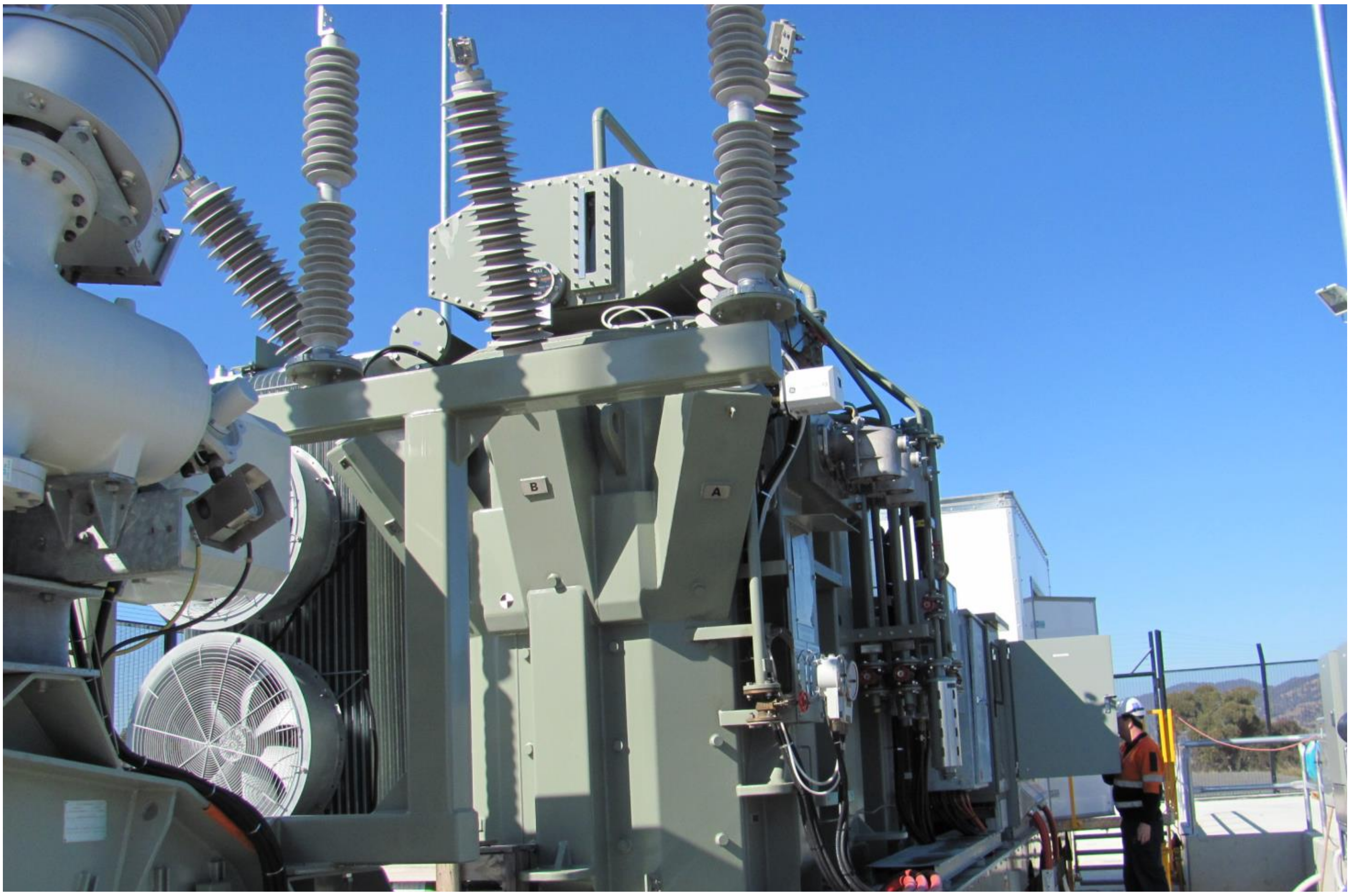
Annual Planning Report 2016

Version 1.0

Date: 23 December 2016



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REVIEW DATE

This document may not be reviewed once published, but will be replaced with the 2017 version by 31 December 2017.

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Version Control

Version No.	Date	Description of Version
1.0	23 December 2016	Final Version

Document Authorisation

Name:	**Dennis Stanley**	**Stephen Devlin**
Position:	Branch Manager Asset Strategy	General Manager Energy Networks
Date:	23 December 2016	23 December 2016

Statement of Purpose

ActewAGL aims to provide efficient, cost-effective transmission and distribution services to our customers, whilst meeting their current and future reliability and power quality expectations, ensuring public safety and minimising environmental impact.

The purpose of the Annual Planning Report is to inform Customers, Generators, Investors, and Government about the ActewAGL electricity transmission and distribution network's current capability, anticipated investments to maintain that capability, drivers of future development needs and options to meet them.

In doing so we aim to provide information in a clear, concise and accurate way that:

- Enables us to have informed dialog with Generators and Customers to contribute to our understanding of their development plans;
- Clearly identifies and promotes opportunities for Generators and Customers to participate in the development of our plans for the network; and
- Informs investment and connection decisions.

It is our priority to have a transparent and accessible approach to the way we plan our network. This will encourage meaningful stakeholder participation in the planning process and improve the planning of the investments necessary to deliver transmission and distribution services to the people of the ACT.

Achieving the above will also meet the obligations in the National Electricity Rules (NER) and the ACT Energy Utilities Technical Regulations (UTR).

ActewAGL welcomes feedback on this Annual Planning Report, especially from external stakeholders considering investments that could either defer or accelerate network development. For all enquiries and for making written submissions please contact:

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Executive Summary

ActewAGL is both a registered Distribution Network Service Provider and a Transmission Network Service Provider, and is required to produce a Distribution Annual Planning Report (DAPR) covering its distribution network and a Transmission Annual Planning Report (TAPR) for the transmission network. To align the publication of the DAPR and TAPR, the National Electricity Rules (NER) permits the publication of both documents in a combined Annual Planning Report.

ActewAGL publishes an Annual Planning Report to provide information about the electricity transmission and distribution networks in the ACT, to discuss current or emerging issues affecting the operation of these networks, proposed solutions to issues, and identify opportunities for external stakeholders to provide non-network solutions to these issues.

Energy is supplied to ActewAGL's network primarily from generation sources in neighbouring states. There is an increasing amount of embedded generation including the Royalla Solar Farm which generates up to 20 MW and a large amount of domestic rooftop solar photovoltaic (PV) generation amounting to approximately 53.5 MW of installed capacity. Two new solar farms have recently been commissioned and will inject 12.85 MW and 10.1 MW respectively into ActewAGL's network. Maximum system demand in the 2016 calendar year was 619 MW.

This Annual Planning Report presents the results of ActewAGL's annual planning review, including joint planning with TransGrid Limited, the provider of bulk transmission network services to ActewAGL.

The objective of this Annual Planning Report (APR) is to provide customers and external stakeholders with an opportunity to:

- Assess the capability of ActewAGL's transmission and distribution system to transfer electrical energy to its present and future customers in the ACT.
- Understand how the transmission and distribution system may affect their operations.
- Identify locations that would benefit from embedded generation or demand-side management initiatives.

The APR also provides an outline of ActewAGL's reliability centred maintenance program and summarises the results of recent reliability improvement initiatives.

1. Introduction

1.1. About ActewAGL

ActewAGL was established in October 2000 when the Australian Gas Light Company (AGL) and Icon Distribution Investments Limited (formerly ACTEW Corporation), an ACT Government owned corporation, entered into Australia's first multi-utility joint venture. Today ActewAGL is made up of two partnerships:

ActewAGL Retail is owned equally by Icon Retail Investments Limited and AGL ACT Retail Investments Pty Ltd.

ActewAGL Distribution is owned equally by Icon Distribution Investments Limited and Jemena Networks (ACT) Pty Ltd.

Although ActewAGL was established in October 2000, with our predecessors we've been supplying reliable essential services to the ACT since 1915.

ActewAGL Distribution is licensed under the ACT Utilities Act 2000 (12 May 2016) to provide electricity transmission, distribution and connection services. ActewAGL is registered with the Australian Energy Market Operator (AEMO) as both a Transmission Network Service Provider (TNSP) and a Distribution Network Service Provider (DNSP), and operates in the National Electricity Market (NEM) as a Registered Participant. The NEM operates on an interconnected power system that includes the power systems of Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania.

The *National Electricity Law (NEL)* and *National Electricity Rules (NER)* are enacted in the ACT by the *Electricity (National Scheme) Act 1997 ACT*.

The National Electricity Objective as stated in the National Electricity Law is:

"to promote efficient investment in and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:

a) price, quality, safety, reliability and security of supply of electricity; and
b) the reliability, safety and security of the national electricity system."

ActewAGL's mission is:

"To offer our customers the safe, reliable and sustainable energy solutions they want."

ActewAGL's revenue for the provision of transmission and distribution network services is regulated. We prepare and submit on a five-yearly basis, a Regulatory Revenue Proposal to the Australian Energy Regulator (AER). The AER reviews this proposal and sets the maximum allowable revenue that ActewAGL can collect from customers for each year of the five-year regulatory period. This determines the revenue that ActewAGL can recover from its customers and hence the funds that can be invested in the network in the form of Operational Expenditure (Opex) and Capital Expenditure (Capex).

Technical regulation is overseen by the ACT Utilities Technical Regulator (UTR) of the Australian Capital Territory Government.

1.2. ActewAGL's operating conditions

ActewAGL is regulated by statutory and legislative requirements, including occupational, health and safety, environmental, competition, industrial, consumer protection and information laws, the National Electricity Rules, the ACT Utilities Act 2000, and the ACT Utilities (Technical Regulation) Act 2014. ActewAGL manages compliance with these laws and regulations through its internal policies and procedures. Management of the physical and financial assets as well as employees is through delegated authorities, from the Board, to executives and staff. Physical infrastructure assets are managed through an Asset Management System, in general compliance with ISO 55001 to meet the requirements of the ACT Utilities (Technical Regulation) Act 2014.

ActewAGL's operating licence to provide Utility Services was granted on 29 June 2001 by the ACT Independent Competition and Regulatory Commission, a body corporate established under the Independent Competition and Regulatory Commission Act 1997 (ACT) ("ICRC") pursuant to the Utilities Act 2000 (ACT)

This licence confers on the ActewAGL the right to provide Authorised Utility Services, including electricity transmission, distribution and connection services. ActewAGL may exercise the rights conferred on it in any part of the Territory.

ActewAGL's licence was varied on 1 July 2009 to provide gas distribution and connection services under the Utilities Act 2000 (ACT)

1.3. ActewAGL's function

ActewAGL provides electricity and gas services over an area of 2,358 square kilometres to 184,962 electricity and 127,143 gas customers, as of 30th June 2016, within the Australian Capital Territory.

ActewAGL is responsible for the operation, maintenance, planning and augmentation of the transmission and distribution system within the ACT. There are a small number of rural cross border high voltage lines feeding 89 rural customers within NSW. Because of the presence of the Brindabella Ranges the developed electricity network is mainly confined to the Canberra urban and surrounding rural areas on the north east side of the ACT.

We supply electricity and natural gas network services to customers in the ACT (and south-east NSW for natural gas). This includes:

- conducting all maintenance, upgrade, and extension work on the distribution networks;
- performing connection, alterations, disconnection and reconnection;
- providing emergency response;
- maintaining quality and reliability of supply; and
- reading and maintaining meters (where these meters are owned by ActewAGL Distribution).

ActewAGL's company values form the basis for all works done by ActewAGL and are:

- Honesty
- Respect
- Health and Safety
- Teamwork
- Continuous Improvement
- Accountability

ActewAGL also owns and operates a telecommunications network that supports the operation of the electricity network.

1.4. Purpose of this document

This Annual Planning Report (APR) has been prepared to comply with the National Electricity Rules (NER) clause 5.12.2 Transmission Annual Planning Report (TAPR) and clause 5.13.2 and Schedule 5.8 Distribution Annual Planning Report (DAPR).

The purpose of this report is to inform Registered Participants, stakeholders and interested parties, of the identified current and future network issues, and the committed and proposed solutions to these issues. It identifies potential opportunities for non-network solutions such as embedded generation and demand-side management.

The APR provides information about ActewAGL's assessment and planning of its transmission and distribution capacity and ActewAGL's plans for development of the transmission network to meet demand over the next ten years, and development of the distribution network to meet demand over the next five years.

This report also details how ActewAGL plans to meet predicted demand for electricity supplied through its transmission lines, zone substations and high voltage feeders and discusses the process to engage with non-network providers and customers to address network constraints and system limitations.

1.5. Audience

This APR provides information to existing customers, potential new load and generation customers, non-network solution providers, AEMO, the AER, and other interested parties.

It also provides information to all readers on the operation, development and planning of ActewAGL's network, and the drivers for network investment.

1.6. Planning horizon of the APR

ActewAGL has used a ten-year planning horizon to prepare the demand and energy forecasts for its distribution network contained in this APR. The load forecasts show a 0.2% per annum average decrease in demand during summer months and a 0.5% per annum average increase in demand during winter months over the planning period, due to steady growth in the residential and commercial sectors of the ACT. Energy demand remains at a constant level and is forecast to decrease slightly over the planning period due to the increasing proliferation of rooftop PV throughout the region, coupled with the increasing efficiency of electrical appliances, and the advent of new battery storage systems.

Network development projects have been identified and are discussed in this APR for the next five-year planning period.

1.7. What has changed since 2015

The major changes for ActewAGL since the publication of the 2015 Annual Planning Report include:

1. System maximum demand during the 2015 calendar year was 623 MW. Peak demand during the 2016 calendar year (to 30 November) was 619 MW. The main reason for this decrease was the milder winter temperatures in 2016 (minimum -4^{o}C) compared with 2015 (minimum -8^{o}C).
2. The requirement for new 11 kV feeders from Gold Creek Zone Substation to supply commercial developments in the Gungahlin town centre area has been identified.
3. The requirement for new 11 kV feeders and inter-zone feeder ties from East Lake Zone Substation to supply commercial developments in the Fyshwick area has been identified.
4. The proposed upgrade of the Theodore–Gilmore 132 kV lines as part of the Second Point of Supply to the ACT project, has been replaced with an alternative proposal by TransGrid to construct a 330/132 kV substation at Stockdill Drive, West Belconnen, and to connect it at 132 kV to ActewAGL's Canberra–Woden 132 V line.
5. The requirement for the installation of additional reactive support in the northern part of the 132 kV network has been identified.

6. A new 12.85 MW solar farm developed by Zhenfa Energy Limited (Mugga Lane Solar Park) has been commissioned and connected at 11 kV to Gilmore Zone Substation.
7. A new 10.1 MW solar farm developed by Impact Investment Group (Williamsdale Solar Farm) has been commissioned and connected at 11 kV to Angle Crossing Mobile Substation. This is a temporary connection only. Permanent connection will be made to the proposed Tennent 132/11 kV Zone Substation during 2017.
8. Major customer-initiated developments currently underway or planned for construction over the next five-year period, include:

   - Ginninderry Estate, West Belconnen – residential development.
   - Throsby Estate, Gungahlin – residential development.
   - Taylor Estate, Gungahlin – residential development.
   - Strathnairn Estate, West Belconnen – residential development.
   - Denman Prospect Estate, Molonglo Valley – residential development.
   - Whitlam Estate, Molonglo Valley – residential development.
   - North Coombs, Molonglo Valley – residential development.
   - North Wright, Molonglo Valley – residential development.
   - Gungahlin Town Centre East development – residential and commercial development.
   - CSIRO Ginninderra Estate, Belconnen – residential development.
   - Capital Metro Light Rail – construction of two 11 kV traction power stations and depot / control centre.
   - Australian National University – replacement of 11 kV bulk supply point switching station and construction of second 11 kV bulk supply point switching station.
   - Belconnen Town Centre – residential and commercial development.
   - Tennent Zone Substation 132/11 kV 15 MVA.
   - Data Centre, Mitchell – commercial development.
   - Data Centre, Fyshwick – commercial development.
   - Constitution Place, Canberra central business district – commercial development.

1.8. Overview of this document

Chapter 1: Introduces ActewAGL and the purpose of the Annual Planning Report, and summarises the main changes since ActewAGL's 2015 Annual Planning Report.

Chapter 2: Explains the framework under which ActewAGL operates; the key aspects of network development and asset management strategies; and how customers and generators can participate in the planning process.

Chapter 3: Describes ActewAGL's electricity network as it exists today and our planning philosophy for its future development.

Chapter 4: Describes the current performance of ActewAGL's network against reliability targets, and summarises information about anticipated reliability performance, anticipated network augmentations, and asset management programs that impact system performance.

Chapter 5: Describes the forecast electricity demand and energy requirements over the next ten years; discusses past and future trends; the impact of emerging technologies on forecasts; and assesses whether the existing generation supply can meet the forecast demand.

Chapter 6: Describes ActewAGL's asset renewals program.

Chapter 7: Describes those parts of ActewAGL's network forecast to require enhancement or development to meet forecast load demands or relieve constraints, and describes the options considered to achieve this. It also highlights any proposed augmentations that may be subject to the Regulatory Investment Tests for Transmission or Distribution.

Chapter 8: Discusses strategies regarding demand-side management and why these are important to ActewAGL from a planning and investment perspective.

Chapter 9: Discusses emerging technologies and why these are important to ActewAGL from a planning and investment perspective.

Appendices: Provide additional and supporting data.

1.9. Feedback and enquiries

ActewAGL welcomes feedback on this Annual Planning Report. We welcome enquiries from interested parties to participate in non-network opportunities, demand-side management, and embedded generation, to assist ActewAGL manage its existing and forecast network issues.

Please address enquiries to:

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Email: dennis.stanley@actewagl.com.au

2. Planning Considerations

This chapter discusses relevant aspects of the legal framework that regulates how ActewAGL carries out network planning and augmentation activities in the ACT, and discusses key aspects of network planning and asset management strategies. It also discusses our engagement of stakeholders and customers in the network planning process.

2.1 The regulatory framework & operating environment

ActewAGL operates under the National Electricity Rules (NER) which are managed and updated by the Australian Energy Market Commission (AEMC).

ActewAGL is a Registered Participant in the National Electricity Market (NEM). This is the Australian wholesale electricity market and the associated electricity transmission grid. The NEM is operated by the Australian Energy Market Operator (AEMO) which controls the wholesale generation, dispatch and transmission of electricity in Queensland, New South Wales, South Australia, Victoria, the ACT and Tasmania. The NEM is not a physical thing but a set of procedures that AEMO manages in line with the National Electricity Law (NEL) and the National Electricity Rules. The market uses sophisticated systems to send signals to generators instructing them how much energy to produce each five minutes so that production is matched to consumer requirements, spare capacity is kept ready for emergencies, and the current energy price can be calculated. NEM infrastructure comprises both state and private assets managed by many participants.

ActewAGL is subject to the NEL and NER which regulate the NEM. ActewAGL operates in the NEM as both a Transmission Network Service Provider (TNSP) and a Distribution Network Service Provider (DNSP). The National Electricity Objective (NEO), as stated in the NEL is to:

"…promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:

(a) price, quality, safety, reliability and security of supply of electricity; and
(b) the reliability, safety and security of the national electricity system."

This objective requires Registered NEM participants to balance the costs and risks associated with electricity supply.

In addition, there are local territory requirements that ActewAGL must comply with under the terms of our license issued by the ACT Government. The ACT has a Utilities Technical Regulator (UTR) whose role is to ensure safe and reliable energy services to the community. In the ACT, the Chief Minister is responsible for technical regulation. The Director-General of the Environment and Planning Directorate is the Technical Regulator who administers technical regulation. The ACT's economic regulator is the Independent Competition and Regulatory Commission (ICRC).

Technical regulation ensures the safe and reliable delivery of energy to the ACT community. The Utilities (Technical Regulation) Act 2014 sets out technical requirements for energy utilities. The specifics of any requirements are set out in technical codes made under the Act.

2.1.1 National Electricity Rules

The NER Chapter 5 describes the planning, design and operating criteria that must be applied by Network Service Providers to their networks. These criteria specify certain electrical performance standards that must be met such as voltage levels, voltage unbalance, voltage fluctuations, harmonics levels, protection operating times, power quality and power system stability.

2.1.2 Electricity Distribution Supply Standards Code

The Electricity Distribution Supply Standards Code (August 2013), issued by the Technical Regulator sets out performance standards for ActewAGL's distribution network. ActewAGL is required to take all reasonable steps to ensure that its Electricity Network will have sufficient capacity to make an agreed level of supply available.

This local jurisdictional code specifies reliability standards that ActewAGL must endeavour to meet when planning, operating and maintaining the distribution network. It also specifies power quality parameters that must be met including limits on voltage flicker, voltage dips, switching transients, earth potential rise, voltage unbalance, harmonics and direct current content.

2.1.3 Electricity Transmission Supply Code

The Electricity Transmission Supply Code issued by the Utilities Technical Regulator (July 2016) sets out performance standards to be met by TransGrid's and ActewAGL's transmission networks in the ACT. Implications for meeting this code are described in Section 7.5.1 Second Point of Supply to the ACT project.

2.1.4 Regulatory Investment Test

Section 5.16 of the NER describes the Regulatory Investment Test for Transmission (RIT-T) and Section 5.17 describes the Regulatory Investment Test for Distribution (RIT-D). These tests must be carried out for any proposed investment where the augmentation or replacement cost of the most expensive credible option exceeds $5 million. The regulatory investment tests provide the opportunity for external parties to submit alternative proposals to the Network Service Provider, who is obliged to consider any credible proposal objectively.

2.1.5 Revenue Determination

The revenue ActewAGL earns from providing transmission and distribution services in the ACT is set by the AER. ActewAGL prepares and submits a revenue proposal to the AER on a five-yearly basis. The current Revenue Determination covers the period 1 July 2014 to 30 June 2019. This revenue amount determines how much ActewAGL is able to invest in capital projects and what it can spend on operational expenditure to maintain and operate the network in a secure and reliable state.

2.1.6 Service Target Performance Incentive Scheme

For the regulatory period from 2014-19 and possibly future regulatory periods ActewAGL is subject to the AER's Service Target Performance Incentive Scheme (STPIS). Because the 2014-15 year was a transitional year the AER declared that STPIS would commence for ActewAGL on 1July 2015.

For full details of the STPIS refer to the *AER Electricity Distribution Network Service Providers - Service Target Performance Incentive Scheme Guideline, November 2009 (STPIS Guidelines)*.

Reliability refers to the extent that customers have a continuous supply of electricity. The main objective of the STPIS is to provide TNSP's and DNSPs with an incentive to maintain or improve reliability levels and consumer response during a regulatory control period. STPIS achieves this by rewarding NSPs that outperform their targets or by penalising NSPs that do not.

The ActewAGL STPIS scheme has two components:

- Reliability of Supply (unplanned SAIDI and SAIFI).
- Customer Service (telephone response time).

Both SAIDI and SAIFI are subdivided into Urban and Rural components. The definitions for the reliability of supply components are:

Unplanned SAIDI (System Average Interruption Duration Index)
The sum of the duration of each unplanned sustained customer interruption (in customer minutes) divided by the total number of distribution customers (urban or rural). Unplanned SAIDI excludes momentary interruptions (one minute or less).

Unplanned SAIFI (System Average Interruption Frequency Index)
The total number of unplanned sustained customer interruptions divided by the total number of distribution customers (urban or rural). Unplanned SAIFI excludes momentary interruptions (one minute or less). Key points:

- The parameters are separately applied to the two feeder types that ActewAGL has – urban and short rural.
- The performance targets are set at the start of each regulatory period and will remain the same for the full 5 year regulatory period.

The targets are generally set based on the average level recorded over the previous five years. For further detailed discussion on performance metrics, refer to Section 4.2.

2.1.7 Capital Expenditure Sharing Scheme

For the regulatory period from 2014-19 and probably future regulatory periods ActewAGL is subject to the AER's Capital Expenditure Sharing Scheme (CESS). Because the 2014-15 year was a transitional year the AER declared that the CESS would commence for ActewAGL on 1July 2015.

For full details of the CESS refer to the *AER Capital Expenditure Incentive Guideline for Electricity Network Service Providers, November 2013 (CESS Guidelines)*.

The main objective of the CESS is to provide DNSPs with an incentive to undertake efficient capital expenditure (capex) during a regulatory control period. It achieves this by rewarding DNSPs that outperform their capex allowance by making efficiency gains and spending less than forecast or by penalising DNSPs that spend more than their capex allowance because of a lack of efficiency gains. ActewAGL's strategies to manage the CESS include:

1. Ensuring that the annual capex budget matches or is lower than the AER Approved Allowance for each regulatory year. This includes the annual reforecast budgets.
2. Ensuring that final actual capex in any regulatory year does not exceed budget and/or the AER Approved Allowance.
3. The development of internal capex benchmarking targets based on optimal industry performance.
4. Close co-ordination of the Asset Management Maintenance and Capital Programs with the Program of Works delivery to achieve a timely capex program.

2.2 ActewAGL integrated planning

2.2.1 Integrated planning strategies - Asset Management, Network Development & Network Reliability.

Significant organisational changes and investments have been made to date which will allow ActewAGL to respond to the regulatory and commercial challenges facing the business, and to optimise network performance through improved alignment of planning, asset management and regulatory compliance. Targeted activities to ensure alignment and improve network performance include:

- Achieve electricity Service Target Performance Incentive Scheme (STPIS) targets through proactive management of:
    - Timely response to network outages.
    - Delivering and implementing risk based defect management of assets.
    - Incorporating reliability performance requirements into network investment business cases.
    - Effective call centre performance management.
    - Targeted reliability improvements upgrading the most unreliable feeders.
    - Root cause analysis of network faults.
    - Expanded use of Failure Mode and Effects Analysis (FMEA).
- Determine and deliver opportunities for asset utilisation improvement, through:
    - Reviewing network supply security standards.
    - Incorporating asset utilisation into network investment business cases.
    - Proactive monitoring of network design practices.
    - Improved alignment of data flow and connection between asset management applications
- Review our bushfire mitigation program prior to the commencement of the bushfire season and conduct an internal exercise to test bushfire emergency preparedness.
- Deliver a Program of Work (PoW) with particular focus on :
    - Achieving budget targets and efficiency of PoW delivery
    - Improved PoW reporting which includes earned value metrics.

2.2.2. Asset Management Strategy

ActewAGL's Asset Management Strategy is intended to define the strategic objectives and approach to the management of its physical assets, in a manner that:

- Is optimised and sustainable in terms of whole-of-life, whole-system cost over the long-term;
- Assists in the delivery of ActewAGL's strategic plans and objectives;
- Appropriately considers how ActewAGL will supply current and future demand via the management of the condition and performance of the asset base, ensuring that asset management plans are coordinated with network development plans;
- Ensures that asset renewals are based on asset condition and risk of failure rather than purely on age;
- Meets the required level of service in the most cost-effective way through the efficient use and maintenance of existing assets and the prudent investment in new assets; and
- Appropriately considers the necessary current and future Asset Management capabilities of the organisation, in terms of people, processes, systems, equipment and data to achieve the identified outputs and objectives.

The priorities for the 2016-17 year are building on works delivered in the previous year and have been set largely in response to the AER's ActewAGL Distribution Determination 2014-19 which reduced business revenue, operational and selected capital investment allowances for the 2014-19 period.

ActewAGL continues to make progress towards compliance with the International Standards Organisation standard for Asset Management ISO 55001. To ensure continual improvement of its Asset Management, ActewAGL conducted an audited assessment of its Asset Management System, and in 2016 participated in an international benchmarking program against other utilities, the results of which indicating above-average performance on all ISO 55001 measures.

ActewAGL prepares technical specifications for the procurement of major primary assets which include requirements for an assessment of whole-of-life costs, including electrical losses. The method of assessing these costs is included in the specification and is taken into account when selecting the successful tenderer.

ActewAGL's Asset Management Strategy and Asset Management Objectives are directed at maintaining assets according to the principles of Risk Centred Maintenance (RCM). The governing factor in RCM analysis is the impact of a functional failure at the equipment level, and tasks are directed at a limited number of significant items - those whose failure might have safety, environmental or economic consequences. More details of how RCM is deployed are in ActewAGL's Asset Management Objectives.

ActewAGL's Asset Management Policy, Strategy and Objectives may be found published on the same site as this document.

2.2.3. Network Development Strategy

ActewAGL's network development strategy incorporates providing adequate supply to existing and new customers with prudent investment decision making, whilst applying risk management principles to achieve an appropriate balance between supply adequacy, security, reliability and safety at the lowest cost to our customers.

ActewAGL incorporates long term strategic planning with short term planning to ensure appropriate network developments meet the long term needs of our customers.

The nature of the transmission and distribution industry is changing rapidly with the emergence of new technologies (refer to Chapter 9) and the development of the network must be done so as to cater for these 'non-traditional' factors.

As assets near the end of their economic lives and require replacement, we consider whether a straight like-for-like replacement is the best solution or whether the network can be reconfigured in a way to minimise the costs of asset renewals.

ActewAGL plans and develops its transmission and distribution networks in an integrated way, for example the best way to resolve a transmission constraint could be to implement a distribution solution.

For all major investment projects we investigate non-network options and seek alternative proposals from external third parties.

2.2.4. Network Reliability Strategy

Transmission network reliability is measured in terms of the number of loss of supply events that occur in a year and the amount of unserved energy that results from such outages. ActewAGL's 132 kV transmission network is very secure in that all zone substations have at least two sources of 132 kV connection (i.e. N-1 security). In addition most zone substations have at least two power transformers and the 11 kV networks are interconnected between zone substations allowing load transfer in the event of a contingency.

Distribution network reliability is measured in terms of the frequency and duration of unplanned interruptions to customers. Measurement factors include SAIDI, SAIFI and CAIDI (refer Section 4.2).

ActewAGL's strategy is to maintain or improve existing levels of reliability throughout the network through the deployment of devices such as auto-reclosers and the use of our Advanced Distribution Management System (ADMS).

2.3. Customer Connections

Customers can connect to ActewAGL's system at either high voltage (11 kV) or low voltage (400/230 V) level, depending on their requirements. Customer connections can be either load or generation or a combination of the two. Most load and embedded generation connections (for example, rooftop PV) are connected to the low voltage system. Larger customer loads or embedded generators (such as solar farms) are generally connected to the high voltage system. Metering is measured at the high or low voltage point of connection accordingly.

Larger load connections such as a greenfield residential estate may require ActewAGL to augment the up-stream portion of the network (e.g. provide a new 11 kV feeder). Such augmentations form part of the shared network that is not funded by a specific customer.

Larger load or generation connections require a detailed technical study to be undertaken to determine the impact on the network to ensure adequacy of the proposed connection point with regards to capacity, safety and power quality.

Proposed customer connections are included in load forecasts which provide a key input to network planning.

2.4. Stakeholder Engagement

ActewAGL firmly believes in the principle of follow through as it applies to stakeholder engagement. After consultations have taken place, stakeholders are advised on how their suggestions have been taken on board, what risk or impact mitigation measures will be put in place to address their concerns, and how project impacts are being monitored. Furthermore, aside from project-affected groups, other stakeholders are consulted on issues that address their particular concerns, such as the environmental, social, economic, and governance performance of the business. This process offers a platform to report back on the process of stakeholder engagement itself, such as

- who has been consulted;
- on what topics; and
- with what results.

Keeping track of the commitments made to various stakeholder groups at various times, and communicating progress made against these commitments on a regular basis, requires appropriate systems and organisation. The following factors have been taken into account in determining ActewAGL's stakeholder engagement strategy: ActewAGL actively

- determines what information needs to be reported to which stakeholders, by what method and how frequently;
- updates its commitments register and discloses progress to affected and interested parties. In particular, ActewAGL publicises any material changes to commitments or implementation actions that vary from publicly disclosed documents;
- makes appropriate monitored results publicly available;
- reports on the process of stakeholder engagement as a whole, both to those stakeholders who are directly engaged, and to other interested parties; and
- provides information reported to stakeholders in non-technical and easily understandable formats.

Further information on ActewAGL's engagement with stakeholders, including media and the public can be found on ActewAGL's Consumer Engagement website[1].

[1] http://www.actewagl.com.au/Networks/About-our-network/Initiatives/Consumer-engagement.aspx

3. The ActewAGL Network

3.1. Overview of the network

This chapter describes ActewAGL's transmission and distribution network in the ACT and how it fits in the supply chain between generating power stations and end use customers, and discusses issues affecting the National Transmission Flow Path (NTFP).

3.2. Characteristics of the ActewAGL network

The ActewAGL network consists of an interconnected 132 kV transmission network supplying eleven 132/11 kV zone substations, one 132/11 kV mobile substation, and two 132 kV switching stations. There is also a single 66/11 kV zone substation. A new permanent 132/11 kV 15 MVA zone substation, Tennent Substation, is currently under construction at Williamsdale and is scheduled to be commissioned in early 2017. This will effectively replace the mobile substation which will become available for redeployment elsewhere. All 132 kV and 66 kV connections have N-1 transmission security with the exception of the Angle Crossing Mobile Substation which is connected via a single circuit 132 kV tee-connection. There are three bulk supply points supplying the ActewAGL network, all owned and operated by TransGrid Limited as follows:

- Canberra 330/132 kV bulk supply substation.
- Williamsdale 330/132 kV bulk supply substation.
- Queanbeyan 132/66 kV bulk supply substation.

ActewAGL's assets include 132 kV transmission lines, 66 kV sub-transmission lines, 132/11 kV and 66/11 kV zone substations, 22 kV and 11 kV distribution feeders, 22/0.415 kV and 11/0.415 kV distribution substations, low voltage 400 V circuits and equipment such as distribution pillars and pits to provide connection points to customers.

East Lake Zone Substation and Angle Crossing Mobile Substation are the two substations that have one power transformer only. All other zone substations have two or three power transformers, providing N-1 transformer security.

There are currently 246 x 11 kV feeders. Most of these are interconnected with other feeders (i.e. a meshed network) and provide links between zone substations. There are also two 22 kV distribution feeders, supplied via 11/22 kV step-up transformers at Woden Zone Substation.

Approximately 53% of ActewAGL's distribution network is underground, although less than 2% of the transmission network is underground.

There are 25 customers directly connected at 11 kV, two customers directly connected at 22 kV, and no customers directly connected at either 66 kV or 132 kV. The remaining customers are connected to the low voltage network (400 V three phase or 230 V single phase). 11/0.415 kV distribution stations are ground-mounted, pole-mounted, or installed inside buildings such as chamber substations, and range in size from 25 kVA to 1500 kVA.

Customers are primarily commercial, light industrial or residential connections. There are no major industrial customers.

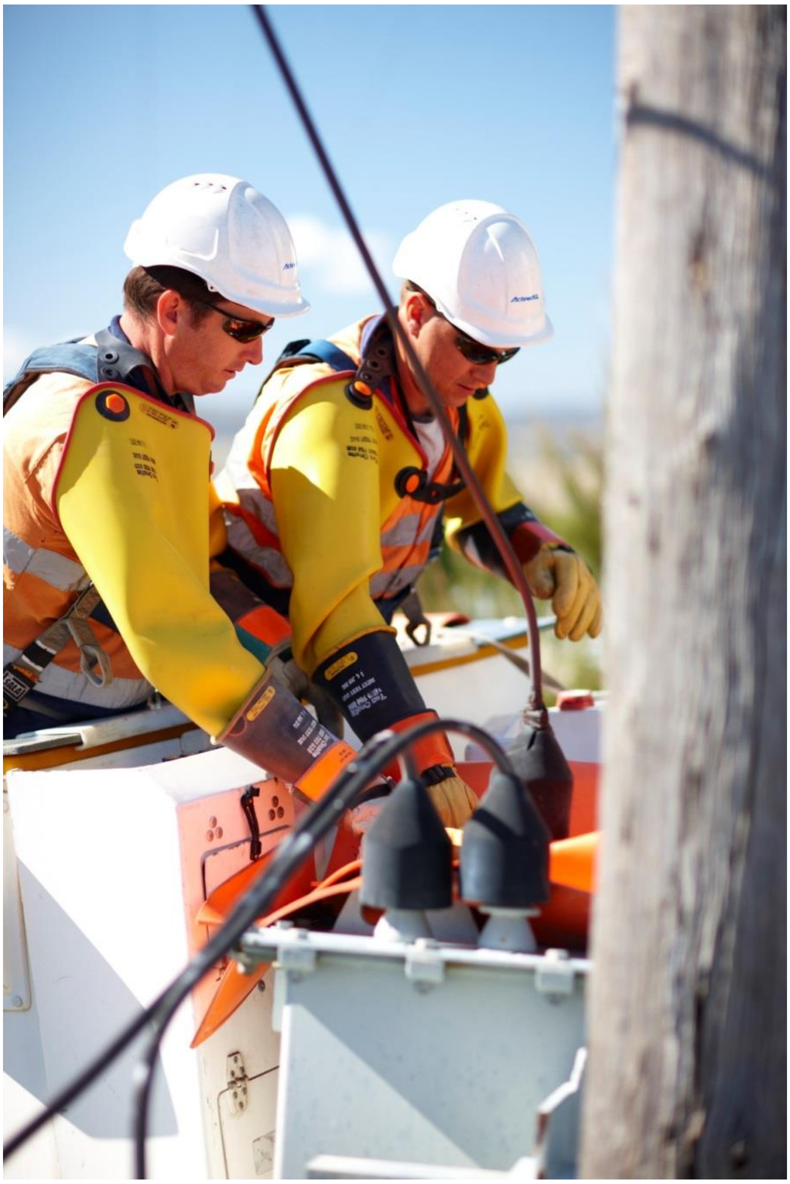
The majority of electricity consumed by customers in the ACT is generated outside the ACT. There are some small embedded generation facilities in the ACT, the largest being the Royalla Solar Farm at Royalla which has a peak output of 20 MW. Mount Majura Solar Farm at Majura with a maximum design output of 3.6 MW was commissioned in September 2016. Mugga Lane Solar Park at Mugga Lane, Hume with a maximum design output of 12.85 MW was commissioned in November 2016. Williamsdale Solar Farm at Williamsdale with a maximum design output of 10.1 MW was commissioned in December 2016. There are two bio-gas generators installed at Mugga Lane (3 MW) and Belconnen (3 MW) waste transfer stations.

There is approximately 53.5 MW of installed domestic rooftop photo-voltaic (PV) generation capacity consisting of 17,476 installations as at 30 November 2016. This represents approximately 9.4% of ActewAGL's customers. These are distributed all over the ACT. Their impact on zone substation summer peak demand is a reduction that ranges from 0.2% - 3.0% depending on the level of penetration in the area. Their impact on zone substation winter peak demand is negligible.

To date there are no battery storage systems connected directly to the ActewAGL distribution network and only a few domestic battery systems connected beyond-the-meter. There are three rapid-charge and five fast-charge electric vehicle charging stations connected to the low voltage network (refer Section 9.5).

System peak demand occurs in winter. In 2016 the winter peak demand was 619 MW and the summer peak demand was 582 MW.

ActewAGL owns, operates and maintains a telecommunications network that supports the operation of the electricity network. It provides bearers for control, protection and data signalling, telephone handsets and mobile radios for operations and maintenance activities. Telecommunications assets include optical fibres on transmission and distribution lines, digital microwave radios and associated repeater stations.



3.3. Transmission/Distribution system

Figure 3.1: ActewAGL Transmission System

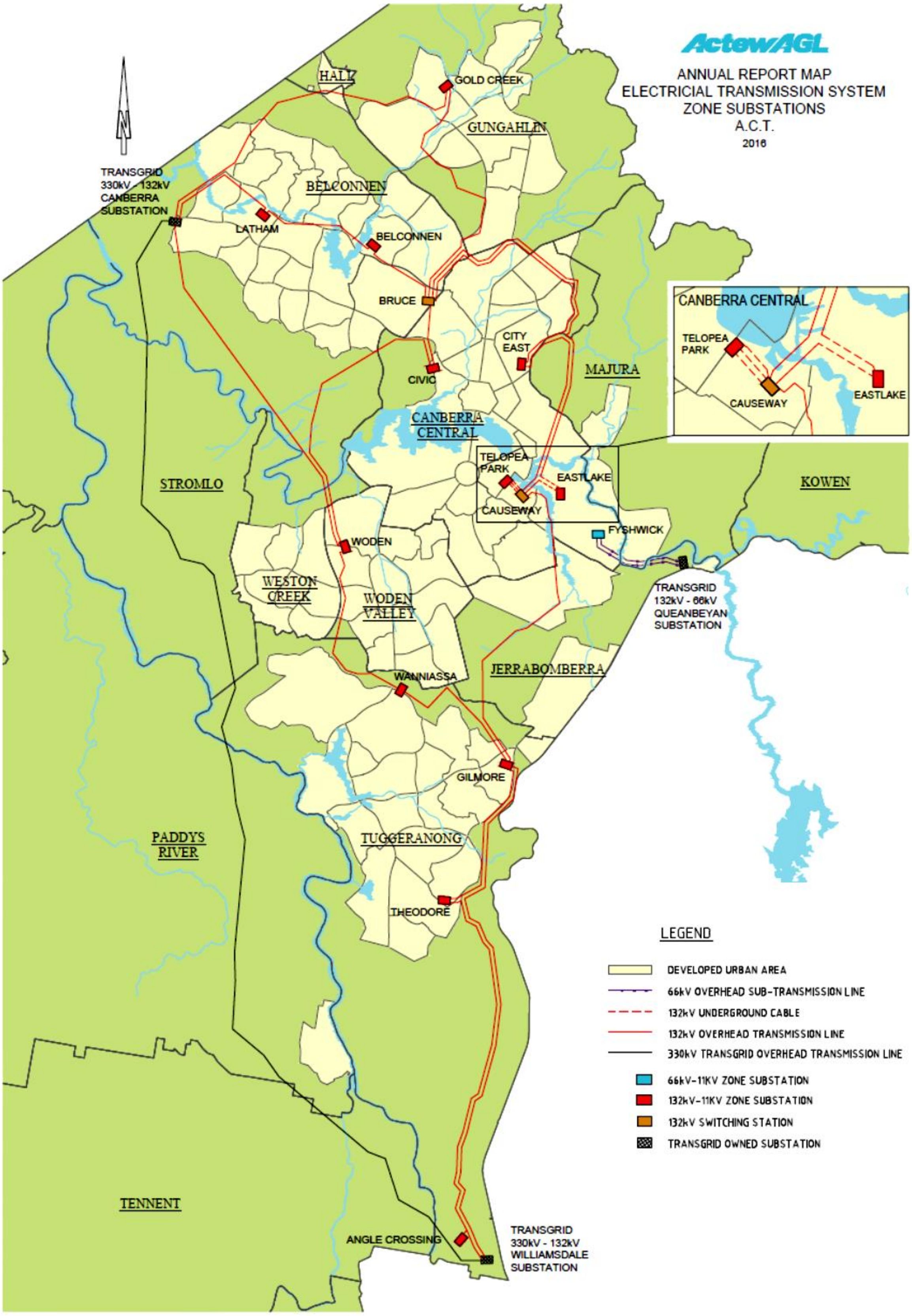


Figure 3.2 presents a schematic diagram of the ACT transmission network.

Figure 3.2: ACT Existing Transmission Network Schematic Diagram

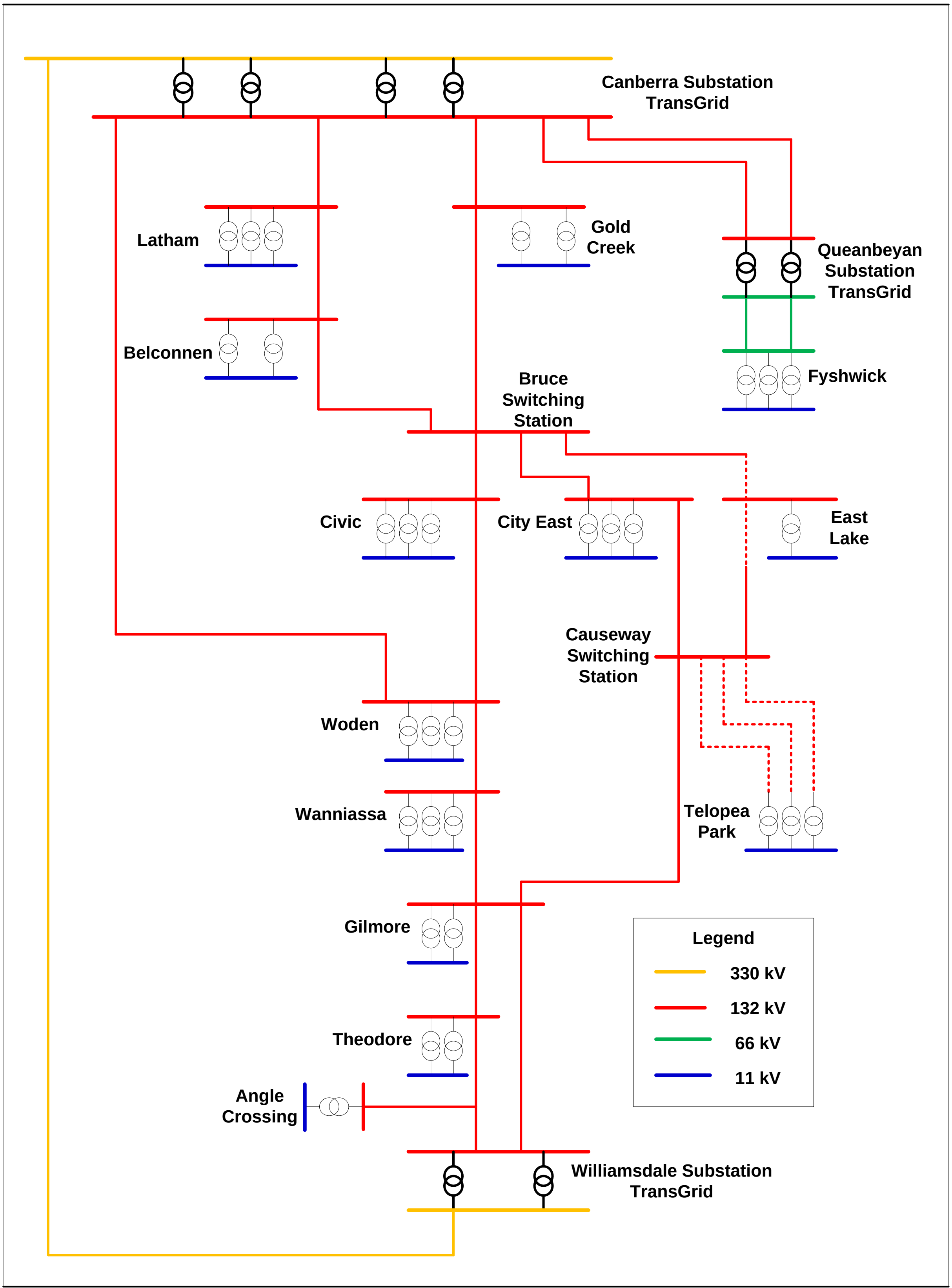
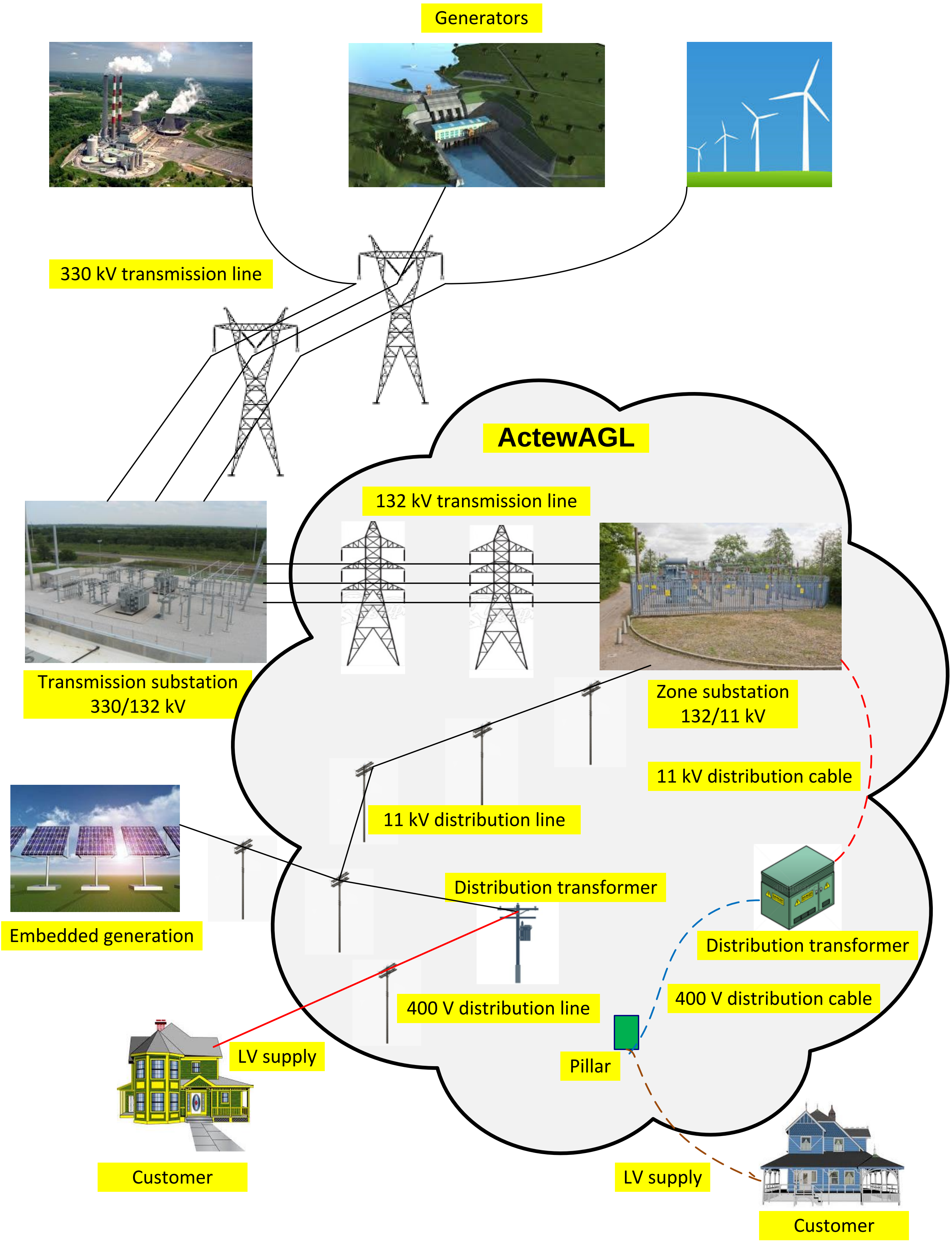


Figure 3.3 illustrates where ActewAGL fits in the supply chain.

Figure 3.3: Electricity Supply Chain



A summary of ActewAGL's major network assets is shown Table 3.1.

Table 3.1: ActewAGL Network Assets

Asset Type	Nominal Voltage	Quantity
Bulk Supply Points	330/132 kV	2
	132/66 kV	1
Transmission Lines	132 kV	189 km Overhead
	132 kV	6 km Underground
Sub-transmission Lines	66 kV	7 km overhead
Switching Stations	132 kV	2
Zone Substations	132/11 kV	11 + 1 mobile substation
	66/11kV	1
Power transformers	132/11 kV	28
	66/11 kV	3
Feeders	22 kV	2
	11 kV	248
22/0.415 kV Substations	22 kV & 400 V	18
11/0.415 kV Substations	11 kV & 400 V	5,079
Number of transmission towers and pole structures	132 kV	917
	66 kV	52
Number of poles	22 kV, 11 kV and 400 V	50,685
Circuit km of distribution overhead lines	22 kV, 11 kV and 400 V	2,365 km
Circuit km of distribution underground cables	11 kV and 400 V	2,946 km
Number of customer connections	22 kV	2
	11 kV	25
	400 V / 230 V	184,935
Coverage area		2,358 km^2
System maximum demand		619 MW
Telecommunications network		Fibre optic and radio

Table 3.2 lists ActewAGL's zone substations, their year of commissioning and their installed power total capacity and firm capacity (N-1 rating).

Table 3.2: ActewAGL's Zone Substations

Zone Substation	Year commissioned	Voltage	Total capacity	Firm capacity	No of transformers
Angle Crossing (mobile substation)	2012	132/11 kV	15 MVA	0 MVA	1
Belconnen	1977	132/11 kV	110 MVA	55 MVA	2
City East	1979	132/11 kV	171 MVA	114 MVA	3
Civic	1967	132/11 kV	165 MVA	110 MVA	3
East Lake	2013	132/11 kV	55 MVA	0 MVA	1
Fyshwick	1982	66/11 kV	75 MVA	50 MVA	3
Gilmore	1987	132/11 kV	90 MVA	45 MVA	2
Gold Creek	1994	132/11 kV	114 MVA	57 MVA	2
Latham	1971	132/11 kV	150 MVA	100 MVA	3
Telopea Park	1986	132/11 kV	150 MVA	100 MVA	3
Theodore	1990	132/11 kV	90 MVA	45 MVA	2
Wanniassa	1975	132/11 kV	150 MVA	100 MVA	3
Woden	1967	132/11 kV	150 MVA	100 MVA	3

3.4. Planning Philosophy

The planning and development process for both transmission and distribution networks, is carried out in accordance with the National Electricity Rules (NER) Chapter 5 Part B Network Planning and Expansion. Planning for the transmission network is carried out in accordance with the NER Section 5.12 Transmission annual planning process and for the distribution network in accordance with the NER Section 5.13 Distribution annual planning process.

The primary objective of planning is to ensure that customers are able to receive a sufficient and reliable supply of electricity now and into the future. ActewAGL's planning standards are set to ensure that peak demand can be met with an appropriate level of backup should a credible contingency event occur. A credible contingency event is the loss of a single network element, which occurs sufficiently frequently, and has such consequences, as to justify the NSP to take prudent precautions to mitigate. This is commonly referred to as an N-1 event. Typically there is a high level of redundancy applied to electricity networks. This reflects the implications of network service failures, noting that communities and businesses have a low tolerance to electricity supply interruptions.

ActewAGL's planning standards are determined on an economic basis but expressed deterministically. ActewAGL uses probabilistic planning techniques when carrying out economic analysis. When assessing the economic benefits of a proposed solution to an issue, we calculate the probability of an event occurring that would result in an interruption of supply to customers. This probability is used as part of the economic analysis to determine whether the benefits of the proposed solution exceed the costs. For example if the supply demand to a part of the network could not be met fully in the event of a contingency, existing assets may be upgraded or new assets may be installed if justified economically. Changes to system losses are included in the economic evaluation of a project.

The early identification, consultation and monitoring of emerging network limitations and prospective network developments is aimed at providing proponents of non-network solutions adequate time to prepare proposals.

ActewAGL's planning approach to addressing load growth or network constraint issues, is to use probabilistic analysis techniques coupled with fully exploring non-network solutions such as demand-side management, before investing in network augmentation. This approach takes into account the combination of demand forecasts, asset ratings and asset failure rates to identify the severity of constraints and the required timing of solutions.

ActewAGL runs a load flow model of the network using a computer software program known as ADMS (Advanced Distribution Management System). This system is linked to our Supervisory Control and Data Acquisition (SCADA) system and obtains and analyses data such as the status of network assets (e.g. positions of circuit breakers), current flows and voltage levels throughout the network, in real time. This system is used to identify issues such as power flow constraints or voltage level issues on the network, and is used to model what-if scenarios such as the effect of a new load or generation connection. Using this tool, ActewAGL is able to identify existing and emerging constraints which form the basis of our asset management and network development plans.

ActewAGL's planning process is an annual process and covers a minimum forward planning period of ten years. The process commences with a comprehensive analysis of all indicators and trends to forecast the future load on the network. A detailed analysis of the network is then carried out to identify performance and capability shortcomings, i.e. constraints.

ActewAGL uses a two hour emergency cyclic rating for all its zone substation power transformers. ActewAGL has adopted the use of two hour emergency ratings and normal cyclic ratings, and uses the ADMS system to regularly record and reassess the cyclic loading capability of zone substation equipment, based on equipment manufacturer's recommendations and relevant Australian and international standards. ActewAGL maintains a high level of zone substation power transformer utilisation by using the two hour emergency cyclic rating, and effective load balancing between zone substations wherever possible. Load balancing is an integral initial solution to network augmentation planning.

Chapter 7 describes the outcomes of our annual planning process. If the augmentation or replacement cost of a proposal exceeds $5 million, we undertake a Regulatory Investment Test in line with the requirements of the NER (section 5.16 for transmission RIT-T and section 5.17 for distribution RIT-D). The purpose of the Regulatory Investment Test is to identify the credible option that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market. A preferred option may have a negative net economic benefit (that is, a net economic cost) where the identified need is for reliability corrective action.

ActewAGL ensures the following prior to committing to any large investment:

- Investments are cost effective and consider whole-of-life costs associated with a new asset.
- Timing of the new investment is such to meet the requirement of the need when it reaches the point that the need cannot otherwise be met.
- Appropriate investment procedures are followed, including business case and Board approval, and execution of RIT-T or RIT-D if required.
- Works are timed to ensure smooth capital and replacement cash flows, and availability of resources.
- Works are coordinated as required with other utilities and/or network service providers, and to meet customer needs.

3.4.1 Deterministic versus probabilistic planning approaches

Planning requirements are generally set as “deterministic” requirements, where rules or standards require investment to meet N (or N-0), N-1 and N-2 contingency criteria, where “N” is a single infrastructure element such as a transformer, transmission line or cable. These criteria basically define the level of reliability and security to which a network is designed. These requirements are intended to ensure that the network can withstand periods of plant outage, without leading to load shedding. The strict use of deterministic planning criteria that consider only supply side options, however, may preclude demand side management options.

Under the “deterministic” planning approach, the timing of augmentations is determined on the basis of peak demand exceeding the planning criteria. If the deterministic planning approach is applied strictly, network investment to augment capacity would be required prior to the year when peak demand exceeds capacity. Deterministic criteria like N-1 and N-2 also assume that network investment occurs in discrete units, with known levels of reliability. It therefore effectively assumes that investment in infrastructure is used to meet planning criteria. This can be a barrier to demand management as demand management projects are not always available in discrete blocks to balance against network investments in infrastructure such as transformers and line upgrades.

The “probabilistic” planning approach is an extension of the deterministic planning approach in the sense that it provides a method of assessing the economic value of network reliability to customers. This can be used as a way to prioritise competing projects. In doing this, probabilistic planning also provides scope for non-network demand management alternatives to reduce load by introducing the economic value of supply for customers, which is the basis for all demand management projects.

Customers will offer demand response capabilities when the reward for demand response is greater than the value they place on that supply. This can include accepting some degree of direct load control or capacity limitation. Deterministic planning criteria, strictly applied, do not facilitate NSPs offering this type of optimisation decision to customers, as it focuses entirely on the level of reliability and security of supply, not the value of that supply to customers. A probabilistic planning framework therefore may offer a different range of opportunities for demand management.

Figure 3.4 illustrates ActewAGL's network planning process.

Figure 3.4: ActewAGL's network planning process

Planning Inputs and Drivers:

Demand forecasts
Security standards
ACT technical regulations
Demand side management criteria
Embedded generation connections
RIT-T and RIT-D processes
Company policies & standards
Financial objectives

Equipment ratings
Reliability standards
Quality of supply
System constraints
Equipment condition reports
Network augmentation criteria
Stakeholder obligations
Strategic benefits

Load transfer capacity
National Electricity Rules
Network performance targets
Customer load connections
Capital approval process
Design manual
Health & Safety
Legal & Statutory obligations

Planning Process:

Load flow studies
Identify emerging constraints
Identify power quality improvements
Joint planning with TransGrid
Prepare Development Applications
Economic analysis – NPV studies
Load forecasting
Strategic alignment

Fault level studies
Identify credible network options
Identify security improvements
Options analysis
Select preferred options
Risks analysis
Capital approval governance
Security of supply

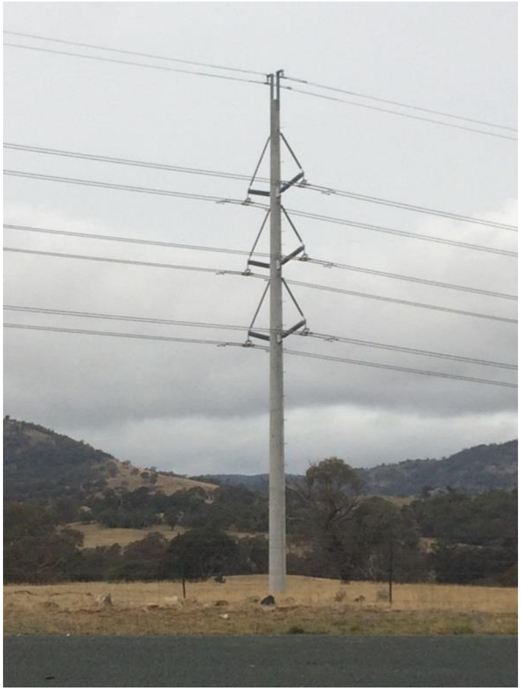
Network capacity analysis
Identify credible non-network options
Identify network reliability improvements
Carry out RIT-T or RIT-D
Prepare business case and project approval
Model/simulate network
Customer consultation
Financial analysis (NPV)

Planning Outputs:

Programme of Works
Zone Substation development reports
Uprate existing assets
Asset renewals & replacements
Meet security & reliability standards
Regulatory Information Notice
Development Application submissions

RIT-T or RIT-D consultation reports
Project technical specifications
Land access & easement agreements
Tender or contract for procurement
Five-yearly regulatory proposal
Network modelling
Non-network solutions

Annual Planning Report
Capital investment approval
Demand-side management contracts
Tender of contract for design & construction
Build new network infrastructure if required
Network augmentation projects
Customer connections



4. Network Performance

4.1. Introduction

This chapter discusses the performance of the ActewAGL electricity network. There are a number of factors that contribute to network performance and these include the following:

- Network reliability which is measured in terms of the number and duration of customer outages.
- Network security which measures the power system's capacity to continue operating within defined technical limits even if a major power system element such as a transmission line or zone substation transformer, fails. Such failures are known as 'credible contingency events'.
- Constraints which restrict access to the network for maintenance purposes without the need to disrupt supply to customers.
- Major system incidents that may have been as a result of structural or geographic weaknesses.
- The level of photovoltaic generation penetration and the ability of the network to cope.
- The condition of the assets making up the network.
- Network fault levels and the ability of the network to cope.
- The quality of the power supply in terms of voltage stability, harmonic content, freedom from flicker, and security from shocks and stray voltages.
- The level of network losses.
- The level of network information systems penetration.
- Any network innovations such as automatic fault isolation and restoration.

4.2. System reliability and performance metrics

ActewAGL's service standards obligations arise mainly from the application of the ACT Utilities (Technical Regulation) Act 2014 (the Act). The Act requires ActewAGL to comply with all relevant industry and technical codes, any directions by the Independent Competition and Regulatory Commission (ICRC) or the ACT Technical Regulator. Relevant codes include the Consumer Protection Code, the Electricity Distribution Supply Standards Code (2013) and the Electricity Transmission Supply Code (2016).

The network reliability measures and standards are adopted from the Supply Standards Code and the referred Australian Standards therein which set out parameters for electricity supply through the ActewAGL network.

The minimum distribution supply reliability standards are detailed in the Supply Standards Code, Schedule 2. Section 6.1 of the Code also specifies that ActewAGL must publish supply reliability targets annually for the following year, which include:

- **SAIDI**: System Average Interruption Duration Index. The ratio of total customer minutes interrupted to total customers served. This is a performance measure of network reliability, indicating the total minutes, on average, that customers are without electricity during the relevant period.
- **SAIFI**: System Average Interruption Frequency Index. The ratio of total customer interruptions to total customers served. This is a performance measure of network reliability, indicating the average number of occasions each customer is interrupted during the relevant period.
- **CAIDI**: Customer Average Interruption Duration Index. The ratio of total customer time interrupted to total customer interruptions. Measured in minutes and indicates the average duration an affected customer is without power. CAIDI = SAIDI/SAIFI.

The reliability targets specified in the Electricity Distribution Supply Standards Code (2013) are shown in Table 4.1.

Table 4.1: Electricity Distribution Supply Standards Code Annual Reliability Targets

Parameter	Target	Units
Average outage duration pa (SAIDI)	91.0	Minutes
Average outage frequency pa (SAIFI)	1.2	Number
Average outage time pa (CAIDI)	74.6	Minutes

ActewAGL has set internal business targets of 32.1 minutes for unplanned SAIDI and 0.62 for unplanned SAIFI within the overall externally set SAIDI target of 91 minutes and SAIFI target of 1.2 in the Electricity Distribution Supply Standards Code.

As previously discussed in Section 2.1.5, the AER introduced on 1 July 2015 a Service Target Performance Incentive Scheme (STPIS) as part of the 2014-19 Regulatory Determination period. The STPIS reliability targets set by the AER for the 2015-19 period for unplanned outages are shown in Table 4.2.

Table 4.2: AER STPIS Reliability Performance Targets for Unplanned Outages:

Year	2015-16	2016-17	2017-18	2018-19
Unplanned SAIDI				
Urban feeder	30.32	30.32	30.32	30.32
Short rural feeder	46.86	46.86	46.86	46.86
Unplanned SAIFI				
Urban feeder	0.585	0.585	0.585	0.585
Short rural feeder	0.895	0.895	0.895	0.895

Table 4.3 shows ActewAGL's actual performance indicator figures for the 2015-16 financial year, for both planned and unplanned outages. Figures for the previous 5 years are included for comparison purposes. Approximately 88.5% of ActewAGL's 11 kV feeders are classified as *urban* with the remaining 11.5% classified as *short rural*.

Table 4.3: ActewAGL Reliability Performance

Key Performance Indicators Distribution Network		Feeder category			Supply Code Overall target
		Urban	Rural Short	Overall network	
SAIDI					
2010-14 average	Overall actual	78.32	88.27	79.40	91.0
	Planned actual	47.47	40.77	46.74	
	Unplanned actual	30.85	47.50	32.66	
2014-15	Overall actual	81.14	85.48	82.56	91.0
	Planned actual	47.33	54.56	49.69	
	Unplanned actual	33.81	30.92	32.87	
2015-16	Overall actual	76.22	56.61	74.01	91.0
	Planned actual	40.49	26.36	38.89	
	Unplanned actual	35.73	30.25	35.12	
	STPIS Unplanned Target for 2015-19	30.32	46.86		
SAIFI					
2010-14 average	Overall actual	0.801	1.079	0.831	1.2
	Planned actual	0.213	0.188	0.210	
	Unplanned actual	0.588	0.890	0.621	
2014-15	Overall actual	0.853	0.762	0.823	1.2
	Planned actual	0.212	0.230	0.218	
	Unplanned actual	0.640	0.532	0.605	
2015-16	Overall actual	0.876	0.725	0.860	1.2
	Planned actual	0.104	0.109	0.185	
	Unplanned actual	0.682	0.616	0.675	
	STPIS Unplanned Target for 2015-19	0.585	0.895		
CAIDI					
2010-14 average	Overall actual	97.82	81.84	95.57	74.6
	Planned actual	223.36	216.30	222.67	
	Unplanned actual	52.46	53.36	52.60	
2014-15	Overall actual	95.20	112.20	100.30	74.6
	Planned actual	223.10	237.20	227.90	
	Unplanned actual	52.80	58.10	54.30	
2015-16	Overall actual	86.97	78.12	86.10	74.6
	Planned actual	208.44	242.43	210.76	
	Unplanned actual	52.38	49.11	52.03	
	No STPIS CAIDI target				

Number of loss of supply events (multi-premise) for the 2015-16 financial year was 698. System minutes off transmission supply for the 2015-16 financial year was 0.

The reliability of supply component of the STPIS scheme will apply financial rewards for each year within the regulatory control period to ActewAGL on the basis of performance relative to targets. The maximum annual revenue at risk for the reliability of supply component is between +5% (upper limit) and –5% (lower limit).

Both SAIDI and SAIFI components exclude major event days such as extreme weather or bushfire conditions.

ActewAGL has various programs underway aimed at improving system reliability. Several of these are associated with asset replacements, for example ground-mounted manually operated oil-insulated switchgear that has reached the end of its economic life is being replaced with remote controlled vacuum-insulated switchgear, and pole-mounted manually operated air-break switches are being replaced with gas-insulated remote controlled switches. The 11 kV network is being developed to reduce the number of radial feeders by installing ties to adjacent feeders. This will improve back-up supply capability and reduce the number of customers affected by a planned or unplanned outage.

Other initiatives to improve reliability such as self-healing networks are being considered with the aid of ActewAGL's Advanced Distribution Management System (ADMS) (refer section 4.10.1).

4.3. System constraints and security

A system constraint is a situation where the power flow through a part of the transmission or distribution network must be restricted in order to avoid exceeding a known technical limit. Examples of technical limits include the thermal rating of conductors or other equipment such as transformers, operating voltage levels, and equipment protection settings. Some constraints can exist under normal operating conditions; however they are most likely to occur when an element (such as a transmission line or distribution feeder) is out of service.

ActewAGL has a meshed 132 kV network in that all 132/11 kV zone substations are connected to two or more 132 kV lines, ie they have N-1 transmission security (refer Figure 3.2). The exception is the Angle Crossing 132/11 kV mobile substation which is connected radially via a 132 kV tee-off. However the load at Angle Crossing is small and a backup 11 kV feeder supply is provided to it from Wanniassa Zone Substation. ActewAGL's sole 66/11 kV zone substation, Fyshwick, is supplied via two single circuit 66 kV lines from TransGrid's Queanbeyan Substation so also has N-1 transmission security.

All 132 kV lines have sufficient capacity to supply full capacity to each zone substation without constraint in the event of an outage of a 132 kV transmission line (refer Appendix D).

The 132 kV network is supplied from two TransGrid 330/132 kV bulk supply substations (Canberra and Williamsdale). As Williamsdale Substation is supplied radially from Canberra Substation at 330 kV, a constraint has been identified jointly by TransGrid and ActewAGL whereby in the event of a total outage of Canberra Substation, supply to ActewAGL's 132 kV network would be interrupted. This issue is to be addressed in the current planning period (refer section 7.5.1).

All zone substations with the exception of East Lake Zone Substation have two or more power transformers (i.e. N-1 transformer security). East Lake Zone Substation has one only 132/11 kV transformer but a second is proposed to be installed in 2019 towards the end of the current regulatory period (refer section 7.5.2). In the interim, in the event of a transformer contingency, supply can be restored via 11 kV feeder ties to Telopea Park and Fyshwick zone substations.

The majority of the 11 kV distribution network is meshed with links between feeders and between zone substations. ActewAGL constantly monitors loads on all feeders and analyses the impact of proposed new connections. Such analysis is done using the Advanced Distribution Management System (ADMS) (refer section 4.10.1). Transfer capability between zone substations via the 11 kV network is carefully monitored and managed, with open points between feeders changed to cater for load growth whilst avoiding constraints such as thermal loading of conductors.

As the majority of generation and bulk transmission is located externally to the ACT, system frequency is not able to be controlled by ActewAGL. However in the event of a major system event such as a large generator or 330 kV transmission line contingency, frequency could drop below the normal operating frequency excursion band. Under clause 4.2.6 (c) of the NER, in such an event all affected TNSPs and DNSPs must be able to shed load quickly until frequency is restored to avoid the problem escalating. NER clause 4.3.1 (k) specifies that a DNSP must be able to shed up to 60% of its total load during an under-frequency event to allow for prompt restoration or recovery of the power system. ActewAGL is in the process of installing under frequency load shedding (UFLS) relays at all of its zone substations, to trip feeders according to a set hierarchy (i.e. feeders supplying critical loads such as hospitals would be the last to be tripped).

ActewAGL's network operations control centre is located at Fyshwick. ActewAGL has a disaster recovery facility (DRF) at Civic Zone Substation. The DRF is basically a backup control centre with full SCADA and remote control facilities. Should a failure of the main control centre occur, the system could continue to be operated fully and securely from the DRF.

4.4. Significant system events

A significant event on ActewAGL's network is classified as an unplanned outage that results in more than two SAIDI minutes (equivalent to all of our customers, on average, having their power supply interrupted for two minutes or longer). Such events are usually the result of major equipment failure, major weather events, or major bushfire events. Two significant systems events occurred during the 2015-16 financial year on 31 December 2015 and 21 January 2016.

4.5. Photovoltaic penetration

Domestic rooftop photovoltaic (PV) generation systems are currently installed on approximately 8.6% of homes in the ACT. These vary in size from 1 kW – 10 kW capacity. The level of penetration is increasing steadily due to a number of reasons that include:

- Cost of PV systems is decreasing as more units are produced (i.e. reduced manufacturing costs) and more suppliers are competing for this market.
- Some developments (notably Denman Prospect Estate) have mandated that PV systems must be installed on all new detached dwellings to be constructed.
- Modern homes are being built with a PV system incorporated into the original design which avoids the costs associated with retrofitting later.
- The climate in the ACT is conducive to PV with long sunshine hours annually.
- The ACT Government is promoting its 100% renewable energy target and encouraging the installation of PV systems.
- Increased awareness of the public to climate change issues and the benefits of renewable energy.

Photovoltaic penetration in the ACT is widespread as shown in Table 4.4 and Appendix E.

Table 4.4: Photovoltaic penetration by zone substation (excluding network level PV)

Zone Substation	Number of PV installations	Total capacity installed (W)
Angle Crossing (mobile substation)	0	0
Belconnen	1,496	4,597,542
City East	1,127	3,579,882
Civic	772	2,324,482
East Lake	14	297,680
Fyshwick	34	454,688
Gilmore	911	3,013,907
Gold Creek	2,456	7,488,308
Latham	2,859	8,540,481
Telopea Park	651	2,291,803
Theodore	1,440	4,331,358
Wanniassa	2,982	8,897,710
Woden	2,344	7,689,273
TOTAL	**17,476**	**53,507,110**

4.6. Ageing assets

Electricity transmission and distribution networks are constructed of a range of asset types that all have their own maintenance, refurbishment and replacement life cycles.

Primary assets, those with the purpose of transmitting and distributing energy, such as poles, conductors and transformers, generally have an asset standard design life of around 45 – 60 years before requiring replacement.

Secondary assets, those with the purpose of measuring, monitoring, controlling, communicating and providing protection for primary assets, generally have an asset standard design life of around 15 – 20 years.

ActewAGL has prepared Asset Specific Plans for each class of asset, and from these plans has developed maintenance programs for each asset for its whole life cycle, including condition monitoring, periodic maintenance, renewal and leading to its ultimate replacement (refer Chapter 6).

Before replacing an asset such as a distribution substation, ActewAGL reviews its network plan for that location. In some cases, load growth (or reduction) may deem it more appropriate to replace with a larger or smaller distribution substation rather than simply a like-for-like replacement. In this way ActewAGL integrates its planning to coordinate asset management spending with network development spending to provide the most appropriate and cost effective solutions.

Assets are replaced as a result of a condition assessment, i.e. an asset is not just replaced because it has reached its 'retirement age'. It is replaced because its future maintenance costs exceed its replacement plus net present value costs.

ActewAGL's network comprises long life assets. It is essential that we invest in growth, replacement and maintenance works to ensure we continue to deliver a highly reliable and safe network for our customers and the community.

During 2015-16, our customers benefited from further improvements in the management of our network assets. We remained focussed on optimising our investments in network augmentation and asset replacement and maintenance to ensure these investments were necessary and well-targeted.

ActewAGL has made significant investments to improve supply quality and reliability but also to ensure the most cost-effective asset management strategy is adopted. The vast majority of expenditure directed to the replacement of ageing assets is for electricity network assets. Typical of these works is the replacement of aged 132 kV SF6 gas-insulated circuit breakers with modern SF6 insulated models (which require a lower volume of SF6 gas). During the 2015-16 financial year ActewAGL replaced four 132 kV circuit breakers; two at City East Zone Substation, one at Belconnen Zone Substation and one at Bruce Switching Station. This program will continue during the 2016-17 financial year with a further two circuit breakers to be replaced at the Bruce Switching Station site, and another two circuit breakers in 2017-18. Each circuit breaker replacement costs approximately $300,000.

In the past year, ActewAGL has replaced approximately 1836 m of 400 V distribution cables of concentric neutral solid aluminium conductor (CONSAC) type in the Canberra suburbs of Scullin, Chapman, Kambah and Rivett. A further 465m of this cable type will be replaced in 2016-17 in Garran. This cable type is obsolete and has caused reliability issues in recent years. These cables have been replaced with XLPE (cross linked polyethylene) - insulated cables.

The ActewAGL network includes approximately 52,000 poles, the majority of which are wooden and subject to gradual rotting and subsequent loss of strength. All poles are inspected and assessed on a rotating annual program. Strengthening works such as nailing or attaching steel armour guards are carried out to prolong the life of wooden poles. Low voltage poles are replaced with two-part fibreglass poles in locations that are difficult to access (typically urban residential property back yards), while high voltage and transmission poles are generally replaced with pre-stressed spun concrete poles.

ActewAGL invested $15.9 million in electricity network maintenance programs during the 2015-16 financial year. Consistent with our shift to reliability-centred maintenance, our overall investment in planned maintenance and condition monitoring activities on the electricity network was $9.6 million (28 per cent of overall operating expenditure on the networks). In our electricity network, we undertook approximately 11,000 pole inspections and condition assessments on other network elements such as underground cables, transformers, circuit breakers and switches.

Managing vegetation encroachment on our overhead electricity distribution system continues to be a key area of focus to mitigate risk to safe and reliable supply. We continue to work closely with the ACT Government to increase legislated vegetation clearance requirements and improve the effectiveness of urban vegetation management.

The following diagrams show the age distribution of ActewAGL's assets as follows:

Figure 4.1 Poles
Figure 4.2 Overhead conductors
Figure 4.3 Underground cables
Figure 4.4 Transformers
Figure 4.5 Service Lines
Figure 4.6 Switchgear
Figure 4.7 SCADA, control and protection equipment

Figure 4.1 - Pole Assets - Quantity Currently in Service by Age and Material

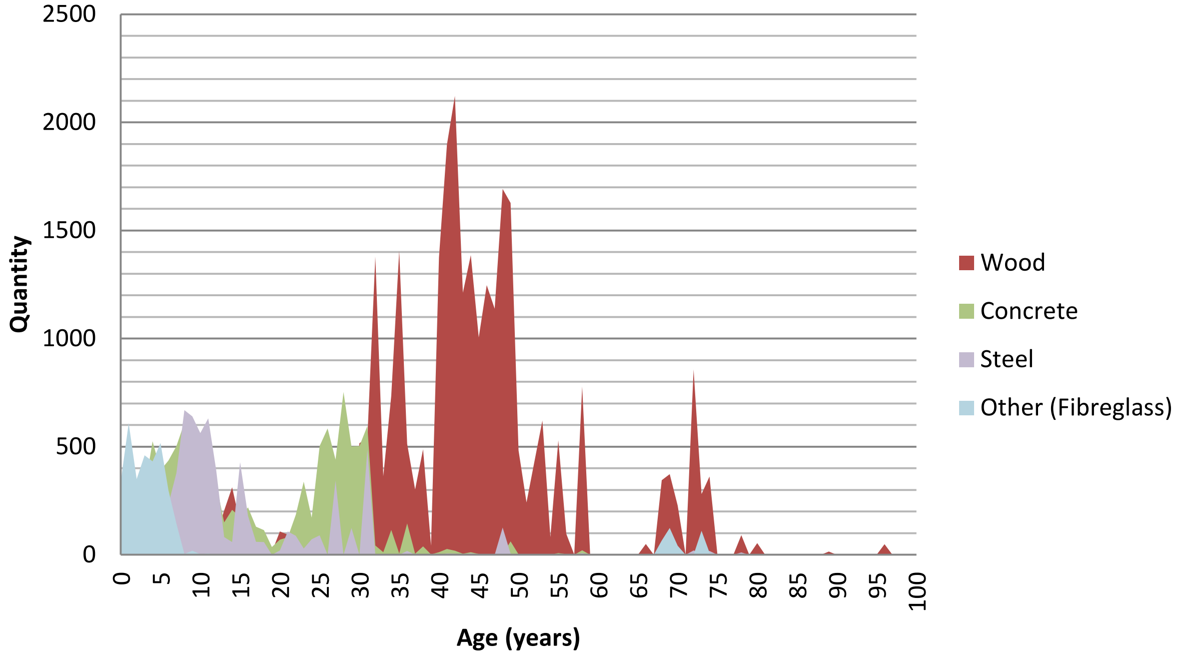
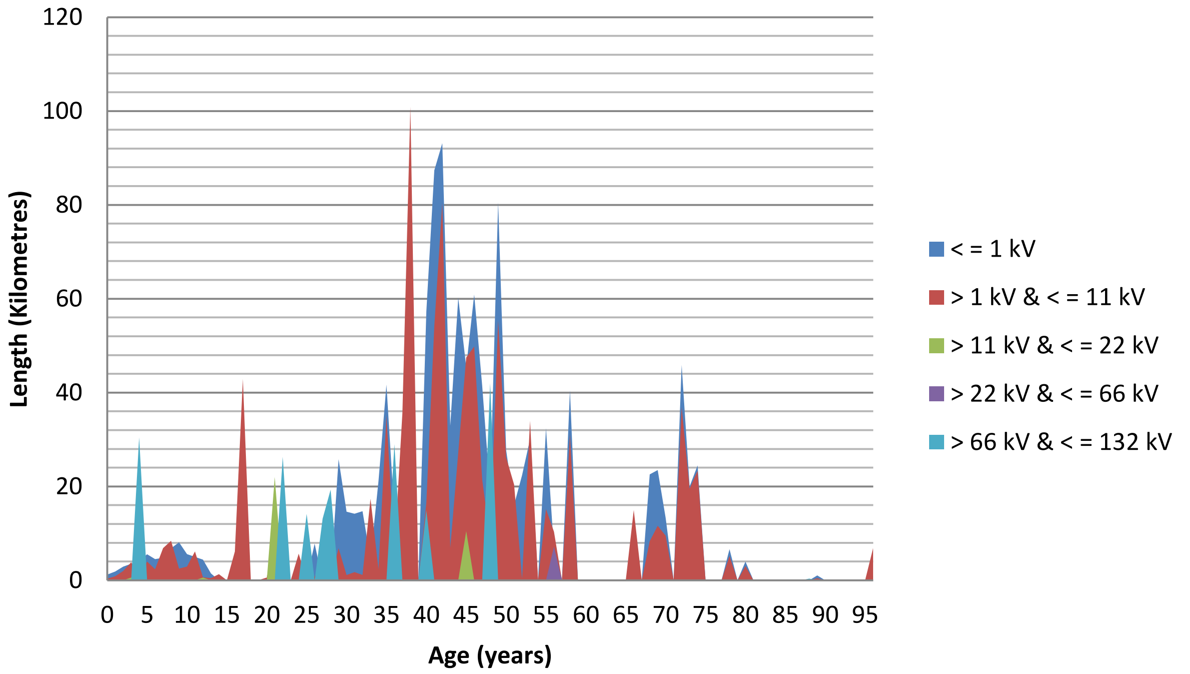


Figure 4.2 - Overhead Conductor Assets - Quantity Currently in Service by Age and Voltage



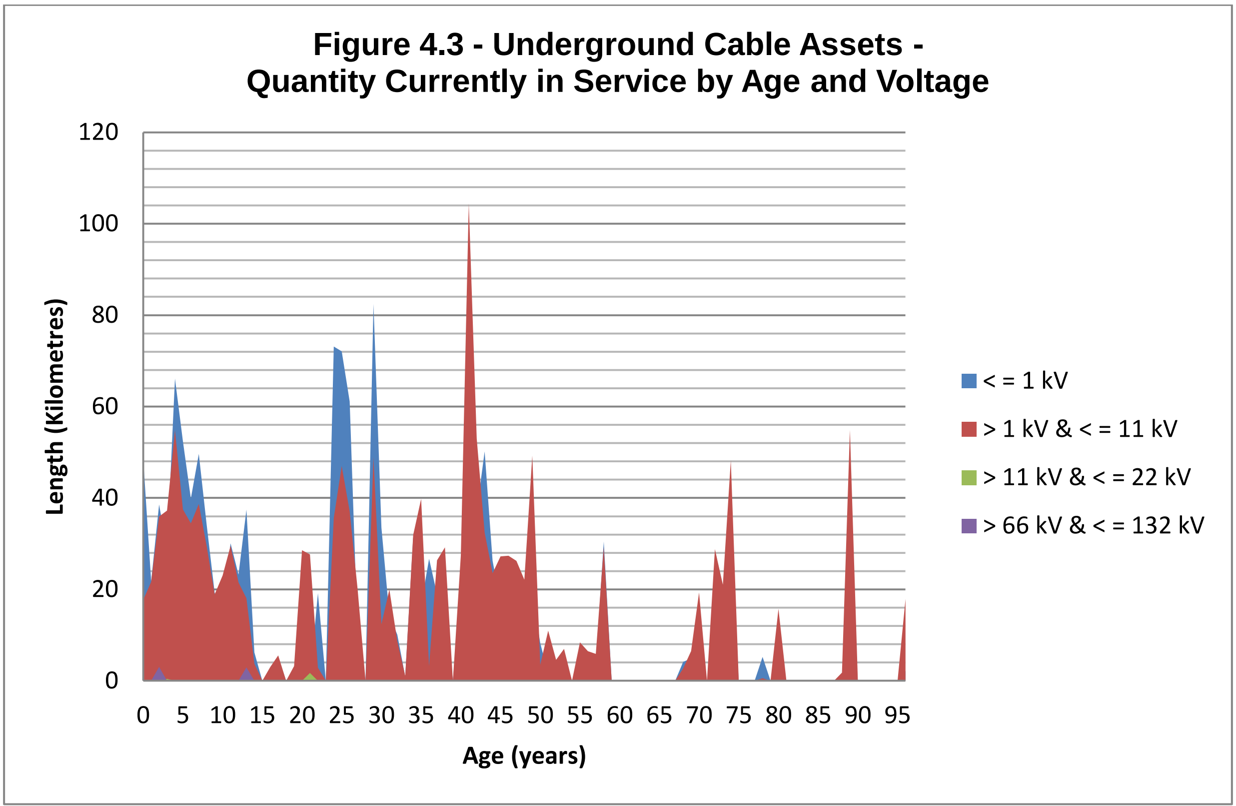


Figure 4.3 - Underground Cable Assets -
Quantity Currently in Service by Age and Voltage
Length (Kilometres)
0
20
40
60
80
100
120
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
Age (years)
< = 1 kV
> 1 kV & < = 11 kV
> 11 kV & < = 22 kV
> 66 kV & < = 132 kV

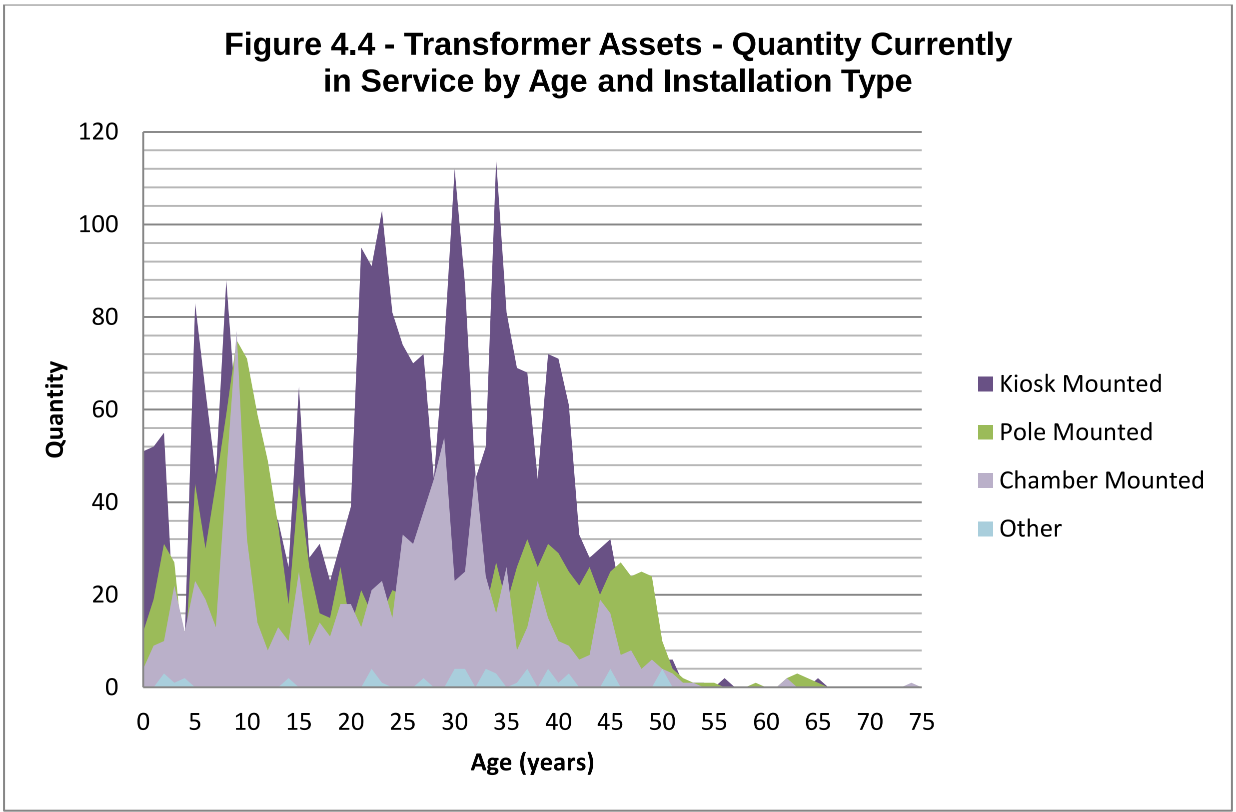


Figure 4.4 - Transformer Assets - Quantity Currently
in Service by Age and Installation Type
Quantity
0
20
40
60
80
100
120
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Age (years)
Kiosk Mounted
Pole Mounted
Chamber Mounted
Other

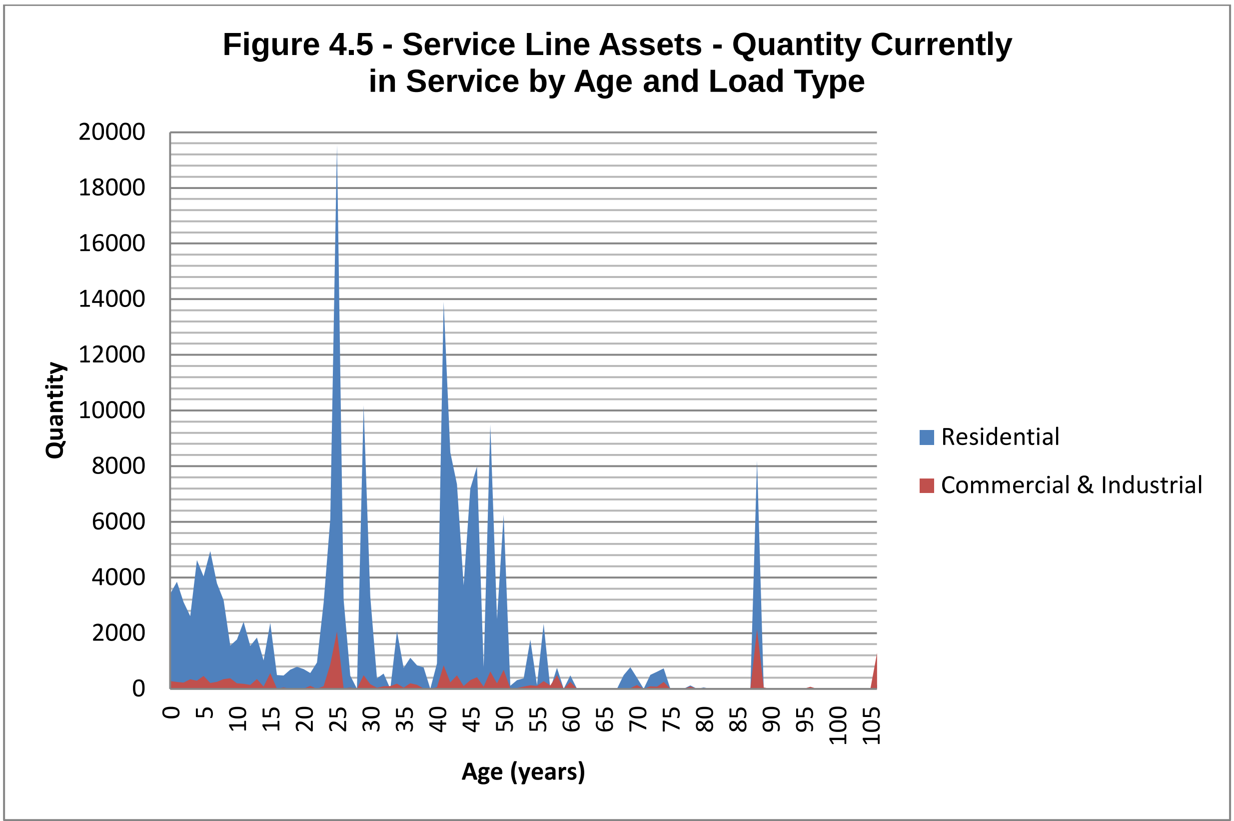


Figure 4.5 - Service Line Assets - Quantity Currently in Service by Age and Load Type
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Quantity
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
Age (years)
Residential
Commercial & Industrial

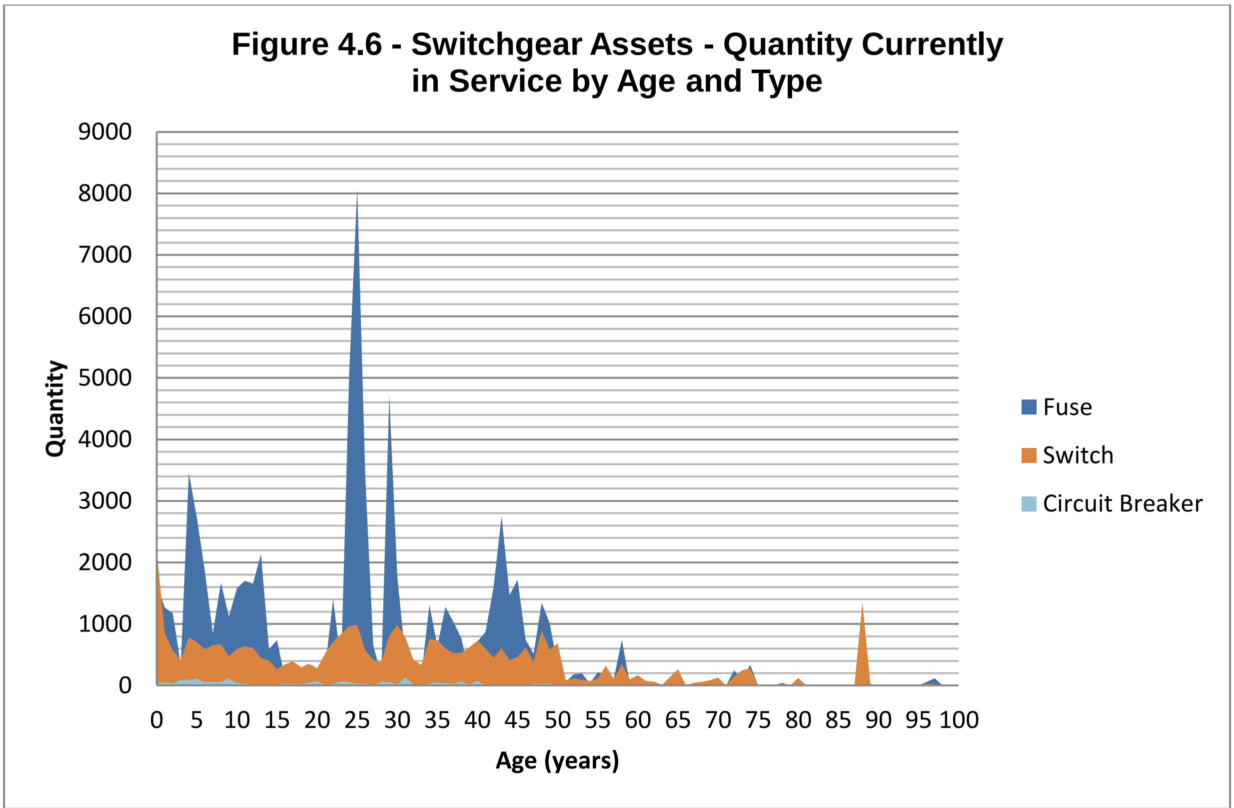
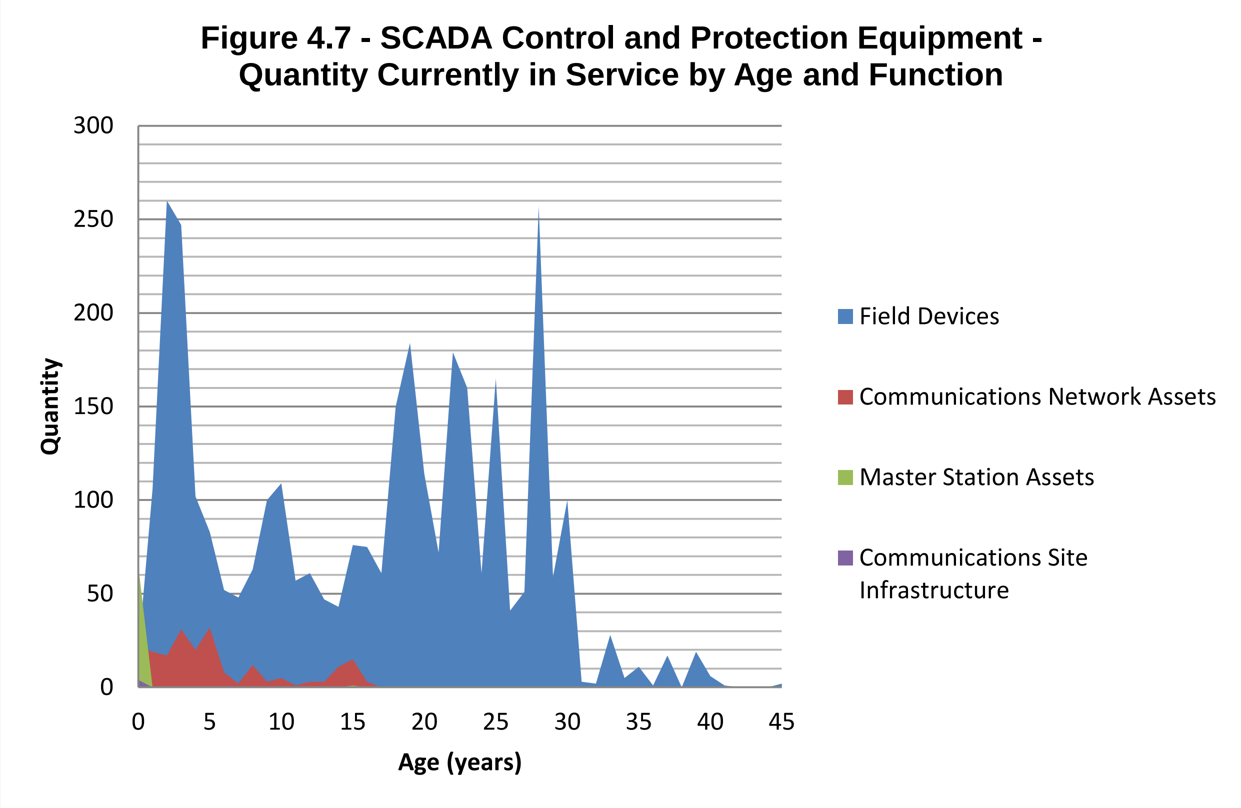


Figure 4.6 - Switchgear Assets - Quantity Currently in Service by Age and Type
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Quantity
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Age (years)
Fuse
Switch
Circuit Breaker



The ActewAGL network has a large number of wooden poles, overhead conductors and underground cables that have been in service for 40 years or more. These assets will be monitored over coming years regarding their condition and risk of failure. Annual replacement programs may need to be increased as more assets reach the end of their economic service lives.

The distribution transformer population is relatively modern, although there are a large number of pole-mounted and kiosk transformers over 30 years of age.

The age profile of switchgear is fairly even, however there are a small number of 11 kV and low voltage switchboards nearing end of life.

The majority of secondary protection and SCADA equipment has an effective life of approximately 15–20 years.

ActewAGL uses the Risk Centred Maintenance approach (as outlined in the Asset Management Objectives), to plan and carry out the replacement of aged assets.

4.7. Fault level

Fault level is defined in terms of current (kA). The fault current is the maximum current that would flow at that point in the network should a short circuit fault occur. Major equipment elements such as circuit breakers, switchgear, cables and busbars are specified to withstand the maximum possible fault level. Fault level is also an indication of a power system's "strength". Higher fault current levels are typically found in a strong power system, while lower fault current levels indicate a weaker power system. A strong power system exhibits better voltage control in response to a system disturbance, whereas a weak power system is more susceptible to voltage instability or collapse.

High voltage overhead lines that are insufficiently fault rated may cause the conductors to clash, sag below minimum ground clearance, or even break when subjected to a fault current. Such situations can occur when network augmentations such as the construction of a new zone substation increase the fault levels in the distribution network.

Conversely increasing amounts of power electronic converter generation (e.g. PV generation) connected to the network, replacing synchronous generation, serves to reduce fault levels and consequently reduce system strength.

ActewAGL specifies new 11 kV equipment to be capable of withstanding 25 kA three-phase short circuit fault current. Maximum 11 kV fault level on the network has been calculated at approximately 12.2 kA.

ActewAGL specifies new 132 kV equipment to be capable of withstanding 31.5 kA three-phase short circuit fault current. Maximum 132 kV fault level on the network has been calculated at approximately 24.0 kA.

4.8 Power quality

Power quality refers to the network's ability to provide customers with a stable sinusoidal waveform free of distortion, within voltage and frequency tolerances.

Power quality issues manifest themselves in voltage, current or frequency deviation, which result in premature failure, reduced service life or incorrect operation of customer equipment.

The NER Schedules 5.1a, 5.1 and 5.3 detail the applicable power quality design and operating criteria that must be met by ActewAGL. ActewAGL's Service and Installation Rules describe the applicable power quality design and operating criteria that must be met by our customers.

Electricity customers have ever-increasing expectations and are becoming less tolerant of power quality and reliability issues. Some modern appliances are not suited to events that occur on distribution networks due to their sensitivity and design.

At all voltages in ActewAGL's network, the quality of supply is maintained to provide a safe and secure source of electricity to our customers.

Power quality is measured by the installation of mobile power quality analysers in various locations on the distribution network. Measurements are taken on both a proactive and reactive basis.

Optimisation of network power quality enhances asset lifetimes due to reductions in operating stresses (e.g. lower transformer iron losses and resultant heating from harmonic voltage distortion).

ActewAGL has a proactive program to survey power quality across our 11 kV distribution network. This program features the following:

Proactive Quality of Supply Survey Program:

- A rotational program across a 10 year period.
- Approximately 25 feeders are tested per year.
- For each feeder, measurements are made at the first distribution substation from the zone substation and the last distribution substation on the feeder.
- For each site, measurements are taken at the distribution substation and at a single installation on an LV circuit supplied by the distribution substation.
- This provides ActewAGL with a network-wide picture of power quality through a structured rotational program.
- The program provides quality of supply data for the highest and lowest voltage points of the selected HV feeders and LV circuits, with the effects of embedded generation in these circuits being addressed by ActewAGL's embedded generation guidelines.
- Parameters measured include steady state voltage, harmonics, power factor, voltage dips and swells.

This program is compliant with AS.61000.4.30 - Testing and measurement techniques - Power quality measurement methods.

During the 2015-16 financial year, in addition to routine pro-active power quality monitoring, ActewAGL investigated and resolved 42 power quality enquiries from customers including:

- 28 high voltage.
- 1 low voltage.
- 9 fluctuating voltage.
- 4 radio interference or EMF.

4.8.1 Steady State Voltage

Voltage levels at customers' premises must be supplied and maintained within regulation limits to ensure correct operation of appliances and safety to equipment and personnel.

Voltage levels on the 132 kV bus at Canberra and Williamsdale bulk supply substations, is controlled by TransGrid via its 330/132 kV interconnecting transformers' on-load tap changers (OLTCs) and 132 kV capacitor banks. Similarly the 66 kV bus voltage at Queanbeyan bulk supply substation is controlled by TransGrid.

The 11kV bus voltage at each zone substation is maintained by the voltage-regulating relay which controls the tap position of the 132/11kV transformers. In order to maintain the voltage within limits along the 11 kV feeders, the bus voltage is varied according to network conditions (loading, incoming voltage, feeder voltage drops etc.).

ActewAGL is currently installing TNSP metering on the 11 kV group circuit breakers at all 132/11 kV zone substations. In addition to providing metering functions, these meters provide accurate voltage measurements and other power quality information to the ADMS in real time.

ActewAGL monitors steady state voltage levels and responds to customer complaints where required. ActewAGL shall use the implementation of the ADMS and the application of smart metering technology to further ensure compliance of steady state voltage levels. ActewAGL has recently reviewed its embedded generation connection guidelines to address the impact of embedded generation on network supply voltage. Documents "Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network" and "Technical performance requirements for the connection of large scale embedded generators to ActewAGL's network" can be accessed from ActewAGL's external website.

Steady state phase-neutral low voltage at the customer's point of supply is maintained at 230 V +10% / -6% in accordance with Australian Standards AS/NZS 60038 and AS/NZS 61000.3.100.

4.8.2 Rapid Fluctuations in Voltage (Flicker)

Voltage fluctuations are defined as repetitive or random variations in the magnitude of the supply voltage. The magnitudes of these variations do not usually exceed 10 per cent of the nominal supply voltage, however small magnitude changes occurring at certain frequencies can give rise to an elect known as flicker. Voltage fluctuations may cause spurious tripping of relays, interference with communications equipment, and may trip electronic equipment.

Flicker is usually customer-generated due to the following:

- Frequent starting of induction motors – mainly the direct on line starting of induction motors.
- Electric welders.
- Arc furnaces.

ActewAGL responds to a customer report of flicker by installing a mobile power quality analyser. ActewAGL advises the customer if the flicker is due to its operations, or rectifies if caused by ActewAGL's equipment.

Maximum permissible voltage flicker levels are specified in Australian Standard AS/NZS 61000.3.7:2001.

4.8.3 Voltage Dips

Voltage dips are typically caused by events such as lightning or faults on adjacent feeders, or are generated by equipment located within customers' premises (e.g. induction motor starting).

Dips caused by faults on adjacent feeders can propagate throughout the network, affecting customers' supply voltage on all feeders at the zone substation. Although only customers on the faulted feeder experience an interruption, many experience the reflected voltage sags generated by the fault.

ActewAGL monitors voltage dips as part of its power quality monitoring program. ActewAGL uses its SCADA system and protection records to analyse events and uses its mobile power quality analysers to assist in the analysis and rectification of voltage dips. ActewAGL shall use the implementation of numerical protection devices and the ADMS to further reduce the overall number of voltage dips on the network. ActewAGL proposes to review fault switching and investigate the use of auto-reclosers, sectionalisers and fault passage indication devices to reduce fault switching.

4.8.4 Switching Voltage Transients

Switching transients are primarily associated with the operation of circuit breakers and are typically the consequence of the switched current being extinguished prior to the natural current zero value of the sinusoidal current waveform. This characteristic is termed as current chopping.

The chopping of the current results in transient voltages being generated which enter and travel through the interconnected network. Switching transients can also be generated by the switching of lumped capacitances (e.g. capacitor banks).

Switching transients are typically high frequency, short duration voltage conditions (mainly overvoltage conditions) which can result in damage to sensitive equipment.

ActewAGL shall manage switching transient voltages through switchgear procurement standards (i.e. utilising switching equipment that has small chopping current characteristics) and asset specific maintenance regimes, and routine maintenance programs designed to avoid excessive switch contact arcing.

4.8.5 Voltage Difference Neutral to Earth

Voltage differences between neutral and earth can present the risk of damage to electrical equipment at customers' premises as well as a risk of electric shock and fire. Typically voltage differences can be caused by such things as:

- Inadequate earthing (high earth resistance or open circuit earth) at substations.
- Inadequate bonding of earth and neutral in Multiple Earth Neutral (MEN) systems.

ActewAGL adheres to the relevant distribution substation earthing requirements and advises customers of correct earthing practices. ActewAGL includes neutral to earth monitoring as part of its power quality monitoring program to assist with classifying neutral to earth voltage non-compliance.

Target voltage difference between neutral and earth is < 10 V steady state (5 minute average) at the point of supply.

4.8.6 Earth Potential Rise

Earth potential rise refers to the localised increase in the voltage of an object that should remain at earth potential, and is typically caused by a fault current passing through an earth connection that is inadequate for the magnitude of the fault current. This can be due to:

- Inadequate sizing of the earth conductor relative to the maximum fault current.
- High impedance between the earth conductor and the mass of earth (true earth).

Under such conditions the passage of the fault current through the inadequate earth connection will result in a voltage increase on the earth connection for the duration of the fault. This condition can present risk of electric shock to a person who may be standing on “true earth” but is in contact with the inadequately earthed device. It can also result in damage to sensitive equipment.

ActewAGL complies with earth potential rise requirements by basing its network designs on reference publications[2]. ActewAGL’s system is designed to ensure that step and touch voltages arising from earth potential rise are within the allowable limits of Australian Standard AS/NZS 7000. ActewAGL inspects the earth connections on its system on a five-yearly program.

4.8.7 Voltage Unbalance

Voltage unbalance typically results from:

- Unbalanced phase impedances.
- Unbalanced phase loadings.
- Interaction between phases (induced voltages) on overhead lines.

Unbalanced voltages can result in high neutral currents which introduce the potential for high neutral to earth voltage difference, and the generation of negative sequence voltages that can damage three-phase induction motors.

ActewAGL manages voltage unbalance within the required limits through appropriate design practices and transformer procurement specifications. ActewAGL uses its mobile power quality analysers and quality of supply survey procedures to identify and rectify voltage unbalance. This is supported through the use of ADMS calculations to ensure compliance.

4.8.8 Direct Current (DC) Component

A high DC component of the neutral voltage can cause damage to electronic devices and impact on the correct operation of protective devices. It can also lead to an increase in losses and result in heating within electrical and electronic equipment.

ActewAGL ensures that customer’s inverters connected to the network adhere to the relevant standards and regulatory requirements. ActewAGL has recently published on its external website a guideline entitled “Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network”. This includes the requirement that inverters must comply with the requirements of the Clean Energy Council (CEC) and Australian Standard AS/NZS 4777.2:2015 (Grid connection of energy systems via inverters).

4.8.9 Harmonics

Harmonics are usually customer-generated. Non-linear loads such as industrial equipment (e.g. arc welders), variable speed drives, uninterruptible power supplies, and office equipment, are all sources of harmonic currents. Harmonic currents flowing in transformers cause an increase in the copper (resistive) losses and iron (magnetising) losses. Harmonic distortion can cause the supply voltage waveform to depart from sinusoidal in a repetitive manner. This can affect the operation of computer equipment, create noise on radio and television receivers, and cause vibration in induction motors.

ActewAGL responds to customer requests to measure and analyse harmonic levels. ActewAGL uses its mobile power quality analysers and undertakes harmonic monitoring as part of its power quality surveys. ActewAGL is currently investigating the use of the ADMS to identify areas of the network where harmonic levels are outside regulation limits and explore the potential of real-time harmonic monitoring at zone substations.

[2] ENA EG-O Power System Earthing Guide
ENA EG-1 Substation Earthing Guide
AS 3835 – EPR – Protection of Telecommunication Network
AS/NZS 4853 – Electrical Hazards on Metallic Pipelines

Customers must ensure that harmonic distortion caused by their equipment does not exceed the limits prescribed in Australian Standard AS/NZS 61000 parts 3.2, 3.4 and 3.12.

4.8.10 Electromagnetic Fields (EMF)

Electromagnetic fields are a key design consideration for bare electrical conductors such as overhead lines and bus-work, particularly those which operate at high voltage. For conductors with an earth shield, such as underground cables, the fields are encapsulated within the cable and do not present external hazards.

Electromagnetic fields incorporate both electric fields resulting from the voltage on conductors and also the magnetic fields generated by the current flowing in the conductors. Both phenomena result in a "grading" of the respective fields from the conductor to the nearest earth location. In terms of voltage there will be a voltage "gradient" between the conductor and earth. In terms of current there will be a grading of the magnetic field (flux density) from the conductor to the earth.

Depending on the strength of these fields minute currents can be induced in the bodies of animals and humans. Research is inconclusive at present but there are concerns as to the health implications of exposure to electromagnetic fields. As such there are strict guidelines for the management of electromagnetic fields incorporated into the design of overhead lines and high current equipment.

The Energy Networks Australia (ENA) Association has published an EMF Management Handbook (January 2016)[3] which describes EMF's in detail and methods to mitigate magnetic fields. ActewAGL follows these guidelines where practicable and complies with the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Guidelines in the design of its network with respect to electromagnetic fields.

4.8.11 Inductive Interference

Inductive interference refers to the ability of the magnetic fields generated by current flowing in typically overhead line conductors, to cause interference with other electromagnetic radiation such as radio, television and communication signals.

ActewAGL shall continue to undertake routine maintenance programs to ensure all equipment is in good working condition, in particular all HV and LV overhead lines, to ensure that inductive interference is within the limits specified in Australian Standard AS/NZS 2344:2007 (Limits of electromagnetic interference from overhead AC power lines and high voltage equipment).

4.8.12 Power Factor

Power factor relates to the relationship between real and reactive power. In an alternating current (AC) system the in-phase portions of voltage and current waveforms produce "active" or real power which is the capacity of the electricity system to perform work. The out of phase portions of voltage and current waveforms produce "reactive" power. The combination of active and reactive power is termed apparent power. A low or poor power factor will result in inefficiency due to high apparent power loading with a low real power delivery.

ActewAGL monitors power factor as part of its programmed proactive and reactive monitoring of the network. ActewAGL uses the ADMS to identify areas of the network that may be experiencing power factor issues. Metering data is also used to identify installations with power factor outside acceptable limits.

Customers can gain significant benefits by improving the power factor at their premises. These benefits include reduced electricity costs, increased plant load capacity and utilisation, and better voltage regulation. Improvement of power factor is usually achieved by the installation of capacitors.

[3] http://www.ena.asn.au/sites/default/files/emf_handbook_2016

ActewAGL requires that the power factor at the point of common coupling between ActewAGL's network and the customer's installation shall be between 0.9 lagging and unity. Leading power factor is unacceptable. Details can be found in ActewAGL's Service & Installation Rules for Connection to the Electricity Distribution Network which can be found on our external website.

4.8.13 Summary of Power Quality Standards, Codes and Guidelines

A summary of the power quality standards, codes and guidelines applicable to the ACT is as follows:

NER Schedule 5.1a – System Standards.
NER Schedule 5.1 – Network Performance Requirements to be provided or co-ordinated by Network Service Providers.
NER Schedule 5.3 – Conditions for Connection of Customers.
AS/NZS 3000:2007 – Australian/New Zealand Wiring Rules.
AS/NZS 7000:2016 – Overhead Line Design.
AS/NZS 61000 – Electromagnetic Compatibility (various sub-standards).
AS/NZS 2344:2007 - Limits of electromagnetic interference from overhead AC powerlines and high voltage equipment installations in the frequency range 0.15 to 1000 MHz.
HB 264:2003 – Power quality handbook.
AS/NZS 4777.2:2015 Grid connection of energy systems via inverters.
ActewAGL Service & Installation Rules for Connection to the Electricity Distribution Network.
ActewAGL Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network.

4.9 System Losses

As power flows through the transmission and distribution networks, a portion is lost due to the electrical resistance and heating of the conductors and transformers. Across the network these losses may be up to 3%–5% of the total energy transported. These losses are allowed for throughout the transmission and distribution networks to ensure that supply meets demand and the power system remains secure, ie more electricity is generated than is consumed by customers.

Distribution Loss Factors (DLFs) represent the average energy loss between the distribution network connection point and the transmission network connection point to which it is assigned.

ActewAGL periodically reviews open points on the network, to enable the network to be reconfigured to reduce losses. This includes load balancing between zone substation transformers.

The cost of electrical losses is factored into the assessment of tenders for new distribution and zone substation power transformers. The life cycle cost assessment ensures that the capital cost is not the dominant factor in the assessment of transformer tenders. The methodology takes into account the estimated losses over the life of the transformer ensuring better energy efficiency and environmental outcomes.

Electrical losses in the network are proportional to the square of the current. Having a higher power factor results in a lower current, for the same amount of useful energy, and therefore reduces network losses. Maximum demand and capacity charges, if they are effective in reducing peak load on the network, will also result in reduced currents and therefore reduced network losses.

Under the NER section 3.6.3, ActewAGL is required to calculate and publish the distribution loss factors on its network. Publishing of the loss factors improves transparency of the network loss performance to retailers and customers. ActewAGL has engaged GHD Hill Michael Consultants to calculate distribution loss factors for both site specific customers (embedded generators with output greater than 10 MW and load customers with maximum demand greater than 10 MW) and average DLFs for non-site specific customers. The entire population of high voltage distribution feeders was analysed for these calculations. ActewAGL's Advanced Distribution Management System (ADMS) was used to calculate the DLFs. This system allows for the entire distribution network from zone substation transformers to distribution transformers to be modelled. All network elements have known loss characteristics including copper and iron losses for both zone and distribution transformers and impedance and length of all conductors.

Losses on the 132 kV transmission network are calculated using a PSS Sincal transmission network model.

The effects and costs of distribution losses are included in the system planning analysis and investment strategy as inputs to determining any augmentation required to the system capacity to maintain the supply-demand balance.

4.10 Information Technology

ActewAGL has recently completed the implementation of two major IT replacement programs:

1. Core Systems Replacement Program; and
2. Operational Systems Replacement Program.

The Core Systems Replacement Program (CSRP) upgraded key Information and Communications Technology (ICT) systems to increase operational efficiency across the business.

The CSRP was made up of three projects that upgraded systems used in Finance, Human Resources and Distribution Billing and included:

- Financial Information Management Systems project; and
- Human Resources Management Information System project.

The purpose of the Operational Systems Replacement Program (OSRP) was to develop an Operational Technology (OT) and Information Technology (IT) roadmap for the business that is suited to an asset intensive organisation that manages linear assets. It is based on a geo-spatial OT environment that is tightly incorporated with the corporate IT environment and based on commercially available applications.

The overall capital expenditure on the replacement program for Operational System applications and enhancements amounts to approximately 4.1% of the total capital budget over the 4 years from 2016-17 to 2019-20.

The following OT business systems have been implemented to improve ActewAGL's operational performance, improve system reliability, improve response to unplanned outages, improve the efficiency of maintenance activities, and to reduce business costs:

- Advanced Distribution Management System
- ArcFM Designer
- Cityworks
- Riva
- Velocity

4.10.1 Advanced Distribution Management System

ActewAGL has recently implemented an Advanced Distribution Management System (ADMS) which has replaced the old Electricity Network Monitoring and Control system (ENMAC). This is a software package that is used to monitor and control the operation of ActewAGL's network. Installed on a dedicated computer network, the system supports network analysis, optimisation, planning and training. ADMS will be used in future to model the effects of increased embedded generation such as rooftop PV, increased use of electric vehicle charging stations, the introduction of battery storage systems and an electric railway network, so that appropriate action can be taken to ensure that security and quality of supply is maintained to all customers.

ADMS is a consolidated network modelling system that combines both network operations functionalities with network analysis and simulation capabilities. It provides a single platform for network load modelling and operations management in a real-time environment. The system has three core integrated components:

1. **Distribution Management System** (DMS) providing network control, optimisation, analysis and planning functions. It is used to perform load flow analysis, protection setting calculations and fault level studies as well as other functions.

2. **Outage Management System** (OMS) facilitates fault calls taking, repair crew dispatch, and planned and unplanned outage management.
3. **Supervisory Control and Data Acquisition** (SCADA) system enables real-time network data acquisition and control.

The system leverages the network connectivity and topology contained within the geographical information system (ArcFM) to automatically replicate the network model in the ADMS. The ADMS also contains advanced analytics and capabilities for automated control of network apparatus.

Having these capabilities available as one integrated solution enables our operators, dispatchers, analysts, planners and managers to work from the same as-operated representation of network information.

Key benefits that the implementation of ADMS will deliver include the following:

- Enables faster fault location, isolation and supply restoration for customers.
- Meeting ActewAGL's commitments to the Australian Energy Regulator (AER) including more accurate and informative reporting.
- Improved information system will provide safer access and operation of the network.
- Improved network utilisation and enablement of future opportunities for improved utilisation.
- Record faults and system events to enable subsequent analysis.
- Calculation of system losses.
- Capacity for future smart grid infrastructure integration.
- A system that provides a backup facility to operate the distribution network in the event of an emergency where the primary control system cannot be used.

ActewAGL proposes to develop the use of the ADMS over the next year to fully utilise its functionality which includes:

- Implement a data-hub to enable broadcast of live data to external applications, including customer portals to facilitate greater customer engagement.
- Roll out ADMS Field Client to network operators for electronic management of switching instructions.

4.10.2 ArcFM Designer

ArcFM is a Geographical Information System (GIS) that provides a suite of configurable data models as well as sophisticated tools that are critical to effective asset management. By using asset attribute information and enabling end-to-end connectivity, ArcFM provides a single platform for documenting and maintaining the electrical network topology. This system provides ActewAGL with the ability to draft network designs directly in the GIS, conducive to a geospatially-centred environment. This avoids the need to draft new designs using a computer-aided design package, and then transfer this information later to the GIS. It also allows all users of the GIS to view proposed designs and changes to the network.

This system is linked to the ADMS so that changes to network topology are updated in both systems in real time.

ActewAGL proposes to develop the use of ArcFM Designer over the next year to fully utilise its functionality which includes:

- Upgrade the software to the latest vendor-supported version
- Automatic volt drop calculations analysis.
- Automatic preparation of bills of materials for works as designed.
- Automatic preparation of cost estimates for works and creation of works orders (by linking to the Cityworks program).

4.10.3 Cityworks

ActewAGL performs works on the electrical network of varying complexity, ranging from high volume fast turnaround connection works, to large scale electricity transmission infrastructure projects.

Every activity performed can be classified and organised to a standardised pattern that determines how it is managed by personnel and systems.

Cityworks is ActewAGL's works management system that is used to schedule cost-effective inspection, monitoring and condition assessment of our assets, as well as initiate, schedule and manage maintenance and capital works on the network. It leverages a geospatial view (GIS) of our assets supported by engineering drawings (unit assemblies) to standardise work practices and maximise utilisation of equipment, labour and materials.

Cityworks is used to prepare detailed cost estimates for works and to monitor actual costs incurred. Such costs are assigned to the assets being created or maintained. Cityworks links to other business systems including financial and procurement systems.

ActewAGL proposes to conclude the roll out over the next year its mobility solution for works management which will enable field staff to pick up, execute and report works in the field using Cityworks via remote hand-held tablet computers.

4.10.4 Riva

Riva is a data base system that contains attribute and historical record details of all of ActewAGL's network assets. It is an asset management decision support tool that provides an opportunity to enhance and expand ActewAGL's asset management framework to align with the international standard for asset management ISO 55001 and support more informed asset investment.

Data stored in Riva is used to prepare Asset Specific Plans for different types of network assets such as transformers and circuit breakers. These plans detail the maintenance requirements and frequency of maintenance for such assets throughout their lifetimes.

An output from Riva is ActewAGL's annual Program of Works (PoW) for the testing and maintenance of all network assets. This is aligned with the operational expenditure (OPEX) budget.

Historical records stored in Riva of the performance of assets are used for Failure Mode and Effects Analysis (FMEA). This assists ActewAGL to identify common or recurring faults with specific types of assets and assists with the development of preventive maintenance and replacement programs to prevent similar faults or failures occurring in the future.

4.10.5 Velocity

Velocity (ActewAGL's billing system) contains ActewAGL's customer database and is used for customer communications and billing purposes. It is a utility-specific billing tool with market integration capabilities. Velocity is a system for providing services for basic customer connections to our Low Voltage network. Velocity supports meter and meter data management, referenced to each specific customer's profile. This system has automated ActewAGL's metering and billing processes, replacing out-dated manual systems.

ActewAGL plans to further develop the Velocity system during the planning period to provide the following:

- To transition to an automated solar inverter monitoring and compliance function as required by the ACT Utilities Act and administered by the Utilities Technical Regulator.
- Improve the Request for Service workflow process through data transfer enhancements between Velocity and Cityworks.

- Enable Velocity to interact with an online customer portal and offer seamless services engagement for customers.

4.11 Metering

ActewAGL has a policy of installing electronic metering as the standard metering installation. An annual replacement program is underway to replace old induction disc type meters at a rate of around 3,000 meters per annum. In addition to this, around 5,000 new meters per annum are installed for new customer connections.

There are two key drivers for the replacement of metering equipment:

- Assets found to be non-compliant with testing regimes must be replaced to ensure compliance with NER – Chapter 7; and
- Planned replacements to address specific business needs such as access, obsolete technologies, obsolete network tariffs and safety issues.

The replacement program is designed to continue to rationalise the meter fleet by removing meter types with small numbers of meters and to future-proof the meter fleet by installing electronic meters. This will allow for reduced use of time switches as the new meters have on-board contactors for time of use type loads.

Electronic meters also allow communications to be installed for remote sites to reduce the cost of meter reading in remote locations (in particular monthly read installations). New technology also allows for monitoring power quality, is capable of remote disconnection / reconnection and can allow for different retail tariffs for customers without changing the meter.

The metering budget is approximately 4.4% of the total capital budget per annum.

4.11.1 Smart Meters

The proposed Power of Choice (PoC) rules to be implemented by the AEMC from 1 December 2017 will require all new and replacement meters to be Type 1-4 meters (smart meters). ActewAGL is considering the installation of devices and communications facilities to enhance smart meters to offer the following functionality in addition to recording energy usage:

4.11.1.1 Outage management

An enhanced smart meter can communicate with the control room when supply is lost thus quickly indicating that a fault has occurred and its location. The operator will also be able to ascertain if the fault is on the network side or the customer's side of the meter.

4.11.1.2 Network planning

Smart meters will provide accurate information of energy use and load data that can be used for network energy and demand forecasts. This will assist the future planning of low voltage networks in particular where standard values of load for customers are currently used, known as After Diversity Maximum Demand (ADMD) values. The impact of embedded generation such as rooftop PV and battery energy storage systems will be able to be analysed accurately so that future networks are designed appropriately. This will enable future network augmentations to be optimised and existing assets to be utilised fully.

4.11.1.3 Demand management

Enhanced smart meters can be used to support demand side management by providing customers with details of their energy consumption and costs via web-portals, and providing customers with a range of energy plans to meet their individual needs.

4.11.1.4 Power quality monitoring

Enhanced smart meters can be used to record condition monitoring parameters that can be used for analysing network power quality to ensure compliance with standards. For example, ActewAGL currently investigates voltage complaints by installing temporary logging equipment at the customer's premises. Such information will potentially be remotely accessible in future from a smart meter.

4.11.1.5 Remote disconnection and reconnection of supply

Smart meters have an integrated mains supply contactor that provides the capability to remotely disconnect or reconnect customers supplies from the network and enables special meter reads to be done remotely.

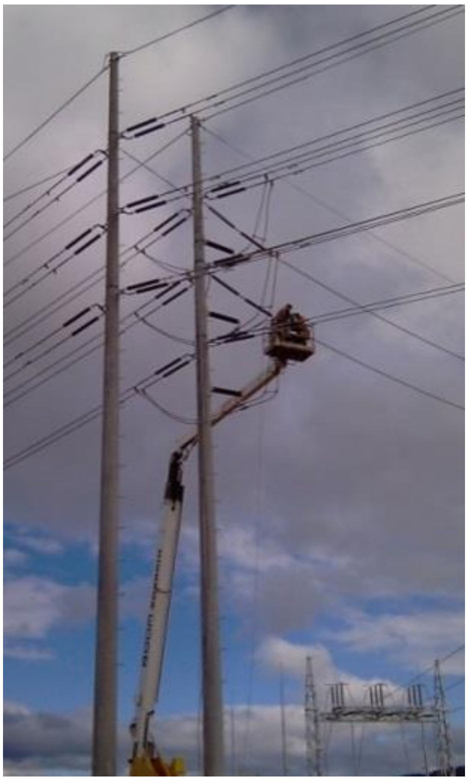
4.11.1.6 Safety

A smart meter can detect a faulty or broken neutral connection at a customer's premises and notify the network operator. This will enhance the safety of the customer and ActewAGL's field staff.

4.11.2 Transmission Network Service Provider (TNSP) Metering

ActewAGL is carrying out a capital works project to install TNSP metering at its zone substations. This project is scheduled to be complete by 30 June 2017. The purpose of the project is for ActewAGL to complete the necessary technical (metering) and associated regulatory works to perform the role of a TNSP as defined in the National Electricity Rules (NER) chapter 7 and administered by the Australian Energy Market Operator (AEMO).

The proposed TNSP metering will interface with other metering and secondary systems equipment at ActewAGL's zone substations. These interfaces will be at defined connection points that comply with the NER. The proposed TNSP metering will be installed in new dedicated metering panels, and will require the installation of new current transformers (CTs), voltage transformers (VTs), and new or upgraded communications equipment. This metering will comply with Australian Standard AS/NZS 1284.13:2002 (Electricity metering in-service compliance testing).



5. System load and energy demand, and the supply-demand balance

5.1. Introduction

This chapter describes the methodology and assumptions made for calculating a ten-year forecast of maximum summer and winter load demands for each zone substation, bulk supply point and whole of system. These forecasts are used to identify potential future constraints in the network.

Load demand forecasting is one of the main inputs to network planning. Load forecasts are used to identify parts of the network that may become overloaded due to load growth and require augmentation, and to identify other parts of the network where spare capacity may be available. Load demand forecasting is complex because of its dependence on a number of factors such as climatic conditions, population growth, uptake of embedded generation and emerging technologies, and economic factors such as electricity prices. ActewAGL prepares and updates a rolling 10-year load forecast, identifying expected summer and winter maximum demands for the whole network, each zone substation and each 11 kV feeder.

Load growth varies from year to year and is not uniform across the whole network. It is not unusual to find parts of the network that grow at three or four times the average network growth rate, while other parts of the network experience no growth at all.

ActewAGL has prepared forecasts of maximum demand for each zone substation and transmission system as follows:

- Whole of system and bulk supply points: refer Appendix B; and
- Zone substations: refer Appendix C.

5.2. Forecasting methodology

5.2.1. Key definitions

5.2.1.1 Maximum Demand

Maximum demand is the highest level of instantaneous demand for electricity averaged over a 30-minute period, and is estimated for summer and winter seasons. Maximum demand projections include load supplied by the network, network losses, and auxiliary loads.

5.2.1.2 Probability of Exceedance (POE)

Probability of Exceedance (POE) is a generalised approach to electricity demand forecasting. Probability of Exceedance is the probability, as a percentage, that the maximum demand level will be met or exceeded (eg due to ambient temperature) in a particular period of time. Due to the high proportion of residential load in the ACT, maximum demand is highly dependent on weather conditions. Thus, there is substantial uncertainty inherent in maximum demand forecasts. ActewAGL prepares maximum demand forecasts with 10%, 50% and 90% POE's:

- A 10% POE maximum demand projection is expected to be exceeded, on average, one year in 10.
- A 50% POE maximum demand projection is expected to be exceeded, on average, five years in 10 (or one year in two).
- A 90% POE maximum demand projection is expected to be exceeded, on average, nine years in 10.

The 50% POE maximum demand forecast is used for planning purposes.

5.2.1.3 Diversity Factor

Diversity factor is the ratio of the sum of the individual non-coincident maximum demands of the parts of a system to the maximum demand of the whole system under consideration. Diversity factor is generally ≥ 1.

$$Diversity\ Factor = \frac{Sum\ of\ non-coincident\ maximum\ demands\ of\ parts\ of\ system}{Maximum\ demand\ on\ whole\ system}$$

5.2.1.4 Load Factor

Load factor is defined as the average load divided by the peak load in a specified time period such as annually, quarterly or monthly. Load factor is generally ≤ 1.

$$Load\ Factor = \frac{Average\ demand\ in\ a\ given\ time\ period}{Maximum\ demand\ in\ the\ same\ given\ time\ period}$$

5.2.1.5 Power Factor

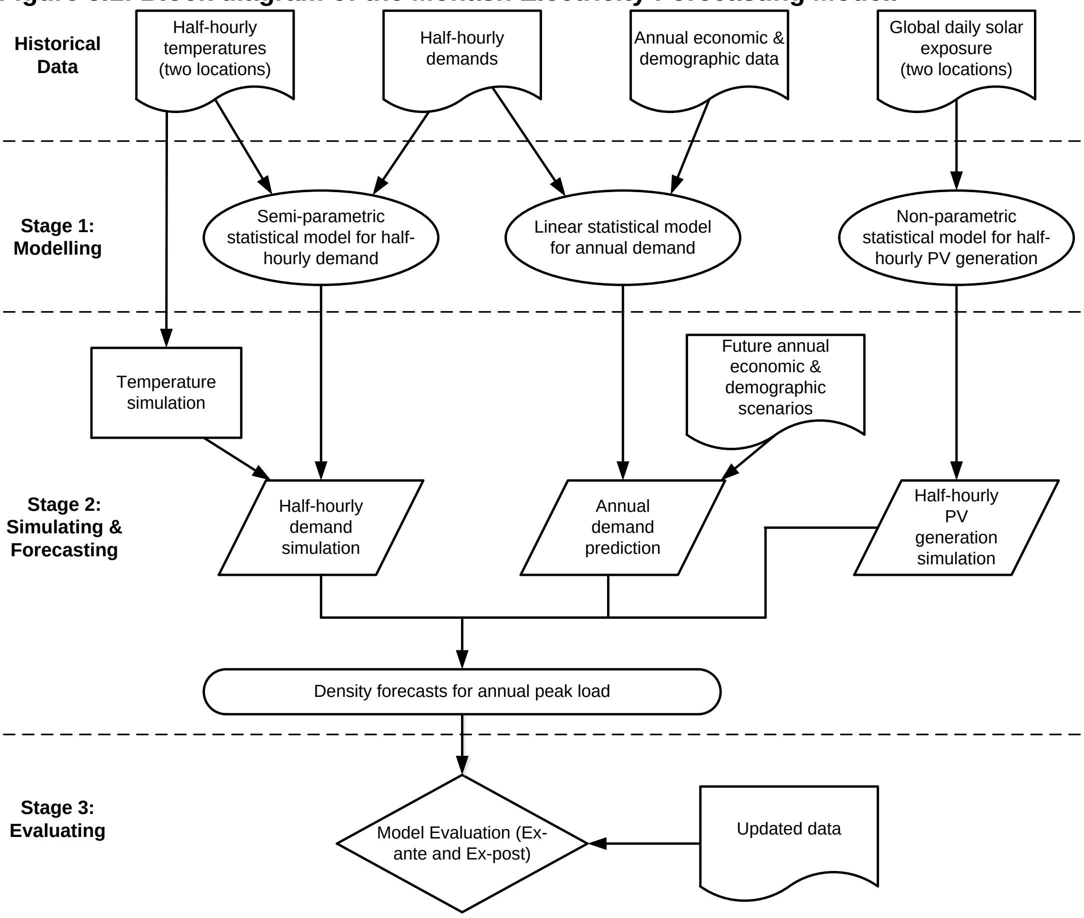
The power factor of an AC electrical power system is defined as the ratio of the real power (MW) used to do work to the apparent power (MVA) supplied to the circuit. Power factor is generally > 0 and ≤ 1.

$$Power\ Factor = \frac{MW}{MVA}$$

5.2.2 Forecasting methodology for distribution

ActewAGL has adopted and implemented AEMO's maximum demand forecast methodology which uses the Monash Electricity Forecasting Model (MEFM) which is based on the paper by Hyndman and Fan (2010)[4]. For more technical details about this methodology, the Monash Electricity Forecasting Model Technical Report is available at AEMO's website. Figure 5.1 illustrates the MEFM load forecasting process.

Figure 5.1: Block diagram of the Monash Electricity Forecasting Model.



[4] R. J. Hyndman and S. Fan (2010) "Density Forecasting for Long-term Peak Electricity Demand", IEEE Trans. Power Systems, 25(2), 1142–1153. http://robjhyndman.com/papers/peak-electricity-demand/

Key features of the Monash Electricity Forecasting Model load forecasting methodology are:

- MEFM has three sub-models: 1) Half-hourly model (HH model); 2) Annual model; and 3) PV generation model (PV model).
- Adjusted half-hourly demand where each year of demand is normalised by seasonal average demand are inputs to the HH model.
- Annual model considers seasonal average demand against all possible economic and demographic drivers.
- Forecasts calculated from half-hourly and PV generation models are based on temperature and daily solar exposure simulations.
- For the HH model, temperature and calendar variables are selected through a cross-validation procedure based on mean squared error (MSE).
- The coincident maximum demand contributions of block loads to the total maximum demand of BSPs and zone substations are calculated using diversity factors.
- The final demand forecast simulation = (Forecast from HH model × Forecast from Annual model) - Forecast from PV model.

ActewAGL has adopted the MEFM methodology to provide an accurate load forecast and minimise estimation bias.

5.2.2.1 Demographic and Economic Factors

Long-term electricity demand is largely dependent on demographic and economic factors. The following three demographic and economic factors are the major ones that impact on ActewAGL's maximum demand and energy consumption forecasts:

1. Population

   Actual population growth rate in the ACT over the last five years has varied from 1.2% pa to 2.0% pa. The forecast average population growth rate for the ACT over the next ten years is 1.2% pa.

2. Gross State Product

   Gross State Product (GSP) is a measurement of the economic output of a state. GSP growth rate in the ACT over the last five years has varied from 0.7% pa to 2.9% pa. The forecast average GSP growth rate for the ACT over the next ten years is 1.8% pa.

3. Electricity Price

   Electricity price growth rate in the ACT over the last five years has varied from 0.6% pa to 1.4% p.a. The forecast average electricity price growth rate for the ACT over the next ten years is 1.2% pa.

5.2.2.2 Rooftop PV Generation

The uptake of rooftop PV generation in the ACT has been increasing steadily over the past five years. There is currently around 53.5 MW of installed capacity.

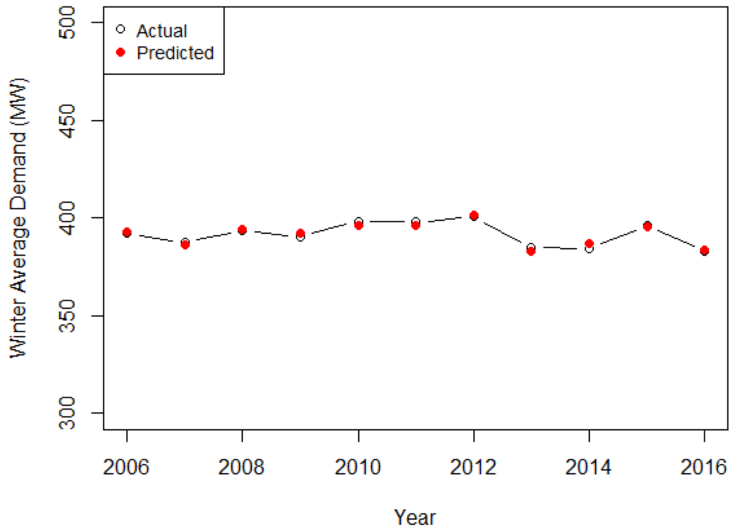
Summer peak demand on ActewAGL's network occurs around 4:00pm during the month of February so rooftop PV generation has a small impact on this (on cloudless days). Winter peak demand occurs around 7:00pm during the month of June so rooftop PV generation has no impact on this. Future installation of battery energy storage systems may impact in these peak demands.

Rooftop PV generation does impact on energy consumption however, throughout the year.

5.2.2.3 Forecasting model verification

The accuracy of the forecasting model has been verified by comparing calculated back cast (a backward looking forecast) values with actual values. Figure 5.2 shows the calculated back cast annual median demand figures with the actual figures. These show a close correlation.

Figure 5.2: Actual winter average demand and calculated winter average demand



5.3. Historical demand

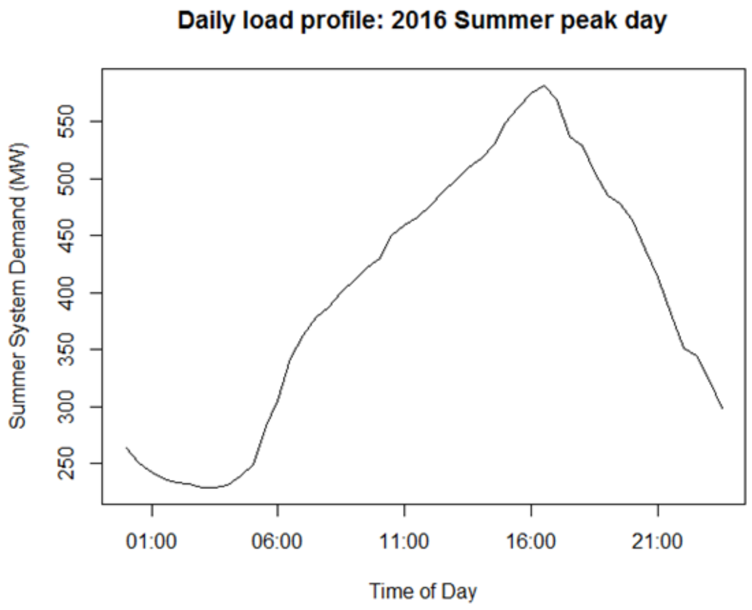
Key features of the past 10 years demand are as follows:

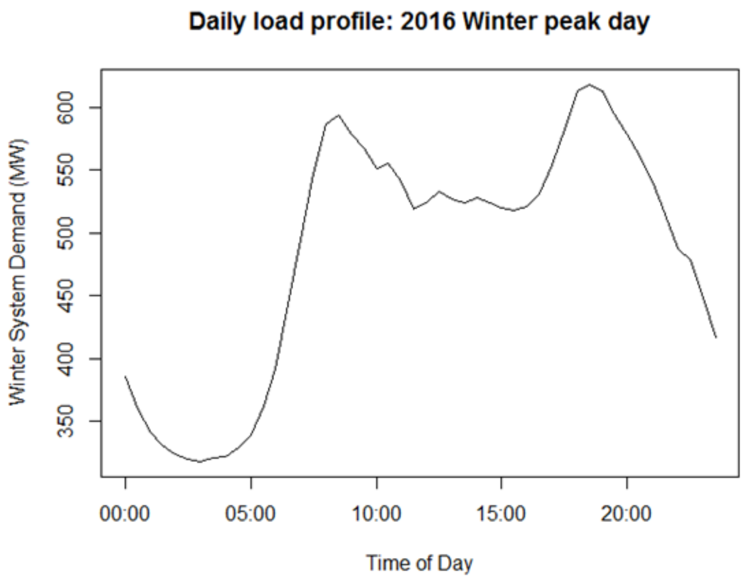
- Summer demand load is very weather dependent. For example summer 2012 and 2015 maximum demands fell below 500 MW due to mild weather conditions.
- Summer peak load increased steadily until 2011 and has experienced a decline from 2012 onwards. This is due to the introduction of the Government's solar generation incentive scheme and subsequent increase in rooftop solar PV installations.
- Winter maximum demand has been more consistent than summer. Improvements in the energy efficiency of space heating and household appliances have resulted in small growth of winter maximum demand. In the 2015-16 summer period, the hottest day was 13 January 2016, whereas the peak demand occurred on 25 February 2016 and was 582 MW[5].
- In the 2016 winter period, the coldest day was 26 June 2016, whereas the peak demand occurred on 30 June 2016 and was 619 MW.

[5] Actual system peak demand during the summer season includes energy imports from both TransGrid and Royalla solar farm.

2016 summer and winter peak day load profiles are shown in Figure 5.3.

Figure 5.3: Daily load profile 2016 summer and winter peak days





5.4. Forecast Demand and Energy

5.4.1 ACT Demand Forecast

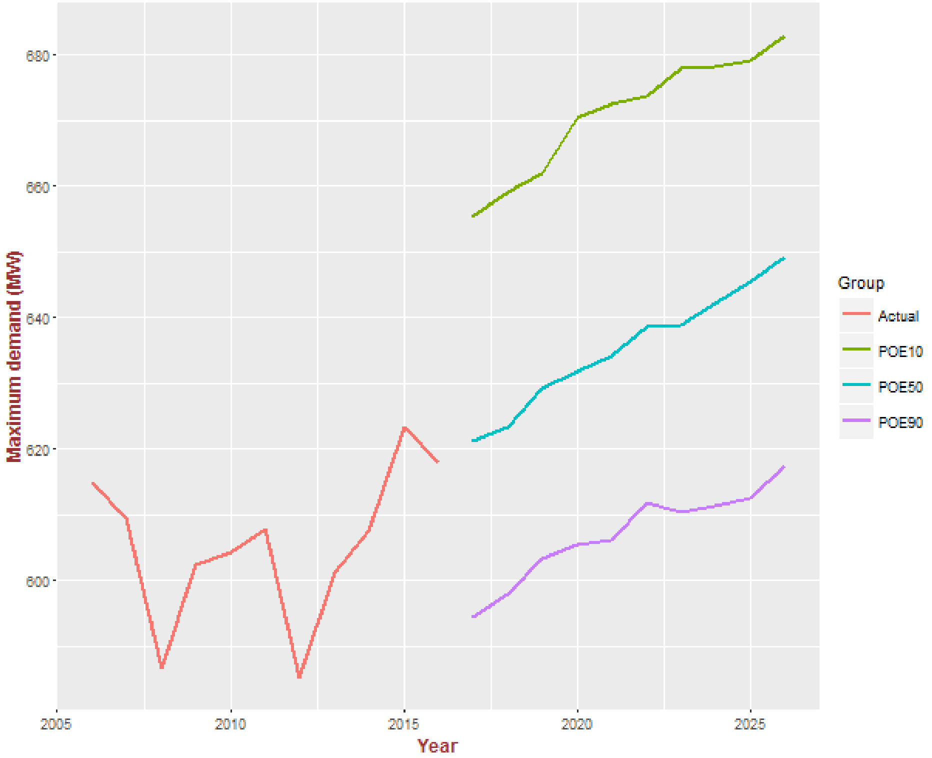
Load forecasts are calculated for three economic scenarios: low, medium and high growth rate conditions. Load forecasts are also influenced by weather conditions, i.e. low (mild weather conditions), medium (normal weather conditions), and high (extreme weather conditions).

In addition to these scenarios, ActewAGL calculates load forecasts based on 10%, 50% and 90% POE. Network planning is based on the medium 50% POE forecast.

ActewAGL's maximum demand forecasts for the ten year period 2016-26 have been calculated based on these different scenarios and are presented in Figures 5.4 and 5.5.

Figure 5.4: Summer 10-year system maximum demand forecast

Figure 5.5: Winter 10-year system maximum demand forecast



5.4.1.1 Key features of the maximum demand forecasts

Table 5.1 summarises summer and winter 10% POE and 50% POE maximum demand annual average growth rates. Key features are as follows:

- Summer maximum demand has fluctuated over the last six years due to increasing installation of rooftop PV systems and milder summer weather conditions.
- The long term (10 years) 10% POE and 50% POE growth rates are very similar.
- A small rate of decline is expected in summer and a small rate of growth is expected in winter.
- Winter maximum demand occurs around 6:00pm, so there is no impact from PV generation, however future battery energy storage systems are expected to have an impact.

Table 5.1: Summer and winter 10% POE and 50% POE maximum demand annual average growth rates

Forecast maximum demand annual average growth rate		Summer			Winter		
		Actual	50% POE	10% POE	Actual	50% POE	10% POE
2011 - 2016	Historical	-1.0%			0.3%		
2016 - 2017	0 -1 year growth		-1.5%	7.6%		0.5%	6.0%
2017 - 2020	2 - 5 years growth		0.2%	0.4%		0.6%	0.8%
2020 - 2026	6 -10 years growth		-0.4%	-0.4%		0.5%	0.3%
2017 - 2026	1 - 10 years growth		-0.2%	-0.2%		0.5%	0.5%

5.4.1.2 Comparison of ActewAGL's forecasts with AEMO's forecasts

Figures 5.6 and 5.7 compare ActewAGL's load forecasts with AEMO's load forecasts for the ACT.

Figure 5.6: ActewAGL summer maximum demand forecast compared with AEMO's forecast

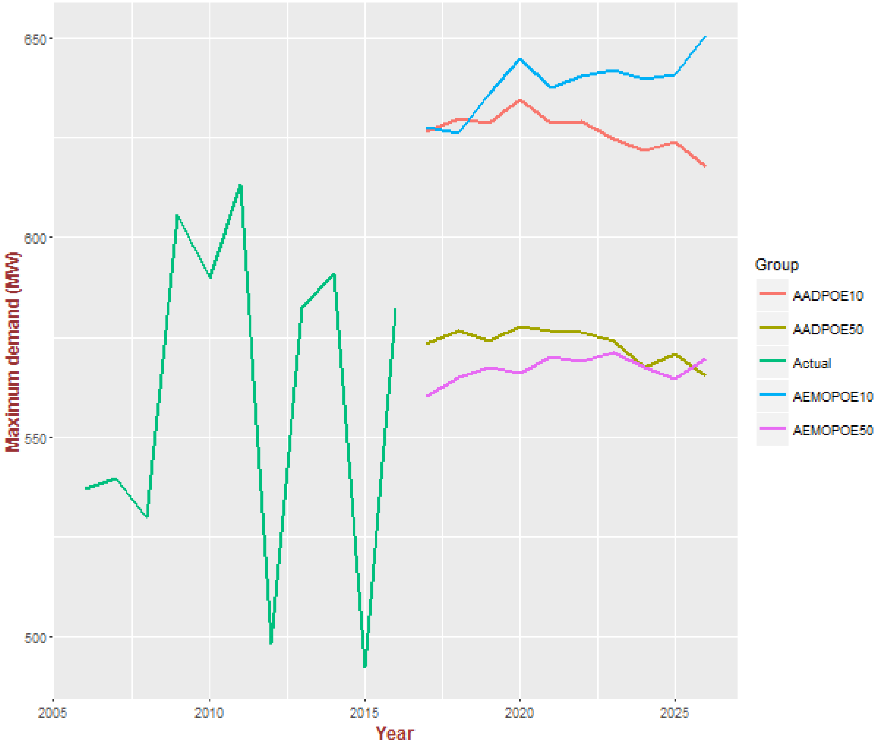
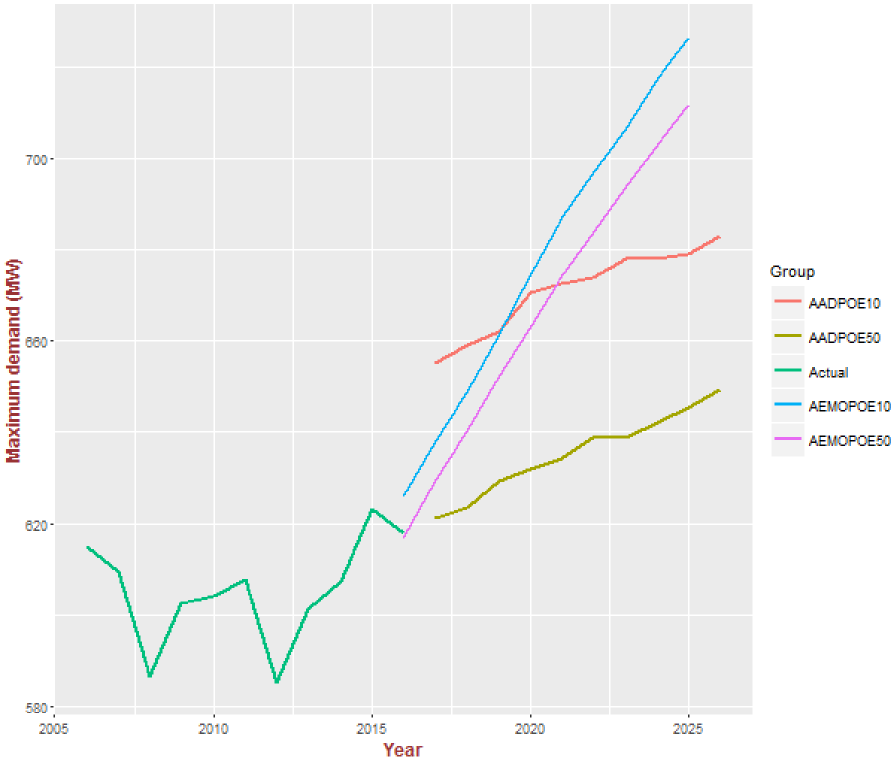


Figure 5.7: ActewAGL winter maximum demand forecast compared with AEMO's forecast



AEMO and ActewAGL's summer 10% POE and 50% POE forecasts are consistent.

AEMO and ActewAGL's winter 10% POE and 50% POE forecasts show different trends. AEMO predicts a steep increase in winter demand primarily due to fuel switching from gas appliances to electricity, including space and water heating. ActewAGL does not predict such a marked rate of fuel switching.

5.4.2 Bulk Supply Point (BSP) forecasts

Appendix B details the summer and winter maximum demand forecasts for the three TransGrid owned bulk supply substations Canberra, Williamsdale and Queanbeyan.

Queanbeyan Substation supplies ActewAGL's Fyshwick Zone Substation only at 66 kV as well as some Essential Energy substations.

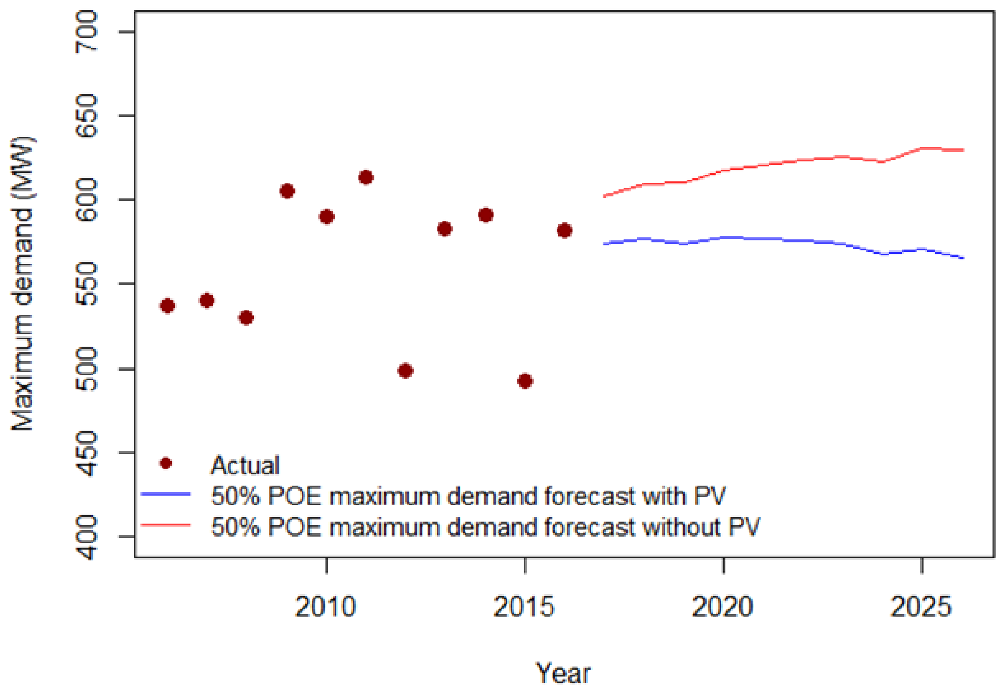
5.4.3 Zone Substation forecasts

Appendix C details the summer and winter maximum demand forecasts for ActewAGL's zone substations.

5.5. Photovoltaic Generation – effect on load forecasts

Figure 5.8 illustrates the impact of solar PV generation on ActewAGL's forecast summer maximum demand.

Figure 5.8: Rooftop solar PV impact on summer maximum demand



5.6. Load Transfer Capability

Table 5.2 shows the load transfer capability (in MW) between ActewAGL's zone substations. Transfer capability is calculated based on spare capacity of zone substation transformers and spare capacity of interconnecting 11 kV feeders between substations.

Table 5.2: Load Transfer Capability (in MW) between ActewAGL's Zone Substations

	Zone Substation	From												
		Latham	Belconnen	Gold Creek	Civic	City East	Telopea Park	Eastlake	Fyshwick	Woden	Wanniassa	Gilmore	Theodore	Angle Crossing
To	Latham		9.97	2.57										
	Belconnen													
	Gold Creek													
	Civic		5.93			9.18								
	City East		5.53		7.99		3.16							
	Telopea Park					2.85		15.78	3.89	5.88	0.44			
	Eastlake													
	Fyshwick						1.15	6.79			0.96	0.96		
	Woden						11.96				10.46			
	Wanniassa						3.05		3.05	18.97		14.24	1.19	
	Gilmore								1.75		15.65		6.78	
	Theodore										7.19	3.36		
	Angle Crossing													

6. Asset Renewals

6.1. Introduction

Asset renewal is simply defined as works that return an asset to its “as-new” condition. Depending on the type of asset, the renewal process may involve the replacement of components, such as overhead line insulators. Major assets such as zone substation power transformers may undergo a “mid-life” refurbishment which would include de-tanking of the core and windings. In order to realise the full potential of any asset, routine maintenance is required. This maintenance does not return the asset to its “as-new” condition, but controls premature deterioration and potential failure.

The cost of asset renewal is included in the “whole-of-life” cost of the asset.

All assets are assigned a “health profile” which is determined by combining the asset’s condition rating with its criticality rating. Condition is determined by the asset’s capacity to meet its service requirements, level of reliability and its level of obsolescence. Obsolescence is determined by maintenance requirements and availability of spares and support from suppliers. Criticality is determined from operational, safety and environmental consequences due to asset failure.

This chapter provides a summary of asset renewal programs across the ACT, in particular those with an estimated capital cost of $2 million or more.

6.1.1. Transmission Asset Renewal Programs

There are currently no transmission asset renewal programs in excess of $2 million per annum.

Four 132 kV circuits breakers were replaced during the 2015-16 financial year at Belconnen and City East Zone Substations and Bruce Zone Switching Station. A further two132 kV circuit breakers will be replaced at Bruce Switching Station during 2016-17. These are replacements of aging assets that have reached the end of their economic life.

6.1.2. Distribution Asset Renewal Programs

There is currently no single distribution asset renewal proposed in excess of $2 million.

However every year, distribution poles are replaced due to poor structural condition identified from condition monitoring program. This asset renewal program exceeds $2 million per annum.

507 distribution poles were replaced in the 2015-16 financial year and 576 distribution poles are planned to be replaced in the 2016-17 financial year.

Other distribution assets are replaced via a rolling program based on an assessment of their condition and remaining economic life. All classes of distribution assets are renewed in this way, including:

- Distribution transformers.
- 11 kV switchgear (switchboards, ring main units and air-break switches).
- 11 kV and 400 V cables and conductors.
- Low voltage distribution pillars.
- Protection relays, communications and SCADA equipment.
- Batteries and battery chargers.
- Earthing equipment and systems.
- Meters.

6.1.3. Telecommunications upgrade programs

Planned telecommunications projects – fibre optic network:

ActewAGL has a program to roll out Optical Ground Wire (OPGW) within our network. This involves replacing the existing overhead earth wire on 132 kV transmission lines with hybrid OPGW cables to provide an optical fibre communications capability to meet the following regulatory and business requirements:

- Updating our 132 kV transmission line protection systems to meet current NER network performance standards, ensuring regulatory compliance and safety for the community. Currently some 132 kV transmission line protection systems within the ActewAGL transmission network are non-compliant with the required fault clearance times under the National Electricity Rules (NER) and need to be updated.
- Providing a secure SCADA communication network enabling the Control Room to monitor and operate zone substations in the ActewAGL network.
- Providing inter control centre SCADA communications and communications to the TransGrid and AEMO control rooms, required by our role as a Transmission Network Service Provider (TNSP) in the national grid.
- Providing communications for security monitoring of substations and other corporate communication services.

Communications Wide Area Network Deployment:

ActewAGL has a program to roll out a Multiprotocol Label Switching (MPLS) based Wide Area Network (WAN) to corporate office and zone substation locations. The WAN will utilise the fibre optic and microwave links. This will deliver the business requirement for a secure SCADA communication network for the effective operation of the electrical network.

Other telecommunications upgrade programs include:

- Telecommunications multiplexer replacement program
- Replacement of aging copper pilot cables with Optical Fibre cables. Pilot cables are used for 11 kV feeder protection and SCADA communications. This is necessary for providing safety and reliability in the 11 kV network.
- Progressive replacement of radio equipment in the SCADA Digital Data Radio Network (DDRN). This program will replace SCADA data radios as they reach the end of their serviceable life.
- Retirement of the aging ActewAGL VHF voice radio system and consolidation of all radio voice communications onto the ActewAGL TMR radio system. The VHF system is at the end of its service life and needs to be replaced. ActewAGL also owns and operates a UHF TMR voice radio system in the ACT. The scope of this project is to fully transfer and consolidate all operational voice communication requirements to TMR.
- Interactive voice response system for Control Centre, to assist callers receive the information they require as quickly as possible.

The telecommunications upgrade program plans to provide communications to all zone substations in the ActewAGL transmission network by 2018. Figures 6.1 and 6.2 depict the proposed communications network program.

Figure 6.1 Proposed Fibre Optic Network – Northern ACT

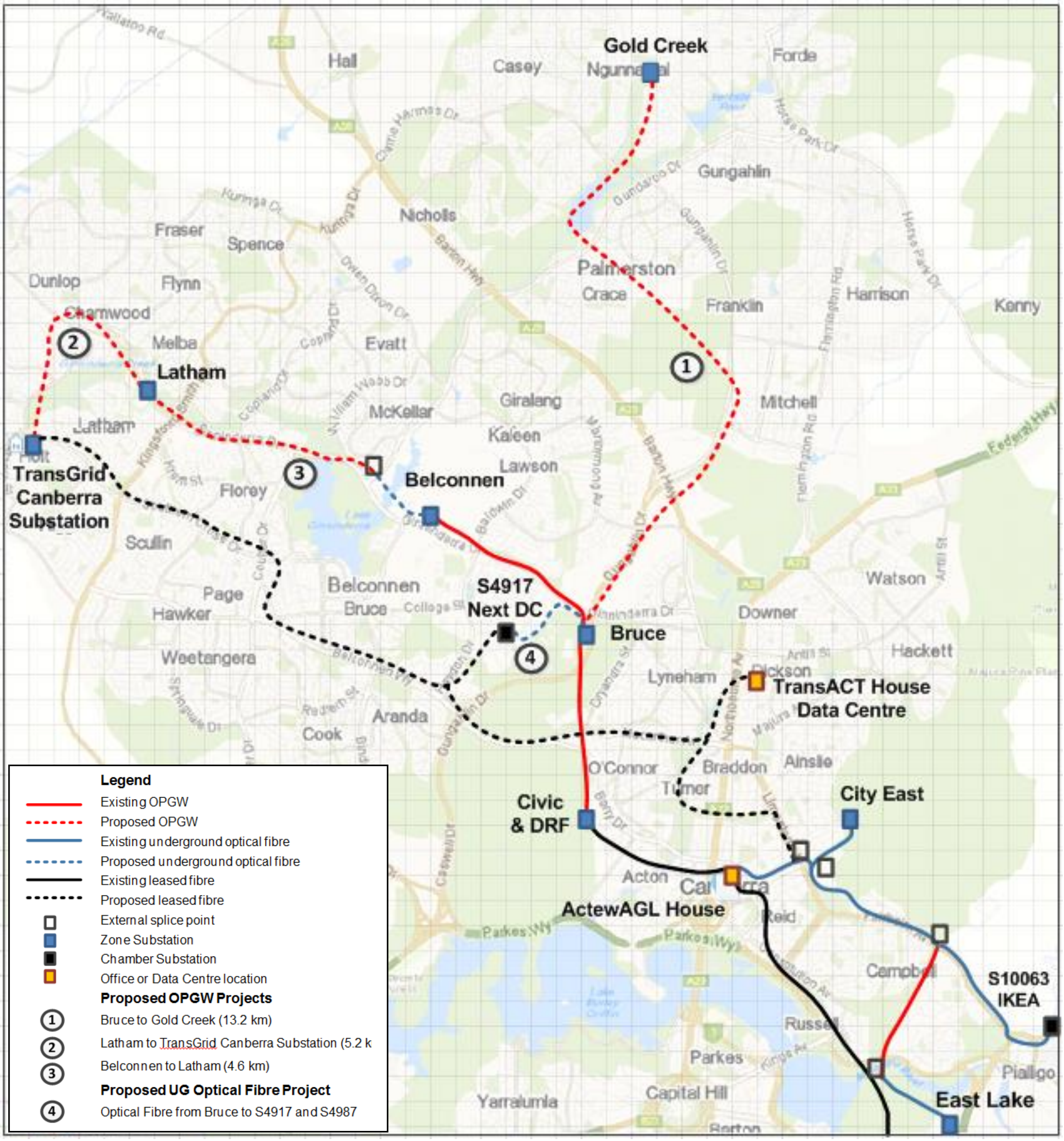
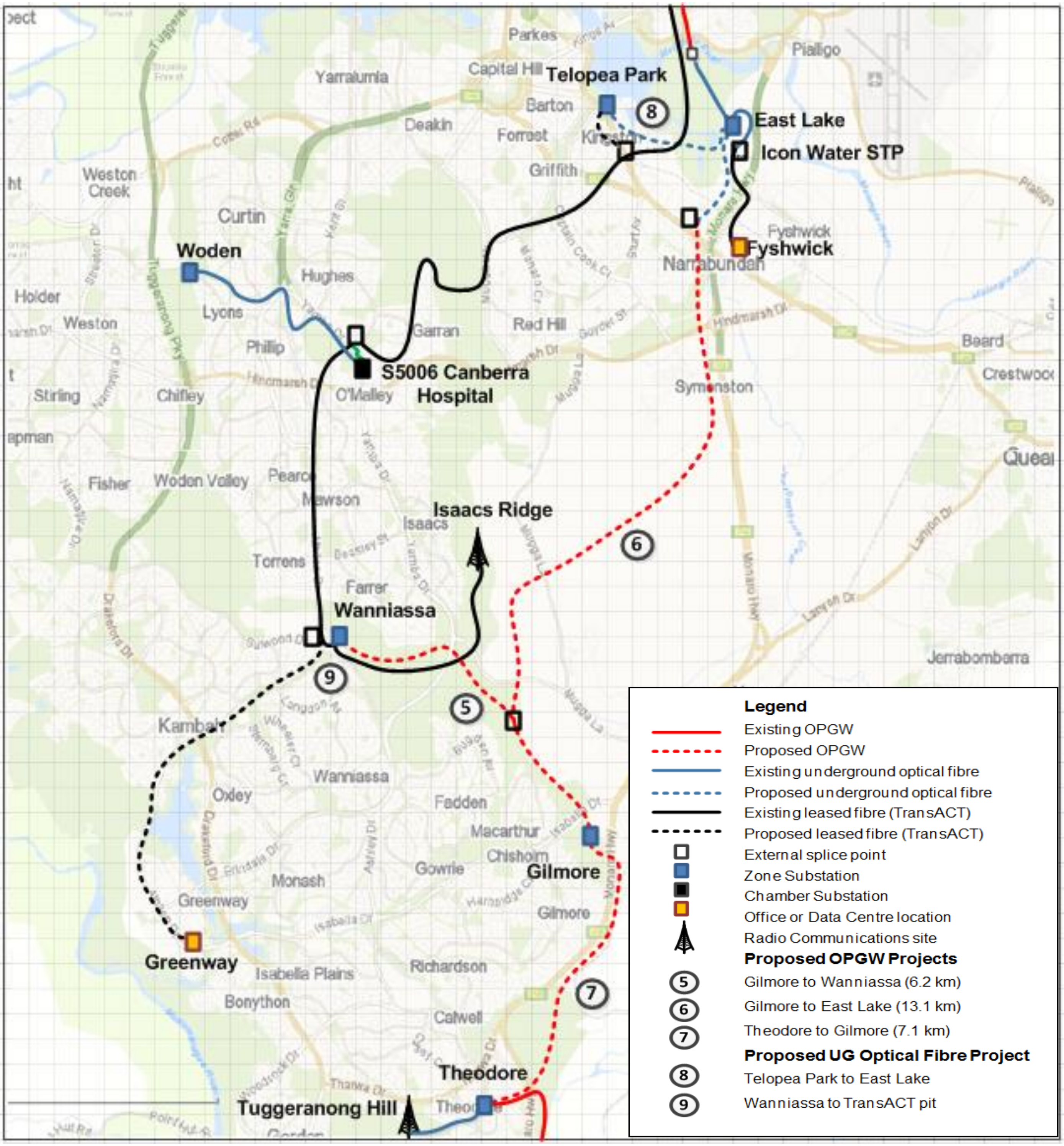


Figure 6.2 Proposed Fibre Optic Network – Southern ACT



7. System Planning

7.1. Introduction

System planning studies are undertaken to assess the adequacy of the transmission and distribution network to meet current and forecast demands whilst meeting the quality of supply criteria stipulated in the NER. The key performance criteria that are addressed are: thermal overloading, voltage performance, supply security, and supply reliability. The studies have been conducted using ActewAGL's 2016 medium growth, 50 per cent POE demand forecast.

System planning is the process of investigating present and future system capability and identifying, evaluating and initiating system upgrade requirements where required and where economically justified to do so. Long term system planning is necessary to ensure the security of the power system is maintained. System upgrades are driven by the need to maintain system reliability, to provide capacity for demand growth, and to relieve current or future system constraints.

The planning process is set out in the NER, and involves consultation with the public on any proposed upgrade requirements and the proposed options to address those requirements. The NER specifies the method for selecting the preferred option to addressing an issue from the feasible alternatives, which must include non-network options.

This chapter describes existing and emerging constraints on the ActewAGL network that have been identified to occur over the next ten years. It describes those issues that are proposed to be addressed over the next five-year planning period, and discusses options identified and proposed solutions. Opportunities for non-network solutions such as demand side management or embedded generation support required to defer the emerging issues are identified.

Details of system performance are included in Chapter 4. Details of demand forecasts are included in Chapter 5 and Appendices B, C, and D.

ActewAGL's network is a meshed 132 kV transmission and meshed 11 kV distribution system, with the exception of Fyshwick Zone Substation which is supplied radially at 66 kV from TransGrid's Queanbeyan Substation. There are also two radial 22 kV feeders emanating from Woden Zone Substation, feeding Cotter and Tidbinbilla.

Figure 3.1 shows the transmission network and location of zone substations and switching stations geographically, and Figure 3.2 shows this information schematically.

7.2. Embedded generation

7.2.1 Solar Photovoltaic (PV)

Embedded generation connected to the ActewAGL network includes 17,476 domestic rooftop PV installations (as at 30 November 2016) of average size 3 kW connected to the low voltage 400 V system. These installations as spread all over the ACT (refer Appendix E). Total installed capacity is around 53.5 MW.

There are currently three large scale solar embedded generation installations connected to the ActewAGL network. PRV Solar Farm, Royalla, which has a peak output capacity of 20 MW is connected to Theodore Zone Substation via two dedicated 11 kV feeders. Mugga Lane Solar Park, Hume which has a peak output capacity of 12.85 MW is connected to Gilmore Zone Substation via a dedicated 11 kV feeder. Williamsdale Solar Farm, Williamsdale, which has a peak output capacity of 10.1 MW is currently connected (temporarily) to ActewAGL's Angle Crossing 132/11 kV mobile substation via a dedicated 11 kV feeder. It is proposed to connect this solar farm permanently to the Williamsdale–Theodore 132 kV line via a new 11/132 kV step-up substation to be known as Tennent Zone Substation, early in 2017.

There is currently one medium scale solar embedded generation installation connected to the ActewAGL network, Mount Majura Solar farm, Mount Majura, which has a peak output capacity of 3.6 MW. This is connected to City East and East Lake zone substations via two shared 11 kV feeders.

There are several solar PV installations in the range 20-200 kW, typically on the roofs of commercial or industrial buildings.

7.2.2 Hydro-electric

There is an existing micro-hydro generator connected to the ActewAGL network, the Stromlo micro-hydro 700 kW. This is connected to Woden Zone Substation via a shared 22 kV feeder.

There is another small hydro generator at Googong Dam, which recovers energy in the event that water is pumped from Angle Crossing to Googong Dam.

7.2.3 Gas

There are two existing bio-gas fuelled open-cycle gas turbine (OCGT) generators connected to the ActewAGL network:

Belconnen Waste Transfer Station 3 MW. This is connected to Latham Zone Substation via a shared 11 kV feeder.

Mugga Lane Waste Transfer Station 3 MW. This is connected to Gilmore Zone Substation via a shared 11 kV feeder.

7.2.4 Co-generation

There is one gas fuelled co-generation plants connected to the ActewAGL network at HMAS Harman 1.2 MW. This is connected to Fyshwick Zone Substation via a shared 11 kV feeder.

7.3. Joint Planning with TransGrid

ActewAGL and TransGrid hold joint planning meetings bi-annually. The joint planning process ensures that the most economic solutions to issues are implemented, whether they are a network or non-network option, transmission or distribution option. The joint planning process covers:

- Evaluation of relevant limitations of both networks and progression of joint planning activities to address these limitations.
- Demand and energy forecasts.
- Non-network development proposals.
- Long term transmission and distribution developments.
- Annual planning reports and presentations.

Major projects are discussed such as TransGrid's proposed Stockdill Drive 330/132 kV bulk supply point substation as required for the second point of bulk supply to the ACT (refer sections 7.5.1 and 7.7). Regular project development meetings and exchanges of information (e.g. design drawings) are exchanged as such projects progress.

ActewAGL and TransGrid also have regular discussions in addition to the formal joint planning meetings, to discuss and resolve technical issues such as bulk supply point (BSP) bus voltage levels.

TransGrid proposes to carry out replacement of some of its aging major assets at Canberra BSP Substation. ActewAGL will liaise closely with TransGrid throughout the implementation of this project to ensure continuity and security of supply to the ACT is maintained. Refer to TransGrid's Transmission Annual Planning Report 2016[6].

7.4. Emerging needs

Customer-initiated load growth is steady in the ACT, around 1.0% per annum. New developments are primarily residential greenfield estates and in-fill housing, community developments such as schools, commercial developments such as shopping centres and data centres, and infrastructure developments such as the proposed Canberra light rail project. Load growth rates are expected to decrease over the planning period due to the increasing effects of embedded generation, energy storage, and energy efficient appliances. This will result in decreasing investment in network augmentations and increasing investment in asset replacements.

Accurate demand forecasting is essential to the planning and development of ActewAGL's distribution network. ActewAGL uses the same demand forecasting model as AEMO. Demand forecasts are calculated at the whole of system level, at each zone substation, and at each distribution feeder for the forward planning period. These forecasts are used to identify emerging network limitations, and identify network risks, that need to be addressed by either network or non-network solutions. The forecasts are then used as an input to the timing and scope of capital expenditure, or the timing required for demand reduction strategies to be established, or risk management plans to be put in place.

ActewAGL has analysed existing and emerging needs on its network using the Advanced Distribution Management System (ADMS). Such needs are met firstly by utilising available spare capacity within the network, e.g. by transferring load between feeders or between zone substations whilst ensuring all security and reliability criteria are maintained. Analysis is conducted on feeder tie points to determine the feeder capacity to support loads of adjacent feeders during contingency events.

Section 7.5 describes network developments with a capital cost in excess of $2 million proposed to be carried out over the five-year planning period to meet emerging needs.

7.5. Proposed Network Developments

Proposed developments have been identified through the planning process for the forward ten-year planning period. Load forecasts and new major customer connection requests have been the inputs for the maximum demand forecasting. Because of the relatively small geographic area of the electricity network within the ACT, it is not broken down into separate regions for planning purposes. The full geographic extent of the network is shown in Fig. 3.1. Figure 7.1 shows a schematic diagram of the existing ACT transmission network.

[6] https://www.transgrid.com.au/newspublications/Documents/Transmission Annual Planning Report 2016.pdf

Figure 7.1 Existing Transmission Network

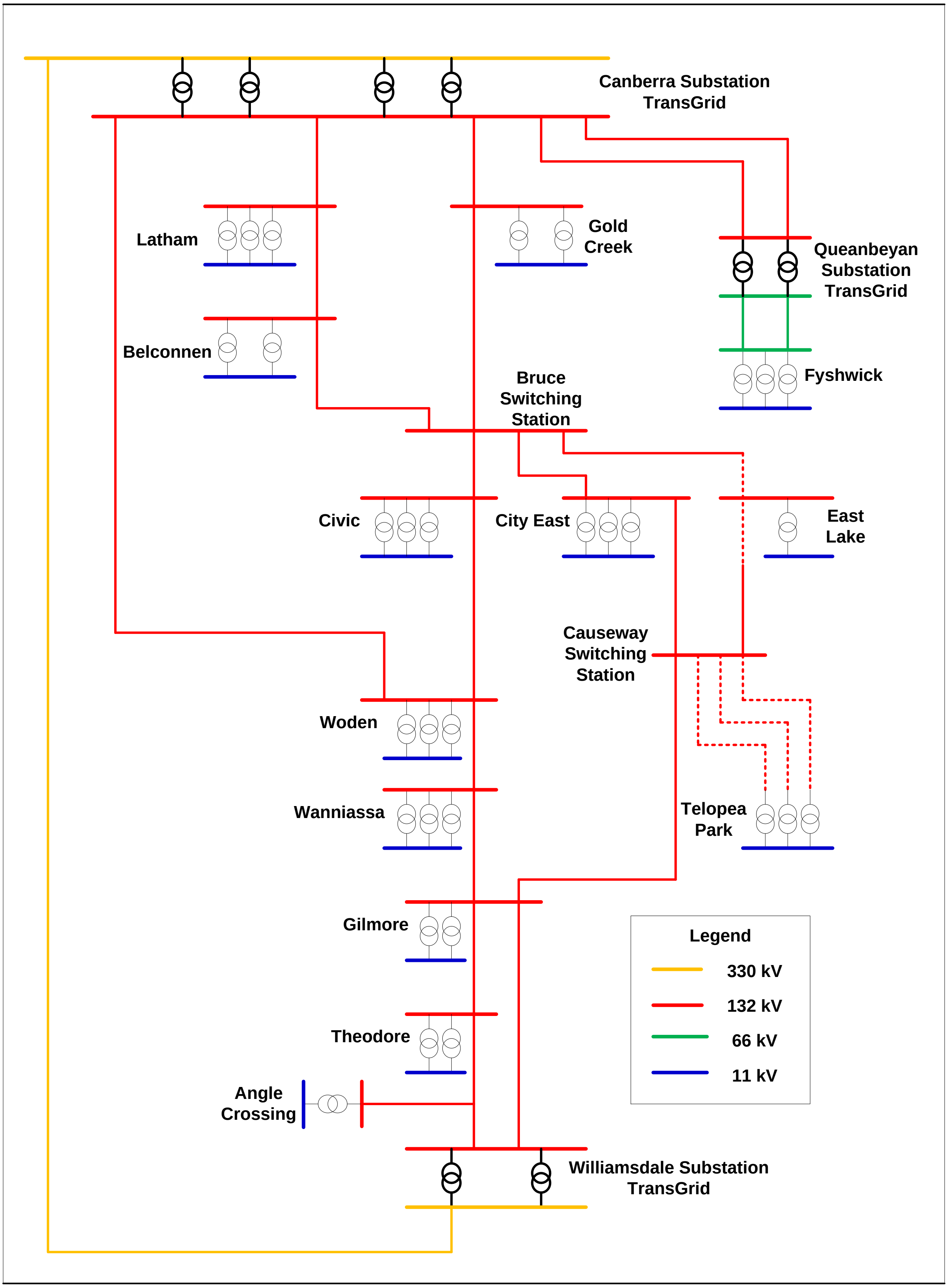


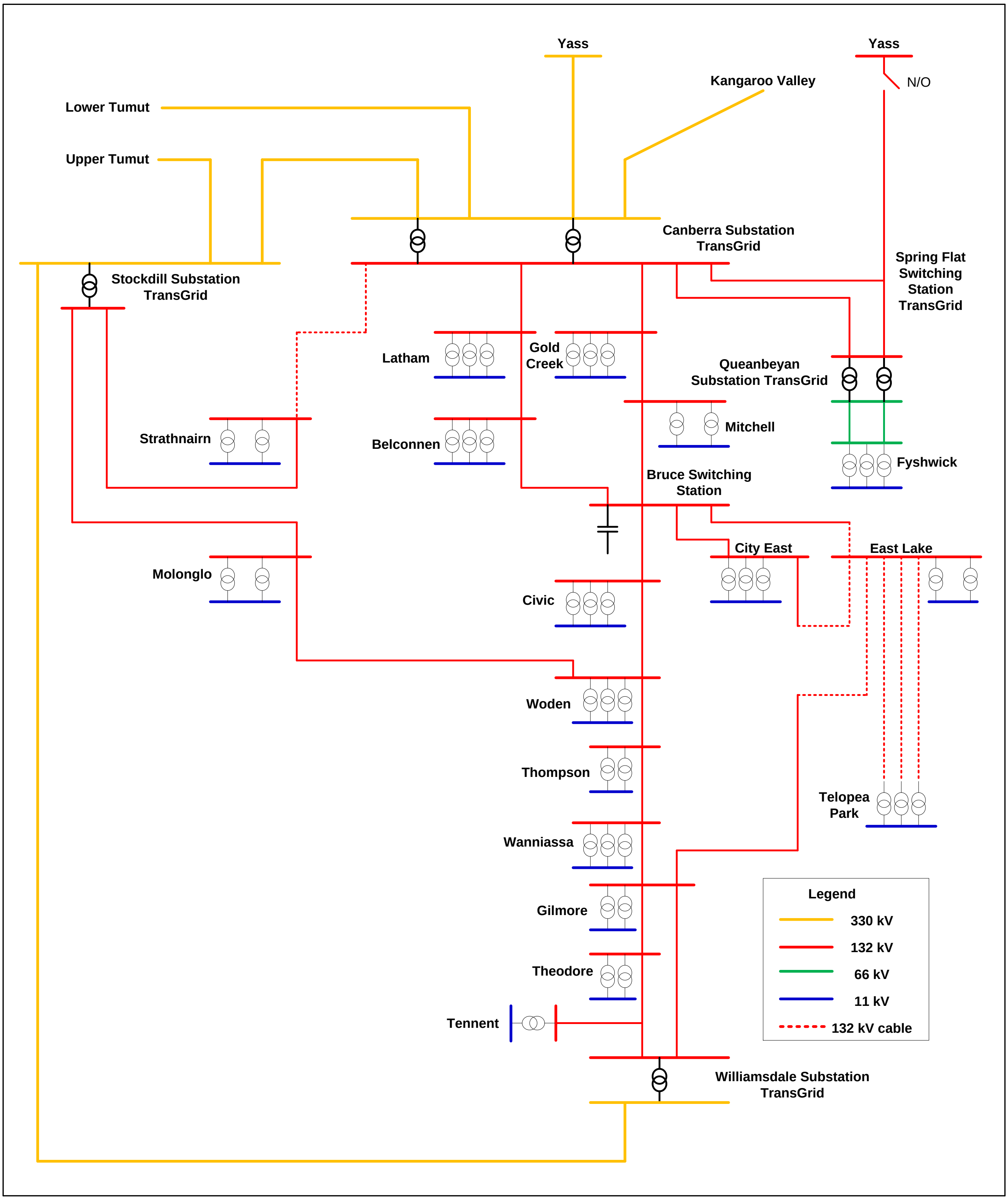
Table 7.1 presents future proposed developments estimated to cost more than $2 million that are programmed to commence during the five-year planning period, and the timing of their completion. These projects are described in the following sections.

Table 7.1: Proposed ActewAGL Network Developments in Excess of $2.0 m

Asset Type	Proposed Development	Estimated Start	Estimated Completion	Estimated Cost
TransGrid – ActewAGL Connection Points	Stockdill Substation	2018	2019	NA
Transmission Lines	Construct 132 kV transmission line connection between Stockdill Substation and Canberra–Woden line.	2018	2019	$4.50 m
Zone Substations	East Lake Zone Substation second transformer	2018	2019	$3.07 m
	Belconnen Zone Substation third transformer	2019	2020	$12.62 m
	Molonglo Zone Substation	2019	2021	$22.00 m
	Mitchell Zone Substation	2021	2023	$23.00 m
	Strathnairn Zone Substation	2020	2022	$23.00 m
Switching Stations	Decommission Causeway 132 kV Switching Station	2019	2020	$2.00 m
	Install 45 MVAr capacitor bank at Bruce 132 kV Switching Station	2018	2019	$3.00 m
Distribution Feeders	11 kV feeder from Gold Creek Zone Substation to Mitchell area	2017	2018	$3.50 m
	11 kV feeders from Gold Creek Zone Substation to Gungahlin Town Centre	2017	2018	$3.60 m
	11 kV feeder from Wanniassa Zone Substation to Tuggeranong Town Centre	2018	2019	$3.02 m
	11 kV feeder from Woden Zone Substation to Molonglo Valley	2018	2019	$2.50 m
	11 kV feeder from Latham Zone Substation to Belconnen Trade Services Area	2018	2019	$3.07 m
	11 kV feeder from Civic Zone Substation to Canberra City Central	2017	2018	$2.77 m
	11 kV feeder from East Lake Zone Substation to Kingston area	2019	2020	$3.01 m
	11 kV feeders from East Lake Zone Substation to Fyshwick	2017	2018	$3.80 m
Secondary systems	Installation of Optical Ground Wire (OPGW) on 132 kV transmission lines	2015	2017	$5.25 m
	SCADA communications upgrade, optic fibre to distribution substations	2015	2024	$4.28 m

Figure 7.2 shows future development of the transmission network over the next ten years.

Figure 7.2 Future (10 year) Transmission Network



7.5.1 Security of Bulk Supply to the ACT

The commissioning of TransGrid's Williamsdale 330/132 kV Substation in February 2013 introduced a second 132 kV bulk supply point into the ACT to address power system security requirements by providing two geographically independent 330 kV points of connection to the ACT network. Williamsdale Substation is linked to ActewAGL's network at Theodore and Gilmore 132 kV Zone Substations (refer Figure 7.1).

The latest version of the ACT Electricity Transmission Supply Code (July 2016) states:

TransGrid must plan, design, construct, test, commission, maintain, operate and manage its electricity transmission networks and geographically separate connection points that supply customers in the ACT and that will operate at 66 kV and above, whether or not those networks and connection points are in the ACT, to achieve the following:

(a) the provision of two or more geographically separate connection points operated at 132 kV and above to supply electricity to the ACT 132 kV network;

(b) at all times provide continuous electricity supply at maximum demand to the ACT 132 kV and 66 kV network throughout and following a single credible contingency event;

(c) until 31 December 2020, provide electricity supply at 30 MVA to the ACT 132 kV or 66 kV network within one hour following a single special contingency event and 375 MVA within 48 hours of this event; and

(d) from 31 December 2020, provide continuous electricity supply at 375 MVA to the ACT 132 kV network immediately following a single special contingency event and agreed maximum demand within 48 hours of this event.

To meet the above criteria TransGrid proposes:

Item (a) is met already by Canberra and Williamsdale 330/132 kV bulk supply point substations.

Item (b) is met already by Canberra and Williamsdale 330/132 kV, and Queanbeyan 132/66 kV bulk supply point substations, all of which have N-1 security.

Item (c) can be met by supplying 30 MVA via Queanbeyan 132/66 kV (to Fyshwick 66/11 kV Zone Substation) in the event of a special contingency event affecting Canberra Substation (and consequently affecting Williamsdale Substation also as Williamsdale is connected radially at 330 kV from Canberra). The 375 MVA criteria within 48 hours requirement would be met by constructing a temporary 330 kV connection between the Upper Tumut–Canberra line and the Canberra–Williamsdale line, thus bypassing Canberra Substation.

To comply with Item (d) TransGrid proposes to construct a 330/132 kV Substation at Stockdill Drive, West Belconnen. This will have one 375 MVA transformer. The Upper Tumut–Canberra and Canberra–Williamsdale 330 kV lines will be reconnected to Stockdill Substation. A new 330 kV line section will be constructed from Stockdill to Canberra. ActewAGL will construct a new double circuit 132 kV line section from Stockdill to connect to the Canberra–Woden 132 kV line to form a Stockdill–Canberra circuit and a Stockdill–Woden circuit. This will provide the immediate 375 MVA back-up capability to the ACT.

Within one hour of a special contingency event affecting Canberra Substation, TransGrid proposes to reconnect Queanbeyan 132 kV from Yass Substation (via Spring Flat Switching Station) and within 48 hours to construct a temporary connection from the Yass 330 kV line to the Canberra–Latham 132 kV line and reconnect to Yass 132 kV bus. This would provide full load capacity to the ACT.

TransGrid proposes to retire two aged single-phase transformer banks at Canberra Substation.

Power systems analysis shows that under this development the originally proposed Theodore–Gilmore 132 kV line upgrade will not be required. However analysis shows that in the event of a total Canberra Substation outage, voltage levels in the northern part of ActewAGL's 132 kV network would fall below regulation levels. In order for voltage levels to be maintained, ActewAGL is investigating the installation of reactive support equipment.

Estimated cost of ActewAGL's works, i.e. construction of a double circuit 132 kV line section from Stockdill Substation to the Canberra–Woden line is $4.5 million and proposed project completion is by December 2019. A reactive power device such as a 132 kV 45 MVAR capacitor bank is estimated to cost $3.0 million and could be installed at Bruce Switching Station by December 2019 also.

A joint Regulatory Investment Test for the Security of Supply project was completed by ActewAGL and TransGrid in 2009.

In the interim period until completion of this project, in the event of a loss of Canberra Bulk Supply Substation, a contingency plan has been made by TransGrid which has constructed assets at its Yass and Canberra substations to deal with this eventuality.

No non-network alternative to this project has been identified.

7.5.2 East Lake Zone Substation second transformer

ActewAGL's network assets include 31 power transformers located at 12 zone substations and one mobile substation (refer Figure 7.1). 28 of these transformers are 132/11 kV and 3 are 66/11 kV.

The age profile of these transformers shows that more than half of them are approaching or exceeding 30 years of age, and the oldest units are 50 years of age. The expected operational life of a power transformer ranges from 45 to 60 years. The typical failure rate of power transformers is estimated at around 3% per annum.

ActewAGL thus proposes to invest in a system spare 132/11 kV 30/55 MVA transformer to mitigate the effect of a power transformer failure on the network. Three options have been investigated regarding the location of such a transformer:

Option 1: Installation as a system spare at an existing zone substation.

As a system spare, the transformer would normally be installed as a fully functional and energised network component, and although energised may not actually be supplying any load.

Option 2: Installation as a rotational system spare to allow refurbishment of ageing transformers.

As a rotational system spare the purpose of the spare transformer would be to support load at substations while transformer testing and refurbishment was undertaken. Refurbishment of a power transformer has the potential to extend its operational life by 10 years or more.

At the majority of ActewAGL's zone substations, testing and refurbishment of a transformer would have to be done in situ as inadequate space is available to allow removal of the transformer and hence the opportunity to deploy a system spare in its place is limited.

Option 3: Permanent installation at East Lake Zone Substation.

East Lake Zone Substation was commissioned in 2013 as a single transformer substation with provision for future second and third transformers. Installation of the system spare transformer permanently at East Lake Zone Substation would establish N-1 supply security at this zone substation, and compliance with the ACT Electricity Distribution Supply Standards Code. Supply security is currently provided via 11 kV feeder inter-ties with neighbouring Telopea Park and Fyshwick Zone Substations

Rapid demand growth at East Lake is forecast over the next five years through the transfer of load to offload Fyshwick Zone substation and to supply new loads in the East Lake, Majura and Fyshwick areas.

As the transformer foundation pad and 132 kV and 11 kV connection equipment is already available at East Lake Zone Substation, this is the preferred option.

Estimated cost is $3.07 million and proposed project completion is by June 2019.

No non-network alternative to this project has been identified.

7.5.3 Belconnen Zone Substation third transformer

Belconnen Zone Substation supplies power to the Belconnen Town Centre, Calvary Hospital, University of Canberra, Canberra Institute of Technology, Australian Institute of Sport and surrounding commercial and residential areas. It has two 132/11 kV 30/55 MVA transformers. These transformers each have an emergency two-hour summer rating of 74 MVA and winter rating of 81 MVA.

ActewAGL's planning criteria requires a power transformer to be able to operate to its two hour emergency rating in the event of a contingency. After the initial two hour period the load must be reduced either by transferring to neighbouring zone substations or load shedding, to enable the load to be reduced on the remaining transformer to below its cyclic rating. The cyclic rating considers a longer term overload condition typically associated with the replacement of long lead items such as power transformers or 11 kV switchgear. The cyclic overload rating is lower than the emergency rating and in the case of the transformers at Belconnen Zone Substation is 63 MVA in summer and 76 MVA in winter.

Summer and winter maximum demands at Belconnen Zone Substation currently exceed 58 MVA and are forecast to grow steadily at around 1.8% per annum due primarily to major residential developments in the Belconnen and Lawson areas, and a new hospital under construction at the University of Canberra. Maximum demand is forecast to exceed 63 MVA for more than 2 hours by 2020.

Four options have been investigated to resolve the capacity issue at Belconnen Zone Substation:

Option 1: Load transfers to neighbouring zone substations.

Zone substations that have 11 kV feeder ties with Belconnen include Latham, Gold Creek and Civic zone substations. These feeder ties have limited transfer capability and load is growing at each of these three zone substations due to strong residential and commercial developments in the Belconnen, Gungahlin, Molonglo Valley and Canberra Central precincts. This option is thus not technically feasible.

Option 2: Non-network and demand side management.

There is no known potential embedded generation to be developed in the Belconnen area in the next five years other than rooftop solar PV. Solar PV has little impact on the winter maximum demand however which usually occurs around 7:00pm during June when PV generation is very low. Future installations of battery energy storage systems may have some impact on maximum demand but this is unquantified at this stage.

A non-network option providing load reduction at Belconnen Zone Substation of around 2.5 MW would be required by 2020.

Option 3: Installation of third transformer at Belconnen Zone Substation.

This option involves:

- Construction of three new 132 kV bays (line bay, transformer bay and bus section bay).
- Installation of new 132/11 kV 30/55 MVA power transformer and associated neutral earthing transformer.
- Installation of third 11 kV switchboard in a new building (the existing switch room does not have

sufficient space for a third switchboard).
- Protection and control equipment associated with the above new assets.

Installation of a third transformer would achieve the objectives of providing sufficient firm capacity to meet the forecast demand, whilst maintaining N-1 security of supply as required by the planning criteria. The estimated cost of this option is $12.62 million. This option has the highest net present value (NPV) of benefits and is preferred. Proposed project completion is by June 2020. The load will be managed by transfers to adjacent zone substations until then.

The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2017.

Viable proposals from third parties that can significantly reduce maximum demand of the Belconnen and Gungahlin area developments and enable ActewAGL to defer installation of the third power transformer at Belconnen Zone Substation are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 2.5 MW in 2020, 5.0 MW in 2021, 7.5 MW in 2022, and 10.0 MW in 2023, to enable the Belconnen Zone Substation third transformer project to be deferred. This would be in addition to the expected uptake of rooftop PV installations on residential dwellings.

7.5.4 Molonglo Zone Substation

The Molonglo Valley District is situated in Canberra's west, approximately 10 km from the Canberra Central Business District (CBD). It lies to the north of the urban areas of Weston Creek and south of Belconnen. Land servicing has commenced for the initial developments and when fully developed over the next 20 years, the Molonglo Valley District including the new suburbs of Coombs, Wright, Denman Prospect and Whitlam will support an estimated 21,000 dwellings plus shopping centres, schools and community facilities.

The first phase of development of the Molonglo Valley is underway, comprising Denman Prospect, Wright and Coombs suburbs. Supply is being provided to these developments through two extended 11 kV feeders from Woden Zone Substation (Hilder feeder @ 2.7 MW and Streeton feeder @ 2.7 MW). The proposed Whitlam suburb is at planning stage.

Load forecasts indicate that these feeders will reach their firm capacity limits around mid-2021 as the load of new developments in the Molonglo Valley increases. ActewAGL proposes to provide long-term capacity and security to the Molonglo Valley District by constructing a new 132/11 kV Molonglo Zone Substation at a site it owns to the west of the National Arboretum.

The *Electricity Distribution (Supply Standards) Code* issued by the ACT Independent Competition and Regulatory Commission (ICRC) sets out certain performance standards for the distribution network in the ACT. A Distribution Network Service Provider (DNSP) is required to 'take all reasonable steps to ensure that its Electricity Network will have sufficient capacity to make an agreed level of supply available'. The processes defined in these criteria serve to limit network augmentation expenditure to instances where the increase in demand is clear and above the secure or firm capacity.

The proposed Molonglo Zone Substation is required to meet the Electricity Distribution (Supply Standards) Code.

ActewAGL has considered four options to supply the Molonglo Valley District as follows:

Option	Option type	Description	Evaluation
1	Network	Construct new 11kV cable feeders from Latham Zone Substation	Discounted
2	Network	Construct new 11kV cable feeders from Belconnen Zone Substation	Discounted
3	Non-network	Demand side management	Insufficient
4	Network	New Molonglo Zone Substation	Preferred

Options 1 & 2 are discounted due to their high capital cost and the forecasted loading on Latham and Belconnen zone substations.

Option 3 considers demand side management initiatives including demand reduction and alternative supply measures such as embedded generation. The majority of demand of these developments is residential dwellings. The developer of Denman Prospect proposes to make detached dwellings in Denman Prospect energy efficient by requiring the mandatory installation of 3 kW rooftop solar PV generation per dwelling. This will reduce energy demand but will require significant uptake of energy storage, e.g. via battery storage installations, to have a major impact on the overall maximum demand of the network. In particular winter demand usually occurs around 6:00pm throughout the month of July when there is no PV generation, so peak shaving will require the use of battery storage devices.

Stage 1B of Denman Prospect Estate includes 34 apartment buildings comprising 1888 units. North Wright and North Coombs developments also include 7 proposed apartment buildings. Installation of solar PV or battery energy storage is not mandatory for apartment buildings so standard demand levels are expected for these units. ActewAGL has calculated After Diversity Maximum Demand (ADMD) of 2.5 kVA per unit for apartment buildings. There is also a recent trend towards the installation of instantaneous electric hot water systems in apartment buildings, which will potentially increase the ADMD per unit.

ActewAGL proposes to undertake a Smart Network trial project (refer section 9.9.2 for details) in Stage 1A of Denman Prospect Estate (comprising 400 dwellings) to assess the viability and effectiveness of network-controlled load demand of customer devices beyond the meter (eg PV output, battery storage systems, hot water heating systems, air conditioning, swimming pool pumps and electric vehicle charging stations). The outcome of this project may enable construction of the proposed Molonglo Zone Substation to be deferred.

Other demand reduction measures such as on-site generation, co-generation and tri-generation[7] which are associated with commercial and industrial businesses will not be applicable in the immediate future and are therefore not considered further.

Option 4 proposes to establish a new 132/11 kV zone substation at Molonglo by winter 2021. ActewAGL (in consultation with the ACT Government) has identified a suitable site in the Molonglo District for the zone substation. This site has been granted the necessary ACT Government approvals. The new Molonglo Zone Substation will initially be equipped with a single 132/11kV 30/55 MVA transformer with provision made for a second transformer to provide future capacity and security. Ultimate maximum demand of Molonglo Zone Substation is forecast to reach 53 MW by 2046 based on a 30-year development plan for the Molonglo Valley. 132 kV connection will be via loop-in-loop-out to the Canberra–Woden 132 kV circuit.

This is the preferred option. Estimated cost is $22.00 million and proposed project completion is by June 2021.

[7] Tri-generation is the production of electricity, heat and cooling in the one process. Typically this means a gas fired generator producing electricity and heat with the exhaust heat going to an absorption chiller which produces chilled water and hot water for air conditioning or alternatively the heat is used to heat a swimming pool.

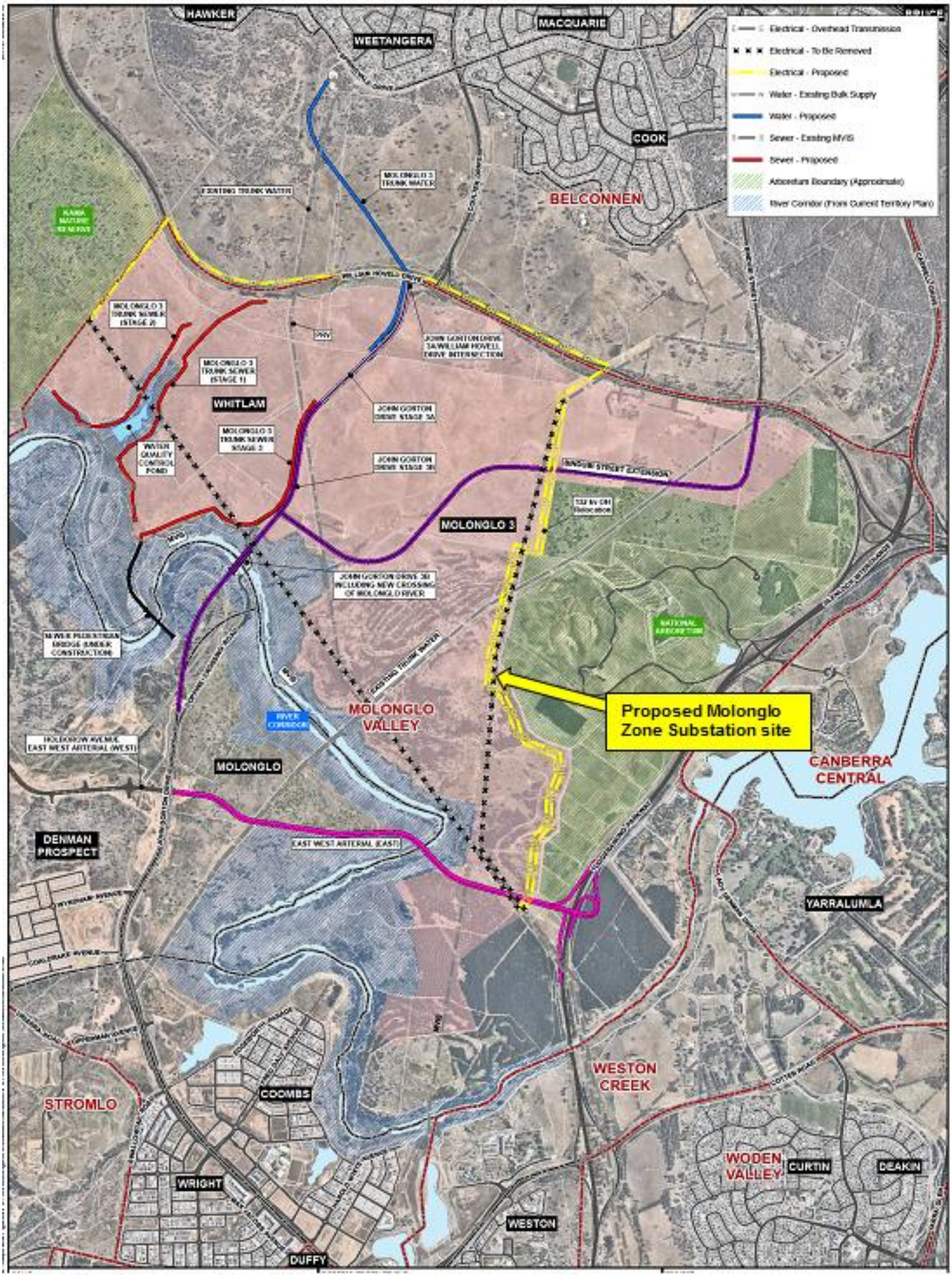
The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). A RIT-D will be commenced in 2017.

Viable proposals from third parties that can significantly reduce maximum demand of the Molonglo Valley developments and enable ActewAGL to defer construction of the Molonglo Zone Substation are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 2.5 MW in 2021, 4.2 MW in 2022, 5.9 MW in 2023 etc, to enable the Molonglo Zone Substation project to be deferred. This would be in addition to currently proposed rooftop PV installations on all detached dwellings.

As part of the Molonglo Valley development, the Land Development Agency has requested the relocation of sections of two ActewAGL 132 kV transmission lines; approx 4.7 km of the Canberra–Woden line and 3.4 km of the Civic–Woden line. These relocations will be done in conjunction with development of the Molonglo Zone Substation.

Figure 7.3 shows proposed development of the Molonglo Valley.

Figure 7.3 Proposed development of Molonglo Valley



7.5.5 Tennent Zone Substation

A new zone substation is being constructed at Angle Crossing in southern ACT to enable connection of the Williamsdale Solar Farm to ActewAGL's 132 kV transmission network. The solar farm will have a maximum design output of 10.1 MW and will be connected at 11 kV to the proposed Tennent Zone Substation via underground cables. The zone substation will comprise a single 11/132 kV 15 MVA step-up transformer and will be connected via a tee-arrangement to the Williamsdale–Theodore 132 kV transmission line.

The site for the new zone substation is adjacent to ActewAGL's Angle Crossing mobile substation. Existing customers supplied from Angle Crossing will be reconnected to Tennent Zone Substation. This will enable the mobile substation to be redeployed elsewhere as required.

Proposed project completion is February 2017. The new Tennent Zone Substation is being funded by the solar farm developer, but will be owned, operated and maintained by ActewAGL.

7.5.6 Mitchell Zone Substation

The Mitchell area is situated in Canberra's north, approximately 10 km from the Canberra Central Business District. Load has been growing steadily in the Mitchell area and is forecast to continue to grow. Proposed new loads include commercial, light industrial and residential developments, and Canberra's new light rail network.

Power supply to the Mitchell area is currently fed from Gold Creek and Belconnen zone substations. Electrical load on Gold Creek and Belconnen zone substations is increasing rapidly with demand from new and proposed residential estates to the north including Jacka, Moncrieff, Ngunnawal, Casey, Taylor, Lawson, Throsby and CSIRO Ginninderra, and commercial and residential developments in the Gungahlin and Belconnen town centres. Gold Creek and Belconnen zone substations have limited capacity available to supply the growth in demand in the Mitchell area other than the proposed 11 kV feeders described in Sections 7.5.8 and 7.5.9.

To meet the increasing demand for electricity in this part of the ACT, ActewAGL has determined that a new 132/11 kV zone substation will be required in the Mitchell area by winter 2023. The increasing penetration of rooftop PV and battery storage systems may impact on timing although loads in the Mitchell area are predominantly industrial or commercial.

ActewAGL is in the process of securing a site for the proposed Mitchell Substation, preferably close to the Gold Creek–Bruce 132 kV transmission line and close to the growing load centre.

The new Mitchell Zone Substation will initially be equipped with a single 132/11kV 30/55 MVA transformer with provision made for a second transformer to provide future capacity and security. Ultimate maximum demand of Mitchell Zone Substation is forecast to reach 30 MW by 2046 based on a 30-year development plan for the Gungahlin District.

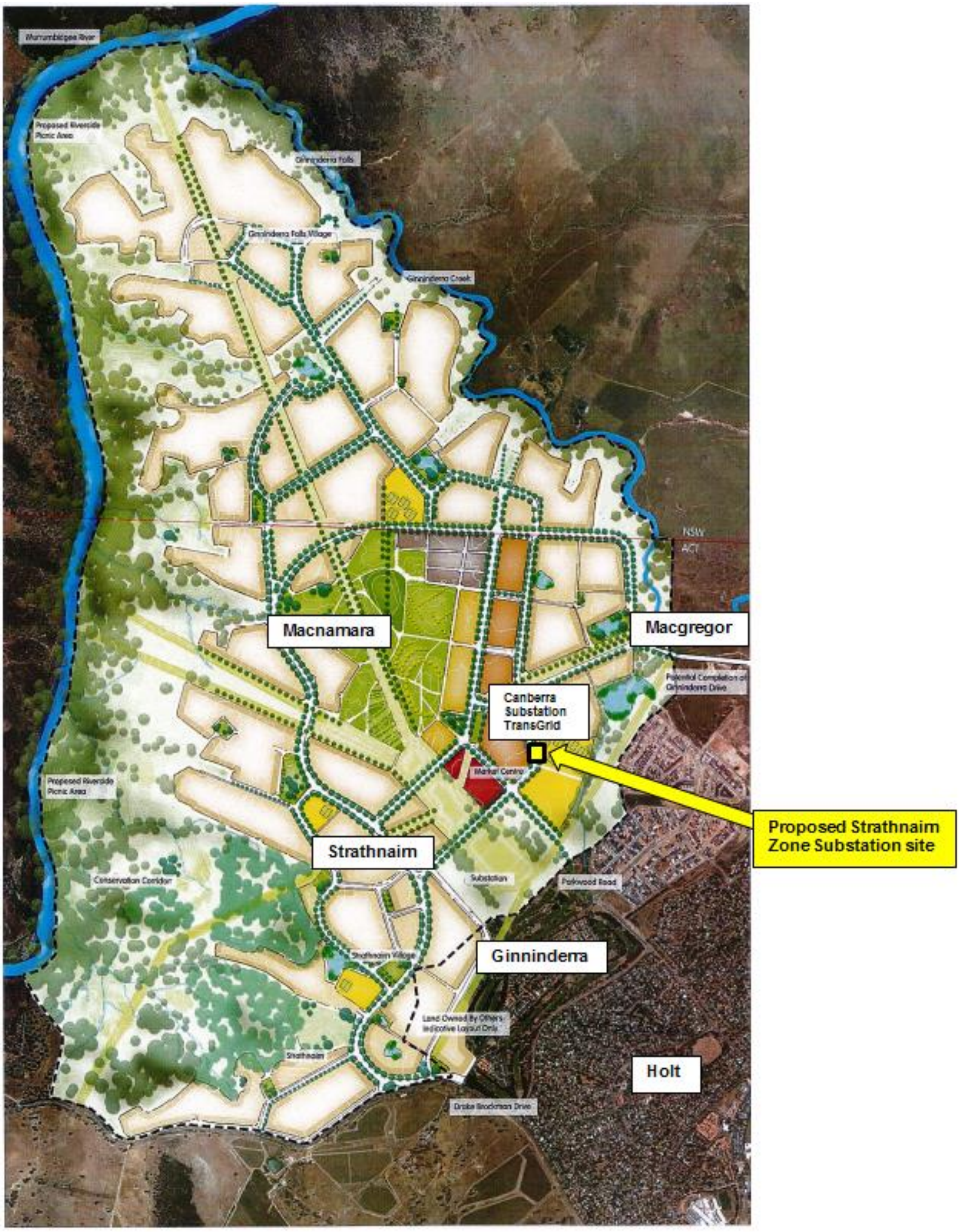
This is the preferred option. Estimated cost is $23.00 million and proposed project completion is by June 2023.The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2019.

Viable proposals from third parties that can significantly reduce maximum demand of the Mitchell area developments and enable ActewAGL to defer construction of the Mitchell Zone Substation are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 2.5 MW in 2021, 4.2 MW in 2022, 5.9 MW in 2023 etc, to enable the Mitchell Zone Substation project to be deferred.

7.5.7 Strathnairn Zone Substation

A large area in the northwest of the ACT is being developed as a residential subdivision. The West Belconnen development will include three new suburbs, the first two to be named Strathnairn and Macnamara. Works have commenced on this development and are proposed to continue over the next 30 years with potentially 11,500 new dwellings plus commercial and community infrastructure being developed. Development will proceed at the rate of approximately 380 dwellings per annum. Figure 7.4 illustrates this.

Figure 7.4 Proposed development of West Belconnen



Future maximum demand based on current ADMD figures for each dwelling type, of the West Belconnen development is approximately 45 MW. The West Belconnen development will feature mandatory rooftop PV installations on all detached dwellings (ranging in size from 1.5 kW to 4.0 kW), plus possible future network sized battery storage banks located adjacent to each 11/0.415 kV distribution substation. Capacity of each battery bank would be around 250 kWh.

These systems will reduce energy demand via ActewAGL's network and potentially also reduce maximum demand with the advent of smart network load control schemes. At times of high generation, energy could be exported back into ActewAGL's 11 kV network.

Initial supply to this development will be from extended Latham and Macrossan 11 kV feeders which emanate from Latham Zone Substation. The spare capacity of these existing feeders is approximately 4 MVA only and will eventually be utilised. ActewAGL will be required to construct a new zone substation to supply future load demand. It is expected that the new zone substation will be required around winter 2022, although timing could be deferred depending on the performance of the proposed embedded generation and energy storage systems. ActewAGL proposes to construct a new 132/11 kV zone substation (to be known as Strathnairn Zone Substation) at a site adjacent to the south-eastern corner of TransGrid's Canberra Substation.

132 kV supply to Strathnairn Zone Substation would be via a loop-in-loop-out connection of the proposed Canberra–Stockdill line (refer Stockdill Substation section 7.5.1). Connection would be via underground 132 kV cable to a spare bay at TransGrid's Canberra Substation and to an underground-to-overhead (UGOH) structure on the existing transmission line. The substation will be a standard outdoor zone substation comprising air-insulated switchgear similar to others owned by ActewAGL, e.g. Gold Creek. The substation will be constructed to accommodate up to three 55 MVA 132/11 kV transformers though initially will be equipped with one transformer only.

A network of up to 20 new 11 kV feeders will be run from Strathnairn Zone Substation throughout Strathnairn and Macnamara suburbs as development proceeds. These feeders will be interconnected to feeders from Latham Zone Substation where possible to provide backup inter-ties.

Estimated cost is $23.00 million and proposed project completion is by June 2022.The augmentation cost of this proposal exceeds $5 million so this project will be subject to the Regulatory Investment Test for Distribution (RIT-D). ActewAGL proposes to commence the RIT-D consultation process in July 2018.

7.5.8 Decommissioning of Causeway Switching Station

The Causeway Switching Station located in the Kingston suburb at the eastern end of Lake Burley-Griffin, provides a point of 132 kV interconnection between City East, East Lake, Telopea Park and Gilmore zone substations. Connections to Causeway Switching Station comprise three 132 kV underground cable circuits to Telopea Park Zone Substation, a single circuit 132 kV overhead line to Gilmore Zone Substation, a single circuit 132 kV overhead line to City East Zone Substation, and a single circuit 132 kV overhead line to East Lake Zone Substation. Sections of these latter two lines traverse the Jerrabomberra wetlands nature reserve.

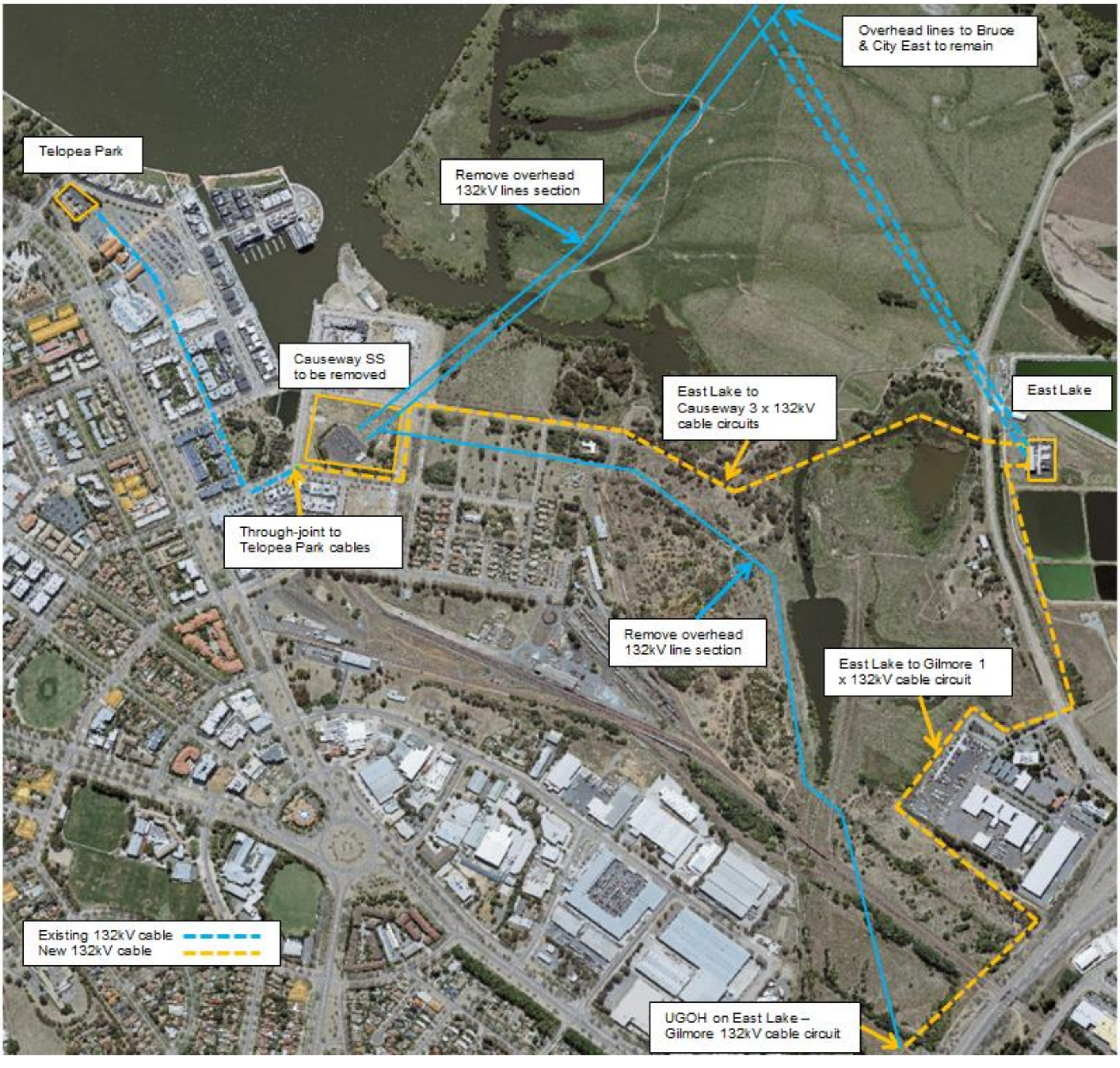
The site of Causeway Switching Station is surrounded by new apartment buildings and there is a desire by the LDA to redevelopment the switching station site for similar residential purposes. The LDA has requested ActewAGL to convert the 132 kV overhead lines in the vicinity of Causeway to underground cables and decommission the switching station. The proposed scope of works is as follows:

- Install three 132 kV cable circuits comprising one single core cable per phase (each circuit 3 x 1c/630mm^2 Cu XLPE) from East Lake Zone Substation through the Jerrabomberra wetlands to Causeway Switching Station to through-joint to the existing Causeway–Telopea Park cable circuits. This route includes directional drilling under the Jerrabomberra Lake. This will create three 132 kV underground cable circuits all the way from East Lake to Telopea Park, each rated at 127 MVA. These existing circuits are currently transformer feeders as there is no 132 kV bus at Telopea Park Zone Substation. It is proposed to retain them as transformer feeders.

- The East Lake–Causeway 132 kV circuit is currently approx 1.4 km underground cable connected to approx 1.6 km overhead line. The cable section will be reconnected to the City East line and the overhead section demolished. This will create a new East Lake–City East 132 kV circuit rated at 220 MVA.
- The Causeway–Gilmore 132 kV circuit is currently all overhead. A 132 kV underground cable circuit comprising twin single core cables per phase (6 x 1c/1200mm^2 Cu XLPE) will be installed approx 2.0 km from East Lake Zone Substation to connect to the existing overhead line at a new three concrete pole UGOH structure to replace pole no T87 at the corner of Canberra Ave and Monaro Highway. This will create a new East Lake–Gilmore 132 kV circuit rated at 457 MVA.
- Causeway Switching Station will be subsequently decommissioned and dismantled.

The overhead to underground conversion works will be funded by the developer. Decommissioning of Causeway Switching Station by ActewAGL is estimated to cost $2.00 million and proposed project completion is by June 2020. Figure 7.5 illustrates this proposed development.

Figure 7.5: Causeway Switching Station – Proposed 132 kV Cabling



7.5.9 11 kV Feeder from Gold Creek Zone Substation to Mitchell

The objective of this project is to provide supply to an existing commercial development in the Mitchell area which has requested a large increase in demand of up to 7.0 MW. The nature of this demand is a flat load profile. There is insufficient spare capacity in existing 11 kV feeders in the area. ActewAGL has considered two options to supply this load as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct new 11 kV cable feeder from Belconnen Zone Substation	$4.38 m	Not Preferred
2	Network	Construct new 11 kV cable feeder from Gold Creek Zone Substation	$3.50 m	Preferred

Option 1 involves the installation of a new 11 kV cable feeder from Belconnen Zone Substation to the Mitchell area. There is no spare 11 kV feeder circuit breaker at Belconnen Zone Substation so the new feeder would have to be connected in parallel with an existing feeder. The length of this feeder would be approximately 9.5 km. This is not the lowest cost option and is not preferred.

Option 2 involves the installation of a new underground 11 kV cable feeder from Gold Creek Zone Substation to the Mitchell area. A feeder circuit breaker will be made available at Gold Creek Zone Substation through another project. The length of this feeder will be approximately 7.0 km. Spare conduits will be installed along the feeder route to provide for future developments. This is the lowest cost option and is preferred.

Estimated cost is $3.50 million and proposed project completion is by June 2018.

7.5.10 11 kV Feeders from Gold Creek Zone Substation to Gungahlin

The objective of this project is to provide supply to existing and proposed commercial and residential developments in the Gungahlin area.

The Proposed Gungahlin Town Centre East development will include 10 new apartment buildings totalling 1,100 units, plus up to 12 office buildings with ground floor shops. Other developments in the Gungahlin area include a cinema complex, three other apartment buildings, Capital Metro traction power station, and the 1,100 dwellings Throsby residential estate. Total forecast additional load is approximately 11.0 MW.

There is insufficient spare capacity in existing 11 kV feeders in the area. ActewAGL has considered two options to supply the Gungahlin area as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct three new 11 kV cable feeders from Belconnen Zone Substation	$8.10 m	Not Preferred
2	Network	Construct three new 11 kV cable feeders from Gold Creek Zone Substation	$3.60 m	Preferred

Option 1 involves the installation of three new 11 kV cable feeders from Belconnen Zone Substation to the Gungahlin area. There are no spare 11 kV feeder circuit breakers at Belconnen Zone Substation so the new feeders would have to be connected in parallel with existing feeders. The length of these feeders would be approximately 13.0 km. This is not the lowest cost option and is not preferred.

Option 2 involves the installation of three new underground 11 kV cable feeders from Gold Creek Zone Substation to the Gungahlin area. Two feeder circuit breakers will be made available at Gold Creek Zone Substation through another project. The length of these feeders will be approximately 3.2 km. Spare conduits will be installed along the feeder route to provide for future developments. This is the lowest cost option and is preferred.

The first part of the route for these feeders, from Gold Creek Zone Substation along Mirrabei Drive to Gundaroo Drive, will be a shared trench with the proposed Gold Creek – Mitchell feeder as described in Section 7.5.9 above.

Estimated cost is $3.60 million and proposed project completion is by June 2018.

7.5.11 11 kV Feeder from Wanniassa Zone Substation to Tuggeranong Town Centre

The ACT Government's Environment and Sustainable Development Directorate (ESDD) has prepared a plan for the development of the Tuggeranong Town Centre, including commercial and residential developments. Construction is underway at the first stage of development which is the Greenway residential development adjacent to the western side of Lake Tuggeranong. The second stage will involve residential development adjacent to the eastern side of Lake Tuggeranong.
The first stage development will comprise approximately 2,400 residential dwellings and 7,400 m^2 of land zoned for commercial development. The residential dwellings will be multi-storey apartment buildings.

The load forecast for this development is estimated to be 7.1 MW, comprising 5.1 MW of residential load and 2.0 MW of commercial load. Load required by any associated community development has not been assessed.

There are several existing 11 kV feeders in the area, all from Wanniassa Zone Substation. Two of these feeders (Pitman and Rowland) have approximately 2.5 MW of spare capacity available between them but all other feeders are heavily loaded. Construction of a large office block at Athllon Drive, Greenway is currently underway and will require around 2.0 MW of this available capacity.

ActewAGL has considered three options to supply the Tuggeranong Town Centre area as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Extend two existing 11 kV cable feeders from Wanniassa Zone Substation	$1.66 m	Discounted
2	Network	Construct new 11 kV cable feeder from Theodore Zone Substation	$3.06 m	Not Preferred
3	Network	Construct new 11 kV cable feeder from Wanniassa Zone Substation	$3.02 m	Preferred

Option 1 involves the extension of the Pitman and Rowland feeders to the Greenway residential development area. The combined length of these feeder extensions would be approximately 3.6 km. This option would provide 2.5 MW capacity only, 2.0 MW of which has been allocated to the office block under construction as mentioned above. This option is thus discounted.

Option 2 involves the installation of a new 11 kV cable feeder from Theodore Zone Substation to the Tuggeranong Town Centre area. There is a spare 11 kV feeder circuit breaker at Theodore Zone Substation. The length of this feeder would be approximately 7.2 km. This is not the lowest cost option and is not preferred.

Option 3 involves the installation of a new underground 11 kV cable feeder from Wanniassa Zone Substation to the Tuggeranong Town Centre area. There is no spare 11 kV feeder circuit breaker at Wanniassa Zone Substation so a circuit breaker would be made available by paralleling two other lightly loaded feeders. Wanniassa Zone Substation has a continuous summer rating of 95 MVA with maximum demand around 80 MVA, so has spare capacity available for this development. The length of this feeder will be approximately 6.3 km. Spare conduits will be installed along the feeder route to provide for future developments. This is the lowest cost option and is preferred.

Estimated cost is $3.02 m and proposed project completion is by June 2017.

Viable proposals from third parties that can significantly reduce maximum demand of the Tuggeranong Town Centre development and enable ActewAGL to defer construction of the new 11 kV feeder are welcome. It is estimated that such proposals would be required to provide an increasing reduction in maximum demand of approximately 2.5 MW in 2016, 4.5 MW in 2017, 5.8 MW in 2018, and 7.1 MW by 2019, to enable the proposed 11 kV feeder project to be deferred.

7.5.12 11 kV Feeder from Woden Zone Substation to Molonglo Valley

A new zone substation is planned to be constructed in the Molonglo Valley by June 2021 (refer section 7.5.4).

Development of the Molonglo Valley district is underway with Wright and Coombs suburbs development nearing completion, North Coombs suburb development at design stage, Denman Prospect suburb development underway and Whitlam suburb development at planning stage.

Two 11 kV feeders from Woden Zone Substation (Hilder and Streeton feeders) have been extended to provide initial supply to the area. It is also proposed to upgrade an existing 11 kV overhead line feeder from Civic Zone Substation (Black Mountain feeder) to provide additional capacity and future feeder inter-tie to the proposed Molonglo Zone Substation.

A new 11 kV cable feeder from Woden Zone Substation to the Molonglo Valley area is proposed to provide additional capacity and future feeder inter-tie to the proposed Molonglo Zone Substation.

These feeder developments will enable construction of the Molonglo Zone Substation to be deferred until 2019-2021.

There are no spare 11 kV feeder circuit breakers available at Woden so one of the three existing 11 kV switchboards will be extended to provide an additional circuit breaker. Woden Zone Substation has a continuous summer rating of 95 MVA with maximum demand around 81 MVA, so has spare capacity available for this development. The length of this feeder will be approximately 6.0 km and it will utilise an existing spare conduit along John Gorton Drive.

Estimated cost is $2.50 million and proposed project completion is by June 2018.

7.5.13 11 kV Feeder from Latham Zone Substation to Belconnen Trade Services Area

The Belconnen Services Trade area is a proposed development located to the west of the Belconnen Town Centre. The development will comprise approximately 800 residential dwellings and 48,300 m^2 of land zoned for commercial and light industrial development, and community use.

The load forecast for this development is estimated to be 11.8 MW, comprising 2.8 MW of residential load and 9.0 MW of commercial and light industrial load. Load required by any community development has not been assessed. There are several existing 11 kV feeders in the area (four from Belconnen Zone Substation and two from Latham Zone Substation). The nearest feeder to the development area is the Fielder Feeder from Latham Zone Substation. There is insufficient spare capacity available in these feeders that could be used to supply this development, so a new feeder is proposed.

ActewAGL has considered two options to supply the Belconnen Trade Services area as follows:

Option	Option type	Description	Cost	Evaluation
1	Network	Construct new 11kV cable feeder from Belconnen Zone Substation	$3.32 m	Not Preferred
2	Network	Construct new 11kV cable feeder from Latham Zone Substation	$3.07 m	Preferred

Option 1 involves the installation of a new underground 11 kV feeder from Belconnen Zone Substation to the Belconnen Trade Services area. There is no spare 11 kV feeder circuit breaker at Belconnen Zone Substation so the new feeder would have to be connected in parallel with an existing feeder. The length of this feeder would be approximately 4.5 km. This option is contingent on the Belconnen Zone Substation third transformer installation proceeding (ref 7.5.3). This is not the lowest cost option and is not preferred.

Option 2 involves the installation of a new 11 kV feeder from Latham Zone Substation to the Belconnen Trade Services area. A spare feeder circuit breaker is available at Latham Zone Substation. Latham Zone Substation has a continuous summer rating of 95 MVA with maximum demand around 60 MVA, so has spare capacity available for this development. The length of this feeder will be approximately 4.9 km. Spare conduits will be installed along the feeder route to provide for future developments. This is the lowest cost option and is preferred.

Estimated cost is $3.07 million and proposed project completion is by June 2019.

7.5.14 11 kV Feeder from Civic Zone Substation to Canberra CBD West

Canberra City CBD west area is experiencing significant growth in terms of residential redevelopments (old detached houses being replaced by multi-unit blocks), particularly in the Acton, Braddon, O'Connor and Lyneham areas. The load forecast for these developments is estimated to be an additional 6.0 MW of residential load.

There are several existing 11 kV feeders in the area, all from Civic Zone Substation, all of which are heavily loaded. There is insufficient spare capacity available in these feeders that could be used to supply these new developments, so a new feeder is proposed. Civic Zone Substation has a continuous summer rating of 110 MVA with maximum demand around 70 MVA, so has spare capacity available for these developments.

It is proposed to install an 11 kV cable feeder to an existing11 kV switching station at Edinburgh St, CBD west, from a spare feeder circuit breaker at Civic Zone Substation. The length of this feeder will be approximately 3.3 km. The first section of this feeder (approximately 2 km) will be installed in a common trench with proposed new feeders to the Australian National University. Spare conduits will be installed along the feeder route to provide for future developments.

Estimated cost is $2.77 million and proposed project completion is by June 2019.

Demand management could possibly defer the need for this project. Potential demand management options to relieve existing and forecast feeder constraints include:

- On-site embedded generation used to reduce peak demands.
- Demand response by larger commercial customers to reduce peak demands.

Suitable embedded generation would be required to operate daily during peak load periods. Demand response by larger customers requires predetermined and guaranteed demand reduction actions at the participating customer sites.

Viable proposals from third parties that can significantly reduce maximum demand of the Canberra Central City area to defer construction of the new 11 kV feeder are welcome.

7.5.15 11 kV Feeders from East Lake Zone Substation to Kingston area

The ACT Government's Environment and Sustainable Development Directorate (ESDD) has prepared a plan for the development of the area of land at the eastern end of Lake Burley-Griffin between Kingston and Fyshwick, including commercial and residential developments.

The development will comprise approximately 3,850 residential dwellings, a commercial area and a school. The residential dwellings will be primarily multi-storey apartments.

The load forecast for this development is estimated to be 9.7 MW, comprising 7.7 MW of residential load and 2.0 MW of commercial and community use (school) load.

There are no existing 11 kV feeders in this area which is approximately 3 km east of Telopea Zone Substation and 2 km west of East Lake Zone Substation. Telopea Zone Substation has a continuous summer rating of 100 MVA with maximum demand around 108 MVA, so has no spare capacity available for this development.

East Lake Zone Substation has a single 55 MVA transformer only at present though a second 55 MVA is planned by June 2018 (refer section 7.5.2), with maximum demand around 16 MVA, so has spare capacity available for this development.

It is proposed to install two 11 kV cable feeders to this area from East Lake Zone Substation from existing spare feeder circuit breakers. The length of each feeder will be approximately 2.0 km. Spare conduits will be installed along the feeder routes to provide for future developments.

Estimated cost is $3.01 million and proposed project completion is by June 2020.

7.5.16 11 kV Feeders from East Lake Zone Substation to Fyshwick

The load in the Fyshwick area is forecast to increase by approximately 15.0 MW over the next five years, driven primarily by the development of two new large data centres, plus other small commercial and light industrial developments.

Existing 11 kV feeders that emanate from Fyshwick Zone Substation are heavily loaded. ActewAGL's long term strategy is to transfer loads from Fyshwick Zone Substation which is the only 66/11 kV zone substation on the network, to the new East Lake 132/11 kV Zone Substation.

It is proposed to install two 11 kV cable feeders to the Fyshwick area from East Lake Zone Substation from existing spare feeder circuit breakers. The length of each feeder will be approximately 4.0 km. Spare conduits will be installed along the feeder routes to provide for future developments.

Estimated cost is $3.80 million and proposed project completion is by June 2018.

7.5.17 Installation of OPGW on 132 kV transmission lines

The existing ActewAGL SCADA telecommunications network is a mix of UHF digital radios (DDRN) and pilot wires, with some small scale use of optical fibre and microwave links. The network is extremely limited in capacity and does not provide adequate and timely real time SCADA information for effective control room operations, with some analogue and digital changes taking several minutes to be reported.

The performance constraints of the network present a roadblock to realising the benefits of the SCADA system and this will only become more apparent with the implementation of the Advanced Distribution Management System (ADMS), where real time data is critical to correctly calculate the network state, load flows and correctly report network outages.

In addition to SCADA communications, the other critical application for communications is with ActewAGL's network protection. Increasingly some aspects of the protection systems will require communications to overcome protection performance and grading issues. In particular, the performance of the existing 132 kV network protection falls short of technical compliance with the current National Electricity Rules. These performance shortcomings are considered acceptable due to 'grandfathering' provisions within the Rules, but as network upgrades and augmentations occur the network protection will need to be brought into compliance with current standards.

Augmentations such as connecting generators to the network, or when the 132 kV network is upgraded or modified, are triggers for protection upgrades. Required protection upgrades may include the implementation of inter-tripping and line differential protection schemes and these are dependent on reliable and secure communications. In the future, the emergence of IEC 61850 as the industry standard substation automation and protection communications standard will require a very high level of reliability in the communications network.

The objective of this project is to replace existing communication networks with an optical fibre network that can deliver the speed, security, reliability and functionality required for the electricity network. It will be used to provide the communications bearer for the following systems:

- Zone substation protection signalling, including communications for inter-tripping and line differential protection.
- SCADA communications to zone substations, fault passage indicators, reclosers, switches and distribution substations.
- Security video and remote access management.
- Substation VoIP telephone.
- Corporate data services.
- Advanced metering infrastructure (AMI) communications.

- Inter station protection and control schemes.
- Intra station protection schemes utilising IEC 61850 and “GOOSE” messaging. Generic Object Oriented Substation Events (GOOSE) is a controlled model mechanism in which any format of data (status or analogue value) is grouped into a data set and transmitted within a time period of 4 milliseconds.
- Substation engineering access, for example remote access to protection relay fault records.
- Mobility communication to vehicles & deployed mobile tablets/computers.
- Network video, for example infrared cameras for switchyard fault detection.
- Monitoring and management of the communication network.

The optical fibre cables will follow each of ActewAGL’s 132 kV transmission lines, and will be strung on the same pole or tower structures.

Estimated cost is $5.25 million and the project will be implemented over a three year period from 2015 to 2017.

No non-network alternative to this project has been identified.

7.5.18 SCADA communications upgrade, optic fibre to distribution substations

The installation of fibre optic cables to individual distribution substations will be required in the following situations:

- Replacement of existing copper pilot cables with fibre due to failure of the metallic pilot.
- Additional business requirement such as chamber substation SCADA or advanced metering infrastructure (AMI).
- Additional network protection requirements such as protection inter-tripping.
- Network automation requirements such as flop-over schemes for critical customers such as hospitals.
- High voltage customer and generator network connections.

It is proposed to roll out an optic fibre network to distribution substations over the next ten years at an annual estimated cost of approximately $407,000 pa.

No non-network alternative to this project has been identified.

7.6 Projects Subject to the Regulatory Investment Test

If the augmentation or replacement cost of a proposal exceeds $5 million, we undertake a Regulatory Investment Test in line with the requirements of the NER (Section 5.16 for transmission RIT-T and Section 5.17 for distribution RIT-D). The purpose of the Regulatory Investment Test is to identify the credible option that maximises the present value of net economic benefit to all those who produce, consume and transport electricity in the market. A preferred option may have a negative net economic benefit (that is, a net economic cost) where the identified need is for reliability corrective action. The RIT process considers all credible options that are technically and economically feasible, including non-network options.

Table 7.2 lists the projects proposed to commence in the five-year planning period that have an augmentation or replacement component cost exceeding $5 million and will be subject to the RIT-D.

Interested parties are invited to participate in the planning process through the RIT-D consultation process.

Table 7.2: Augmentation Projects Subject to the Regulatory Investment Test for Distribution

Proposed project	Identified Need	Estimated Cost	Start RIT-D
Establishment of a new zone substation in the Molonglo District	The existing network will not be able to meet forecast demand from new residential developments in the Molonglo District due to supply capacity and load transfer capability constraints.	$21.94 m	July 2017
Belconnen Zone Substation third transformer	Belconnen Zone Substation is forecast to exceed its emergency rating limit by summer 2019-20.	$12.62 m	July 2017
Establishment of a new zone substation in the Mitchell District	The existing network will not be able to meet forecast demand from new residential and commercial developments in the Mitchell and Gungahlin areas due to supply capacity and load transfer capability constraints.	$22.00 m	July 2019

Note the proposed Second Point of Supply to the ACT project (as described in Section 7.5.1) was part of a joint RIT-T completed in 2009 by ActewAGL and TransGrid for the programme of projects required to provide a second point of supply to the ACT. Works are expected to be completed on this project by December 2020.

ActewAGL has no projects subject to the RIT-D currently underway or completed within the last year.

7.7 Inter-Regional Impact of Projects & Relevant National Transmission Flow Path developments

National Transmission Flow Paths (NTFPs) are those portions of transmission networks used to transport large amounts of electricity between generation and load centres. These are generally transmission lines of nominal voltage 220 kV and above. The Australian Energy Market Operator (AEMO) publishes an annual National Transmission Network Development Plan (NTNDP), the purpose of which is to facilitate the development of an efficient national electricity network that considers forecasts of constraints on the NTFPs.

ActewAGL has no network infrastructure above 132 kV operating voltage.

The only major infrastructure development proposed for the ACT during the five-year planning period referred to in the 2014 NTNDP is TransGrid's proposed 330/132 kV substation to be constructed at Stockdill Drive, approximately 3 km south-west of Canberra Substation. This is required to meet the ACT Government's requirement that the ACT network must be connected to two geographically independent 330 kV supplies, be capable of providing 375 MVA capacity to the ACT immediately following a single special contingency event, and be capable of providing full capacity to the ACT within 48 hours of a single special contingency event. This project must be completed by December 2020.

The 2015 NTNDP focusses on the integration of renewable generation and emerging technologies to the transmission grid, and the trend of expenditure to replacing ageing infrastructure outweighing investment in new network capacity. Ancillary services such as Network Support and Control Ancillary Services (NSCAS) and Frequency Control Ancillary Services (FCAS) are not regarded as an issue for ActewAGL due to the relatively small size of our network compared with other networks in the NEM, and the relatively small percentage of embedded generation connected to our network.

The 2015 NTNDP suggests there could be significant growth of large-scale solar PV generation in the ACT over the next 20 years. This could cause future congestion on the transmission network if there is a requirement to export this generation from the Canberra zone to the Central New South Wales zone[8].

None of the proposed projects described in this chapter will have a material inter-regional impact, ie they will not impose power transfer constraints or adversely influence the quality of supply to adjoining transmission or distribution networks.

7.8 Strategic Planning

ActewAGL is preparing a long-term strategy (ie 30-year plan) for development of the transmission and distribution network. This strategy document will examine the long term load forecasts for the ACT; long term known developments such as the Molonglo Valley, Mitchell, West Belconnen, Gungahlin and Tuggeranong precincts; the potential impact of emerging technologies such as micro grids, embedded generation, smart networks, smart metering, electric vehicles, battery storage, hydronic and vacuum waste services; dynamic ratings for transmission lines and power transformers; and identify any opportunities for stakeholder input.

The impact of our changing environment, e.g. climate change and the Government's renewable energy targets and plan to reduce greenhouse gas emissions, are key drivers in determining future investment in

[8] Refer 2015 NTNDP http://www.aemo.com.au/Electricity/Planning/National-Transmission-Network-Development-Plan.

both the generation and demand-side management sectors. The extent that customers will generate and store energy both for their own use and export, will have a major impact on the topology and dynamic control of the distribution network. These factors will influence future transmission and distribution infrastructure development and operation.

The ACT's climate provides for future extensive solar power generation, though is not conducive to generation from other sources such as hydro and wind. The effectiveness of future battery energy storage systems coupled with solar PV generation, could have a major impact on ActewAGL's future network operations.

Many of ActewAGL's distribution assets are approaching the end of their economic life and strategies will be developed regarding their replacement. Such assets include urban backyard overhead low voltage lines. With increasing in-fill housing developments, these backyard lines are becoming increasingly difficult to access and maintain.

The long-term strategy plan will provide strategic direction for the efficient utilisation of existing assets and future development of ActewAGL's transmission and distribution networks, to ensure a long-term sustainable and reliable electricity supply to the ACT.

8. Demand Management

8.1. Overview of Demand Management

Demand management in the context of an electricity distribution network is deliberate action taken to reduce demand from the grid, rather than increasing supply capacity to meet increased demand.

Traditionally customers have consumed energy as and when they require it and network service providers such as ActewAGL have constructed their infrastructure to meet the maximum demand on the network allowing for adequate redundancy. Existing regulatory and revenue models in the Australian electricity industry have not provided any incentive for network service providers to manage peak energy use.

Demand management seeks to influence the patterns of energy consumption including the amount and rate of energy use, the timing of energy use and the source and location of energy supply. Demand management is an important part of efficient and sustainable network operations and can involve the voluntary reduction of customer electricity demand at peak times, network service provider controlled reduction of electricity demand, or the supply of electricity from generators or storage connected at customer's premises or to the distribution network.

The majority of Australian electrical grids have very uneven loading, with a major portion of the grid capacity being unused for the majority of any given day or year. Nevertheless, significant expenditure is required to install and maintain this capacity to meet very short peak demand periods. By reducing peak load on the grid, security of supply can be maintained without installing additional infrastructure and its associated expenditure.

Historically there has been limited ability to manage peak demand on a network, but recent advances in smart metering and communications technologies mean that there are now a large number of methods to control loads and the cost of these options are reducing. ActewAGL recognises that in order for the network to continue to provide high quality low cost service to consumers, demand management including peak load management, energy efficiency and distributed generation will be an integral part of future operations.

ActewAGL actively engages with its customers and non-network solution providers to identify demand management options and will be striving to achieve significant advances in demand management in the future.

Effective use of demand management can remove or defer the need to augment load-constrained parts of the network to meet growth in demand, and reduce the cost of replacing ageing assets, leading to lower costs to customers.

A demand management solution is referred to as a non-network solution and a demand management provider is referred to as non-network provider.

Demand in some parts of ActewAGL's network is relatively constant with little or no growth. In other areas demand is growing rapidly, particularly in new greenfield residential areas, urban renewal areas (where single level houses are being demolished and replaced by apartment buildings), and in some commercial/industrial areas, eg due to new data centres.

ActewAGL is investigating ways to maximise the benefits of non-network technologies such as PV generation and battery energy storage, as well as manage the use of new loads such as electric vehicle charging stations, to reduce daily system peaks and produce as smooth a load profile as possible. The future use of alternative energy sources such as natural gas will greatly influence the demand on the electricity network.

8.2 Demand Side Engagement Strategy

ActewAGL's Demand Side Engagement Strategy (DSES) aims to create a cooperative and proactive relationship with customers and proponents of non-network solutions and involve them with ActewAGL's network planning and expansion. ActewAGL encourages customers and potential non-network service providers to participate in the ActewAGL demand management activities with the objective that future network problems can be met by a full range of solutions to achieve optimal economical and technical outcomes.

ActewAGL's Demand Side Engagement Strategy is currently undergoing revision to ensure that it meets its objectives which are:

- embracing Demand Side Management (DSM) and providing opportunities for our customers and non-network service proponents to participate in resolving network and customer supply limitations;
- developing and applying a transparent DSM process for network planning and development;
- identifying DSM options for individual and broad based demand management situations;
- providing proponents of non-network solutions with simple and effective mechanisms for obtaining information on network development proposals; and
- developing demand management tools and industry alliances to readily facilitate non-network options.

A non-network option may involve reducing overall demand or demand at critical times on a particular part of the network by DSM including demand response (DR) programs, peak shaving generation, embedded generation, energy storage connected at customers' premises or to the distribution network or other DSM solutions.

Customers and non-network proponents who are involved with DSM that is able to effectively defer costly network solutions will be able to access a revenue stream developed through this deferral. This approach reduces the overall cost to maintain the network and results in lower electricity costs to customers.

8.3 Demand Side Management Programs

DSM programs are developed in a way that residential, commercial and industrial customers and third party businesses such as demand aggregators and curtailment service providers can easily participate.

These programs encourage customers to reduce their demand or use alternative energy sources for their energy needs when the network capacity is constrained.

Electricity retailers in the ACT offer opportunities to their residential customers to reduce load, such as offering free replacement of incandescent light bulbs with energy efficient LED light bulbs and offering free energy audits.

ActewAGL has introduced a number of initiatives under the AER's Demand Management Incentive Scheme (DMIS) which includes a Demand Management Innovation Allowance (DMIA). The capped allowance is to encourage distributors to investigate and conduct broad based and/or peak demand projects. ActewAGL's current innovation allowance of $0.1 million) per annum will continue through the 2015-19 regulatory period.

The majority of DMIS expenditure to date has been for trials of batteries within residential customer installations. These trials will demonstrate the ability to impact network loading through the use of customer side energy storage.

Additional funds under this program have been earmarked for a collaborative trial of demand management through a virtual demand trading platform. It is anticipated that such a platform will be a world first and will enable real time response to peak demands through a market mechanism.

Beyond this ActewAGL is working on a “smart suburb” in a new Canberra residential development, with smart meters providing customers with consumption data that they can use to reduce their electricity peak demand by making simple changes to how and when they operate a broad range of appliances and processes.

ActewAGL is looking to the future and investigating the Power to Grid potential of electric vehicles.

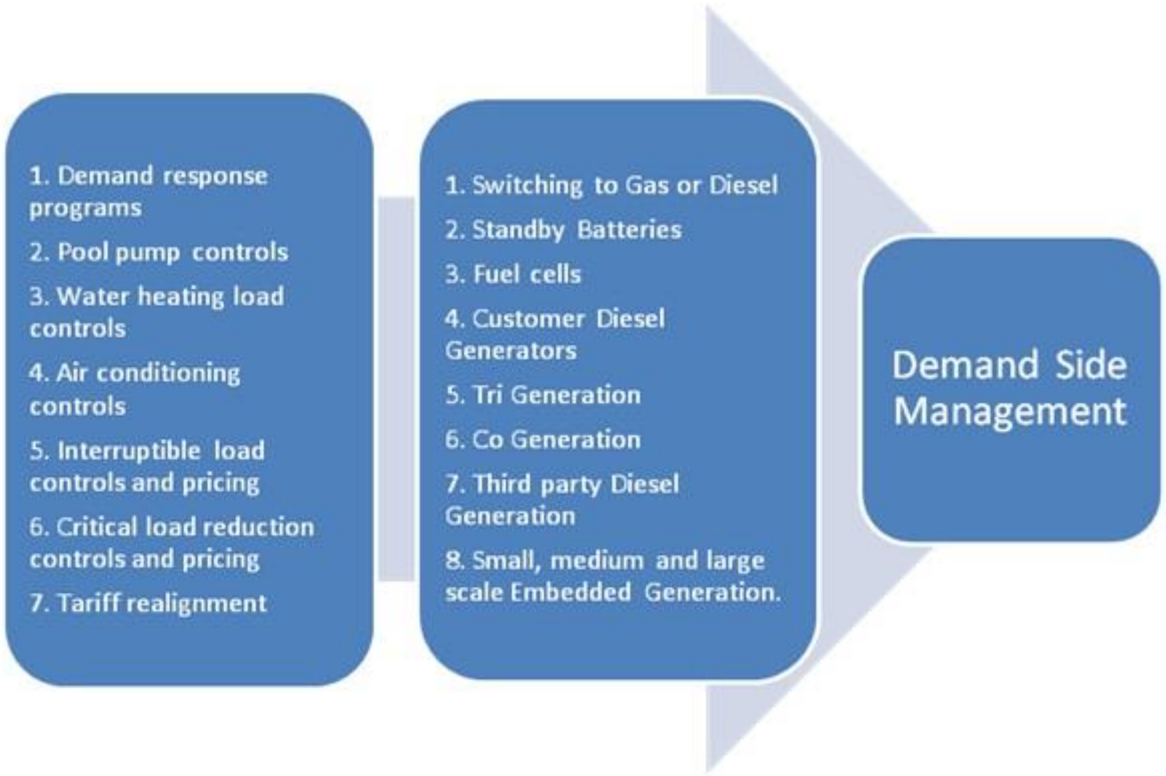
ActewAGL is working with a number of partners on additional research and development projects, some of which may be funded through the DMIS scheme.

Future changes to tariffs will include pricing signals to encourage customers to reduce demand at certain times of the day. This would serve to reduce maximum demand on the network as well as provide financial benefit to customers.

ActewAGL is investigating the potential to supply customers in new micro-grid developments (see section 9.7 on micro-grids) with smart meters providing consumption data that they can use to reduce their electricity peak demand by making simple changes to how and when they operate a broad range of appliances and processes.

Potential DSM programs are illustrated in Figure 8.1.

Figure 8.1: Potential DSM programs



ActewAGL's demand management staff will consult with customers and customer groups to identify their expectations and drivers for DSM participation and what they can offer in terms of demand reduction or switching to alternative energy sources. ActewAGL Distribution maintains a Register of Interested Parties for Demand Management, and actively consults with those parties. Public consultations, awareness programs and trial programs will also form part of this investigation process. Details of potential DSM programs to be investigated will be published on the ActewAGL website.

ActewAGL continues to comply with the ACT Government's Energy Efficiency Improvement Scheme (EEIS), which sets territory-wide energy savings targets.

8.4 Demand Management Options

ActewAGL's demand management strategy aims to identify demand management options and assess their potential to solve network limitations and constraints for broad based and more specific local situations. Demand management options may be to reduce demand or supply the increasing demand from alternative sources. Some practical demand management options have been identified and categorised into the following groups.

8.4.1 Demand Reduction

The following demand management options are examples of schemes that aim to reduce demand and may be applicable to residential, commercial and industrial situations.

1. Demand response programs – AAD are currently investigating a number of options for these including directly controlling customer installations, working with demand aggregators who will get us the desired response, and creation of a demand response trading platform that will enable an open market;
2. Power factor correction;
3. Pool pump controls;
4. Water heating load controls;
5. Air conditioning controls;
6. Under-floor heating controls;
7. EV charging station control - discharging EV batteries into the home at peak demand times or simply controlling when they do charge to avoid a new increased peak;
8. Automated feeder load sharing - this could be either permanent transfers or transfers done dynamically to relieve pressure during peak demand periods;
9. Interruptible load controls and pricing;
10. Critical load reduction controls and pricing;
11. Tariff realignment;
12. Use of stored energy – e.g. battery banks, reversible fuel cells (e.g. hydrogen), thermal storage;
13. On-site generation – e.g. gas micro turbine, photovoltaic cells, micro-wind turbines, diesel generators, co-generation and tri-generation;
14. Energy efficiency – e.g. replace all streetlight mercury vapour and high pressure sodium luminaires with LED dimmable streetlights;
15. Building management systems for office buildings and apartment blocks.

8.4.2 Alternative Supply

The following demand management options are examples of where demand may be shifted by using alternative sources of supply.

1. Fuel switching to gas to supply space heating, water heating, cooking appliances and evaporative cooling systems.
2. Energy and thermal storage using battery banks and fuel cells.
3. Standby electricity supply such as diesel generators or open cycle gas turbines.
4. Embedded generation such as rooftop PV.
5. Alternative fuel sources such as rooftop solar hot water heating or ground-source heat pumps.
6. On site / scheduled generation using co-generation and tri-generation.
7. Leasing generators by ActewAGL or non-network proponents.
8. Small, medium and large scale embedded generation.

Residential battery energy storage systems could assist demand management if controlled effectively. If batteries are charged during the day by rooftop PV they could reduce the ability of that generation to reduce the morning peak demand period. Ideally they would be charged during off peak or shoulder demand periods, then discharged during peak demand periods.

It is anticipated that customers and non-network proponents will be able to respond to demand management options and programs, or propose new innovative demand management options, by participating in the demand side management process.

9. Emerging Technologies

9.1 Overview of Emerging Technologies

The generation, transmission and distribution of electrical energy is changing rapidly with new advances in technology. These emerging technologies are impacting on all parts of the supply chain, for example:

Generation – traditional hydro and thermal generation is being supplemented by wind and solar generation, and emerging technologies such as fuel-cells, biomass generation and geothermal generation. This is being driven by an international desire to reduce carbon emissions and expand the use of renewable energy sources. Large generating plants which are typically distant from load centres are being supplemented with local embedded generation facilities located close to load centres.

Transmission – large capacity transmission lines are required to transport bulk energy from power stations to load centres. With the generation landscape changing to more local embedded generation, the need for such large transmission lines will decrease. Conductor types and shapes are changing, e.g. circular stranded copper and steel-cored aluminium conductors are being replaced by lighter aluminium alloy and composite-cored conductors with trapezoid-shaped strands to produce a smooth-bodied conductor that can operate at higher temperature and have lower wind drag than conventional conductors. The changes to conductor types as well as developments in materials science, are allowing a change in the size and shape of support structures from traditional lattice steel towers with suspension insulators to steel or concrete poles with cantilever insulators.

Distribution – areas of new development within the ACT such as greenfield estates are all reticulated with underground cables and underground pits where previously they would have featured surface-mounted pillars. Areas with high rooftop PV penetration are experiencing reverse power flow and voltage fluctuations which need to be managed. Energy storage systems such as batteries are becoming more efficient and affordable, and electrical appliances are becoming more energy efficient. These advances have the potential to reduce maximum demands on distribution systems which will reduce the required capacity of these systems. The proliferation of instantaneous hot-water heating systems and electric vehicles may have the opposite effect, driving an increase in demand. Remote-controlled and automated devices are leading to smart networks (e.g. automatic load transfer), self-healing networks (e.g. automatic isolation of faults), and smart meters that allow customers to monitor and control their energy usage, will lead to an entirely different load profile on the network.

ActewAGL is keeping abreast of these emerging technologies and future network planning will embrace these technologies to shape our network and benefit our customers.

9.2 Distributed Energy Resources

Distributed Energy Resources (DER) include localised embedded generation and energy storage facilities provided by a variety of small grid-connected devices. Conventional power stations such as hydro and coal-fired power stations are centralised and often require electricity to be transmitted over long distances. DER systems however, are decentralised, use a variety of non-conventional fuels (typically renewable energy sources such as solar, wind, bio-gas or bio-mass), and are located close to the load they serve. They usually have capacities of less than 10 MW.

ActewAGL's transmission and distribution network has grown from its inception in 1915 to an extensive overhead and underground network covering the ACT. Many assets are approaching the end of their economic lives. Increasing proliferation of DERs is forecast to decrease energy and demand growth on the network over the planning period. As demand growth decreases or flattens the requirement for network augmentation works decreases. Asset replacement is becoming a greater investment driver than network augmentation. ActewAGL is investigating ways to reduce future asset replacement costs, and the increasing use of DERs is regarded as a means to achieve this.

9.3 Embedded Generation

Generators connected directly to ActewAGL's distribution network rather than through the transmission network are called Embedded Generators (EGs).

There are a number of different types of embedded generator connected to our network as follows:

- Solar Photovoltaic
- Bio-gas (from land fill sites)
- Micro Hydro
- Cogeneration
- Fuel Cell

Capacities of these EGs varies from a 1 kW domestic solar PV system to a 20 MW solar PV farm. The total installed capacity of embedded generation is approximately 107 MW. Of this 53.5 MW is rooftop solar PV (refer Appendix E) and the remainder is a mixture of solar, hydro, gas and co-generation (refer Section 7.2).

The process for connecting an Embedded Generator to our network depends mainly on its capacity. Capacity is divided into three categories: micro, medium and large. Table 9.1 below lists the categories, capacities and network connection points that apply to each.

Table 9.1: Embedded Generator Network Connection Points

<table>
<tr><th>Category</th><th>Capacity</th><th>Network Connection Point</th><th>Type of Generator</th></tr>
<tr><td>Micro</td><td>Less than 30 kW</td><td>230 V ~ 400 V – Low Voltage Network</td><td>Solar PV
Micro Wind (Future)
Micro Gas (Future)</td></tr>
<tr><td>Medium</td><td>30 kW – 200 kW</td><td rowspan="2">400 V – Low Voltage Network</td><td rowspan="4">Any</td></tr>
<tr><td rowspan="3">Large</td><td>200 kW – 1500 kW</td></tr>
<tr><td>1500 kW – 5000 kW</td><td rowspan="2">11 kV to 132 kV High Voltage Network</td></tr>
<tr><td>> 5000 kW</td></tr>
</table>

Large scale embedded generators connected to ActewAGL's network are required to be scheduled in accordance with AEMO's operating rules as intermittent generators whereas smaller PV units are not required to be registered as they have either automatic or small generation exemption.

ActewAGL has developed technical guidelines and business processes to facilitate the connection of embedded generators. The published charges improve the clarity and transparency of requirements for embedded generators. Details are available on ActewAGL's external website. Refer to document "Requirements for Connection of Embedded Generators up to 5 MW to the ActewAGL Distribution Network (August 2016)".

The ACT Government has mandated that the ACT will be supplied by 100% renewable energy by 2020. This rules out any standby, back-up or peak shaving generation fuelled by non-renewable sources such as natural gas, diesel, compressed natural gas, liquefied petroleum gas, oil or coal.

Other than solar PV generation there is little potential for other renewable energy generation within the ACT such as wind power, hydro power or bio-gas fuelled generation.

9.3.1 Solar Photovoltaic Generation

There are 17,086 rooftop solar PV installations in the ACT (as at 30 November 2016) with a total installed capacity of around 53.5 MW. Most of the generation produced by these installations is used by the customers at their premises, although some is exported into ActewAGL's low voltage distribution network. As these installations are widely distributed on the network (refer Appendix E) they have not as yet caused technical issues experienced by other utilities such as excessive voltage rise, thermal overload of low voltage feeders, harmonic saturation, or load balancing issues on 11 kV distribution feeders.

Several new residential developments in the ACT are mandating that rooftop solar be installed on all detached dwellings. It is anticipated that the take-up rate will be sufficient that during times of peak generation and low load the total local generation will exceed demand by such a large margin that the net export from the region will be greater than the peak import to the region, meaning that the PV will be driving system sizing decisions. Potential power quality issues are discussed in Section 9.3.2.

This low voltage inverter based generation can contribute to higher voltages being seen on some parts of the low voltage network. ActewAGL has reviewed its connection standards regarding the maximum export voltages allowable from such inverters (refer Section 4.8.8).

Reliability of solar PV generation is inherently high as the equipment is primarily electronics based with no moving parts, compared with other forms of generation such as hydro or thermal. PV generation is unpredictable due to intermittent cloud cover. It is difficult to forecast availability and output accurately although research is being undertaken to correlate weather forecast information more closely with solar generation to provide a degree of forecasting capability in real time.

There is a large solar farm at Royalla which has a rated peak output of 20 MW, another at Hume which has a rated peak output of 12.85 MW, and another at Williamsdale which has a rated peak output of 10.1 MW.

9.3.2 Power Quality Issues Associated with Embedded Generation

Maintaining the supply-demand balance of the network will become more challenging as synchronous generation is replaced with wind, large-scale PV and rooftop PV generation (possibly combined with battery storage) which are subject to intermittency as wind strength fluctuates and passing clouds affect solar generation. It will be particularly difficult at times when demand is low and renewable generation is high and it is conceivable that the network could become a net importer of energy in certain areas in the future, such as residential areas will 100% penetration of rooftop PV and battery storage. The challenges relate to how the system behaves during disturbances, and how much generation can be dispatched in order to match supply and demand.

Large-scale solar PV generation has a lower capacity factor (average power generated divided by rated peak power) than other forms of generation, and can be intermittent and difficult to forecast. The same applies to small-scale rooftop PV. Consecutive days of rain or cloud cover will significantly reduce PV output, so the network cannot rely on such generation and must be capable of operating without it.

Power quality issues that could result from an increase in asynchronous generation include voltage stability, frequency stability due to a lack of system inertia, and low fault levels which would impact on protection schemes.

Synchronous generators such as the Snowy Hydro scheme generators, produce power through directly connected alternating current machines, rotating at a speed synchronised to power system frequency. These generators produce inertia, which lessens the impact of changes in power system frequency following a disturbance such as loss of a generator or transmission line, resulting in a more stable system. Power systems with low inertia experience faster changes in system frequency following a disturbance, which could lead to system instability and under frequency load shedding. Asynchronous generators such as wind turbines and solar PV generators are connected to the power system via power electronic converters. These generators contribute little inertia to the system unless coupled with a fly-wheel or similar.

Synchronous generators provide dynamic voltage support to the power system, particularly during and immediately following system faults. Synchronous generators provide considerably more fault current to the power system than asynchronous generators. Fault current helps maintain voltage stability during network faults. The replacement of synchronous generation with asynchronous generation reduces the fault current and can lead to a “weak” system. This can cause the following issues:

- DC/AC converters not remaining operational through network faults, tripping off and requiring resetting to reconnect their generation. This is commonly known as ‘fault ride-through’ capability.
- Inability to achieve steady-state stability during system normal.
- Protection schemes unable to distinguish between system normal load current and fault current leading to an inability to detect and clear faults on the system.
- Slow rate of recovery following network faults.

Access to real time information of equipment connected beyond-the-meter such as rooftop PV generation, battery storage, EV charging etc, will also become increasingly important in order to maintain power system stability and security

9.3.2.1 Voltage Stability

Synchronous generators provide considerable fault current to the network which helps maintain voltage stability during and immediately following network faults. Asynchronous generators provide much less fault current. This could lead to voltage instability during network faults. Most wind and large-scale PV generators in areas with poor voltage stability will struggle to remain connected to the network during network faults, and their power output may need to be restricted to manage this risk. Increasing rooftop PV could eventually cause high voltage issues on the distribution network so output from DC/AC converters will need to be strictly adhered to.

ActewAGL’s distribution network has been designed and constructed to allow for voltage drop from power flow through the high voltage network to the end of the low voltage network. With increasing connections of rooftop solar PV to the low voltage network, at times of low load and high generation, power flows in the reverse direction from the low voltage network to the high voltage network. This reverse power flow can cause voltage rise on the distribution network which has to be managed to keep voltage within regulatory limits, ie 230 V +10% / -6% at customer points of connection. High voltage may affect or damage connected appliances or electronic equipment.

9.3.2.2 Frequency Stability

Traditional synchronous generators (rotating plant) have inertia which can support system frequency following a system disturbance such as loss of a transmission line or large generator. Asynchronous generators such as wind turbines and solar PV have little or no inertia, so a fast change to system frequency could result from a fault (sudden loss of generator or transmission line) which could lead to under-frequency load shedding on the distribution network. As the amount of non-scheduled embedded generation in the ACT increases, ActewAGL’s network could become reliant on frequency controlled ancillary services (FCAS) provided by other regions to maintain frequency stability and the supply-demand balance.

9.4 Battery Energy Storage

Small battery energy storage systems (BESS) are becoming more popular for domestic use (associated with rooftop PV generation) as technology improves and costs reduce. Larger battery energy storage systems are used by some utilities for peak shaving and load balancing, day to night shifting of renewable PV energy, and reducing the fluctuations in PV generation output caused by passing clouds or wind power output caused by changing wind conditions.

The battery industry is changing rapidly with several different battery technologies available, such as lithium-ion, zinc-bromine, lead-acid, nickel-cadmium, and sodium-sulphur. Lithium-ion batteries are recommended for high power applications and lead-acid batteries for high capacity applications. Lead-acid batteries cannot be charged at the same rate as lithium-ion batteries, but their discharging behaviour is equivalent. Lead-acid batteries are a proven technology; their main advantages continue to be their low price, high availability and simplicity. Lithium-ion batteries offer high energy density and are low maintenance. Zinc-bromine batteries offer high energy density, have 100% depth of discharge capability on a daily basis, and last longer than other battery types.

ActewAGL is currently participating in a trial of small scale 8 kWh lithium-ion battery storage systems which could be applicable for residential or small commercial customers, and also assist demand management during peak demand periods. In addition we are looking at situations in which larger batteries may provide a network benefit.

Although residential battery storage can reduce regional demand peaks when the residential and regional peaks coincide, it could also increase regional peaks. For example, if the regional peak occurs during the middle of the day and residential battery storage is charging from rooftop PV, this reduces the PV generation available to contribute towards meeting the regional peak. How storage operates in relation to both residential and regional demand profiles is likely to be driven by the tariff structure. A benefit to the customer is ‘arbitrage’ where the customer can charge the battery during off-peak periods when energy prices are lowest, then use this stored energy during peak demand periods when energy is more expensive.

9.5 Electric Vehicles & Light Rail

The ACT Government is undertaking the construction of a light rail system (known as Capital Metro) which will feature electric passenger trams running on purpose-laid tracks, the first stage of which will run from Central Canberra City northwards to Gungahlin town centre. This rail network will include the installation of two main traction power stations that will require an 11 kV 5.0 MW supply to each from ActewAGL’s distribution network, plus a depot / control centre that requires an 11 kV 1.2 MW supply. Construction is to be carried out over the next five years. Further expansion of this network is planned for the future.

ActewAGL is working with Capital Metro to monitor and mitigate the effects of stray currents emanating from the light rail network.

There are few electric cars on the streets of the ACT at present but it is anticipated that their prevalence will increase significantly in coming years as costs decrease and battery range increases. ActewAGL is trialling the installation of electric vehicle charging stations in the ACT. To date three rapid chargers type Tritium Veefil Level 3 have been installed. These have a capacity of 50 kW and can fully charge a car within 30 minutes. In addition five fast chargers type eBee Level 2 have been installed. These have a capacity of up to 22 kW and can fully charge a car in 2-6 hours.

As part of this trial, ActewAGL is investigating:

Roaming: allowing EV customers to access ActewAGL's EV charging solution at public charging stations or privately in the customers home or business premises, whereby a driver would be able to drive freely and access the network.

Load levelling: allowing ActewAGL or other commercial operators to run a cluster of chargers without exceeding the maximum available load of a distribution substation.

Bi-directional chargers: allowing ActewAGL to use energy available within the EV's battery and also charge the EV to optimise the network.

Open Smart Charging Protocol (OSCP): can be used in the optimisation of the network by providing constant feedback and communications between the charging hardware and the software cloud environments. This protocol also allows dynamic allocation of available capacity, load levelling and management of hardware which will ensure our network is up to date with the latest technology available. ActewAGL has representation on the OASIS Open Charge Point Protocol Technical Committee and has actively engaged with this development.

To avoid electric vehicle charging stations creating new peak demands on distribution feeders or substations, intelligent controls will be required to distribute charging throughout the day and maintain system voltage within regulation levels. Ideally public charging stations will be sited to meet customer needs and at locations on the electricity network where they will not create loading issues. If sufficient charging stations are installed in public places such as shopping centres and workplace carparks, this would minimise the impact of EV drivers plugging in to recharge their vehicles upon arriving home from work which could overload residential LV and HV feeders.

In the future it is expected that electric vehicles (EV's) will be driverless. As well as providing increased safety to passengers, this will increase their appeal and could potentially increase the electrical demand to charge their batteries – eg a driverless EV could provide a 24 hours per day taxi service, stopping only to recharge itself when required.

EV energy consumption in the ACT is forecast to grow steadily over the next 20-30 years. This will serve to offset the reduction in energy demand caused by embedded generation and storage systems.

In the future the energy stored in an EV's battery could be used to back-feed into the network via an inverter at times of maximum demand. Similar to fixed battery storage systems, EV's could be considered as a potential distributed energy resource.

9.6 Micro-grids

A micro-grid is a regional power system with generation and consumption occurring locally. Micro-grids can function autonomously as well as being connected to the distribution network. Energy sources can include PV, wind, diesel generators, fuel cells and micro-hydro amongst many others. Around the world micro-grids can be found in scales varying from a single residential house or industrial/production site to a complete island power system. A micro-grid can balance generation and demand with or without energy storage and is capable of operating in 'island-mode' whether connected or not connected to the electricity distribution network.

ActewAGL is currently investigating the viability of micro-grids within its network with proponents of such schemes. To date none of the proposed schemes has proven to be viable but we continue to assess schemes as the technical and financial barriers reduce and regulatory barriers are clarified.

9.7 Dynamic Rating of Transmission Lines and Power Transformers

Dynamic rating of transmission lines is done by assigning conductor current ratings in real time taking into account the heating effects of the electrical current, ambient air temperature, solar radiation and reflected radiation, and the cooling effects of wind and emitted radiation, so that the conductors do not heat to such an extent that they sag below allowable ground clearances.

Weather stations are installed at various points along a transmission line to measure such data in real time and transmit it to the control room's computer where it is analysed and a dynamic current rating assigned to the transmission line. This allows the network operator to apply load to a line based on its dynamic rating which enables increased power flows above its static rating when weather conditions are favourable. This permits such assets to be fully utilised without the risk of overloading.

The same principle can be applied to zone substation power transformers to enable them to be operated above their normal continuous name-plate rating when conditions are favourable.

ActewAGL currently does not have dynamic rating capability on its network, but is investigating it as a possible future development as system load increases.

9.8 Smart Networks

9.8.1 Smart Networks

Emerging technologies such as embedded generation, energy storage, electric vehicles, and smart street lighting networks, are rapidly changing the electricity distribution industry. To improve the supply-demand balance and meet all standard power quality standards, ActewAGL will need to monitor and control load and generation flows at the domestic customer level. In order to do this, a reliable and secure means of communicating with customers will be required along with means to remotely control load and generation flows.

ActewAGL's Advanced Distribution Management System (ADMS) will be developed to provide real time information allowing for network switching decisions and the realisation of self-healing network principles. A self-healing system will detect and isolate a fault on the network and automatically restore power to as much of the network as possible until repairs have been carried out.

ActewAGL is investigating the installation of additional smart devices such as voltage regulators, dynamic volt-amp reactive compensators (D-VARs), auto-reclosers and sectionalisers on its distribution network to improve quality, security and reliability of supply.

9.8.2 Denman Prospect Smart Network Trial

Denman Prospect is a new residential suburb currently under development to the west of Canberra. Stage 1 will comprise 400 dwellings that will all be equipped with mandatory 3 kW solar PV generation panels, and it is anticipated that some will also feature battery storage systems. This will be the first residential estate in the ACT and one of the first in Australia with 100% PV penetration.

To support this ActewAGL has identified an opportunity to establish an industry leading multi-utility smart network including smart metering for electricity, gas and water. ActewAGL is also developing a customer portal to provide customers with up to date access to their electricity and gas consumption to pass on the benefits of smart metering to customers.

ActewAGL recognises that smart metering is a fundamental element to the smart grid and is necessary to support a continually expanding portfolio of devices and applications. ActewAGL recognises that a smart grid is much more than just Smart Meters and includes grid sensors, distribution automation equipment, monitoring and control devices for renewable resources, load control devices, in-home energy management devices and smart charging stations for electric vehicles. We understand that emerging technologies such as embedded generation, energy storage, electric vehicles, and smart street lighting networks, are rapidly changing energy retailing and the electricity distribution industry.

The Denman Prospect Trial will specifically investigate issues related to data collection and trial devices for intelligent street lighting and electric vehicle charging. This will be achieved through the following investments and activities:

- Install and pilot a radio mesh network for communications supporting a multi-utility smart network platform.
- Trial the ability of ActewAGL's network control software, ADMS, to use real time data and respond dynamically.
- Install and trial electricity demand management of customers' devices including PV inverters and battery storage systems, and remote control of smart street light luminaires and electric vehicle charging stations.
- Provide a network gateway at each house to enable:
  - Monitoring and capture of solar generation data in real time.
  - Monitoring and control of demand data and power quality data in real time.
- Trial of gas and water metering with our partners.

9.9 Smart Meters

ActewAGL has been managing the supply, installation, maintenance and metering data management of metering infrastructure for over 100 years. Since 2003 ActewAGL has been operating in the NEM as a Responsible Person and an accredited Metering Provider and Metering Data Provider, and currently provides metering services for over 200,000 customer metering points. ActewAGL's managed services include metering for domestic and commercial customers within the ACT.

The proposed Power of Choice (PoC) rules to be implemented by the AEMC from 1 December 2017 will require all new and replacement meters to be Type 1-4 meters (smart meters) and be provided by independent Metering Coordinators. The PoC will enable customers to have a greater ability to manage their power usage and costs through choosing demand-side management (DSM) products and services that may better suit their needs, and will assist DNSPs to reduce capital and operating costs. New meters will be smart meters that are specified by the relevant retailer. These meters may have the capability to be enhanced to provide power quality monitoring and remote control features but distributor access to any of these features is unclear.

This rule change redefines who will have the overall responsibility for the provision of metering services. The role and responsibilities of the Responsible Person must be undertaken by a new type of Registered Market Participant – a Metering Coordinator. Metering Provider and Metering Data Provider are retained as separate accredited roles; however a Retailer will now be required to appoint the Metering Coordinator to coordinate suitably qualified parties to conduct metering services for their retail customers.

ActewAGL is able to use two communications technologies to establish connectivity with smart meters at customer premises which would enable the delivery of value added solutions for customers. These are Next Generation RF Mesh in the Canberra metropolitan area and Telstra 3G and 4G /LTE Communication for the remaining service areas.

The RF Mesh communication network will be capable of servicing multi-utility metering i.e. electricity, gas and water.

Smart meters enable energy consumption data to be available to both customers and utilities on a real time basis via two-way communications networks. This would assist the customer and the service provider with demand management initiatives, to respond to price signals and automatically control or shift demand during high demand periods, and facilitate future retail contestability.

Some of the potential uses of smart meters are as follows (refer section 4.11.1 for further details):

- Outage management
- Support and enhance network modelling functionality of ADMS
- Improved network forecasting and planning
- Reduced network investment
- Power quality monitoring
- Reduced manual meter reads
- Remote connection and disconnection of customers
- Demand management
- Support smart network initiatives, e.g. battery storage and embedded generation

9.10 Remote Area Power Supplies

ActewAGL's network is primarily urban, but there are some long overhead 11 kV distribution feeders in rural areas that supply remote small loads only. As these feeders age, their maintenance costs increase. Vegetation management is also costly, particularly where a feeder traverses a bushfire prone area.

ActewAGL is currently installing Remote Area Power Supplies (RAPS) to supply loads at the ends of two such long rural feeders. These RAPS will consist of a mixture of solar PV generation, battery energy storage, with back-up diesel generators. The two RAPS being installed are at:

Gudgenby Homestead – the ACT Department of Parks, Conservation and Lands owns and operates this facility within the Namadgi National Park. Maximum demand of this facility is around 10 kW. Current supply to this site is via a single phase overhead 11 kV line (Matthews feeder) approximately 7 km long.

Corin Dam – the ACT Department of Parks, Conservation and Lands owns and operates this facility within the Namadgi National Park. Maximum demand of this facility is around 9 kW. Current supply to this site is via a three phase overhead 11 kV line (Reid feeder) approximately 9.5 km long.

At both sites following installation and commissioning of the RAPS, it is proposed to operate and monitor their performance over the next two years. If successful, the overhead 11 kV feeder line sections connected to these sites will be decommissioned and dismantled.

ActewAGL is investigating the feasibility and economics of establishing RAPS at other similar sites.

Appendix A: Glossary of Terms

Term	Definition
ACT	Australian Capital Territory
ActewAGL	ActewAGL Distribution
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
APR	Annual Planning Report
BESS	Battery Energy Storage System
BSP	Bulk Supply Point
CAIDI	Customer Average Interruption Duration Index
CESS	Capital Expenditure Sharing Scheme
DMIS	Demand Management Incentive Scheme
DMP	Demand Management Process
DNSP	Distribution Network Service Provider
DR	Demand Response
DSES	Demand Side Engagement Strategy
DSM	Demand Side Management
DSMP	Demand Side Management Planning
DUOS	Distribution Use of System
ENA	Energy Networks Australia
EOI	Expression of Interest
HV	High voltage
ICRC	Independent Competition and Regulatory Commission
MVA	Mega Volt Amperes
MW	Mega Watts
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
NPV	Net Present Value
NTFP	National Transmission Flow Path
NTNDP	National Transmission Network Development Plan
N-1	Security Standard where supply is maintained following a single credible contingency event
OPGW	Optical Ground Wire
PFC	Power Factor Correction
PoC	Power of Choice
PoE	Probability of Exceedance
PV	Photovoltaic
QOS	Quality of Supply
RDSE	Register of Demand Side Engagement
RIT-D	Regulatory Investment Test for Distribution
RIT-T	Regulatory Investment Test for Transmission
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
STPIS	Service Target Performance Incentive Scheme
TNSP	Transmission Network Service Provider
TOU	Time of Use
TUOS	Transmission Use of System
Utilities Act	ACT Utilities Act 2000
UTR	Utilities Technical Regulation team

Appendix B: Bulk Supply Point Load Forecasts

Figures B.1 – B.6 illustrate the summer and winter maximum demand forecasts for the three TransGrid owned bulk supply point substations Canberra, Williamsdale and Queanbeyan.

Figure B.1: Canberra Substation summer maximum demand forecast

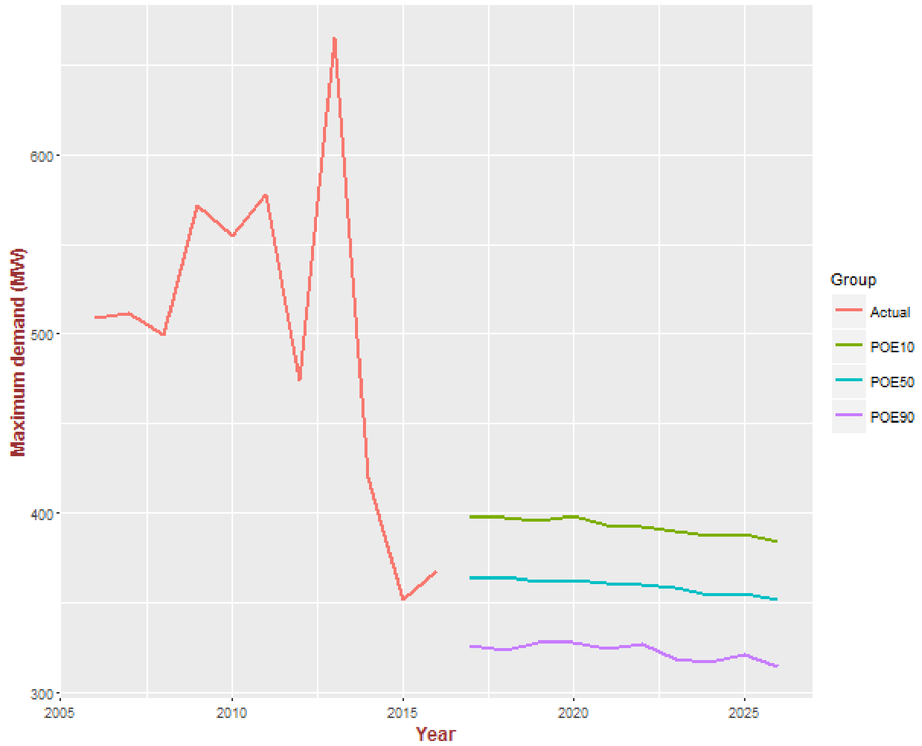


Figure B.2: Canberra Substation winter maximum demand forecast

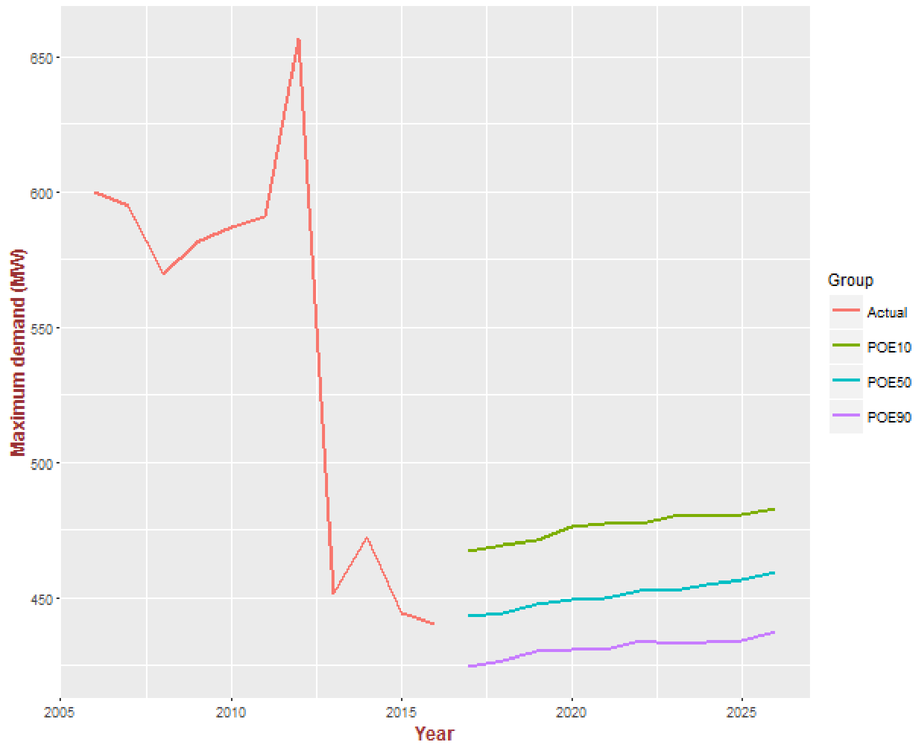


Figure B.3: Williamsdale Substation summer maximum demand forecast

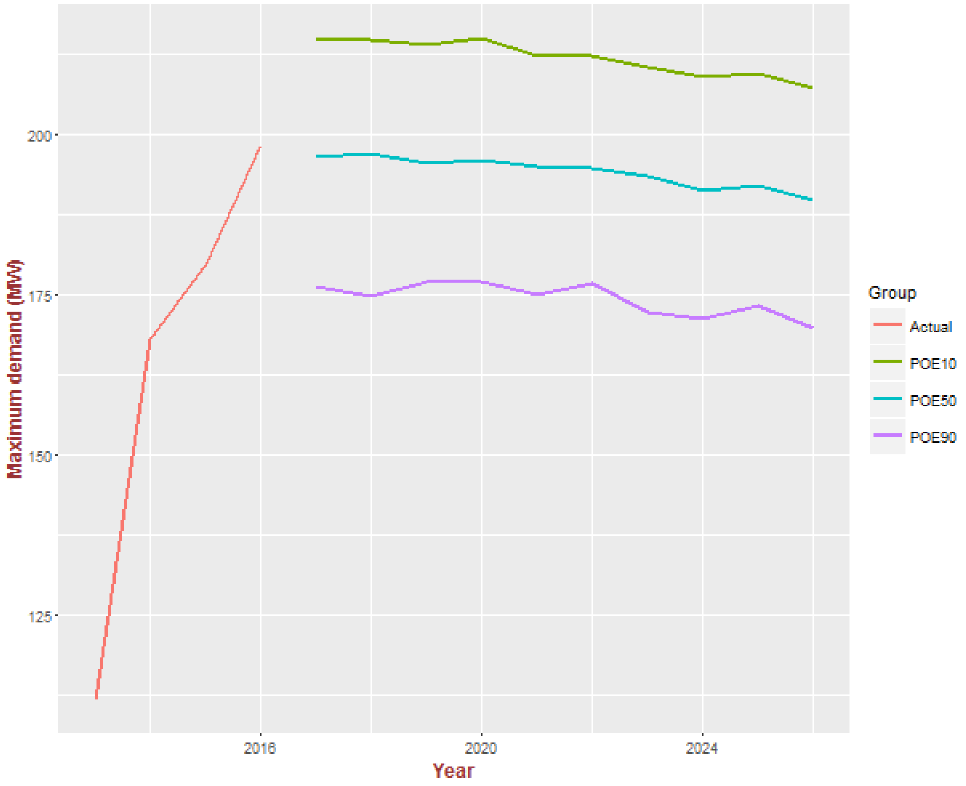


Figure B.4: Williamsdale Substation winter maximum demand forecast

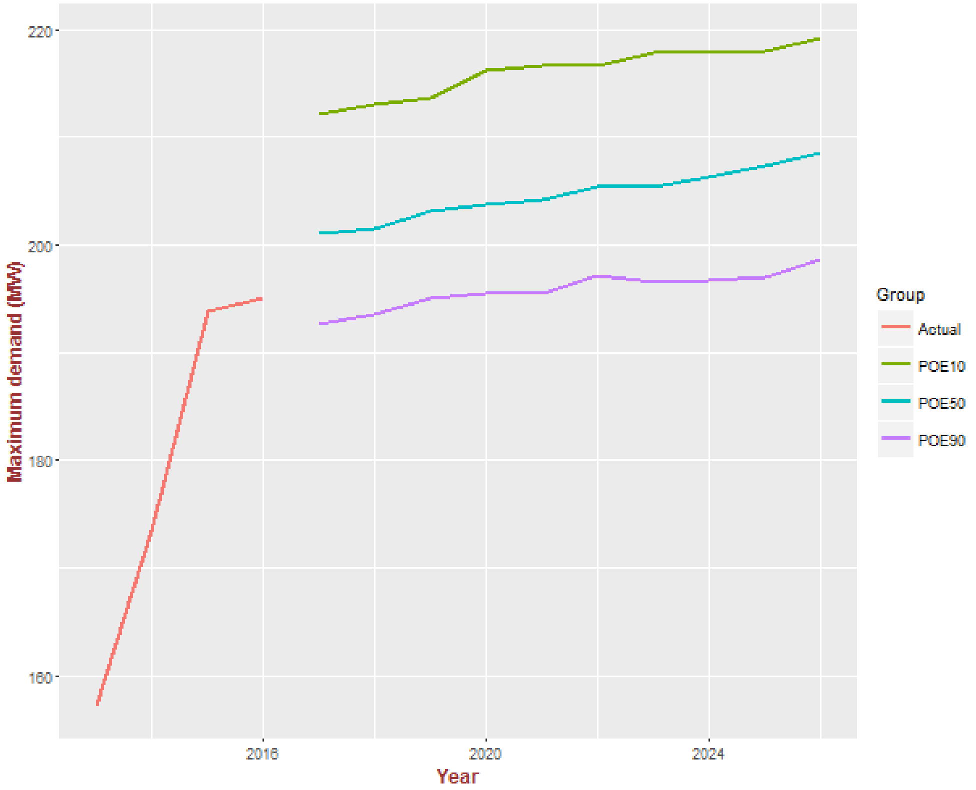


Figure B.5: Queanbeyan Substation summer maximum demand forecast

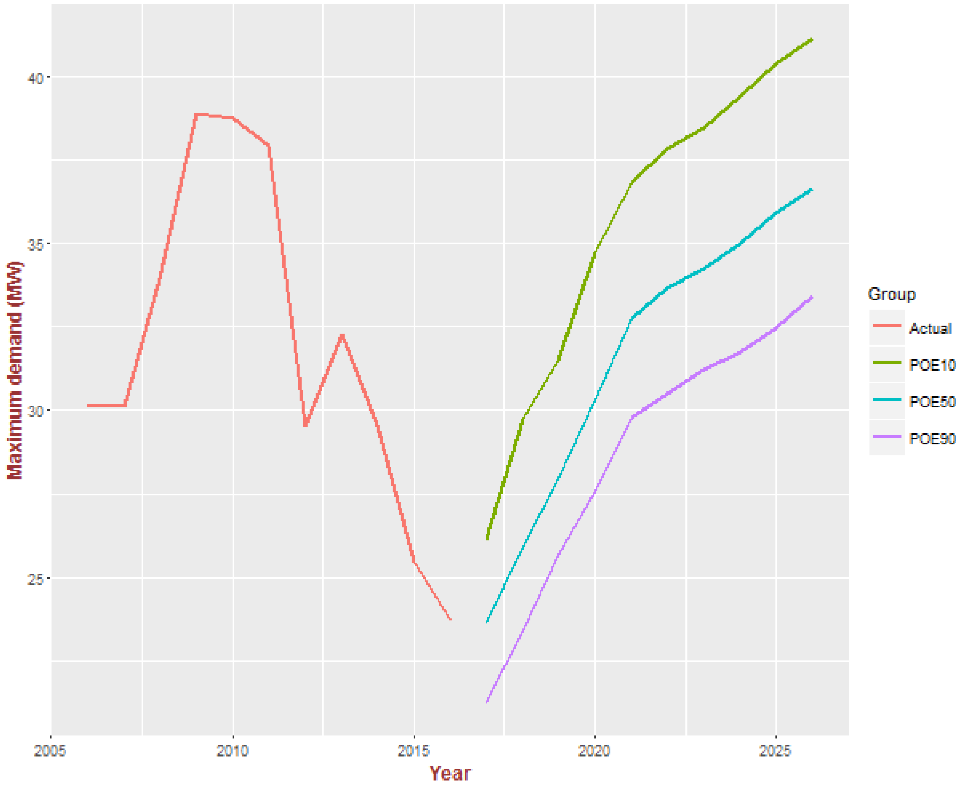
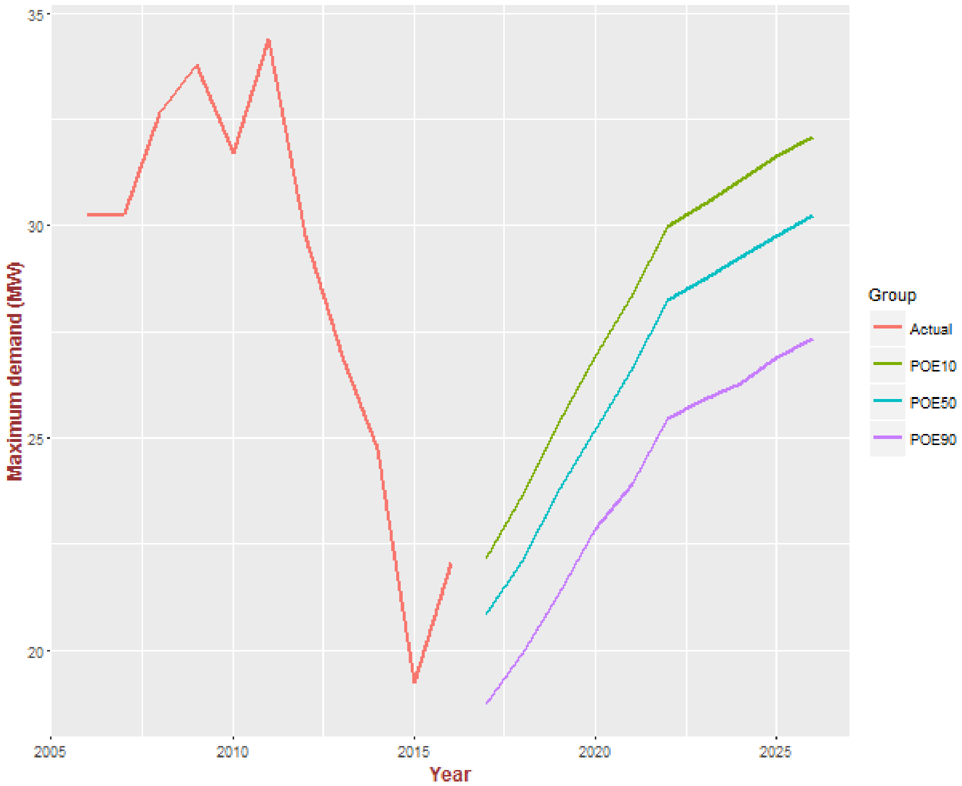


Figure B.6: Queanbeyan Substation winter maximum demand forecast



Appendix C: Zone Substations Load Forecasts

Figures C.1.1 – C.14.2 illustrate the 10-year summer and winter maximum demand forecasts for the twelve zone substations: Belconnen, City East, Civic, East Lake, Fyshwick, Gilmore, Gold Creek, Latham, Telopea Park, Theodore, Wanniassa and Woden; one mobile substation Angle Crossing; and one proposed zone substation Tennent.

Figure C.1.1: Angle Crossing Mobile Substation summer maximum demand forecast

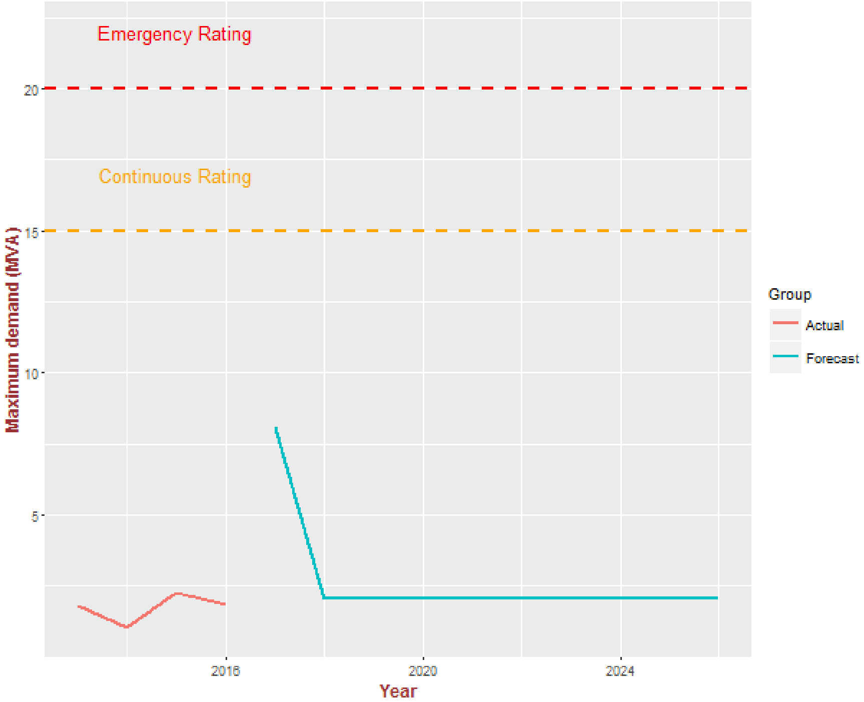


Figure C.1.2: Angle Crossing Mobile Substation winter maximum demand forecast

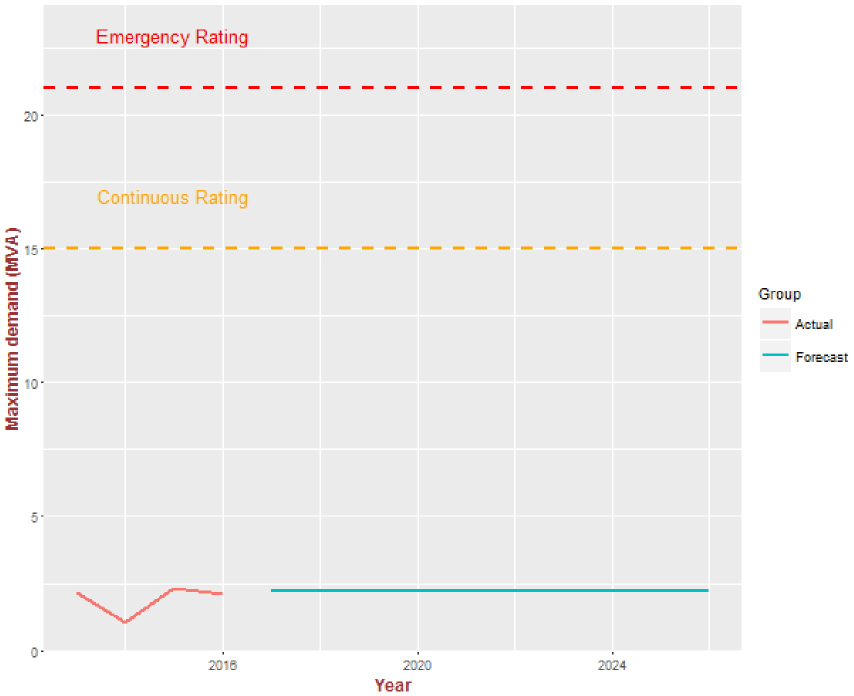


Figure C.2.1: Belconnen Zone Substation summer maximum demand forecast

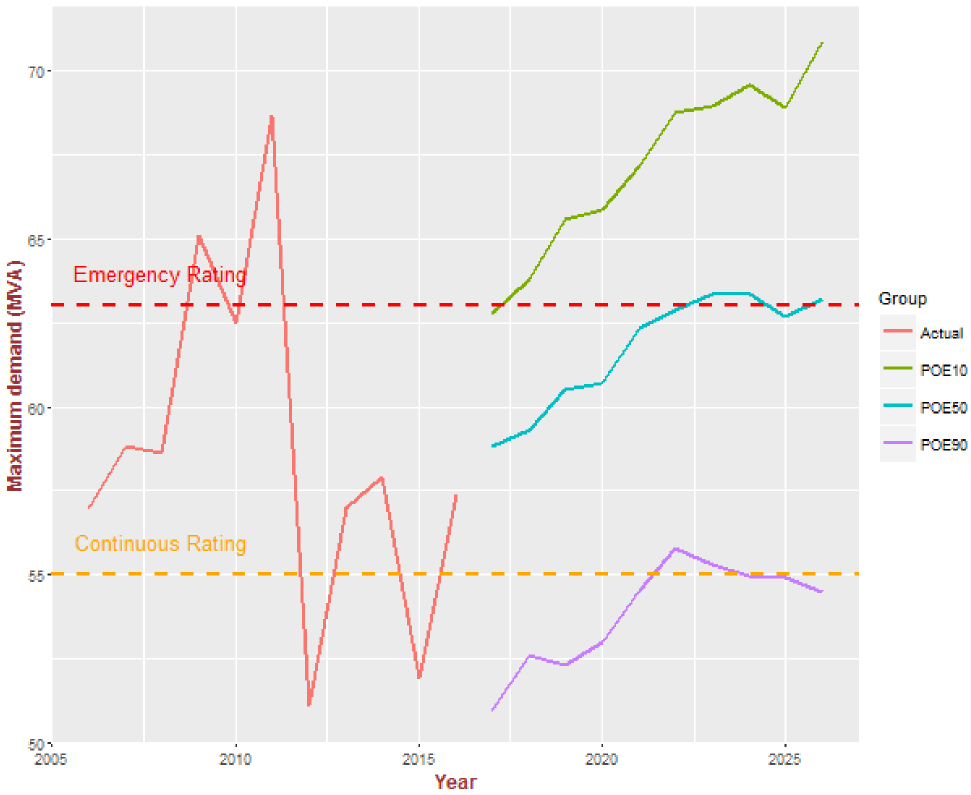


Figure C.2.2: Belconnen Zone Substation winter maximum demand forecast

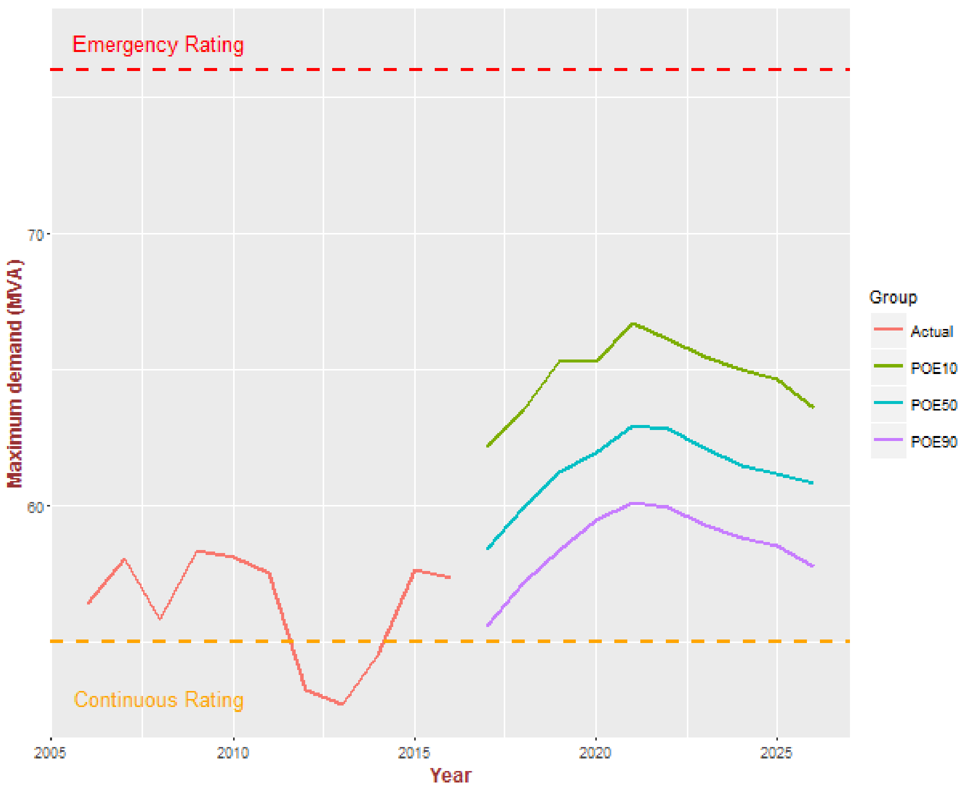


Figure C.3.1: City East Zone Substation summer maximum demand forecast

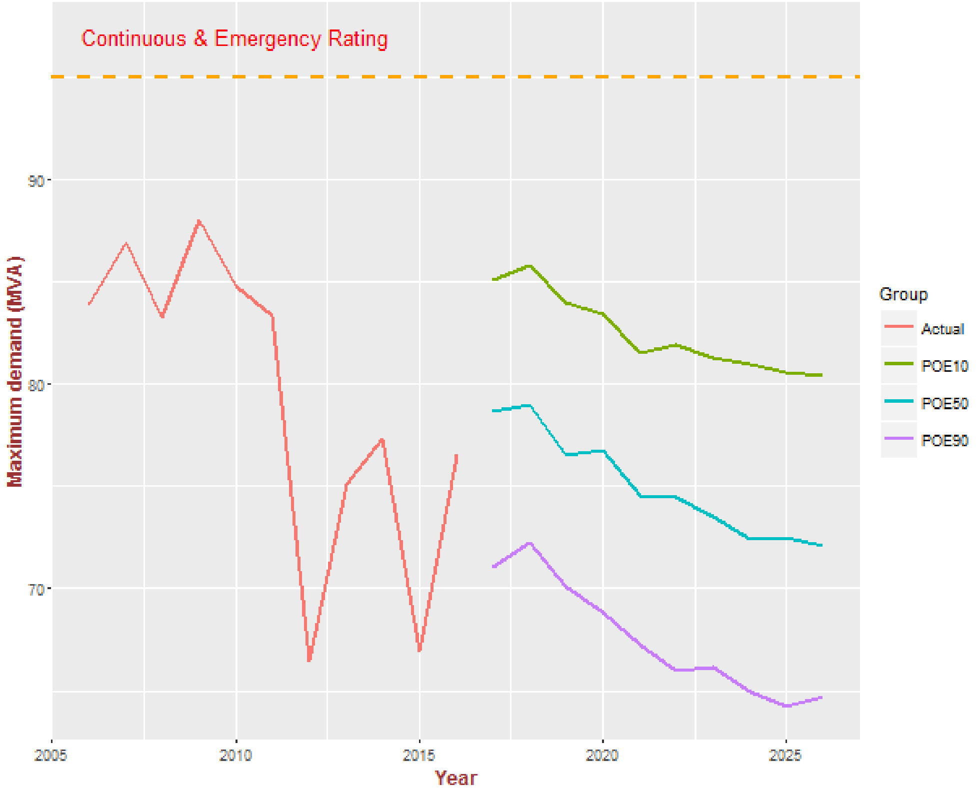


Figure C.3.2: City East Zone Substation winter maximum demand forecast

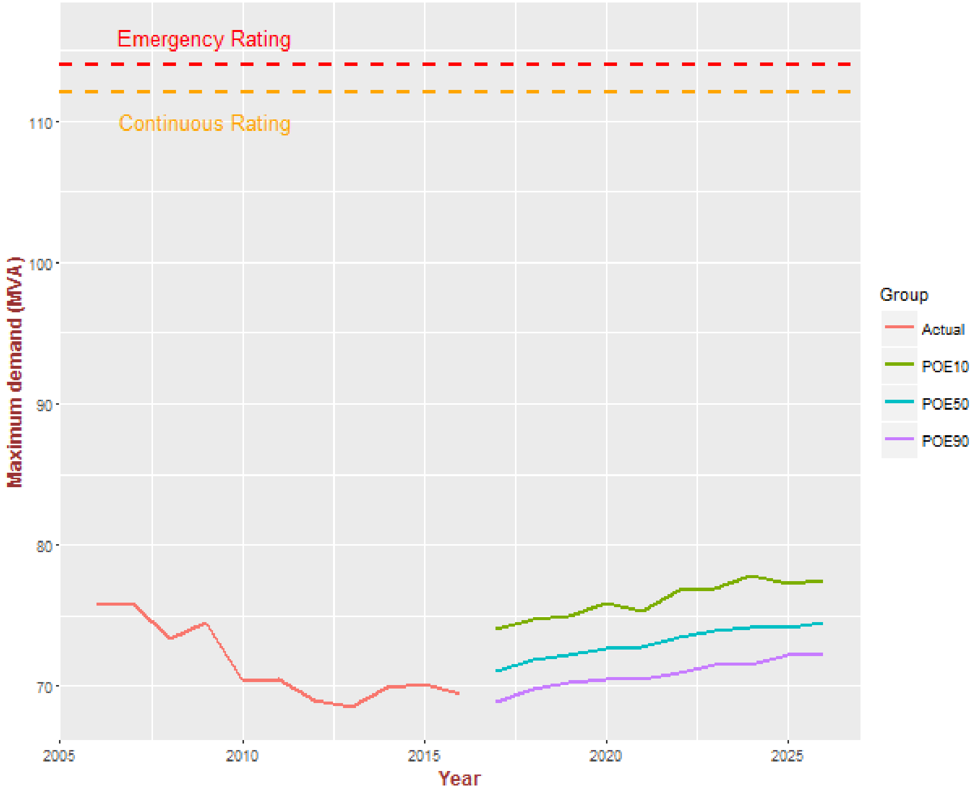


Figure C.4.1: Civic Zone Substation summer maximum demand forecast

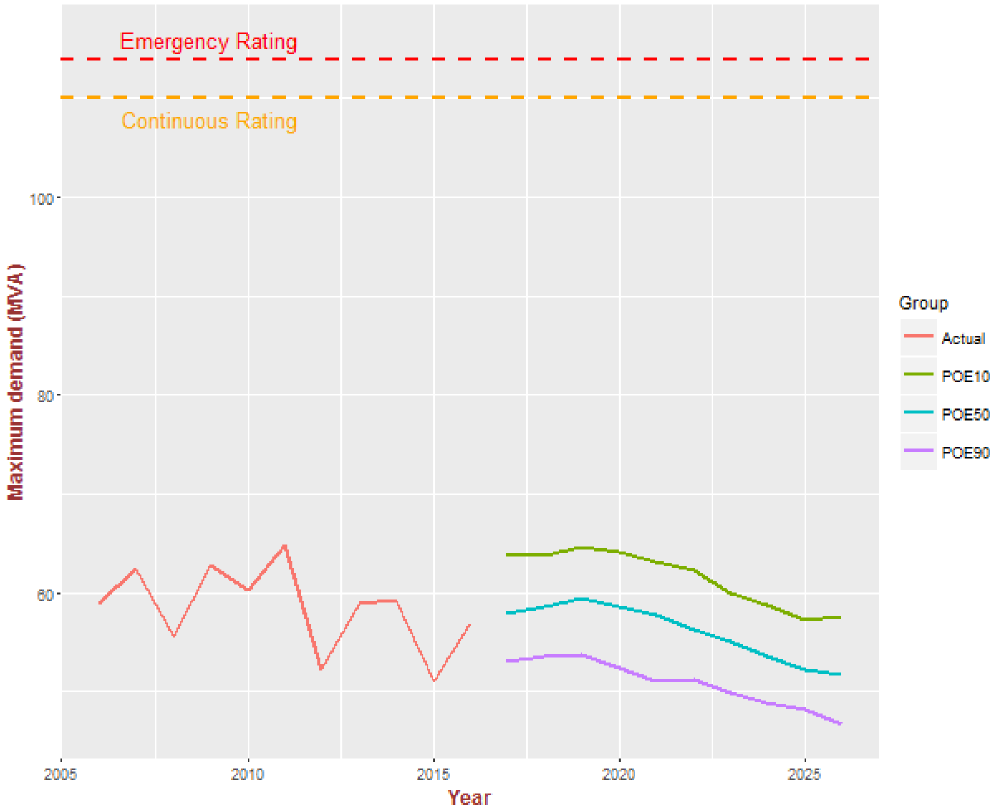


Figure C.4.2: Civic Zone Substation winter maximum demand forecast

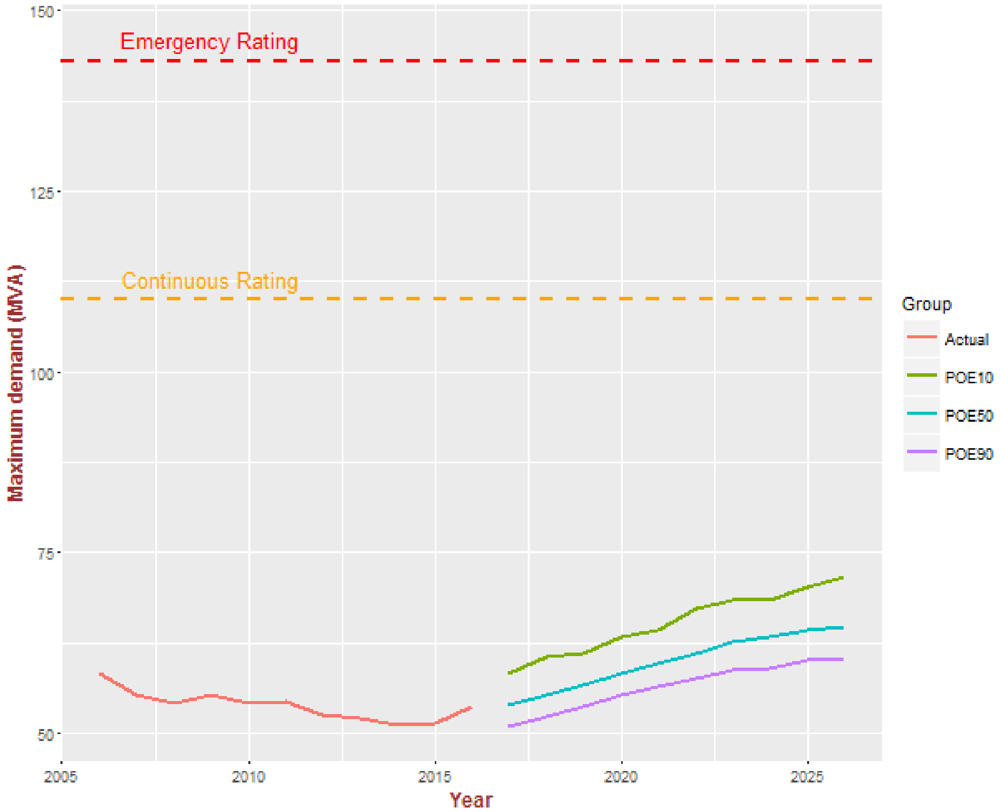


Figure C.5.1: East Lake Zone Substation summer maximum demand forecast

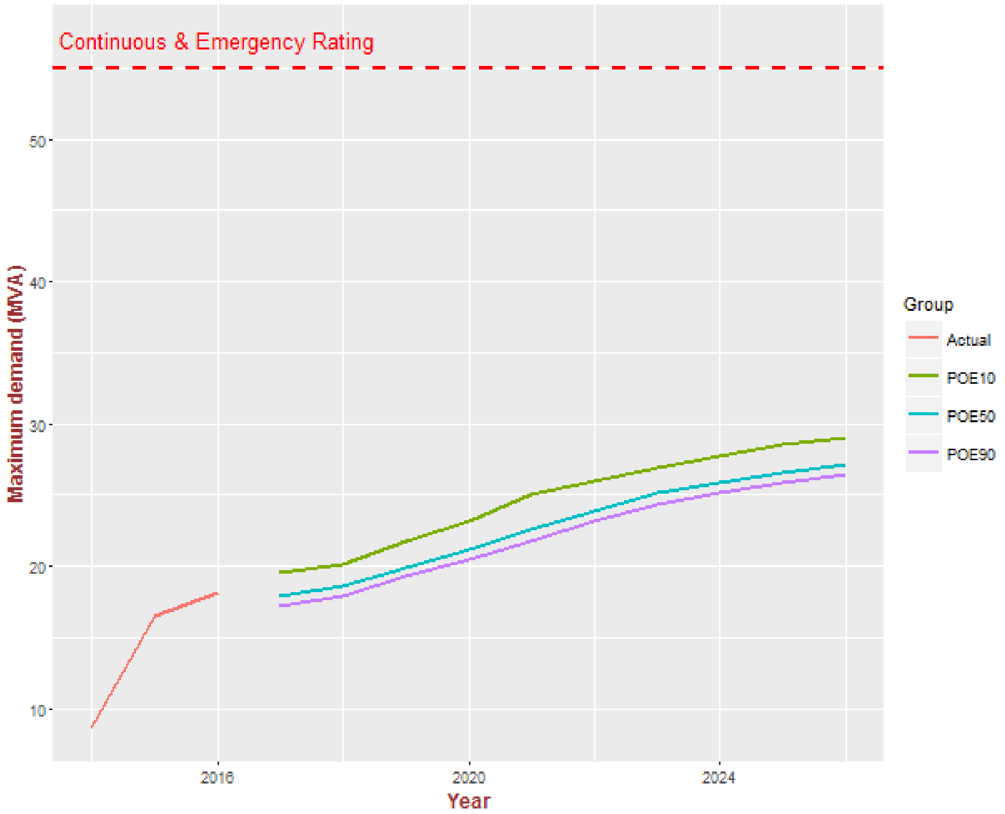


Figure C.5.2: East Lake Zone Substation winter maximum demand forecast

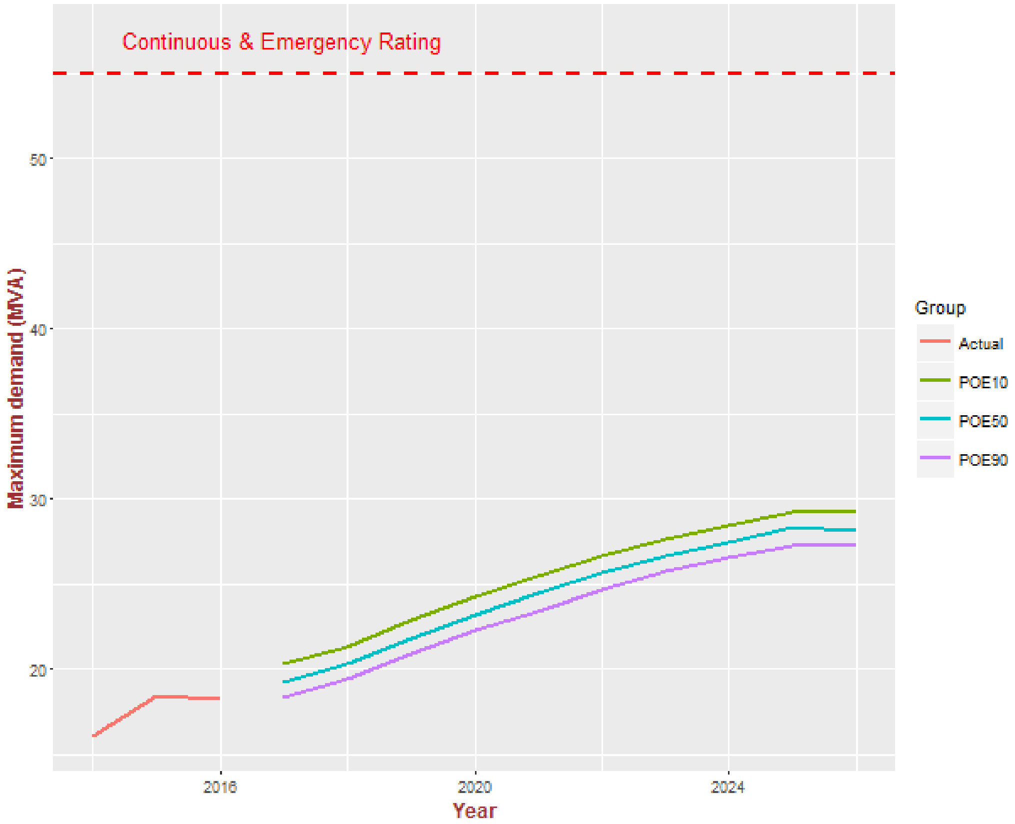


Figure C.6.1: Fyshwick Zone Substation summer maximum demand forecast

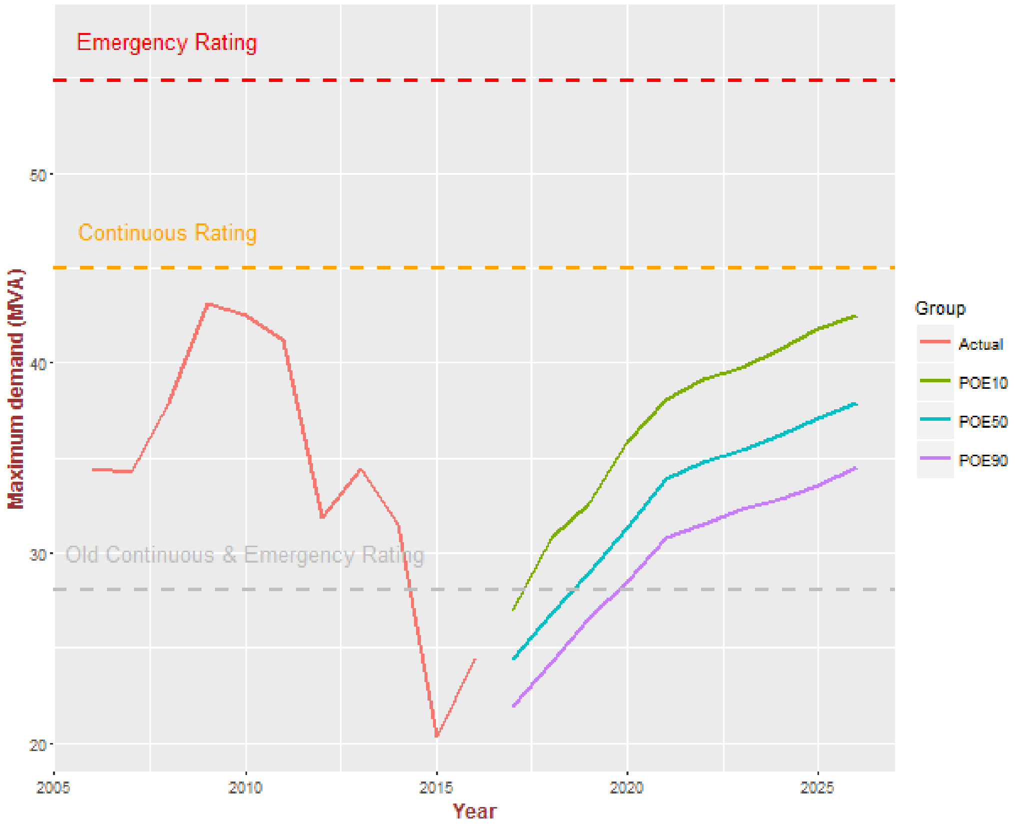


Figure C.6.2: Fyshwick Zone Substation winter maximum demand forecast

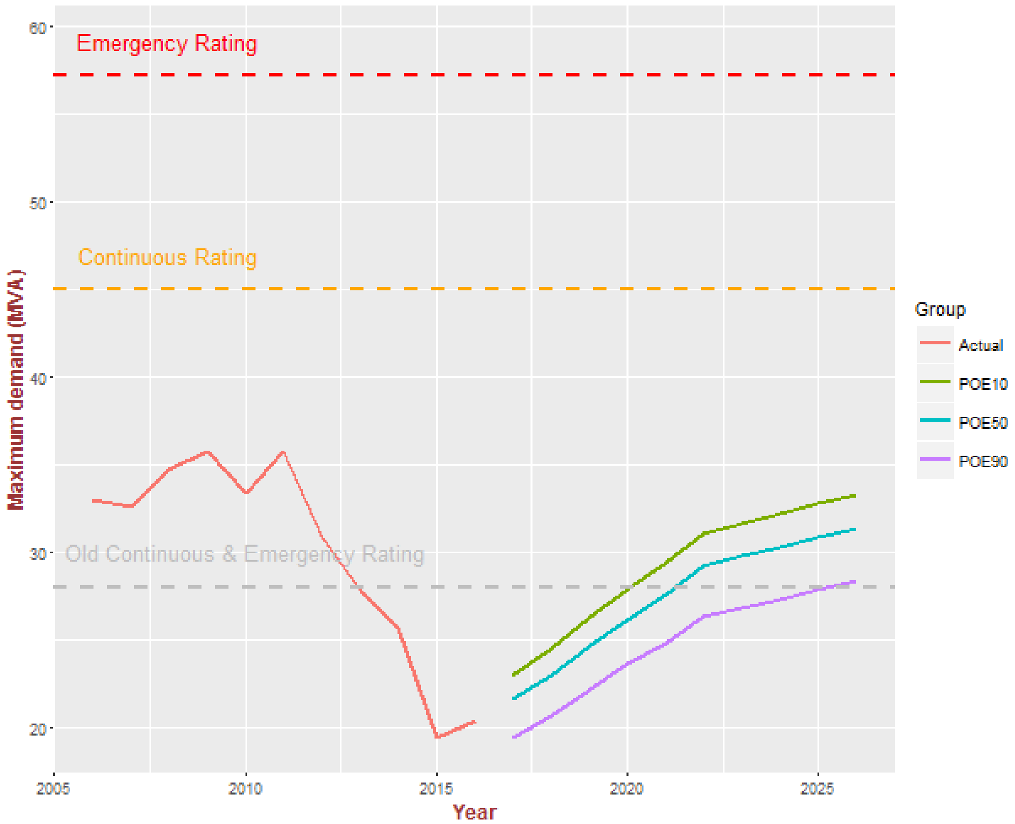


Figure C.7.1: Gilmore Zone Substation summer maximum demand forecast

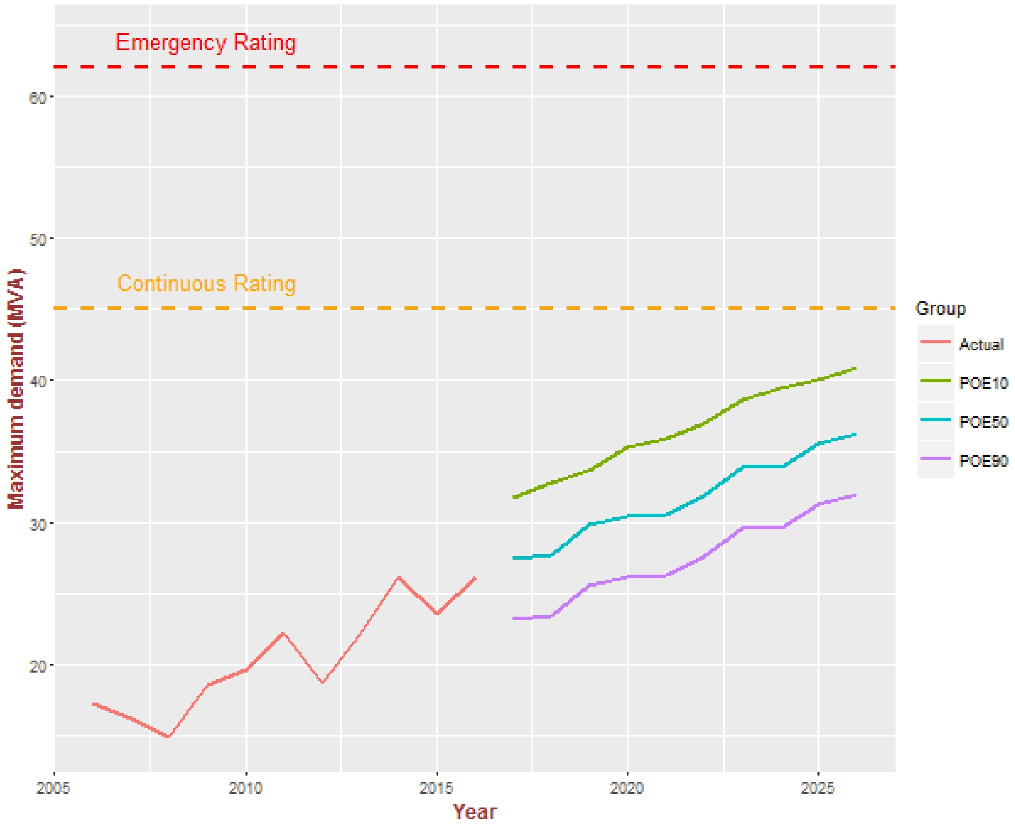


Figure C.7.2: Gilmore Zone Substation winter maximum demand forecast

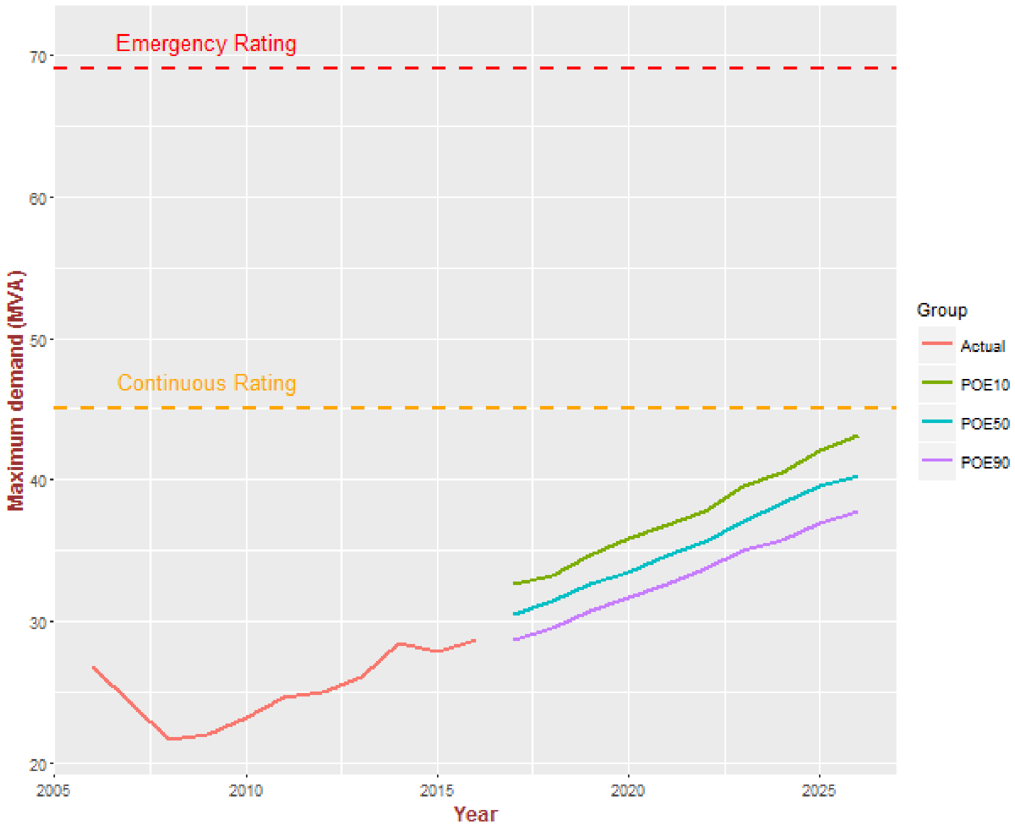


Figure C.8.2: Gold Creek Zone Substation winter maximum demand forecast

Figure C.8.1: Gold Creek Zone Substation summer maximum demand forecast

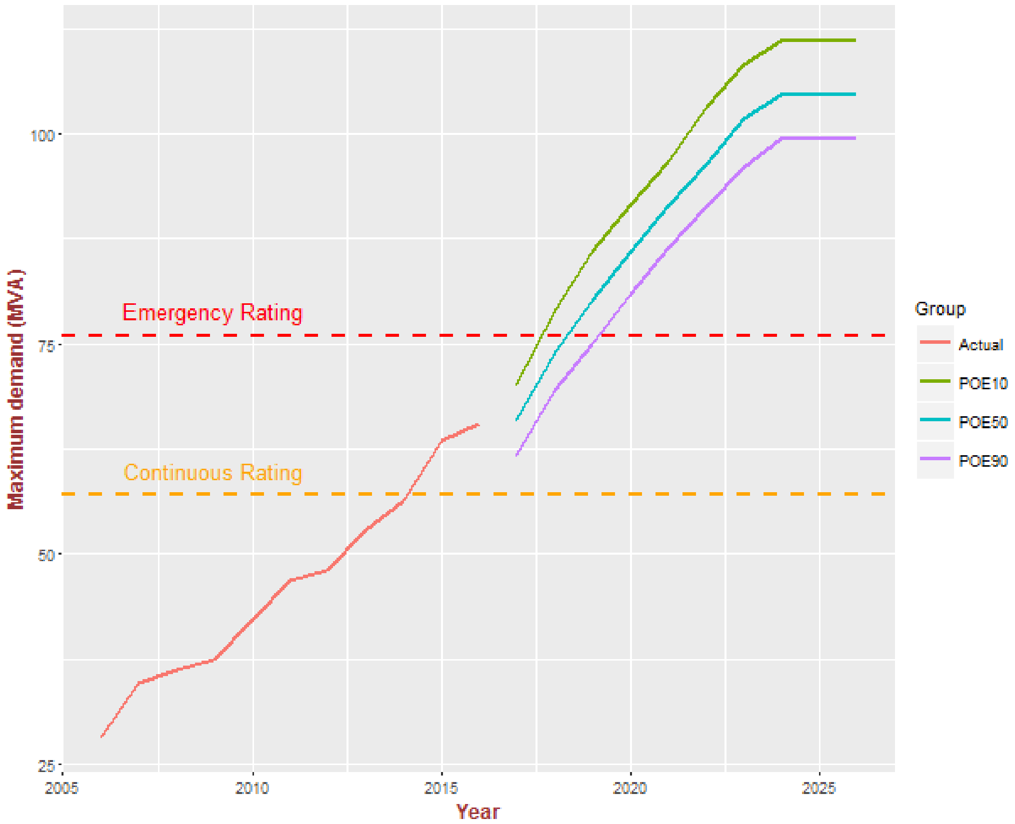


Figure C.9.1: Latham Zone Substation summer maximum demand forecast

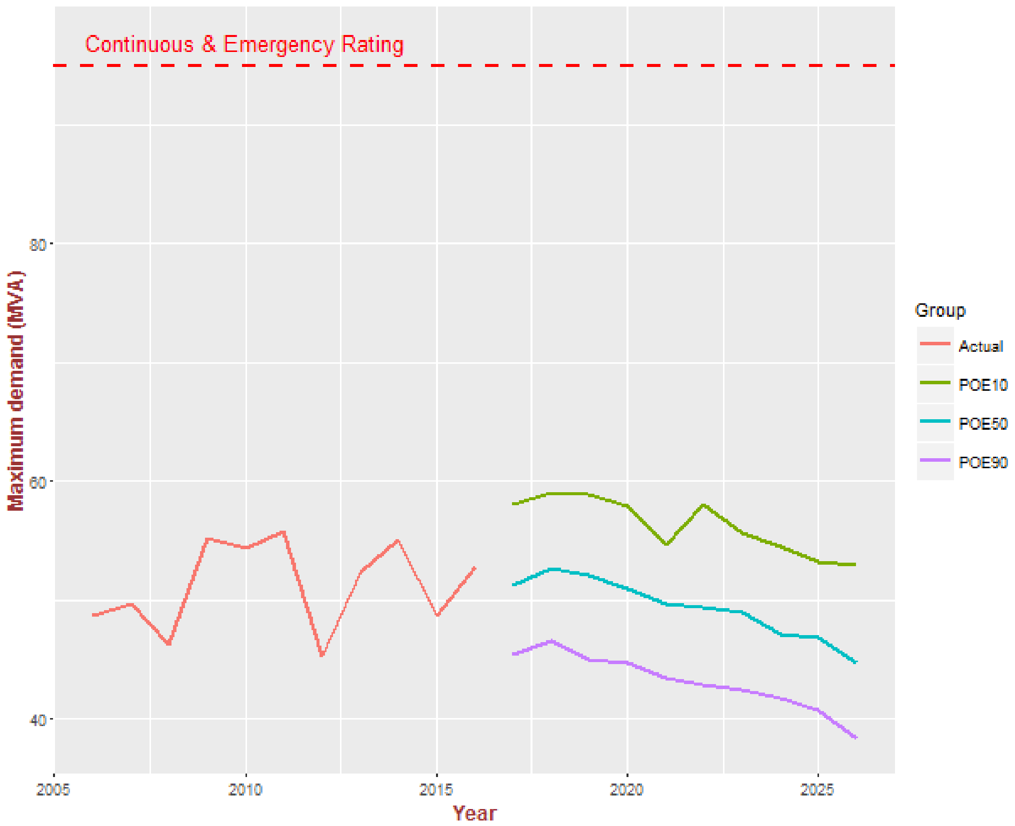


Figure C.9.2: Latham Zone Substation winter maximum demand forecast

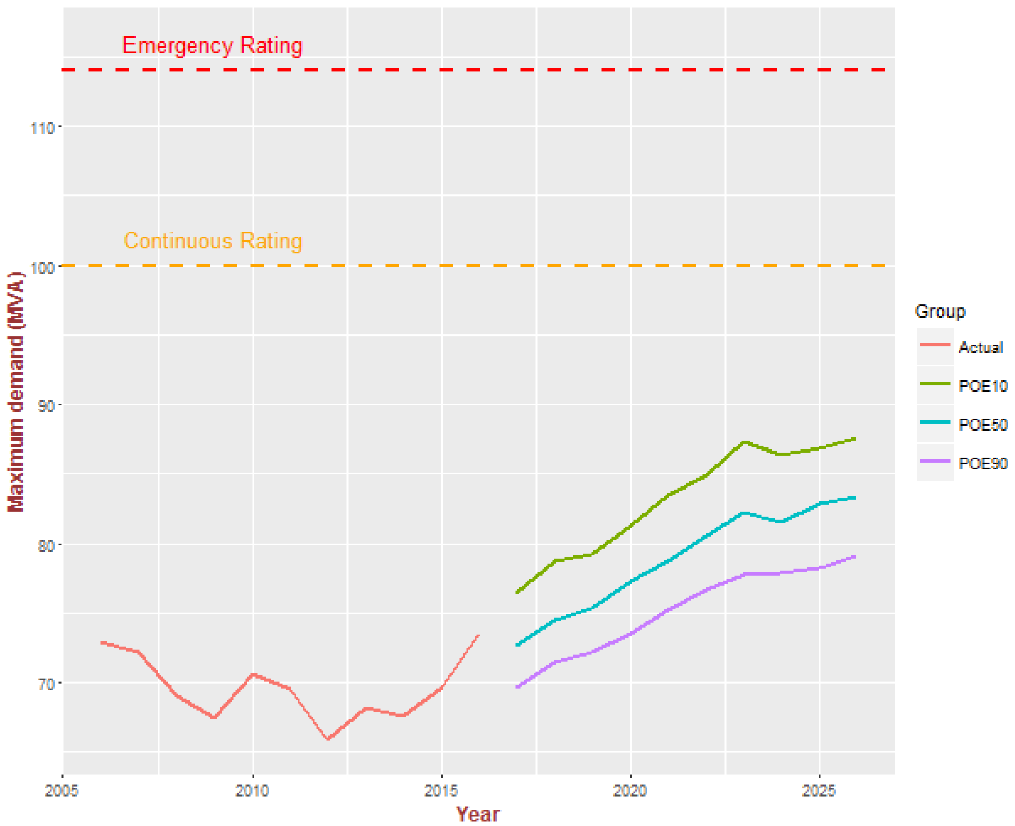


Figure C.10.1: Telopea Park Zone Substation summer maximum demand forecast

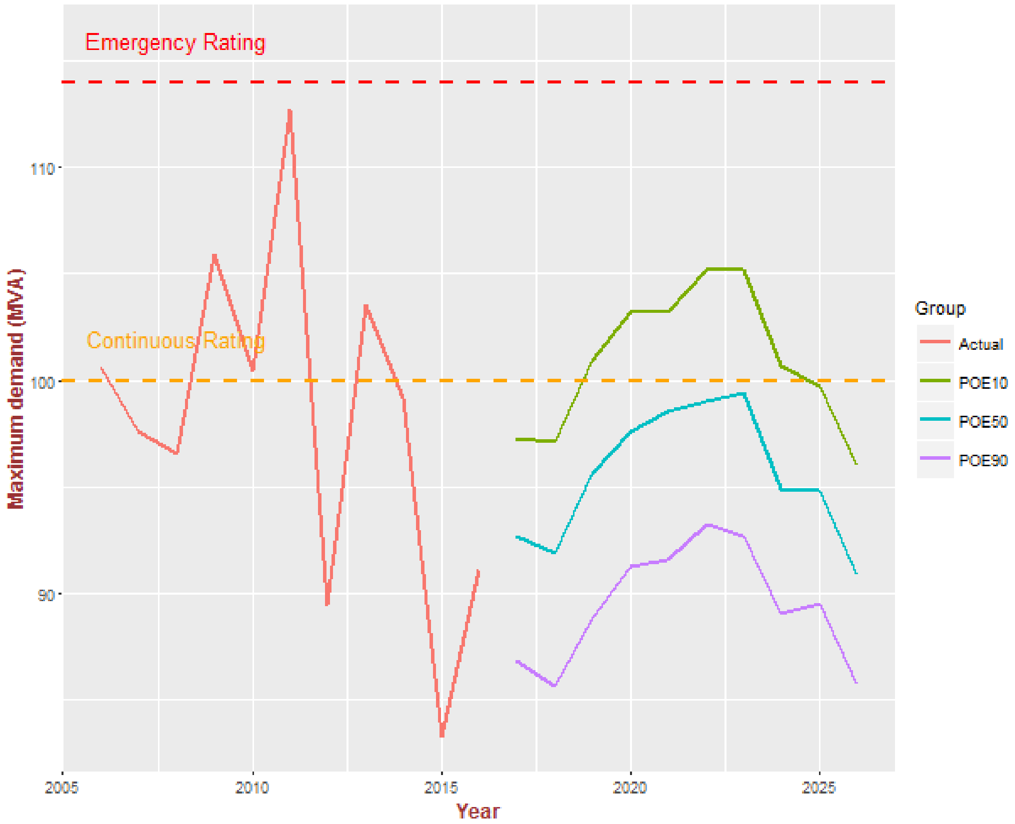


Figure C.10.2: Telopea Park Zone Substation winter maximum demand forecast

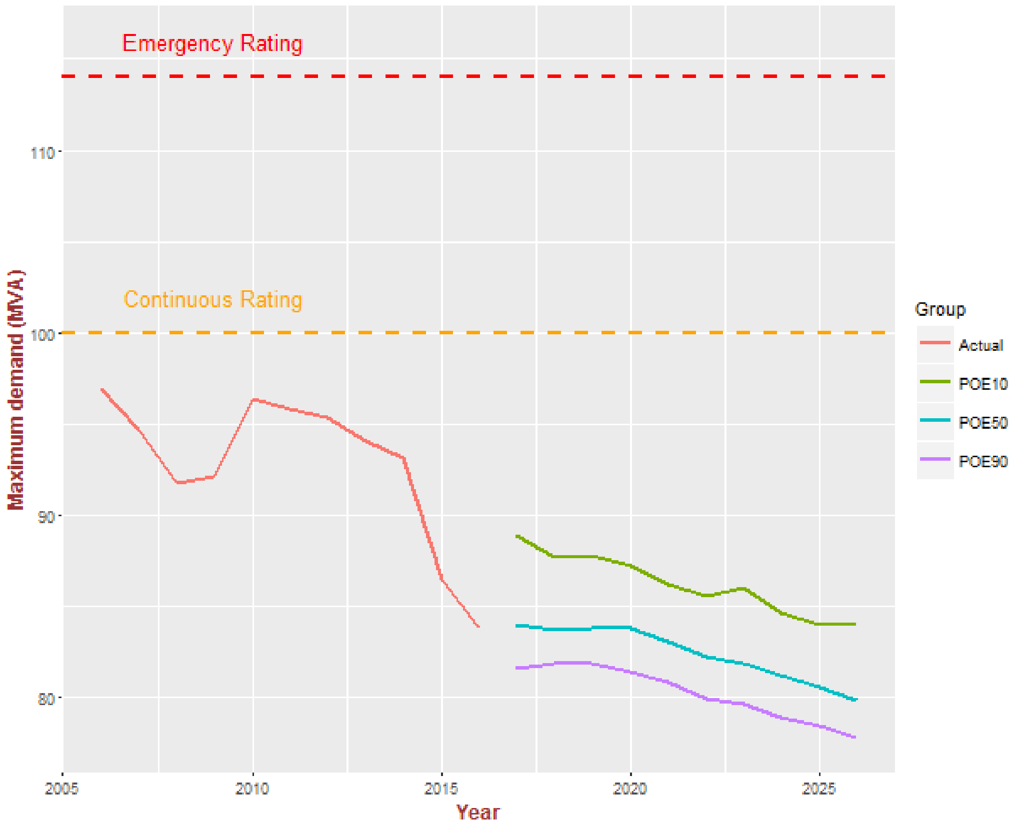


Figure C.11.1: Theodore Zone Substation summer maximum demand forecast

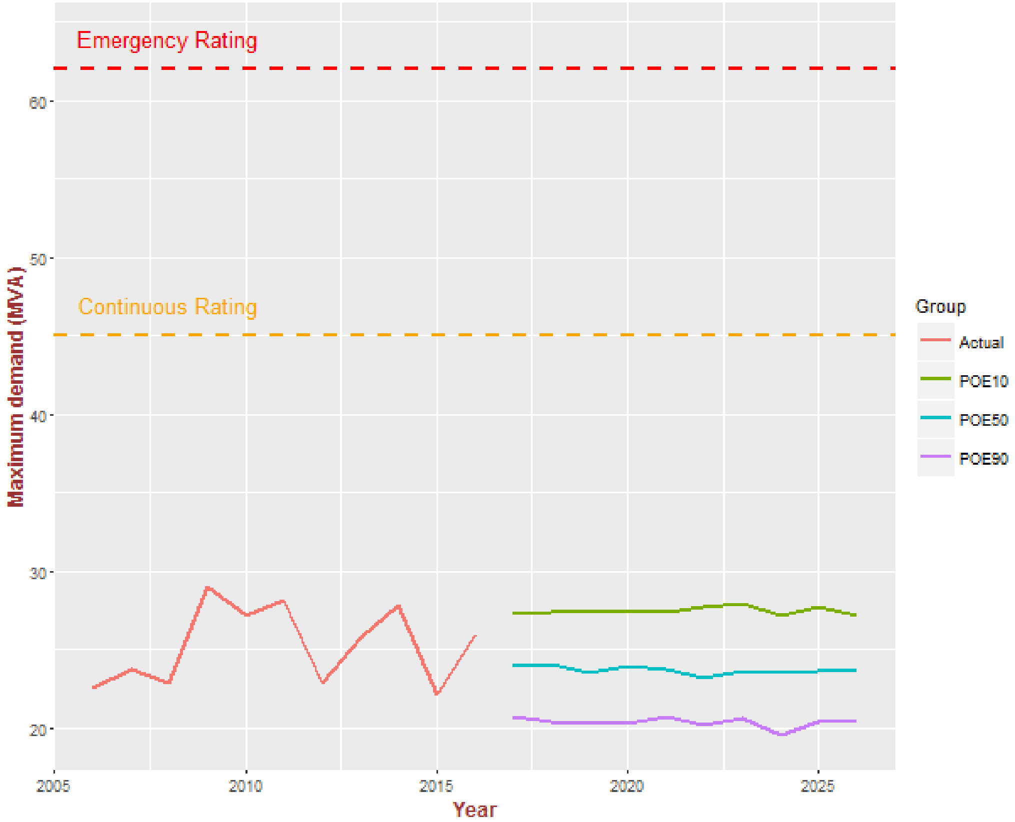


Figure C.11.2: Theodore Zone Substation winter maximum demand forecast

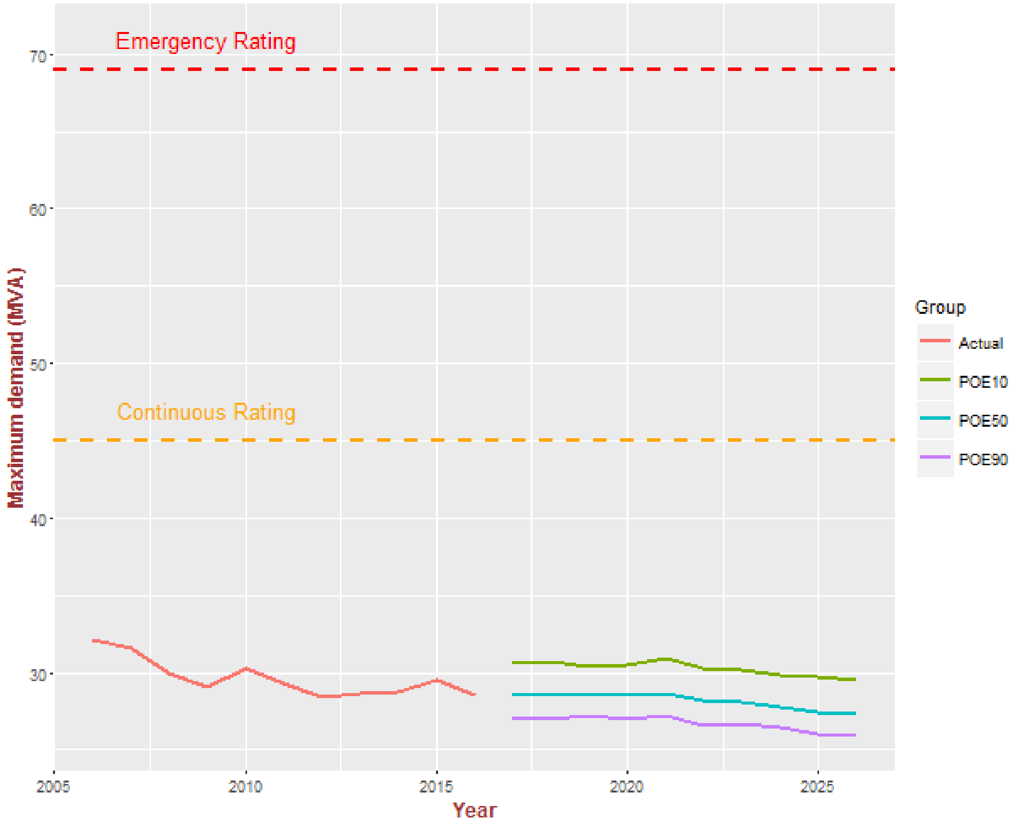


Figure C.12.1: Wanniassa Zone Substation summer maximum demand forecast

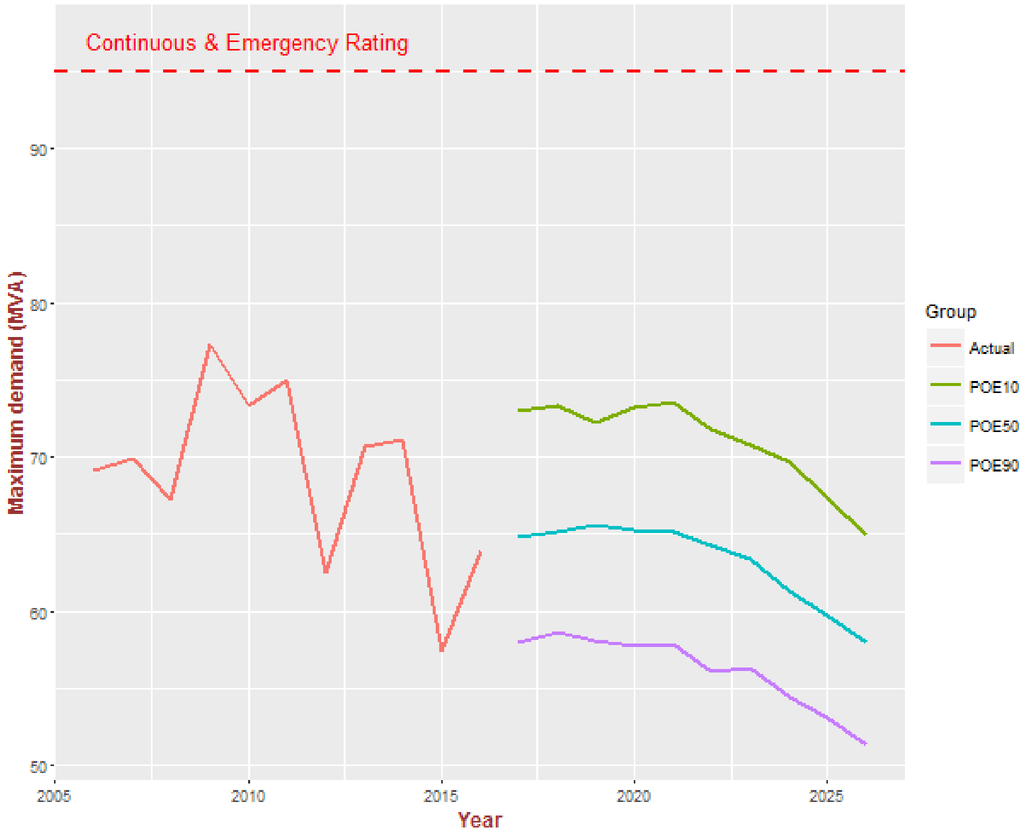


Figure C.12.2: Wanniassa Zone Substation winter maximum demand forecast

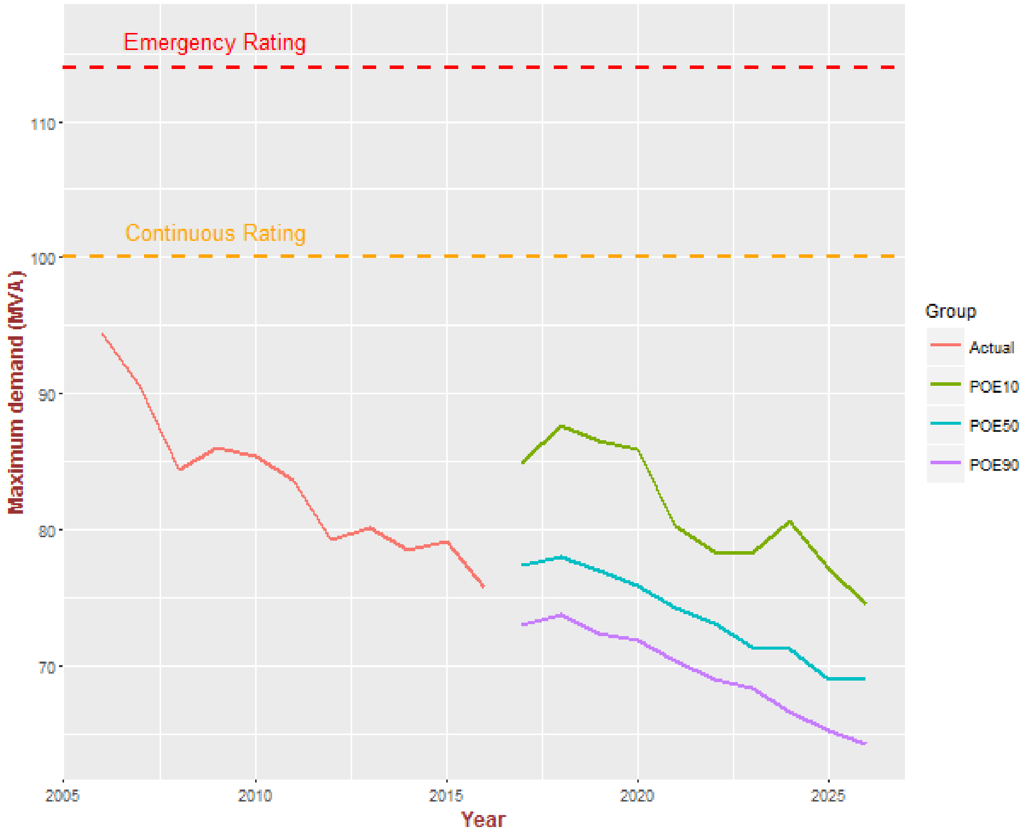


Figure C.13.1: Woden Zone Substation summer maximum demand forecast

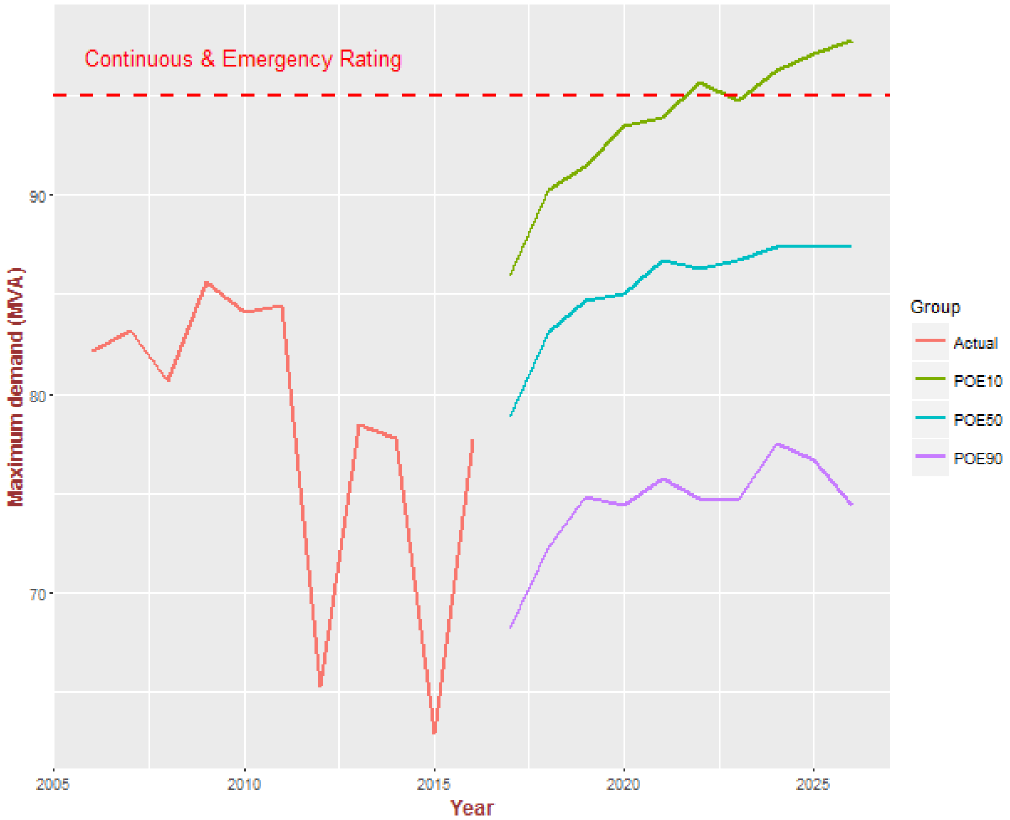


Figure C.13.2: Woden Zone Substation winter maximum demand forecast

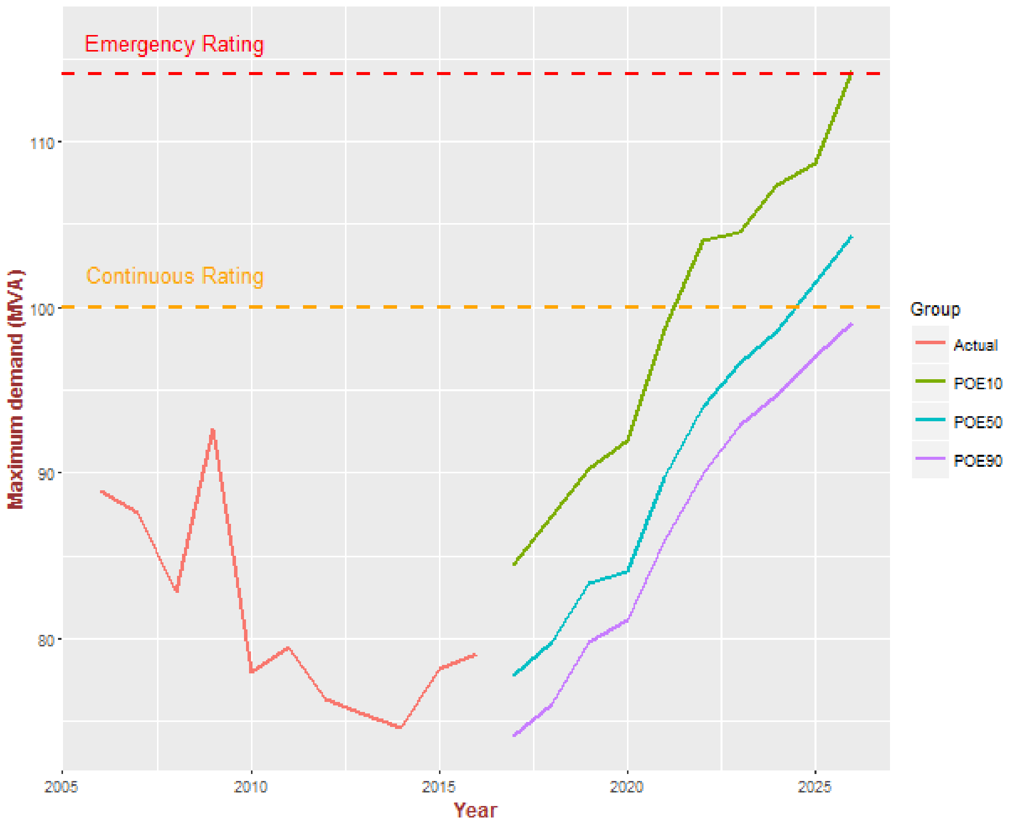


Figure C.14.1: Tennent Zone Substation summer maximum demand forecast

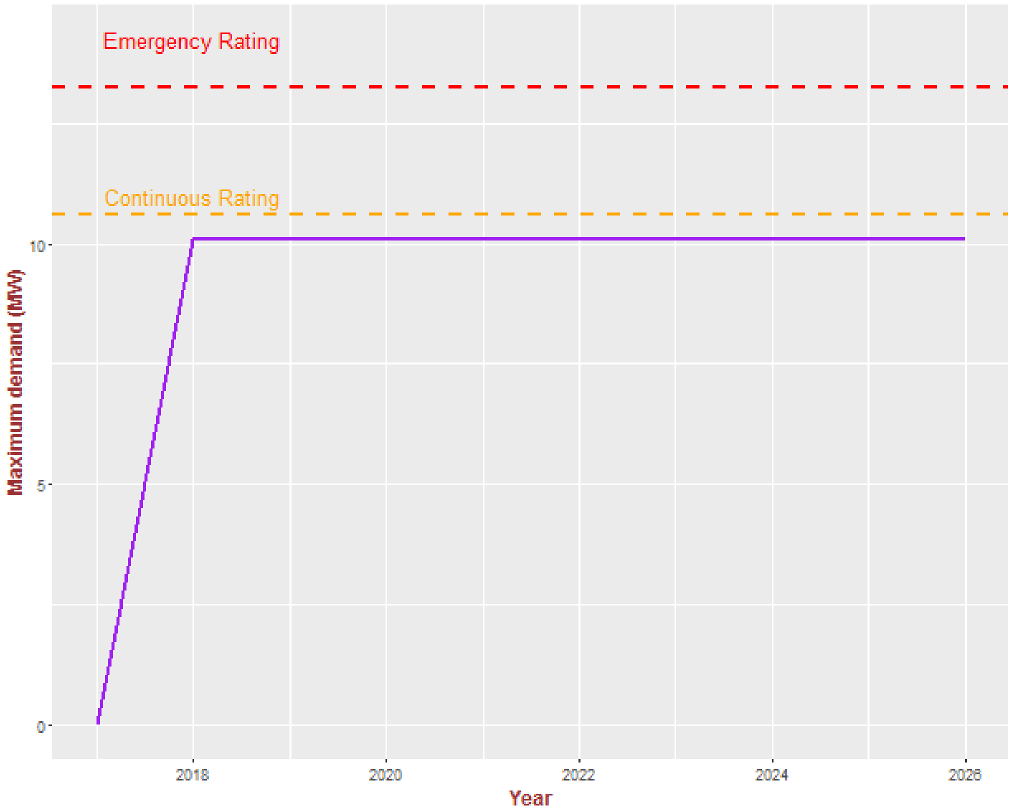
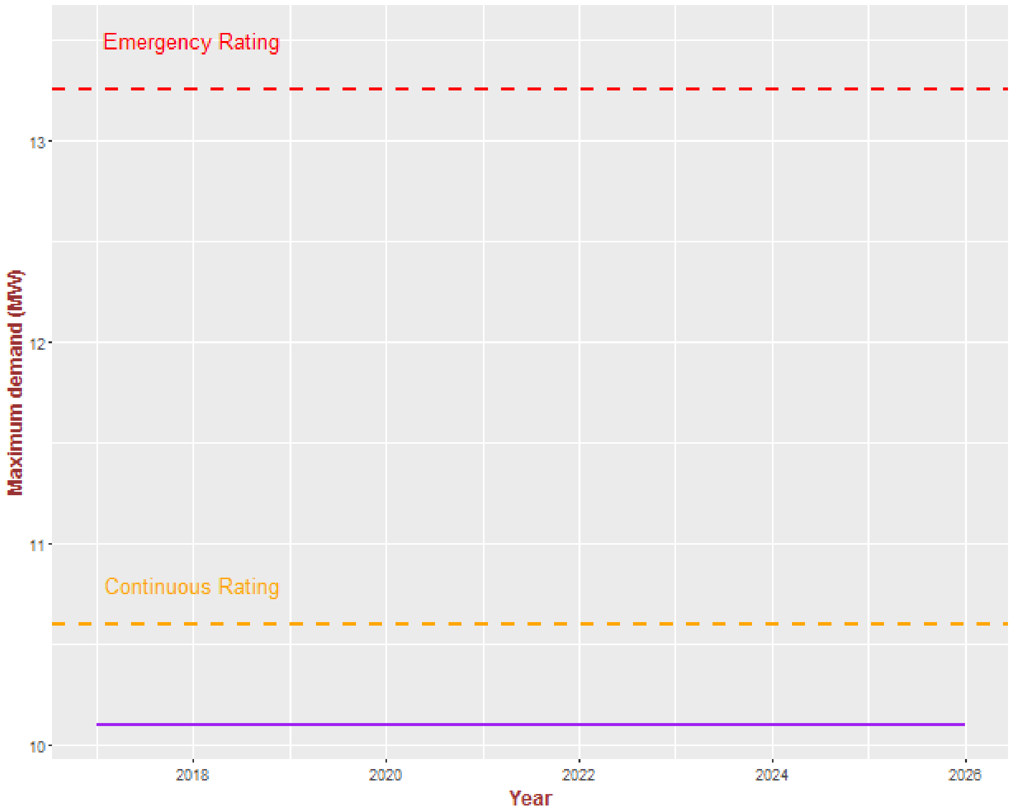


Figure C.14.2: Tennent Zone Substation winter maximum demand forecast



Appendix D: Transmission Line Ratings

LINE		VOLTAGE	CURRENT RATING (AMPS)			
			SUMMER DAY (35°C ambient temp)		WINTER DAY (15°C ambient temp)	
FROM	TO		CONTINUOUS	EMERGENCY	CONTINUOUS	EMERGENCY
Canberra	Woden	132 kV	1950	2960	2540	3320
Canberra	Latham	132 kV	1950	2958	2540	3320
Canberra	Gold Creek	132 kV	1930	2920	2520	3280
Latham	Belconnen	132 kV	1950	2960	2540	3320
Bruce	Belconnen	132 kV	1930	2920	2520	3280
Bruce	Gold Creek	132 kV	1930	2920	2520	3280
Bruce	Civic	132 kV	1930	2930	2520	3290
Bruce	City East	132 kV	970	1460	1260	1640
East Lake	Bruce	132 kV	1080	1270	1220	1440
East Lake	Causeway	132 kV	1080	1270	1220	1440
Woden	Wanniassa	132 kV	1990	3000	2590	3370
Civic	Woden	132 kV	1950	2960	2540	3330
Causeway	City East	132 kV	970	1460	1260	1640
Gilmore	Causeway	132 kV	1930	2920	2510	3280
Wanniassa	Gilmore	132 kV	1930	2960	2510	3280
Gilmore	Williamsdale	132 kV	970	1460	1260	1640
Gilmore	Theodore	132 kV	970	1460	1260	1640
Theodore	Williamsdale	132 kV	970	1460	1220	1640
Causeway	Telopea Park	132 kV	1170	1170	1170	1170
Fyshwick	Queanbeyan	66 kV	500	840	820	1040

Appendix E: Small Scale (≤ 200 kW) PV Generation by Feeder

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Belconnen	Aikman	0	0	City East	Chisholm	87	239,466
Belconnen	Baldwin	154	446,035	City East	CNBP2	0	0
Belconnen	Battye	2	12,210	City East	Constitution	1	36,000
Belconnen	Bean	92	288,908	City East	Cooyong	0	0
Belconnen	Benjamin	10	29,285	City East	Cowper	75	232,799
Belconnen	CAE No 1	0	0	City East	Duffy	110	461,222
Belconnen	CAE No 2	0	0	City East	Ebden	199	551,398
Belconnen	Cameron North	3	5,530	City East	Electricity House	0	0
Belconnen	Cameron South	20	47,830	City East	Fairbairn	5	22,760
Belconnen	Chan	0	0	City East	Ferdinand	111	382,819
Belconnen	Chandler	0	0	City East	Haig	15	72,450
Belconnen	Chuculba	126	366,560	City East	Ijong	6	16,249
Belconnen	Eardley	38	95,27	City East	Lonsdale	0	0
Belconnen	Emu Bank	0	0	City East	Mackenzie	183	544,541
Belconnen	Haydon	91	281,577	City East	Masson	2	34,500
Belconnen	Joy Cummins	66	155,555	City East	Northbourne	4	13,280
Belconnen	Lampard	30	96,745	City East	Petrie	3	75,200
Belconnen	Laurie	125	353,743	City East	Quick	9	29,640
Belconnen	Maribyrnong	31	197,395	City East	Stott	169	470,721
Belconnen	McGuinness	112	383,611	City East	Wakefield	84	256,341
Belconnen	Meacham	268	824,429	City East	Wolseley	66	185,168
Belconnen	Shannon	151	425,202				
Belconnen	Swinden	13	40,005	Civic	ANU No1	0	0
Belconnen	William Slim	165	485,104	Civic	ANU No2	0	0
				Civic	ANU No3	0	0
City East	Aero Park	0	0	Civic	ANU No4	0	0
City East	Ainslie	0	0	Civic	ANU No5	0	0
City East	Akuna	0	0	Civic	Belconnen Way North	114	330,527
City East	Allara	0	0	Civic	Belconnen Way South	179	502,654
City East	Binara	0	0	Civic	Black Mountain	100	334,799
City East	Braddon	1	30,528	Civic	Christian	0	0
City East	Bunda	0	0	Civic	CSIRO	0	0

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Civic	Dryandra	165	491,386	Gilmore	Tralee	1	30,450
Civic	Girrahween	0	0	Gilmore	Willoughby	78	264,468
Civic	Hobart Long	2	14,995				
Civic	Hobart Short	0	0	Gold Creek	Anthony Rolfe	153	515,906
Civic	Jolimont	0	0	Gold Creek	Barrington	237	679,908
Civic	McCaughey	10	26,625	Gold Creek	Birrigai	69	193,028
Civic	Miller	170	506,835	Gold Creek	Boulevarde North	14	48,565
Civic	Nicholson	22	60,269	Gold Creek	Bunburung	34	97,162
Civic	Telecom Tower	0	0	Gold Creek	Ferguson	289	802,571
Civic	Wattle	10	56,392	Gold Creek	Gribble	11	58,460
				Gold Creek	Gungahlin	5	60,030
East Lake	Dairy North	7	37,560	Gold Creek	Gurrang	107	341,508
East Lake	Isa	4	237,120	Gold Creek	Hughes	118	330,589
Fyshwick	Abattoir	13	54,002	Gold Creek	Lander	343	1,100,061
Fyshwick	Airport	0	0	Gold Creek	Lexcen	186	627,517
Fyshwick	Barrier	4	358,430	Gold Creek	Ling	39	131,846
Fyshwick	Collie	4	258,400	Gold Creek	Magenta	87	315,262
Fyshwick	Domayne	1	149,820	Gold Creek	Nona	258	738,256
Fyshwick	Gladstone	3	17,100	Gold Creek	Riley	86	278,942
Fyshwick	Newcastle	0	0	Gold Creek	Saunders	169	498,322
Fyshwick	Pialligo	5	128,018	Gold Creek	Wanganeen	41	114,111
Fyshwick	Tennant	9	216,148	Gold Creek	Wellington	0	0
Fyshwick	Whyalla	4	39,420	Gold Creek	West Street	210	556,264
Gilmore	Alderson	4	79,240	Latham	Bowley	214	622,857
Gilmore	Beggs	93	299,148	Latham	Conley	105	306,428
Gilmore	Edmond	122	367,127	Latham	Copland	122	351,795
Gilmore	Falkiner	83	263,773	Latham	Elkington	153	421,212
Gilmore	Findlayson	120	369,117	Latham	Fielder	28	170,415
Gilmore	Harman	0	0	Latham	Florey	143	441,223
Gilmore	Jackie Howe	142	442,383	Latham	Homann	138	519,212
Gilmore	May Maxwell	119	332,783	Latham	Latham	138	401,408
Gilmore	Monaro	2	138,228	Latham	Lhotsky	335	866,388
Gilmore	Penton	40	111,191	Latham	LM East	32	85,922
Gilmore	Rossman	98	274,216	Latham	LM West	28	74,728

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Latham	Macrossan	246	614,965	Telopea Park	NSW	8	136,350
Latham	Markell	156	571,737	Telopea Park	Ovens	8	40,365
Latham	Melba	124	376,483	Telopea Park	Parliament House No 1	0	0
Latham	O'Loghlen	173	535,646	Telopea Park	Parliament House No 4	0	0
Latham	Paterick	75	223,397	Telopea Park	Power House	41	110,320
Latham	Powers	90	255,318	Telopea Park	Queen Victoria	0	0
Latham	Seal	146	435,643	Telopea Park	Riverside	1	2,310
Latham	Tillyard	134	395,485	Telopea Park	Russell No 1	0	0
Latham	Verbrugghen	87	277,818	Telopea Park	Russell No 2	0	0
Latham	Weir	192	592,010	Telopea Park	Russell No 3	0	0
				Telopea Park	Sandalwood	7	35,520
Telopea Park	ANU Backup	0	0	Telopea Park	Strzelecki	58	207,270
Telopea Park	Belmore	25	103,437	Telopea Park	Sturt	56	181,709
Telopea Park	Blackall	0	0	Telopea Park	Telopea Park East	4	14,241
Telopea Park	Bowen	0	0	Telopea Park	Throsby	91	329,630
Telopea Park	Brisbane	0	0	Telopea Park	York Park 1	0	0
Telopea Park	Broughton	0	0	Telopea Park	York Park 2	0	0
Telopea Park	CNBP1	0	0	Telopea Park	Young	0	0
Telopea Park	Cunningham	153	461,335				
Telopea Park	Edmond Barton	0	0	Theodore	Banyule	147	396,661
Telopea Park	Empire	102	297,683	Theodore	Callister	262	792,234
Telopea Park	Forster	42	167,076	Theodore	Chippindall	153	455,986
Telopea Park	Gallery			Theodore	Eaglemont	204	618,094
Telopea Park	Giles	36	118,245	Theodore	Fairley	146	477,841
Telopea Park	Jardine	0	0	Theodore	Lawrence Wackett	160	407,935
Telopea Park	Kelliher	0	0	Theodore	Lethbridge	128	465,448
Telopea Park	Kingston Foreshore 1	3	19,460	Theodore	Morison	154	429,635
Telopea Park	Kingston Foreshore 2	10	48,082	Theodore	Templestowe	73	210,674
Telopea Park	Kurrajong	1	3,150				
Telopea Park	Mildura	0	0	Wanniassa	Ashley	106	318,050
Telopea Park	Monash	5	15,620	Wanniassa	Athllon	147	368,546
Telopea Park	Mundaring	0	0	Wanniassa	Bissenberger	156	435,558

Zone Substation	Feeder	Number Sites	Installed capacity (W)	Zone Substation	Feeder	Number Sites	Installed capacity (W)
Wanniassa	Brookman	128	519,482	Woden	Deakin No 2	36	160,732
Wanniassa	Conolly	119	341,762	Woden	Devonport	28	82,974
Wanniassa	Erindale	0	0	Woden	Easty	1	9,900
Wanniassa	Fincham	1	1,500	Woden	Folingsby	181	728,049
Wanniassa	Gaunson	92	287,925	Woden	Garran	0	0
Wanniassa	Gouger	82	253,175	Woden	Hilder	164	574,867
Wanniassa	Grimshaw	455	1,010,097	Woden	Hindmarsh	0	0
Wanniassa	Hawker	90	263,810	Woden	Kent	0	0
Wanniassa	Hawkesbury	169	513346	Woden	King	12	53,771
Wanniassa	Hemmings	91	251,067	Woden	Launceston	1	99,840
Wanniassa	Lambrigg	81	301,356	Woden	Lyons West	223	612,663
Wanniassa	Langdon	141	408,013	Woden	McInnes	131	433,907
Wanniassa	Longmore	163	504,263	Woden	Phillip North	4	48,145
Wanniassa	Mannheim	90	261,035	Woden	Phillip South	0	0
Wanniassa	Marconi	136	384,359	Woden	Streeton	154	465,069
Wanniassa	Matthews	148	410,962	Woden	Theodore	119	421,829
Wanniassa	Mugga	1	199,386	Woden	Tidbinbilla 22 kV	3	20,085
Wanniassa	Muresk	201	670,399	Woden	Weston East	144	400,516
Wanniassa	Pitman	2	201,520	Woden	Wilson	161	524,960
Wanniassa	Pridham	82	235,780	Woden	Yamba	0	0
Wanniassa	Reid	163	507,037	Woden	Yarralumla	53	200,005
Wanniassa	Rowland	0	0				
Wanniassa	Sainsbury	53	148,729		**TOTAL**	**17,476**	**53,507,110**
Wanniassa	Sternberg	2	5,900				
Wanniassa	Symers	77	246,569				
Woden	Bunbury	197	637,967				
Woden	Carruthers	119	349,793				
Woden	Cooleman	84	235,830				
Woden	Corrina	2	31,710				
Woden	Cotter 11 kV	188	663,566				
Woden	Cotter 22 kV	0	0				
Woden	Curtin North	133	391,491				
Woden	Daplyn	123	321,480				
Woden	Deakin No 1	83	220,124				