DISTRIBUTION ANNUAL PLANNING REPORT

December 2018

Disclaimer

The purpose of this document is to provide information about actual and forecast constraints on CitiPower's distribution network and details of these constraints, where they are expected to arise within the forward planning period. This document is not intended to be used for other purposes, such as making decisions to invest in generation, transmission or distribution capacity.

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This Distribution Annual Planning Report (**DAPR**) has been prepared in accordance with the National Electricity Rules (**NER**), in particular Schedule 5.8, as well as the Electricity Distribution Code.

This document contains certain predictions, estimates and statements that reflect various assumptions concerning, amongst other things, economic growth and load growth forecasts that, by their nature, may or may not prove to be correct. This document also contains statements about CitiPower's plans. These plans may change from time to time without notice and should therefore be confirmed with CitiPower before any action is taken based on this document.

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1 Overview

The Distribution Annual Planning Report (**DAPR**) provides an overview of the current and future changes that CitiPower proposes to undertake on its network. It covers information relating to 2018 as well as the forward planning period of 2019 to 2023.

CitiPower is a regulated Victorian electricity distribution business. It distributes electricity to around 330,500 homes and businesses in Melbourne's central business district (**CBD**) and inner suburbs.

The report sets out the following information:

- forecasts, including capacity and load forecasts, at the zone substation, sub-transmission and primary distribution feeder level;
- system limitations, which include limitations resulting from the forecast load exceeding the capacity following an outage of an asset, or retirements and de-ratings of assets;
- projects that have been, or will be, assessed under the regulatory investment test; and
- other high level summary information to provide context to CitiPower's planning processes and activities.

The DAPR provides a high-level description of the balance that CitiPower will take into account between capacity, demand and replacement of its assets at each zone substation and sub-transmission line over the forecast period. This document should be read in conjunction with the System Limitation Report and the Forecast Load Sheet. Transmission-distribution connection assets are addressed in a separate report.[1]

Data presented in this report may indicate an emerging major constraint, where more detailed analysis of risks and options for remedial action by CitiPower are required.

The DAPR also provides preliminary information on potential opportunities to prospective proponents of non-network solutions at zone substations, sub-transmission lines and primary distribution feeders where remedial action may be required. Providing this information to the market facilitates the efficient development of the network to best meet the needs of customers.

The DAPR is aligned with the requirements of clauses 5.13.2(b) and (c) of the National Electricity Rules (**NER**) and contains the detailed information set out in Schedule 5.8 of the NER. In addition, the DAPR contains information consistent with the requirements of section 3.5 of the Electricity Distribution Code, as published by the Essential Services Commission of Victoria.

[1] Transmission-distribution connection assets are discussed in the Transmission Connection Planning Report which is available on the CitiPower website at http://www.citipower.com.au/Electricity_Networks/CitiPower_Network/CitiPower_-_Network_Planning/

1.1 Public consultation

CitiPower intends to hold a public forum to discuss this DAPR in early 2019. All interested stakeholders are welcome to attend, including interested parties on CitiPower's demand-side engagement register, and local councils.

CitiPower invites written submissions from interested parties to offer alternative proposals to defer or avoid the proposed works associated with network constraints. All submissions should address the technical characteristics of non-network options provided in this DAPR and include information listed in the demand-side engagement strategy.

All written submissions or enquiries should be directed to:
DMInterestedParties@citipower.com.au

Alternatively, CitiPower's postal address for enquiries and submissions is:

CitiPower
Attention: Head of Network Planning and Development
Locked Bag 14090
Melbourne VIC 8001

2 Background

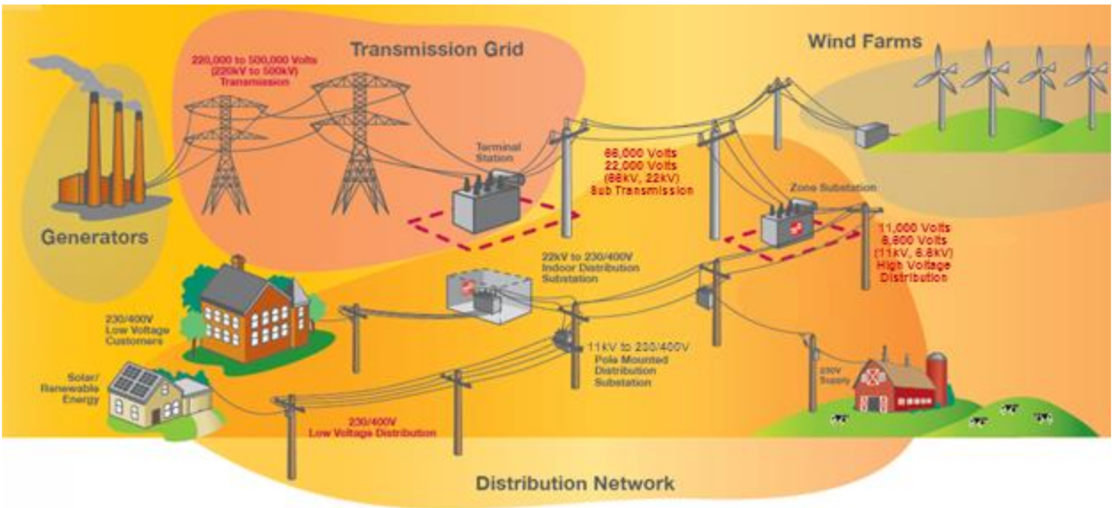
This chapter sets out background information on CitiPower Pty Ltd (**CitiPower**) and how it fits into the electricity supply chain.

2.1 Who we are

CitiPower is a regulated Distribution Network Service Provider (**DNSP**) within Victoria. CitiPower own the poles and wires which supply electricity to homes and businesses.

A high level picture of the electricity supply chain is shown in the diagram below.

Figure 2.1 The electricity supply chain



The distribution of electricity is one of four main stages in the supply of electricity to customers. The four main stages are:

- **Generation**: generation companies produce electricity from sources such as coal, wind or sun, and then compete to sell it in the wholesale National Electricity Market (**NEM**). The market is overseen by the Australian Energy Market Operator (**AEMO**), through the co-ordination of the interconnected electricity systems of Victoria, New South Wales, South Australia, Queensland, Tasmania and the Australian Capital Territory. It is recognised that a growing amount of generation is occurring at lower voltages including individual household photovoltaic arrays.
- **Transmission**: the transmission network transports electricity from generators at high voltage to five Victorian distribution networks. Victoria's transmission network also connects with the grids of New South Wales, Tasmania and South Australia.
- **Distribution**: distributors such as CitiPower convert electricity from the transmission network into lower voltages and deliver it to Victorian homes and businesses. The major focus of distribution companies is developing and maintaining their networks to ensure a reliable supply of electricity is delivered to customers to the required quality of supply standards.

- **Retail**: the retail sector of the electricity market sells electricity and manages customer accounts. Retail companies issue customers' electricity bills, a portion of which includes regulated tariffs payable to transmission and distribution companies for transporting electricity along their respective networks.

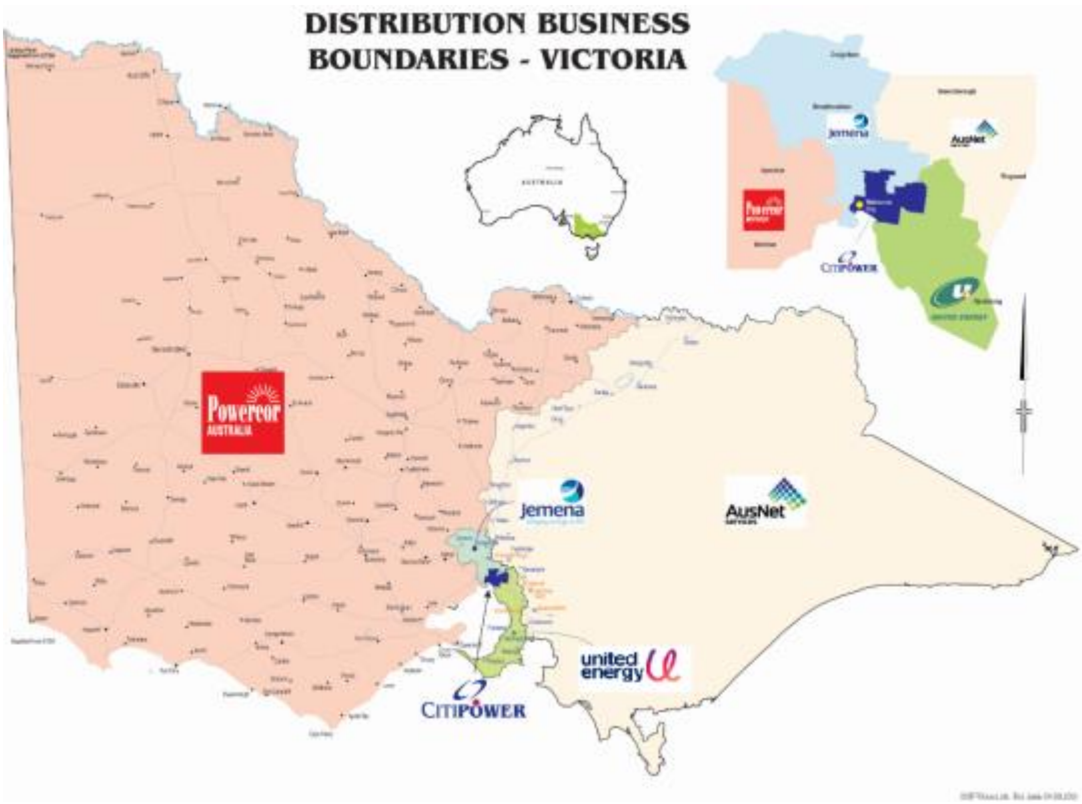
2.2 The five Victorian distributors

In the distribution stage of the supply chain, there are five businesses operating in Victoria. Each business owns and operates the electricity distribution network. CitiPower is one of those distribution businesses.

The CitiPower network provides electricity to customers in Melbourne's central business district (**CBD**) and inner suburbs, and supplies world-class cultural and sporting facilities such as Federation Square, the Melbourne Cricket Ground, the Victorian Arts Centre and Melbourne Park.

The coverage of CitiPower and other Victorian distributors is shown in the figure below.

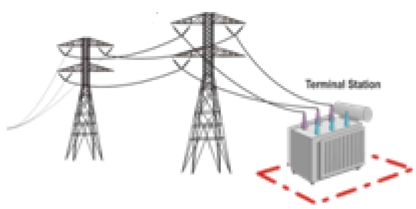
Figure 2.2 CitiPower and other Victorian distributors areas



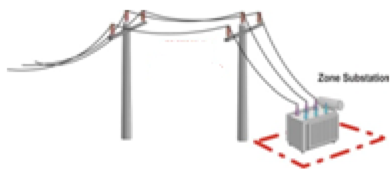
In Victoria, each DNSP has responsibility for planning the augmentation of their distribution network. In order to continue to provide efficient, secure and reliable supply to its customers, CitiPower must plan augmentation and asset replacement of the network to match network capacity to customer demand. The need for augmentation is largely driven by customer peak demand growth and geographic shifts of demand due to urban redevelopment.

2.3 Delivering electricity to customers

Power that is produced by large-scale generators is transmitted over the high voltage transmission network and is changed to a lower voltage before it can be used in the home or industry. This occurs in several stages, which are simplified below.

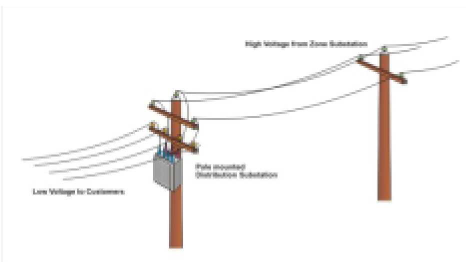


Firstly, the voltage of the electricity that is delivered to **terminal stations** is reduced by transformers. Typically in Victoria, most of the transmission lines operate at voltages of 500,000 volts (500 kilovolts or kV) or 220,000 volts (220kV). The transformer at the terminal station reduces the electricity voltage to 66kV. The CitiPower network is supplied from the terminal stations.



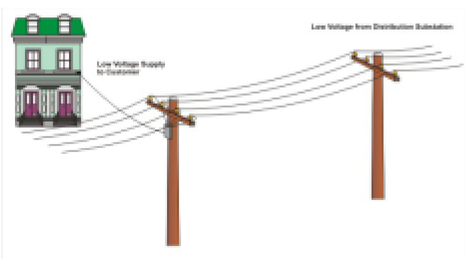
Second, CitiPower distributes the electricity on the **sub-transmission system** which is made up of large concrete or wooden power poles and powerlines, or sometimes underground powerlines. The sub-transmission system transports electricity to CitiPower's zone substations at 66kV or 22kV.

Third, at the **zone substation** the electricity voltage is converted from 66kV or 22kV, to 11kV or 6.6kV. Electricity at this voltage can then be distributed on smaller, lighter power poles.



Fourth, **high voltage distribution lines (**or distribution feeders) transfer the electricity from the zone substations to CitiPower's distribution substations.

Fifth, electricity is transformed to 400 / 230 volts at the **distribution substations** for supply to customers.



Finally, electricity is conveyed along the **low voltage distribution lines** to homes and businesses.

A growing amount of generation is occurring at lower voltages including individual customer level PV arrays.

2.4 Operating environment and asset statistics

CitiPower delivers electricity to around 330,500 homes and businesses in a 157 square kilometre area, or around 2,104 customers per square kilometre.

The CitiPower electricity network comprises a sub-transmission network which consists of predominately overhead lines which operate at 66kV with some at 22kV and a distribution network that generally operates at a voltage of 11kV with some 6.6kV. The overall network consists of around 60 per cent overhead lines and 40 per cent underground cables.

The sub-transmission network is supplied from a number of terminal stations which typically operate at a voltage of 220kV. This transmission network, including the terminal stations, is owned and operated by AusNet Services.

The sub-transmission network nominally operates at 66kV or 22kV and is often configured in loops to maximise reliability. The sub-transmission network supplies electricity to zone substations which then transform (step down) the voltage suitable for the distribution to the surrounding area.

The distribution network consists of both overhead and underground lines connected to substations, switchgear, and other equipment to provide effective protection and control. Whilst the majority of the high voltage distribution system nominally operates at 11kV, there are some notable exceptions. For example, although they are being progressively decommissioned, 6.6kV distribution systems can still be found in areas of:

- Port Melbourne;
- CBD;
- North Melbourne;
- Brunswick; and
- Fitzroy.

Distribution feeders are generally operated in a radial mode from their respective zone substation supply points with inter-feeder tie points which can be reconfigured to provide for load transfers and other operational contingencies.

The final supply to small consumers is provided through the low voltage distribution systems that nominally operate at 230 or 400 volts. These voltages are derived from distribution substations which are located throughout the distribution network and typically range in size from 200kVA to 2000kVA. Both overhead and underground low voltage reticulation, including service arrangements, complete the final connections to the low voltage consumer’s points of supply. CitiPower’s customer base comprises of high rise domestic and commercial customers, some industrial customers through to small domestic customers.

At the start of 2018, the CitiPower network comprised approximately:

Table 2.1 CitiPower network statistics

Item	Number / km
Poles	58,207
Overhead lines	4,273
Underground cables	3,252
Sub-transmission lines	84
Zone substation transformers	102
Distribution feeders	662
Distribution transformers	4,843

Appendix A shows the extent of CitiPower's network.

3 Factors impacting network

This chapter sets out the factors that may have a material impact on the CitiPower network:

- demand: changes in demand causing thermal capacity constraints, such as that caused from population growth resulting in new residential customers connecting to the network, new or changed business requirements for electricity or increased take-up of distributed energy resources and associated exports into the network;
- fault levels: the increasing amount of embedded generation being directly connected to the CitiPower network is increasing the overall fault levels on the network which is reaching its fault level capacity in certain areas;
- voltage levels: the short distances between the customer and the voltage regulating equipment in the CitiPower network means that the voltage levels have generally not been a concern however recent increases in PV have created overvoltage issues to be addressed;
- other system security requirements: there will be greater resilience in the network as the Melbourne CBD security of supply upgrade plan continues to be implemented;
- quality of supply: CitiPower may carry out system studies on a case-by-case basis as part of the new customer connection process; and
- ageing and potentially unreliable assets: CitiPower utilises a Health Index as a guide to determining the condition, and therefore risk of the assets. Many of the ageing assets that are in deteriorated condition in the CitiPower network exist within the 22kV sub-transmission network.
- solar enablement: the rapid uptake of distributed energy resources are driving voltage variations and reverse flow capacity constraints.

These factors are discussed in more detail below.

3.1 Demand

Changes in maximum demand on the network are driven by a range of factors. For example, this may include:

- population growth: increases in the number of residential customers connecting to the network;
- economic growth: changes in the demand from small, medium and large businesses and large industrial customers;
- prices: the price of electricity impacts the use of electricity;
- weather: the effect of temperature on demand largely due to temperature sensitive loads such as air-conditioners and heaters; and
- customer equipment and embedded generators: the equipment that sits behind the customer meter including solar panels (which may mask the real demand behind the meter) and cause capacity constraints, televisions, pool pumps, electric vehicles, solar panels, wind turbines, batteries, etc.

Forecasting for demand is discussed later in this document.

3.2 Fault levels

A fault is an event where an abnormally high current is developed as a result of a short circuit somewhere in the network. A fault may involve one or more line phases and ground, or may occur between line phases only. In a ground/ earth fault, charge flows into the earth or along a neutral or earth-return wire.

CitiPower estimates the prospective fault current to ensure it is within allowable limits of the electrical equipment installed, and to select and set the protective devices that can detect a fault condition. Devices such as circuit breakers, automatic circuit reclosers, sectionalisers, and fuses can act to break the fault current to protect the electrical plant, and avoid significant and sustained outages as a result of plant damage.

Fault levels are determined according to a number of factors including:

- generation of all sizes;
- impedance of transmission and distribution network equipment;
- load including motors; and
- voltage.

The following fault level limits are generally applied within CitiPower:

Table 3.1 Fault level limits

Voltage	Fault limit (kiloAmps, kA)
66kV	21.9 kA
22kV	13.1 kA for distribution lines
	26.2 kA for sub-transmission lines
11kV	18.4 kA
6.6kV	21.9 kA
<1kV	50 kA

Where fault levels are forecast to exceed the allowable fault level limits listed above, then fault level mitigation projects are initiated. This may involve, for example, introducing extra impedance into the network or separating network components that contribute to the fault such as opening the bus-tie circuit breakers at constrained zone substations to divide the fault current path.

Fault level mitigation programs are becoming increasingly common on the CitiPower network as the level of embedded generation being directly connected to the network increases. This is because of the increasing fault level contribution from generators which the network was not designed for when originally conceived.

3.3 Voltage levels

Voltage levels are important for the operation of all electrical equipment, including home appliances with electric motors or compressors such as washing machines and refrigerators, or farming and other industrial equipment. These appliances are manufactured to operate within certain voltage threshold ranges.

Electricity distributors are obligated to maintain customer voltages within specified thresholds, and these are further discussed in section 16.2. Similarly, manufacturers can only supply such appliances and equipment that operate within the Australian Standards. Supply voltage at levels outside these limits could affect the performance or cause damage to the equipment as well as industry processes.

Voltage levels are affected by a number of factors including:

- generation of electricity into the network;
- impedance of transmission and distribution network equipment;
- length of sub-transmission or distribution feeders;
- load; and
- capacitors in the network.

For CitiPower, the length of sub-transmission and distribution feeders in the network is relatively short compared with rural areas and this reduces the potential for customer voltage variations due to load however this situation is rapidly changing due to the impact of local solar generation.

CitiPower also installs additional voltage regulation equipment at zone substations where a bus-tie circuit breaker is opened as a result of fault level constraints.

3.4 System security

This section sets out other power system security requirements for the CitiPower network. In particular, it discusses the Melbourne CBD security of supply upgrade plan including:

- an outline of the capital and other works undertaken in 2018 to implement the plan;
- an evaluation of whether the relevant security of supply objectives specified in the plan were achieved in 2018; and
- an outline of the capital and other works connected to the plan that is proposed to be carried out over the next 5 years.

The majority of works for the CBD upgrade plan were completed in 2016, and the new Waratah Place (**WP**) zone substation is due to be completed by November 2020.

3.4.1 2018 implementation of CBD security of supply upgrade plan

The Melbourne CBD security upgrade plan is an obligation under clause 3.1A of the Victorian Electricity Distribution Code. This obligation followed the publication of a Regulatory Test Final Report by CitiPower that economically justified the scope of works defined to upgrade the 66kV sub-transmission network in the Melbourne CBD to an 'N-1 Secure' standard.

The following Table 3.2 outlines the capital and other works carried out in 2018 as part of the plan. For completeness, the table also provides information on related project works which, while not part of the scope of security works, are required as part of the overall network development scenario to enable the security upgrade works to be completed.

Table 3.3 2018 CBD Upgrade plan works

Description of capital works	**2018 Progress**	**Evaluation of 2018 against objectives**
Transmission, Capacity Related		
Establish a 66kV point of supply at Brunswick terminal station (**BTS**), including 3 x 220/66kV transformers, associated switchgear and protection.	Completed.	Achieved target.
Distribution, Capacity Related		
Establish 2 x 66kV high capacity cables from BTS to Bouverie/Queensberry (**BQ**) zone substation, and associated protection.	Completed.	Achieved revised targets.
BQ zone substation refurbishment. Install 9 x 66kV circuit breakers, 2 x 66/11kV transformers and associated switchgear and protection.	Completed.	Achieved revised targets.
Distribution, Security Enhancement		
Establish 66kV connection circuit breakers, and associated protection at BTS.	Completed.	Achieved revised targets.
Establish a 66kV high capacity cable from BTS to Victoria Market (**VM**) zone substation, and associated protection.	Completed.	Achieved revised targets.
Establish 2 x 66kV high capacity cables from BQ to VM, and associated protection.	Completed.	Achieved revised targets.

Description of capital works	2018 Progress	Evaluation of 2018 against objectives
VM zone substation refurbishment. Install 19 x 66kV circuit breakers and associated protection.	Completed.	Achieved revised targets.
Waratah Place (**W**, to be renamed **WP**) zone substation re-build. Install 16 x 66kV circuit breakers, 2 x 66/11kV transformers and associated switchgear and protection.	Project has commenced.	Objectives remain. Proceeding to revised targets.
Establish 2 x 66kV high capacity cables from BQ to new WP zone substation, and associated protection.	Project nearing completion, pending WP completion.	Objectives remain. Proceeding to revised targets.
Re-configure existing VM to W and W to Celestial Avenue (**WA**) 66kV cables to establish one VM to WA 66kV cable and by-pass W zone substation.	Completed.	Achieved revised targets.
McIllwraith Place (**MP**) zone substation 66kV bus tie switch / re-configuration	Completed	Achieved revised targets.

3.4.2 Future CBD upgrade works

Table 3.3 below presents the project timeline for the CBD security of supply project.

Table 3.3 Future planned CBD upgrade works

Description of capital works	2019	2020
Distribution, Security Enhancement		
Waratah Place (**W**, to be renamed **WP**) zone substation re-build. Install 16 x 66kV circuit breakers, 2 x 66/11kV transformers and associated switchgear and protection.	x	x
Establish 2 x 66kV high capacity cables from BQ to new WP zone substation, and associated protection.	x	x

The 66kV bus-tie switch at Flinders Ramsden (**FR**) zone substation has been replaced by equivalent 11kV load transfer capability between FR, MP and BQ.

A final component of the security of supply enhancement strategy is the establishment of additional 11kV feeder transfer capability and distribution remote switching at the following zone substations:

- Little Bourke Street (**JA**);
- McIllwaith Place (**MP**);
- Celestial Avenue (**WA**); and
- Little Queen (**LQ**).

These additional 11kV distribution works will ensure security of supply enhancement to the CBD. These works are intended to be carried out in conjunction with demand growth projects on 11kV feeders from these zone substations at the completion of the above mentioned CBD Security upgrade works.

3.5 Quality of supply to other network users

Where embedded generators or large industrial customers are seeking to connect to the network and the type of load is likely to result in changes to the quality of supply to other network users, CitiPower may carry out system studies on a case-by-case basis as part of the new customer connection process.

3.6 Ageing and potentially unreliable assets

There are many ageing assets within the CitiPower network. CitiPower carries out routine maintenance on all its assets to reduce the probability of plant failure, and ensure they are fit for operation.

There are two key areas of ageing and potentially unreliable assets that are a priority for CitiPower:

- assets with a high Health Index; and
- assets in the 22kV sub-transmission network.

These are further discussed below.

3.6.1 Health Index

CitiPower uses the Condition Based Risk Management (**CBRM**) methodology to plan any required interventions to manage risks associated with the performance of major items of plant and equipment.

The model is an ageing algorithm that takes into account a range of inputs including:

- condition assessment data, such as transformer oil condition;
- environmental factors, such as whether the assets are located indoors or outdoors, or coastal areas; and
- operating factors, such as the load utilisation, frequency of use and load profiles that the asset is supplying.

These factors are combined to produce a Health Index for each asset in a range from 0 to 10, where 0 is a new asset and 10 represents end of life. The Health Index provides a means of comparing similar assets in terms of their calculated probability of failure.

CitiPower will closely monitor assets with a Health Index in the range 5 to 7 to determine options for intervention, including replacement or retirement, in the context of energy at risk. Interventions are planned when asset health index exceeds 5.5 and intervention prioritised when asset health index exceeds 7.

A Health Index profile gives an immediate appreciation of the condition of all assets in a group and an understanding of the future condition of the assets.

As part of the CBRM process, a consequence of failure of the asset is also calculated. This assesses the consequence to customers due to loss of supply. The loss of a large amount of load (in MW) to a large industrial customer or to a large number of residential customers will indicate a high consequence of failure. This consequence of failure consists of four elements:

- network performance;
- safety;
- financial; and
- environment.

The risk to CitiPower is calculated by combining the probability of failure of the asset and the consequence of failure of the asset. CBRM is used to calculate how the risk will change in future years and determine the optimum timing for any intervention.

For the purposes of this DAPR, the Health Index of some assets has been provided where CitiPower has assessed the risk to be sufficient to require intervention in the next five years.

3.6.2 Replacement of 22kV sub-transmission network

The 22kV sub-transmission network contains many ageing assets that are in a deteriorated condition. These assets include transformers underground sub transmission oil/paper cables and indoor switchgear within existing zone substations. CitiPower reviews the Health Indexes of these assets as a factor to assist in determining whether or not to trigger intervention.

CitiPower is planning to continue replacing the 22kV sub-transmission network by upgrading to a 66kV sub-transmission network or transferring the zone substation customer to an adjoining distribution network. We are also working with AusNet Services to align our works programs so that the removal of 220/22kV transmission assets are coordinated with our 22kV sub-transmission upgrades (see section 10.1). Operation of the sub-transmission network at the higher voltages also reduces the amount of distribution losses from the network. At the same time CitiPower intends to upgrade the associated 6.6kV distribution network to 11kV.

3.6.3 Replacement of 6.6kV high voltage feeder network

A number of the older zone substations have secondary voltages of 6.6kV, which is inconsistent with the current 11kV standard in the CBD and inner suburbs. These non-standard 6.6kV secondary voltages have many technical limitations when compared with the standard 11kV secondary voltage including a limited loading capability. Having 6.6kV distribution feeders limits system flexibility with regard to load transfers and with encroachment by the 11kV network has created islands within the 6.6kV network which are now not able to be backed up from the surrounding 11kV network.

Now that many plant items in these older zone substations are reaching their end of life, it is time to consider a planned upgrade to 11kV to eliminate the limitations the 6.6kV system imposes. This will renew these areas, enabling higher loads to be supported and providing backup possibilities from surrounding areas. This is especially important for a number of urban renewal projects occurring in these older areas of CitiPower.

3.7 Solar Enablement

Distributed Energy Resources (particularly solar PV) connected to the network are creating voltage variations and reverse flow is restricted by capacity issues. These are expected to significantly increase, in part due to penetration levels reaching a tipping point and a new Victorian Government policy subsidising solar PV for up to 650,000 households over the next 10 years.

In areas with a higher proportion of solar customers, solar PV exports are causing the localised network voltage to rise. This can affect the quality of electricity supply to all customers in the area, trip solar customers' solar PV systems (from export and in-home-use) and raise network voltages towards the limits set by the Electricity Distribution Code (Code).

Solar PV exports are also creating capacity constraint concerns on the LV network (not experienced on HV network to date). This is due to the increasing solar PV penetration, increasing average solar PV system sizes (to a point that households' export capacity can exceed their load requirements) and the relatively low diversity of exports when compared to load diversity, for which the network was traditionally designed to accommodate.

CitiPower is adopting and exploring ways to limit these issues including:

- requiring changes to customers' inverter settings and the use of smart inverters;
- undertaking remedial works such as phase rebalancing, distribution transformer tapping, distribution transformer replacement, installing dynamic voltage controllers and undertaking conductor works and replacements;
- implementing advanced network management systems allowing for more dynamic control of network elements to support exported electricity; and
- limiting/constraining exports when network ratings are met.

4 Network planning standards

This chapter sets out the process by which CitiPower identifies constraints in its network.

4.1 Approaches to planning standards

In general there are two different approaches to network planning.

Deterministic planning standards: this approach calls for zero interruptions to customer supply following any single outage of a network element, such as a transformer. In this scenario any failure or outage of individual network elements (known as the “N-1” condition) can be tolerated without customer impact due to sufficient resilience built into the distribution network. A strict use of this approach may lead to inefficient network investment as resilience is built into the network irrespective of the cost of the likely interruption to the network customers, or use of alternative options.

Probabilistic planning approach: the deterministic N-1 criterion is relaxed under this approach, and simulation studies are undertaken to assess the amount of energy that would not be supplied if an element of the network is out of service. As such, the consideration of energy not served may lead to the deferral of projects that would otherwise be undertaken using a deterministic approach. This is because:

- under a probabilistic approach, there are conditions under which all the load cannot be supplied with a network element out of service (hence the N-1 criterion is not met); however
- the actual load at risk may be very small when considering the probability of a forced outage of a particular element of the sub-transmission network.

In addition, the probabilistic approach assesses load at risk under system normal conditions (known as the “N” condition). This is where all assets are operating but load exceeds the total capacity. Contingency transfers may be used to mitigate load at risk in the interim period until an augmentation is completed.

4.2 Application of the probabilistic approach to planning

CitiPower adopts a probabilistic approach to planning its zone substation and sub-transmission asset augmentations. The probabilistic planning approach involves estimating the probability of an outage occurring within the peak loading season, and weighting the costs of such an occurrence by its probability, to assess:

- the expected cost that will be incurred if no action is taken to address an emerging constraint, and therefore
- whether it is economic to augment the network capacity to reduce expected supply interruptions.

The quantity and value of energy at risk (which is discussed in section 6.1) is a critical parameter in assessing a prospective network investment or other action in response to an emerging constraint. Probabilistic network planning aims to ensure that an economic balance is struck between:

- the cost of providing additional network capacity to remove constraints; and
- the cost of having some exposure to loading levels beyond the network's capability.

In other words, recognising that very extreme loading conditions may occur for only a few hours in each year, it may be uneconomic to provide additional capacity to cover the possibility that an outage of an item of network plant may occur under conditions of extreme loading. The probabilistic approach requires expenditure to be justified with reference to the expected benefits of lower unserved energy.

This approach provides a reasonable estimate of the expected net present value to consumers of network augmentation for planning purposes. However, implicit in its use is acceptance of the risk that there may be circumstances (such as the loss of a transformer at a zone substation during a period of high demand) when the available network capacity will be insufficient to meet actual demand and significant load shedding could be required. The extent to which investment should be committed to mitigate that risk is ultimately a matter of judgment, having regard to:

- the results of studies of possible outcomes, and the inherent uncertainty of those outcomes;
- the potential costs and other impacts that may be associated with very low probability events, such as single or coincident transformer outages at times of peak demand, and catastrophic equipment failure leading to extended periods of plant non-availability; and
- the availability and technical feasibility of cost-effective contingency plans and other arrangements for management and mitigation of risk.

5 Forecasting demand

This chapter sets out the methodology and assumptions for calculating historic and forecast levels of demand for each existing zone substation and sub-transmission system. These forecasts are used to identify potential future constraints in the network.

Please note that information relating to transmission-distribution connection points are provided in a separate report entitled the "Transmission Connection Planning Report" and available on the CitiPower website.[2]

5.1 Maximum demand forecasts

CitiPower has set out its forecasts for maximum demand for each existing zone substation and sub-transmission system in the Forecast Load Sheet.

5.2 Zone substation methodology

This subsection sets out the methodology and information used to calculate the demand forecasts and related information that is referred to in the Forecast Load Sheet and System Limitation Reports.

5.2.1 Historical demand

Historical demand is calculated in Mega Volt Ampere (**MVA**) and is based on actual load and demand values recorded across the distribution network.

As peak demand in CitiPower is very temperature and weather dependent, the actual peak demand values referred to in the Forecast Load Sheet are normalised for the purpose of forecasting, in accordance with the relevant weather conditions experienced across any given summer loading period. The correction enables the underlying peak demand growth year-by-year to be estimated, which is used in making future forecast and investment decisions.

The temperature correction seeks to ascertain the "*50th percentile maximum demand*". The 50th percentile demand represents the peak demand on the basis of a normal season (summer and winter). For summer, it relates to a maximum average load that will be exceeded, on average, once every two years. By definition therefore, actual demand in any given year has a 50 per cent probability of being higher than the 50th percentile demand forecast.[3] The 50th percentile forecast can therefore be considered to be a forecast of the "most-likely" level of demand, bearing in mind that actual demand will vary depending on temperature and other factors. It is often referred to as 50 per cent probability of exceedance (**PoE**).

2 http://www.citipower.com.au/Electricity_Networks/CitiPower_Network/CitiPower_-_Network_Planning/

3 Consequently there is also a 50% probability that demand will not reach forecast.

5.2.2 Forecast demand

Historical demand values taking into account local generation inputs are trended forward and added to known and predicted loads that are to be connected to the network. This includes taking into account the number of customer connections and the calculated total output of known embedded generating units.

CitiPower has taken into account information collected from across the business relating to the load requirements of our customers, and the timing of those loads. This includes population growth and economic factors as well as information on the estimated load requirements for planned, committed and developments under-construction across the CitiPower service area. CitiPower, however, has not yet assessed the impact of a significant increase in solar PV penetration following the Victorian Government's recently announced Solar Homes Program (offering a rebate on solar PV systems to eligible homes). CitiPower will look to support the program in its planning and management of the network.

These bottom-up forecasts for demand have been reconciled with top–down independent econometric forecasts for CitiPower as a whole.

These forecasts are set out in the Forecast Load Sheet.

5.2.3 Definitions for zone substation forecast tables

The Forecast Load Sheet contains other statistics of relevance to each zone substation, including:

- **Nameplate (N) rating**: this provides the maximum capacity of the zone substation according to the equipment in place;
- **Cyclic N-1 rating**: this assumes that the load follows a daily pattern and is calculated using load curves appropriate to the season and assuming the outage of one transformer. This is also known as the "firm" rating;
- **Hours load is ≥ 95% of maximum demand** (**MD**): based on at least the most recent 12 months of data, assesses the load duration curve and the total hours during the year that the load is greater than or equal to 95 per cent of maximum demand;
- **Station power factor at maximum demand (MD):** based on the most recent maximum demand achieved in a season at the zone substation, this is a measure of how effectively the current is being converted into output and is also a good indicator of the effect of the load current on the efficiency of the supply system. It is calculated as a ratio of real power and apparent power and is used to inform load forecasts. A power factor of:
  - less than one: indicates a lagging or leading current in the supply system which may need correction, such as by increasing or reducing capacitors at the zone substation;
  - one: efficient loading of the zone substation

- **Load transfers**: forecasts the available capacity of adjacent zone substations and feeder connections to take load away from the zone substation in emergency situations; and
- **Generation capacity**: calculates the total capacity of all embedded generation units that have been connected to the zone substation at the date of this report. Summation of generation above and below 1MW is provided.

5.3 Sub-transmission line methodology

This section sets out the methodology for calculating the historical and forecast maximum demands for the sub-transmission lines.

5.3.1 Historical demand

The sub-transmission line historical N-1 maximum demand loads for different line configurations are determined using a powerflow analysis tool called Power System Simulator for Engineering (**PSS/E**).

The tool models the sub-transmission line from the terminal station to the zone substation to determine the theoretical N-1 maximum demand, by utilising historical actual loads and assessing:

- system impedances;
- transformer tapping ratios, which are used to regulate the transformer voltages;
- capacitor banks; and
- other technical factors relevant to the operation of the system.

The historical maximum demand data for the relevant zone substations is applied to the load flow analysis to enable calculation of the theoretical N-1 maximum demand of the sub-transmission line.

The zone substation forecast maximum demands are diversified to the expected zone substation loads at the time of the respective sub-transmission loop/ line maximum demand. Historical diversity factors are derived and applied.

The data is used to assess the maximum demand in the worst case “N-1” conditions. This is for a single contingency condition where there is the loss of an element in the power system, in particular the loss of another associated sub-transmission line. For a zone substation the load is identical whether the zone substation is operating under N or N-1 (loss of a transformer). Therefore the N-1 cyclic rating is used to compare against the load forecast. However for the loss of a sub-transmission line, other associated lines are loaded more heavily so it is appropriate to consider the N-1 condition for the forecast and compare to the line rating.

5.3.2 Forecast demand

Similar to the sub-transmission line historical maximum demand loads, bottom-up forecasts for maximum demand are predicted utilising a powerflow analysis tool, PSS/E for different line configurations.

The present sub-transmission system is modelled from the terminal stations to the zone substations, taking into account system impedances, transformer tapping ratios, voltage settings, capacitor banks and other relevant technical factors.

The reconciled maximum demand forecasts at each zone substation are used in calculating the maximum demand forecasts for the sub-transmission lines. As discussed in section 5.2 above, the bottom-up forecasts for demand at each zone substation have been reconciled with top–down independent econometric forecasts.

The zone substation forecast maximum demands are diversified based on the historical diversity factors mentioned above.

The data is used to forecast the maximum demand under “N-1” conditions. These forecasts are referred to in the Forecast Load Sheet.

5.3.3 Definitions for sub-transmission line forecast tables

The Forecast Load Sheet refers to other statistics of relevance to each sub-transmission line, including:

- **Line rating**: this provides the maximum capacity of the sub-transmission line as measured by its current and expressed in MVA;
- **Hours load is ≥ 95% of maximum demand** (**MD**): based on at least the most recent 12 months of data, assesses the load duration curve and the total hours during the year that the load is greater than or equal to 95 per cent of maximum demand;
- **Power factor at maximum demand (MD):** based on historical data**,** is a measure of how effectively the current is being converted into output and is also a good indicator of the effect of the load current on the efficiency of the supply system. It is calculated as a ratio of real power and apparent power and is used to inform load forecasts. A power factor of:
  - less than one: indicates a lagging or leading current in the supply system which may need correction, such as by increasing or reducing capacitors at the zone substation;
  - one: efficient loading of the zone substation;
- **Load transfers**: forecasts the available capacity of alternative sub-transmission lines that can carry electricity to the zone substation in emergency situations; and
- **Generation capacity**: calculates the total capacity of all embedded generation units that are greater than 1MW that have been directly connected to the sub-transmission line at the date of this report.

5.4 Primary distribution feeders

This section sets out the methodology for calculating the forecast maximum demands for the primary distribution feeders.

5.4.1 Forecast demand

Primary distribution feeder maximum demand forecasts are calculated using a similar methodology to our zone substation forecasts. The historical feeder demand values are trended forward using the underlying feeder growth rate including known or predicted loads that are forecast for connection.

Temperature correction and top down reconciliation occurs on the feeder and zone substation forecasts and is therefore inherent in the sub-transmission forecasts.

6 Approach to risk assessment

This chapter outlines the high level process by which CitiPower calculates the risk associated with the expected balance between capacity and demand over the forecast period for zone substations and sub-transmission lines.

This process provides a means of identifying those stations or lines where more detailed analyses of risks and options for remedial action are required.

6.1 Energy at risk

As discussed in section 4.1, probabilistic network planning aims to strike an economic balance between:

- the cost of providing additional network capacity to remove any constraints; and
- the potential cost of having some exposure to loading levels beyond the network's firm capability.

A key element of this assessment for each zone substation and sub-transmission line is "energy at risk", which is an estimate of the amount of energy that would not be supplied if one transformer or a sub-transmission line was out of service during the critical loading period(s).

For zone substations, **energy at risk** is defined as:

- the amount of energy that would not be supplied from a zone substation if a major outage[4] of a transformer occurs at that station in that particular year, the outage has a mean duration of 2.6 months and no other mitigation action is taken.

This statistic provides an indication of magnitude of loss of load that would arise in the unlikely event of a major outage of a transformer without taking into account planned augmentation or operational action, such as load transfers to other supply points, to mitigate the impact of the outage.

For sub-transmission lines, the same definition applies however, the mean duration of an outage due to a significant failure is 8 hours for overhead sub-transmission lines and 1 week for underground sub-transmission lines.

Estimates of energy at risk are based on the 50th percentile demand forecasts, which were discussed in sections 5.2 and 5.3.

6.2 Interpreting "energy at risk"

As noted above, "energy at risk" is an estimate of the amount of energy that would not be supplied if one transformer or sub-transmission line was out of service during the peak loading period(s).

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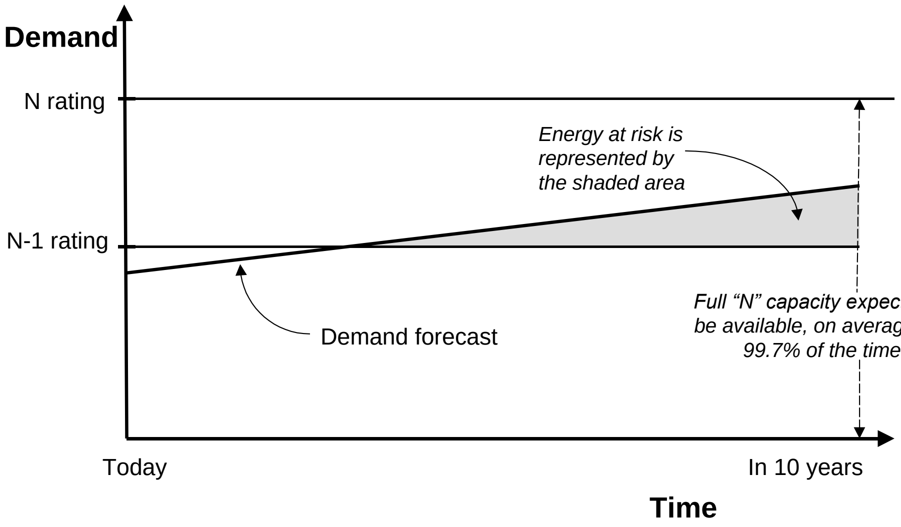
4 The term 'Major Outage' refers to an outage that has a duration of 2.6 months, typically due to a significant failure within the transformer.

The capability of a zone substation with one transformer out of service is referred to as its "N minus 1" rating. The capability of the station with all transformers in service is referred to as its "N" rating. The relationship between the N and N-1 ratings of a station and the energy at risk is depicted in Figure 6.1 below.

Figure 6.1 Relationship between N, N-1 rating and energy at risk



Note that:

- under normal operating conditions, there will typically be more than adequate zone substation capacity to supply all demand; and
- the risk of prolonged outages of a zone substation transformer leading to load interruption is typically very low.

The capability of a sub-transmission line network with one line out of service is referred to as the (**N-1**) condition for that sub-transmission network:

- under normal operating conditions, there will typically be more than adequate line capacity to supply all demand; and
- the risk of prolonged outages of a sub-transmission line leading to load interruption is typically very low and is dependent upon the length of line exposed and the environment in which the line operates.

In estimating the expected cost of plant outages, this report considers the first order contingency condition ("N-1") only.

6.3 Load Index

To enhance the use of probabilistic planning, CitiPower collaborated with EA Technology to develop a suitable band of Load Indices. These indices are intended to provide a 'top down' lead indication of risk and performance, and to verify in a tangible way the reasonableness of the 'bottom-up' investment plans.

The Load Index, which is a measure of asset utilisation, is generated from two factors:

- demand driver – measure of maximum demand relative to firm capacity; and
- duration driver – measure of hours or energy at risk.

The Load Indices developed cover a range of conditions, including several bands for increasing hours above firm capacity (N-1 rating) and the 2 top bands for situations where the load is approaching or even exceeding the N capacity. The bandings are intended to provide sufficient breadth and sufficient discrimination to both visualise/communicate the overall level of load, and to show the effects of modest load increases over the next few years. The bandings are shown in the table below.

Table 6.1 Load Index bands

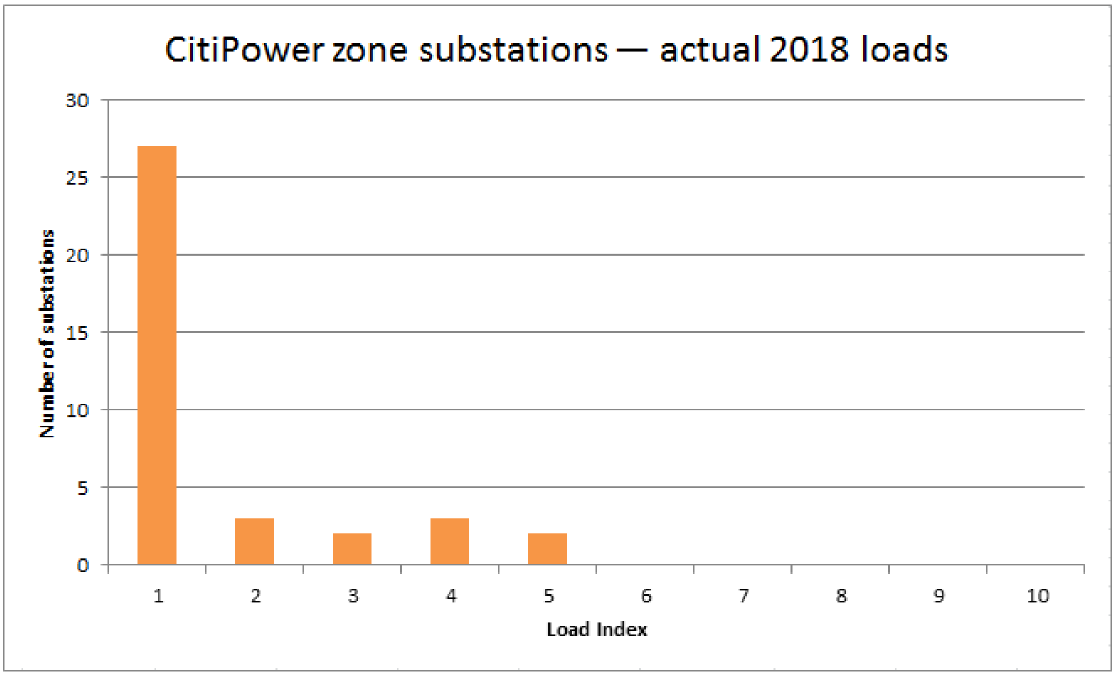
Load Index	Condition	Load%		Hrs above Firm Capacity	
		>Minimum	≤ Maximum	>Minimum	≤ Maximum
1	N-1	0	90	N/A	N/A
2	N-1	90	100	N/A	N/A
3	N-1	100	110	N/A	N/A
4	N-1	110	…	N/A	100
5	N-1	110	…	N/A	250
6	N-1	110	…	N/A	500
7	N-1	110	…	N/A	750
8	N-1	110	…	750	7500
9	N	90	100	N/A	N/A
10	N	100		N/A	N/A

CitiPower uses the Load Indices for zone substations and sub-transmission lines.

It is noted that for a single transformer substation or radial sub-transmission line, the firm capacity is taken as the transfer capacity. As the time over firm capacity is not supplied for this definition, where the maximum demand exceeds the transfer capacity it is assumed that the number of hours over firm capacity is >750, so the asset is classified as LI8.

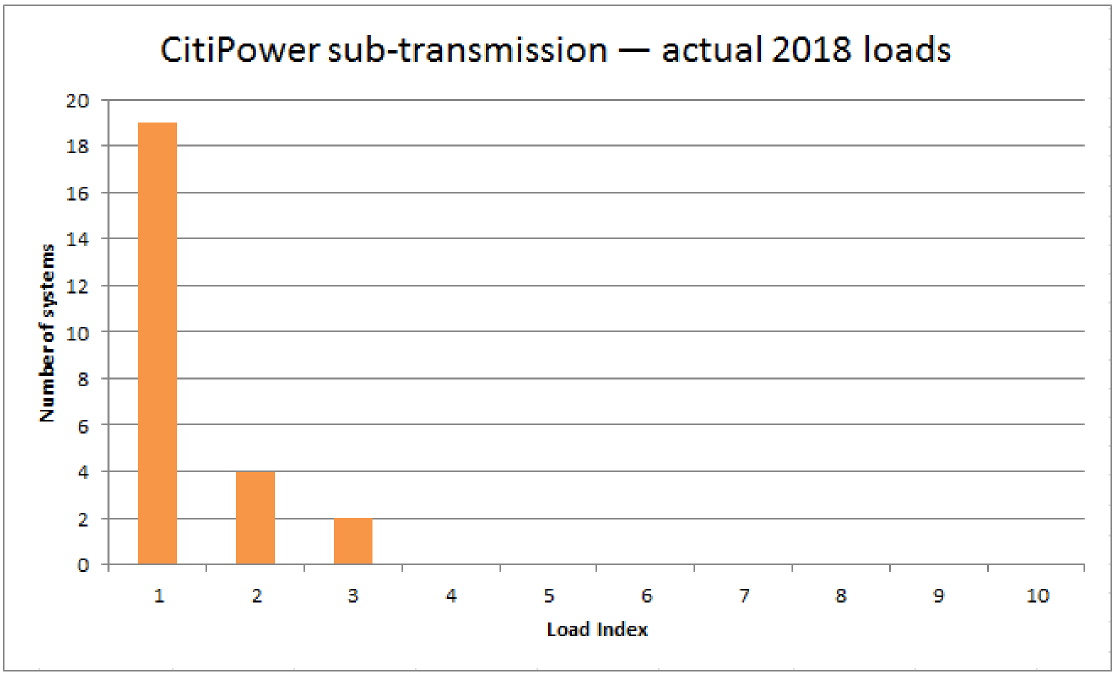
The 2018 actual Load Index profile for zone substations is shown below.

Figure 6.2 Load Index for zone substations



The 2018 actual Load Index profile for sub-transmission systems (line loops) is shown below.

Figure 6.3 Load Index for sub-transmission systems



6.4 Valuing supply reliability from the customer's perspective

For large augmentation or replacement projects over $6 million that are subject to a Regulatory Investment Test for Distribution (**RIT-D**), CitiPower will undertake a detailed assessment process to determine whether or not to proceed with the augmentation.

In order to determine the economically optimal level and configuration of distribution capacity (and hence the supply reliability that will be delivered to customers), it is necessary to place a value on supply reliability from the customer's perspective.

Estimating the marginal value to customers of reliability is inherently difficult, and ultimately requires the application of some judgement. Nonetheless, there is information available (principally, surveys designed to estimate the costs faced by consumers as a result of electricity supply interruptions) that provides a guide as to the likely value.

CitiPower relies upon surveys undertaken by the Australian Energy Market Operator (**AEMO**) to establish the Value of Customer Reliability (**VCR**). AEMO published the latest Victorian VCR values in its final report dated 28 November 2014 which have been escalated using the ratio of March 2014 to March 2018 CPI figures as per the AEMO Application Guide to the following amounts:

Table 6.2 Values of customer reliability

Sector	**VCR for 2018 ($/kWh)**
Residential	$26.45
Commercial	$47.77
Agricultural	$50.93
Industrial	$47.07

These values are multiplied by the relative weighting of each sector at the zone substation or for the sub-transmission line, and a composite single value of customer reliability is estimated.

This is used to calculate the economic benefit of undertaking an augmentation, and where the net present value of the benefits outweighs the costs, and is superior to other options, CitiPower will proceed with the works.

CitiPower notes that there has been a significant reduction in the VCR estimates for the commercial and agricultural sectors compared to the results of the 2007/08 VCR study, which was conducted on behalf of VENCorp (AEMO's predecessor) by CRA International. This has led to a reduction in AEMO's estimate of the composite VCR from $63 per kWh in 2013 to $42.20 per kWh in 2018.

From a planning perspective, it is appropriate for CitiPower to have regard to the latest available VCR estimates. It is also important to recognise, however, that all methods for estimating VCR are prone to error and uncertainty, as illustrated by the wide differences between:

- AEMO's VCR estimate for 2013 of $63 per kWh, which was based on the 2007/08 VENCorp study[5];
- Oakley Greenwood's 2012 estimate of the New South Wales VCR[6], of $95 per kWh; and
- AEMO's latest Victorian VCR (escalated from 2014 to 2018) estimate of $42.20 per kWh.

The wide range of VCR estimates produced by these three studies is likely to reflect estimation errors and methodological differences between the studies, rather than changes in the actual value that customers place on reliability. Moreover, the magnitude of the reduction in the AEMO's VCR estimates since 2013 raises concerns that the investment decisions signalled by applying the current VCR estimate may fail to meet customers' reasonable expectations of supply reliability.

It should be noted that the Australian Energy Regulator (**AER**) plans to release an update to the VCR estimate by 31 December 2019.

5 See section 2.4 of the 2013 Transmission Connection Planning Report.

6 AEMO, Value of Customer Reliability Review Appendices, Appendix G, November 2014.

7 Zone substations review

This chapter reviews the zone substations where further investigation into the balance between capacity and demand over the next five years is warranted, taking into account the:

- forecasts for maximum demand to 2023; and
- summer and winter cyclic N-1 ratings for each substation.

Where the zone substations are forecast to operate with maximum demands greater than 5 per cent above their firm summer or winter rating during 2019, then this section assesses the energy at risk for those assets.

If the energy at risk assessment is material, then CitiPower sets out possible options to address the system limitations. CitiPower may employ the use of contingency load transfers to mitigate the system limitations although this will not always address the entire load at risk at times of maximum demand. At other times of lower load the available transfers may be greater. As a result, the use of load transfers under contingency situations may imply a short interruption of supply for customers to protect network elements from damage and enable all available load transfers to take place.

Non-network providers may wish to review the limitations and consider whether alternative solutions to those set out in the analysis may be suitable. Solutions may also address sub-transmission constraints at the same time.

CitiPower notes that all other zone substations that are not specifically mentioned below either have loadings below the relevant rating or the loading above the relevant rating is minimal and can be addressed using load transfer capability via the distribution network to adjacent zone substations. In these cases, all customers can be supplied following the failure or outage of an individual network element.

Finally, zone substations that are proposed to be commissioned during the forward planning period are also discussed.

7.1 Zone substations with forecast system limitations overview

Using the analysis undertaken below in section 7.2, CitiPower proposes to augment the zone substations listed in the table below to address system limitations during the forward planning period.

Table 7.1 Proposed zone substation augmentations

Zone substation	Description	Direct cost estimate ($ million)				
		2019	**2020**	**2021**	**2022**	**2023**
RP	Convert to 11kV from WP	0.5	2.0	4.5	5.0	
C	Augment WB and offload C	0.8	8.0	7.8		
BK	Offload to WB and decommission			4.2	9.4	
F	Offload to CW and decommission			1.8	10.7	
PM	Offload to WG and decommission					3.8
E	Offload to WG and decommission					0.9
TOTAL		**1.3**	**10.0**	**18.3**	**25.1**	**4.7**

The analysis in section 7.2 below shows that that there are no demand-driven augmentation projects forecast over the forward planning period.

That said, CitiPower intends to undertake replacement-driven augmentation projects over the forecast period, including:

- upgrading West Brunswick (**WB**) zone substation to offload the Brunswick (**C**) zone substation, based on the poor condition of C;
- installing new feeders to offload Russell Place (**RP**) to the new Waratah Place (**WP**) zone substation after conversion from 6.6kV to 11kV, based on the poor condition of RP; and
- conducting a program of works to enable decommissioning of the 22kV sub-transmission network served from West Melbourne terminal station (**WMTS**).
- Offloading of Brunswick (**BK**) and Fitzroy (**F**) zone substations and conversion of their distribution areas from 6.6kV to 11kV.
- Offloading of Port Melbourne (**PM**) and Fishermans Bend (**E**) zone substations and conversion of their distribution area from 6.6kV to 11kV.

The replacement-driven augmentation projects are discussed in section 14.1

The options and analysis is undertaken below.

7.2 Zone substations with forecast system limitations

7.2.1 Armadale (AR) zone substation

The Armadale (**AR**) zone substation is served by sub-transmission lines from the Richmond terminal station (**RTS**). This station supplies the areas of Armadale, St. Kilda and Toorak.

Currently, the AR zone substation is comprised of two 20/27 MVA transformers operating at 66/11kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 6.5 MVA of load at risk and for 57 hours it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at AR. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at AR zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11 kV links to adjacent zone substations of Toorak (**TK**) and Balaclava (**BC**) up to a maximum transfer capacity of 4.6 MVA;
- establish an 11 kV link with the BC zone substation to permanently transfer load for an estimated cost of $2.8 million.

CitiPower's preferred option is to establish an 11 kV link to permanently transfer load to BC zone substation over the longer term. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand is forecast to exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.2 Collingwood (B) zone substation

The Collingwood (**B**) zone substation is served by two sub-transmission lines from Richmond terminal station (**RTS**). This zone substation supplies areas of Collingwood and Fitzroy, which are a mixed-use area.

Currently, B zone substation is comprised of two 20/27MVA transformers operating at 66/11kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 8.1 MVA of load at risk and for 64 hours it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at B. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at B zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Collingwood (**CW**) and North Richmond (**NR**) up to a maximum transfer capacity of 11.3 MVA;
- install a third transformer at B for an estimated cost of $3.6 million;
- establish an 11kV link with the zone substation in North Richmond (**NR**) to permanently transfer load for an estimated cost of $4.0 million.

CitiPower's preferred option is to establish a third transformer at B over the longer term. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.3 Deepdene (L) zone substation

The Deepdene (**L**) zone substation is served by sub-transmission lines from the Templestowe terminal station (**TSTS**). It supplies the Balwyn, Canterbury and Kew areas.

Currently, the L zone substation is comprised of two 20/30MVA transformers operating at 66/11kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 11.1 MVA of load at risk and for 92 hours it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at L. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at the L zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Kew (**Q**), West Doncaster (**WD**) and Camberwell (**CL**) up to a maximum transfer capacity of 14.2 MVA;
- install a third transformer at L for an estimated cost of $3.6 million.

CitiPower's preferred option is to establish a third transformer at L over the longer term. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.4 Kew (Q) zone substation

The Kew (**Q**) zone substation is served by sub-transmission lines from the Templestowe terminal station (**TSTS**). It supplies the Kew area.

Currently, the Q zone substation is comprised of two 20/30MVA transformers operating at 66/11kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 13.4 MVA of load at risk and for 106 hours it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at Q. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at the Q zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of North Richmond (**NR**), Deepdene (**L**) and Camberwell (**CL**) up to a maximum transfer capacity of 7.4 MVA;
- install a third transformer at Q for an estimated cost of $3.6 million
- install a third transformer at L and permanently transfer load away from Q to L at an estimated cost of $4.6 million.

CitiPower's preferred option is to install a third transformer at L and permanently transfer load away from Q to L over the longer term. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.5 Riversdale (RD) zone substation

The Riversdale (**RD**) zone substation is served by sub-transmission lines from the Springvale terminal station (**SVTS**). It supplies the Camberwell area.

Currently, the RD zone substation is comprised of two 20/30MVA transformers operating at 66/11kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 4 MVA of load at risk and for 137 hours it would not be able to supply all customers from the zone substation if there is a failure of one of the transformers at RD. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

To address the anticipated system constraint at the RD zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Burwood (**BW**), Deepdene (**L**), Gardiner (**K**), West Doncaster (**WD**) and Camberwell (**CL**) up to a maximum transfer capacity of 5.3 MVA;
- install a third transformer at RD at cost of $3.6 million.

CitiPower's preferred option is to install a third transformer at RD over the longer term. However given that the forecast annual hours at risk is low, this project is not expected to occur during the forecast period. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period.

7.2.6 Russell Place (RP) zone substation

The Russell Place (**RP**) zone substation is served by two sub-transmission lines from Richmond terminal station (**RTS**). This zone substation supplies the Central CBD Town Hall area.

Currently, the RP zone substation is comprised of two 10/13MVA transformers operating at 22/6.6kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 2.8 MVA of load at risk and there are 221 hours for which it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at RP. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

Also at RP the transformers have an average health index of 7 which indicates an elevated risk of failure. (refer chapter 14.1.10).

To address the anticipated system constraint at RP zone substation, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 6.6kV links to adjacent zone substation Little Queen (**LQ**) up to a maximum transfer capacity of 4.5 MVA;
- convert area to 11kV establish HV feeder ties and transfer load to the new Waratah Place (**WP**) zone substation in 2022, at an estimated cost of $12.0 million.

CitiPower's preferred option is to convert to 11kV and establish 11kV links to permanently transfer load to WP zone substation in 2022. The use of contingency load transfers will mitigate the risk in the interim period.

A demand side initiative to reduce the load by 12.1MVA at RP would defer the need for this capital investment by one year.

7.2.7 West Brunswick (WB) zone substation

The West Brunswick (**WB**) zone substation is served by sub-transmission lines from the West Melbourne terminal station (**WMTS**). This station supplies the areas of Brunswick West.

Currently, the WB zone substation is comprised of two 20/30 MVA transformers operating at 66/6.6kV. For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load Sheet.

CitiPower estimates that in 2023 there will be 8.0 MVA of load at risk and there are 387 hours for which it will not be able to supply all customers from the zone substation if there is a failure of one of the transformers at WB. That is, it would not be able to supply all customers during high load periods following the loss of a transformer.

However nearby Brunswick (**C**) zone substation is aged and the major plant including transformers and switchgear has been condition assessed using the CBRM methodology and determined to be in poor condition at or near end of life and requires replacement by 2021. Refer to the C zone substation analysis in the Asset Replacement section 14.1. Retirement of the C transformers and or the 6.6kV switchboard results in the inability to supply all of the zone substation customers.

To address the anticipated system constraint at WB and C zone substations, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- contingency plan to transfer load away via 6.6kV links to adjacent zone substations of Brunswick (**BK**) and Brunswick (**C**) up to a maximum transfer capacity of 4.2 MVA;
- install a new 20/30 MVA third transformer at WB zone substation with third 6.6kV bus, offload C zone substation to WB at 6.6kV for an estimated cost of $17 million.

CitiPower's preferred and committed option following a RIT-D process undertaken in 2018 is to install a new 20/30 MVA third transformer at WB zone substation with a third 6.6kV bus, offload C to WB zone substation at 6.6kV and decommission existing aged and poor condition assets at C zone substation in 2021. This is less expensive than rebuilding C for over $26 million. Please refer to section 14.1.2 for further details on the C asset replacement strategy. Although the expected demand will exceed the station's N-1 cyclic rating, the use of contingency load transfers will mitigate the risk in the interim period. Please refer to the Asset Replacement System Limitation Report for further information regarding the preferred network investment.

This project is driven by the total substation load being transferred from zone substation C.

7.3 Proposed new zone substations

This section sets out CitiPower's plans for new zone substations. These substations are not taken into account in the forecasts that have been referred to in the Forecast Load Sheet or in the analysis in section 7.1 above which relates to existing substations.

In summary, CitiPower has committed to building the zone substations set out below in Table 7.2 during the forward planning period.

Table 7.2 Proposed new or redeveloped zone substations

Name	Location	Proposed commissioning date	Reason
Waratah Place (WP)	Melbourne CBD	Nov 2020	Achieve CBD Security of Supply project objectives

Greater detail on the new zone substation is provided below.

In addition to the new zone substation noted in the table above, CitiPower is also in discussions with the State Government of Victoria and local councils relating to new developments and the demand for new electricity services in areas including:

- E Gate: located at gate 'E' in the rail yard area near North Melbourne rail station, Major Projects Victoria is considering a development to provide housing for up to 10,000 residents and 50,000 square metres of commercial and associated retail space. Such a development may result in a requirement for 25MVA of capacity;
- Federation Square East: Major Projects Victoria is exploring options to develop the area to the east of Federation Square.[7] Depending on the extent of the urban renewal project, such a development may result in a requirement for an additional 40MVA of capacity;
- Fishermans Bend precinct: Places Victoria has released its updated strategic framework for the redevelopment of this area to provide homes for more than 80,000 residents and new workplaces for up to 60,000 people. This urban renewal will involve a variety of residential and commercial developments ranging from townhouses to high rise towers and small to large commercial spaces[8]. This may result in a requirement for an additional 30MVA of capacity;
- Arden Macaulay: the City of Melbourne has identified the 147 hectare precinct in parts of Kensington and North Melbourne as an urban renewal area that will accommodate significantly more residents and employment growth over the next 30 years.[9]

These loads are not yet included in the demand forecasts in the Forecast Load Sheet. These developments are likely to result in significant augmentation to the CitiPower network, including the construction of new zone substations.

7.3.1 Waratah Place (WP) zone substation

CitiPower is building a new zone substation in Waratah Place (**WP**), located in the Chinatown district of the Melbourne CBD. It will replace the previous switching station, known as W.

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7 Refer: http://www.majorprojects.vic.gov.au/our-projects/our-current-projects/Federation-Square-East

8 Refer: http://www.fishermansbend.vic.gov.au/

9 Refer http://www.melbourne.vic.gov.au/building-and-development/urban-planning/local-area-planning/pages/arden-macaulay-structure-plan-2012.aspx

Elements of the new zone substation are required as part of the Melbourne CBD security program which seeks to increase resilience into the 66kV sub-transmission network given the critical nature of reliable electricity supply to the area. The CBD security work associated with WP involves the replacement of 66kV isolators with seven 66kV circuit breakers using gas insulated switchgear, refer to sections 3.4.1 and 3.4.2. The construction work commenced in 2014 and is expected to be completed by November 2020. The cost of the 66kV switchgear and re-connection of pre-existing and new CBD Security 66kV cables is estimated at $27.8 million. Other elements of the new zone substation are related to reconstructing the W building due to its deteriorating condition, refer to section 14.1.12.

The new zone substation is also required to reduce load at McIllwraith Place (**MP**) and Celestial Avenue (**WA**), such that there is adequate capacity to sustain two outages on the MP or WA 66kV sub-transmission lines, consistent with the CBD Security of Supply project objectives. CitiPower has completed a regulatory test for this element of the project – see section 15.

Other benefits of the zone substation are to off-load the 22kV Russell Place (**RP**) zone substation which currently has ageing assets (refer chapter 14.1.10).

The planned commissioning date for the WP zone substation is November 2020, at an estimated total cost of $35.2 million.

The WP zone substation will take load from the following adjacent zone substations:

- Russell Place (**RP**): 12.1 MVA; and
- McIllwraith Place (**MP**): 10.3 MVA.
- Celestial Avenue (**WA**): 6.7 MVA.

CitiPower estimates that the future maximum demand loading level in summer 2020 will be 25.4 MVA however final coincident demand may be less due to the addition of diverse load from the above zone substations.

8 Sub-transmission lines review

This chapter reviews the sub-transmission lines where further investigation into the balance between capacity and demand over the next five years is warranted, taking into account the:

- forecasts for N-1 maximum demand to 2023; and
- line ratings for each sub-transmission line.

Where the sub-transmission line is forecast to operate with maximum demands greater than 5 per cent above their summer or winter rating, under N-1 conditions during 2019, then this section assesses the energy at risk for those assets. Solutions may also address zone substation constraints at the same time.

If the energy at risk assessment is material, then CitiPower sets out possible options to address the system limitations. CitiPower may employ the use of contingency load transfers to mitigate the system limitations although this will not always address the entire load at risk at times of maximum demand. At other times of lower load the available transfers may be greater. As a result, the use of load transfers under contingency situations may imply a short interruption of supply for customers to protect network elements from damage and enable all available load transfers to take place.

Non-network providers may wish to review the limitations and consider whether alternative solutions to those set out in the analysis may be suitable.

CitiPower notes that all other sub-transmission lines that are not specifically mentioned below either have loadings below the relevant rating or the loading above the relevant rating is minimal and can be addressed using the load transfer capability. In these cases, all customers can be supplied following the failure or outage of an individual network element.

Finally, sub-transmission lines that are proposed to be commissioned during the forward planning period are also discussed.

8.1 Sub-transmission lines with forecast system limitations overview

Using the analysis undertaken below in section 8.2, CitiPower proposes to augment the sub-transmission lines listed in the table below to address system limitations during the forward planning period.

Table 8.1 Proposed sub-transmission line augmentations

Sub-transmission line	Description	Direct cost estimate ($ million)				
		2019	2020	2021	2022	2023
RTS-FR-MP	Establish new and re-configure existing 66kV sub-transmission cables to transfer MP zone substation to BTS via WP	9.8	7.6			
TOTAL		9.8	7.6			

The options and analysis is undertaken below.

8.2 Sub-transmission lines with forecast system limitations

8.2.1 RTS-FR-MP 66kV sub-transmission lines

The RTS-FR-MP sub-transmission loop supplies the Flinders/Ramsden (**FR**) and McIllwraith Place (**MP**) zone substations fed from Richmond terminal station (**RTS**) at 66kV.

For the historic and forecast asset ratings and forecast station maximum demand, please refer to the Forecast Load.

CitiPower estimates that in 2019 there will be:

- 9.5 MVA of load at risk on the RTS-FR1 sub-transmission line and for 35 hours it will not be able to supply all customers if there is a worst case outage on the RTS-FR2 sub-transmission line;
- 8.5 MVA of load at risk on the RTS-FR2 sub-transmission line and for 30 hours it will not be able to supply all customers if there is a worst case outage on the RTS-FR1 sub-transmission line;
- 8.5 MVA of load at risk on the RTS-FR3 sub-transmission line and for 30 hours it will not be able to supply all customers if there is a worst case outage on the RTS-FR1 sub-transmission line.

To address the anticipated system constraints on these sub-transmission lines, CitiPower considers that the following network solutions could be implemented to manage the load at risk:

- Contingency plan to transfer load away via 11kV links to adjacent zone substations of Celestial Avenue (**WA**), Little Queen (**LQ**), Little Bourke St (**JA**), and Bouverie/Queensberry (**BQ**) zone substations up to a maximum transfer capacity of 17 MVA;

- establish new and re-configure existing 66kV sub-transmission cables to transfer McIllwraith Place (**MP**) zone substation from Richmond terminal station (**RTS**) to the Brunswick terminal station (**BTS**), via the new Waratah Place (**WP**) zone substation, for an estimated cost of $23.4 million.

CitiPower's preferred and committed option is to establish new and re-configure existing 66kV sub-transmission cables to transfer MP to BTS via WP before summer 2020/21. This transfer of load will address the constraint on the RTS-FR 66kV cables, as well as the constraint forecast for Richmond terminal station (**RTS**). It also addresses an aspect of the CBD Security requirements to offload the FR and MP sub-transmission system, and as such, a system limitation report is not provided for this limitation. A regulatory test has been completed for this augmentation, and is further discussed in section 15.

Although the expected demand until summer 2020/21 will exceed the sub-transmission line ratings, for a worst case outage per above, the use of contingency load transfers will mitigate the risk in the interim period.

8.3 Proposed new sub-transmission lines

This section sets out CitiPower's plans for new sub-transmission lines. These lines are taken into account in the forecasts that have been set out in the Forecast Load Sheet and the analysis in section 8.2 above which relates to existing sub-transmission lines.

In summary, CitiPower has committed to building the sub-transmission lines set out below in table 8.2 during the forward planning period.

Table 8.22 Proposed new sub-transmission lines

Name	Location	Proposed commissioning date	Reason
BQ–WP2, BQ–WP3	Carlton to Melbourne CBD	Nov 2020	CBD security requirements
BTS-WP, FR–WP1, FR–WP2 MP–WP1 MP–WP2	Brunswick to Melbourne CBD, and within Melbourne CBD	Nov 2020	New lines for connection point capacity/resilience

Each of these lines is described in more detail below.

8.3.1 BQ-WP2, BQ-WP3

CitiPower is building new sub-transmission cables from the Bouverie/ Queensberry St (**BQ**) zone substation in Carlton to the new Waratah Place (**WP**) zone substation in the CBD.

These form part of the Melbourne CBD security of supply enhancement plan which seeks to increase resilience into the 66kV network given the critical nature of reliable electricity supply to the Melbourne CBD, discussed in section 3.4.

These new cables will provide the required security to maintain supply from alternate supply points at West Melbourne terminal station (**WMTS 66kV**), and Brunswick terminal station at 66kV (**BTS 66kV**), for the loss of two 66kV sub-transmission cables supplying the RTS to Flinders Ramsden (**FR**) to Waratah Place (**WP**) and McIllwraith Place (**MP**) 66kV sub-transmission systems.

The cables from BQ to WP were installed in 2014 in preparation for the commissioning of the new WP zone substation in 2020. In the interim, these cables will be used for contingency purposes.

CitiPower estimates that the future N-1 maximum demand loading level in summer 2020/21 will be 43.3 MVA.

8.3.2 BTS-WP, FR-WP1, FR-WP2, MP-WP1, MP-WP2

To reduce load at the Richmond terminal station (**RTS**) and on the RTS-Flinders Ramsden (**FR**) sub-transmission lines, CitiPower intends to transfer the McIllwraith Place (**MP**) zone substation from being served by RTS and the RTS-FR sub-transmission cables to instead being served from the Brunswick terminal station (**BTS**).

To achieve this, CitiPower is constructing a new sub-transmission line from BTS 66kV to the new Waratah Place (WP) zone substation. In addition, CitiPower is reconfiguring the existing cables supplying the MP zone substation from FR. These re-configured cables will transfer MP zone substation from RTS to BTS (when upgraded to 66kV), via the new WP zone substation:

- FR-WP1, reconfiguring the existing FR-MP1;
- FR-WP2: reconfiguring the existing FR-MP2;
- MP-WP1, reconfiguring the existing FR-MP1; and
- MP-WP2: reconfiguring the existing FR-MP2.

This transfer of load will address the constraint on the RTS-FR 66kV cables, as well as the constraint forecast for RTS.

The planned commissioning date for these sub-transmission cables is November 2020, at an estimated cost of $23.4 million comprising of $7.9 million for new BTS-WP and $15.5 million for two sets of FR-WP and MP-WP 66kV cables.

For these new lines: CitiPower estimates that the future N-1 maximum demand loading levels in summer 2020/21 will be:

- BTS–WP: 105.2 MVA;
- FR– WP1: 10.3 MVA (with planned load transfer from RP & MP);
- MP– WP1: 66.9 MVA;
- FR–WP2: 10.7 MVA (with planned load transfer from RP & MP); and
- MP–WP2: 66.8 MVA.

These new lines are relevant to the regulatory test that has been completed from the upgrade of BTS, which is further discussed in section 15.

9 Primary distribution feeder reviews

This chapter reviews the primary distribution feeders where further investigation into the balance between capacity and demand over the next two years is warranted, taking into account the:

- forecasts for maximum demand to 2020; and
- summer and winter cyclic ratings for each feeder.

Where the feeders are forecast to operate with maximum demands at their firm summer or winter rating over the next two years, then this section assesses the energy at risk for those assets.

This review considers the primary section of a feeder, or what is commonly known as the backbone of the feeder exiting the zone substation to the first point of load for a customer.

If the energy at risk assessment is material, then CitiPower sets out possible options to address the system limitations. CitiPower may employ the use of contingency load transfers to mitigate the system limitations although this will not always address the entire load at risk at times of maximum demand. At other times of lower load the available transfers may be greater. As a result, the use of load transfers under contingency situations may imply a short interruption of supply for customers to protect network elements from damage and enable all available load transfers to take place.

Non-network providers may wish to review the limitations and consider whether alternative solutions to those set out in the analysis may be suitable. Solutions may also address distribution feeder constraints at the same time.

Finally, distribution feeders that are proposed to be commissioned during the next two years are also discussed.

9.1 Primary distribution feeders with forecast system limitations overview

CitiPower does not propose to augment any feeders to address system limitations in the next two years.

9.2 Proposed new primary distribution feeders

The following primary distribution feeder projects are currently sitting outside of the primary feeder forecast period. It is however proposed to commence scope investigation and option analysis in 2019-20.

Table 9.1 Future primary distribution feeder projects

BC012 and BC013 Feeder offload	CL034 New 11kV feeder
Multiple HV feeders in the CBD subject to constraint on the mesh network	FR to MP New 11kV feeder ties
JA to BQ New 11kV feeder ties	NR New 11kV feeder (multiple)
B New 11kV feeder	RD New 11kV feeder
L New 11kV feeder	

10 Joint Planning

This chapter sets out the joint planning with DNSPs and TNSPs in relation to zone substations and sub-transmission lines. Joint planning in relation to terminal stations in isolation is discussed in the Transmission Connection Planning Report.

CitiPower has not identified any new required projects from our joint planning activities with other DNSPs in 2018. Our joint planning activities have included sharing load forecast information and load flow analysis between Victorian distributors relating to the sub-transmission system. Where a constraint is identified on our network that may impact another distributor, then project specific joint planning meetings are held to determine the most efficient and effective investment strategy to address the system constraint.

10.1 West Melbourne terminal station 22kV sub-transmission

CitiPower and AusNet Services have been jointly planning options for the replacement of the 220/22kV assets at West Melbourne terminal station (**WMTS**). During 2015 a study assessed the overall costs, including both distribution and transmission costs, depending on whether:

- Option 1: the assets are replaced on a like-for-like basis; or
- Option 2: the WMTS 22 assets are not replaced and CitiPower transfers all load from the 22kV sub-transmission network to the 66kV network.

The joint analysis shows that the least cost alternative to replacing the 220/22kV assets at WMTS is to retire the WMTS 220/22kV and CitiPower 22kV sub-transmission assets, replace the minimum ageing CitiPower assets and transfer the majority of the 22/6.6kV load to the 66/11kV network.

Further details of the retirement and transfer works required are discussed below in section 14.1.13.

11 Changes to analysis since 2017

The following information details load forecasts and project timing changes that have occurred since the publication of the 2017 DAPR.

11.1 Constraints addressed or reduced due to projects completed

CitiPower has undertaken the following projects in 2018 to address constraints which were identified in the 2017 DAPR:

- Balaclava (**BC**), St Kilda (**SK**) and Toorak (**TK**) feeder uprates were completed.
- Deepdene (**L**) feeder augmentations were completed.
- Riversdale (**RD**) feeder augmentations were completed.

11.2 New constraints identified

Changes in load forecasts or other factors during 2018 have resulted in CitiPower undertaking risk assessments for the following zone substations which were not included in the 2017 DAPR:

Russell Place (**RP**) zone substation: load forecasts have increased on the zone substation resulting in load and hours at risk above threshold limits.

11.3 Other material changes

In addition to the matters identified above, material changes compared to the 2017 DAPR include:

- Toorak (TK): load forecasts have decreased resulting in load and hours at risk below threshold limits;
- BTS-F 22kV subtransmission lines: load forecasts have decreased resulting in load and hours at risk below threshold limits;
- FBTS-FB-WG 66kV subtransmission loop: load forecasts have decreased resulting in load and hours at risk below threshold limits;
- RTS-AR-BC-TK 66kV subtransmission loop: load forecasts have decreased resulting in load and hours at risk below threshold limits;
- RTS-CW-B-NR-RTS 66kV subtransmission loop: load forecasts have decreased resulting in load and hours at risk below threshold limits;
- TSTS-L 66kV subtransmission loop: load forecasts have decreased resulting in load and hours at risk below threshold limits;

  WMTS-NC-WB 66kV subtransmission loop: load forecasts have decreased resulting in load and hours at risk below threshold limits.

12 Asset Management

This section provides information on the CitiPower asset management approach including the strategy employed, impacts on system limitations and where further details can be obtained.

12.1 Asset Management Framework

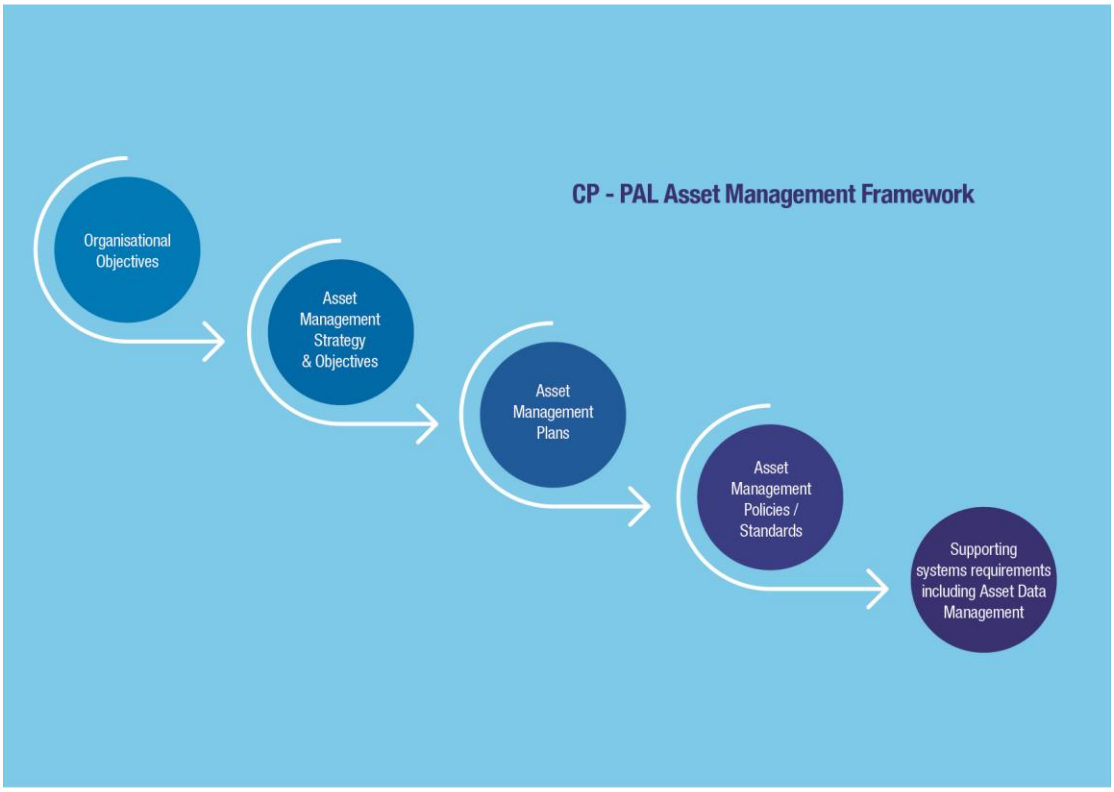
CitiPower are committed to the application of best practice asset management strategies to ensure the safe and reliable operation of our electrical network.

Our asset management framework aligns with the principles of PAS 55, which is the British Standards Institution's publicly available specification for the optimised management of physical assets. It is currently being reviewed and updated to align with the requirements of ISO 55001, the international standard in asset management.

The Asset Management Framework is a high level document that describes the asset management system that is applied to CitiPower's network assets. The Asset Management Framework encompasses the full range of the asset life cycle activities from identification of need, to creation, operation, maintenance and eventual disposal of network assets.

The structure and hierarchy of the Asset Management Framework is illustrated in Figure 12.1.

Figure 12.1 Asset Management Framework



12.1.1 Asset Management Strategy and Objectives

The CitiPower Asset Management Strategy requires that all physical assets installed on the electricity distribution network are maintained, refurbished or replaced in accordance with documented Network Asset Management Plans.

The Asset Management Objectives for CitiPower are:

Reliability, Availability & Maintainability

- Meet or exceed agreed regulatory and business targets;
- Optimise utilisation and performance of physical assets.

Regulatory Compliance

- Ensure that all relevant regulatory obligations are met;
- Ensure all significant network related safety issues are effectively managed to achieve an acceptable risk profile;
- Provide flexibility to encourage innovation, continuous improvement and the effective use of resources.

Network Safety

- Meet bushfire mitigation regulatory obligations, plans and strategies;
- Eliminate public and employee safety incidences as far as practical..

Financial

- Optimise whole of life costs for owning, operating and managing assets;
- Optimise capital expenditure;
- Optimise operational and maintenance expenditure.

Health, Safety & Environment

- Zero LTIs;
- Increase reuse and recycling;
- Dispose of assets in a safe and environmentally responsible manner;
- Minimise impact on the environment.

Risk Management

- Maintain an acceptable corporate risk profile and have active management plans for all significant risks identified.

Work Force Development

- Ensure asset management resources and skills meet future challenges.

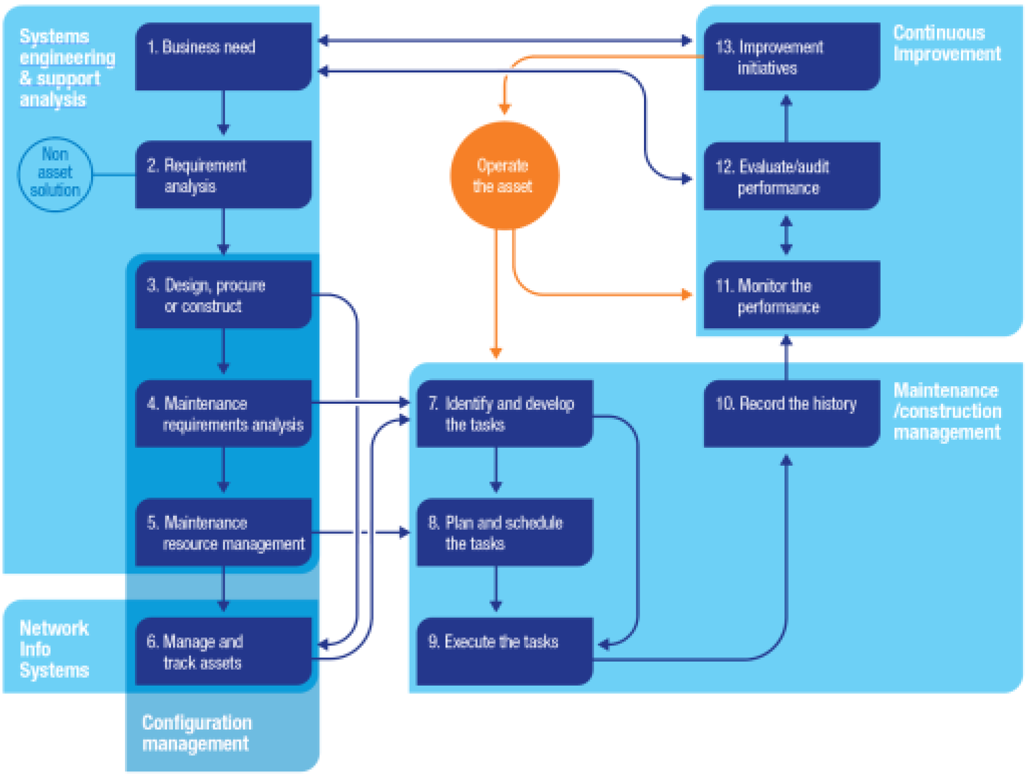
12.1.2 Asset Management System Process

To complement our Asset Management Strategy and Objectives, we utilise an asset management system process, as shown in Figure 12.2. The objective of this system process is to identify all significant steps and processes involved in the total management of assets throughout their life cycle, the typical roles in each and the roles and accountabilities of CitiPower.

Our Asset Management System process consists of five key areas:

- systems engineering & support analysis;
- configuration management;
- network information systems;
- maintenance / construction management; and
- continuous improvement.

Figure 12.2 Asset Management System Process



12.1.3 Network Management Plans

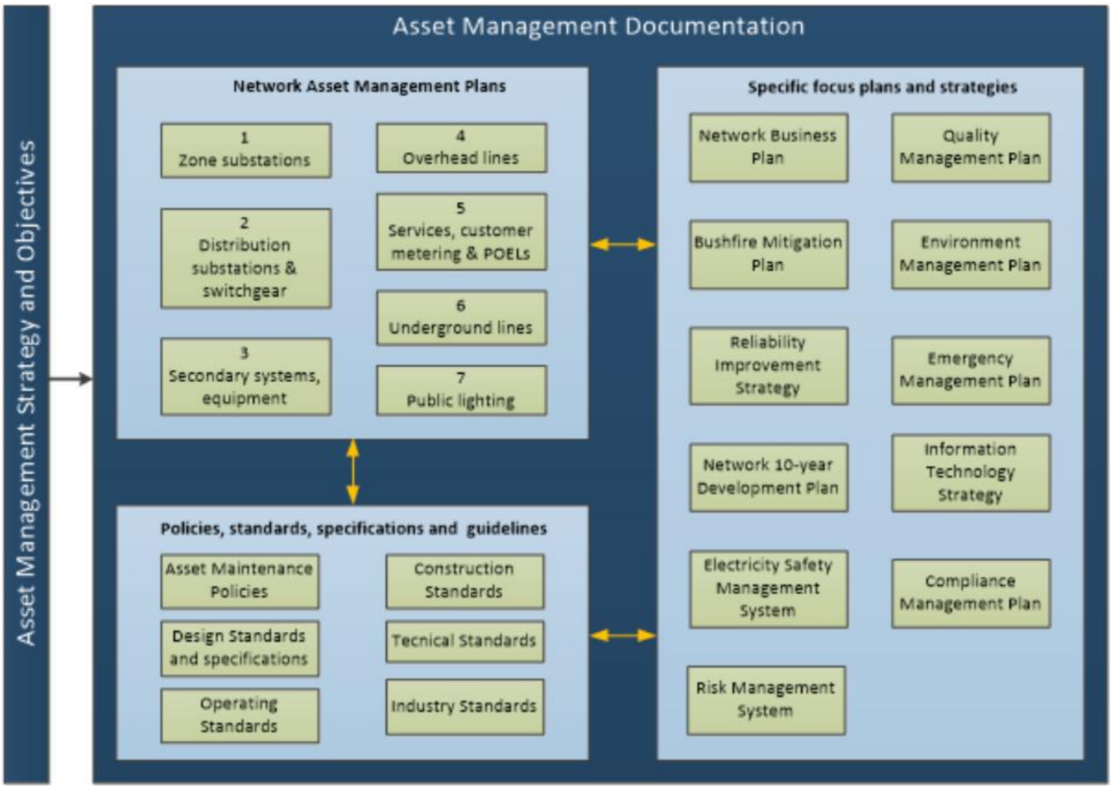
There are many documents that underpin CitiPower's Asset Management Framework. The main documents for ongoing asset management are described collectively as Network Management Plans, comprising the following:

- Asset Management Plans by asset type and major asset group;
- Supporting systems, strategies and plans for management of network assets;

- Standards, specifications, guidelines and policies for specific tasks or activities.

The diagram below shows how these documents are related.

Figure 12.3 Network Management Plans



12.1.4 Asset Management plans

Asset Management Plans (**AMP**) document the management strategies and plans for each of the major asset groups. Each AMP is formed from analysis of the required performance in terms of reliability and quality of supply, risk profile, functionality, availability and safety. The AMPs drive maintenance and inspection plans, condition monitoring, maintenance policies and work instructions. Refer to appendix D for a detailed list of asset management plans in use by CitiPower.

12.1.5 Specific Focus Plans and Strategies

Specific focus plans and strategies outline CitiPower's approach to management of activity that is relevant to or common across many network asset groups and include the following:

- Operational policies that relate to specific asset management objectives linked to corporate objectives;
- Strategies required for a group of assets or a specific local geographic area where the general asset management plans may not be adequate;
- Strategies that impact on the asset management plans (e.g. bushfire mitigation strategy plan);

- Supplementary or supporting strategies or plans.

12.1.6 Policies, Standards and Guidelines

Network asset maintenance policies, technical standards and specifications are supporting documents which provide more specific information on how assets are managed or maintained.

12.1.7 Impact of Asset Management on System Limitations

Electrical plant and conductor ratings may be affected by asset management activities in that a condition assessment could result in a higher or lower operating temperature. This could improve ratings to defer augmentation costs or lower ratings which will tend to bring forward expenditure whilst maximising system reliability, safety and security of supply. In addition, sections 3 and 14 cover the effect on the system of ageing and potentially unreliable assets.

12.1.8 Distribution Losses

Distribution losses refer to the energy used in transporting it across distribution networks. In 2017/18, 3.54 per cent of the total energy into the CitiPower network was made up of losses. This is essentially calculated as the difference between the energy that CitiPower procures and that which it supplies. These losses represent 89.6 per cent of CitiPower's total greenhouse gas emissions, as defined under the *National Greenhouse and Energy Report Act*.

CitiPower has a process to identify, justify and implement augmentation plans to address network constraints. Whilst loss reduction alone is not the main contributing factor in the decision of the preferred option, it is seen as the deciding factor if all other factors are equal. CitiPower, as part of its plant selection process takes into account the cost of losses in its evaluation for transformer purchases.

12.1.9 Contact for further information

Further information on CitiPower's asset management strategy and methodology can be obtained from contacting CitiPower Customer Service:

- General Enquiries 13 22 06
- Website www.citipower.com.au

Detailed enquiries may be forwarded to the appropriate representatives within CitiPower.

13 Asset management methodologies

The Asset Management Framework describes the asset management system that is applied to CitiPower's network assets and requires that all assets are either maintained, refurbished or replaced in accordance with the asset management plans.[10]

CitiPower's assets are subject to relevant condition assessment methods through planned inspection and monitoring programs. These programs have been developed taking into account regulatory obligations, industry knowledge as well as proven and established asset management methodologies.

CitiPower applies the following asset management methodologies to its network assets:

- reliability and safety based regime — this methodology is based on the principles of Reliability-Centred Maintenance (**RCM**) together with regulatory obligations and risk assessment that are built into the asset management procedures. It is applied to routine replacement expenditure for high- volume assets such as poles, pole top-equipment, cross-arms, insulators, batteries etc. The approach has regard for the asset age, condition and operating environment; and
- Condition Based Risk Management (**CBRM**) — this methodology is applied to assess the condition of assets, including the risk of the deterioration, of major items of plant, which involve significant expenditure. This includes assets such as zone substation transformers and switchgear.

These are discussed in more detail in the sections below.

13.1.1 'Poles and wires'

The reliability and safety based regime, based on RCM principles, regulatory obligations and risk assessment, is applied to high-volume assets such as poles, cross-arms, conductors etc.

The RCM process is used to determine what must be done to ensure that our physical network assets continue to operate at their intended performance levels at the most efficient cost. It is an internationally recognised and widely used methodology used to determine the most appropriate maintenance strategy for a particular class of asset at efficient cost.

For each asset type, the RCM process identifies possible ways in which a defect may occur in an asset, and the root cause of that defect. For each different type of defect, the possible impact on the safety, operations and other equipment in the network is assessed and a maintenance strategy is determined.

10 CitiPower, *Asset Management Framework*, 2015.

When implementing the RCM methodology for the inspection of assets, the risks associated with asset failures have been considered together with the inspection and repair costs to determine the most efficient inspection frequency and timeframe for repair of identified defects. Where a defect is identified, the maintenance strategy to address that defect is implemented. This may involve either asset replacement or maintenance measures to prolong the asset's life, such as pole staking.

The RCM process can be summarised by a series of steps, as follows.

Figure 13.1 Steps in the RCM process to develop a maintenance strategy

1. Select functions and performance standard of asset	• ensure the asset continues to do what its users want it to do • consider primary functions and secondary functions of asset
2. Identify function failures	• identify the ways in which the asset may fail to fulfil its functions
3. What causes each functional failure	• identify all of the events which are reasonably likely to cause each failed state • includes failures which have occured on the same or similar equipment; are prevented by existing maintainence procedures; and those which possibly may occur
4. What happens when failure occurs	• list all failure effects that describe what happens when a failure mode occurs, including supporting evidence • e.g. what is the evidence that a failure has occured, how does it pose a threat to safety or the environment
5. How does the failure matter	• consequences of failure of a hidden function, where failure will not become evident to operators under normal circumstances • consequence of failure of an evident function in terms of the impact on safety, environment, operational and non-operational matters
6. How to prevent or predict each failure	• identify the most appropriate maintenance strategy for each failure mode, which is also technically and economically feasible • where it is not possible to identify a pro-active task, select default actions such as proof testing, re-design or run to failure
7. Regularly review process	• once maintenance recommendations are put into practice, these are routinely reviewed and renewed as additional information is found

RCM analysis is undertaken by taking into account the equipment manufacturer's recommendations, the physical and electrical environment in which the asset is installed, fault and performance data, test data, condition data, regulations, duty cycles as well as many years of field-based experience.

The combination of general maintenance requirements and the specific requirements based on the environments in which the assets operate, may result in varying maintenance and condition monitoring regimes for the same type of asset. Tests and inspections are undertaken using tools such as thermal imagery, visual inspections, and invasive pole testing to assess asset condition.

The following example demonstrates how we apply RCM methodology in the case of wood poles, in practice:

1. Data collection — population demographics are determined so that the volume, age, strength, location and timber species is known. Each of these parameters are analysed to determine how they impact on the performance of poles and may require differing maintenance strategies. Performance data is gathered to determine defect rates, population condition, failure rates and root causes of failures.

2. RCM analysis team — a team of subject matter experts are assembled comprising employees and industry representatives (wood pole suppliers, other authorities, research bodies) to undertake the analysis.

3. Failure mode analysis — all the known and potential failure modes are identified. This generally includes identification of the following:
   - function of the asset;
   - failure types;
   - potential impacts of failure; and
   - potential causes of failure.

4. Maintenance policy developed — appropriate maintenance policies are determined for each failure mode to meet the required performance. This performance is generally expressed as an availability rate for the asset. The maintenance strategies include inspection frequencies, pole treatment frequencies (fungal decay), pole reinstatement, redesign, pole replacement and termite treatment.

5. Systems updated — the policy development/RCM process determines the frequency of inspections based on risk and economics. SAP (our corporate asset management system) then applies the policy rules to the poles to ensure that inspections take place with the right frequency based on that prioritisation. Prioritised inspections are automatically generated and notifications are created to undertake any required maintenance actions triggered during the inspection process.

6. Monitoring — performance of maintenance strategies are monitored such as defect and failure rates to ensure effective implementation and verification of expected outcomes. A further review may be undertaken should performance not meet expectation.

Maintenance and associated condition monitoring policies are reviewed every five years. When new assets are introduced into the network, existing maintenance and condition monitoring plans are reviewed to ensure coverage of the change or new plans are created as appropriate.

Maintenance plans, policies, tasks and work instructions are captured and managed in the SAP Maintenance Management system. The RCM rules are configured in

SAP, which automatically generates time based work orders for inspection and maintenance planning.

Location and timing of asset retirements

The location and the timing of the retirements of the ‘poles and wires’ types of assets are not available at the start of any planning year. The location of the asset is determined only once an inspection is carried out and if a defect is detected. The severity of the inspected defect will determine the maximum time that can lapse before action is taken.

13.1.2 Transformers and switchgear

CBRM is a structured process that combines asset information, engineering knowledge and practical experience to define future condition, performance and risk for network assets.

CitiPower applies the CBRM methodology to certain plant-based asset classes, namely transformers and circuit breakers. The CBRM methodology that CitiPower uses has been developed by EA Technology.

The methodology draws upon CitiPower’s knowledge and experience relating to degradation, failure, condition assessment, performance and influence of environment, duty, operational policy and specification of network assets. It is used to define current and future condition and performance of the assets.

The CBRM process can be summarised by a series of sequential steps, which is set out below.

Table 13.1 Steps in the CBRM process

Step	Description
1	**Define asset condition** Health indices (**HI**) are derived for individual assets within different asset groups. Health indices are described on a scale of 0 to 10, where 0 indicates the best condition and 10 the worst.
2	**Link current condition to performance** Health indices are calibrated against relative probability of failure (**PoF**). The HI/PoF relationship for an asset group is determined by matching the HI profile with the relevant observed failure rates.
3	**Estimate future condition and performance** Knowledge of degradation processes is used to trend health indices over time. This ageing rate for an individual asset is dependent on its initial HI and operating conditions. Future failure rates can then be calculated from aged HI profiles and the previously defined HI/PoF relationship.
4	**Evaluation of potential interventions in terms of PoF and failure rates** The effect of potential replacement, refurbishment or changes to maintenance regimes can then be modelled and the future HI profiles and failure rates reviewed accordingly.
5	**Define and weight consequences of failure (CoF)** A consistent framework is defined and populated in order to evaluate consequences in significant categories such as network performance, safety, financial, environmental, etc. The consequence categories are weighted to relate them to a common unit.
6	**Build risk model** For an individual asset, its probability and consequence of failure are combined to calculate risk. The total risk associated with an asset group is then obtained by summing the risk of the individual assets.
7	**Evaluate potential interventions in terms of risk** The effect of potential replacement, refurbishment or changes to maintenance regimes can then be modelled to quantify the potential risk profile associated with different strategies.
8	**Review and refine information and process** Building and managing a risk based process driven by asset specific information is not a one-off process. The initial application will deliver results based on available information and crucially, identify opportunities for ongoing improvement that can be used to build an improved asset information framework.

In terms of the steps in the process:

- steps 1 to 4 essentially relate to condition and performance and provide a systematic process to identify and predict end-of-life. Future investment plans can then be linked to probability of failure and failure rates;
- steps 5 to 7 deal with consequence of failure and asset criticality that are combined with PoF values to enable definition and quantification of risk; and
- step 8 is a recognition that building and operating a risk-based process using asset specific information is not a one-off exercise.

Each year, CitiPower updates the data in its CBRM model, which is contained in a MS Excel spreadsheet. CitiPower reviews the outputs of the CBRM and identifies the projects that deliver the greatest risk reduction. The latter projects are determined by calculating the difference between the risk in a future year if the asset is not replaced and the risk that would result if the plant is replaced, and then assessing the various options to deliver the risk reduction.

While the CBRM methodology identifies a proposed year for the replacement of an asset, the project is then reviewed in conjunction with other augmentation and development plans in order to identify opportunities for synergies, such that the replacement schedule can coincide with other major works. The project is then captured within a future works plan.

13.1.3 Other items of plant and equipment

Condition-based monitoring and risk-based economic assessment is not possible or cost-effective for all types of plant and equipment. Some plant and equipment rely upon inspection cycles, similar to poles and wires, while others rely on age as the best estimate of condition. Some assets that do not directly impact the performance of the network, and for which the cost of implementing a condition-based or a risk-based approach outweighs the benefit, are run to failure. Other assets, such as surge arrestors, are designed to only be used once and are replaced upon use.

Details of retirement and replacement methodologies for these assets are set out in the relevant asset management plans, and explained in the next chapter.

14 Retirements and de-ratings

This chapter sets out the planned network retirements over the forward planning period. The reference to asset retirements includes asset replacements, as the old asset is retired and replaced with a new asset.

In addition, this chapter discusses planned asset de-ratings that would result in a network constraint or system limitation over the planning period.

The System Limitation Report details those asset retirements and de-ratings that result in a system limitation.

Where more than one asset of the same type is to be retired or de-rated in the same calendar year, and the capital cost to replace each asset is less than $200,000, then the assets are reported together below.

14.1 Individual assets

A summary of the individual assets that are planned to be retired in the forecast planning period is provided in the table below. A more detailed and accurate assessment including the assessment of non-network alternatives will be carried out at the business case or RIT-D stage.

Table 14.1 Planned asset retirements and de-ratings

Location	Asset	Project	Retirement date
Armadale (**AR**) zone substation	66kV 1-2 Bus Tie CB	Replacement	2020
Brunswick (**BK**) zone substation	Transformer No.1 and 6.6kV Switchboard	Retirement and transfer load to West Brunswick (**WB**)	2022
Celestial Avenue (**WA**) zone substation	Transformer No 2	Replacement	2022
Celestial Avenue (**WA**) zone substation	Transformer No 1	Replacement	2023
Collingwood (**B**) zone substation	66kV 2-3 Bus Tie CB	Replacement	2019
Collingwood (**B**) zone substation	11kV Switchboard	Replacement	2023

Fitzroy (**F**) zone substation	Transformer No 3 and 6.6kV Switchboard	Retirement and transfer load to Collingwood (**CW**)	2022
North Richmond (**NR**) zone substation	66kV 1-2 Bus Tie CB	Replacement	2021
Port Melbourne (**PM**) zone substation	66kV 1-2 Bus Tie CB	Retirement and transfer load to West Gate (**WG**)	2020
Richmond (**R**) zone substation	Transformer No. 1	Replacement	2022
Richmond (**R**) zone substation	Transformer No. 2	Replacement	2021
Russell Place (**RP**) zone substation	Transformers and 6.6kV Switchboard	Retirement and transfer load to new Waratah Place (**WP**)	2022
South Melbourne (**SO**) zone substation	66kV 1-2 Bus Tie CB	Replacement	2022
St Kilda (**SK**) zone substation	Capacitor Bank	Replacement	2019
Victoria Market (**VM**) zone substation	Transformer No 1	Replacement	2021
West Brunswick (**WB**) zone substation	66kV 1-2 CB	Replacement	2023
Waratah Place (**WP**) zone substation	Building	Replacement	2019
West Melbourne terminal station (**WMTS**)	22kV sub-transmission network	Retirement and transfer load to adjacent zone substations or convert to 66kV supply	2018-20

For the forward planning period there are no committed investments worth $2 million or more to address urgent and unforeseen network issues.

14.1.1 Armadale (AR) zone substation 66kV 1-2 bus tie circuit breaker

The Armadale (**AR**) zone substation is served by sub-transmission lines from the Richmond terminal station (**RTS**) in a loop with Balaclava (**BC**) and Toorak (**TK**) zone substations. This station supplies the Armadale, St. Kilda and Toorak areas.

Currently, the AR zone substation is comprised of two 20/27 MVA transformers operating at 66/11kV and connected to 66kV sub-transmission lines from RTS and BC separated by a single 66kV bus tie circuit breaker. The Condition Based Risk Management (**CBRM**) analysis determined that the 66kV 1-2 bus tie circuit breaker has high risk and a health index of 5.03 rising to 6.2 in 2023 that can be efficiently mitigated by replacement in 2020. Retirement of this circuit breaker would require the 66kV bus be bridged resulting in the automatic loss of both sub-transmission lines and transformers for a fault on either line or transformer or the No.1 transformer at BC.

CitiPower estimates that with the 66kV No.1-2 bus tie circuit breaker retired in 2020, there will be 37.4 MVA of load at risk and for 8760 hours it will not be able to supply all customers from the zone substation if there were a failure of any transformer or 66kV line at AR or the failure of the No.1 transformer at BC. In the event of a fault, manual restoration of load could take up to two hours. That is, all customers would experience an outage of at least two hours for any sub-transmission or station transformer fault and therefore retirement without replacement is not recommended.

To address the anticipated system constraint at AR zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11 kV links to adjacent zone substations of Toorak (**TK**) and Balaclava (**BC**) up to a maximum transfer capacity of 5.1 MVA;
- replace the 66kV 1-2 bus tie circuit breaker at an estimated cost of $0.5 million;

CitiPower's preferred option is to replace the 66kV 1-2 bus tie circuit breaker in 2020. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 24 MW at AR zone substation would defer the need for this capital investment by one year.

14.1.2 Brunswick (C) zone substation

The Brunswick (**C**) zone substation is served by 22kV sub-transmission cables from the Brunswick terminal station (**BTS**). This station supplies the Brunswick area. The

C zone substation is comprised of three 10 MVA 22/6.6kV transformers, two 6.6kV busses and eight 6.6kV feeders.

The assets at C are over 75 years old and CBRM analysis determined that all three transformers have a health index of 7.0 with a HV switchgear health index of 6.05. The transformer health indices rise to a maximum of 8.00 in 2021 and the HV switchgear health index rises to 6.27 in 2021. The transformers and HV switchgear require replacement by 2021 and would leave all customers at C without supply if the assets were retired only.

To address the anticipated system constraint at C zone substation, CitiPower has undertaken a RIT-D and determined that the most efficient solution is to offload zone substation C completely to zone substation WB at 6.6kV as discussed below in 15.1.3.

This solution entails the installation of a new 20/27 MVA third transformer at WB zone substation with 3rd 6.6kV bus, replacement of the ageing 66kV 1-2 bus tie circuit breaker and offload C zone substation to WB zone substation at 6.6kV.

The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. No demand side initiative able to sufficiently reduce the forecast maximum demand load at C zone substation was discovered during the RIT-D process.

14.1.3 Brunswick (BK) zone substation transformer No.1 and switchboard

The Brunswick (**BK**) zone substation is served by 22kV sub-transmission lines from the Brunswick terminal station (BTS). This station supplies the Brunswick area. The BK zone substation is comprised of three 10 MVA 22/6.6kV transformers, three 6.6kV busses and ten 6.6kV feeders.

The assets at BK are over 70 years old and CBRM analysis determined that No.1 transformer has a health index of 8.25 with a HV switchgear health index of 4.59. The transformer health indices rise to a maximum of 10.14 in 2023 and the HV switchgear health index rises to 5.35 in 2023. The transformers and HV switchgear require replacement by 2023 and would leave all customers at BK without supply if the assets were retired only.

CitiPower estimates that in 2023 there will be 15.5 MVA of unserved load above the system normal rating and for 8,760 hours it will not be able to supply all 5,200 customers from the zone substation when the transformers and switchgear are retired.

To address the anticipated system constraint at BK zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 6.6kV links to adjacent zone substation of West Brunswick (**WB**) up to an estimated maximum transfer capacity of 4.0 MVA;

- rebuild of BK for an estimated cost of $35 million;
- replace busses 1 and 2 at WB zone substation , convert to 11kV and offload BK to WB for an estimated cost of $13.6 million.

CitiPower preferred option is to replace busses 1 and 2 at WB and offload BK zone substation to WB zone substation at 11kV and decommission existing aged and poor condition assets at BK zone substation in 2022. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 14.6 MW at BK zone substation would defer the need for this capital investment by one year.

14.1.4 Celestial Avenue (WA) zone substation transformer No.2

The Celestial Avenue (**WA**) zone substation is supplied at 66kV via sub transmission lines originating from West Melbourne terminal station (**WMTS**) and Brunswick terminal station (**BTS**) and currently comprises of two 66/11kV 20/27 MVA transformers and one 66/11kV 20/30 MVA transformer. WA zone substation supplies a portion of the central and eastern CBD in Melbourne.

CBRM analysis determined that the No.2 66/11kV 20/27 MVA transformer has a health index of 7.35 rising to 9.38 in 2023 and that the associated risk can be efficiently mitigated by replacement in 2022. Retirement of the No.2 transformer would result in a significant shortfall of transformation capacity at WA zone substation. This would place the customers supplied at risk of extended outages during times of unplanned network contingencies.

With No.2 transformer retired, CitiPower estimates that in 2024 there will be 37.9 MVA of load at risk and for 5156 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at WA. Also it would not be possible to maintain the CBD security standard.

To address the anticipated system constraint at WA zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Bouverie/Queensberry (**BQ**), and Victoria Market (**VM**) up to an estimated maximum transfer capacity of 12.2 MVA;
- replace the existing No.2 transformer in 2022 with a new transformer of similar rating for an estimated cost of $3.5 million.

CitiPower's preferred option is to replace the No.2 transformer in 2022. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. For more details and data on the limitation please refer to the attached Systems Limitations Spreadsheet.

A demand side initiative to reduce the forecast maximum demand load by 4 MW at WA zone substation would defer the need for this capital investment by one year.

14.1.5 Celestial Avenue (WA) zone substation transformer No.1

The Celestial Avenue (**WA**) zone substation is supplied at 66kV via sub transmission lines originating from West Melbourne terminal station (**WMTS**) and Brunswick terminal station (**BTS**) and currently comprises of two 66/11kV 20/27 MVA transformers and one 66/11kV 20/30 MVA transformer. WA zone substation supplies a portion of the central and eastern CBD in Melbourne.

CBRM analysis determined that the No.2 66/11kV 20/27 MVA transformer has a health index of 9.1 rising to 11.84 in 2023 and that the associated risk can be efficiently mitigated by replacement in 2022. Retirement of the No.1 transformer would result in a significant shortfall of transformation capacity at WA zone substation. This would place the customers supplied at risk of extended outages during times of unplanned network contingencies.

With No.1 transformer retired, CitiPower estimates that in 2023 there will be 38 MVA of load at risk and for 14136 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at WA. Also it would not be possible to maintain the CBD security standard.

To address the anticipated system constraint at WA zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Bouverie/Queensberry (**BQ**), and Victoria Market (**VM**) up to an estimated maximum transfer capacity of 12.2 MVA;
- replace the existing No.1 transformer in 2023 with a new transformer of similar rating for an estimated cost of $3.5 million.

CitiPower’s preferred option is to replace the No.1 transformer in 2023. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. For more details and data on the limitation please refer to the attached Systems Limitations Spreadsheet.

A demand side initiative to reduce the forecast maximum demand load by 4 MW at WA zone substation would defer the need for this capital investment by one year.

14.1.6 Collingwood (B) zone substation 66kV 2-3 bus tie circuit breaker

The Collingwood (**B**) zone substation is served by two sub-transmission lines from the Richmond terminal station (**RTS**) in a loop with North Richmond (**NR**) and Collingwood (**CW**) zone substations. This zone substation supplies the Collingwood and Fitzroy areas.

Currently, the B zone substation is comprised of two 20/27 MVA transformers operating at 66/11kV and connected to 66kV sub-transmission lines from CW and NR separated by a single 66kV bus tie circuit breaker. CBRM analysis determined that the 66kV 2-3 bus tie circuit breaker has a health index of 4.24 rising to 5.19 in 2023, and is nonetheless forecast to require replacement in 2019 due to other factors including availability of spares and the large number of customers connected.

Retirement of this circuit breaker would require the 66kV bus to be bridged resulting in the automatic loss of both sub-transmission lines and transformers for a fault on either line or transformer or the No.1 transformer at CW or the No.3 transformer at NR.

CitiPower estimates that with the 66kV No.2-3 bus tie circuit breaker retired in 2019 there will be 36 MVA of load at risk and for 8760 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of any transformer or 66kV line at B, the No.1 transformer at CW or the No.3 transformer at NR. In the event of a fault, manual restoration of load could take up to two hours. That is, all customers would experience an outage of at least two hours for any sub-transmission or station transformer fault.

To address the anticipated system constraint at B zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Collingwood (**CW**) and North Richmond (**NR**) up to a maximum transfer capacity of 11.3MVA;
- replace 66kV 2-3 BT CB at B in 2019 for an estimated cost of $0.5 million;
- establish an 11kV link with the zone substation in North Richmond (**NR**) to permanently transfer load for an estimated cost of $4.0 million.

CitiPower's preferred option is to replace the 66kV 2-3 bus tie circuit breaker in 2019. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 19 MW at B zone substation would defer the need for this capital investment by one year.

14.1.7 Collingwood (B) zone substation 11 kV switchboard

The Collingwood (**B**) zone substation is served by two sub-transmission lines from the Richmond terminal station (**RTS**) in a loop with North Richmond (**NR**) and Collingwood (**CW**) zone substations. This zone substation supplies the Collingwood and Fitzroy areas.

Currently, the B zone substation is comprised of two 20/27 MVA transformers operating at 66/11kV and connected to 66kV sub-transmission lines from CW and NR separated by a single 66kV bus tie circuit breaker. The insulation on the 11kV switchboard has been compromised from CB failure in 2016 and cannot be reconditioned. Whilst fit for service, these repairs are not a long term solution as evident from the low level PD (partial discharge) detected from the online monitoring system, and is nonetheless forecast to require replacement in 2023.

CitiPower estimates that with the 11kV switchboard retired in 2023 there will be 39.2 MVA of load at risk and for 8760 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of the switchboard.

To address the anticipated system constraint at B zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Collingwood (**CW**) and North Richmond (**NR**) up to a maximum transfer capacity of 11.3MVA;
- replace 11kV switchboard at B in 2023 for an estimated cost of $7.46 million;
- establish an 11kV link with the zone substation in North Richmond (**NR**) to permanently transfer load for an estimated cost of $4.0 million.

CitiPower's preferred option is to replace the 11kV switchboard in 2023. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 35.1 MW at B zone substation would defer the need for this capital investment by one year.

14.1.8 Fitzroy (F) zone substation transformer No.3 and 6.6kV switchboard

The Fitzroy (**F**) zone substation currently comprises 2 x 22/6.6kV transformers each served by a single 22kV sub-transmission cable from the Brunswick terminal station (**BTS**). This zone substation supplies the area of Fitzroy.

CBRM analysis determined that the No.3 22/6.6kV 10/13 MVA transformer has a health index of 6.72 rising to 8.32 in 2023 and the switchgear has a health index of 6.05 rising to 6.73 in 2023. Note that No 2 transformer failed over summer 2016/17 due to age and condition. Retirement of the No.3 transformer would require the existing No.1 transformer to solely supply the entire station demand. The transformers and HV switchgear require replacement by 2023 and would leave all customers at F without supply if the assets were retired only.

To address the anticipated system constraint at F zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency load transfers via the 6.6kV network to C zone substation to a maximum transfer capacity of 4.4 MVA;

- installation of additional 11kV links involving upgrade to 11kV and extension and augmentation of existing 6.6kV feeder assets to increase the transfer capacity to CW 11kV zone substation supply areas from 1 MVA to 13 MVA at an estimated cost of $12.5 million. This enables zone substation F to be decommissioned;
- replace the existing No.3 transformer switchgear and 22kV cables sequentially by 2027 for an estimated cost of $35 million.

CitiPower's preferred option is to offload to CW at 11kV in 2022. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 13 MW at F zone substation would defer the need for this capital investment by one year.

14.1.9 North Richmond (NR) zone substation 66kV 1-2 bus tie circuit breaker

The North Richmond (NR) zone substation is served by sub-transmission lines from the Richmond Terminal Station (**RTS**) in a loop with Collingwood (**B**) zone substations. This station supplies the North Richmond area.

Currently, the NR zone substation is comprised of two 23/28 MVA transformers and one 20/27 transformer operating at 66/11kV and connected to 66kV sub-transmission lines from RTS and B separated by two 66kV bus tie circuit breaker. The Condition Based Risk Management (**CBRM**) analysis determined that the 66kV 1-2 bus tie circuit breaker has high risk and a health index of 3.69 rising to 4.5 in 2023 that can be efficiently mitigated by replacement in 2021.

CitiPower estimates that with the 66kV No.1-2 bus tie circuit breaker retired in 2021, there will be 59 MVA of load at risk and for 8760 hours it will not be able to supply all customers from the zone substation if there were a failure of any transformer or 66kV line at NR or the failure of the No.1 transformer at NR. In the event of a fault, manual restoration of load could take up to two hours. That is, all customers would experience an outage of at least two hours for any sub-transmission or station transformer fault and therefore retirement without replacement is not recommended.

To address the anticipated system constraint at NR zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11 kV links to adjacent zone substations of Collingwood (**B**) and Collingwood (**CW**) up to a maximum transfer capacity of 5.1 MVA;
- replace the 66kV 1-2 bus tie circuit breaker at an estimated cost of $0.5 million;

CitiPower's preferred option is to replace the 66kV 1-2 bus tie circuit breaker in 2021. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 2.2 MW at NR zone substation would defer the need for this capital investment by one year.

14.1.10 Port Melbourne (PM) zone substation 66kV 1-2 bus tie circuit breaker

The Port Melbourne (**PM**) zone substation is served by two sub-transmission lines from the Fishermans Bend terminal station (**FBTS**) in a loop with Fishermans Bend (**E**) zone substation. This zone substation supplies the Port Melbourne area.

Currently, the PM zone substation is comprised plant that is over 60 years old including three 10/13.5 MVA transformers operating at 66/11kV and connected to 66kV sub-transmission lines from FBTS and E zone substation separated by two 66kV bus tie circuit breakers. CBRM analysis determined that the 66kV 1-2 bus tie circuit breaker has a health index of 6.88 rising to 8.72 in 2023 and is forecast to require replacement in 2019. Retirement of this circuit breaker would require the 66kV bus to be bridged and this reduces the ability to switch the station in the event of an unplanned outage.

If the 66kV circuit breaker is retired, CitiPower estimates that in 2019 there will be 4.5 MVA of load at risk and for 134 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of transformer No.1 or No.2 at PM, or the sub-transmission line supplying the station from E. In the event of a fault, manual switching to isolate the fault to restore supply to the remaining transformer(s) could take up to two hours. That is, all customers would experience an outage of at least two hours for any sub-transmission or station transformer fault.

To address the anticipated system constraint at PM zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency load transfers via the 6.6kV network to E zone substation to a maximum transfer capacity of 3.8 MVA;
- replace 66kV 1-2 BT CB at PM for an estimated cost of $0.39 million, followed by progressive replacement of the remaining aged plant;
- offload zone substation PM and E to Westgate (**WG**) zone substation and retirement of all plant at PM and E by 2024.

CitiPower's preferred option is to offload the substation by 2024. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. For more details and data on the limitation please refer to the attached Systems Limitations Spreadsheet

A demand side initiative to reduce the forecast maximum demand load by 15 MW at PM zone substation would defer the need for this capital investment by one year.

14.1.11 Richmond (R) zone substation transformer No.1

The Richmond (**R**) zone substation is served by three 22kV sub-transmission lines from Richmond terminal station (**RTS22**) and currently comprises of two 22/11kV

10/13.5 MVA transformers and one 22/11kV 10/13 MVA transformer. R zone substation supplies the areas of Richmond and South Yarra.

CBRM analysis determined that the 10/13.5 MVA No.1 transformer has a health index of 5.78 rising to 6.99 in 2023 and is forecast to require replacement in 2022. Retirement of this transformer would result in a significant shortfall of transformation capacity at R zone substation. This would place the customers supplied at risk of extended outages during times of unplanned network contingencies.

With No.1 transformer retired, CitiPower estimates that in 2023 there will be 11.7 MVA of load at risk and for 742 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at R, or the sub-transmission lines supplying the station from RTS. To address the anticipated system constraint at R zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Balaclava (**BC**), Northcote (**NC**) and Toorak (**TK**) up to a maximum transfer capacity of 9.2 MVA;
- replace No.1 transformer at R with a new transformer of similar rating for an estimated cost of $3.5 million;

CitiPower's preferred option is to replace the No.1 transformer at R in 2022. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. For more details and data on the limitation please refer to the attached System Limitation Report.

A demand side initiative to reduce the forecast maximum demand load by 4 MW at R zone substation would defer the need for this capital investment by one year.

14.1.12 Richmond (R) zone substation transformer No.2

The Richmond (**R**) zone substation is served by three 22kV sub-transmission lines from Richmond terminal station (**RTS22**) and currently comprises of two 22/11kV 10/13.5 MVA transformers and one 22/11kV 10/13 MVA transformer. R zone substation supplies the areas of Richmond and South Yarra.

CBRM analysis determined that the 10/13.5 MVA No.2 Transformer has a health index of 7.00 rising to 8.6 in 2023 and is forecast to require replacement in 2021. Retirement of this transformer would result in a significant shortfall of transformation capacity at R zone substation. This would place the customers supplied at risk of extended outages during times of unplanned network contingencies.

With No.2 transformer retired, CitiPower estimates that in 2022 there will be 11.4 MVA of load at risk and for 683 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two remaining transformers at R, or the sub-transmission lines supplying the station from RTS.

To address the anticipated system constraint at R zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Balaclava (**BC**), Northcote (**NC**) and Toorak (**TK**) up to a maximum transfer capacity of 9.2 MVA;
- replace No.2 transformer at R with a new transformer of similar rating for an estimated cost of $3.5 million;

CitiPower's preferred option is to replace the No.2 transformer at R in 2021. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. For more details and data on the limitation please refer to the attached System Limitation Report.

A demand side initiative to reduce the forecast maximum demand load by 4 MW at R zone substation would defer the need for this capital investment by one year.

14.1.13 Russell Place (RP) zone substation transformers and 6.6kV switchboard

The Russell Place (**RP**) zone substation is served by 22kV sub-transmission cables from the Richmond terminal station (**RTS**). It supplies a portion of the inner eastern Melbourne CBD and comprises of two 10 MVA transformers operating at 22/6.6kV, three 6.6kV busses and twelve 6.6kV feeders.

The RP zone substation is approximately 65 years old and the CBRM determined that both transformers have a health index of 5.64 rising to 6.78 in 2023 with a HV switchgear health index of 6.05 rising to 6.89 in 2023 and requires replacement by 2020. Retirement of these assets alone would result in an inability to supply any load at RP zone substation.

With all transformers and the 6.6kV HV switchgear retired, CitiPower estimates that in 2022 there will be 12.1 MVA of unserved load above the system normal limit and for 8,760 hours it will not be able to supply all 1,015 CBD customers from the zone substation when the transformers and HV switchgear are retired.

To address the anticipated system constraint at RP zone substation due to the planned de-commissioning of the zone substation and retirement of the transformers and 6.6kV switchgear, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 6.6/11kV links to adjacent zone substation of Little Queen (**LQ**) up to a maximum transfer capacity of 4.5 MVA;
- establish additional HV links involving extension and augmentation of existing HV feeder assets to 11kV to transfer RP load to the new Waratah Place (**WP**) zone substation, for an estimated cost of $12 million (also refer to section 7.3.1);
- rebuild RP zone substation at estimated cost of $80 million. The existing 6.6kV switchgear would be replaced as part of this option.

CitiPower's preferred option is establish additional HV links involving extension and augmentation of existing HV feeder assets to transfer RP load to the new WP zone substation by 2022. The use of contingency load transfers will mitigate the risk should assets fail ahead of the forecast replacement date. For more details and data on the limitation please refer to the attached System Limitation Report.

A demand side initiative to reduce the forecast maximum demand load by 8.4 MW at RP zone substation would defer the need for this capital investment by one year.

14.1.14 St Kilda zone substation (SK) Capacitor Bank

The St Kilda (**SK)** zone substation is supplied at 66kV via sub transmission lines from Richmond terminal station (**RTS)** and is comprised of three 66/11kV 20/27 MVA transformers. SK zone substation supplies suburb of St Kilda.

CBRM analysis determined that the No.1 66/11kV 20/27MVA transformer has a Health Index of 9 and is forecast to be replaced in 2019. Retirement of the capacitor bank would result in a significant shortfall reactive capability leading to low voltage issues for customers in St Kilda. This would place the customers supplied at risk of under voltage and consequently equipment failure.

With the capacitor bank retired, CitiPower estimates that in 2020 there will be probability of low voltage at high load times and CitiPower's power quality obligations would be breached.

To address the anticipated system constraint at SK zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Balaclava (**BC**),up to an estimated maximum transfer capacity of 6 MVAr;
- replace the existing No.1 capacitor bank in 2019 with a new capacitor bank of similar rating for an estimated cost of $0.40 million.

CitiPower's preferred option is to replace the capacitor bank in 2019. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. For more details and data on the limitation please refer to the attached System Limitation Report.

A demand side initiative to reduce the forecast maximum demand load by 6 MVar at SK zone substation would defer the need for this capital investment by one year.

14.1.15 South Melbourne (SO) zone substation 66kV 1-2 bus tie circuit breaker

The South Melbourne (**SO**) zone substation is served by sub-transmission lines from the Fishermans Bend Terminal Station (**FBTS**) in a loop with South Bank (SB) zone substations. This station supplies the South Melbourne area.

Currently, the SO zone substation is comprised of three 20/30 MVA transformers operating at 66/11kV and connected to 66kV sub-transmission lines from FBTS and SB separated by two 66kV bus tie circuit breaker. The Condition Based Risk Management (**CBRM**) analysis determined that the 66kV 1-2 bus tie circuit breaker has high risk and a health index of 4.31 rising to 5.37 in 2023 that can be efficiently mitigated by replacement in 2022.

CitiPower estimates that with the 66kV No.1-2 bus tie circuit breaker retired in 2022, there will be 36.9 MVA of load at risk and for 6220 hours it will not be able to supply all customers from the zone substation if there were a failure of any transformer or 66kV line at SO or the failure of the No.1 transformer at SO. In the event of a fault, manual restoration of load could take up to two hours. That is, all customers would experience an outage of at least two hours for any sub-transmission or station transformer fault and therefore retirement without replacement is not recommended.

To address the anticipated system constraint at SO zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11 kV links to adjacent zone substations of Southbank (**SB**) and Albert Park (**AP**) up to a maximum transfer capacity of 8.4 MVA;
- replace the 66kV 1-2 bus tie circuit breaker at an estimated cost of $0.5 million;

CitiPower's preferred option is to replace the 66kV 1-2 bus tie circuit breaker in 2022. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast replacement date. Please refer to the System Limitation Report for further information regarding the preferred network investment.

A demand side initiative to reduce the forecast maximum demand load by 2.8 MW at SO zone substation would defer the need for this capital investment by one year.

14.1.16 Victoria Market (VM) zone substation transformer No.1

The Victoria Market (**VM**) zone substation is supplied at 66kV via sub transmission lines from West Melbourne terminal station (**WMTS**) and Brunswick terminal station (**BTS** and is comprised of two 66/11kV 20/27 MVA transformers and one 66/11kV 20/30 MVA transformer. VM zone substation supplies the northwest corner of the Melbourne CBD as well as parts of West Melbourne and North Melbourne.

CBRM analysis determined that the No.1 66/11kV 20/27MVA transformer has a Health Index of 5.95 rising to 7.55 in 2023 and is forecast to be replaced in 2021. Retirement of the No.1 transformer would result in a significant shortfall in transformation capacity at VM zone substation. This would place the customers supplied at risk of extended outages during unplanned network contingencies.

With No.1 transformer retired, CitiPower estimates that in 2022 there will be 24.7 MVA of load at risk and for 2357 hours in the year it will not be able to supply all customers from the zone substation if there is a failure of one of the two transformers at VM.

To address the anticipated system constraint at VM zone substation, CitiPower considers that the following network solutions could be implemented to manage the risk:

- contingency plan to transfer load away via 11kV links to adjacent zone substations of Bouverie/Queensberry (**BQ**), and Celestial Avenue (**WA**) up to an estimated maximum transfer capacity of 6.2 MVA;
- replace the existing No.1 transformer in 2021 with a new transformer of similar rating for an estimated cost of $3.5 million.

CitiPower's preferred option is to replace the No.1 transformer in 2021. The use of contingency load transfers will mitigate the risk should the asset fail ahead of its forecast retirement date. For more details and data on the limitation please refer to the attached System Limitation Report.

A demand side initiative to reduce the forecast maximum demand load by 13.8 MW at VM zone substation would defer the need for this capital investment by one year.

14.1.17 West Melbourne terminal station (WMTS) 22kV sub-transmission network

The West Melbourne terminal station (**WMTS**) proposed works are detailed in section 10.1 above. It is comprised of two transformers that each has a capacity of 165MVA operating at 22kV and four transformers that each has a capacity of 150MVA operating at 66kV. The 22kV connection is used by CitiPower however the 66kV load is shared by CitiPower (90 per cent) and Jemena Electricity Networks (10 per cent).

AusNet Services are undertaking significant works to rebuild WMTS due to the condition and age of the plant and equipment.[11] As part of these works, AusNet Services proposed to rebuild the 22kV switchgear given its deteriorated condition.

CitiPower's 22kV sub-transmission network is also aged and deteriorated, particularly the transformers and indoor switchgear within existing zone substations. Some of these zone substations also have a secondary voltage of 6.6kV that is inconsistent with the current standard of 11kV used in those areas. CitiPower's strategy is to progressively replace the 22kV sub-transmission network with the 66kV sub-transmission network and convert existing 6.6kV distribution feeders to 11kV.

To reduce the cost of rebuilding WMTS, AusNet Services will now retire the 22kV supply assets which include transformers and switchgear.[12] This is consistent with CitiPower's strategy.

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[11] AER Final Decision SP AusNet Transmission determination 2014-15 to 2016-17, January 2014, page 73. http://www.aer.gov.au/sites/default/files/AER%20final%20decision%20for%20SP%20AusNet%27s%202014-17%20regulatory%20control%20period%20-%2031%20January%202014.pdf

CitiPower's 22kV WMTS sub-transmission network included Bouverie St/Bouverie Queensberry (**BSBQ**), Spencer St (**J**), Laurens Street (**LS**) and Dock Area (**DA**) zone substations. As per the preferred strategy below, BSBQ was transferred to Bouverie/Queensberry (**BQ**) during 2017 and decommissioning will be completed by end of 2018. The following table details the deterioration in health indexes of the transformers at the above zone substations and at nearby Tavistock Place (**TP**), which are high indicating an elevated risk of failure:

Table 14.2 CitiPower WMTS 22kV zone substation health indices

Zone substation	**2018 Health Index**		**2023 Health Index (no augmentation)**	
	Transformers	6.6kV switchgear	Transformers	6.6kV switchgear
Dock Area (DA)	3.27, 5.50, 5.78	3.14	3.69, 6.13, 6.44	3.82
Laurens St (LS)	7.00, 5.95, 5.95	5.78	8.18, 6.9, 6.78	6.72
Spencer St (J)	5.95, 7.35, 7.00, 7.00	5.30 (22kV & 6.6kV)	6.67, 8.43, 8.01, 8.11	5.87 (22kV & 6.6kV)
Tavistock Place (TP)	4.11 (all units)	5.50	4.59 (all units)	6.34

In the absence of any alternative strategies, the scheduled 'like for like' replacements are outlined below:

- Dock Area (**DA**) zone substation also requires replacement of three transformers due to age and condition. The first transformer is planned to be replaced in 2022 and the remaining two transformers replaced in 2024 and 2037;
- Laurens Street (**LS**) zone substation 'end of life' replacement of the 6.6kV switchgear was originally scheduled in 2012 however this has been delayed due to inability to offload to enable replacement to take place;
- Spencer St (**J**) zone substation requires replacement of all transformers in 2018 as they are at end of life (HI 7.0) and replacement of both the 6.6kV (HI 5.11 rising to 6.62 in 2027) and 22kV switchgear (HI 5.18 rising to 6.71 in 2027) in 2027. The building requires new lighting, fire, and oil containment systems.

[12] AER, Final Decision, AusNet Services transmission determination 2017-2022, April 2017, Attachment 6 – Capital expenditure, pp 6-39 to 6-41. https://www.aer.gov.au/system/files/AER%20-%20AusNet%20Services%202017-22%20-%20Attachment%206%20-%20Capital%20expenditure%20-%20April%202017.pdf

Refurbishment of the building internal structure is also required due to deterioration.

An alternative and preferred strategy is to retire the 22kV sub-transmission network earlier than scheduled, by offloading the Bouverie St/Bouverie Queensberry (**BSBQ**), Spencer St (**J**), and Laurens Street (**LS**) zone substations served by WMTS 22kV assets, and upgrade the Dock Area (**DA**) zone substation to 66kV with supply from WMTS 66kV, in collaboration with the AusNet Services rebuild of WMTS. As a consequence of offloading J, the adjacent Tavistock Place (**TP**) 22/6.6kV zone substation will lose its 6.6kV ties. Rather than upgrading TP to 66/11kV, the feeders will be transferred to the Little Bourke St (**JA**) 66/11kV zone substation. The J, LS and TP feeders will be upgraded from 6.6kV to 11kV.

The Vic Rail (**VR**) customer substation will also need to be transferred to the WMTS 66kV point of supply.

The impact of no alternative supply for WMTS 22kV sub-transmission supplied zone substations is as follows:

- At DA zone substation, CitiPower will be unable to supply all load and customers when 22kV supply from WMTS is retired. This would lead to an unserved load of 25.4 MVA for 8760 hours in the year. The reduction in demand to defer the project would be 25.4 MW;
- At LS zone substation, CitiPower will be unable to supply all load and customers when 22kV supply from WMTS is retired. This would lead to an unserved load of 21.8 MVA for 8760 hours in the year. The reduction in demand to defer the project would be 21.8 MW;
- At J zone substation, CitiPower will be unable to supply all load and customers when 22kV supply from WMTS is retired. This would lead to an unserved load of 7.2 MVA for 8760 hours in the year. The reduction in demand to defer the project would be 7.2 MW.

The exact timing of these works is currently being co-ordinated with AusNet Services, and the table below provides the estimated timing and cost of the major components of this plan. As these works are driven by asset replacement needs, CitiPower considers these works to be non-demand driven augmentation.

Table 14.3 WMTS 22kV offload plan

Zone substation	Description	Direct cost estimate ($ million)				
		2019	**2020**	**2021**	**2022**	**2023**
Bouverie St/Bouverie Queensberry (BS/BQ)	Transfer load from BSBQ to BQ (approved and completed in 2017).					
Laurens St (LS)	Permanently transfer the entire LS load to the BQ zone substation, by extending 11kV high voltage feeders from LS to BQ (approved)	7.8	9.6			
Spencer St (J)	Transfer load to JA, by extending high voltage feeders (approved).	3.7	0.3			
Tavistock Place (TP)	Transfer load to JA, by extending high voltage feeders (approved). (Combined with J offload)					
Dock Area (DA)	Upgrade DA and associated sub-transmission cables to 66kV	1.8	11.3	8.3		

The above costs do not take into account the decommissioning of BS/BQ, LS or J.

CitiPower and AusNet Services have identified that the costs to offload the 22kV network are far lower than replacing the existing aged 22kV assets and rectifying the building issues necessary to maintain the WMTS 22kV and associated sub-transmission network.

14.2 Group of assets

This section discusses planned retirements and replacements for groups of assets.

14.2.1 Poles and towers

CitiPower intends to replace poles and towers in various locations across the network in each year of the forward planning period. The number of poles and towers replaced each year is determined by condition assessments undertaken on each pole/tower inspected. The forecast number of poles/towers to be replaced in the coming five years is in line with historic replacements. CitiPower has a range of poles in its network, including hardwood, steel and concrete, supporting different voltages of conductor. All towers on the network are steel lattice structures.

Poles and towers are assessed using the RCM methodology. The inspection frequency is based on priority and economic optimisation. This methodology was discussed in the previous chapter. Where the pole or tower is inspected and found to be defective, and a routine maintenance option is not viable to remedy the defect, it is necessary and prudent to replace the pole or tower.

14.2.2 Pole top structures

CitiPower intends to replace pole top structures in various locations across its network in each year of the forward planning period. Pole top structures includes the following assets:

- Wood or steel cross arms are inspected at the same time as the pole using the RCM methodology discussed in the previous section.
- Insulators are generally made of porcelain, are inspected at the same time as the pole using the RCM methodology discussed in the previous section.
- Surge arrestors are attached to the pole and provide an alternate current path for the electricity to ground in the event of a lightning strike. These are generally replaced after they operate; otherwise they are replaced based upon age.
- Other pole top structure equipment include: fuses, dampers, armour rods, spreaders, brackets, etc. These are all inspected at the same time as the pole.

The number of pole top structures replaced each year is determined by condition assessments undertaken on each pole top structure inspected. The forecast number of pole top structures to be replaced in the coming 5 years is in line with the historic replacements.

14.2.3 Switchgear

CitiPower intends to replace switchgear assets in each year of the forward planning period which are expected to be in line with historical volumes. Switchgear can be classified as overhead or ground-mounted. Switchgear includes the following assets:

- Automatic circuit reclosers (**ACR**) interrupt fault current and automatically restore supply after a dead time in the event of a transient fault.
- Air-break switches (**ABS**) use air as an insulating medium to interrupt load current.
- Gas switches use SF6 gas as an insulating medium to interrupt load current.
- Isolators use air as an insulating medium to interrupt load current.

Switchgear assets are replaced based on condition, which is monitored through routine maintenance and inspection. When a defect is found and it cannot be rectified through maintenance, a refurbishment or replacement of the asset is prudent.

The replacement need and timing are prioritised through risk and economic assessments. The location and the timing of the asset retirement is only determined when a defect is identified.

14.2.4 Overhead services

Overhead services, which are required to connect a customer supply point to the network are inspected at the same time as the pole and pole top structures using the same RCM methodology discussed in the previous sections.

CitiPower intends to replace overhead services in various locations across its network in each year of the forward planning period. The number of overhead services replaced each year is determined by condition assessments undertaken on each overhead service inspected. The forecast number of overhead services to be replaced in the coming 5 years is expected to increase above the historic replacements due to deteriorated insulation associated with dogbone terminations and also during 2019 a special project aided by AMI meter analysis will be undertaken to detect assess and replace services where the neutral is suspect as part of a targeted program to address a safety issue.

14.2.5 Overhead conductor

Overhead conductors are an integral part of the distribution system. Overhead conductors may be bare or covered and are made of aluminium, copper and galvanised steel.

Conductor replacements are based on two methodologies:

- through inspection, asset failures or defect reports; and
- proactively through risk-assessment using health indices.

CitiPower plans to replace sections of overhead conductors each year over the forward planning period. The location and the timing of the conductor replacement will be determined based on condition assessments. The forecast number of sections of overhead conductor to be replaced in the coming 5 years is in line with historic replacements. As data and modelling improves, a better understanding of the location and timing of the conductor replacement at the planning stage of the proactive replacement program may be available in the future. In addition CitiPower plans to address insulation deficiencies around foreign objects such as sewer vents.

14.2.6 Underground cable

Underground sub-transmission cables are performance monitored and condition assessed by a scheduled cyclic testing program. Cables found by the test program to be in unacceptable condition are generally repaired as the issue is normally location specific or the result of damage by third parties. Sections of cable may be replaced from time to time on an unplanned basis as a response to identified defects or damage. No sub-transmission cables are planned for replacement due to condition in the next five year period.

HV and LV Underground cables are performance monitored and condition assessed when the cable is exposed for augmentation works or defect repairs. Cables identified in unacceptable condition are prioritised for replacement using an economic assessment of risk associated with the identified defect.

Over the forward planning period CitiPower plans to replace underground cables in line with historic volumes.

14.2.7 Other underground assets

Other underground assets include the following:

- Cable-head termination, which is the termination of an underground cable. Over the forward planning period CitiPower plans to replace aged metal box type terminations in line with historic volumes.
- Pits which are the point where the underground service connects to the customer premises, typically concrete or steel. Over the forward planning period CitiPower plans to replace large roadway pits due to identified defects in line with historic volumes. Recent inspection has also highlighted a need to address corroded reinforcing in CBD pits.
- Low-voltage pillars are typically concrete or steel, where low voltage underground cables are terminated. CitiPower plans to replace or refurbish large type LV distribution pillars due to identified defects and condition in line with historic volumes.
- Services (underground), which are required to connect a customer supply point (underground pit) to the network, are replaced as a result of defect reports

Underground assets replacements are prioritised using an assessment of risk associated with the identified defect. The timing of replacement is determined by the risk assessment.

14.2.8 Distribution plant

In the forward planning period, CitiPower plans to replace distribution plant assets in line with historic volumes. Distribution plant assets include a variety of assets listed below:

- HV Circuit breakers (22kV, 11kV and 6.6kV) which are required to interrupt load or fault current are replaced based on the CBRM results, as explained in the previous chapter.
- Distribution substation transformers include indoor, kiosk, ground mounted (compound) or pole mounted types. Transformers are replaced based on condition, as identified through schedule inspections and defect reporting. Replacement prioritisation is determined by conducting risk and economic assessments.
- Ring Main Units, which are banked switching units that enable switching between three or more underground cables, are replaced based on condition identified by scheduled inspection and defect reports, and then prioritised through risk and economic assessment.

- Earthing cables, which are required as one measure to prevent de-energised assets from becoming energised in the event of insulation breakdown or contact with live assets, are replaced following an inspection and/or condition monitoring.
- Combination switches, which are a high voltage switch and fuse combined, are replaced based on age with prioritisation of replacement determined by economic and risk assessment, given that neither the condition nor performance can readily be measured.

The location and the timing of the replacement of distribution plant assets are determined at the time of inspection and detection of defect, or upon failure of the asset.

14.2.9 Zone substation switchyard equipment

In the forward planning period, CitiPower plans to replace station switchyard assets in line with historic volumes. Zone substation switchyard equipment assets include a variety of assets including those listed below:

- Surge arrestors, which are required to protect primary plant from voltage surges, are generally replaced after failure. They can also be replaced based on age and condition, or opportunistically where other asset replacements take place at the zone substation.
- Busses, which allow multiple connections to a single source of supply, are usually replaced as part of the associated zone substation equipment being replaced, e.g. 11kV busses usually form part of modular switchgear and thus are included as part of switchgear replacement.
- Joints, terminations and connector assets are replaced on inspection, or as part of the replacement of the assets to which they are connected.
- Steel structures, which are required to hold energised assets in place, are replaced based on inspection and observed condition.

The location and the timing of the replacement of zone substation assets are determined at the time of inspection or upon identification of defects.

Note; Testing of the Little Queen (**LQ**) 11kV switchboard undertaken just prior to the release of this report indicated that a potential replacement may need to occur within the forecast period 2019-23.

14.2.10 Protection and control room equipment and instrumentation

Protection and control systems are designed to detect the presence of power system faults and/or other abnormal operating conditions and to automatically isolate the faulted network by the opening of appropriate high voltage circuit breakers. CitiPower plans to replace a large number of protection and control room equipment and instruments each year over the forward planning period. This includes the following assets:

- Protection relays: are replaced based on age and/or economic assessment of risk.

  - CitiPower's relay replacement program focusses on electro-mechanical and electronic protection relays. The risk profile of these types of relays is forecast to significantly increase as the technology is approaching end of life.
  - The relays will be replaced at the following zone substations over the forward planning period: AP, AR, B, CW, DA, JA, L, NC, R, SK, SO, WB, MG, RD, BC and WG.
  - As the need to replace the assets will be reassessed on a risk based approach closer to the replacement period, the date of replacement is unknown at time of writing.
- Voltage regulating relay (**VRR**) replacements.
- Capacitor Bank controllers (or VAR controllers), are usually run-to-failure and as such it is prudent for CitiPower to maintain asset spares.
- Battery banks are replaced based on the results of condition tests.
- Voltage/current transformers: are usually run-to-failure and as such it is prudent for CitiPower to maintain asset spares.

Aside from the proactive replacement of protection relays where the location of the zone substation is known in advance, the timing and the location of the replacement of other assets are determined upon inspection and detection of defects, or upon asset failure.

14.3 Planned asset de-ratings

CitiPower has no planned asset deratings in the forward planning period.

14.4 Committed projects

This section sets out a list of committed investments worth $2 million or more to address urgent and unforeseen network issues.

CitiPower does not have any committed projects to address urgent and unforeseen network issues.

14.5 Timing of proposed asset retirements / replacements and deratings

CitiPower are now also required detailed information on its asset retirements / replacement projects and deratings in its DAPR as described above. The timing of these may change subject to updated asset information, portfolio optimisation and realignment with other network projects, or reprioritisation of options to mitigate the deteriorating condition of the assets.

CitiPower have made improvements to the risk assessment quantification. These changes primarily involve a refinement of the estimated failure probability for transformers, taking into account failures and replacements, and the inclusion of analysis at a substation level, considering common-cause failure risk for substations with identical assets. As a result, some asset retirements have been deferred, and other future retirements have been brought forward.

Error! Reference source not found. below summarises the change in timing of proposed major network retirements/replacements.

Table 14.4 Changes in timing of asset retirements / replacements and deratings

Proposed Asset Replacement	**2018 DAPR**	**2017 DAPR**
Brunswick (**BK**) zone substation Transformer No.1 and 6.6kV Switchboard	2022	Not included
Celestial Avenue (**WA**) zone substation Transformer No 1	2023	Not included
Collingwood (**B**) zone substation 11kV Switchboard	2023	Not included
Fitzroy (**F**) zone substation Transformer No 3 and 6.6kV Switchboard	2022	2021
North Richmond (**NR**) zone substation 66kV 1-2 Bus Tie CB	2021	Not included
Port Melbourne (**PM**) zone substation 66kV 1-2 Bus Tie CB	2020	2018
Russell Place (**RP**) zone substation Transformers and 6.6kV Switchboard	2022	2020
South Melbourne (**SO**) zone substation 66kV 1-2 CB	2022	Not included
St Kilda (**SK**) zone substation Capacitor Bank	2019	Not included
West Brunswick (**WB**) zone substation 66kV 1-2 CB	2023	Not included

15 Regulatory tests

This section sets out information about large network projects that CitiPower has assessed, or is in the process of assessing, using the Regulatory Investment Test for Distribution (**RIT-D**) during the forward planning period.

This chapter also sets out possible RIT-D assessments that CitiPower may undertake in the future.

Large network investments are assessed using the RIT-D process. The RIT-D relates to investments where the cost of the most expensive credible option is more than $5 million. The RIT-D has historically been used for large augmentation projects, and was extended to include replacement projects from 18 September 2017.

Transitional arrangements apply for the introduction of the RIT-D for replacement projects that have been "committed" to by a distributor on or prior to 30 January 2018. These projects are also listed in this chapter, as well as published on our website.[13]. There is no material impact on connection charges and distribution use of system charges that have been estimated.

15.1 Current regulatory tests

The table below provides an overview of the Regulatory Test projects that are underway or completed by CitiPower in 2018

Table 15.1 Status of CitiPower regulatory tests

Project name	Regulatory Test status	Proposed commissioning date	Comments
MP to BQ & WP 11 kV feeders	Completed	November 2020	Part of the CBD security plan
BTS upgrade	Completed	November 2020	Commissioning date refers to 66kV cables associated with new WP zone substation
Brunswick Area Supply	Completed	November 2021	Transfer of 6.6kV load at C to WB and install 3rd transformer at WB.
DA upgrade to	In progress	October 2021	Upgrade required

13 https://www.powercor.com.au/about-us/electricity-networks/network-planning/network-limitations/

66kV supply			to retire the WMTS 22kV network
RP retirement and offload to WP	To be issued in 2019	October 2022	Secures supply to part of CBD

These projects are further discussed below.

15.1.1 MP to BQ & WP 11 kV feeders

CitiPower completed a Regulatory Test relating to new 11kV feeders at the Bouverie/ Queensberry (**BQ**) and Waratah Place (**WP**) zone substations in July 2014.

The new feeders from BQ to McIllwraith Place (**MP**) and WP to MP are both required to relieve the emerging N-1 load at risk at MP, and N-2 on the Flinders Ramsden (**FR**) to MP 66kV sub-transmission cables. This is related to the CBD security 11kV feeder upgrade works discussed in section 3.4.

The table below sets out the options and estimated cost of each option.

Table 15.2 Assessment of options

Option	Description	Estimated cost ($ million)
1	New 11kV feeders from BQ to Exhibition Exchange and WP to Lonsdale St	7.1
2	New 11kV feeders from WP to Exhibition Exchange and WP to Lonsdale St	7.7
3	New 11kV feeders from BQ to 310 Latrobe St Distribution Substation and BQ to Exhibition Exchange	11.5
4	New 11kV feeders from BQ to 310 Latrobe St Distribution Substation and WP to Exhibition Exchange	14.5

CitiPower's preferred option is to construct the new feeders from BQ to Exhibition Exchange and WP to Lonsdale St. This project has a planned commissioning date of November 2020.

15.1.2 Brunswick terminal station

The purpose of the Regulatory Test was to reduce the constraints at the Richmond terminal station and West Melbourne terminal station. The preferred solution was to add a 66kV point of supply in addition to the existing 22kV supply at Brunswick terminal station.

Part of the Regulatory Test was to reduce the load at RTS by transferring the RTS-CW-B-NR-RTS loop to BTS. As a result of delays to the construction of the 66kV point of supply at BTS, a constraint subsequently arose on the RTS-FR sub-transmission lines.

An alternative solution was identified that would address both the constraints at RTS as well as on the RTS-FR sub-transmission lines. That alternative solution involves the transfer of the McIllwraith Place (**MP**) zone substation from being served by RTS and the RTS-FR sub-transmission cables to instead being served by BTS. To achieve this alternative solution, CitiPower proposes to reconfigure existing cables and construct a new sub-transmission cable:

- BTS-WP, construct a new sub-transmission cable;
- FR1-WP1, reconfiguring the existing FR1-MP1;
- FR2-WP2: reconfiguring the existing FR2-MP2;
- MP1-WP1, reconfiguring the existing FR1-MP1;
- MP1-WP2: reconfiguring the existing FR2-MP2.

For this part of the Regulatory Test, the original solution was estimated to cost $36 million. The estimated cost of this alternative solution was $23.4 million (comprising of $7.9 million for new BTS-WP and $15.5 million for two sets of FR-WP and MP-WP 66kV cables), which is significantly lower than the original solution. This project has a planned commissioning date of November 2020.

15.1.3 Brunswick Area Project

CitiPower completed a Regulatory Test relating to transfer of Brunswick (**C**) zone substation load to West Brunswick (**WB**) zone substation at 6.6kV.

The credible options address the identified need—namely, the increasing risks to safety and reliability of supply caused by the deterioration of the 80 year old assets at Brunswick (C) zone substation.

There are no potential material impacts on network users from any of these credible options.

The RIT-D presents the following credible options:

Option 0: Business as usual which includes:

- Replace 22kV sub-transmission cables
- Replace transformers
- Replace switchboard and auxiliary equipment

Option 1: Offload C to WB at 6.6kV which includes:

- Install transformer and 66kV plant at West Brunswick (WB) zone substation
- Install 6.6kV switchboard at WB

- Install new feeder ties between C and WB
- Decommission zone substation C

Option 2: Offload C to WB at 11kV which includes:

- Install transformer and 66kV plant at West Brunswick (WB) zone substation
- Convert C and WB distribution network to 11kV
- Install 11kV switchboard at WB
- Install new feeder ties between C and WB
- Decommission zone substation C

Option 3: Rebuild zone substation C:

- Install 66kV plant at C
- Install new 6.6kV switchboard and auxiliary plant at C
- Decommission existing plant at C

The cost, benefit and timing of these options are presented in table 15.3 below.

Option	Economic Benefit	Present value cost ($ million, $2018)	Commissioning date
0	Equal	28.62	2021
1	Equal	14.86	2021
2	Equal	22.43	2021
3	Equal	26.55	2021

Option 1 has been chosen as the most efficient option.

15.2 Future regulatory investment tests

Based on the information contained within sections 7, 8, and 14, CitiPower expects to commence reviewing options to address the identified system limitations. The table below sets out the possible timeframes for consideration of RIT-D under clause 5.17 of the NER relating to investments where the cost of the most expensive credible option is more than $6 million.

Table 15.3 Future RIT-D projects

Project name	Proposed RIT-D start date	Comments

RP Offload to WP	March 2019	Transfer of Russel Place (**RP**) load to Waratah Place (**WP**) by converting the 6.6kV to 11kV and establishing new 11kV feeder ties
Brunswick Area Strategy – Retirement of the 22kV sub transmission and 6.6kV distribution network	March 2020	Transfer of Fitzroy (**F**) zone substation load to Collingwood (**CW**) and Brunswick (**BK**) to West Brunswick (**WB**) zone substation and conversion to 11kV
Port Melbourne Area Strategy – Retirement of the 6.6kV network	March 2021	Transfer of Port Melbourne (**PM**) and Fishermans Bend (**E**) zone substations load to Westgate (**WG**) and conversion to 11kV
HV Switchboard Replacement B 11kV Email J18	March 2020	Replace the 11kV switchboard
HV Switchboard Replacement LQ 11kV Email HQ (Compound)	March 2022	Replace the 11kV switchboard

RIT-D consultation documents will be made available from the CitiPower website and notified to participants registered on the Demand Side Engagement Register.

15.3 Excluded projects

The table below provides a list of the excluded projects from the RIT-D under the transitional arrangements relating to the extension of the RIT-D to replacement projects.

Table 15.4 Excluded RIT-D projects

Project name	**Description**	**Scheduled completion date**
Waratah Place (**WP**) building replacement	Replacement and upgrading of the Waratah Place switching station to a new zone substation. Involves demolishing the existing building, which was in poor condition, and rebuilding the zone substation, which	Project underway, expected completion in Q4 2020

	will house new 66kV switchgear. Forms part of the CBD Security of Supply project.	
Decommission of Bouverie Street/Bouverie Queensberry (**BS/BQ**) zone substation	Transfer of load to Bouverie/Queensberry (**BQ**) zone substation and decommission of BS zone substation.	Project completed in 2017
Decommission of Laurens Street (**LS**) zone substation	Transfer of load to BQ zone substation and decommission of LS zone substation. The LS zone substation assets are aged and poor condition. We have committed to decommissioning these 22kV sub-transmission assets rather than the more expensive option of replacing them. Required as part of the program to decommission the 22kV sub-transmission network from WMTS and replace with the 66kV network.	Project underway expected completion in Q4 2019
Decommission of Spencer Street (**J**) zone substation	Transfer of load to Little Bourke Street (**JA**) zone substation and decommission of J zone substation. The J zone substation assets are aged and poor condition. We have committed to decommissioning these 22kV sub-transmission assets rather than the more expensive option of replacing them. Required as part of the program to decommission the 22kV sub-transmission network from WMTS and replace with the 66kV network.	Project underway, expected completion in Q4 2019
Decommission of Tavistock Place (**TP**) zone substation	Transfer of load to Little Bourke St (**JA**) zone substation and decommission of TP zone substation. The TP zone substation assets are aged and poor condition. We have committed to decommissioning these 22kV sub-transmission assets rather than the more expensive option of replacing them. Required as part of the program to decommission the 22kV sub-transmission network from WMTS and	Project underway, expected completion in Q4 2019

	replace with the 66kV network, as TP and J from a CBD feeder group with secondary voltages at 6.6kV rather than at 11kV, and provide back-up for each other.	

16 Network Performance

This chapter sets out CitiPower's performance against its reliability targets in 2017 and its plans to improve reliability over the forward planning period.

16.1 Reliability measures and standards

CitiPower is subject to a range of reliability measures and standards.

The key reliability of supply metrics to which CitiPower is incentivised under the Service Target Performance Incentive Scheme (**STPIS**) are:

- System average interruption duration index (**SAIDI**): Unplanned SAIDI calculates the sum of the duration of each unplanned sustained customer interruption (in minutes) divided by the total number of distribution customers. It does not include momentary interruptions that are one minute or less;
- System average interruption frequency index (**SAIFI**): Unplanned SAIFI calculates the total number of unplanned sustained customer interruptions divided by the total number of distribution customers. It does not include momentary interruptions that are one minute or less. SAIFI is expressed per 0.001 interruptions; and
- Momentary average interruption frequency index (**MAIFI**): calculates the total number of momentary interruptions divided by the total number of distribution customers (where the distribution customers are network or per feeder based, as appropriate).

The reliability of supply parameters are segmented into CBD and urban feeder types.

The table below shows the reliability service targets set by the AER for CitiPower in its Distribution Determination in May 2016.[14] CitiPower reported to the AER its 2017 performance against those targets in the 2017 calendar year in its Regulatory Information Notice (**RIN**), and these figures are included in the table. In addition, CitiPower has also forecast its outturn performance for the 2018 calendar year, based on actual performance for the period from 1 January 2017 to 31 August 2018 , and then projected forward taking into account seasonal factors.

[14] AER, CitiPower - Distribution Determination 2016–2020, Final, May 2016.

Table 16.1 Reliability targets and performance

Feeder	Parameter	AER target (2016-20)	2017 performance	2018 forecast performance (at 31August 2018)
CBD	SAIDI	9.130	4.707	14.609
	SAIFI	0.129	0.067	0.171
	MAIFI	0.005	0.000	0.003
Urban	SAIDI	32.696	26.339	31.465
	SAIFI	0.484	0.446	0.437
	MAIFI	0.152	0.212	0.171

In 2017, CitiPower achieved its targets for all parameters except unplanned MAIFI for Urban lines.

In 2018, CitiPower is forecast to exceed its targets for all parameters except for the unplanned MAIFI for CBD lines and also SAIFI and MAIFI for Urban lines.

Actual network performance is also often influenced by external events such as storms, heat, flood, or third party damage which may be outside of CitiPower's control. The influence of these factors on network performance can also vary significantly from one year to the next.

16.1.1 Corrective reliability action undertaken or planned

Actual network reliability performance is the result of many factors and reflects the outcomes of numerous programs and practices right across the network. To achieve long term and sustainable reliability improvements, CitiPower continues to refine and target existing asset management programs as well as reliability specific works.

The processes and actions which CitiPower undertakes to sustain reliability include:

- undertaking the various routine asset management programs, including:
  - inspection of nearly 15,000 poles and pole tops;
  - testing of lines such as sub-transmission cables in the CBD;
  - maintenance and replacement programs for overhead and underground lines, primary plant (for example, CitiPower replaced 10 x 66kV transformer bushings, at various zone substations in 2017) and secondary systems; and
  - civil works to restore zone substation buildings, switchrooms and transformer enclosures at various zone substations.

- deployment of portable auxiliary cooling fans at several substations to assist in cooling heavily loaded transformers;
- targeted installation of smart technologies to improve network monitoring, control and restoration of supply including intelligent circuit reclosers, gas switches and line fault indicators at strategic locations;
- targeted reduction of the exposure to faults on the distribution network by using:
  - thermography programs to detect over-heated connections;
  - Partial Discharge detection program for indoor 6.6kV and 11kV switchgear in Zone substations; including several continuous on line monitoring systems
  - vegetation management programs to improve line clearances;
  - animal and bird mitigation measures to reduce the risk of 'flash-overs';
  - targeted insulator washing and pole-top fire mitigation to reduce the risk of pole fires; and
  - dehydration of power transformer.
- use of innovative solutions such as auxiliary power generation or by-pass cables to maintain supply where practicable;
- conduct fault investigations of significant outages to understand the root cause, in order to prevent a re-occurrence;
- undertake asset failure trend analysis and outage cause analysis to identify any emerging asset management issues and to mitigate those through enhancing the related asset management plans, maintenance policies or technical standards.

Evaluation of the 2018 reliability improvement initiatives should be considered in the context of the longer term goals stipulated above and the volatility caused by uncontrollable events such as severe storms and the effect of third party events.

16.2 Quality of supply measures and standards

The main quality of supply measures that CitiPower control are:

- Voltage; and
- harmonics.

16.2.1 Voltage

Voltage requirements are governed by the Electricity Distribution Code and the NER.

The NER essentially requires that CitiPower adheres to the 61000.3 series of Australian and New Zealand Standards.

In addition, the Electricity Distribution Code requires that CitiPower must maintain nominal voltage levels at the point of supply to the customer's electrical installation in accordance with the Electricity Safety (Network Assets) Regulations 1999 or, if these regulations do not apply to the distributor, at one of the following standard nominal voltages:

(a) 230V;

(b) 400V;

(c) 460V;

(d) 6.6kV;

(e) 11kV;

(f) 22kV; or

(g) 66kV.

The Electricity Safety (Network Assets) Regulations 1999 were revoked on 8 December 2009 by regulation 104 (Schedule 1) of the Electricity Safety (Installations) Regulations 2009. Therefore the standard nominal voltages specified in the Code apply.

Variations from the standard nominal voltages listed above are permitted to occur in accordance with the following table:

Table 16.2: Permissible voltage variations

Standard nominal voltage variations				
Voltage Level in kV	**Voltage Range for Time Periods**			**Impulse Voltage**
	Steady State	**Less than 1 minute**	**Less than 10 seconds**	
< 1.0	+10% -6%	+14% -10%	Phase to Earth +50% -100% Phase to Phase +20% -100%	6kV peak
1-6.6	± 6% (± 10% Rural Areas)	±10%	Phase to Earth +80% -100% Phase to Phase +20% -100%	60kV peak
11				95kV peak
22				150kV peak
66	±10%	±15%	Phase to Earth +50% -100% Phase to Phase +20% -100%	325kV peak

As required by the Electricity Distribution Code, CitiPower uses best endeavours to minimise the frequency of voltage variations listed in Table 16.2 above for periods of less than one minute.

CitiPower is able to measure voltage variations at zone substations, as many have power quality meters installed. This enables CitiPower to address any systemic voltage issues. The table below provides a forecast of the number of instances of voltage variations at CitiPower zone substations in the 2017 calendar year, based on actual instances to the end of September 2017, although many of these instances would have occurred from abnormalities or transients in the system.

Table 16.3 Forecast zone substation voltage variation in 2017

Voltage variations	Number of occurrences
Steady state (zone substation)	707
One minute (zone substation)	0
10 seconds (zone substation) Min<0.7	633
10 seconds (zone substation) Min<0.8	90
10 seconds (zone substation) Min<0.9	156

CitiPower responds quickly to investigate and resolve voltage issues. The issues may be identified through the system monitoring undertaken by CitiPower or as a result of customer complaints. The Supply Quality team may subsequently carry out projects to address concerns relating to voltages.

The solutions that CitiPower may adopt include:

- installation of voltage regulators which will bring voltage levels at customer connection points within the applicable requirement;
- the upgrade of existing distribution transformers, or the installation of new distribution transformers, to increase the ability of the network to meet customers' demand for electricity and improve voltage performance;
- replacing small sized conductors with large conductors in order to improve the voltage performance; or
- installation of additional reactive power compensation, such as capacitor banks, to improve voltage performance.

CitiPower may also identify issues with voltage following applications from potential "disturbing load" customers, such as an embedded generator or a large industrial customer, to connect to the network. System studies are carried out on a case-by-case basis to identify voltage or harmonic constraints relating to proposals, with recommendations for corrective action provided to the party seeking to connect.

16.2.2 Harmonics

Voltage harmonic requirements are governed by the Electricity Distribution Code and the NER.

The NER essentially requires that CitiPower adheres to the 61000.3 series of Australian and New Zealand Standards.

In addition, CitiPower is required under the Electricity Distribution Code to ensure that the voltage harmonic levels at the point of common coupling (for example, the service pole nearest to a residential premise), with the levels specified in the following table:

Table 16.4 Voltage harmonic distortion limits

Voltage at point of common coupling	Total harmonic distortion	Individual voltage harmonics	
		Odd	Even
< 1kV	5%	4%	2%
> 1kV and ≤ 66kV	3%	2%	1%

CitiPower responds quickly to investigate and resolve voltage issues. The issues may be identified through the power quality meters that CitiPower has installed to monitor the quality of supply or as a result of customer complaints. The Supply Quality team may subsequently carry out projects to address concerns relating to voltages.

Where the voltage harmonics are measured to be consistently outside of the required levels, CitiPower will investigate and resolve the issue. The solutions that CitiPower may adopt include:

- alter the switching sequencing of the network equipment to reduce the voltage harmonic distortions;
- replacing small sized conductors with large conductors in order to improve the voltage harmonic performances ; or
- installation of harmonic filtering equipment to improve voltage harmonic performance.

CitiPower may also identify issues with harmonics following applications from potential "disturbing load" customers, such as an embedded generator or a large industrial customer, to connect to the network. System studies are carried out on a case-by-case basis to identify voltage or harmonic constraints relating to proposals, with recommendations for corrective action provided to the party seeking to connect.

17 Embedded generation and demand management

This section sets out information on embedded generation as well as demand management activities during 2018 and over the forward planning period.

17.1 Embedded generation connections

The table below provides a quantitative summary of the connection enquires under chapter 5 of the NER and applications to connect EG units received in 2018.

Table 17.1 Summary of embedded generation connections

Description	Quantity (> 5MW)
Connection enquires under 5.3A.5	0
Applications to connect received under 5.3A.9	0
The average time taken to complete application to connect	N/A

Key issues to connect embedded generators to CitiPower's network include:

- available capacity of the sub-transmission network is limited due to the existing and committed large-scale generators
- fault levels in the Melbourne CBD and tight allocations where applicants have sought to connect in dense supply areas;

17.2 Non-network options and actions

In 2018, CitiPower considered non-network alternatives for the following projects:

- CitiPower to negotiate network support agreements with urban embedded generators, to address short term constraints, however whilst there has been a need in previous years for network support, there was no need this year.

CitiPower actively seeks opportunities to promote non-network alternatives for both general and project-specific purposes. For 2018, the following details some of CitiPower's activities:

- CitiPower monitors industry developments and engages with providers of demand management and smart network technologies
- CitiPower completed a 3 year trial of residential battery storage systems that ran until 2018. The systems tested were from a range of vendors with a range of capabilities. These long running tests will be used to develop knowledge around the application, operation and long term costs of small scale storage in the residential sector. They will also help CitiPower to understand the application of such systems to provide network support in the future.

- For the summer of 2018/19, CitiPower will bid into the Reliability and Emergency Reserve Trader Market (**RERT**) using their Smart Meter Voltage Management (**SMVM**) scheme when called upon by AEMO. SMVM is an improvement upon the current method of lowering the voltage set points at the zone substation, which in turn lowers the amount of Power (MW) supplied to the network and reduces demand on peak days.
- Over the next year CitiPower is actively exploring opportunities in the industry of Electric Vehicles (EV) technology and use cases. The purpose will be to determine future network effects of large uptake of the technology by customers as well as a variety of other considerations.

Over the forward planning period, CitiPower intends to continue to consider demand side options via its Demand Side Engagement Strategy and will consult with Powercor on the outcome of the ‘Energy Partner’ project.

17.3 Demand side engagement strategy and register

CitiPower updated the published Demand Side Engagement Strategy in July 2017. The strategy is designed to assist non-network providers in understanding CitiPower’s framework and processes for assessing demand management options. It also details the consultation process with non-network providers. Further information regarding the strategy and processes is available from:

https://www.citipower.com.au/our-services/demand-management/

https://www.citipower.com.au/media/3013/demand-side-engagement-strategy-v20_final.pdf

CitiPower have also published their Demand Side Engagement Interested Parties Register. The register was established in mid-2013. It currently allows interested parties to provide contact details and other relevant information, but will be enhanced in the near future to become an online form portal. To register as a Demand Management Interested Party, please email the following:

- DMInterestedParties@citipower.com.au

In 2018, no formal submissions from non-network providers were received however thirty-two entities registered.

18 Information Technology and communication systems

This section discusses the investments we have undertaken in 2018, or plan to undertake over the forward planning period 2019-2023, relating to information technology (**IT**) and communications systems.

18.1 Security Program

Our IT security program continues to refine and update our response to the ever-changing risk landscape that is unique to digitalised utility networks. Our ongoing program of works introduces increasingly sophisticated processes and systems that align with our commitment to proactively identify security threats and reduce information security vulnerabilities.

In 2018 we built on work in 2017 in developing a security program of work as well as introducing a number of changes identified as essential by the Australian Signals Directorate (**ASD**) and similar frameworks. These changes address targeted cyber intrusions (e.g. executed by advanced persistent threats such as foreign intelligence services), ransomware and external adversaries with destructive intent, malicious insiders, business email compromise and industrial control systems.

During the forward planning period we will continue to invest in protecting our network and customer information from increasingly sophisticated and persistent cyber threats. We will continue to co-ordinate security initiatives in line with industry standards such as National Energy Reliability Corporation Critical Infrastructure Protection (**NERC CIP**) and ASD recommendations to introduce additional protection to our systems. A key part of the program is to provide effective security between our Operational Technology and IT systems and enhancing security monitoring.

Furthermore, we will undertake IT security initiatives, through our best practice program, focusing on the capabilities of identify, detect, monitor, protect and govern. This program seeks to maintain our current capability and proactively look forward to new and emerging threat protection.

18.2 Currency

We routinely undertake system currency upgrades across the IT landscape in line with vendor software release life cycles and support agreements. These refresh cycles are necessary to ensure system performance and reliability are maintained and that the functional and technical aspects of our systems remain up-to-date.

In 2018 we completed a number of activities including to:

- enhance the Fault Detection Isolation and Restoration system (**FDIR**), to ensure network faults remain visible and actionable in real time, allowing us to reduce and averter outages;
- establish an Electricity Distribution Network Access Register (**EDNAR**), to ensure outage systems and customer outage notifications are unified and operate seamlessly;

- establish a Data Platform to manage critical Network Testing and Inspection Results;
- implement statutory changes to SAP HR Payroll data (annual obligation);
- update the Market Systems suite to meet ‘Power of Choice’ obligations.

During the forward planning period, we will continue to maintain the currency of our systems so that we can continue to provide fully supported systems that underpin the operation of our network and core business activities, including Billing, the Enterprise Service Bus, Meter Data, People Management, Reporting & Analytics Data, Workforce Mobility, Finance and Planned Notifications functionality. Other key systems due for life cycle replacement include commencing an upgrade to the SAP system that was originally installed in 1996.

18.3 Compliance

We are focused on ensuring that, as regulated businesses, our IT systems support all regulatory, statutory, market and legal requirements for operating in the National Electricity Market (**NEM**). This is achieved via investment in systems, data, processes and analytics to provide the functionality and reporting capability to efficiently comply with statutory and regulatory obligations.

In 2018, we reconfigerated the meter data management system and associated market transaction suite. This was done to facilitate the ‘Power of Choice’ program mandated by the Australian Energy Market Commission (**AEMC**) through changes to the National Electricity Rules (**rules**). The Power of Choice program seeks to provide consumers with more opportunities to make informed choices about electricity products and services.

Other initiatives involve making changes to system and data controls to ensure customer, employee and asset data is hosted in Australia and ensuring systems and processes comply with strengthened obligations for life support customers. Changes to ensure compliance with AMI estimated data and change request objection requirements were also undertaken.

Enterprise Management enhancements were also implemented to support compliance and regulatory obligations for Finance, Payroll and Regulation reporting.

We are also implementing 5 minute settlement, under which the settlement period for the electricity spot price is altered from 30 minutes to 5 minutes. The first stage was met with the provisioning of advanced interval meters capable of recoding 5 minute data from December 2018.

To continue to comply with statutory and regulatory obligations during the forward planning period, we will continue to implement 5 minute settlement. Under this project we will equip our systems to manage significant increases in data. The scope of this project includes enhancing storage to handle significantly more data, changes to system architecture (e.g. Market Transaction System (**MTS**), Enterprise Edition (**IEE**), CIS/OV, Utility IQ (UIQ), Salesforce, SAP) as well as business and operational processes (e.g. billing, contract centres, reporting, network, AMI Operations and network analytics).

Compliance will also be maintained through automation of changes to • Distribution Loss Factor (**DLF**) and Transmission Node Identity (**TNI**) values for all connection points on our systems.

Compliance obligations will also be met through enhancements to our Vegetation Management system and strengthening of our Technology Security systems.

18.4 Infrastructure

We have an ever-growing need to store and recall data and information and to support applications, processes and functions within our IT systems.

To support this, IT infrastructure must be refreshed to meet technical currency requirements and pro-actively manage maintenance of the IT infrastructure to meet service level requirements.

In 2018, we undertook technical refreshes, server hardening, firmware updates, capacity uplifts and upgrading of firewalls and IT environments in accordance with our IT infrastructure life cycles.

We are also implementing a strategy to move some key and supporting applications to the cloud. This will provide us with greater ability to scale our IT capabilities and reduce reliance on infrastructure in future.

During the forward planning period, we will focus on upgrading our underlying infrastructure that supports the IT environments to ensure ongoing capacity, performance and availability to ensure continuity of service and a comprehensive business continuity capability.

18.5 Customer Enablement

The customer engagement stream incorporates our response to ongoing changes and demands from our customers for greater access and greater choice in electricity services.

In 2018, we delivered:

- changes mandated as part of the Metering Contestability initiative;
- improvements to data management, data quality resulting in better compliance;
- the ability for greater volumes of customer transfers between retailers;
- improvements/efficiencies to our connections process(es);

- improvements to our online customer experience and making it easier to find information;
- provision of more consistent and accurate outage information to customers.

In the forward planning we will continue to proactively respond to anticipated industry and regulatory changes, including those that are designed to encourage greater demand side participation as well as allowing customer's access to their data. We will continue to perform the necessary upgrades to our billing system, to provide continued assurance of accurate and timely billing for our customers. Improvements to our corporate website will also ensure our customers can find the information they need, when they need it.

18.6 Other communication system investments

To facilitate and maintain the protection and control of the network, we have continued to invest in Supervisory Control and Data Acquisition (**SCADA**) and associated network communication and control equipment. This is used to monitor and control the distribution network assets, including zone substations and feeders.

In 2018, we have continued to invest in SCADA, in particular:

- working to reduce dependency on copper supervisory cables with the upgrade of street light control to AMI Network control and transitioning control and protection on selected services;
- modernising the communications network and transitioning protection and SCADA services from mostly aerial copper supervisory cables to optical fibre and private IP/Ethernet network infrastructure;
- initiating replacement programs for aged remote telemetry units (**RTU**s) and associated Local/ Metropolitan Area Networks (**LAN**/ **MAN**) assets in zone substations to continue reliable monitoring of primary and second equipment;
- selectively trialled an 4G Upgrade program for ACR Pole Top Controller to improve wireless communications reliability supporting Fault Detection, Isolation and Restoration (**FDIR**) schemes.

Over the forward planning period, our investment in SCADA will continue to increase, consistent with the growth and complexity of the network. Our SCADA expenditure will continue to modernise the communications network and ensuring adequate capability and capacity by installing larger systems.

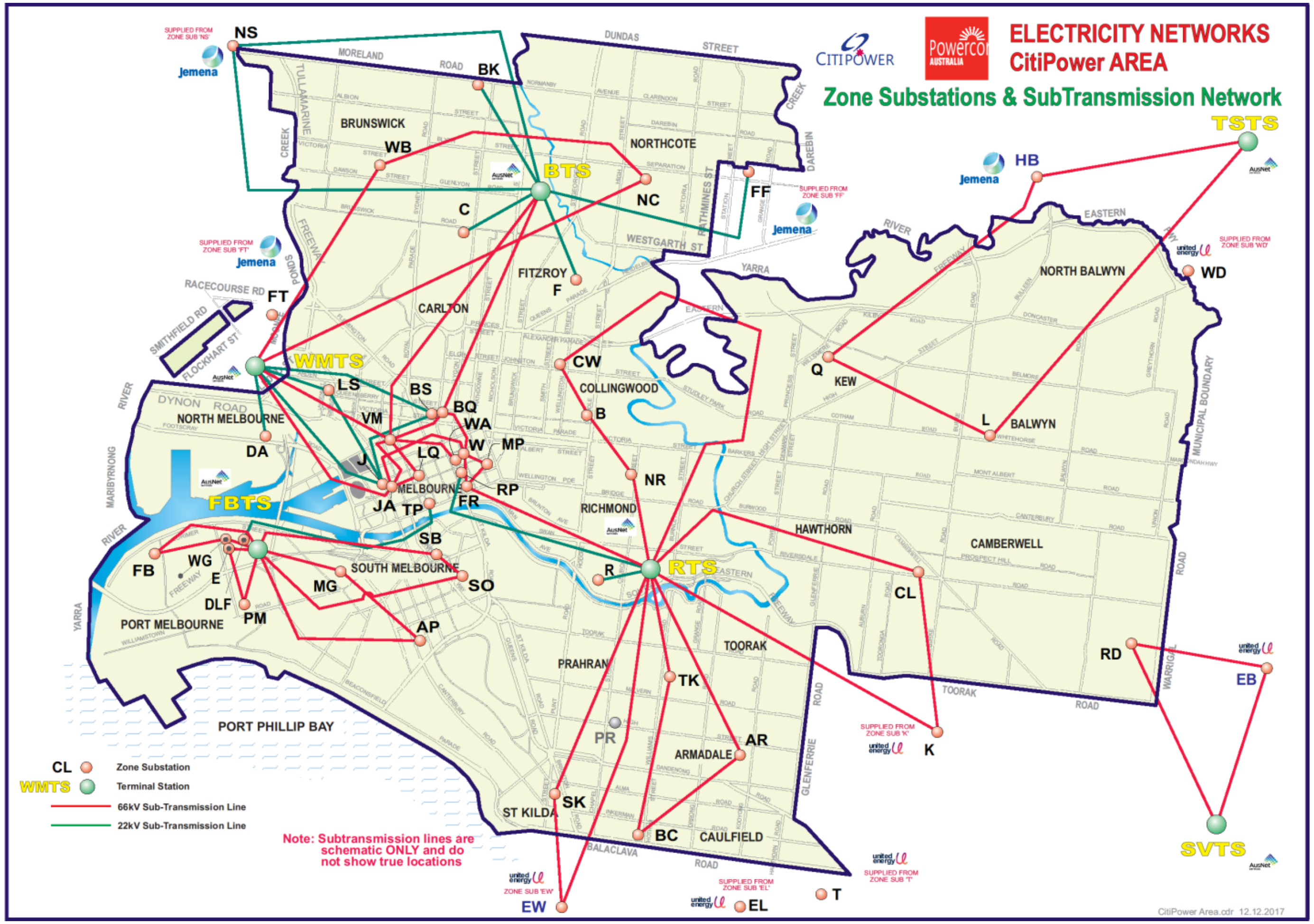
In addition, we will continue to replace old communications systems with newer up-to-date systems. In some cases, this will be to address technical obsolescence where the manufacturer no longer supports the equipment, which we are no longer able to upgrade and there is a reduced pool of skilled workers able to maintain the system.

We will also modernise systems that rely on communications systems. For example, as Telstra is intending to switch off its 3G network, we will upgrade remote communications devices using the 3G network, such as Automatic Circuit Reclosers (**ACR**s) and switches, to 4G and 5G.

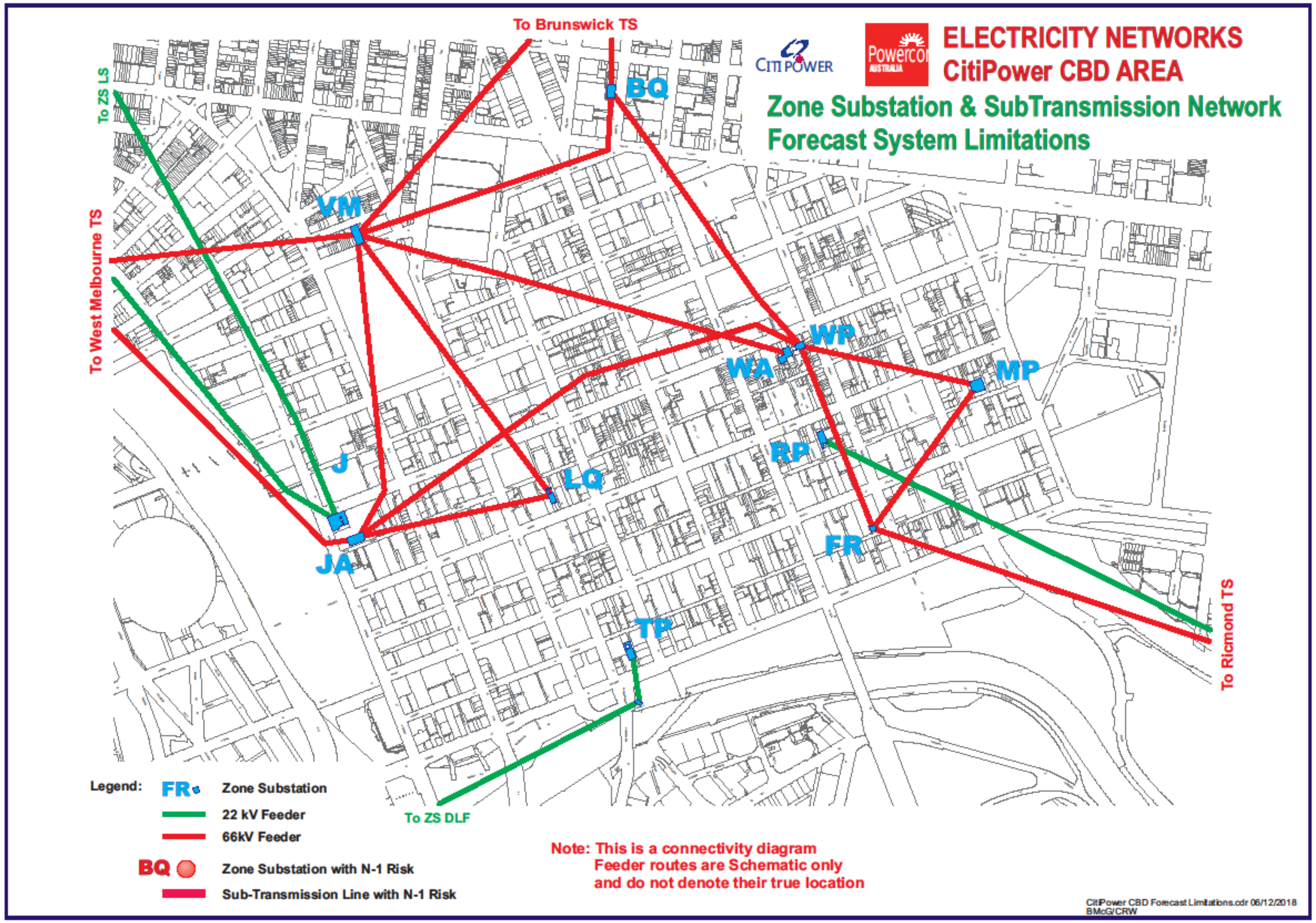
Furthermore, we will utilise new technologies, where appropriate and if it aligns with our strategy, such as the Internet of Things (**IoT**), and continue to leverage existing capabilities and AMI smart meter functionality.

Appendix A Maps

A.1. CitiPower area zone substations and sub-transmission lines

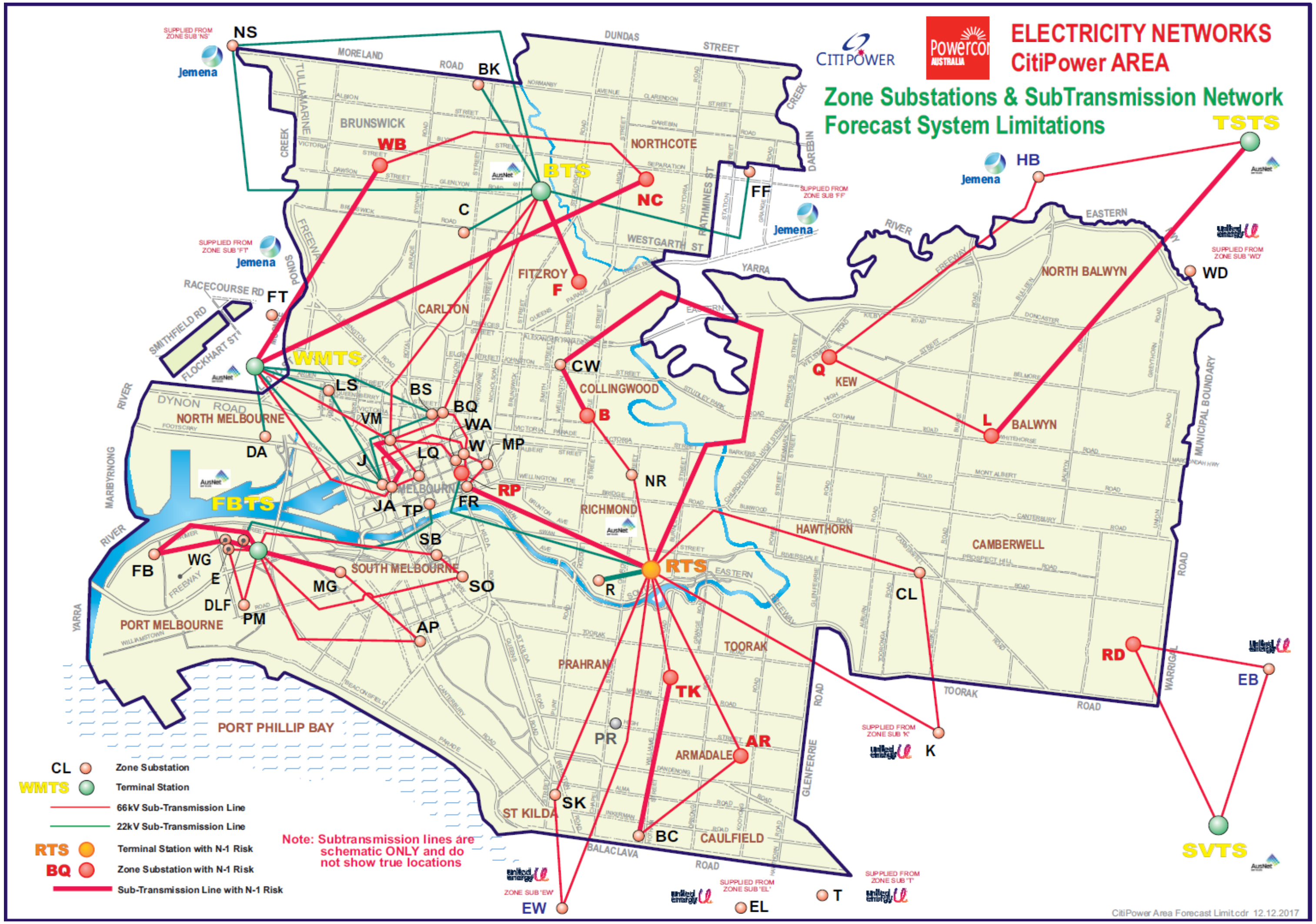


A.2. CBD area zone substations and sub-transmission lines

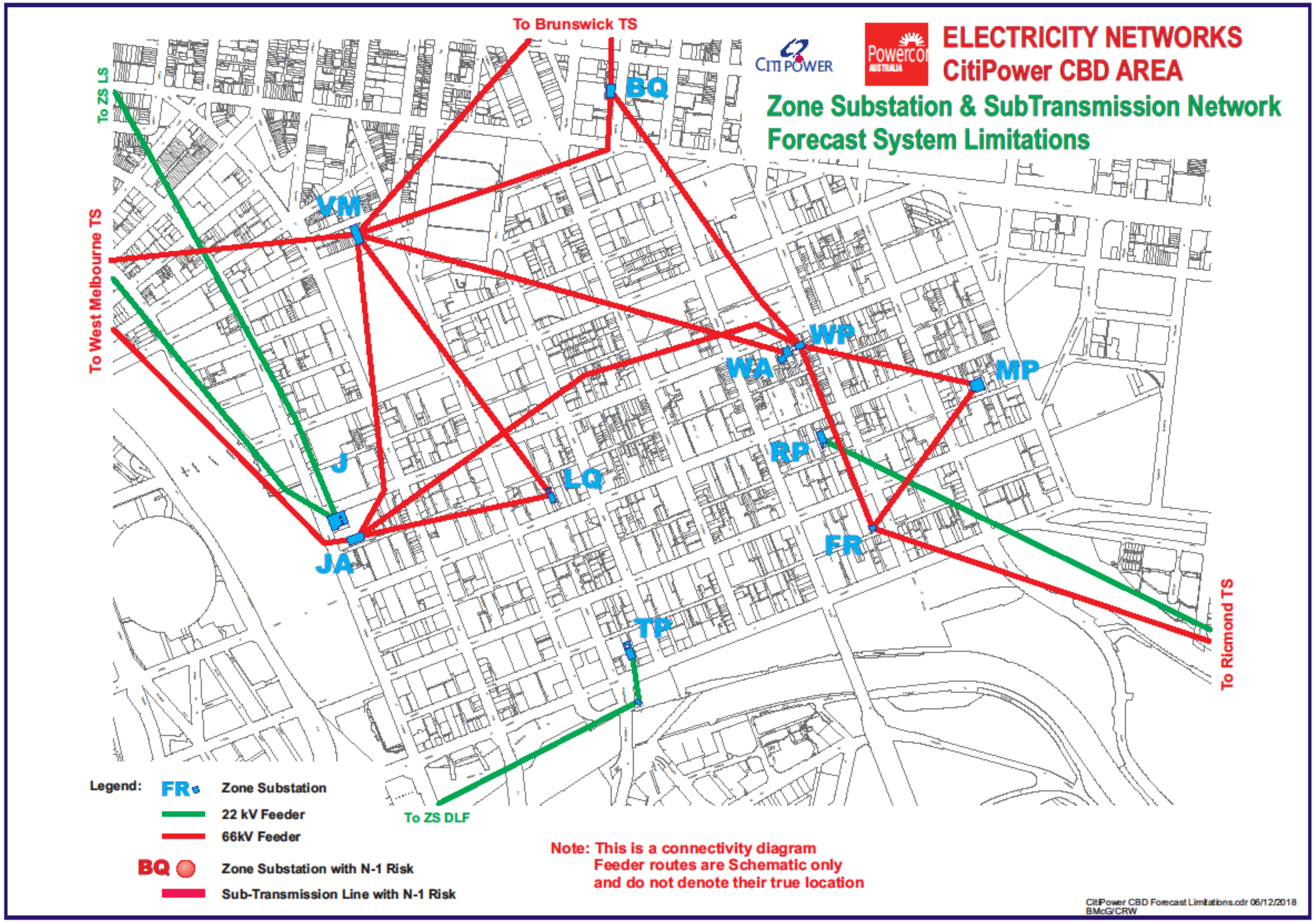


Appendix B Maps with system limitations and assets to be retired or replaced

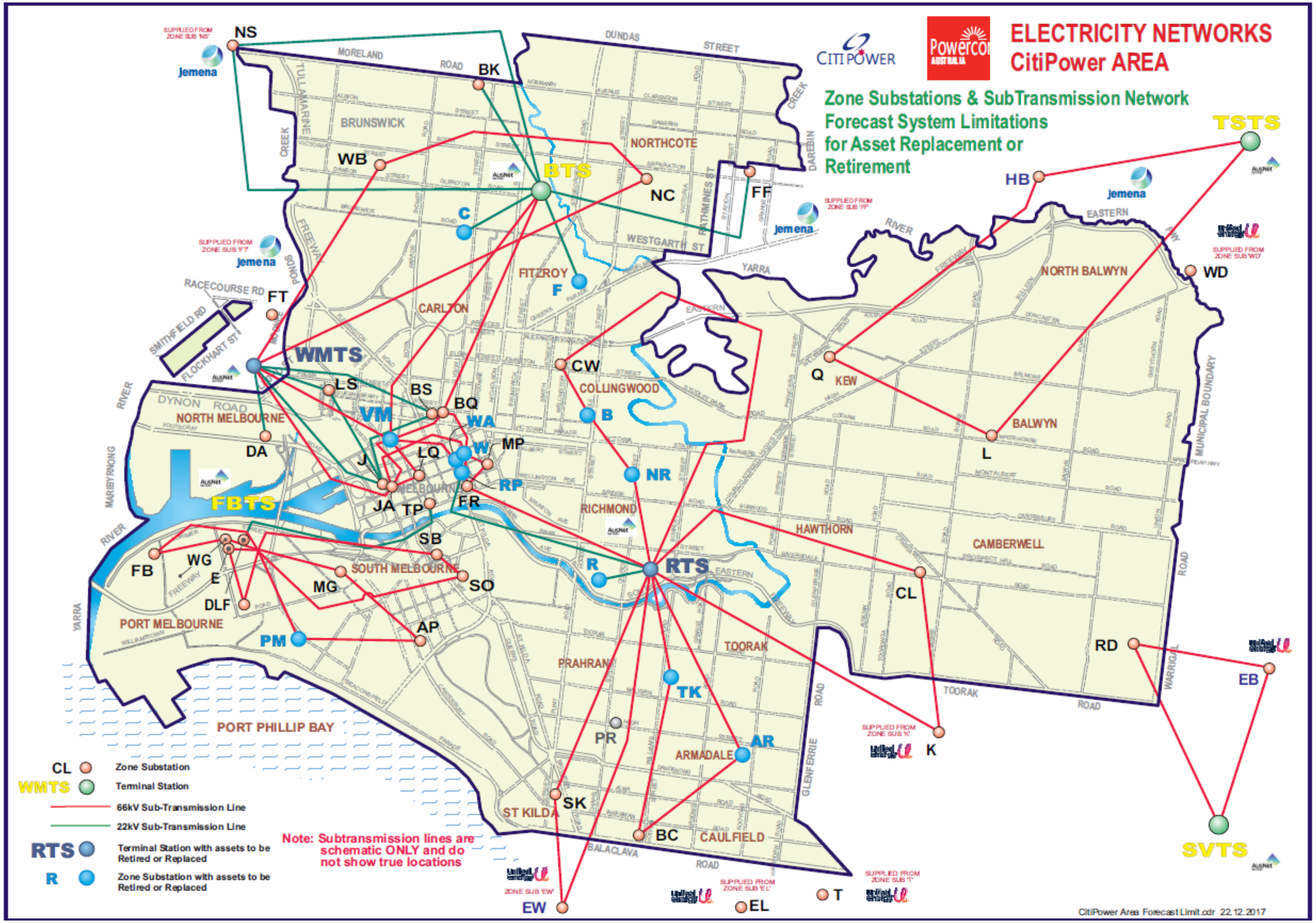
B.1. CitiPower area map with forecast system limitations



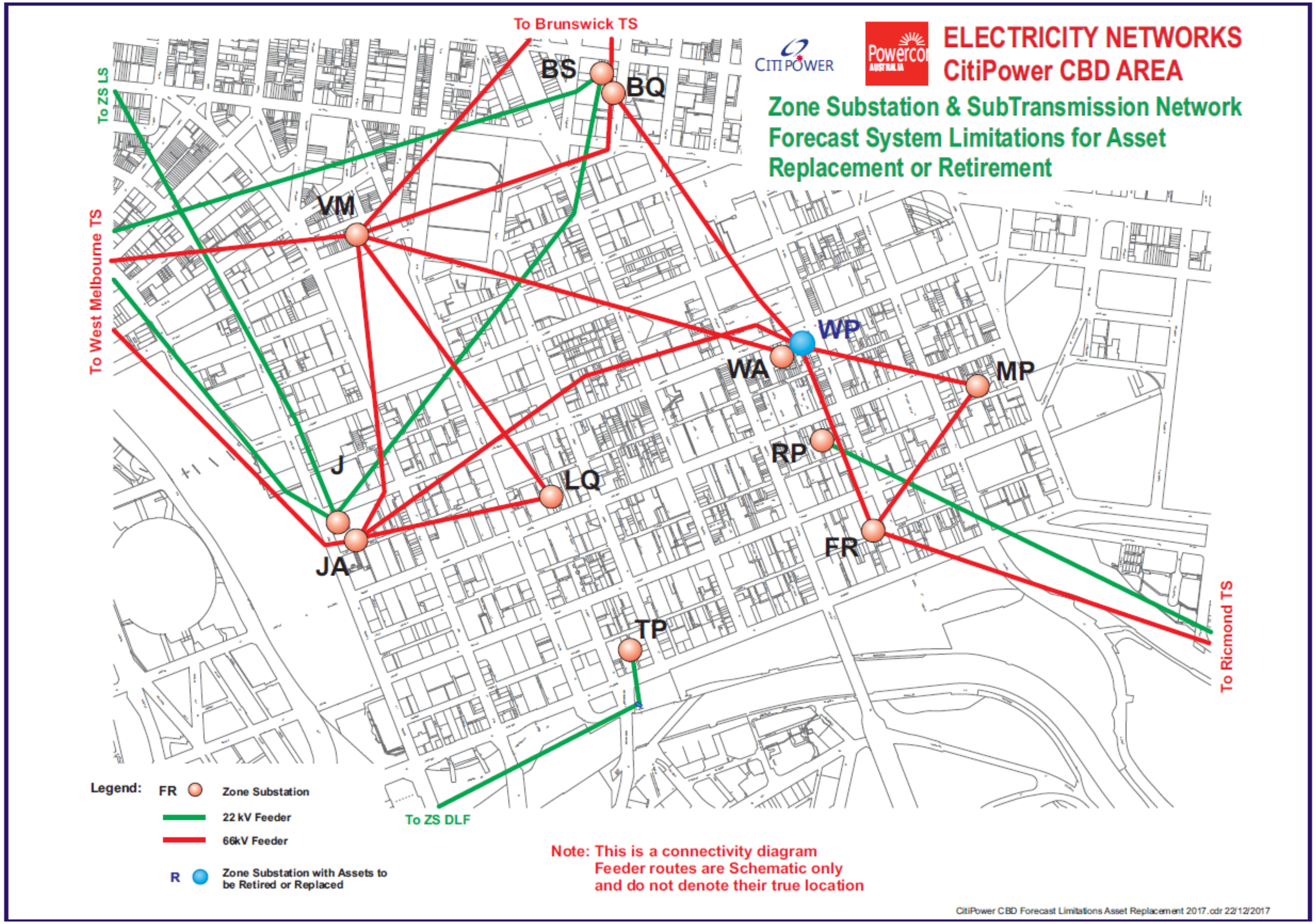
B.2. CBD area map with forecast system limitations



B.3. CitiPower area map with assets to be retired or replaced



B.4. CBD area map with assets to be retired or replaced



Appendix C Glossary and abbreviations

C.1. Glossary

Common Term	Description
kV	kilo Volt
Amps	Ampere
MW	Mega Watt
MWh	Mega Watt hour
MVA	Mega Volt Ampere
Firm Rating	The cyclic station output capability with an outage of one transformer. Also known as the N-1 Cyclic Rating.
N Cyclic Rating	The station output capacity with all transformers in service. Cyclic ratings assume that the load follows a daily pattern and are calculated using load curves appropriate to the season. Cyclic ratings also take into consideration the thermal inertia of the plant.
N-1 Cyclic Rating	The cyclic station output capability with an outage of one transformer.
Capacity of Line (Amps)	The line current rating which takes into consideration the type of line, conductor materials, allowable insulation temperature, effect of adjacent lines, allowable temperature rise and ambient conditions. It should be noted that CitiPower operates many types of underground cables in its sub-transmission system. The different types of underground cables have varying operating parameters that in turn define their ratings.
MVA above either WCR or SCR	The amount of demand forecast to exceed the Winter Cyclic Rating or the Summer Cyclic Rating.
% Above Capacity	The percentage by which the forecast maximum demand exceeds the N-1 cyclic rating.
Energy at risk	The amount of energy that would not be supplied if a major outage of a transformer or sub-transmission line occurs at the station or sub-transmission loop in that particular year, and no other mitigation action is taken.
Annual hours per year at risk	The number of hours in a year during which the 50^{th} percentile demand forecast exceeds the zone substation N-1 Cyclic Rating or sub-transmission line rating.

C.2. Zone substation abbreviations

Abbreviation	CitiPower Zone Substation	Abbreviation	CitiPower Zone Substation
AP	Albert Park	**NT**	Newport (Jemena Asset)
AR	Armadale	**MG**	Montague
B	Collingwood	**MP**	McIllwraith Place
BC	Balaclava	**NC**	Northcote
BK	Brunswick	**NR**	Nth Richmond
BQ	Bouverie Queensberry	**PM**	Port Melbourne
BSBQ	Bouverie St/Bouverie Queensberry	**PR**	Prahran
C	Brunswick	**Q**	Kew
CL	Camberwell	**R**	Richmond
CW	Collingwood	**RD**	Riversdale
DA	Dock Area	**RP**	Russell Place
DLF	Docklands	**SB**	Southbank
E	Fishermans Bend	**SK**	St Kilda
F	Fitzroy	**SO**	South Melbourne
FB	Fishermans Bend	**TK**	Toorak
FR	Flinders/Ramsden	**TP**	Tavistock Place
J	Spencer Street	**VM**	Victoria Market
JA	Little Bourke Street	**W (switching station only)**	Waratah Place
L	Deepdene	**WA**	Celestial Avenue
LQ	Little Queen	**WB**	West Brunswick
LS	Laurens Street	**WG**	Westgate

C.3. Terminal station abbreviations

Abbreviation	Terminal Station (AusNet Services Asset)	Abbreviation	Terminal Station (AusNet Services Asset)
BTS	Brunswick	**SVTS**	Springvale
FBTS	Fishermans Bend	**TSTS**	Templestowe
RTS	Richmond	**WMTS**	West Melbourne

Appendix D Asset Management Documents

CitiPower document references are:

Asset management framework: CP-AMF-0001

Asset Management Plans - the following table lists the AMPs relating to key network assets:

Major Asset Group	Asset Management Plan	AMP No
Zone Substations	Zone Substation Transformers & Regulators	CP-AMP-04 PAL-AMP-04
	HV Circuit Breakers (66,22 & 11 kV)	CP-AMP-05 PAL-AMP-05
	Indoor HV switchgear	CP-AMP-06
	Zone Substation – Instrument transformers	PAL-AMP-19
	Surge Arresters	PAL-AMP-15
	Zone Substation – Cooling Systems	CP-AMP-10
	Zone Substation Building & Property	CP-AMP-30 PAL-AMP-51
Distribution Substations & Switchgear	Distribution Substations	CP-AMP-09 PAL-AMP-41
	Distribution Voltage Regulators	PAL-AMP-13
	Automatic Circuit Recloses	PAL-AMP-30
	Distribution HV Switches (Outdoor, Load Breaking)	PAL-AMP-40
Secondary, protection & Earthing Systems	Protection Equipment (Relays)	CP-AMP-11 PAL-AMP-11
	Earthing Systems	CP-AMP-30 PAL-AMP-50
Overhead Lines	Pole Top Structures	CP-AMP-03 PAL-AMP-03
	Poles	CP-AMP-02 PAL-AMP-02
	Overhead conductors – Sub transmission, HV & LV, excluding LV Services	CP-AMP-07 PAL-AMP-07
	Fault Indicators – Overhead Lines	PAL-AMP-18
	High Voltage Fuses	CP-AMP-12 PAL-AMP-12
Underground Lines	Underground Cables	CP-AMP-01 PAL-AMP-01
	Pits and Pillars	CP-AMP-33