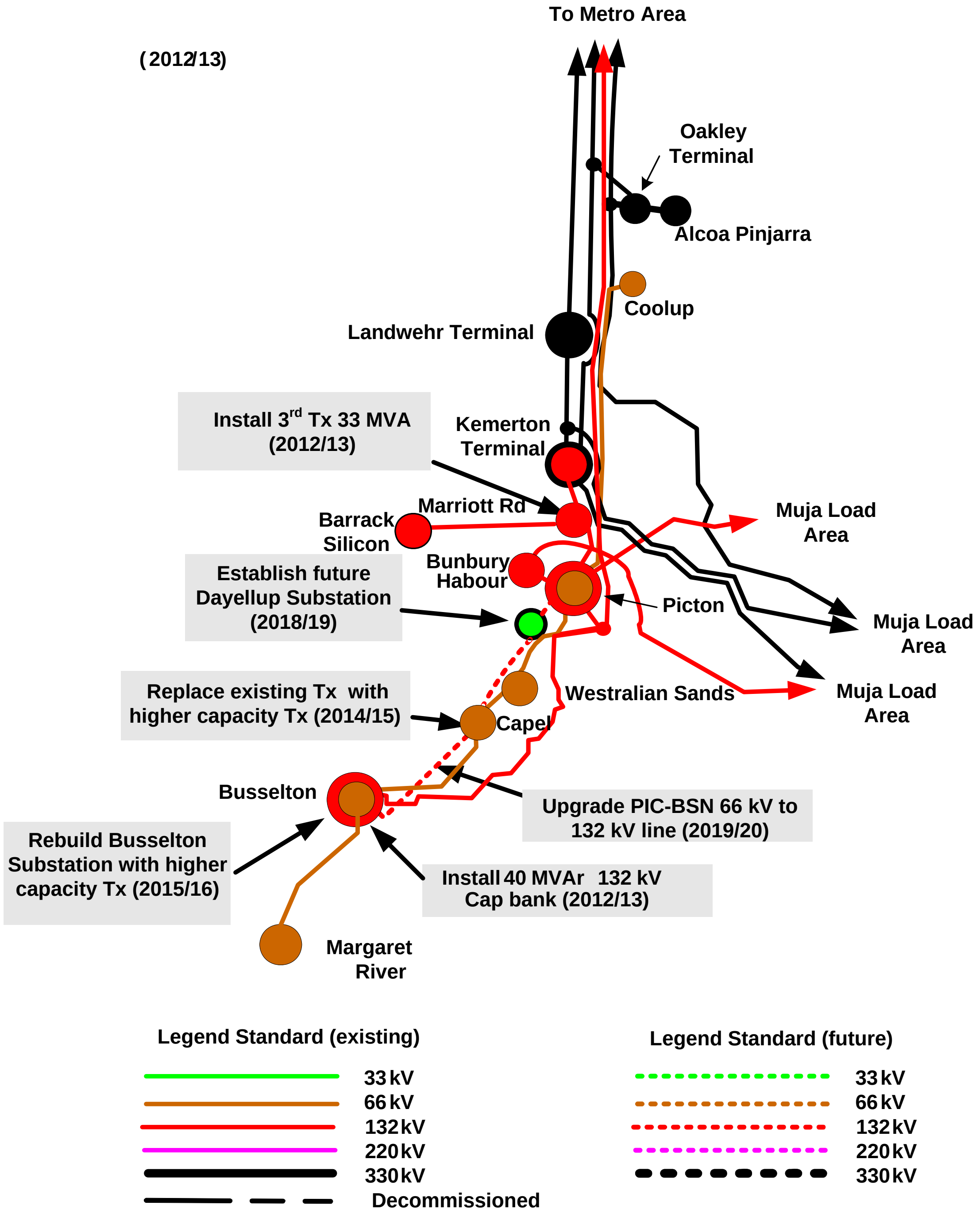

Figure 10: Bunbury Load Area – preferred transmission solution

The specific projects planned for the Bunbury load area over the next 10 years include:

- Installation of a 132kV 40 MVAr Shunt capacitor bank at Busselton by summer 2012/13;
- Installation of a 22 kV 10 MVAr capacitor bank at Marriott Road by summer 2014/15;
- Installation of a 22 kV 10 MVAr capacitor bank at Marriott Road by summer 2018/19;

- Installation of a 66 kV 20 MVAr capacitor Bank at Capel by summer 2019/20; and
- Upgrade of an existing 66 kV line from Picton to Busselton to 132 kV by summer 2019/20.

It is anticipated that the post contingent step change in voltage at some buses in the area may be in excess of the Technical Rules requirments until the upgrade of the 66kV line from Picton to Busselton in 2019/20. Western Power will consider use of special control schemes to manage the step change and defer additional investment prior to 2019/20.

A runback scheme at Alcoa Pinjarra is currently used to control power flows on the Southern River to Alcoa Pinjarra / Wagerup 132 kV line. A modification to this runback scheme is proposed, as necessary, to address the thermal overload on this circuit which appears under contingent conditions.

The preferred solution offers the following benefits:

- Use of lower cost capacitor bank solutions to defer more costly transmission line reinforcements;
- Use of lower cost special protection runback schemes to defer the need for costly reinforcement; and
- Optimisation of reinforcements to address emerging reactive reserve deficits as well as future thermal overloads, whilst also providing a security margin for voltage stability issues.

4.6 Mandurah

4.6.1 Geographic load area

The Mandurah Load Area includes the southern metropolitan coastal strip bound by Safety Bay Road in the north (including Waikiki Substation), Mandurah and Harvey Estuary in the south and extends east to encompass the Pinjarra Substation.

4.6.1.1 Load area characteristics

In previous years Western Power has encapsulated the Mandurah Load Area within the Kwinana Load Area. It is anticipated that network development over the 10 year horizon will electrically isolate Mandurah and Kwinana load areas across the Rockingham/ Waikiki boundary. Western Power adopted this new load area in 2011 for this reason, coupled with the fact that the Mandurah and Kwinana Load Areas' growth rates and customer composition are considerably different.

Each substation in this load area is summer peaking reflecting the load mix of residential with a relatively small number of commercial and light industrial loads.

Recently completed major infrastructure projects are expected to contribute to the already strong demand growth in the area.

4.6.1.2 Demand

4.6.1.2.1 Historic growth rates

Since 2000 the Mandurah Load area has exhibited a steady growth of 11 MW / year.

As noted above, the Kwinana Load Area has been split into two to form the Mandurah Load Area in recognition of the demographic changes at the northern and southern ends of the load area and future plans for the network. .

4.6.1.2.2 Customers served

The approximate number of customers supplied in this load area is 42,000. Commercial customers account for almost 2,300 connections. Domestic customers make up nearly 40,000. Farming customers represent more than 120 connections. There are only a very small number of industrial customers.

4.6.1.2.3 Projected growth rates

From 2011, the Mandurah load area is forecast to grow at 7 MW / year over the next 10 years reaching a peak demand of 246 MW in 2021.

In this 10 year period, 2 block loads have been included in the forecast.

Two recently completed infrastructure developments are anticipated to have a major long-term impact on the area. These include:

- The South West Metropolitan Railway project which extends the South West Metropolitan Railway to Rockingham and Mandurah; and
- Extension of the Kwinana freeway to Safety Bay and a further section between the Mandurah bypass and Lake Clifton.

Both of these major infrastructure projects bring the convenience and mobility of rapid transit systems to the south-west metropolitan area, providing a more attractive environment for residential development. These projects facilitate rapid load growth, particularly in the area from Rockingham to south of Mandurah.

4.6.1.3 Generation

There is no generation in the Mandurah Load Area. Supply to the area currently comes from 132 kV transmission lines in the north via Rockingham and from the east via Pinjarra.

4.6.1.4 Current network

The following figure represents the existing transmission network within the Mandurah Load Area.

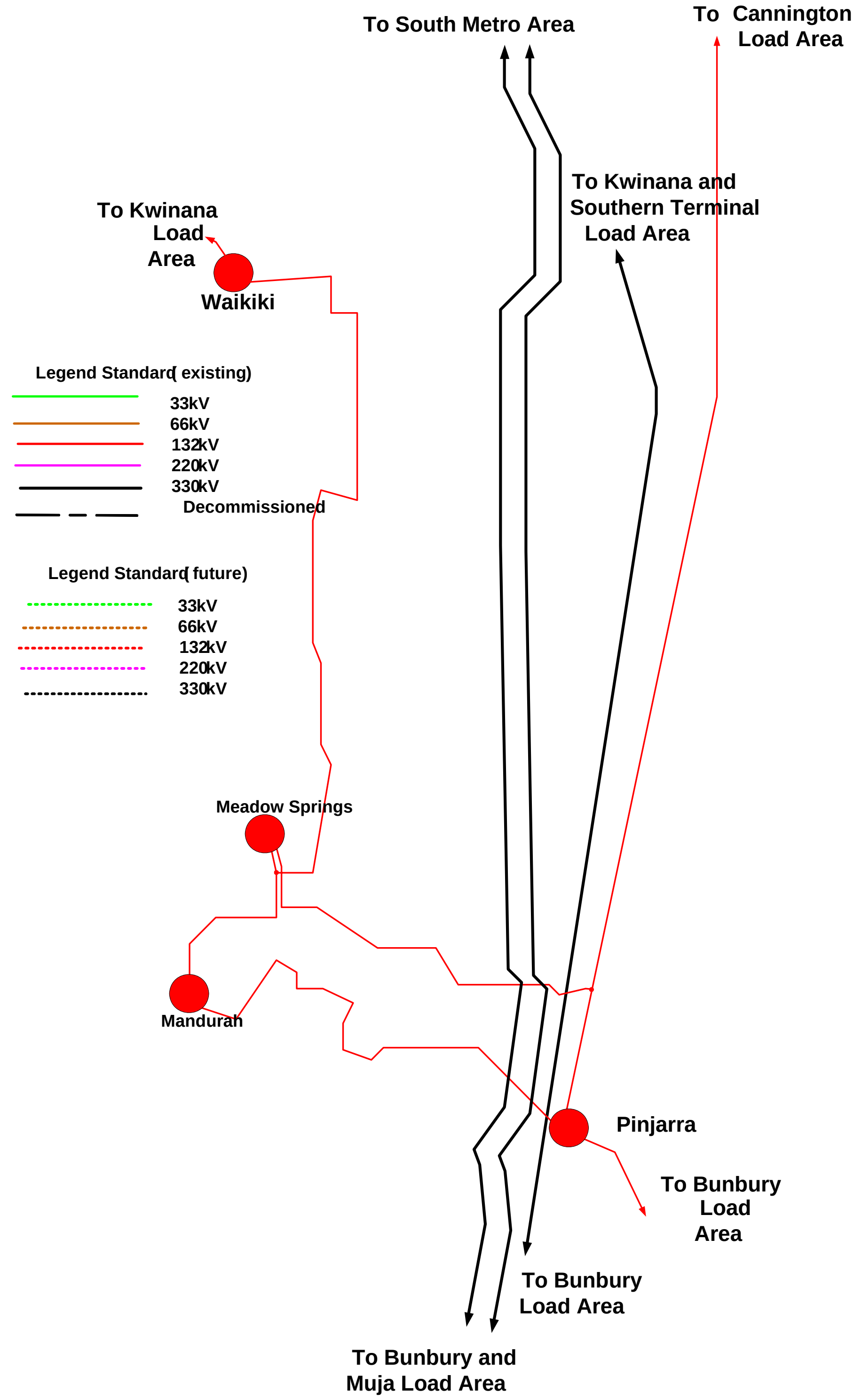

Figure 11: Transmission System – Mandurah Load Area

4.6.1.4.1 Purpose (Relationship with other load areas)

The network in the area serves primarily to supply the load in the southern metropolitan coastal strip bound by Safety Bay Road in the north (including Waikiki Substation), Mandurah and Harvey Estuary in the south. Neighbouring load areas include Kwinana and Bunbury which supply the area with power. There is currently a single 132 kV connection to the Kwinana area between Waikiki and Rockingham.

There are also two relatively weak and aged 132 kV transmission connections between Mandurah and Pinjarra, where the Mandurah Load Area receives its supply from the Bunbury Load Area.

4.6.1.4.2 General considerations

The rapid growth in this area presents considerable challenges to ensuring ongoing reliability of supply in the area.

Given the reasonably weak and old transmission infrastructure it is anticipated that significant reinforcement will be required over a 10 year horizon and is likely to be optimised with asset replacement strategies.

Furthermore, the lead times for selection of appropriate sites for future substations coupled with requirements for potential future transmission line corridors and deliverability constraints may prove difficult to manage.

4.6.1.4.3 Substations

There are four substations in the Mandurah Load Area which are owned and operated by Western Power.

- Waikiki
- Meadow Springs
- Mandurah
- Pinjarra

All Western Power substations are subject to peak demand conditions during the summer months.

4.6.1.4.4 Transmission lines

A 132 kV sub-transmission system extends south from Kwinana Terminal to Rockingham where it neighbours the Mandurah Load Area at the Waikiki Substation.

From Waikiki, a single 132 kV line extends south along the coast connecting with both Meadow Springs and Mandurah substations. Each of these substations is also connected to Pinjarra in the east, via single circuit 132 kV transmission lines.

4.6.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.6.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Mandurah Load Area over a 10 year horizon.

Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Waikiki (WAI)

Waikiki Substation has two transformers and operates under the NCR criteria. A third transformer is planned to be commissioned late 2012. Following installation of the third transformer load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Meadow Springs (MSS)

Meadow Springs Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2016/17.

Mandurah (MH)

Mandurah Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the NCR capacity of this substation is exceeded around summer 2011/12.

Pinjarra (PNJ)

Pinjarra Substation has three transformers and operates under the N-1 criteria. Following installation of the third transformer in 2011 load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.6.2.2 Fault levels

There are no notable fault level issues within the Mandurah Load Area forecast to arise over the 10 year horizon.

4.6.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on the:

- Mandurah to Pinjarra 132 kV circuit following loss of the Cannington to Meadow Springs / Pinjarra 132 kV circuit;
- Cannington to Meadow Springs / Pinjarra 132 kV circuit following loss of the Mandurah to Pinjarra 132 kV circuit.

Limitations also arise on the 132 kV Alcoa Pinjarra to Pinjarra transmission line which connects the Mandurah Load Area with the Bunbury Load Area. These limitations appear under pre-contingent conditions resulting in constraints on generation dispatch, but are significantly worse for a range of contingencies including the outage of:

- Various 132 kV lines from Kwinana Terminal to Waikiki which also provide supply to Mandurah and Meadow Springs from the north;
- Pinjarra to Mandurah 132 kV; and
- Lines south of Pinjarra including the Pinjarra to Busselton / Picton line.

These thermal issues are driven, in part, by the meshed nature of the Rockingham and Mandurah/Meadow Springs areas. This mesh creates uneven load sharing on lines supplying Mandurah and Meadow Springs and impacts operational controllability from a generation dispatch perspective.

4.6.2.4 Voltage limits

There are currently no notable voltage instability issues in the Mandurah Load Area forecast to arise over the 10 year horizon.

4.6.2.5 Asset condition

The Mandurah sub-transmission network contains a number of aging circuits. Of particular note is the Pinjarra-Mandurah 132 kV circuit which is now in excess of 40 years old.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.6.3 Network development within a 10 year period

4.6.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.6.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.6.3.2 Preferred substation solutions

- Transfer of load from Mandurah to Meadow Springs by summer 2013/14. This brings forward the timing which Meadow Springs Substation requires augmentation to around summer 2017/18;
- Installation of a third transformer at Waikiki by summer 2012/13 [27];
- Establish a new substation in the Mandurah/Meadow Springs township area around summer 2015/16. Additional load to be

[27] This is a committed project that will commence during the AA2 period and be concluded/commissioned during the AA3 period; as such funding has been budgeted in both Access Arrangements.

transferred from Mandurah Substation to the new site to defer any further augmentation at Mandurah Substation outside a 10 year horizon;

- Install additional 33MVA transformer at Meadow Springs Substation by summer 2017/18; and
- Establish a new substation (Golden Bay Substation) around summer 2020/21. It is proposed that this substation be connected into the Waikiki-Mandurah-Meadow Springs 132 kV circuits (see section 3.6.3.3 for more information on the proposed transmission line developments in the 10 year horizon). It is anticipated that this substation will be required to support new load growth focused on the coast between Meadow Springs and Waikiki and limit the number of long feeders from Meadow Springs and Waikiki to support this load.

4.6.3.3 Transmission reinforcement

Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

The following aspects were key influences on the preferred network solutions in the Mandurah Load Area:

- Operational flexibility and controllability;
    - o The meshed nature of the Mandurah, Kwinana and Bunbury Load areas can create power flow control difficulties following contingencies. This can result in suboptimal generation dispatch (in preparation for possible contingencies), or conditions where significant changes in generation may be required after a contingency. Future network reinforcement in the area should look to alleviate generation constraints and where necessary minimise necessary post contingent response by System Management in accordance with an N-1 planning criteria.
- The southern metropolitan coastal strip is growing rapidly and new residential developments are spreading along the coast. At present, lengthy feeders supply the bulk of this new load. This can become uneconomic and inefficient if numerous feeders run long distances. To ensure reliability of supply to

the area it is anticipated that a new substation will be required and could be demonstrated as the most economic solution for maintaining regulated service delivery standards and compliance with the Technical Rules. Furthermore, any network development plan will need to consider the longer term transmission supply requirements for new substations in the area.

- Ability for Kwinana Load Area to continue supporting the Mandurah Load Area via the Rockingham-Waikiki 132 kV connection, and further south from Waikiki to Mandurah.
  - With the current network configuration, the power transfer requirements on the Rockingham/Waikiki/Mandurah 132 kV circuits increase with annual demand growth in the Mandurah area. Over the longer term significant reinforcement would be required to support power transfer from Kwinana Terminal all the way to Mandurah should this configuration be maintained.
- Ability for Bunbury Load Area to continue supporting the Mandurah Load Area via the Alcoa Pinjarra and Pinjarra to Picton / Busselton 132 kV transmission lines.
  - At present, under peak demand conditions supply to the Mandurah area comes, in part, from Picton via Pinjarra 132 kV. This exacerbates post-contingent loading issues into the Picton area on transmission lines from Muja and Kemerton Terminals. Due to the distances (and likely costs) involved in augmenting the system to reinforce supply from Muja and Kemerton into Picton, these augmentations should be deferred as long as possible. Network development options should look to use the existing 132 kV line from Pinjarra to Picton as a supply for Picton, rather than as a supply for Mandurah.
- Load forecasts indicate the Mandurah, Meadow Springs and Waikiki total load exceeds 250MVA by 2020. Options considered to supply the developing demand in the area include:
  - reinforcing the transfer capability from Kwinana Terminal south down to Mandurah;
  - reinforcing the transfer capability from the east of Mandurah (near Pinjarra) to the Mandurah area. Within a 10 year period the Pinjarra-Mandurah 132 kV line will be in excess of 50 years old and may need replacement. This presents opportunities to rebuild this line to a stronger double circuit;
  - reinforcing the transfer capability from Alcoa Pinjarra 132 kV to Pinjarra 132 kV and potentially from Picton or Kemerton to Pinjarra 132 kV.
  - isolating the Mandurah/Meadow Springs load area (up to Waikiki) from the Kwinana load area and forming a new Mandurah Load Area supplied radially from east of Mandurah, off a new 330 kV terminal; and

- o a combination of the above, including staging opportunities.

4.6.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

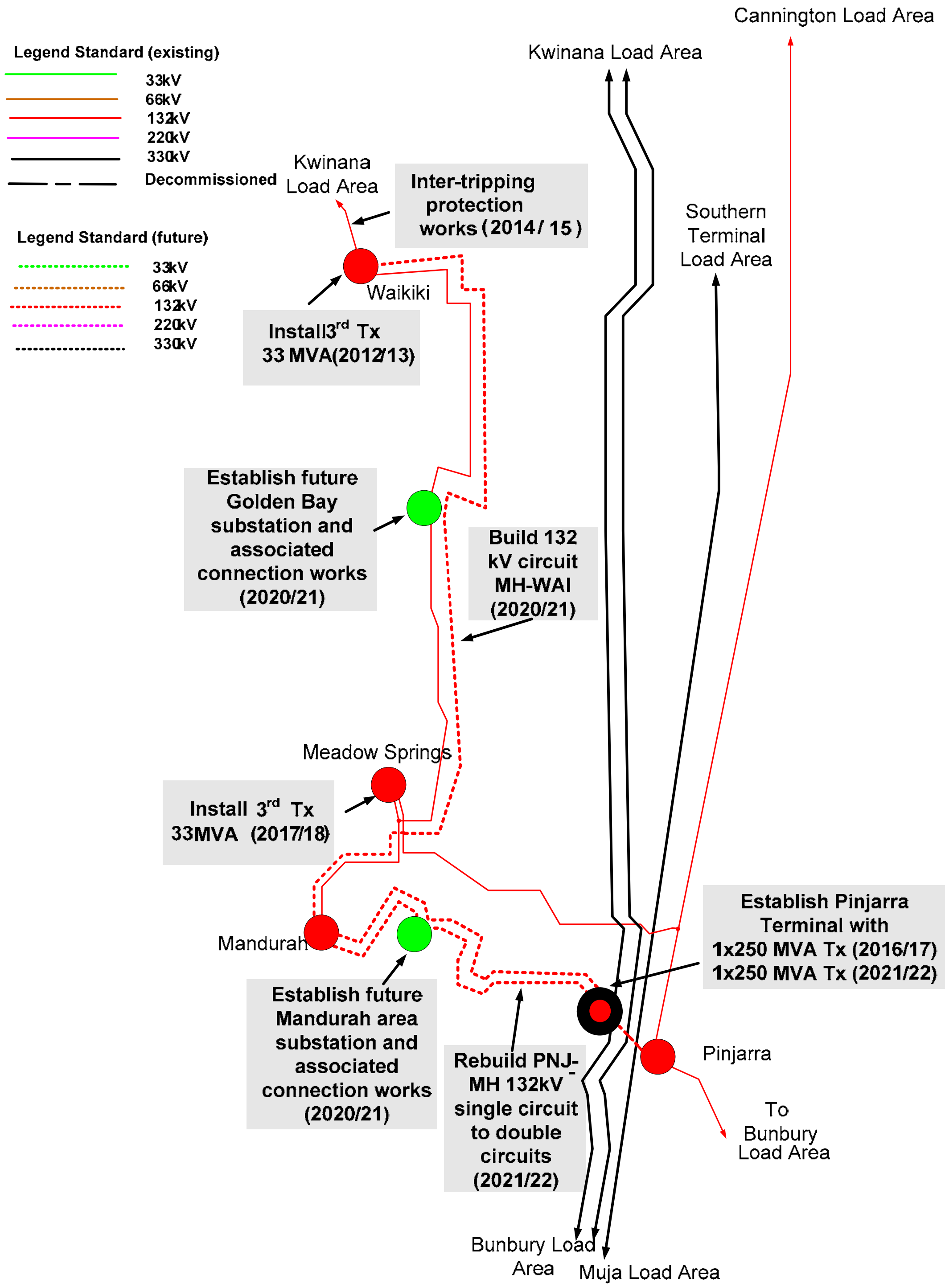

Figure 12: Mandurah Load Area – preferred transmission solution

The specific projects planned for the Mandurah Load Area over the next 10 years include:

- Inter-tripping protection works on Rockingham to Waikiki 132 kV circuit by summer 2014/15 (see Kwinana Load Area);
- Establish Pinjarra 330/132 kV Terminal by summer 2016/17;
- Build 2nd Mandurah to Waikiki 132 kV single circuit by summer 2020/21;
- Add 2nd 330/132 kV 250MVA transformer at Pinjarra Terminal and rebuild Pinjarra Terminal to Mandurah single circuit to double circuit by summer 2021/22.

The preferred solution offers the following benefits:

- Radialises the Mandurah Load Area off a strong 330 kV terminal at Pinjarra. This eliminates through-flows from the Kwinana Load Area and significantly improves operational control of power flows;
- Increases utilisation of the existing 330 kV network as it moves to support a significant portion of the Mandurah Load Area. This also reduces congestion on the Kwinana sub transmission systems and Alcoa Pinjarra to Pinjarra 132 kV circuit;
- Places less reliance on Picton for supply into Pinjarra under peak demand conditions. This improves utilisation of existing assets and defers considerable investment in reinforcement from Muja and Kemerton to Picton;
- Use of lower cost special protection control schemes provides for staging of network reinforcements and deferral of extensive augmentations. This allows the Rockingham-Waikiki 132 kV circuit to be utilised until complete isolation of the Mandurah and Kwinana Load Areas around 2019/20;
- Optimises asset replacement and network reinforcement strategies by rebuilding existing circuits with higher capacity when they are expected to reach the end of their economic life;
- Establishes strong transmission supply for future substations along the southern metropolitan coastal strip, including Golden Bay Substation; and
- Supports longer term supply needs of the Mandurah Load Area through use of additional 330/132 kV transformation capacity at the Pinjarra Terminal.

4.7 Kwinana

4.7.1 Geographic load area

The Kwinana Load Area lies along the southern metropolitan coastal strip bound by Beeliar Drive in the north spreading to Safety Bay Road in the south.

4.7.1.1 Load area characteristics

In previous years Western Power has encapsulated the Mandurah Load Area within the Kwinana Load Area. It is anticipated that network development over the 10 year horizon will electrically isolate Mandurah and Kwinana load areas across the Rockingham/Waikiki boundary. Western Power split the Kwinana and Mandurah Load Areas in 2011 for this reason, coupled with the fact that the Mandurah and Kwinana Load Areas' growth rates and customer composition are considerably different.

Load in the Kwinana Load Area is comprised of residential, commercial, light industrial and heavy industrial demand. Kwinana has historically been a site for generation connection to support heavy industry in the area, as well as opportunistic market driven proponents. The area plays a significant role in state development through existing large scale heavy industry as well as presenting attractive opportunities for future developments.

Due to the highly industrialised nature of the load in this area the load profiles met by substations are relatively flat when compared with most substations in the Western Power Network. This, together with considerable generation in the area, leads to higher energy utilisation factors per MVA of connected load.

Recently completed major infrastructure projects are expected to contribute to the already strong demand growth in the area.

4.7.1.2 Demand

4.7.1.2.1 Historic growth rates

Since 2000 the Kwinana Load Area has exhibited a steady growth of 5 MW / year. Forecast growth is consistent with historical patterns.

4.7.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 55,500. Commercial customers account for more than 3,000 connections. Domestic customers make up more than 52,200 and farming and industrial customers total approximatelty 200 customer connections.

4.7.1.2.3 Projected growth rates

From 2011, the Kwinana load area is forecast to grow at 14 MW / year over the next 10 years reaching a peak demand of 398 MW in 2021.

In this 10 year period, 21 block loads have been included in the forecast.

The Kwinana freeway was extended to Safety Bay in 2007 and has brought the convenience and mobility of rapid transit systems to the south-west metropolitan area. This has provided a more attractive environment for residential development within Rockingham and further south, and is expected to continue to drive high growth rates.

4.7.1.3 Generation

Due to the availability of fuel resources, particularly gas, there has been a strong attraction for generation to be sited in the area and Western Power continues to receive considerable interest for new entrant generation developments. These interests are reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

As a result of the existing and projected generation connections the Kwinana area serves the purpose of a generation hub and a key supply point for the rest of Western Power Network. It is therefore particularly important to ensure sufficient network capacity is available for this generation to efficiently supply major load centres for the foreseeable future.

4.7.1.4 Current network

The following figure represents the existing transmission network within the Kwinana Load Area.

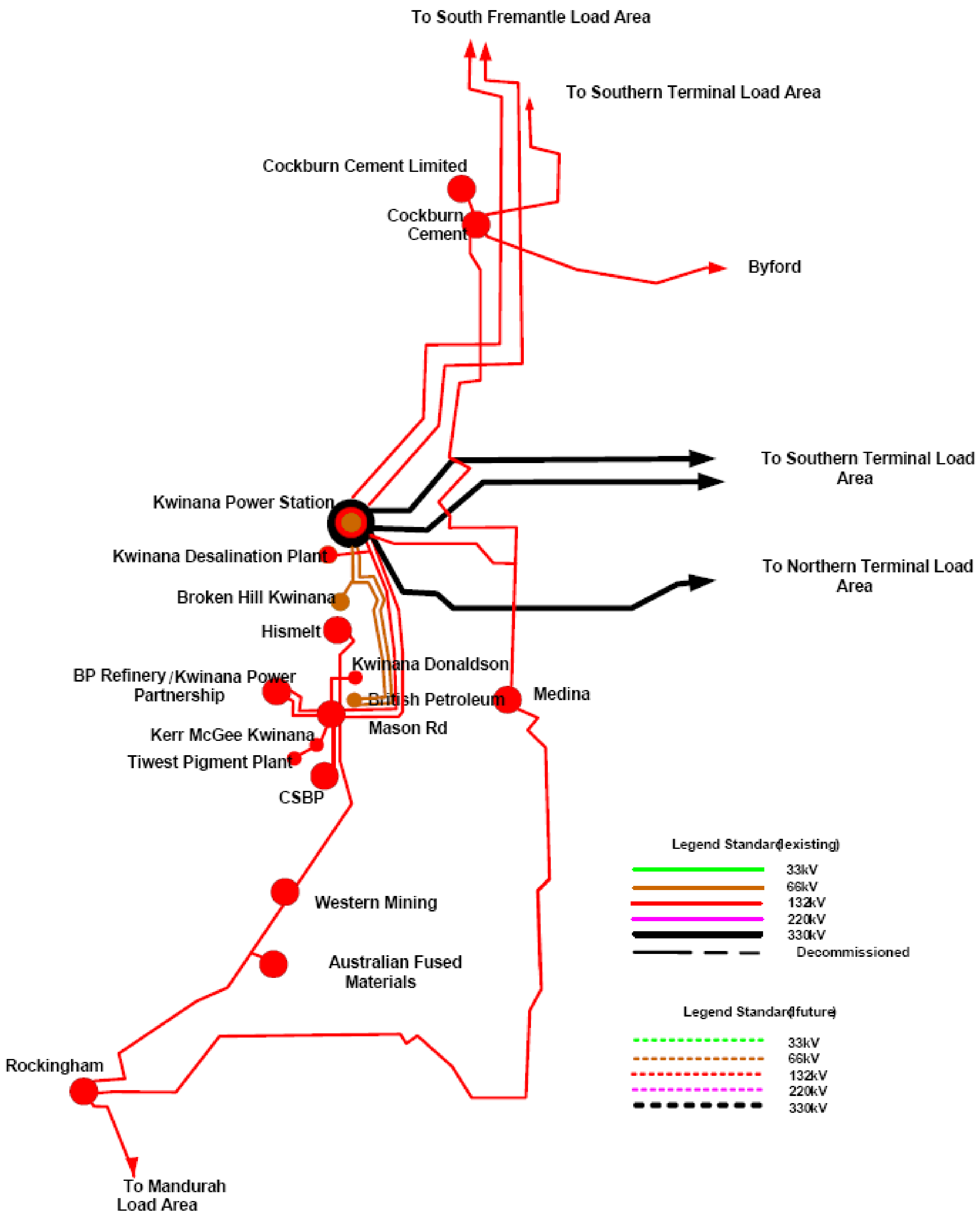

Figure 13: Transmission System - Kwinana Load area

4.7.1.4.1 Purpose (Relationship with other load areas)

The network in the area is characterised by strong 330 kV ties with generation centres in the south of the Western Power Network (Muja and Bunbury areas) as well as 330 kV connections with large load areas supported by Southern Terminal and Northern Terminal. A number of load areas rely heavily on supply via Kwinana Terminal, both through the 330 kV and 132 kV transmission systems. Kwinana

Terminal is therefore a key node on the Western Power Network 330 kV backbone system and represents an important site for system security purposes.

4.7.1.4.2 General considerations

Due to the meshed nature of the network in the area, coupled with high levels of generation, fault level issues can be problematic. Typically under peak demand conditions most generation in the area is operational and the single 330/132 kV transformer at Kwinana Terminal must be out of service contain this issue.

Having this transformer out of service disconnects the 330 kV bulk transmission and 132 kV sub transmission systems. This can constrain generation capacity at Kwinana, reduce the effectiveness of the 330 kV bulk transmission system to transfer power around the Western Power Network, and causes increased congestion at the 132 kV level between Kwinana and neighbouring load areas.

4.7.1.4.3 Substations

There is one terminal in the load area, Kwinana Terminal and 18 substations of which the following 5 are owned and operated by Western Power.

- Cockburn Cement
- Medina
- Mason Rd
- British Petroleum
- Rockingham

All Western Power substations are subject to peak demand conditions during the summer months.

4.7.1.4.4 Transmission lines

The transmission network in this area is focused around Kwinana Terminal, which is connected to other major terminals including South Fremantle, Southern Terminal, Northern Terminal, Kemerton and Oakley via 330 kV and 132 kV transmission systems.

Kwinana Terminal is currently one of the largest Terminals in the Western Power Network and is characterised by significant generation connection and strongly meshed networks with neighbouring areas.

The 330 kV and 132 kV bus sections within Kwinana Terminal are connected via a single 490 MVA transformer.

A 132 kV sub transmission system extends south from Kwinana Terminal to Rockingham where it neighbours the Mandurah Load Area. A number of 132 kV lines also extend north of Kwinana Terminal connecting to Cockburn Cement Substation, Bibra Lake Substation, South Fremantle Terminal and Southern Terminal. The role of this 132 kV sub-transmission network is primarily to transfer power from the generating plant in Kwinana Load Area to nearby industrial loads and to neighbouring load areas.

The transmission lines in this load area are generally designed to meet the N-1 criteria. Kwinana Terminal is subject to the N-1-1 criteria at 80% peak load.

4.7.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.7.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Kwinana Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Cockburn Cement (CC)

Cockburn Cement Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2018/19.

Medina (MED)

Medina Substation has two transformers and operates under the NCR criteria. A third transformer is expected to be commissioned late 2011. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Mason Road (MSR)

Mason Road Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14.

There is approximately 18.4 MVA of additional capacity available to Mason Road via feeders from British Petroleum Substation, however this site is particularly old and due for significant asset replacement in the coming 10 year horizon. Western Power is considering options to decommission the British Petroleum Substation and transfer its load to Mason Road. This would bring forward the timing for additional transformation capacity at Mason Road but may be the most economic solution to support demand in the area.

British Petroleum (BP)

British Petroleum Substation has two transformers and operates under the N-1 criteria. The two transformers at BP are due to be replaced or refurbished within a 10 year horizon, together with a number of Circuit

Breakers and other primary switchgear. Western Power is considering options to decommission the British Petroleum Substation and transfer its load to Mason Road Substation. This would bring forward the timing for additional transformation capacity at Mason Road but may be the most economic solution to support demand in the area.

Rockingham (RO)

Rockingham Substation contains three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14.

4.7.2.2 Fault levels

As significant generation is connected in close vicinity to the Kwinana Terminal, coupled with its very meshed nature, fault level issues at the Terminal are problematic. Series reactors have been installed on a number of 132 kV bus sections within the terminal although this has not been sufficient to contain fault levels within limits under all operating conditions.

Currently under peak demand conditions with all generation in the area in service the 330/132 kV transformer at Kwinana Terminal must be out of service to contain fault levels. This presents considerable inefficiencies as generation in the area is not able to access the bulk 330 kV transmission system effectively, resulting in additional constraints between Kwinana and other load areas at the 132 kV level. Fault levels also present limitations on the connection of future generation in the area. Left unattended fault levels will continue to rise.

It is important for Western Power to address these fault level issues in order to remove constraints on new generation connection, improve the bulk transmission capability and improve system security. As there are also a number of emerging thermal limitations on transmission lines in the area Western Power has looked to develop a network strategy which addresses both fault level and thermal limitations with minimal network reinforcement.

4.7.2.3 Thermal limits

A number of thermal overloads are evident following various contingencies in the area. These include overloads on 132 kV network from Kwinana Terminal to:

- the Rockingham area (and further south to Waikiki) following loss of parallel circuits between Kwinana Terminal and Rockingham; and
- Southern Terminal via Cockburn Cement, following the loss of various transmission elements between Kwinana Terminal and South Fremantle, and a 330/132 kV transformer at Southern Terminal.

These overloads are evident from around 2014 onwards.

These thermal issues are driven, in part, by the meshed nature of the Rockingham and Mandurah/Meadow Springs areas. This mesh creates uneven load sharing on lines supplying Mandurah and Meadow Springs and impacts operational controllability. Similar issues are also driven by the configuration of the 132 kV network between Kwinana Terminal, Southern Terminal and South Fremantle Terminal.

4.7.2.4 Voltage limits

Due to the localised generation in the area, heavily meshed configuration and interconnection between the 330 kV and 132 kV networks, no voltage instability issues are apparent.

4.7.2.5 Asset condition

The Kwinana sub-transmission networks contain a number of aging circuits. Of particular note are the following circuits that are now in excess of 40 years old:

- Kwinana Terminal to Southern Terminal 132 kV; and
- Kwinana Terminal to British Petroleum 66 kV.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.7.3 Network development within a 10 year period

4.7.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.7.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.7.3.2 Preferred substation solutions

- Transfer of load from Rockingham Substation to Medina Substation by summer 2014/15. This brings forward the timing which Medina Substation requires augmentation to around summer 2019/20;
- Install additional 33MVA transformer at Mason Road Substation by summer 2014/15;
- Establish a new substation (East Rockingham) by around summer 2015/16. Load to be transferred from Rockingham Substation to the new site to defer any further augmentation at Rockingham Substation outside a 10 year horizon;
- Transfer of load from Medina Substation to East Rockingham Substation by summer 2019/20; and
- Establish a new substation (Henderson Substation) around summer 2020/21. It is proposed that this substation be connected to Cockburn Cement Substation via new 132 kV double circuit lines and supply new load in the area, in particular the Australian Marine Complex. Transfer of load

from Cockburn Cement Substation to this new substation by summer 2020/21.

4.7.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network, as well as existing fault level issues. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

Options were developed with a view to allowing the 330 kV and 132 kV busbars at Kwinana Terminal to be connected under peak demand conditions via the existing 330/132 kV transformer.

Of the options assessed it was discovered that without considerable reconfiguration it is particularly difficult to reduce the fault levels at Kwinana Terminal, allowing for the existing 330/132 kV transformer to be kept in service to allow for optimum generation dispatch.

Options that reinforce existing circuits to address thermal limitations tend to increase fault levels and were found to exaggerate poor line sharing issues. Western Power determined that additional fault limiting series reactors or other combinations of fault limiting devices and additional circuits present an inefficient and uneconomic solution to address fault level problems and more favourable lower cost solutions have been identified.

To ensure efficient use of the existing 330 kV bulk transmission system, reduce constraints on existing generation and facilitate future generation connection, it is critical to allow power transfer between the Kwinana 330 kV and 132 kV systems via the 330/132 kV transformer. Reconfiguration of the network was found to be the preferred solution.

As part of developing a strategy to reconfigure the network Western Power considered the longer term supply needs in the area, and the reliance of neighbouring areas on the Kwinana network. In particular the following aspects were key influences on the preferred solution:

- Reliability of the network and operational flexibility and controllability;
  - Reconfiguration of the network should not degrade its reliability or ability to schedule planned outages. Furthermore reconfiguration of the network should consider implications on management of power transfers through generation dispatch.

- Southern Terminal and South Fremantle rely heavily on power transfer capability from Kwinana Terminal. Any reconfiguration of the network should look to expand this capability;
    - The Kwinana area appears attractive for new entrant generation under most generation development scenarios. This suggests an ongoing need for considerable power transfer from Kwinana north through to the CBD and Western Terminal.
- There are a number of forecast large new load developments in the Kwinana area, including the Cockburn Coast Development, Latitude 32 and the Australian Marine Complex. Furthermore there is considerable residential development east of Thomson Lake and a new substation in the area could prove to be an economic solution. Reconfiguration of the network should facilitate options for connection of these potential future loads;
- Ability for existing and future generation to operate unconstrained under various dispatch conditions [28];
- Ability to continue supporting the Mandurah Load Area via the Rockingham to Waikiki 132 kV connection;
    - With the current network configuration the power transfer requirements on the Rockingham to Waikiki 132 kV circuit increase with annual demand growth in the Mandurah Area. Consideration was given to reinforcing this connection as well as establishing a radial Mandurah Load Area network from Pinjarra up to Waikiki.
- Efficient use of the bulk 330 kV transmission network to transfer generation to major load centres and opportunities to reduce system losses; and
- Ongoing use of existing aged sub transmission assets and their role in the future strategy.

4.7.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon. As the reconfiguration affects both the Southern and South Fremantle Terminals these have been shown for clarity.

[28] Whilst studies were performed using merit order dispatch, consideration was given to sizing augmentations to allow for unconstrained operation under various dispatch conditions.

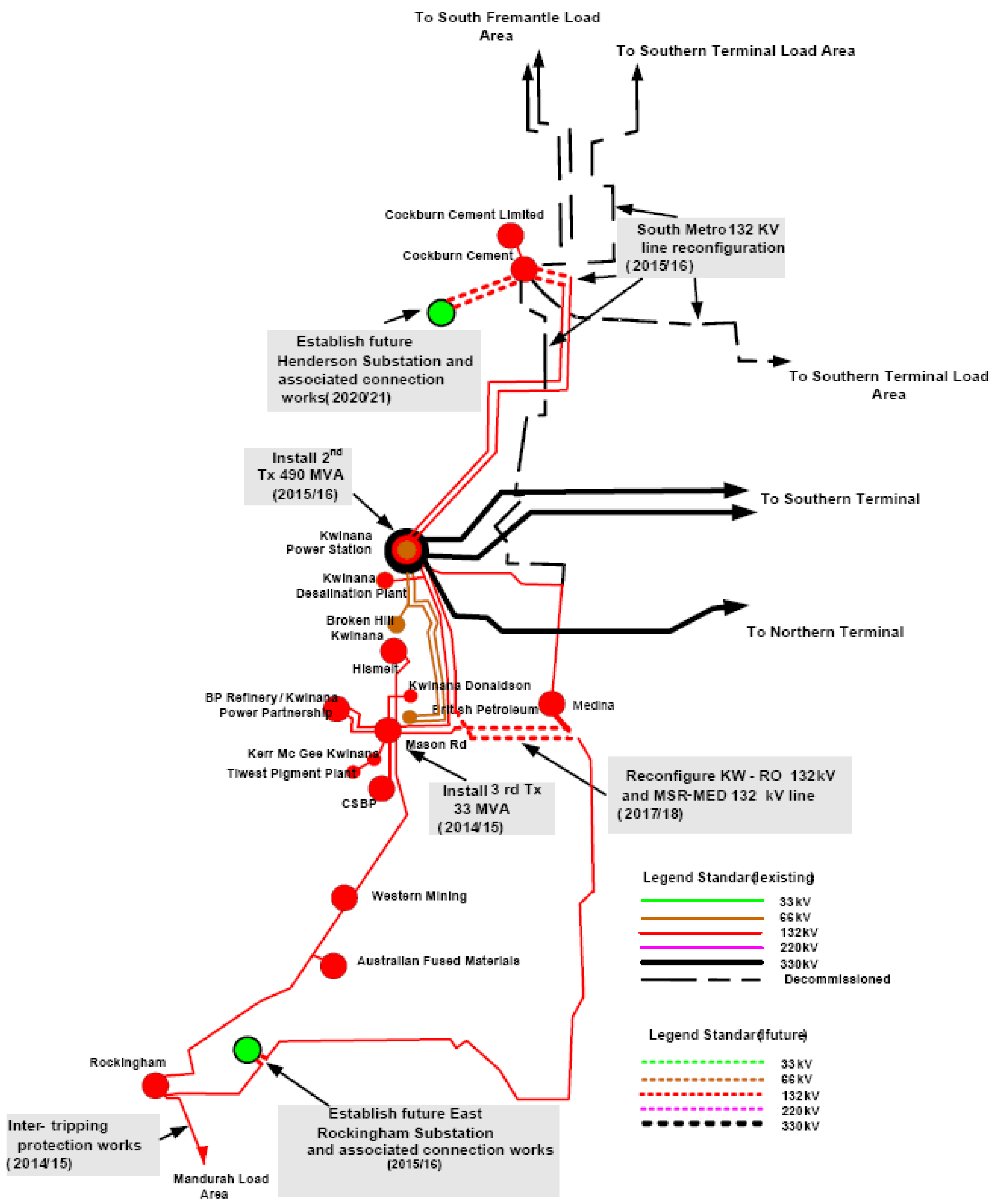

Figure 14: Kwinana Load Area - preferred transmission solution

The specific projects planned for the Kwinana Load Area over the next 10 years include:

- Inter-tripping protection works on Rockingham to Waikiki 132 kV circuit by summer 2014/15;
- South Metro Reconfiguration by summer 2015/16;

- Reconfigure network to create Kwinana to Rockingham 132 kV circuit and Medina to Mason Road 132 kV circuit by summer 2017/18;
- Line decommissioning works following South Metro Reconfiguration by summer 2017/18; and
- New double circuit 132 kV line to connect Henderson Substation to Cockburn Cement Substation by around summer 2020/21.

The preferred solution offers the following benefits:

- Reduces fault levels at Kwinana Terminal considerably, allowing for the existing 330/132 kV transformer to be in service as well as a second 330/132 kV transformer to be in service under peak demand conditions;
- Additional 330/132 kV transformation capacity at Kwinana Terminal provides for unconstrained generation dispatch in the area and capacity for future generation connection at the 132 kV level at or near Kwinana Terminal;
- Reduces congestion at the 132 kV sub-transmission level by providing a lower impedance path for generation access to the 330 kV bulk transmission system;
- Allows for the potential re-use of existing Southern Terminal-Kwinana Terminal 132 kV circuits (currently double circuit bonded arrangement) as the double circuit supply to a new future substation in the Success area;
- Provides for the decommissioning of assets in poor condition between Cockburn Cement and Byford, where reinforcement or replacement is unlikely to be an attractive option;
- Radialises South Fremantle Load Area off Southern Terminal (no longer connected to Kwinana Terminal) with minimal additional asset build (5.5km from Southern Terminal to Bibra Lake largely along existing corridors). This also offers improved power flow controllability and attempts to optimise use of existing assets;
- Establishes strong supply point to Cockburn Cement from Kwinana Terminal to facilitate connection of future large block loads in the Henderson area such as the Australian Marine Complex; and
- Defers investment in the Mandurah Load Area by retaining the Rockingham to Waikiki 132 kV circuit until isolation of the two load areas around 2019/20.

4.8 Southern Terminal

4.8.1 Geographic load area

Southern Terminal load area covers the region bound by Riverton and Canning Vale in the north, Cockburn in the west and Byford in the south east.

4.8.1.1 Load area characteristics

Southern Terminal Load Area consists of residential, commercial, industrial and semirural load with domestic activity representing the bulk of demand. There is significant undeveloped land and due to its proximity to the inner metropolitan area, development is proceeding quickly. It is anticipated that in the short to medium term the bulk of new residential estates will occur to the south of the suburbs of Canning Vale and Gosnells towards Southern River and Armadale, and in the suburbs of Byford and Brookdale. There is also considerable activity around suburbs of Spearwood, Atwell, Success, Beeliar, Yangebup, Munster and Coogee. There is generally much less interest in industrial load applications and commercial activity is tending to smear throughout the load area, although mainly focused in the north.

4.8.1.2 Demand

4.8.1.2.1 Historic growth rates

Since 2000 the Southern Terminal Load Area has exhibited a steady growth of 16 MW / year.

4.8.1.2.2 Customers served

The number of customers supplied in this load area is approximately 93,000. Commercial customers account for more than 5,300 connections, domestic customers make up almost 87,200 connections. Farming customers represent almost 240 connections and industrial customers make up 149 connections.

4.8.1.2.3 Projected growth rates

From 2011, the Southern Terminal Load Area is forecast to grow at 12 MW / year over the next 10 years reaching a peak demand of 516 MW in 2021.

In this 10 year period, 23 block loads have been included in the forecast.

4.8.1.3 Generation

There is no notable generation in the Southern Terminal Load Area. Power supply predominantly comes via the 330 kV bulk transmission system connected to Southern Terminal. A number of other 132 kV circuits connected to neighbouring load areas also support the demand. Western Power has received only a very small number of new generation connection enquiries in this area, which is reflected in the new entrant generation schedule used as part of the Network Development Plan studies.

4.8.1.4 Current network

The following figure represents the existing transmission network within the Southern Terminal Load Area.

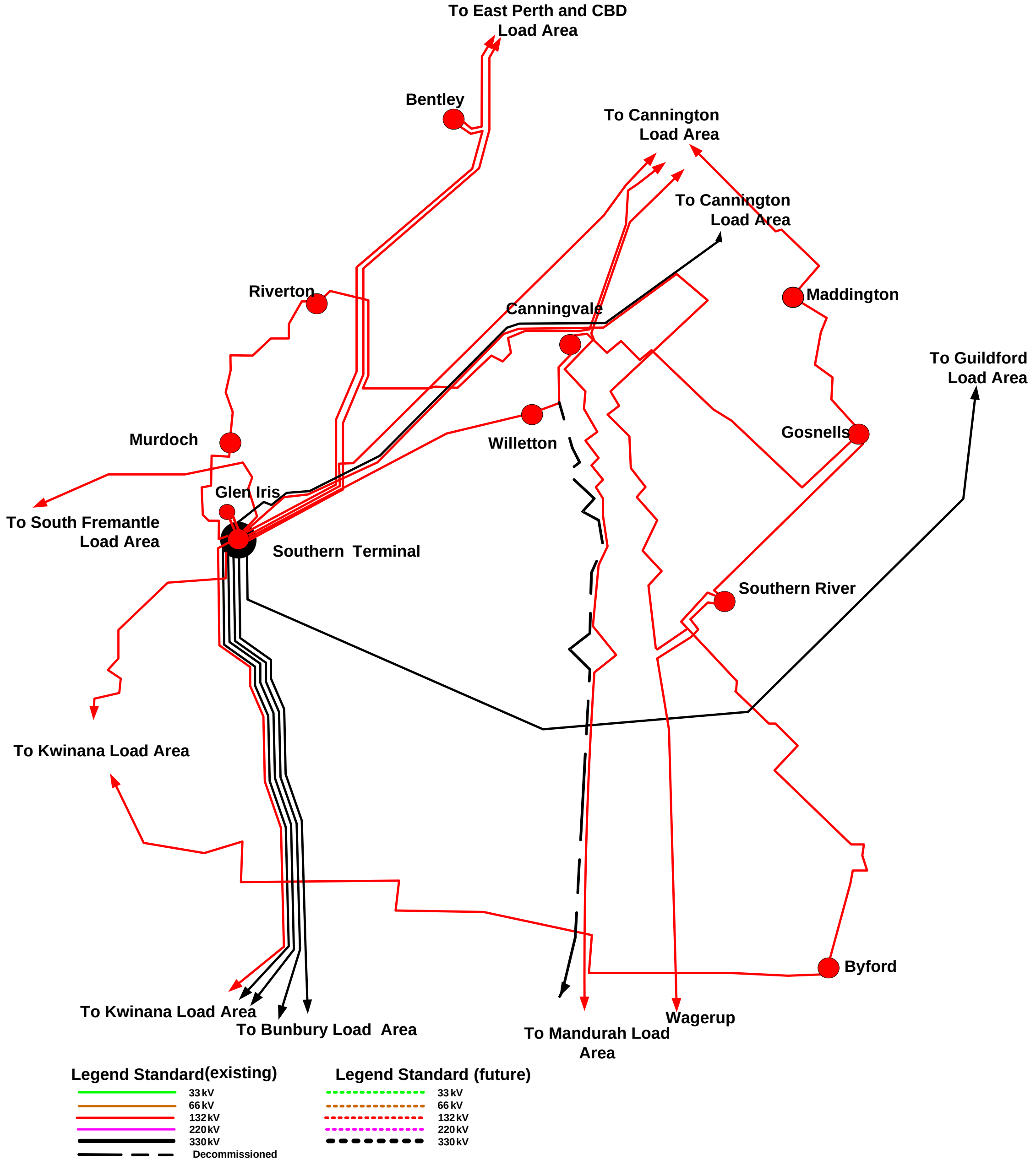

Figure 15: Transmission System – Southern Terminal Load Area

4.8.1.4.1 Purpose (Relationship with other load areas)

Southern Terminal is an important site for the interconnection of circuits on the bulk transmission network. It is a focus point for power take off from the 330 kV system and subsequent supply to numerous

132 kV sub-transmission systems supporting the broader south metropolitan load.

The two Southern Terminal to East Perth 132 kV circuits are particularly critical to the reliability of supply in the East Perth and CBD Load Area.

4.8.1.4.2 General considerations

Southern Terminal currently operates with three 330/132 kV bulk transformers. It is anticipated that without offloading this site its capacity will be exhausted within about 15 years. Whilst the site is quite large the installation of a fourth 330/132 kV transformer would present fault level issues and is likely to necessitate uprating switchgear. This process is costly, can require extensive outages and may require additional series reactors at bus sections. With load rapidly growing in the south near Southern River a new 330 kV terminal may be an economic option. This would offload Southern Terminal, as well as the 132 kV sub-transmission network that it, and Cannington Terminal currently supports.

The meshed nature of the 132 kV network between Cannington and Southern Terminal provides challenges for its development. Existing infrastructure has largely been established as multiple single circuit connections between various substations, Southern and Cannington terminals, rather than double circuit transmission network from each of the terminals connected to radialised substation loads dedicated to a single load area. Whilst the existing practice attempts to make good utilisation of existing assets it presents considerable challenges for longer term network development in the area as new circuits are likely. It also has a tendency to increase fault levels as well as reduce utilisation of the 330 kV network. This is because the multiple meshed 132 kV circuits provide a lower impedance path over 330 kV routes, particularly between Southern Terminal and Cannington.

4.8.1.4.3 Substations

There are currently nine substations in the Southern Terminal Load Area which are owned and operated by Western Power.

- Bentley
- Byford
- Canning Vale
- Gosnells
- Maddington
- Murdoch
- Riverton
- Southern River
- Willetton

All Western Power substations in the load area are subject to peak demand conditions during the summer months.

4.8.1.4.4 Transmission lines

The network in the area is characterised by strong 330 kV ties with generation centres in the South of the Western Power Network (Muja and Bunbury areas) as well as 330 kV connections with Kwinana, Cannington (via Kenwick Link) and Guildford Terminal. A number of load areas rely heavily on Southern Terminal through the 330 kV and 132 kV transmission systems, including South Fremantle (and further north to Western Terminal) and East Perth.

Multiple 132 kV sub-transmission circuits extend from Southern Terminal where they form a meshed arrangement supplying substations as far south as Byford and north towards Cannington Terminal. Both Southern Terminal and Cannington Terminal support these substations within the mesh, depending on operating conditions. From Southern River a 132 kV circuit extends south to Alcoa Pinjarra in the Bunbury Load Area.

Kwinana and Southern Terminals are directly connected by transmission network at 132 kV providing Southern Terminal with access to 132 kV generation at Kwinana. This connection, however, is a key source of high fault levels at both terminals. South Fremantle and Southern Terminal are also directly connected via 132 kV transmission, as is East Perth Terminal. These connections provide a significant power supply to the South Fremantle, East Perth and CBD demand. Given the interconnectivity between Southern Terminal and other terminals at both 330 kV and 132 kV, as well as the number of 132 kV substations fed from Southern Terminal, it represents one of the most critical sites in the Western Power Network.

The transmission lines in this load area are generally designed to meet the N-1 criteria. Southern Terminal is subject to the N-1-1 criteria at 80% peak load.

4.8.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.8.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Southern Terminal Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Byford (BYF)

Byford Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2017/18.

Bentley (BTY)

Bentley Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2019/20.

Canning Vale (CVE)

Canning Vale Substation has four transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14.

Gosnells (G)

Gosnells Substation has three transformers and operates under the NCR criteria. Following the recent commissioning of Maddington Substation in June 2011 Western Power plans to transfer load from Gosnells Substation to this new site across a number of years. After this load transfer the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Maddington (MDN)

Maddington Substation has one transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Murdoch (MUR)

Murdoch Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2019/20.

Riverton (RTN)

Riverton Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Southern River (SNR)

Southern River Substation has two transformers and operates under the NCR criteria. Following the installation of a 3rd transformer by summer 2012/13, load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Willetton (WLN)

Willetton Substation has one transformer and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2014/15.

4.8.2.2 Fault levels

Due to the heavily meshed 330 kV and 132 kV network at Southern Terminal the fault levels are very high. Installation of series reactors on the 132 kV bus sections lowered the fault current although it has now increased again to around 40 kA.

Uprating limiting switchgear and other components is particularly costly and requires extensive outages.

As part of its longer term development strategy Western Power has looked to address fault level issues through strategic reconfiguration of the network, rather than installation of fault current limiting equipment.

4.8.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on the:

- Southern Terminal to Cannington Terminal132 kV circuits including the direct connection, as well as the connection via Willeton and Canning Vale substations. These overloads occur following loss of a number of transmission elements that make the 330 kV connection between Southern Terminal and Kenwick Link, as well as the 132 kV connection between Kenwick Link and Cannington Terminal, and occur from around 2016/17 onwards;
- Southern Terminal to South Fremantle 132 kV circuit following loss of T3 330/132 kV transformer at Southern Terminal from around summer 2014/15 and
- Southern Terminal to East Perth 132 kV circuits following loss of a parallel circuit, or loss of the South Fremantle to Amherst 132 kV circuit from around summer 2014/15.

4.8.2.4 Voltage limits

Due to ongoing load growth in the area it is projected that there will be a deficit in reactive reserve at Southern Terminal around summer 2013/14.

4.8.2.5 Asset condition

The Southern Terminal sub-transmission networks contain a number of aging circuits. Of particular note is the following circuits that are now in excess of 40 years old:

- Kwinana Terminal to Southern Terminal 132 kV;
- Southern Terminal to Cannington Terminal 132 kV; and
- Southern Terminal to South Fremantle132 kV.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.8.3 Network Development within a 10 year period

4.8.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in Section 3.8.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.8.3.2 Preferred substation solutions

- Transfer load from Gosnells to Maddington Substation by summer 2011/12, and again by summer 2018/19.
- Install a third 33MVA transformer at Southern River Substation by summer 2012/13 [29].
- Install a second 33MVA transformer at Willetton Substation by summer 2014/15. Transfer load from Canning Vale Substation to Willetton Substation by summer 2014/15. This defers any further augmentation at Canning Vale Substation outside a 10 year horizon.
- Establish a new substation (Armadale) by summer 2018/19. Transfer load from Byford Substation to the new substation.

4.8.3.3 Transmission reinforcement

Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following existing line routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

There were numerous key influences on the strategic network development within this load area. The bulk of the emerging limitations across a 10 year horizon were identified as issues between Southern Terminal and neighbouring load areas, rather than solely within the Southern Terminal area. In particular issues were largely due to constraints on the ability for Southern Terminal to support neighbouring load area demand. The emerging limitations, options and key influences regarding network development are discussed in detail in relevant load area sections of this report.

Due to the strong electrical coupling between Southern Terminal and neighbouring load areas the development of projects needs to consider the broader system impacts. It is paramount that options to address these emerging constraints in neighbouring areas have consideration to the longer term impacts on Southern Terminal Load Area. The following points were key considerations:

[29] This is a committed project that will commence during the AA2 period and be concluded/commissioned during the AA3 period; as such funding has been budgeted in both Access Arrangements.

- To address the emerging limitations in the Kwinana load area a comprehensive reconfiguration project is proposed. This project has positive impacts on the supply capacity to Southern Terminal as well as reductions in the Southern Terminal 132 kV fault level (see Kwinana Load Area for more information);
- Proposed development in the Western Terminal Load Area (132 kV reinforcement from South Fremantle to Western Terminal Load Area) will have a tendency to increase power transfer from Southern Terminal to South Fremantle and further north, under some operating conditions (see Western Terminal Load Area for more information);
- To address the emerging limitations in the Cannington Load Area a number of reinforcements between Southern Terminal and Cannington Terminal are proposed. These projects heavily impact on the Southern Terminal transmission system (see Cannington Load Area for more information); and
- To address the emerging limitations in the South Fremantle Load Area a number of reinforcements between Southern Terminal and South Fremantle Terminal are proposed. These projects have a minor impact on the Southern Terminal transmission system (see South Fremantle Load Area).

4.8.3.3.1 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

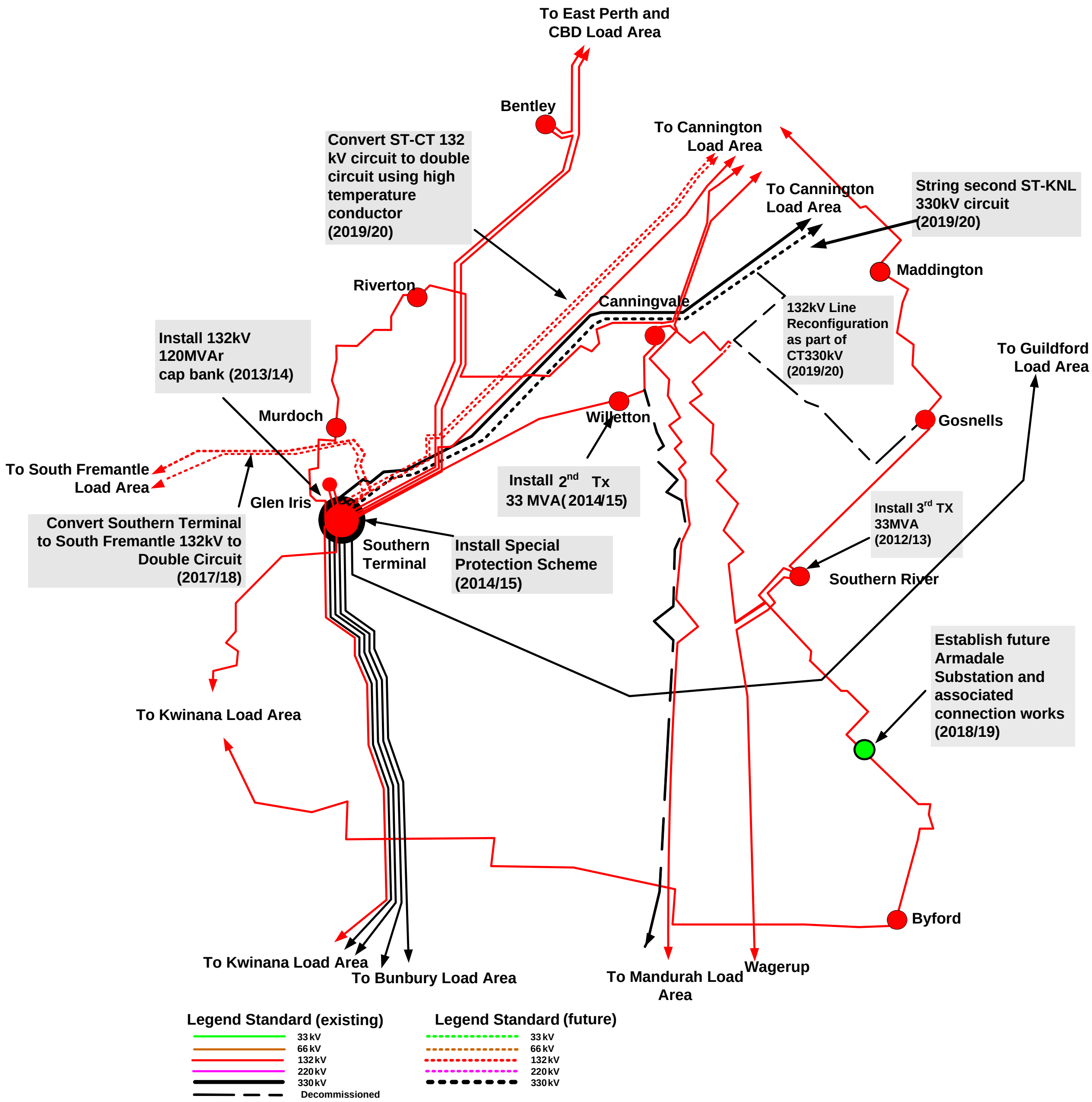

Figure 16: Southern Terminal Load Area – preferred transmission solution

The specific projects planned for the Southern Terminal Load Area over the next 10 years include:

- Installation of a 132 kV 120MVAr shunt capacitor bank by summer 2013/14;
- Reinforcements between Southern Terminal and South Fremantle Terminal. Refer to South Fremantle Load Area;
- Reinforcements between Southern Terminal and Western Terminal. Refer to Western Terminal Load Area;
- Reinforcements between Southern Terminal and Cannington Terminal. Refer to Cannington Load Area; and

- Reconfiguration of the network around Southern Terminal, South Fremantle Terminal and Kwinana Load Area. Refer to Kwinana Load Area.

The preferred projects above provide considerable benefits. See the relevant load areas for more information.

4.9 South Fremantle

4.9.1 Geographic load area

The South Fremantle Load Area extends from Beeliar Drive in the south to the Swan River at its northern boundary, and from the west coast to the Canning River in the East.

4.9.1.1 Load area characteristics

Demand in the area is a mixture of residential, commercial and light/heavy industrial load with a summer peaking profile. The load area includes the City of Fremantle as well as Fremantle Port Authority.

Most of South Fremantle is relatively well-established with moderate development activity. However, some of the areas to the South, such as Beeliar and Spearwood, are classified as major housing development areas.

4.9.1.2 Demand

4.9.1.2.1 Historic growth rates

Since 2000 the South Fremantle Load Area has exhibited a steady growth of 7 MW / year.

4.9.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 64,000. Commercial customers account for some 5,800 connections. Domestic customers make up almost 58,000 connections and industrial customers number just more than 200 connections.

4.9.1.2.3 Projected growth rates

From 2011, the South Fremantle Load Area is forecast to grow at 6 MW / year over the next 10 years reaching a peak demand of 313 MW in 2021.

In this 10 year period, no block loads have been included in the forecast.

4.9.1.3 Generation

There is no notable generation installed in the South Fremantle Load Area. There is no generation projected to connect to the South Fremantle Load Area over the next 10 years.

4.9.1.4 Current network

The following figure represents the existing transmission network within the South Fremantle Load Area.

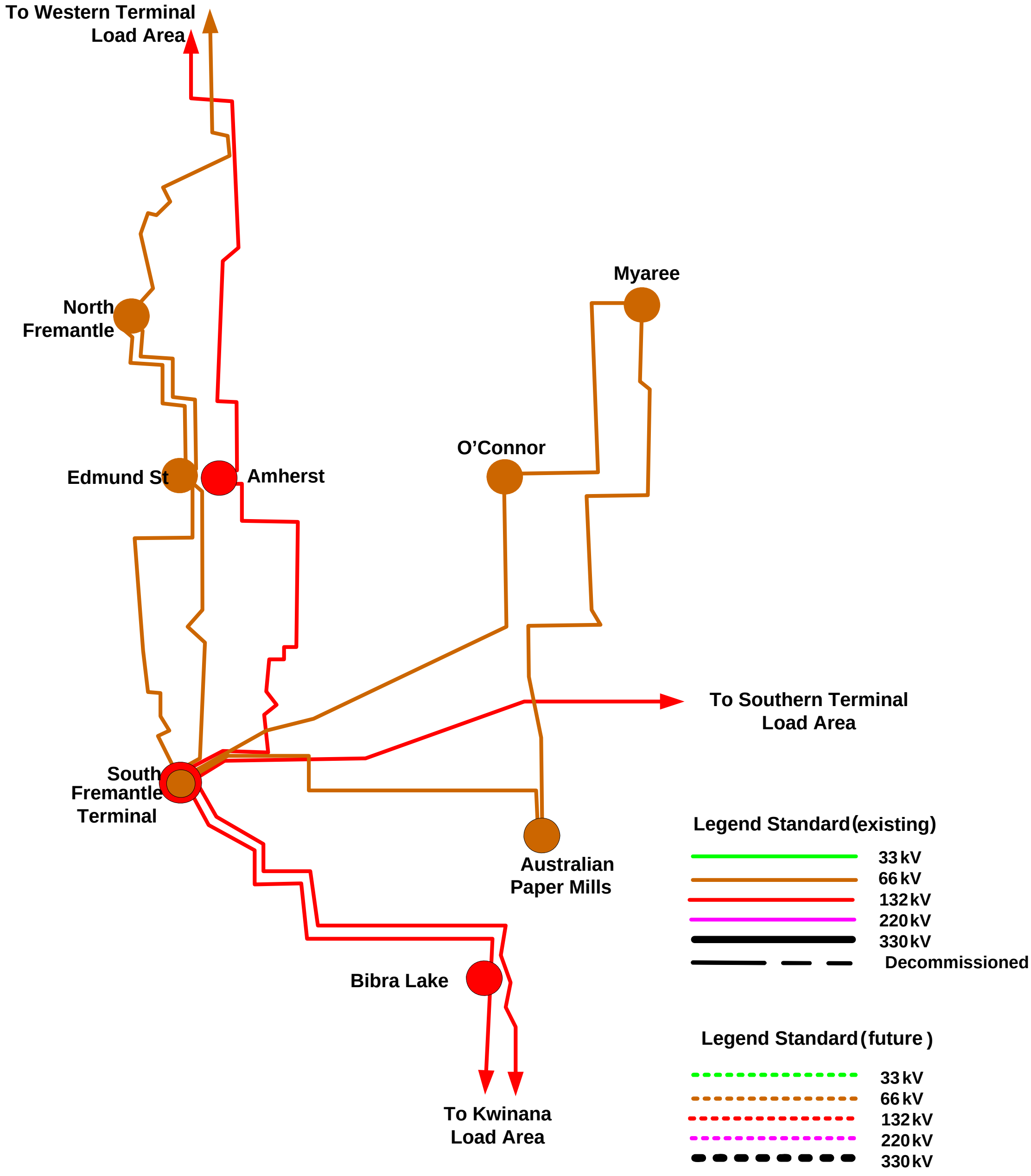

Figure 17: Transmission System – South Fremantle Load Area

4.9.1.4.1 Purpose (Relationship with other load areas)

The network in the area serves primarily to supply local substation loads, the bulk of which are connected to South Fremantle Terminal via a 66 kV sub-transmission network. As there is no local generation South Fremantle Terminal relies heavily on power transfer from Southern Terminal and Kwinana Terminal via the 132 kV transmission system. Western Terminal also relies on support from these terminals in the south, via a 132 kV circuit to South Fremantle Terminal.

4.9.1.4.2 General considerations

The bulk of the existing substations in the area are supported by an aging 66 kV network. The capacity of these substations as well as the age and capacity of the 66 kV network is expected to drive substantial reinforcement over the next 20 years, including a potential voltage upgrade from 66 kV to 132 kV. Upgrades of this nature can be difficult to stage and are typically delivered over numerous years.

As part of the Cockburn Coast Development, Western Power has been requested to investigate the impact of relocation of the South Fremantle Terminal. Due to the complexity involved with such a relocation considerable planning is required to ensure the ongoing reliability of supply to the area. Should the Terminal be relocated consideration will be given to the benefits associated with bringing forward the potential 66 kV to 132 kV voltage upgrade described above. One of the difficulties associated with large scale developments of this nature is that the load take up can be hard to predict accurately. As a result optimising the timing for new substations in the area to supply projected load, as well as offload existing sites can be challenging.

Given the well established nature of South Fremantle community acceptance for future infrastructure is difficult to achieve. Lead time for negotiation of appropriate sites for future substations and line corridors presents considerable hurdles.

4.9.1.4.3 Substations

There are currently seven substations in the South Fremantle Load Area which are owned and operated by Western Power.

- Amherst
- Australian Paper Mills
- Bibra Lake
- Edmund Street
- Myaree
- O'Connor
- North Fremantle

All Western Power substations in the load area are subject to peak demand conditions during the summer months.

4.9.1.4.4 Transmission lines

The South Fremantle Terminal is the focus of this load area and provides transformation capacity to support the 66 kV sub-transmission system supplying local substations. Supply to the Terminal comes from Southern Terminal via a double circuit bonded transmission line as well as from Kwinana Terminal via two 132 kV circuits, one of which supplies Bibra Lake Substation on route. An additional 132 kV circuit connects South Fremantle to Amherst then onto the Western Terminal Load Area.

A 66 kV circuit connects North Fremantle Substation with the Western Terminal 66 kV network and is normally operated out of service. The circuit is typically used to increase reliability of supply to substations at either end under outage conditions.

4.9.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.9.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the South Fremantle Terminal load area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Amherst (AMT)

Amherst Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Australian Paper Mills (APM)

Australian Paper Mills Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2017/18.

Bibra Lake (BIB)

Bibra Lake Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2020/21.

Edmund Street (E)

Edmund Street Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Myaree (MYR)

Myaree Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2019/20.

North Fremantle (NF)

North Fremantle Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

O'Connor (OC)

O'Connor Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2019/20.

4.9.2.2 Fault levels

There are no notable fault level issues within the South Fremantle Load Area forecast to arise over the 10 year horizon.

4.9.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on the:

- South Fremantle to Amherst 132 kV circuit following loss of either of the 132 kV circuits from Southern Terminal to East Perth Terminal; and
- Southern Terminal to South Fremantle 132 kV circuit following loss of T3 330/132 kV transformer at Southern Terminal by summer 2014/15.

4.9.2.4 Voltage limits

There are no notable voltage instability issues in the South Fremantle Terminal Load Area across a 10 year horizon.

4.9.2.5 Asset condition

The South Fremantle Load Area contains a number of aging circuits, particularly in the 66 kV sub-transmission system, most of which is now in excess of 50 years old.
As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.9.3 Network development within a 10 year period

4.9.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.9.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.9.3.2 Preferred substation solutions

Establish a new substation in the South Fremantle area by around summer 2020/21. Load to be transferred from Myaree Substation, O'Connor Substation and Australian Paper Mills Substation to the new site over a number of years.

4.9.3.3 Transmission reinforcement

Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following existing line routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

The following aspects were key influences on the preferred network solutions in the South Fremantle Load Area;

- Opportunity for lower cost special protection schemes to defer more costly investment;
  - When addressing emerging limitations consideration should be given to special protection schemes which may be installed temporarily, or permanently, to defer investment or to facilitate project staging.
- Existing assets with opportunity for low cost reinforcement;
  - At present the Southern Terminal to South Fremantle Terminal 132 kV circuit is of double circuit bonded configuration. This circuit can be converted to double circuit at low cost;
  - A number of circuits in the 66 kV sub-transmission system in the area are built to 132 kV capability, although operated at 66 kV. These works occurred as part of asset replacement strategies. Options which consider re-energising existing circuits at higher operating voltages can present considerable cost savings.
- Longer term reliance on supply from South Fremantle Terminal to Western Terminal;
  - Network reinforcement strategies should consider optimising the need for power transfer capacity to Western Terminal load area with reinforcement needs between Southern Terminal and South Fremantle Terminal.
  - The majority of 66 kV network connecting Edmund St Substation to North Fremantle Substation then further north to Western Terminal is in particularly poor condition.
  - Asset replacement strategies should consider replacing the 66 kV network with 132 kV network to facilitate a larger transfer capacity across this corridor.
  - Due to the difficulties in establishing future circuits from South Fremantle to Western Terminal alternative strategies that look to reduce this power transfer requirement could be more economic over the long

term. However, similar difficulties are also presented when reinforcing into Western Terminal from the north or via the CBD.

- Possible relocation of the South Fremantle Terminal as part of the Cockburn Coast Development;
  - Due to the uncertainty surrounding this proposal there is considerable option value in deferring augmentations until more firm commitment is made by the proponent.
- Impact of augmentations in neighbouring load areas.
  - To address the emerging limitations in the Kwinana Load Area a comprehensive reconfiguration project is proposed. This project has positive impacts on the supply capacity to South Fremantle as a result of improved load sharing on existing circuits (see Kwinana Load Area for more information).
  - Proposed development in the Western Terminal Load Area (132 kV reinforcement from South Fremantle to Western Terminal Load Area) will have a tendency to increase power transfer from Southern Terminal to South Fremantle and further north, under some operating conditions. However, under N-1-1 conditions at South Fremantle this circuit also provides improved reliability of supply to the South Fremantle Load Area.

4.9.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

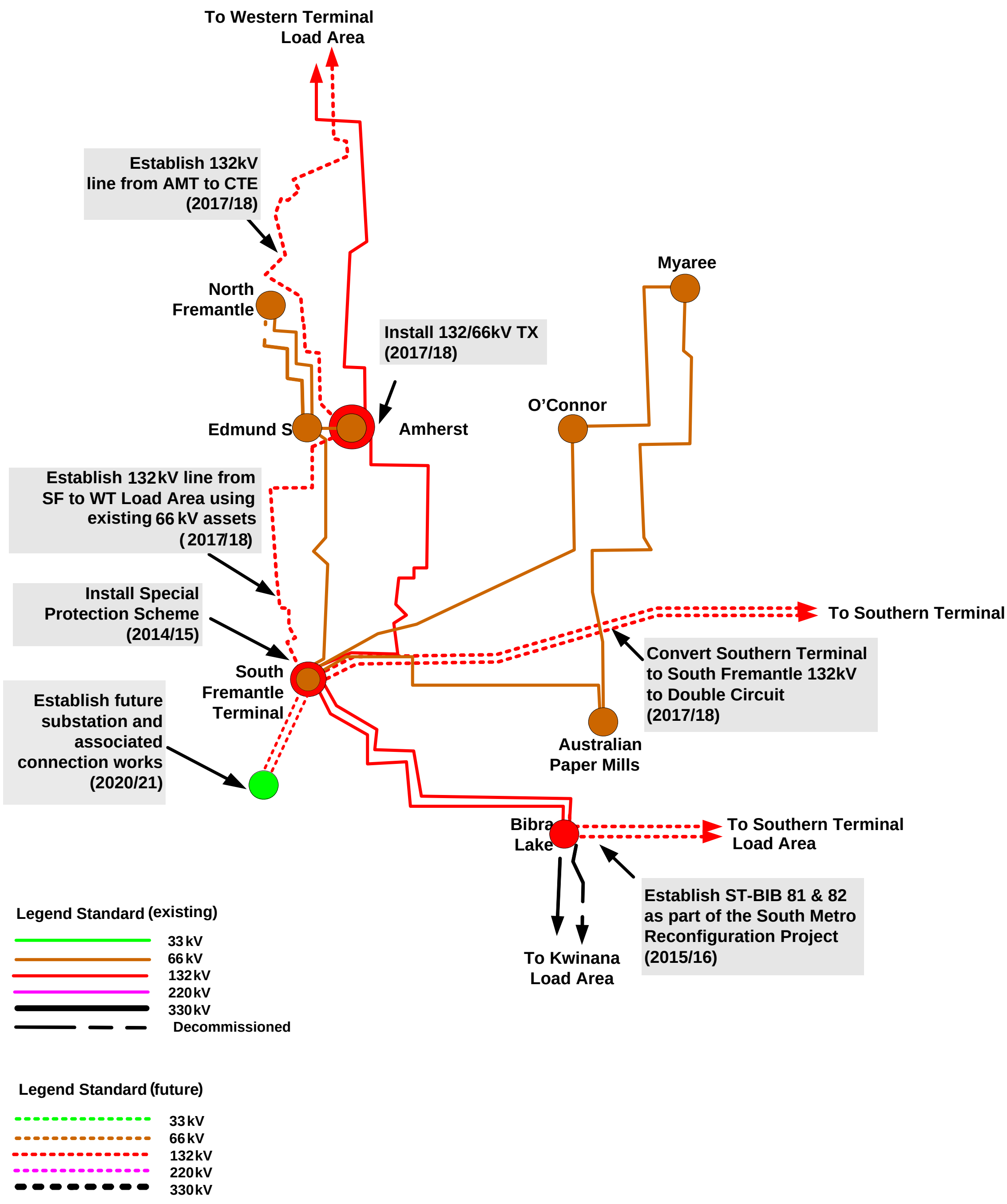

Figure 18: South Fremantle Load Area – preferred transmission solution

The specific projects planned for the South Fremantle Load Area over the next 10 years include:

- Installation of a special protection scheme which isolates the Southern Terminal to South Fremantle 132 kV circuit following loss of T3 330/132 kV transformer at Southern Terminal. Installation proposed by summer 2014/15;
- Reconfigure the network around Southern Terminal, South Fremantle and Kwinana Load Areas by summer 2015/16 (see Kwinana Load Area for more information);

- Convert Southern Terminal to South Fremantle 132 kV transmission line from double circuit bonded circuit to double circuit configuration by summer 2017/18;
- 132 kV reinforcement from South Fremantle to Western Terminal Load Area by summer 2017/18 (see Western Terminal Load Area for more information); and
- New double circuit 132 kV line to connect the new South Fremantle Substation to South Fremantle Terminal (or nearby 132kV transmission connection point depending on location of new substation) by around summer 2020/21.

The preferred solution offers the following benefits:

- Lower cost special protection control scheme provides for deferral of more costly augmentations;
- Adopts strategies that look to use existing assets that were previously built to higher standards to increase their utilisation;
- Uses lower cost options such as conversion of a double circuit bonded transmission line to double circuit configuration;
- Optimises asset replacement and network reinforcement strategies by rebuilding the existing aged 66 kV circuits between South Fremantle and Western Terminal to 132 kV; and
- Please refer to Kwinana and Western Terminal load areas for benefits delivered by projects in these areas that impact South Fremantle.

4.10 Western Terminal

4.10.1 Geographic load area

The Western Terminal Load Area supplies the area bound by the Perth CBD to the east, the Swan River to the South, the west coast and Wembley Downs to the north.

4.10.1.1 Load area characteristics

Western Terminal Load Area is mature and well established. The area contains mostly residential, commercial and some light industrial load. Developments in the area are expected to be centred on the rationalisation of existing land uses such as higher density residential and commercial buildings, with very few greenfield developments.

The area contains most of the affluent suburbs of Western Australia and is experiencing a considerable infiltration of air-conditioning use, which is believed to be the cause of the area's load growth in the past few years. The re-zoning and re-development in parts of the Western Terminal load area to high density residential and commercial land uses, has also contributed to growth.

4.10.1.2 Demand

4.10.1.2.1 Historic growth rates

Since 2000 the Western Terminal Load area has exhibited a steady growth of 4 MW / year.

4.10.1.2.2 Customers served

The approximate number of customers supplied in this load area is 37,500. Commercial customers account for almost 3,000 connections and domestic customers make up more than 34,500 connections. Industrial customers account for a little more than 12 connections.

4.10.1.2.3 Projected growth rates

From 2011, the Western Terminal load area is forecast to grow at 5 MW / year over the next 10 years reaching a peak demand of 223 MW in 2021.

In this 10 year period, 5 block loads have been included in the forecast.

4.10.1.3 Generation

There is no notable generation capacity installed in the Western Terminal Load Area and none proposed across the 10 year horizon.

4.10.1.4 Current network

The following figure represents the existing transmission network within the Western Terminal Load Area.

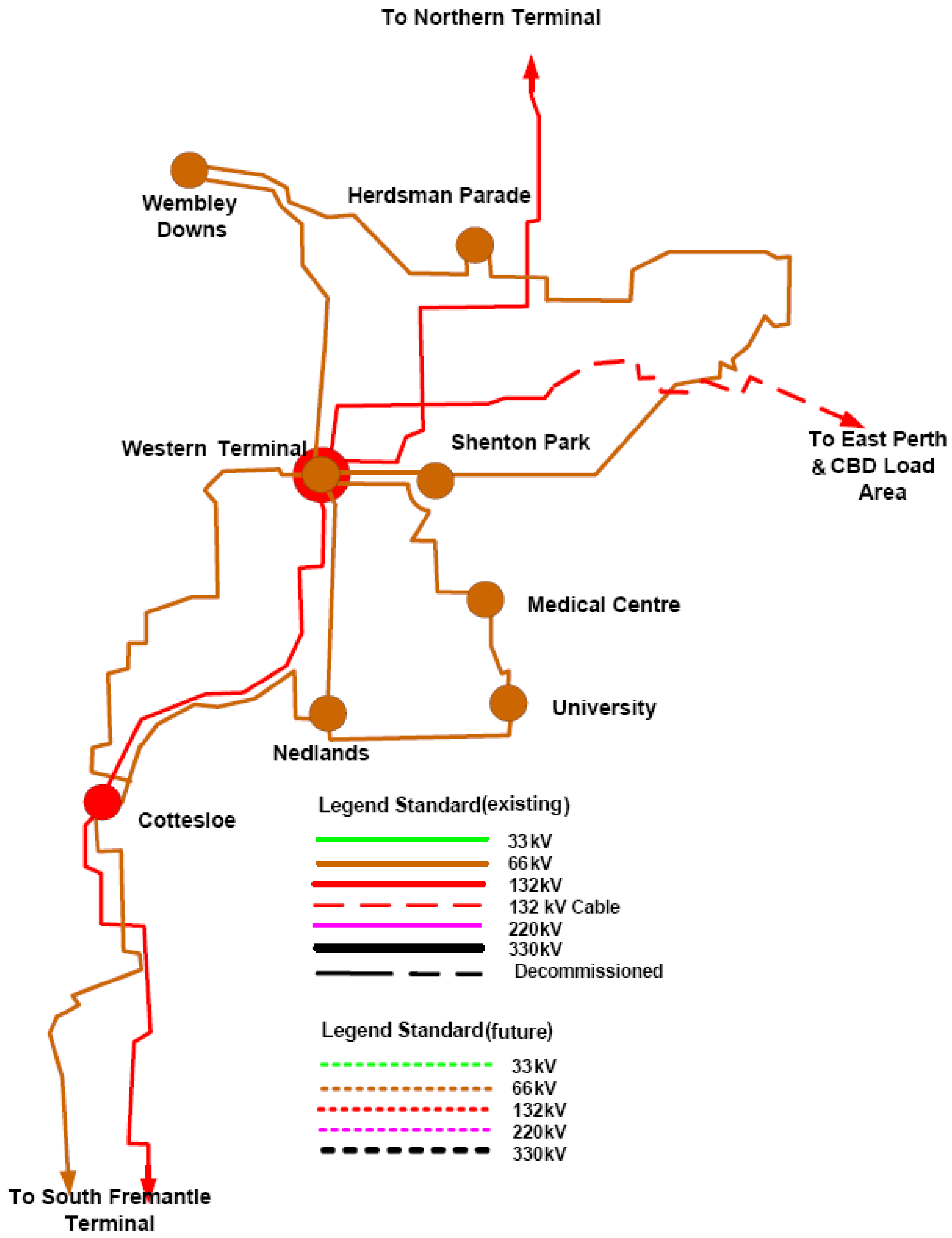

Figure 19: Transmission System – Western Terminal Load Area

4.10.1.4.1 Purpose (Relationship with other load areas)

The purpose of the network in this area is primarily to support load in the western suburbs. There is heavy reliance on supply from neighbouring load areas South Fremantle, Northern Terminal and CBD.

The majority of the power flow into the load area originates from South Fremantle and Northern Terminal. A connection from Western Terminal to Cook St Substation also supports the area's demand.

Substations within the load area are supplied primarily off a 66 kV sub-transmission network from Western Terminal.

4.10.1.4.2 General considerations

Substations in the Western Terminal Load Area are quickly exhausting their transformer capacity, with multiple sites already operating at capacity or expected to reach limits within a 3 year period. Many of these sites are also approaching the end of their economic life, with the majority of Western Terminal substations and transmission lines over 40 years of age.

New reinforcements in the area need to take into account the retirement of existing 66 kV assets and the potentially economic conversion of the sub-transmission network to 132 kV.

Construction of new substations within the Western Terminal load area is made difficult due to scarcity of land and difficulties with environmental and community consents. Substation reinforcements in most cases are constrained to using existing operational sites. Historically, this has translated into some difficulties with staging of construction and execution of planned projects and is anticipated to be the case looking forward.

4.10.1.4.3 Substations

There are seven substations in the Western Terminal Load Area which are owned and operated by Western Power.

- Cottesloe
- Herdsman Parade
- Medical Centre
- Nedlands
- Shenton Park
- University
- Wembley Downs

All Western Power substations in this load area are subject to peak demand conditions during the summer months.

4.10.1.4.4 Transmission lines

The network in the Western Terminal Load Area is centred on Western Terminal.

There are three 132 kV transmission circuits connected to Western Terminal which provide its supply. The majority of power is delivered into the load area from an overhead line originating from South Fremantle Terminal, which crosses the Swan River and travels north through the suburbs of Cottesloe and Nedlands. The circuit supplies the recently upgraded Cottesloe Substation, in addition to the Amherst Substation which is located in the South Fremantle Load Area.

A second and third 132 kV circuit connects Western Terminal with Northern Terminal and the Cook St Substation respectively. These lines provide additional reliability of supply to the load area.

Supply to substations in the area is achieved through a 66 kV sub-transmission network, which forms two distinct rings. A northerly 66 kV ring supplies the Wembley Downs, Herdsman Parade and Shenton Park substations and a southerly ring supplies the Medical Centre, University and Nedlands substations.

The transmission lines in the area are designed to meet the N-1 Criteria. Supply to Western Terminal is subject to the N-1-1 criteria at 80% peak load.

4.10.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.10.2.1 Substation Capacity

This section provides a summary of emerging limitations at each substation in the Western Terminal load area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Cottesloe (CTE)

Cottesloe Substation has two transformers and operates under the NCR criteria. The substation was expanded and upgraded to 132 kV operation in summer 2010/11. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Herdsman Parade (HE)

Herdsman Parade Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Medical Centre (MC)

Medical Centre Substation has three transformers and operates under a reduced N-1 criterion. Of the three transformers installed, only two are operated at any one time due to a limited number of switchboards. Under current forecasts, accounting for the expansion of the QEII Medical Centre Sir Charles Gairdner Hospital, the capacity of the substation is exceeded around summer 2018/19. As part of the development of the new hospital an 11 kV distribution supply has been requested. This also presents some constraints on the existing substation which operates at 6.6 kV.

Nedlands (N)

Nedlands Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14

Shenton Park (SP)

Shenton Park Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

University (U)

University Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Wembley Downs (WD)

Wembley Downs Substation has two transformers and operates under the NCR criteria. The substation was recently upgraded with the replacement of its transformers in 2010/11. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.10.2.2 Fault levels

There are no notable fault level issues within the Western Terminal Load Area forecast to arise over the 10 year horizon.

4.10.2.3 Thermal limits

A number of thermal overloads impact the reliability of supply to the Western Terminal Load Area following various contingencies. These include overloads on 132 kV network from:

- South Fremantle to Amherst following loss of a 132 kV circuit between Southern Terminal, Bentley and/or East Perth; and
- Western Terminal to Cook Street following loss of Northern Terminal to Western Terminal 132 kV circuit whilst the South Fremantle to Amherst 132 kV circuit is undergoing maintenance (N-1-1) , or vice-versa, at 80% system loading.

These N-1 and N-1-1 overloads are evident from around summer 2013/14 and 2015/16 respectively.

4.10.2.4 Voltage limits

Due to ongoing load growth in the area it is projected that there will be a deficit in reactive reserve at Western Terminal around 2017/18.

4.10.2.5 Asset condition

The transformers at all Western Terminal 66 kV substations are in excess of 40 years of age, with the exception of the recently upgraded Wembley Downs and 132kV Cottesloe substations, with Wembley Downs being fitted with refurbished units. Of particular note are the transformers at Shenton Park and Medical Centre substations, which are in excess of 50 years of age.

The age and residual capacity of the 66 kV infrastructure provides a major point of consideration when assessing substation reinforcements and future operating voltage in the area. As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.10.3 Network development within a 10 year period

4.10.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.10.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below:

4.10.3.2 Preferred substation solutions

- Transfer of load from University Substation to Medical Centre Substation by 2011/12. This advances the need for additional transformer capacity a few years at Medical Centre Substation to support this load as well as Sir Charles Gairdner Hospital;
- Transfer of load from Shenton Park Substation to Wembley Downs Substation by summer 2013/14. This helps alleviate loadings on Shenton Park transformers until the new Shenton Park Substation is built and additional transformer capacity is made available (see below);
- Transfer of load from Nedlands Substation to Cottesloe Substation by summer 2013/14. This defers the need for significant investment at Nedlands Substation beyond a 10 year horizon;
- Establish a new 132 kV ready substation at Medical Centre [30] to replace the existing 66 kV site by June 2014 (initially energised to 66 kV). All load from the existing substation and from University Substation to be transferred in stages to the newly constructed site over a number of years. The new substation provides additional transformer capacity and distribution circuit capacity in the area to supply load growth, as well as supporting the retirement of aged assets at University Substation, which have reach the end of their economic life. As part of the development of this substation the distributions system operating voltage will be upgraded from 6.6 kV to 11 kV; and
- Establish a new 132 kV substation at Shenton Park to replace the existing 66 kV site by summer 2015/16. All load from the existing substation and from Herdsman Substation to be transferred in stages to the newly constructed site over a number of years. The new substation provides additional transformer capacity and distribution circuit capacity in the area to supply load growth, as well as supporting the retirement of

[30] This is a customer driven project.

aged assets at Herdsman Substation which have reached the end of their economic life. As part of the development of this substation the distribution system operating voltage will be upgraded from 6.6 kV to 11 kV.

4.10.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term (10-25 years) and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

As discussed in the East Perth and CBD Load Area section it is proposed that a special protection scheme be installed which places the tee section of line joining Belmont Substation to East Perth Terminal and Northern Terminal back into service following various contingencies. This protection scheme is initiated following loss of either Southern Terminal to East Perth 132 kV circuits or the Southern Terminal to Amherst 132 kV circuits and avoids post-contingent overloads on other circuits within the scheme.

Although Western Terminal is required to meet the N-1-1 criteria, it currently has only three 132 kV supplies. For an N-1-1 operating situation, there is a single circuit supplying the entire Western Terminal Load Area. Historically, the total load within Western Terminal has not been sufficiently advanced to cause thermal overloads on any of the circuits supplying the area. However, projected load growths have now triggered the need for an additional circuit within the 10 year period. Options were developed to provide reinforcement into Western Terminal originating from South Fremantle, Northern Terminal and Cook St.

Of the options assessed, it was found that a 132 kV circuit from South Fremantle into Western Terminal was an attractive option. The additional line would strengthen power transfers from the southern networks into the Western Terminal and East Perth and CBD Load Areas and alleviate loadings on multiple lines currently functioning in a similar role. The reinforcement would result in a strong 132 kV supply corridor from South Fremantle into Western Terminal, whilst also supporting the lines from Southern Terminal into East Perth under certain operating conditions.

The option is also expected to provide multiple net benefits in comparison to other options considered. The new 132 kV circuit proposes to make use of existing 66 kV assets which are 132 kV ready and use existing line routes which currently house aging and out of service assets that are in very poor condition.

It is currently anticipated that this option is will have a less difficult consenting process. It also facilitates conversion of the 66 kV sub-transmission network in Western Terminal Load Area to 132 kV.

4.10.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

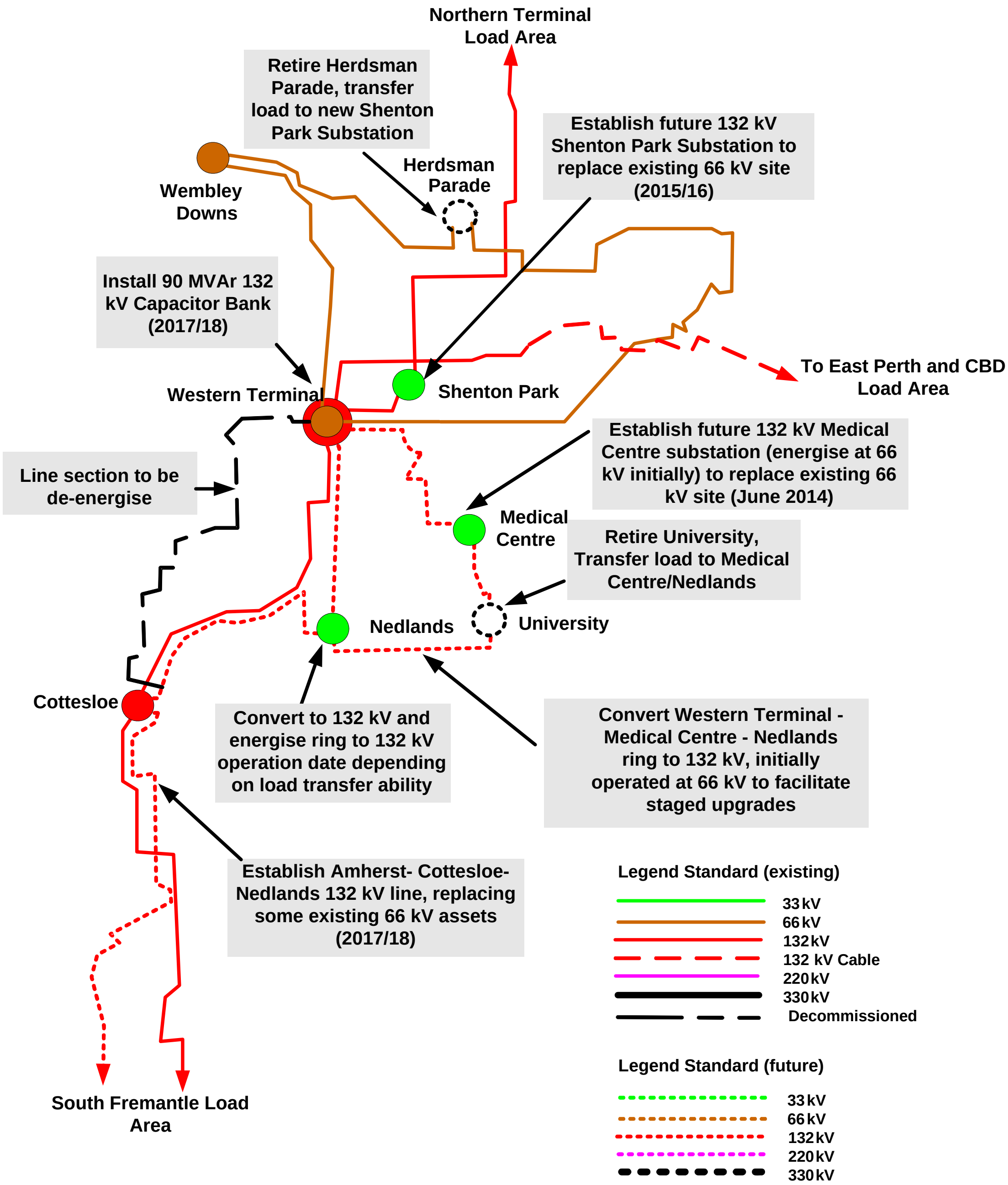

Figure 20: Western Terminal Load Area – preferred transmission solution

The specific projects planned for the Western Terminal load area over the next 10 years include:

- Install a 132 kV 90 MVAr shunt capacitor bank at Western Terminal by summer 2017/18;
- Establish a new 132 kV circuit from South Fremantle Terminal to Western Terminal using some existing 66 kV assets by summer 2017/18. This involves:
    - Upgrade 66 kV line to 132 kV between South Fremantle Terminal and Edmund Street substation (line already built to 132 kV standard);
    - Install a 132/66 kV transformer to connect Amherst 132 kV to Edmund Street 66 kV to provide N-1 reliability to Edmund Street substation (see South Fremantle Load Area);
    - Establish Amherst to Cottesloe to Nedlands to Western Terminal 132 kV line, replacing existing 66 kV assets in poor condition along the route, where possible. Leave Nedlands isolated from this new 132 kV circuit initially;
    - Convert Western Terminal to Medical Centre from 66 kV to 132 kV and operate at 66 kV initially to facilitate the operation of the new Medical Centre Substation at 132 kV;
    - Convert Medical Centre to Nedlands and Nedlands-Western Terminal 66 kV circuits to 132 kV and operate at 66 kV initially; and
    - Re-energise and connect all new circuits at 132 kV following upgrade of the existing Nedlands Substation to 132 kV capability. Depending on load transfer capability from Nedlands Substation to Medical Centre and Cottesloe substations this work may be deferred beyond the 10 year study horizon.

The preferred solutions offer the following benefits:

- Alleviate thermal overloads on the Western Terminal to Cook St 132 kV circuit for N-1-1 conditions, at 80% peak loadings;
- Strengthen power transfer capability from the southern networks into the Western Terminal and East Perth and CBD Load Areas;
- Makes use of existing 66 kV assets which are 132 kV ready and use existing line routes which currently house aging and out of service assets; and
- Aids in the 132 kV conversion of the 66 kV sub-transmission network in Western Terminal as required.

4.11 Cannington

4.11.1 Geographic load area

The Cannington Load Area is situated in the south eastern corridor of the metropolitan area and bounded by the Swan and Canning Rivers and extends east from the CBD to Mundaring.

4.11.1.1 Load area characteristics

The load area supplies a broad mix of load types ranging from industrial, commercial, residential to semi-rural consumers.

Urban consolidation and major development projects, many of which are expected to be located within the confines of the rivers precincts will be the principal drivers of domestic load growth.

4.11.1.2 Demand

4.11.1.2.1 Historic growth rates

Since 2000 the Cannington Load Area has exhibited a steady growth of 10 MW / year.

4.11.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 72,000. Commercial customers account for almost 8,000 connections, domestic customers make up almost 64,000 connections and, combined, farming customers and industrial customers total almost 150 connections.

4.11.1.2.3 Projected Growth Rates

From 2011, the Cannington Load Area is forecast to grow at 11 MW / year over the next 10 years reaching a peak demand of 449 MW in 2021.

In this 10 year period, 14 block loads have been included in the forecast.

4.11.1.3 Generation

There is no notable generation installed in the Cannington Load Area and no forecast generation over the next 10 years.

4.11.1.4 Current network

The following figure represents the existing transmission network within the Cannington Load Area.

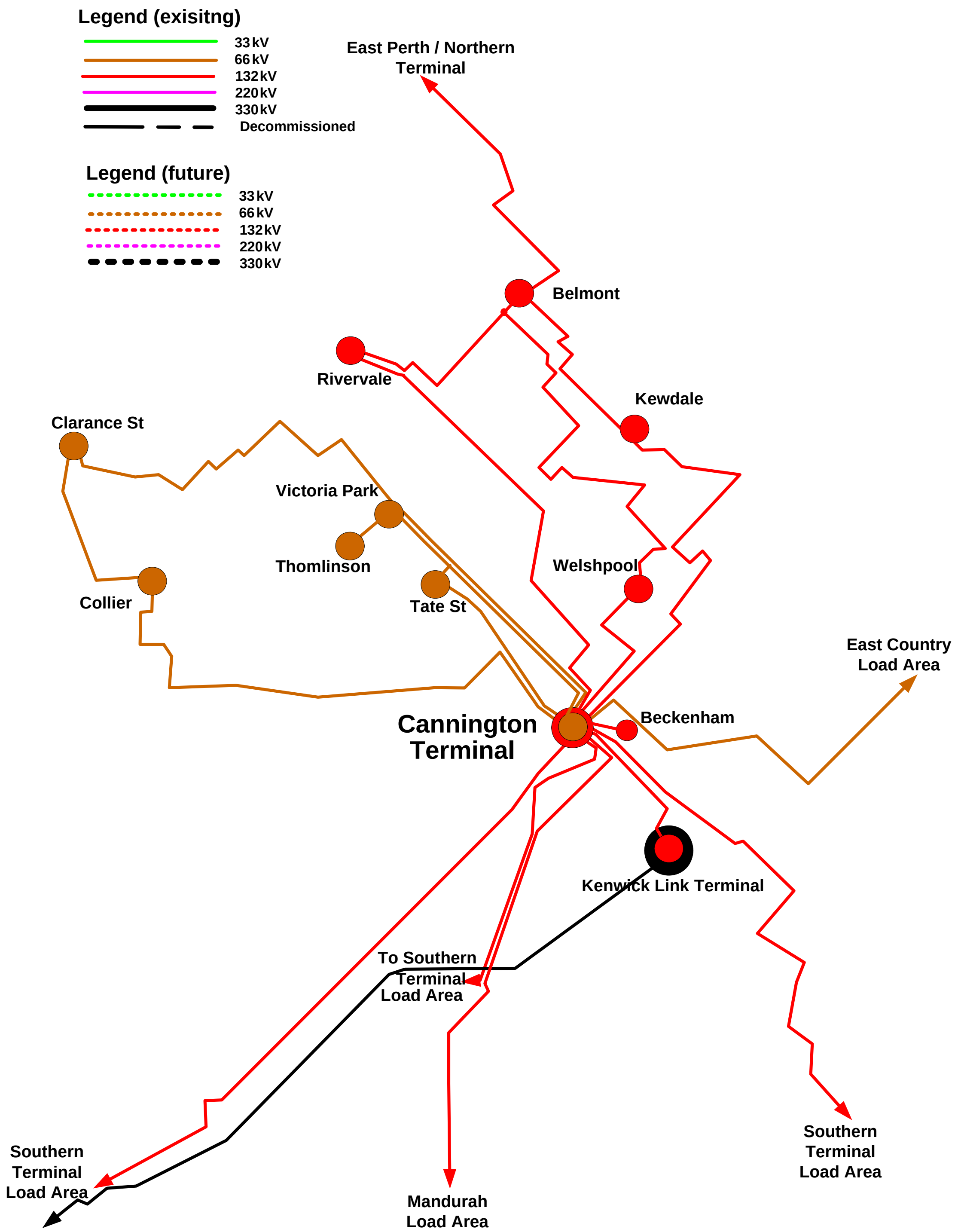

Figure 21: Transmission System – Cannington Load Area

4.11.1.4.1 Purpose (Relationship with other load areas)

The network within Cannington Load Area serves the primary purpose of supplying substations connected in the 132 kV and 66 kV sub-transmission networks extending from Cannington Terminal. Cannington Terminal is the focal point of the load area where bulk transmission connections to Southern Terminal provide the majority of the areas power requirements. These connections are at 132 kV level, however a single 330 kV transmission line connects Southern

Terminal to Kenwick Link, about 5 kilometres away from Cannington Terminal, where it then connects to Cannington Terminal via 132 kV infrastructure.

Over time Cannington Load Area has become heaviliy meshed with Southern Terminal load area via a 132 kV sub-transmission network supplying substations between them.

4.11.1.4.2 General considerations

Under the current network configuration Cannington transfers power to East Perth via connections with Belmont Substation. This provides an inefficient corridor for supply to the CBD and unnecessarily increases power transfer on the sub-transmission network connecting substations in the Cannington Load Area.

The meshed nature of the 132 kV network between Cannington Terminal and Southern Terminal provides challenges for network development. Existing infrastructure has largely been established as multiple single circuit connections between various substations, Southern and Cannington terminals, rather than double circuit transmission network from each of the terminals connected to radialised substation loads. Whilst the existing practice attempts to make good utilisation of existing assets it presents considerable challenges for longer term network development in the area as new circuits are likely. This heavily meshed arrangement also reduces network impedance relative to the bulk 330 kV transmission network between Southern Terminal and Cannington Terminal increasing congestion at 132 kV.

Cannington Load Area is well established and like most areas close to the CBD achieving consent for network reinforcements can be very challenging.

Cannington is primarily a load terminal and there is little opportunity for generation re-dispatch around the area to resolve system security issues.

4.11.1.4.3 Substations

There are 11 substations in the Cannington Load Area of which the following eight are owned and operated by Western Power.

- Belmont
- Rivervale
- Welshpool
- Kewdale
- Clarence St
- Collier
- Tate St
- Victoria Park

All Western Power substations in the load area are subject to peak demand conditions during the summer months.

4.11.1.4.4 Transmission lines

The bulk of supply to Cannington is via single 132 kV circuits from Southern Terminal and Kenwick Link. A 132 kV sub-transmission system extends north from Cannington Terminal to connect Welshpool, Rivervale, Belmont and Kewdale substations. From Belmont substation there is also a 132 kV Tee connection to the Northern Terminal and East Perth circuit.

To the South of Cannington Terminal lies a number of substations that are in the Southern Terminal Load Area, although they are supplied by both Southern and Cannington Terminal 132 kV circuits meshing the load areas together.

Cannington Terminal also supports a 66 kV network to the east which connects Clarence St, Collier, Tate St, Victoria Park and two customer owned substations. Another 66 kV transmission line extends west to connect to Mundaring Weir, which is in the East Country Load Area.

4.11.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.11.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Cannington Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Cannington Terminal (CT)

There are no projected shortfalls in 132/66 kV transformation capacity at Cannington Terminal across a 10 year horizon.

Belmont (BEL)

Belmont Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Rivervale (RVE)

Rivervale Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Welshpool (WEL)

Welshpool Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2016/17.

Kewdale (KDL)

Kewdale Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Clarence St (CL)

Clarence St Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2016/17.

Collier (C)

Collier Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Tate St (TT)

Tate St Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2018/19.

Victoria Park (VP)

Victoria Park Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.11.2.2 Fault levels

There are no notable fault level issues in the Cannington Load Area forecast to arise across the 10 year horizon.

4.11.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on the:

- 132 kV sub-transmission network north of Cannington Terminal, following loss of a number of 132 kV circuits in the same network. These overloads are exacerbated by through flows from Belmont Substation to East Perth; and
- Southern Terminal to Cannington 132 kV circuits including the direct connection, as well as the connection via Willeton and Canning Vale substations. These overloads occur following loss of a number of transmission elements that make the 330 kV connection between Southern Terminal and Kenwick Link, as well as the 132 kV connection between Kenwick Link and

Cannington Terminal. Issues arise under N-1 and N-1-1 conditions.

4.11.2.4 Voltage limits

Due to ongoing load growth in the area it is projected that there will be a deficit in reactive reserve at Cannington Terminal by summer 2014/15.

4.11.2.5 Asset condition

The Cannington sub-transmission networks contain a number of aging circuits, particularly those in the 66 kV system, most of which are now in excess of 50 years old. The 132 kV direct connected circuit between Southern Terminal and Cannington Terminal is one of the bulk supply circuits to the Cannington area and is now around 60 years old.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.11.3 Network development within a 10 year period

4.11.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.11.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below:

- Transfer of load from Belmont Substation to Rivervale Substation by summer 2012/13;
- Transfer of load from Clarence St Substation to Collier Substation by summer 2016/17; and
- Establish a new 132 kV substation in the area between Belmont and Cannington Terminal by around summer 2018/19. Load to be transferred from Belmont Substation to the new site to defer any further augmentation at Belmont Substation outside a 10 year horizon. This new substation may be deferred by the establishment of Munday Substation, which is a customer driven project.

4.11.3.2 Transmission reinforcement

Western Power has developed a number of options that look to address the emerging limitations in the transmission network. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;

- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

The following aspects were key influences on the preferred network solutions in the Cannington Load Area:

- A low cost option is available to alleviate power through flows (wheeling of power) from Cannington Terminal through the Cannington 132 kV sub-transmission system to supply East Perth. This involves opening of the circuit breaker at Belmont Substation disconnecting Belmont Substation from Northern Terminal and East Perth Terminal;
- Ability for Southern Terminal to continue supporting the Cannington Load Area via the existing 132 kV network, and 330 kV infrastructure through Kenwick Link.
    - o Cannington Terminal relies heavily on support from Southern Terminal via the 132 kV network, most of which supplies substation loads along the way. As load grows at the substations on these 132 kV circuits the maximum supportable demand at Cannington is decreased.
    - o The bulk of 132 kV circuits that form a mesh between Southern Terminal and Cannington are single circuit construction. As a result increasing their capacity presents considerable challenges when looking to maintain supply reliability. Alternatively new corridors are required, which also presents consenting issues. Network developments strategies should consider releasing the 132 kV capacity for substation load and use of the bulk transmission network to support the terminals. Essentially, strategies should consider radialising substation load off terminal sites.
- Underutilisation of the existing 330 kV transmission circuit from Southern Terminal to Kenwick Link;
    - o At present the Southern Terminal to Kenwick link 330 kV circuit is transformer ended at Kenwick Link. This 330 kV circuit is constrained to the capacity of the 132 kV circuit connecting the transformer at Kenwick Link to Cannington. This arrangement reduces the effective capacity of the bulk transmission network considerably. Future development should look to use the full potential of the 330 kV line from Southern Terminal;
- Existing Kenwick Link 330 kV poles are only strung one side at 330 kV with capability to string both sides;
    - o Kenwick Link is currently strung one side with 330 kV and the other side of the poles is used to support the 132 kV network south of Cannington Terminal. Future development should look to use the full potential of the

330 kV transmission poles from Southern Terminal to Kenwick Link.

- Age of Southern Terminal to Cannington 132 kV circuit;
  - This circuit is now around 60 years old. Future network development should look to optimise asset replacement and capacity expansion needs.
- Southern Terminal 330/132 kV transformer requirements and relationship with ongoing 132 kV connection with Cannington;
  - As the load at Cannington grows the reliance on 330/132 kV transformer capacity at Southern Terminal also increases due to 132 kV connections between the sites. Rather than expand the transformer capacity at Southern Terminal consideration should be given to establishing a 330 kV bulk supply point at Cannington Terminal.

With consideration to the above influences on a preferred network strategy, the following options were considered. These options look to address the emerging constraints in the area and work towards delivering on the Strategic Network Objectives.

- Reinforcing the transfer capability from Southern Terminal to Cannington Terminal via rebuild of existing aged 132 kV infrastructure;
- Reinforcing the transfer capability from Southern Terminal to Kenwick Link and Cannington Terminal by stringing the second side of Kenwick Link and reinforcing the 132 kV connections between Kenwick Link and Cannington Terminal;
- Establishing a 330 kV switchyard at Cannington Terminal with 2 x 490MVA transformers (one of which is relocated from Kenwick Link) and reinforcement of Kenwick Link by stringing of the second circuit. This also involves 330kV cable works from Kenwick link to the new Cannington 330kV switchyard;
- Reinforcing supply to Cannington Terminal by stringing second side of the Southern Terminal to Guildford circuit as far as Cannington and turning into Cannington Terminal along with a 330 kV switchyard and 490 MVA transformer;
- Isolating the Cannington Terminal and Southern Terminal load areas altogether by establishing radialised substation rings off each terminal and demeshing over time. This also involves establishing a 330 kV switchyard at Cannington Terminal; and
- A combination of the above, including staging opportunities.

4.11.3.3 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

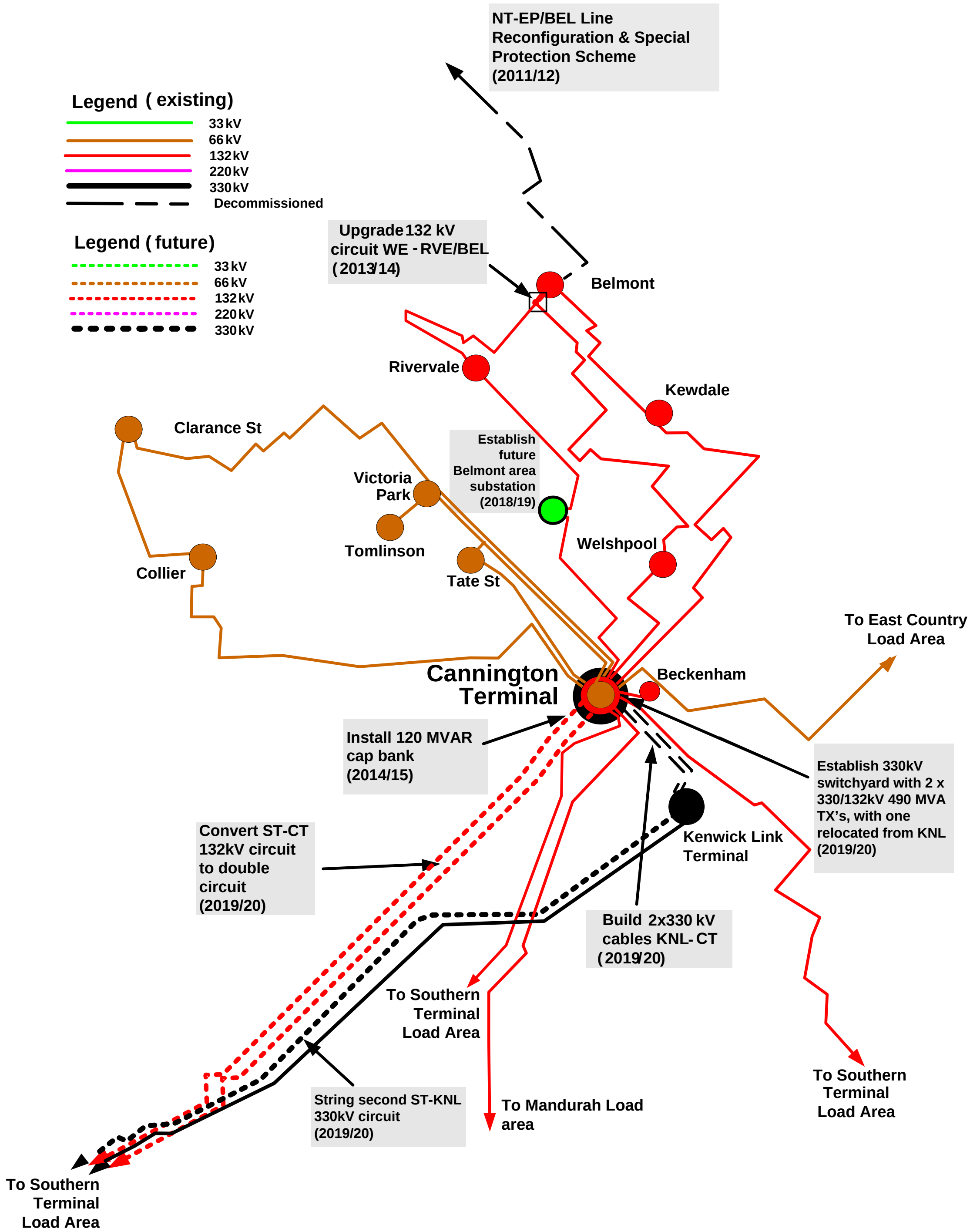

Figure 22: Cannington Load Area – preferred transmission solution

The specific projects planned for the Cannington Load Area over the next 10 years include:

- Open breaker at Belmont end of Belmont to Northern Terminal to East Perth Tee by summer 2011/12;
- Installation of a special protection scheme which closes the breaker at the Belmont end of the BEL-NT/EP Tee following a number of contingencies by summer 2012/13;

- Upgrade of a small section of line joining Belmont Substation with the Welshpool and Rivervale 132 kV circuit by summer 2013/14;
- Install a 120 MVAr Capacitor Bank at Cannington Terminal by summer 2014/15;
- Establish a new 132 kV substation in the area between Belmont and Cannington Terminal by summer 2018/19;
- Establish a 330 kV switchyard at Cannington Terminal with 2 x 490 MVA transformers (one of which is relocated from Kenwick Link), string the second side of the Southern Terminal to Kenwick Link 330 kV poles with 330kV conductor and build 2 330kV cable circuits from Kenwick Link Terminal to the new 330kV Cannington Terminal switchyard by summer 2019/20 (Kenwick Link would then become a 330kV overhead to underground transition site); and
- Convert ST-CT to double circuit using high temp conductor by summer 2019/20.

The preferred solution offers the following benefits:

- Adopts reinforcement strategies that move to radialise the Cannington Terminal and Southern Terminal load area away from one another to be supported by independent terminals. This will provide significant long term benefits by relieving the existing 132 kV sub-transmission system of through flows between terminals. It is not anticipated that these load areas will be completely de-meshed in this 10 year time frame, although network development in this period is working towards it;
- Uses low cost solutions to reconfigure the existing 132 kV network to free up Kenwick Link 330 kV poles of current 132 kV infrastructure. The reconfiguration attempts to maximise the use of existing 132 kV assets;
- Increases utilisation of the existing 330 kV network through reinforcement of the Kenwick Link from Southern Terminal through to Cannington Terminal. This is done be stringing the second circuit on the existing 330 kV poles and establishing a 330 kV switchyard at Cannington Terminal;
- Optimises asset replacement and network reinforcement strategies by rebuilding the existing aged 132 kV circuit between Southern Terminal and Cannington with higher capacity;
- Relieves transformer loading at Southern Terminal;
- Does not hinder the probable voltage migration of the Cannington 66 kV system to 132 kV; and
- Supports transmission supply needs of the Cannington Load Area for many years into the future by supporting installation of additional 330/132 kV transformation.

4.12 East Perth and CBD

4.12.1 Geographic load area

The East Perth and CBD Load Area incorporates the Perth Central Business District (CBD), the City of Subiaco and the town of Vincent.

4.12.1.1 Load area characteristics

Load in this area is concentrated in the densely populated areas of West Perth, East Perth and the CBD.

The majority of substations in the area are supplied directly from the East Perth Terminal and from Northern Terminal via Mt Lawley.

The current land use is a mixture of commercial, retail and residential and also supports a PTA owned substation used to supply rail infrastructure.

4.12.1.2 Demand

4.12.1.2.1 Historic growth rates

Since 2000 the East Perth and CBD Load Area has exhibited a steady growth of 12 MW / year.

4.12.1.2.2 Customers served

The total number of customers supplied in this load area is approximately 44,000. Commercial customers account for 7,750 connections while domestic customers make up more than 36,000 connections. Industrial customers represent just over 50 connections.

4.12.1.2.3 Projected growth rates

From 2011, the East Perth load area is forecast to grow at 9 MW / year over the next 10 years reaching a peak demand of 472 MW in 2021.

In this 10 year period, 4 block loads have been included in the forecast.

4.12.1.3 Generation

There is no notable generation capacity installed in the East Perth and CBD Load Area and none proposed across the 10 year horizon.

4.12.1.4 Current network

The following figure represents the existing transmission network within the East Perth and CBD Load Area.

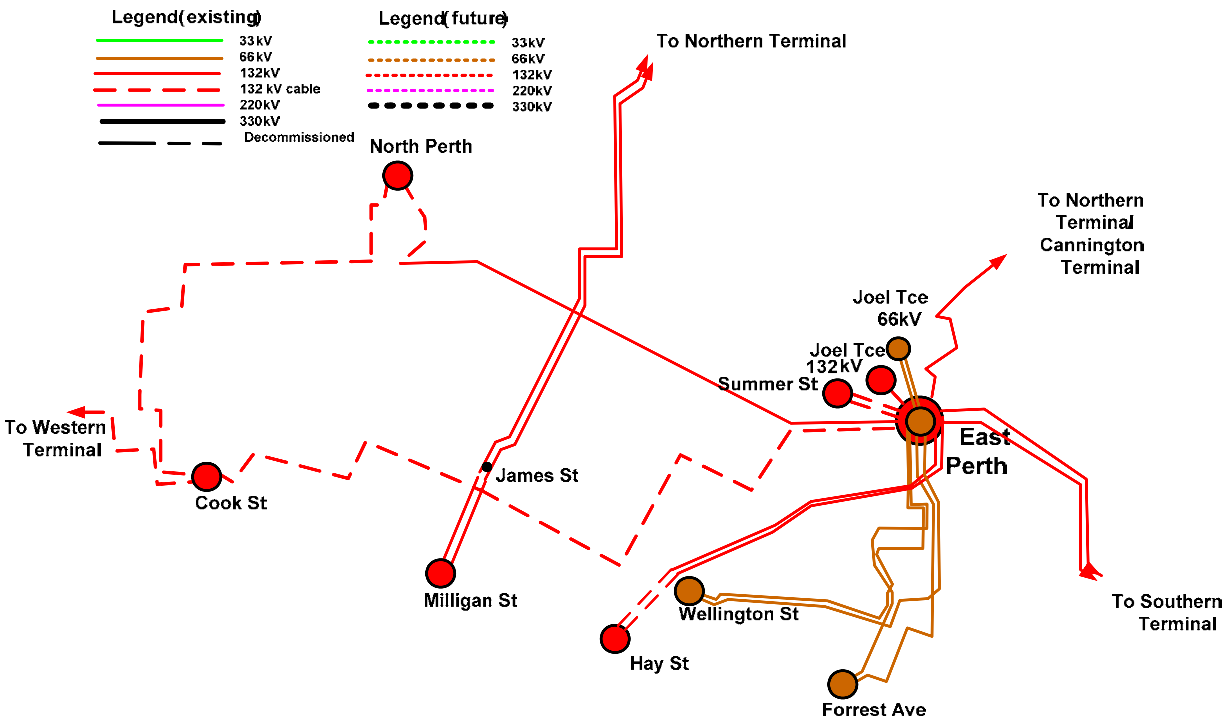

Figure 23: Transmission System – East Perth and CBD Load Area

4.12.1.4.1 Purpose (Relationship with other load areas)

The purpose of the network in this area is primarily to support the inner metropolitan load, including the CBD. Given the centralised high density nature of load, the area has a heavy reliance on supply from neighbouring load areas including Southern Terminal, Northern Terminal and Cannington. A connection to Western Terminal Load Area via Cook St Substation also provides some support to the CBD under certain operating conditions.

The majority of substations within the East Perth and CBD Load Area are supplied from radial double circuit transmission network from either East Perth Terminal or Mt Lawley. As a result there is little opportunity on most circuits for through flows from the south of the load area to the north. Power transfer can, however, go from East Perth Terminal to Northern Terminal under lightly loaded conditions in the load area, particularly with minimal generation operating in the north of the SWIS.

4.12.1.4.2 General considerations

Construction of new transmission lines in the load area is made difficult due to limited access points across the Swan River, service congestion and scarcity of available land. This translates to significant difficulties in planning new injection points and new substation connections.

Both new transmission lines and zone substations are subject to difficult environmental and community approvals and incur significant expenditure associated with construction and planning. As such, reinforcements in the load area inherently incur higher project costs.

There is also an aging 66 kV network which supplies much of East Perth which has the potential for considerable growth. The 66 kV infrastructure in East Perth provides a major point of consideration for any substation or transmission reinforcement within the area.

There are a number of large block loads enquiring about connection into the load area. These connections can be very responsive to the current economic climate and this, coupled with the risks associated with funding such ventures, can make these connections somewhat volatile. This in turn drives difficult load forecasting decisions which can result in load forecasts that fluctuate considerably from year to year. This presents challenges for transmission planning as the optimum timing and size of new augmentations, as well as the risk associated with these projects can be hard to substantiate.

11 kV distribution circuit capacity in the CBD is also becoming an issue, and as a result, the distribution transfer capacity which is used to support the CBD substations is approaching its limits.

4.12.1.4.3 Substations

There are seven substations in the East Perth and CBD Load Area which are owned and operated by Western Power.

- Cook St
- Forrest Avenue
- Hay St
- Milligan St
- Joel Terrace
- North Perth
- Wellington St

All Western Power substations in the load area are subject to peak demand conditions during the summer months.

4.12.1.4.4 Transmission lines

The network in the East Perth and CBD Load Area is largely centred around the East Perth Terminal, which has a primary purpose to deliver power to substations within the Perth inner metropolitan region including the CBD. It acts almost entirely as a load terminal and supplies a total of seven zone substations via 132 kV and 66 kV sub-transmission networks.

Two 132 kV cables cross the Swan River via the Graham Farmer freeway to connect Southern Terminal and East Perth load areas. The cables transition to an overhead double circuit in Burswood and continue south to Southern Terminal. There is also one 132 kV transmission line/cable between Western Terminal and Cooks St Substation.

A transmission line from Belmont Substation forms a Tee line with a 132 kV circuit connecting East Perth to Northern Terminal and two

132 kV circuits from Northern Terminal also support the CBD substations via Mount Lawley.

The transmission lines in this load area are generally designed to meet the N-1 capacity criteria with the exception of supply capacity into Hay St and Milligan St, which is designed to the CBD criteria. East Perth Terminal is subject to the N-1-1 criteria at 80% peak load.

4.12.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.12.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the East Perth and CBD Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Cook St (CK)

Cook St Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2014/15.

Forrest Avenue (F)

Forrest Avenue Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Milligan St (MIL)

Milligan St Substation has two transformers and operates under the CBD criteria. Load forecasts indicate that the N-1 capacity of this substation is exceeded around summer 2015/16, however low cost upgrades to metering equipment extend this capacity beyond the 10 year horizon.

Under N-2 conditions, forecasts indicate that capacity within the CBD will be exceeded around summer 2016/17.

Hay St (HAY)

Hay St Substation has two transformers and operates under the CBD criteria. Load forecasts indicate the N-1 and N-2 capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Joel Terrace (JT)

Joel Terrace Substation has three transformers and operates under the N-1 criteria. The substation was recently expanded with the installation of a third transformer in summer 2010/11. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

North Perth (NP)

North Perth Substation has three transformers and operates under the NCR criteria. The substation was recently reinforced with the third transformer in summer 2010/11. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Wellington St (W)

Wellington St Substation has two transformers and operates under the N-1 criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2014/15.

4.12.2.2 Fault levels

Although the East Perth 132 kV fault level is well below the 40 kA design standard of new 132 kV terminal yards in the Western Power Network, there is still a subset of older switchgear components which are approaching fault level limits.

All other fault levels at zone substations within the load area level remain within switchgear ratings. However, any new 132 kV connections at Hay St or Milligan St will necessitate minor switchgear fault up-rates.

4.12.2.3 Thermal limits

A number of thermal overloads impact the reliability of supply to the East Perth and CBD Load Area following various contingencies. These include overloads on 132 kV network from:

- Southern Terminal to East Perth Terminal for loss of a parallel circuit, as well as loss of a 132 kV circuit between South Fremantle and Amherst;
- South Fremantle Terminal to Amherst following loss of Southern Terminal to East Perth Terminal circuits; and
- Western Terminal to Cook St Substation for the loss of the South Fremantle to Amherst 132 kV circuit whilst the Northern Terminal to Western Terminal line is undergoing maintenance (N-1-1), or vice-versa, at 80% system loading.

These N-1 and N-1-1 overloads are evident from around summer 2013/14 and 2015/16 respectively.

For more information on these N-1-1 related issues please refer to the Western Terminal Load Area.

4.12.2.4 Voltage limits

Due to ongoing load growth in the area it is projected that there will be deficit in reactive reserve at East Perth Terminal around summer 2014/15. Furthermore the transfer of reactive power between sites exacerbates line loading issues.

4.12.2.5 Asset condition

The transformers at all East Perth 66 kV substations are approximately 40 years old.

Joel Terrace has recently completed the first stage of a 132 kV upgrade in preparation for the eventual retirement of the 66 kV assets. The East Perth and CBD Load Area sub-transmission networks also contain a large percentage of circuits which are now in excess of 40 years of age

The aging 66 kV infrastructure provides a major point of consideration when assessing future substation reinforcements in the area. New substations need to take into account the possibility that the load currently supplied via the 66 kV network may need to be transferred to adjacent substations in the medium term.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.12.3 Network development within a 10 year period

4.12.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.12.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.12.3.2 Preferred substation solutions

- Transfer of load from Forrest Avenue Substation to Milligan St or Hay St Substation by summer 2013/14. This defers the need for a significant Forrest Avenue Substation reinforcement outside of the 10 year horizon. However this in turn advances the need for a future substation within the area (potentially at the existing James St site or a rebuild of the existing Wellington St Substation) to support ongoing load growth in the area;
- Install additional 80 MVA transformer at Cook St Substation by summer 2014/15; and
- Establish a new substation (potentially at the existing James St site or a rebuild of the existing Wellington St Substation) around summer 2016/17. Load to be transferred from Milligan St and Hay St substations as required to relieve existing N-2 limitations. The new substation will provide additional transformer capacity to support new growth as a result of

expected redevelopment in the Northbridge and CBD areas. The substation would additionally facilitate replacement of 11kV switchgear at Milligan St Substation and provide additional distribution circuit capacity necessary to connect new distribution feeders in the area. It also aids in the eventual retirement/upgrading of the East Perth 66 kV network, by providing additional transformer capacity in the region to accept load transfers from aging substations (such as Forrest Avenue and Wellington St for example).

There have been enquiries for large block load connections as part of the Perth Waterfront development along the foreshore. Depending on the size and timing of the development, an additional substation reinforcement may be required. During the formulation of the 2010 Network Development Plans, it was considered that the project was not sufficiently advanced to include it in the substation capacity expansion plan. There are a number of options to accommodate the initial load at Perth Waterfront should the development proceed quickly. Connection to the Cook St Substation, Hay or Milligan St Substations are potentially viable solutions.

4.12.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network, as well as existing fault level issues. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term (10-25 years) and include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

Under normal operating conditions, the majority of the East Perth and CBD Load Area is supplied by generation sources located in the southern parts of the network, resulting in high loadings on transmission lines from Southern Terminal and the sub-transmission network within the Cannington Load Area. As part of shorter term plans to address the emerging issues in the Cannington sub-transmission network the 132 kV Tee section of line joining Belmont Substation to East Perth Terminal and Northern Terminal is to be operated normally out of service.

As a result of operating this Tee section normally out of service, the power transfer on the remaining 132 kV lines supplying the East Perth and CBD Load Area from the south is increased. Whilst loading is satisfactory under pre-contingent conditions across a 10 year horizon, thermal overloads are evident following loss of other parallel circuits supplying the area from the south.

Options were initially developed to encourage improved load sharing on 132 kV circuits into the area from the north by increasing power transfer from Northern Terminal. Of the options assessed, it was found that it was difficult to decrease the relative 132 kV network impedance north of East Perth Terminal to a point where there was sufficient power flowing from Northern Terminal to significantly relieve loadings on southerly circuits.

Options that reinforced the transmission lines from the south demonstrated significant deliverability risk due to likely consenting difficulty and also reflected high investment costs. In addition these options would require a significant extension of the East Perth 132 kV terminal yard, possible river crossings, and would also result in an increase in the 132 kV fault level at East Perth Terminal.

In order to defer more costly reinforcements a special protection scheme is proposed which places the Tee section of line joining Belmont Substation to East Perth Terminal and Northern Terminal back into service following various contingencies. Studies indicated this presents a viable low cost option to address the issues. In the medium to long term (10+ years) studies indicate that additional transfer capacity into the load area may be required as this scheme presents risk to system security given some transmission elements become heavily overloaded. There are a number of options for reinforcement, including potential 330 kV injections, as well as additional 132 kV circuits.

With increased generation in the north of the SWIS the load sharing on 132 kV circuits supplying the East Perth and CBD Load Area is improved and can defer the need for reinforcing into the area. With uncertainty surrounding location of future generation in the SWIS it was recognised that the special protection scheme offers considerable option value.

Under certain N-1-1 conditions involving loss of the 132 kV network supplying Western Terminal, the East Perth and CBD Load Area can also be required to support Western Terminal via Cook St Substation. Under these operating conditions, this cable is subject to high loadings.

4.12.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

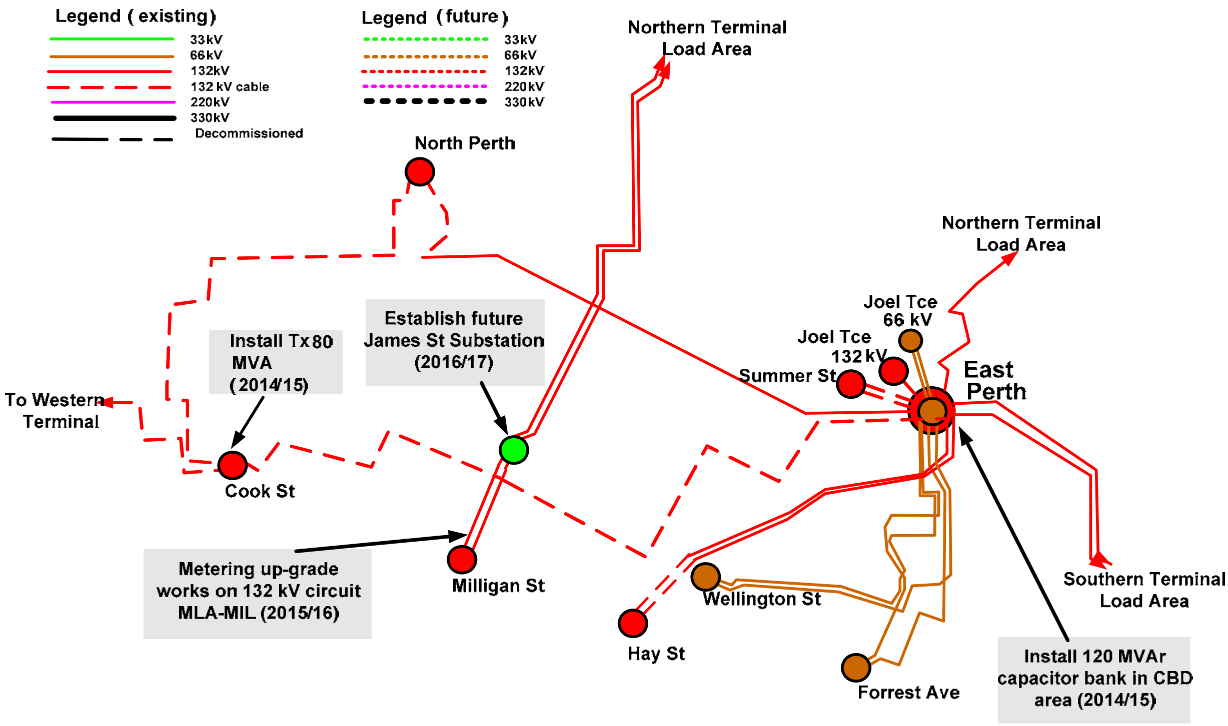

Figure 24: East Perth/ CBD Load Area – preferred transmission solutions

The specific projects planned for the East Perth and CBD Load Area over the next 10 years include:

- Open breaker at Belmont end of Belmont to Northern Terminal/East Perth Tee by summer 2011/12 (see also Cannington Load Area);
- Install a 120 MVAr Capacitor Bank in CBD area by summer 2014/15;
- Install an additional 80 MVA transformer at Cook St Substation by summer 2014/15;
- Metering upgrade works on the Mount Lawley-Milligan 132 kV circuits by summer 2015/16; and
- Construct new double circuit 132 kV cable works to connect new Wellington St or James St Substation by summer 2016/17. Figure 24 shows a new substation site at James St Substation, which requires less 132kV cable works than a Wellington St alternative (which is more likely to be connected to East Perth Terminal).

The preferred solution offers the following benefits:

- Eliminates power flows into East Perth from Cannington which causes a number of thermal overloads in the Cannington Load Area (see Cannington Load Area for more information);
- Reinforces the role of the 132 kV bulk transmission network between East Perth, Southern Terminal and Northern Terminal as the preferred path for power transfers into the East Perth and CBD Load Area;

- Reduces the East Perth 132 kV fault level, deferring the need for fault uprates on 132 kV switchgear;
- The new substation site within the load area:
    - provides reliable supply to incremental and larger block loads in the CBD over the medium to long term. These include Northbridge and Perth Waterfront, among others. This instils confidence in large customers in the area that their requirements can be satisfied whilst minimising delivery risk;
    - supports the need for extended and complex asset replacement requirements at existing substations in the area by providing transformer capacity to accept load transfers;
    - reduces the need for complicated and costly distribution switchboard expansion at existing sites to allow them to accommodate additional feeders;
    - provides options for voltage migration from 11kV to 22 kV at the distribution level and opportunity for use of improved cable ducting technology;
    - provides option value for future expansion of transmission network to the area, including possible 330 kV injection; and
    - supports progressive retirement/upgrading of the aging 66 kV network and associated substations via providing transformer capacity to accept load transfers beyond the 10 year horizon.

4.13 Guildford

4.13.1 Geographic load area

The Guildford Load Area supplies the area bound by Perth Airport in the west, Midland area to the north and Kalamunda to the south. The area is a likely development area given a large amount of undeveloped land within reasonable proximity to the city.

4.13.1.1 Load area characteristics

The load area supplies a broad mix of load types ranging from industrial, commercial, residential to semi-rural consumers.

As with the Cannington Load Area urban consolidation and major development projects, many of which are expected to be located within the confines of the rivers precincts will be the principal drivers of domestic load growth.

4.13.1.2 Demand

4.13.1.2.1 Historic growth rates

Since 2000 the Guildford Load Area has exhibited a steady growth of 7 MW / year.

4.13.1.2.2 Customers served

The number of customers supplied in this load area is approximately 40,000. Commercial customers account for almost 2,700 connections. Domestic customers make up almost 37,000 connections and farming and industrial customers total less than 200 connections.

4.13.1.2.3 Projected growth rates

From 2011, the Guildford Load Area is forecast to grow at 7 MW / year over the next 10 years reaching a peak demand of 246 MW in 2021.

In this 10 year period, 7 block loads have been included in the forecast.

4.13.1.3 Generation

There is no notable generation connected within the Guildford Load Area and no forecast generation across a 10 year horizon.

4.13.1.4 Current network

The following figure represents the existing transmission network within the Guildford Load Area.

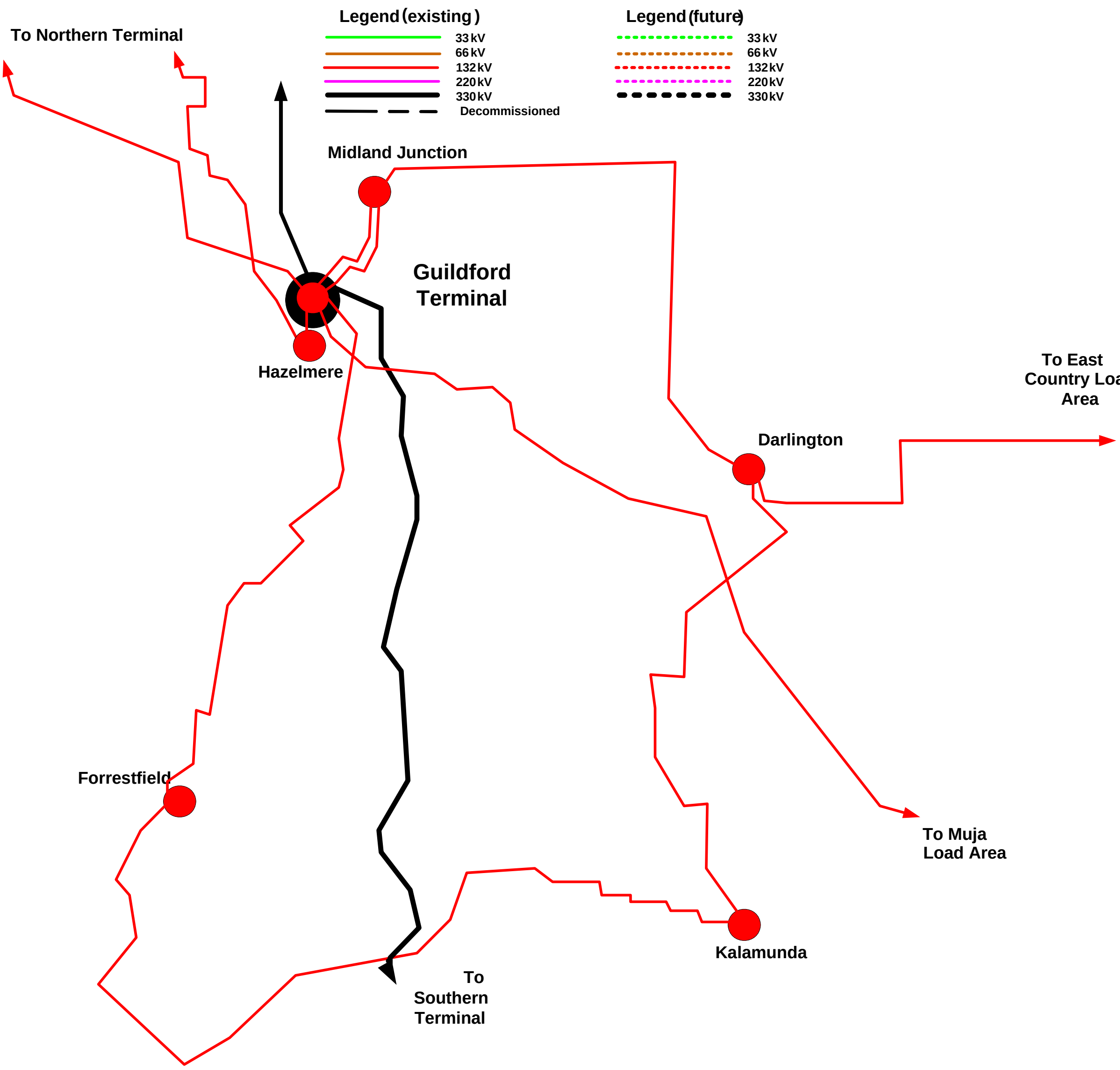

Figure 25: Transmission System – Guildford Load Area

4.13.1.4.1 Purpose (Relationship with other load areas)

The network within Guildford Load Area serves the primary purpose of supplying substations connected in the 132 kV sub-transmission networks extending from Guildford Terminal. 132 kV networks connect Guildford Terminal to neighbouring load areas of Northern Terminal, Muja and East Country. Guildford Terminal provides a strong 330 kV supply point to the load area with 330 kV connections to Southern Terminal and Northern Terminal.

4.13.1.4.2 General considerations

At present there is a double circuit 330 kV line between Guildford Terminal and Northern Terminal, which is currently operated at 132 kV on one circuit. Operation at 132 kV defers the need for further 330/132 kV transformation capacity at Northern Terminal by providing an additional 132 kV supply, as well as providing support for N-1-1 conditions. Whist these benefits are clear operation at 132 kV also increases loading on the Guildford Terminal 330/132 kV transformer and reduces utilisation at the 330 kV level between Northern and Guildford Terminals, along with increased loss. These issues are manageable within the study period without further investment although it is anticipated that within 15 years it will be economic to operate both circuits at 330 kV at which time two transformers may be required at Guildford Terminal

Due to its proximity to the airport special consideration must be given to transmission tower structures

4.13.1.4.3 Substations

In addition to Guildford Terminal there are five substations in the Guildford Load Area which owned and operated by Western Power. These include:

- Hazelmere
- Midland Junction
- Kalamunda
- Darlington
- Forrestfield

All Western Power substations in the load area are subject to peak demand conditions during the summer months.

4.13.1.4.4 Transmission lines

The transmission network in this area is focused around Guildford Terminal, which is connected to other major terminals including Northern and Southern Terminals, by 330 kV and 132 kV network.

The 330 kV and 132 kV bus sections within Guildford Terminal are connected via a single 490 MVA transformer which facilitates the bulk of supply to the surrounding substations. Following an outage of this transformer Guildford relies on support from Northern Terminal and other 132 kV injections from neighbouring load areas.

A 132 kV sub-transmission system extends south from Guildford Terminal in a ring supplying Forrestfield, Kalamunda, Darlington and Midland Junction substations. A 330 kV circuit, currently operated at 132 kV, connects Guildford Terminal and Northern Terminal and under most system conditions provides support to the Northern Terminal Load Area. 132 kV sub-transmission systems extend east from Darlington substation to Northam in the neighbouring East Country Load Area as well as from Guildford Terminal to Wells Terminal in the Muja Load Area.

The transmission lines in this load area are generally designed to meet the N-1 Capacity criteria. Guildford Terminal is subject to the N-1-1 criteria at 80% peak load.

4.13.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.13.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Guildford Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Guildford Terminal

There are no projected shortfalls in 330/132 kV transformation capacity at Guildford Terminal within a 10 year horizon.

Forrestfield (FFD)

Forrestfield Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Kalamunda (K)

Kalamunda Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Darlington (D)

Darlington Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Midland Junction (MJ)

Midland Junction Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Hazelmere (HAZ)

Hazelmere Substation has one transformer and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

4.13.2.2 Fault levels

There are no notable fault level issues in the Guildford Load Area forecast to arise across the 10 year horizon.

4.13.2.3 Thermal limits

A small number of thermal overloads emerge towards the end of the 10 year horizon although the severity of these does not warrant significant network augmentation. These include high loading conditions on the:

- Guildford to Forrestfield circuit following loss of the Darlington to Midland Junction circuit; and
- Guildford 330/132 kV transformer following outage of two Northern Terminal 330/132 kV transformers at 80% of peak load.

Western Power has received a number of connection enquiries for new block loads around the airport area. The need and necessary timing to address the emerging issues on the Guildford to Forrestfield circuit is very dependent on how much of this load materialises.

4.13.2.4 Voltage limits

Given the relative close proximity of the 132 kV sub-transmission network to the Guildford 330 kV Terminal, as well as the 132 kV connections to Northern Terminal, voltage stability is currently not an issue. As load grows, however, the need for reactive compensation increases and post contingent voltage levels on the 132 kV network begin to fall below minimum acceptable levels. Furthermore the transfer of reactive power between sites exacerbates line loading issues. It is projected that a reactive reserve deficit is likely around summer 2017/18.

4.13.2.5 Asset condition

There are no notable age related issues with respect to the transmission network in this area.

4.13.3 Network Development within a 10 year period

4.13.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.13.2.1 a number of augmentations are required including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.13.3.2 Preferred substation solutions

- Transfer of load from Midland Junction Substation to Hazelmere Substation by summer 2012/13;
- Install additional 33MVA transformer at Hazelmere Substation by summer 2014/15; and

- Replace existing transformer at Midland Junction with 33MVA transformer by summer 2014/15.

4.13.3.3 Transmission reinforcement

It is anticipated that with the present rates of load growth the transmission network in the Guildford Load Area should not require any significant augmentation within the 10 year horizon. To address the emerging reactive reserve issues Western Power considered placement and sizing of capacitor banks at a number of locations.

4.13.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

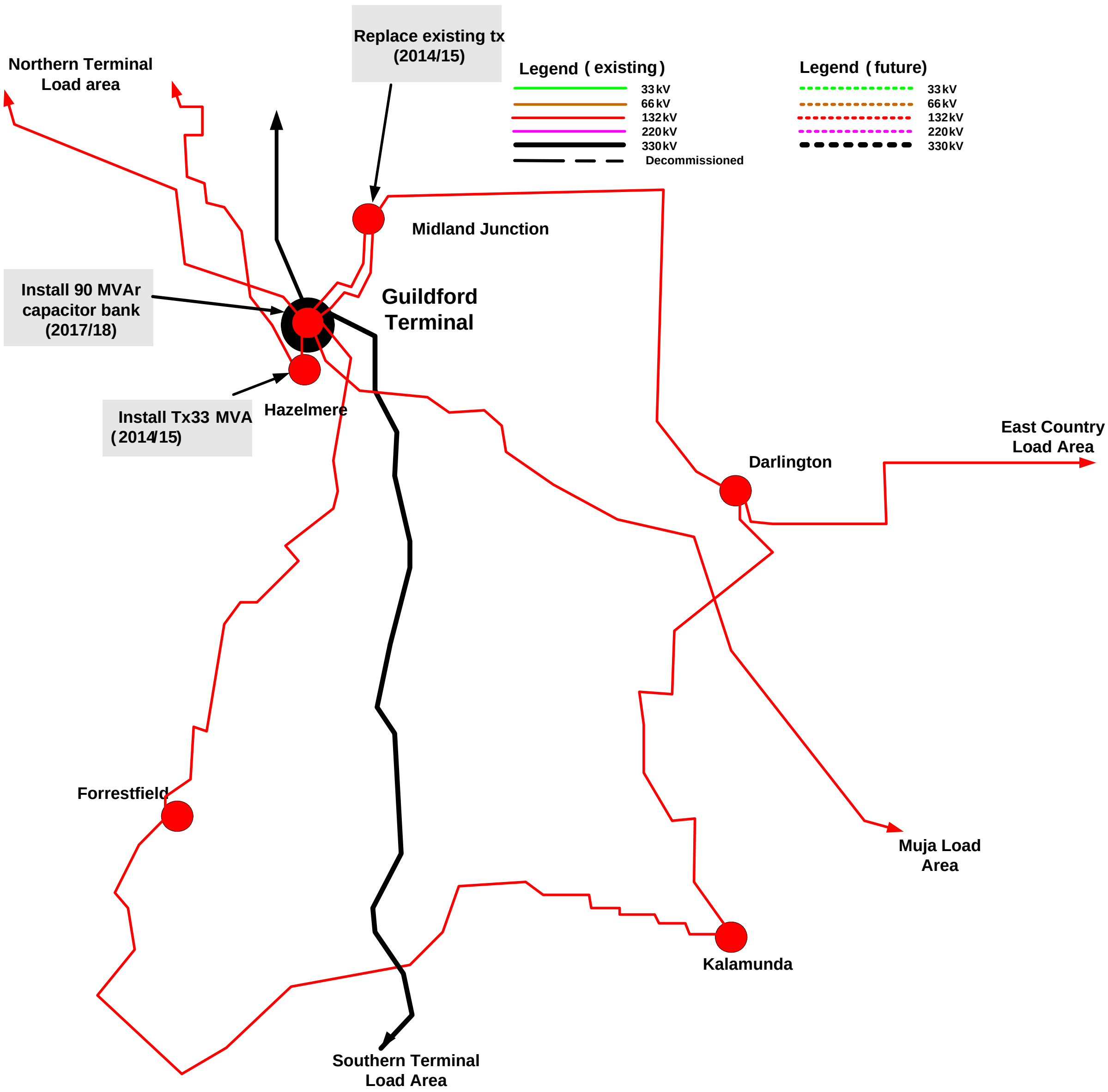

Figure 26: Guildford Load Area – preferred transmission solution

The specific projects planned for the Guildford Load Area over the next 10 years include the installation of a 90 MVAr Capacitor Bank at Guildford Terminal by summer 017/18.

The preferred solution offers voltage regulation benefits to substations within the Guildford area, as well as further east to Northam in the East Country Load Area.

4.14 Neerabup Terminal

4.14.1 Geographic load area

The Neerabup Load Area covers the northern-most part of the Perth Metropolitan region, from Padbury and West Swan in the south to Yanchep in the north, and Muchea in the east.

4.14.1.1 Load area characteristics

In previous years Western Power has encapsulated the Neerabup Load Area within the Northern Terminal Load Area. It is anticipated that network development over the 10 year horizon will move to electrically isolate Neerabup and Northern Terminal at the 132 kV sub-transmission level, creating two distinct load areas fed from 330 kV terminals. Western Power adopted this new load area in 2011 for this reason.

The area contains a variety of loads from commercial, light industrial, residential and semi-rural. Parts of the area are sparsely populated at present although rapid development in the northern suburbs is expected to continue, with intensive development likely in the medium to long term.

4.14.1.2 Demand

4.14.1.2.1 Historic growth rates

Since 2000 the Neerabup Load area has exhibited a steady growth of 28 MW / year.

4.14.1.2.2 Customers served

The number of customers supplied in this load area is approximately 98,300. Commercial customers account for almost 7,500 connections and domestic customers make up more than 90,000 connections. Combined, farming and industrial customers, total almost 400 connections.

4.14.1.2.3 Projected growth rates

From 2011, the Neerabup Load Area is forecast to grow at 13 MW / year over the next 10 years reaching a peak demand of 623 MW in 2021.

In this 10 year period, 24 block loads have been included in the forecast.

4.14.1.3 Generation

The Neerabup Load Area is supplied by a number of generation sources through 132 kV and 330 kV transmission lines, including peaking generation plant which is located near the Neerabup Terminal site.

Due to the availability of fuel resources, particularly gas, Western Power has received interest for new entrant gas fired generation developments. Some interest has also been received from renewable energy sources, such as biomass facilities, which is reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

4.14.1.4 Current network

The following figure represents the existing transmission network within the Neerabup Load Area.

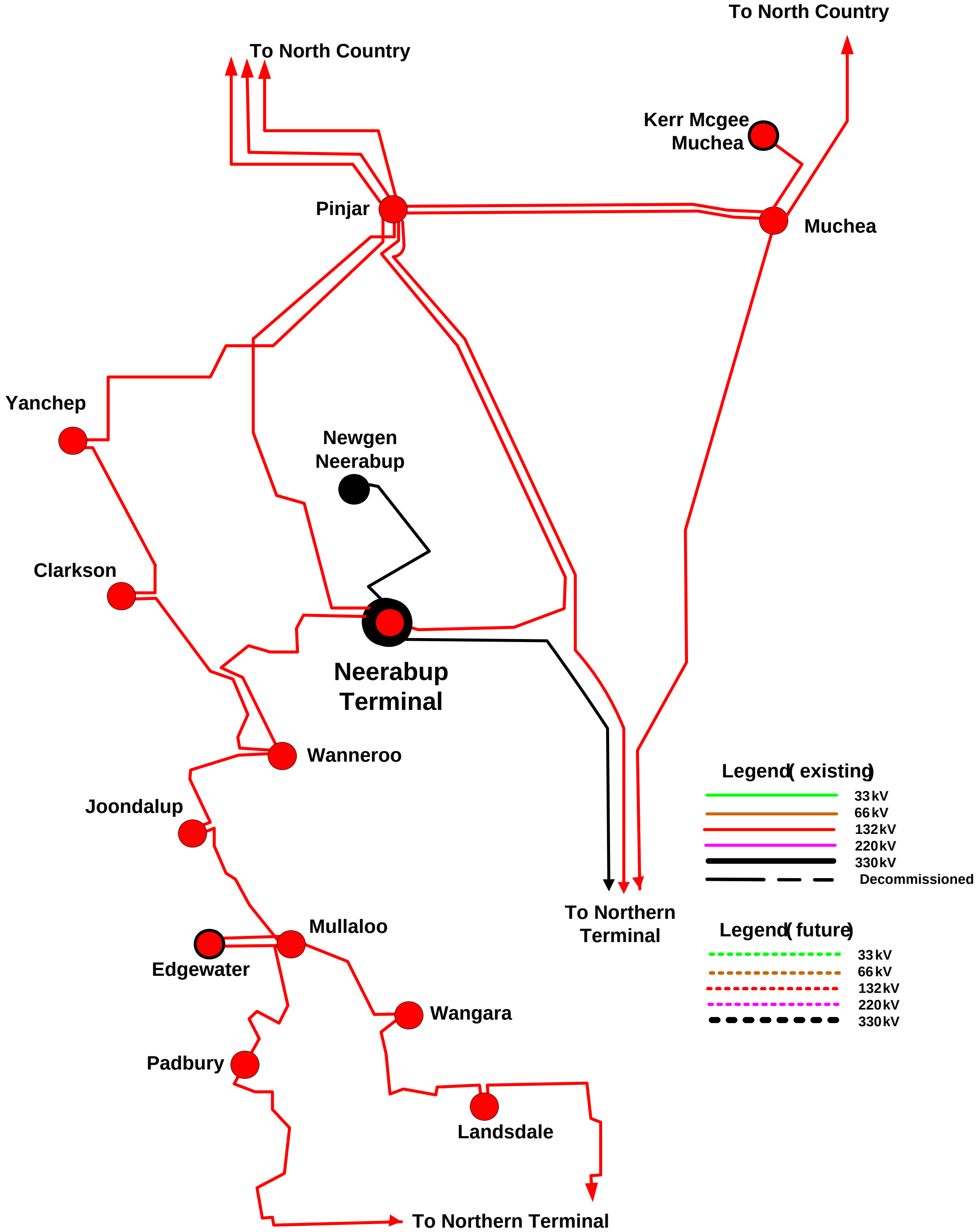

Figure 27: Transmission System – Neerabup Load Area

4.14.1.4.1 Purpose (Relationship with other load areas)

The network in the area is characterised by 330 kV ties with generation centres in the south of the Western Power Network (Muja and Kwinana areas via Northern Terminal), as well as numerous 132 kV sub-transmission connections with Northern Terminal and North Country. The network has evolved over time largely to support the continued high growth associated with urban development in the area, as well as around Northern Terminal.

Neerbup Terminal is the focus point of the load area and relies heavily on supply from neighbouring load areas, as well from local generation at 132 kV and 330 kV. The Neerabup Terminal is a strategically important terminal for the connection of the Mid West Energy Project as well as the future development of transmission infrastructure to the North Country Load Area.

4.14.1.4.2 General considerations

The network within Neerabup Load Area is highly meshed with the Northern Terminal and North Country Load Areas. This mesh can create considerable challenges as numerous contingencies within the areas can generate power system security problems under some operating conditions. The meshed network is also a key cause of high fault levels at Northern Terminal.

In the past development of the network within Neerabup and Northern Terminal Load Areas has generally followed a philosophy of retaining a meshed network. Whilst there are some benefits associated with this more recent longer term studies indicate that splitting the networks into two relatively isolated areas offers significant advantages. Optimising the timing of this split, along with the need to address shorter term transmission issues in the area is difficult, Furthermore rapid development of greenfield sites in the Neerabup load area presents development approval issues for new transmission infrastructure given associated lead times.

4.14.1.4.3 Substations

There are 10 substations in the Neerabup Load Area of which the following 9 are owned and operated by Western Power.

- Yanchep
- Muchea
- Wanneroo
- Clarkson
- Joondalup
- Mullaloo
- Padbury
- Wangara
- Landsdale

Each of these substations is subject to peak demand conditions in the summer months.

4.14.1.4.4 Transmission lines

The transmission network in this area is currently heavily meshed with Northern Terminal Load Area at the 132 kV level. A sub-transmission system extends south from Neerabup Terminal along the coast supplying a number of substations in the Northern metropolitan region.

A 132 kV system also extends North to Yanchep and onto North Country Load Area. There is also 132 kV network to the East connecting Muchea Substation with Henley Brook Substation, and Pinjar to Northern Terminal.

The 330 kV network extends south to Northern Terminal and will also extend north to Three Springs following completion of the Mid West Energy Project (Southern Section Stage 1).

Supply to the area comes from the 330 kV system via a single 490MVA transformer at Neerabup Terminal, as well as via 132 kV generation at Pinjar, and further north in the North Country Load Area. Given the meshed nature of Northern Terminal and Neerabup Load Areas these areas currently provide support to one another in different ways, depending on system conditions.

The transmission lines in this load area are generally designed to meet the N-1 criteria. Neerabup Terminal is subject to the N-1-1 criteria at 80% peak load.

4.14.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.14.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Neerabup Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Yanchep (YP)

Yanchep Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2017/18.

Muchea (MUC)

Muchea Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Wanneroo (WNO)

Wanneroo Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Clarkson (CKN)

Clarkson Substation has two transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Joondalup (JDP)

Joondalup Substation has one transformer and operates under the NCR criteria. Following installation of a second transformer by summer 2012/13 load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Mullaloo (MUL)

Mullaloo Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2012/13.

Padbury (PBY)

Padbury Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14.

Wangara (WGA)

Wangara Substation has one transformer and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Landsdale (LDE)

Landsdale Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2015/16.

4.14.2.2 Fault levels

There are no notable fault level issues in the Neerabup Load Area forecast to arise across the 10 year horizon.

4.14.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on:

- Joondalup to Wanneroo 132 kV circuit following loss of the Northern Terminal to Landsdale 132 kV circuit, Pinjar to Northern Terminal 132 kV circuit or Neerabup to Northern Terminal 330 kV circuit;

- Pinjar to Yanchep 132 kV circuit following loss of Neerabup to Wanneroo 132 kV circuit; and
- Mullaloo to Joondalup 132 kV circuit following loss of Northern Terminal to Landsdale 132 kV or Pinjar to Northern Terminal 132 kV circuits.

These overloads are evident from around 2015 onwards.

4.14.2.4 Voltage limits

Due to the localised generation in the area, heavily meshed configuration and interconnection between the 330 kV and 132 kV networks, no voltage instability issues are apparent across the 10 year horizon.

4.14.2.5 Asset condition

There are no notable issues with respect to aged assets in the Neerabup Load Area.

4.14.3 Network development within a 10 year period

4.14.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.14.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.14.3.2 Preferred substation solutions

- Transfer of load from Wanneroo Substation to Joondalup Substation by summer 2012/13. This brings forward the timing which Joondalup Substation requires augmentation to around summer 2014/15;
- Install a second 33 MVA transformer at Joondalup Substation by summer 2012/13 [31] and a third 33MVA transformer by summer 2014/15;
- Transfer of load from Mullaloo Substation to Wangara Substation by around summer 2012/13 and from Landsdale Substation to Wangara Substation by around summer 2014/15. This brings forward the timing which Wangara Substation requires augmentation to around summer 2014/15;
- Install additional 33MVA transformer at Wangara Substation by summer 2014/15;
- Transfer of load from Wanneroo Substation to Clarkson Substation by summer 2015/16. This brings forward the timing

[31] This is a committed project that will commence during the AA2 period and be concluded/commissioned during the AA3 period; as such funding has been budgeted in both Access Arrangements.

which Clarkson Substation requires augmentation to around summer 2015/16;

- Install additional 33MVA transformer at Clarkson Substation by summer 2015/16;
- Install additional 33MVA transformer at Yanchep Substation by summer 2017/18; and
- Establish a new substation (Wanneroo East) by around summer 2018/19. Load to be transferred from Joondalup and Wanneroo Substations to the new site to defer any further augmentation at Joondalup and Wanneroo Substations outside a 10 year horizon.

4.14.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network within Neerabup Load Area. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term (10-25 years) and also have consideration to the emerging limitations in the Northern Terminal Load Area. Options include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

To ensure efficient use of the existing 330 kV bulk transmission system and reduce underlying congestion at the 132 kV level and lower fault levels at Northern Terminal, reconfiguration of the network was found to be the preferred solution. In particular reconfiguration to isolate Neerabup and Northern Terminal Load areas across the 132 kV network was most attractive.

As part of developing a strategy to reconfigure the network Western Power considered the longer term supply needs in the area. In particular the following aspects were key influences on the preferred solution;

- Operational flexibility and controllability;
    - o The meshed nature of the Northern Terminal and Neerabup load areas can create power flow control difficulties following contingencies. This can result in suboptimal generation dispatch (in preparation for possible contingencies), or conditions where significant changes in generation may be required after a contingency. Future network reinforcement in the area should look to alleviate generation constraints and

where necessary minimise necessary post contingent response by System Management in accordance with an N-1 planning criteria.
  - Reconfiguration of the network should not degrade its reliability or ability to schedule planned outages.
  - As part of reconfiguration if lines are operated normally out of service options to use these lines to assist with power system security and outage management should be favoured.

- Staging development to optimise asset utilisation;
  - It is important to ensure that network reinforcement is staged to ensure deliverability as well as optimise use of existing infrastructure. It is not proposed that the Neerabup and Northern Terminal Load areas will be completely radialised within the 10 year horizon, although intermediate network development will be moving in that direction;

- The Neerabup Load Area is growing rapidly and load sharing between Neerabup Terminal and Northern Terminal is poor;
  - Reconfiguration strategy should consider the benefits of balancing load across these terminals by optimising the allocation of substation loads to each network. There are a number of ways this can be done and the most economic long term solution must be deployed. Improving load balancing on these sites offloads an already heavily congested Northern Terminal, reduces fault level at Northern Terminal, improves utilisation of the bulk 330 kV network and is likely to improve overall system losses.

- Ability for existing and future generation to operate unconstrained under various dispatch conditions [32];
  - Under current network configuration constraints on generation at Pinjar and Neerabup are required to prevent overload under some system conditions. This is due to the meshed nature of the networks and ability for through flows between Neerabup and Northern Terminal 132 kV networks. Reconfiguration to form radialised load areas will mitigate this congestion and subsequent generation constraints.

- Maximising use of existing single circuit assets;
  - The bulk of transmission assets in the Neerabup and Northern Terminal load areas are of single circuit construction. As a result increasing their capacity presents considerable challenges when looking to maintain supply reliability. Alternatively new corridors are required, which also presents consenting issues. Reconfiguration of the network should attempt to

[32] Whilst studies were performed using merit order dispatch, consideration was given to sizing augmentations to allow for unconstrained operation under various dispatch conditions.

optimise use of existing assets by eliminating through-flows;

- Strategic importance of Neerabup Terminal in longer term reinforcement needs between Northern Terminal and North Country Load Area.
  - Northern Terminal is a particularly strong 330 kV Terminal with connections to Guildford, Kwinana and Muja, as well as Neerabup. There is considerable spare capacity on these 330 kV circuits and a number of relatively low cost options exist to expand this capacity further. As the North Country Load Area evolves and its demand on the remainder of the Western Power Network network increases, there will be increased reliance on this infrastructure. Neerabup is situated between Northern Terminal and North Country and its development should be optimised to best utilise existing network capacity to the south as well as support strategic development of bulk transmission capacity further north. This will ultimately lead to improved generation sharing opportunities and a strong bulk power transfer capacity for the length of the Western Power Network.

With consideration to the above influences on a preferred network strategy a number of reconfiguration options were considered. These options look to address the emerging constraints in the area, defer costly investment and work towards delivering on the Strategic Network Objectives.

4.14.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

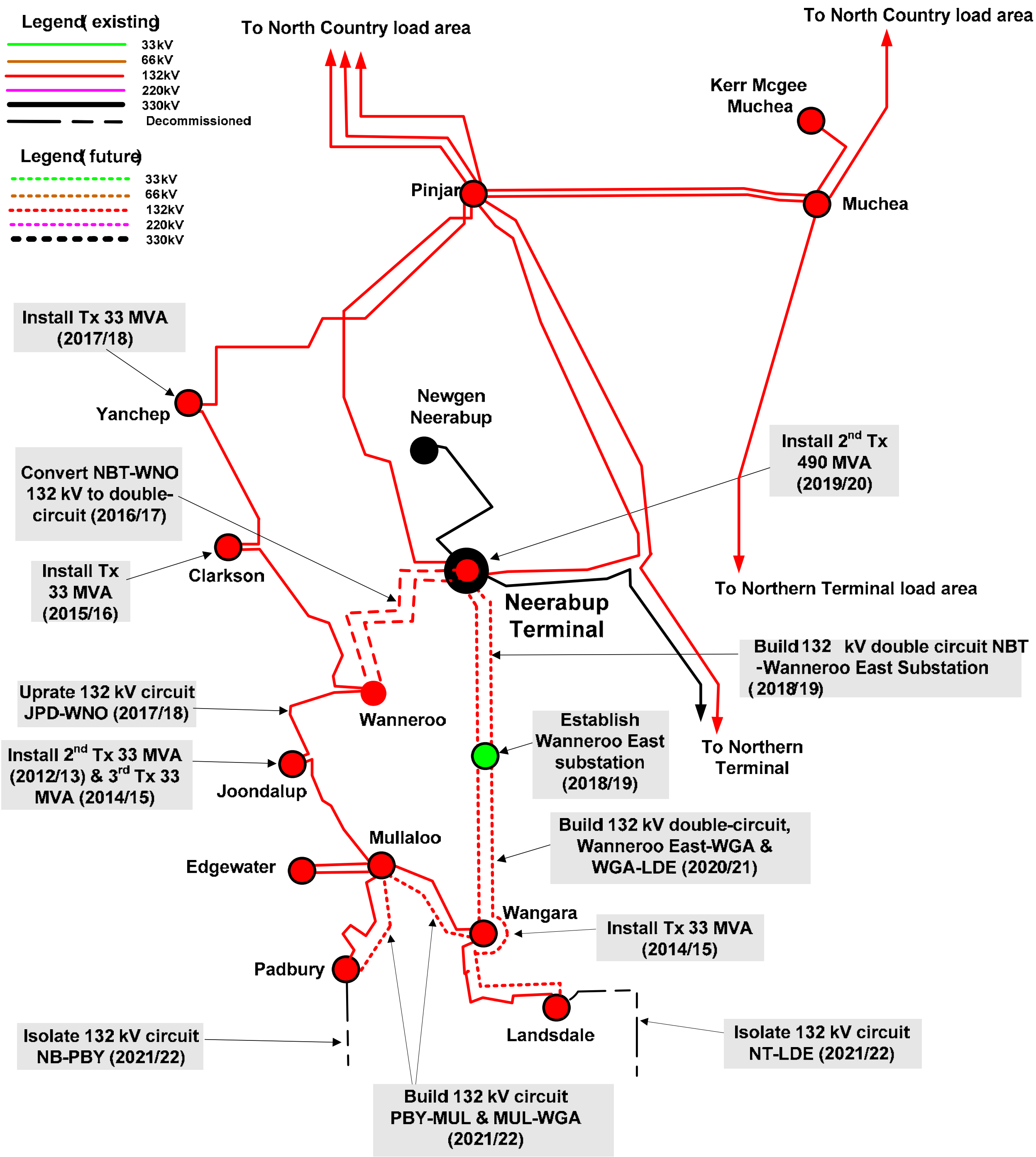

Figure 28: Neerabup Load Area – preferred transmission solutions

The specific projects planned for the Neerabup Load Area over the next 10 years include:

- Convert Neerabup to Wanneroo 132 kV double circuit bonded conductor to double circuit by summer 2016/17;
- Uprate Joondalup to Wanneroo 132 kV circuit with higher capacity conductor by summer 2017/18;

- Installation of a temporary special protection scheme that isolates the Mullaloo to Padbury 132 kV circuit following loss of the Northern Terminal to Landsdale 132 kV circuit;
- Use of special protection schemes to control fault level issues at Northern Terminal and defer de-meshing of Northern Terminal and Neerabup Load Areas;
- Install double circuit 132 kV line from Neerabup Terminal to new Wanneroo East substation by summer 2018/19;
- Installation of 2nd 330/132 kV 490MVA transformer at Neerabup Terminal by summer 2019/20;
- Install double circuit 132 kV line from Wanneroo East Substation to Wangara and Landsdale substations by summer 2020/21;
- Radialise Neerabup and Northern Terminal 132 kV sub-transmission networks on the west coast around summer 2021/22 by:
  - isolating the Northern Terminal to Landsdale and North Beach to Padbury 132 kV circuits [33]; and
  - establishing a second 132 kV circuit from Padbury to Mullaloo and from Mullaloo to Wangara.

The preferred solution offers the following benefits:

- Adopts reinforcement strategies that move to radialise the Neerabup and Northern Terminal load area away from one another to be supported by independent terminals. This will provide significant long term benefits by relieving the existing 132 kV sub-transmission system of through flows between terminals;
- Increases utilisation of the existing 330 kV network between Northern Terminal and Neerabup Terminal;
- Relieves transformer loading at Northern Terminal, deferring the need for additional transformation capacity in an already heavily congested site;
- Reduces fault levels at Northern Terminal considerably through use of low cost special protection schemes;
- Lower cost special protection control schemes provides for staging of network reinforcements and deferral of extensive augmentations;
- Radialising the 132 kV networks between Northern Terminal and Neerabup relieves constraints on generation dispatch and improves power flow controllability;

[33] These circuits may be continue to be used under planned outage conditions, or under non credible contingency events.

- Provides for the use of transmission lines that are operated normally out of service to be used to support system security in the event of unplanned outage events;
- Provides longer term transmission capacity to support rapid load growth in the Wanneroo East area, and further south near Wangara; and
- Supports longer term 330 kV bulk transmission strategies between North Country and the rest of the Western Power Network.

4.15 Northern Terminal

4.15.1 Geographic load area

The Northern Terminal Load Area covers the majority of the north Perth metropolitan area extending from the coast to Osborne Park and Morley in the south, North Beach and Arkana in the north and to West Swan in the east.

4.15.1.1 Load area characteristics

In previous years Western Power has encompassed the Neerabup Load Area within the Northern Terminal Load Area. It is anticipated that network development over the 10 year horizon will move to electrically isolate Neerabup and Northern Terminal at the 132 kV sub-transmission level, creating two distinct load areas fed from 330 kV terminals. Western Power adopted this new Neerabup Load Area in 2011 for this reason.

The area contains a variety of loads from commercial, light industrial and residential. Rapid development in the northern suburbs is expected to continue, with intensive development likely in the medium term.

It is expected that overall development will moderate as vacant land is utilised and load density increased. However, localised parts of the load area will be subjected to continued high growth levels of especially industrial or commercial development in Osborne Park area. In residential areas, it is anticipated land will be re-zoned including new multi-story building along Scarborough Beach to high density residential in the areas close to city centre.

4.15.1.2 Demand

4.15.1.2.1 Historic growth rates

Since 2000 the Northern Terminal Load Area has exhibited a steady growth of 7 MW / year.

4.15.1.2.2 Customers served

The number of customers supplied in this load area is approximately 148,000. Commercial customers account for more than 9,200 connections and domestic customers make up more than 138,000 connections. Together, farming and industrial customers total almost 200 connections.

4.15.1.2.3 Projected growth rates

From 2011, the Northern Terminal Load Area is forecast to grow at 24 MW / year over the next 10 years reaching a peak demand of 682 MW in 2021.

In this 10 year period, 2 block loads have been included in the forecast.

4.15.1.3 Generation

There is currently no notable generation in the Northern Terminal Load area, with supply provided from external load areas via the 330 kV and 132 kV networks.

Western Power has received some interest for new entrant generation developments in the Northern Terminal Load Area including renewable energy sources. This is reflected in the forward looking generation scenarios used as part of the 10 year TNDP.

4.15.1.4 Current network

The following figure represents the existing transmission network within the Northern Terminal Load Area.

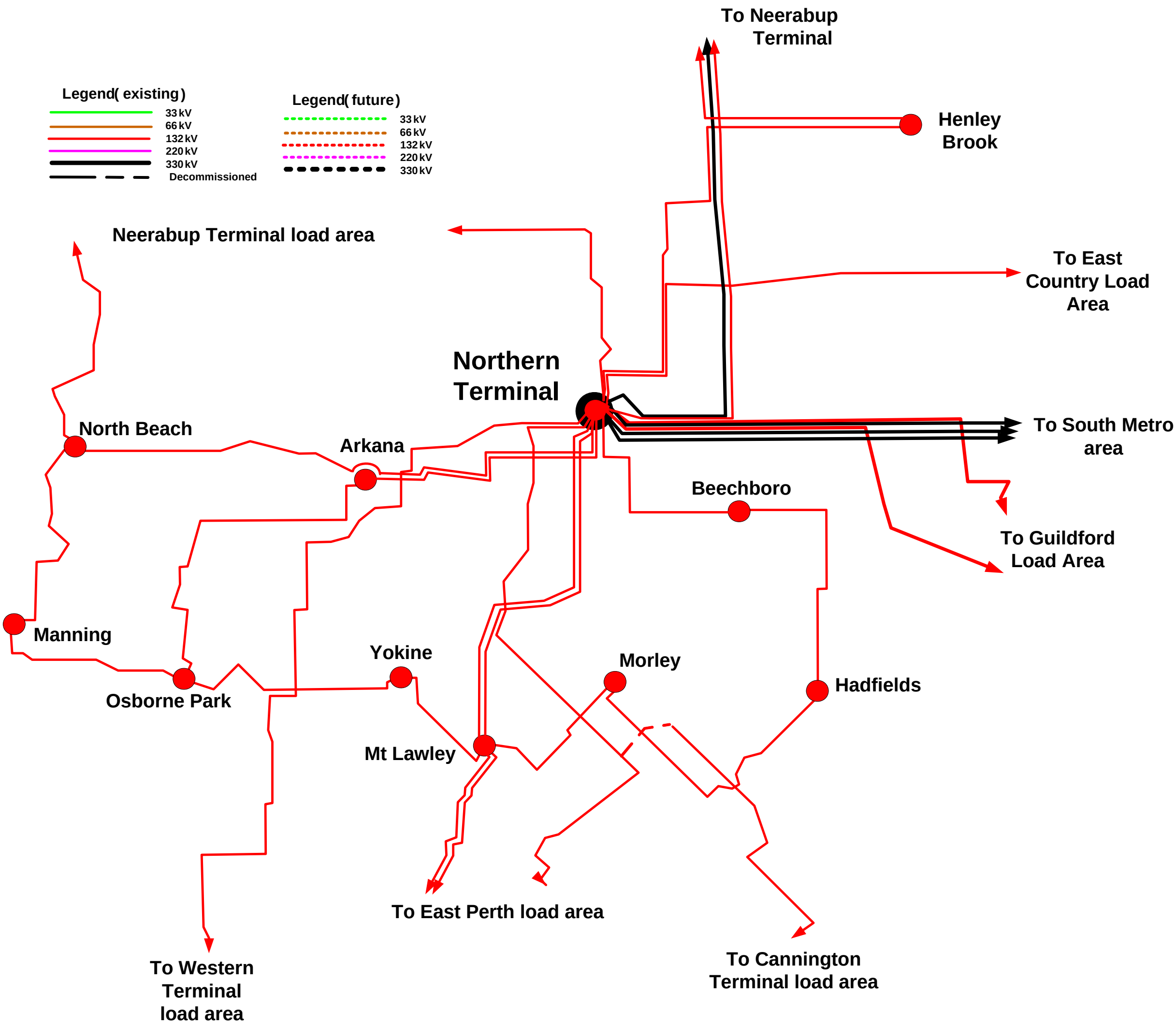

Figure 29: Transmission System – Northern Terminal Load Area

4.15.1.4.1 Purpose (Relationship with other load areas)

The purpose of the network in the area is primarily to support large local load connected via numerous 132 kV transmission lines. The network currently also serves to support the Neerabup Load Area under some operating conditions.

The northern metropolitan region is continuing to experience high growth associated with urban development and Northern Terminal currently represents one of the largest load centres in the Western Power Network.

Northern Terminal relies heavily on supply from numerous neighbouring load areas and is a strategically important terminal for future reinforcement to the north, including Neerabup Terminal and further north into the North Country Load Area. Northern Terminal plays an important role in the staged development of the Mid West Energy Project (Southern Section).

4.15.1.4.2 General considerations

The network within Northern Terminal Load Area is highly meshed with Neerabup Load Area. This mesh can create considerable challenges as numerous contingencies within the Northern Terminal and Neerabup Load Areas can generate power system security problems under some operating conditions. The meshed network is also a key cause of high fault level issues at Northern Terminal.

In the past development of the network within Neerabup and Northern Terminal has generally followed a philosophy of retaining a meshed network. Whilst there are some benefits associated with this more recent longer term studies indicate that splitting the networks into two relatively isolated areas offers significant advantages. Optimising the timing of this split, along with the need to address shorter term transmission issues in the area is difficult. Furthermore the lack of availability of suitable land for network reinforcement and future substation sites presents difficulties, driving more costly options such as underground cable and high capacity gas insulated switchgear alternatives. Residential density also increases lead times associated with development approvals.

4.15.1.4.3 Substations

In additional to Northern Terminal there are nine substations in the Northern Terminal Load Area all of which are owned and operated by Western Power.

- Arkana
- Beechboro
- Hadfields
- Henley Brook
- Malaga
- Manning St
- Morley
- Osborne Park
- Yokine

Each of these substations is subject to peak demand conditions in the summer months.

4.15.1.4.4 Transmission lines

The network in the area is characterised by strong 330 kV ties with generation centres in the South of the Western Power Network (Muja and Kwinana areas) and north in the Neerabup Load Area, as well as 330 kV connections with large load areas supported by Southern Terminal and Guildford Terminal.

The transmission network in this area is currently heavily meshed with Neerabup Load Area at the 132 kV level. Several 132 kV sub-transmission systems extend in rings both south east and south west of Northern Terminal supplying all of the substations in the area. The 132 kV network to the west of Northern Terminal is meshed with the Neerabup Load Area at Padbury and Landsdale substations, and north of Henley Brook Substation. A single 132 kV circuit extends east to Northam Substation in the East Country Load Area.

The bulk of supply to the area comes from the 330 kV system via two 490MVA transformers at Northern Terminal, as well as via 132 kV links to Guildford Terminal. Given the meshed nature of Northern Terminal and Neerabup Load Areas these areas currently provide support to one another in different ways, depending on system conditions.

The transmission lines in this load area are generally designed to meet the N-1 criteria. Northern Terminal is subject to the N-1-1 criteria at 80% peak load.

4.15.2 Emerging network limitations within a 10 year period

Network limitations that arise over the next 10 year period are the principal focus of current planning activities and the resultant work program articulated in this development plan.

4.15.2.1 Substation capacity

This section provides a summary of emerging limitations at each substation in the Northern Terminal Load Area over a 10 year horizon. Limitations emerge when the projected load forecast at the substation exceeds its capacity, accounting for any committed reinforcements.

This timing does not reflect the impact of non committed load transfers between substations which are proposed to minimise total costs associated with capital expansion over time. In some cases these transfers increase the loading at substations and bring forward the timing at which capacity is exceeded.

Arkana (A)

Arkana Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2012/13.

Beechboro (BCH)

Beechboro Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Hadfields (H)

Hadfields Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2014/15.

Henley Brook (HBK)

Henley Brook Substation has one transformer and operates under the NCR criteria. Following installation of a second transformer by summer 2012/13 load forecasts indicate the capacity of the substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Malaga (MLG)

Malaga Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Manning St (MA)

Manning St Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2013/14.

Morley (MO)

Morley Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is not exceeded within a 10 year horizon, assuming no additional load is transferred to it from other substations.

Osborne Park (OP)

Osborne Park Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2011/12.

Yokine (Y)

Yokine Substation has three transformers and operates under the NCR criteria. Load forecasts indicate the capacity of this substation is exceeded around summer 2017/18.

4.15.2.2 Fault levels

Northern Terminal is a particularly congested site with numerous 330 kV and 132 kV transmission line connections. Under current network configurations fault levels are becoming problematic, particularly at the 132 kV level. Left unattended it is anticipated that fault levels will be in excess of switchgear capability around summer 2014/15. Beyond this period, increased constraints on generation dispatch is necessary, resulting in degradation in system security and market inefficiency.

As there are also a number of emerging thermal limitations within the Northern Terminal Load Area Western Power has looked to develop a network strategy which addresses both fault level and thermal limitations through use of low cost special protection schemes and reconfiguration of the network in the area.

4.15.2.3 Thermal limits

Several thermal overloads emerge over a 10 year horizon. These include overloads on the:

- Northern Terminal to Beechboro 132 kV circuit following loss of the Mt Lawley to Morley 132 kV circuit;
- Mt Lawley to Morley 132 kV circuit following loss of the Northern Terminal to Beechboro 132 kV circuit; and
- Northern Terminal to Mt Lawley 132 kV circuit following loss of a parallel circuit.

4.15.2.4 Voltage limits

Whilst high capacity 330 kV network connects Northern Terminal and the major generation centre at Muja, the distances between these sites limits the ability to transfer reactive power to support the increase in reactive power demand. Furthermore under current network configuration the existing 330/132 kV transformer at Kwinana Terminal is operated out of service to contain fault levels, preventing direct access between Kwinana generation and Northern Terminal at 330 kV. Even with this transformer in service it is anticipated that there will be a reactive reserve deficit at Northern Terminal around summer 2014/15.

It is anticipated that Network Control Services (NCS) for reactive reserve will provide some benefit, although the use of generation for this service also increases fault levels at Northern Terminal, which is already approaching equipment specifications.

4.15.2.5 Asset condition

The Northern Terminal sub-transmission networks contain a number of aging circuits which are now approaching 40 years. Of particular note is the Northern Terminal to Northam 132 kV circuit which is already in excess of 40 years old.

As part of its long term development strategy Western Power has looked to optimise its asset replacement and network reinforcement plans.

4.15.3 Network development within a 10 year period

4.15.3.1 Substation capacity expansion

To address the emerging substation capacity limitations identified in section 3.15.2.1 a number of augmentations were considered including substation capacity reinforcements, coupled with load transfers between existing sites. The proposed augmentation and timings have been identified below.

4.15.3.2 Preferred substation solutions

- Install additional 33 MVA transformer at Henley Brook Substation by summer 2012/13 [34];
- Establish a new substation (Balcatta) by summer 2013/14. Load to be transferred (and converted to 22 kV in some cases) over a number of years from Arkana, North Beach, Manning and Osborne Park to relieve congestion at these substations [34];
- Transfer of load from Hadfields Substation to Beechboro Substation by summer 2015/16;
- Establish a new substation in the Osborne Park area by summer 2016/17. Load to be transferred from Osborne Park to this new substation over a number of years to relieve congestion at Osborne Park and allow for eventual retirement or rebuild; and
- Transfer of load from Yokine Substation to new Osborne Park area substation by summer 2017/18.

4.15.3.3 Transmission reinforcement

As part of the 2010 TNDP Western Power has developed a number of options that look to address the emerging limitations in the transmission network within Northern Terminal Load Area. Options have been developed with consideration to the anticipated needs of the network in the area over the longer term (10-25 years) and also have consideration to the emerging limitations in the Neerabup Load Area. Options include:

- reinforcing overloaded transmission elements with parallel conductors, where feasible;
- installation of special protection schemes as solutions to defer investment;
- use of network control services, including demand management options;
- reinforcing overloaded transmission elements with new circuits following different routes; and
- reconfiguration of the network in the area to improve the efficiency of existing assets.

Of the options assessed it was discovered that without reconfiguration it is particularly difficult to reduce the fault level at Northern Terminal. Whilst there are a number of options to address this issue, such as installation of series reactors, these were found to create additional inefficiencies in the transmission system and were not economic solutions. Space constraints and outage scheduling issues also present challenges for these solutions.

[34] This is a committed project that will commence during the AA2 period and be concluded/commissioned during the AA3 period; as such funding has been budgeted in both Access Arrangements.

To ensure efficient use of the existing 330 kV bulk transmission system and reduce underlying congestion at the 132 kV level, reconfiguration of the network was found to be the preferred solution. In particular reconfiguration to isolate Neerabup and Northern Terminal Load areas across the 132 kV network was most attractive.

As part of developing a strategy to reconfigure the network Western Power considered the longer term supply needs in the area. In particular the following aspects were key influences on the preferred solution;

- Operational flexibility and controllability;
    - The meshed nature of the Northern Terminal and Neerabup load areas can create power flow control difficulties following contingencies. This can result in suboptimal generation dispatch (in preparation for possible contingencies), or conditions where significant changes in generation may be required after a contingency. Future network reinforcement in the area should look to alleviate generation constraints and where necessary minimise necessary post contingent response by System Management in accordance with an N-1 planning criteria.
    - Reconfiguration of the network should not degrade its reliability or ability to schedule planned outages.
    - As part of reconfiguration if lines are operated normally out of service options to use these lines to assist with power system security and outage management should be favoured.
- Staging development to optimise asset utilisation;
    - It is important to ensure that network reinforcement is staged to ensure deliverability as well as optimise use of existing infrastructure. It is not proposed that the Neerabup and Northern Terminal Load areas will be completely radialised within the 10 year horizon, although intermediate network development will be moving in that direction.
- The Northern Terminal Load Area is growing rapidly and load sharing between Neerabup Terminal and Northern Terminal is poor.;
    - Reconfiguration strategy should consider the benefits of balancing load across these terminals by optimising the allocation of substation loads to each network. There are a number of ways this can be done and the most economic long term solution must be deployed. Improving load balancing on these sites offloads an already heavily congested Northern Terminal, reduces fault level at Northern Terminal, improves utilisation of the bulk 330 kV network and is likely to improve overall system losses.
- Ability for existing and future generation to operate unconstrained under various dispatch conditions [35];

[35] Whilst studies were performed using merit order dispatch, consideration was given to sizing augmentations to allow for unconstrained operation under various dispatch conditions.

  - Under current network configuration constraints on generation at Pinjar and Neerabup are required to prevent overload under some system conditions. This is due to the meshed nature of the networks and ability for through flows between Neerabup and Northern Terminal 132 kV networks. Reconfiguration to form radialised load areas will mitigate this congestion and subsequent generation constraints.
  - It is envisaged that constraints on generation dispatch may be required to mitigate fault level issues at Northern Terminal should augmentation of the network not occur.
- Maximising use of existing single circuit assets;
  - The bulk of transmission assets in the Neerabup and Northern Terminal load areas are of single circuit construction. As a result increasing their capacity presents considerable challenges when looking to maintain supply reliability. Alternatively new corridors are required, which also presents consenting issues. Reconfiguration of the network should attempt to optimise use of existing assets by eliminating through-flows.
- Strategic importance of Northern Terminal in longer term reinforcement needs between Northern Terminal and North Country Load Area;
  - Northern Terminal is a particularly strong 330 kV Terminal with connections to Guildford, Kwinana and Muja, as well as Neerabup. There is considerable spare capacity on these 330 kV circuits and a number of relatively low cost options exist to expand this capacity further. As the North Country Load Area evolves and its demand on the remainder of the Western Power Network network increases, there will be increased reliance on this infrastructure. Future development of Northern Terminal should be optimised to best utilise existing network capacity to the south as well as support strategic development of bulk transmission capacity further north. This will ultimately lead to improved generation sharing opportunities and a strong bulk power transfer capacity for the length of the Western Power Network.

With consideration of the above influences on a preferred network strategy a number of reconfiguration options were considered. These options look to address the emerging constraints in the area, defer costly investment and work towards delivering on the Strategic Network Objectives.

4.15.3.4 Preferred transmission solutions

The following figure represents the preferred transmission network strategy for the coming 10 year horizon.

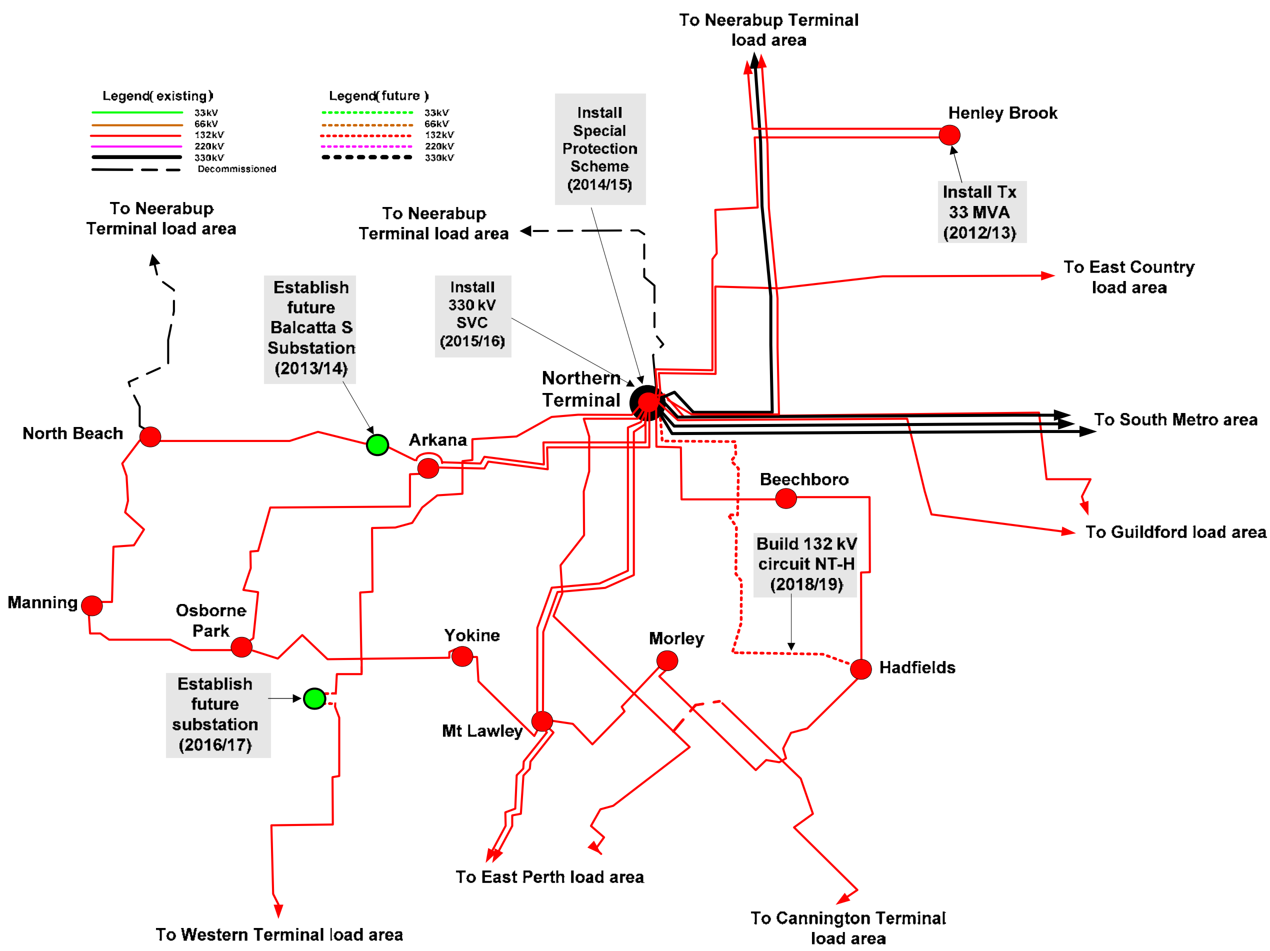

Figure 30: Northern Terminal Load Area – preferred transmission solution

The specific projects planned for the Northern Terminal Load Area over the next 10 years include:

- Use of Network Control Services (NCS) from around summer 2011/12 in the Northern Terminal area to defer more costly reactive compensation projects;
- Installation of a special protection scheme to allow Northern Terminal 132 kV bus sections to be operated independently under system normal conditions by summer 2014/15;
- Installation of a 330 kV Static VAr Compensator at Northern Terminal by summer 2015/16;
- Install single 132 kV circuit from Northern Terminal to Hadfields by summer 2018/19; and
- Radialise Neerabup and Northern Terminal 132 kV sub-transmission networks on the west coast around summer 2021/22 by:
  - o isolating the Northern Terminal to Landsdale and North Beach to Padbury 132 kV circuits; and
  - o establishing a second 132 kV circuit from Padbury to Mullaloo and from Mullaloo to Wangara.

The preferred solution offers the following benefits:

- Adopts reinforcement strategies that move to radialise the Neerabup and Northern Terminal load area away from one another to be supported by independent terminals. This will provide significant long term benefits by relieving the existing 132 kV sub-transmission system of through flows between terminals;
- Increases utilisation of the existing 330 kV network between Northern Terminal and Neerabup Terminal;
- Lower cost special protection control schemes provides for staging of network reinforcements and deferral of extensive augmentations (see also Neerabup Load Area);
- Relieves transformer loading at Northern Terminal, deferring the need for additional transformation capacity in an already heavily congested site;
- Reduces fault levels at Northern Terminal considerably through use of low cost special protection schemes;
- Radialising the 132 kV networks between Northern Terminal and Neerabup relieves constraints on generation dispatch and improves power flow controllability; and
- Supports longer term 330 kV bulk transmission strategies between North Country and the rest of the Western Power Network.

5 Resourcing

5.1 Deliverability

Each of the transmission projects outlined in the TNDP has a specific Required-in-Service (RIS) date which is aligned with achieving compliance with the Technical Rules at the time when the network constraint arises.

A range of elements influence the determination of RIS dates. The most significant determinant is the load forecast which provides a specific trigger date when an asset will be operating outside of compliance specifications and therefore, action to mitigate the forecast noncompliance needs to be achieved prior to the load materialising.

Other variables also play a key role in determining RIS dates, such as particular generation dispatch conditions, although these are second order, particularly under peak demand conditions when nearly all generation is operational.

RIS dates, however, are not always achievable and a range of factors impact Western Power's ability to complete and commission projects by the RIS date including:

- Environmental conditions;
- Legal requirements;
- Government policy requirements;
- Individual customer requirements;
- Generation development;
- Sequential project timing;
- Budgetary constraints;
- Management of outages to accommodate projects works; and
- Availability of resources.

As projects move from the proposal stage to a formal business plan, a project manager is assigned to the project and is involved in determining an Agreed-in-Service date (AIS) with the project planner.

AIS dates are determined after a deliverability assessment is performed to review the availability of resources, the impact of project staging constraints and the efficient deployment of resources.

Clearly, budgetary and other constraints impact the development of Western Power's transmission Works Program and, given the need to economically deploy available resources, projects can be delayed to achieve a flatter work profile and better utilisation of available resources.

Western Power acknowledges that AIS dates will, at times, result in a risk of non-compliance with the Technical Rules however, Western Power recognises the importance of balancing this risk against the economic benefits of prudent network management.

To enable this, Western Power develops a risk-based understanding of the impact of extending delivery deadlines beyond, in some cases, the point at which the assets are expected to be operating outside of their individual compliance specifications. Furthermore an assessment is performed to identify if there may be operational measures that can be adopted to mitigate risk resulting from the delay of projects.

As part of the TNDP Western Power engaged various internal stakeholders to identify a program of works which is deliverable across this period. As a result of this process a number of the projects identified in the TNDP exhibit an AIS date later than the identified RIS date for the reasons noted above. As the TNDP forms the basis of the AA3 transmission capital expansion plan the projects in the AA3 submission are also on this basis.

In essence, the TNDP should be seen as a works program which forms a suite of individual projects that are all considered deliverable in the timeframe specified. As the timing specified for some projects may be delayed beyond the RIS date, this means Western Power trends towards compliance with the Technical Rules over a number of years, rather than achieving compliance from the first year of the period.

5.2 Risk

Western Power's proposed transmission capital expansion projects, as outlined in the TNDP, are based on timings that accommodate the deliverability constraints identified above.

In order to effectively manage risks associated with profiling the Work Program to ensure deliverability, and to provide regulators with a view to the risks ameliorated by the proposed Works Program, Western Power undertakes a range of simulations to determine the:

1. Customers at risk (CAR) if the projects detailed in the transmission plan are not implemented at all;
2. CAR if projects detailed in the transmission plan are delivered at the RIS dates; and
3. CAR if projects detailed in the transmission plan are delivered at the AIS dates.

Results from these simulations provide valuable information about Western Power's risk exposure and forecast trending towards compliance with the Technical Rules. These studies also provide information about particular projects which, if delayed, cause considerable additional risk and should therefore be priorities in the broader program of works.

5.2.1 CAR – No transmission capital expansion

Using forecast load data and new generation development scenarios, coupled with data on emerging system constraints, simulations are performed to determine the point at which local demand is likely to exceed available network capacity. This provides an illustration of excessive demand at various points on the transmission system and the customers load that may need to be interrupted following a contingency to avoid dangerous overloads on the power system. This measurement of excessive demand can be quantified in terms of customers at risk of losing power supply (CAR).

Through simulation and use of this process Western Power can estimate the CAR as a result of not proceeding with any projects in the 10 year development plan at all.

5.2.2 CAR – RIS Dates

Western power is also able to demonstrate the amelioration of risk of non-supply through the execution of the transmission augmentation projects as per the individual project RIS dates.

As RIS dates are set according to the timing where network capability is exceeded, implementation of all projects at their respective RIS dates would ultimately result in technical compliance from day one. However, when determining the RIS dates for various projects in the TNDP a minimum lead time of three years was assigned for transmission line projects and three years for other equipment (capacitor banks etc), with exception to projects that are already being progressed. As a result, even under RIS date timings, the measure of customers at risk can be the same as that under AIS timings, particularly in the first few years.

There are no constraints on RIS dates beyond a three year timeframe, which would suggest under a RIS scenario compliance is reached in the fourth year when there are no customers at risk. However, included in the TNDP is a number of special protection schemes that are implemented to address emerging constraints across the 10 year horizon. These schemes offer an operational short-term solution to alleviate overloads which would normally require additional network investment to address and work to defer capital expenditure by a number of years.

As part of quantifying the CAR under a RIS scenario the impact of these proposed special protection schemes is not included, as by their very nature they present a risk of mal-operation. This results in a non zero CAR beyond the third year in the study period, which is expected to be mitigated by the proposed works.

5.2.3 CAR – AIS Dates

The projected view of CAR is determined by the suite of projects delivered at their respective AIS dates. Using the same approach identified above, the CAR can be quantified based on the residual non compliance on the transmission network following the installation of various projects, accounting for a deliverability constraints. This view of CAR, under an AIS scenario, reflects Western Power's estimate of CAR across the next 10 year horizon.

Quantifying the CAR under the AIS scenario also excludes the impact of any proposed special protection schemes, as per the CAR quantified by RIS dates.

The simulations outlined above afford Western Power a clear view of the impact of the workload smoothing that takes place as part of the development of the Works Program.

Figure 31 below demonstrates the impact on CAR for the three scenarios. The following observations can be made:

- Under the "No transmission capital expansion" scenario the number of customers whose supply would be put at risk is shown to increase significantly over a short period of time with an almost exponential growth in risk toward the end of the decade.
- The level of risk of non-supply by completing all projects by the Required-in-Service date (RIS) is shown to significantly reduce the number of CAR (after the initial three year delay period). The small amount of residual CAR in future years represents the impact of proposed special protection schemes which have not been included in the calculations, as discussed above. Taking into account all special protection schemes would result in a residual CAR tending to zero by 2017 (compliance) and continuing in future years.
- The level of risk of non-supply by completing all projects by the Agreed-in-Service date (AIS) demonstrates the number of customers-at-risk of non-supply tending towards compliance at the end of the 10 year period. Notably the difference in the CAR between the RIS and AIS dates is relatively small from around 2017/18 onwards, with this difference diminishing further in time.

The proposed Works Program achieves compliance with the Technical Rules around 2020 with the small amount of forecast CAR mitigated by proposed protection inter-tripping schemes. This is achieved some four years later than what would be achieved if each project was delivered by its RIS date.

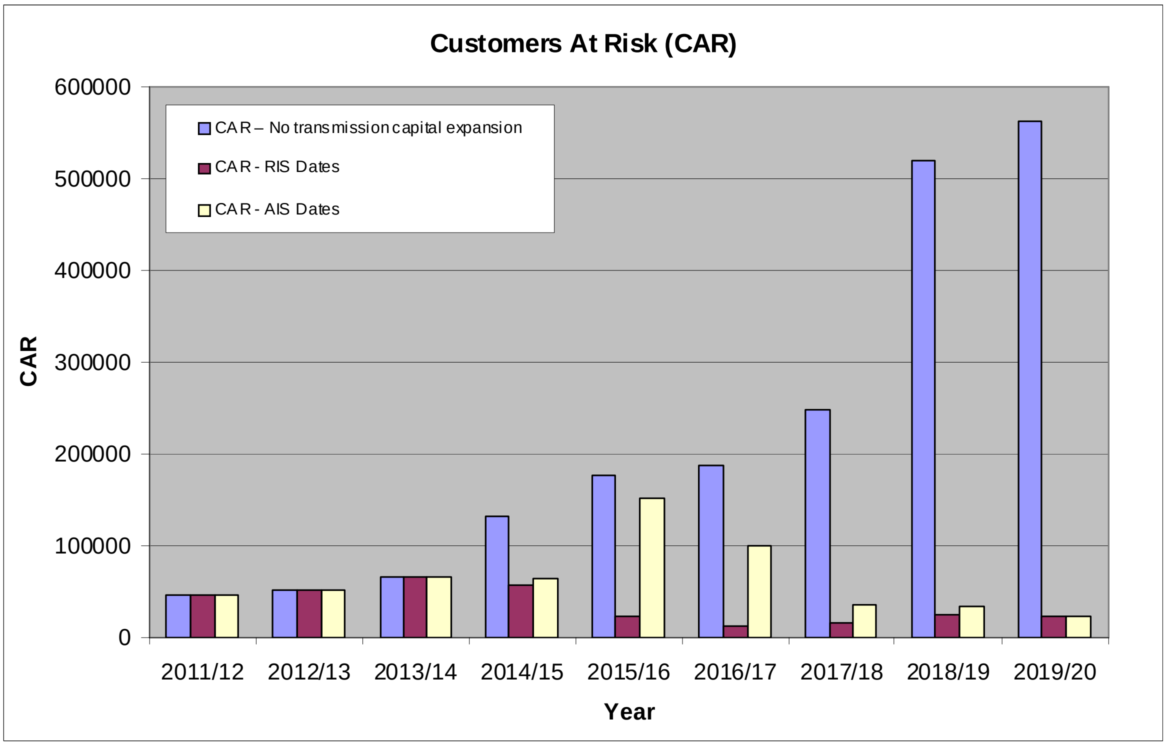

Figure 31: Customers at Risk (CAR)