Zone substation Capacitor Banks

AMS – Electricity Distribution Network

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1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' electricity distribution network. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of zone substation capacitor banks.

The strategy covers the 62 capacitor banks located in zone substations. The most common type being the 22kV 6 MVAr capacitor banks ,that contribute to 54.8% of the capacitor bank population.

Most capacitor banks are in reasonable health 67.7% of the total population are either in a "Very Good" condition (C1), "Good" condition (C2) or "Average" condition (C3). The remaining 32.3% of the total population are either in "Poor" condition (C4) or "Very Poor" condition (C5). The current period Rapid Earth Fault Current Limiter (REFCL) program is replacing a number of these poorer condition capacitor banks, as they are unable to have their neutral points isolated.

Capacitor bank network criticality studies, combined with condition, has identified a number of major station redevelopment sites where risk warrants wholesale replacement. After taking into account these station redevelopment projects and REFCL related replacements, only a smaller condition based component replacement program, such as selected capacitor cans and series reactors, is recommended for the 2022-26 regulatory period.

Proactive management of zone substation capacitor banks condition based maintenance and replacement practice is required to ensure that stakeholder expectations of cost, reliability, safety and environmental performance are met. The summary of proposed asset strategies is listed below.

1.1 Asset Strategies

1.1.1 New Assets

- Continue to purchase capacitor banks to the latest specification with capacitors internally fused and capacitor bank detuned against harmonic resonance.

1.1.2 Maintenance

- Continue maintaining capacitor banks in accordance with PGI 02-01-04.
- Monitor and review settings of capacitor bank neutral unbalance , auto operation in order to minimise nuisance tripping and mal operations
- Continue with annual thermo-vision scans of all capacitor banks (as part of station scan and as per SMI 67-20-01).

1.1.3 Spares

- Maintain strategic spares holding of capacitor cans and series reactors as per spare holding policies

1.1.4 Replacement

- Replacement of poor condition critical capacitor banks during major redevelopment projects
- Selective replacement of capacitor cans and series reactors in poor condition at capacitors banks at BWN, FTR, FGY, PHI,TT, PHM, BRA, LGA, CYN , EPG

2 Introduction

2.1 Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of zone substation capacitor banks installed in zone substations in AusNet Services' Victorian electricity distribution network. This document is intended to be used to inform asset management decisions and communicate the basis for activities.

In addition, this document forms part of our Asset Management System for compliance with relevant standards and regulatory requirements. It is intended to demonstrate responsible asset management practices by outlining economically justified outcomes.

2.2 Scope

This asset management strategy applies to all 22 kV, 11 kV and 6.6 kV capacitor banks located in zone substations and capacitor bank stations within the AusNet Services' electricity distribution network. There are no capacitor banks that operate at the 66 kV sub transmission voltage level.

The key components of the capacitor banks covered by this strategy are capacitor cans and series inrush reactors.

The associated capacitor bank circuit breakers, step switches and neutral current transformers and capacitors outside of zone substations are covered under other strategies ;

- AMS 20-54 Circuit breakers:
- AMS 20-63 Instrument Transformers
- AMS 20-69 Pole Top Capacitors

2.3 Asset Management Objectives

As stated in *AMS 01-01 Asset Management System Overview*, the high-level asset management objectives are:

- Comply with legal and contractual obligations;
- Maintain safety;
- Be future ready;
- Maintain network performance at the lowest sustainable cost; and
- Meet customer needs.

As stated in *AMS 20-01 Electricity Distribution Network Asset Management Strategy*, the electricity distribution network objectives are:

- Improve efficiency of network investments;
- Maintain long-term network reliability;
- Implement REFCL's within prescribed timeframes;
- Reduce risks in highest bushfire risk areas;
- Achieve top quartile operational efficiency; and
- Prepare for changing network usage.

3 Asset Description

3.1 Asset Function

Capacitor banks in zone substations provide voltage support by compensating reactive power and improved stability to the sub transmission and distribution networks. They also assist in minimising system power losses and maximising utilisation of transformers and HV lines. When a capacitor bank fails, the VAR (reactive power) support provided at the zone substation is lost, and this gives rise to increased system losses and restricted ratings mainly on lines and zone substation transformers. It lowers the effective station loading capability.

3.2 Asset Population

AusNet Services has a total of 62 capacitor banks in service installed in AusNet services zone substations as at end 2017. The population of capacitor banks by bank nominal rating is given in figure 1. Capacitor bank ratings range from 1.5MVAr to 12.5MVAr. The most common sizes are 6 MVAr (54.8%) and 12 MVAr (27.4%) contribute to about 82% of the total population. The service voltage of capacitor banks are 22kV except in two stations, namely YN and YPS operating at 6.6 kV and 11kV respectively.

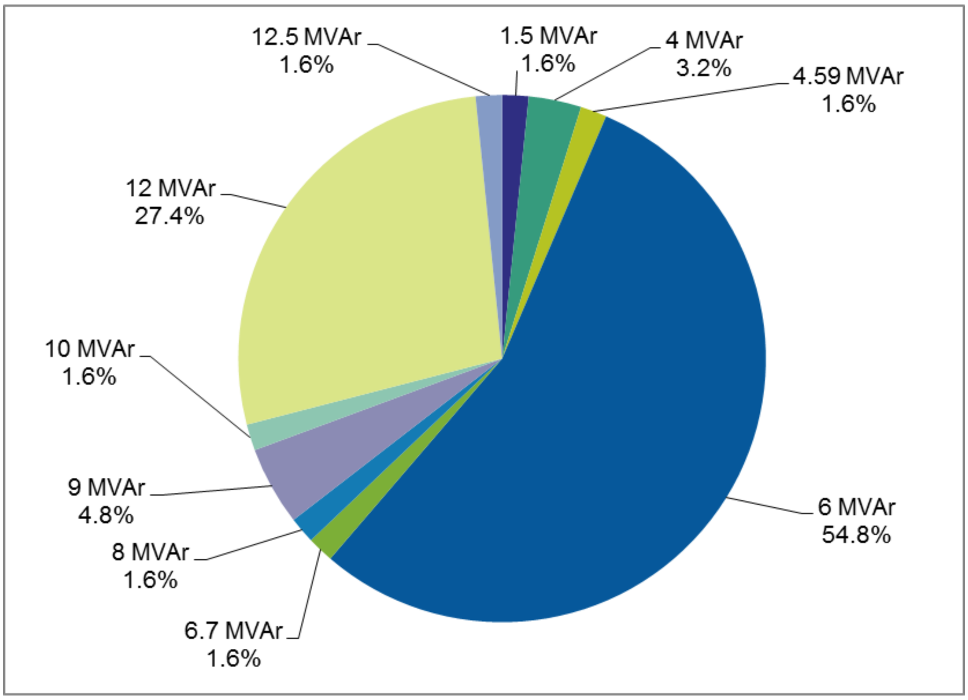

Figure 1 – Population of capacitor banks by nominal rating in MVAr

Figure 2 below illustrates various types of capacitor bank enclosures available in zone substations. Approximately 63% of the capacitor banks are outdoor - fenced type and approximately 29% are of outdoor caged design adopted to minimise capacitor bank faults due to fauna.

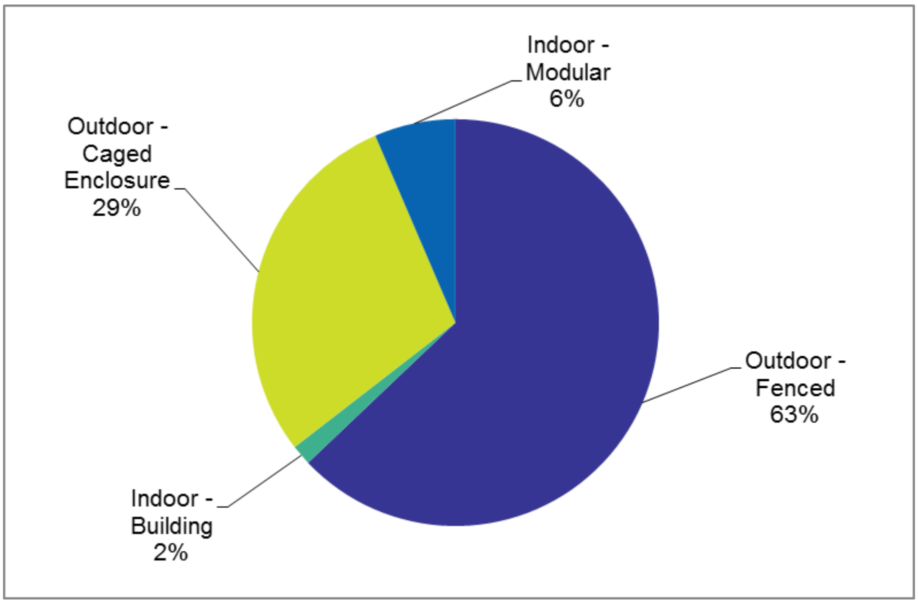

Figure 2 – Capacitor Banks by Enclosure Type

C-I-C

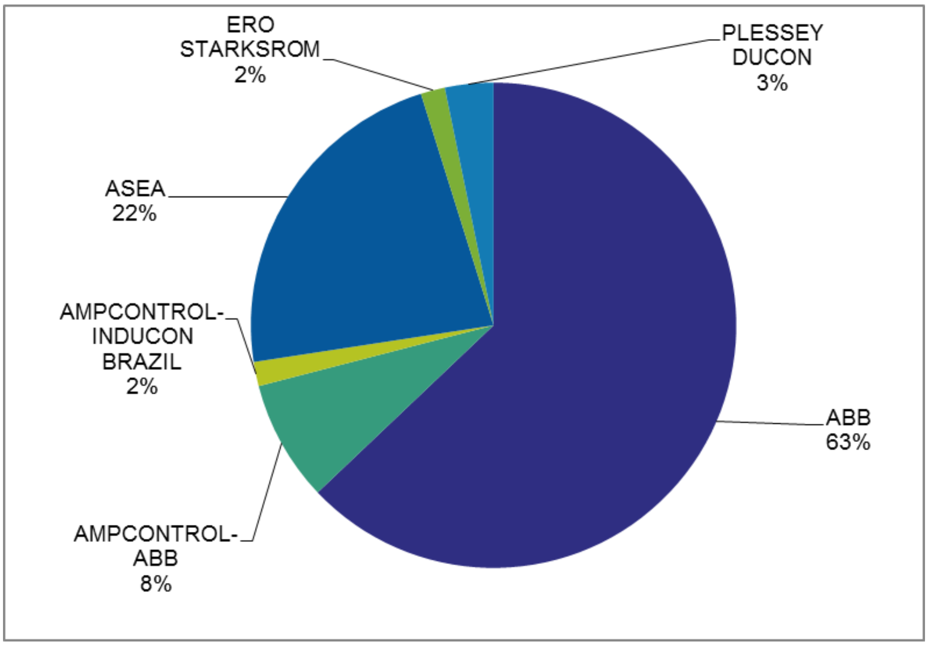

Figure 3 – Capacitor banks by Capacitor Cans Manufacturer

Series reactors manufacturer types used in capacitor banks are given in Figure 4. There are 2 construction types, the air cored type, used in outdoor installations and iron cored type , used in the indoor installations.

The largest population are the air cored wound type of Trench make which consists of approximately 59.7% of the capacitor bank population. Their series reactance is higher ranging from 14 -60 mH in order to detune capacitor banks against harmonic resonance. The smaller population is Endurance and Tyree reactors which are also air cored cast resin construction and used in about 19.4 % of capacitor banks. They all have a fixed value of 150 µH used as inrush reactors in capacitor banks. [C-I-C] are the oldest of the series reactors and they are oil filled tank type have larger reactance similar [C-I-C] reactors are installed in Ampcontrol capacitor banks contribute to about 8.1 % of the capacitor banks and they are air cored and resin coated wound type.

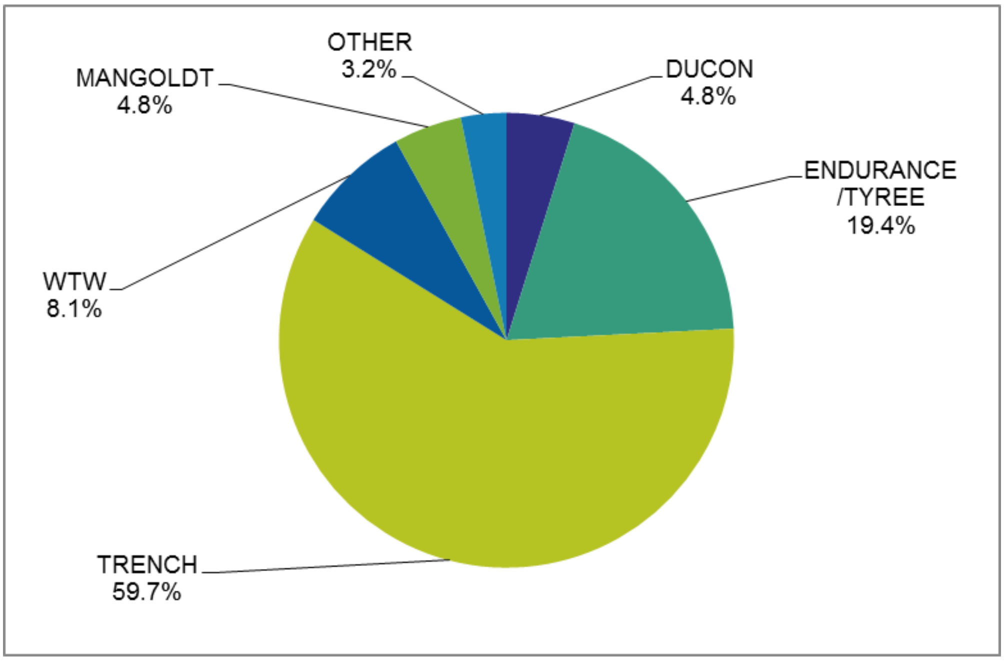

Figure 4 – Capacitor banks by Series Reactor Manufacturer

3.3 Asset Age Profile

Average age of capacitor banks is 19.7 years with oldest being 53 years at WT capacitor bank. The service age profile of zone substation capacitor banks against capacitor can manufacturer and series reactor manufacturer are shown in figure 5 and 6 respectively.

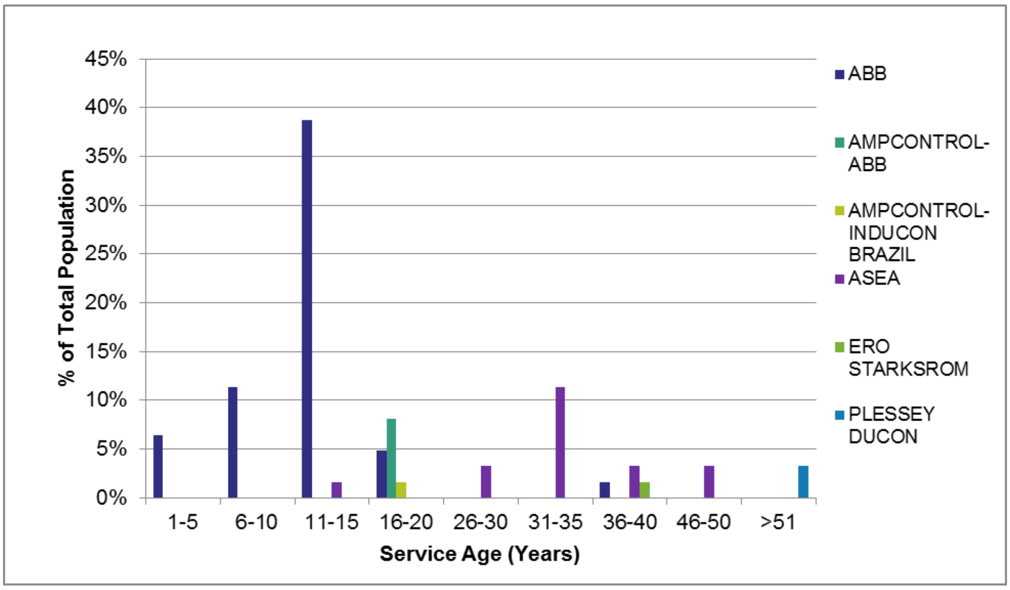

Figure 5 – Age Profile of Capacitor banks by Capacitor Can Make

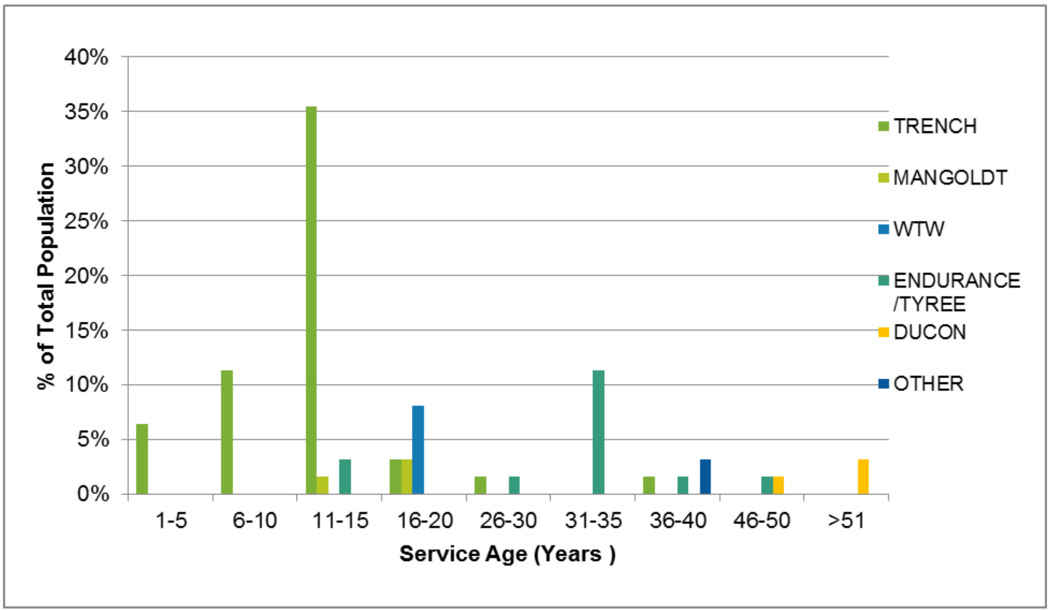

Figure 6 – Age Profile of Capacitor banks by Series Reactor Make

C-I-C

3.4 Asset Condition

Table 1 provides the condition assessment criteria of Capacitor banks in zone substations.

C-I-C

Condition profile of Capacitor banks is shown in Figure 7.

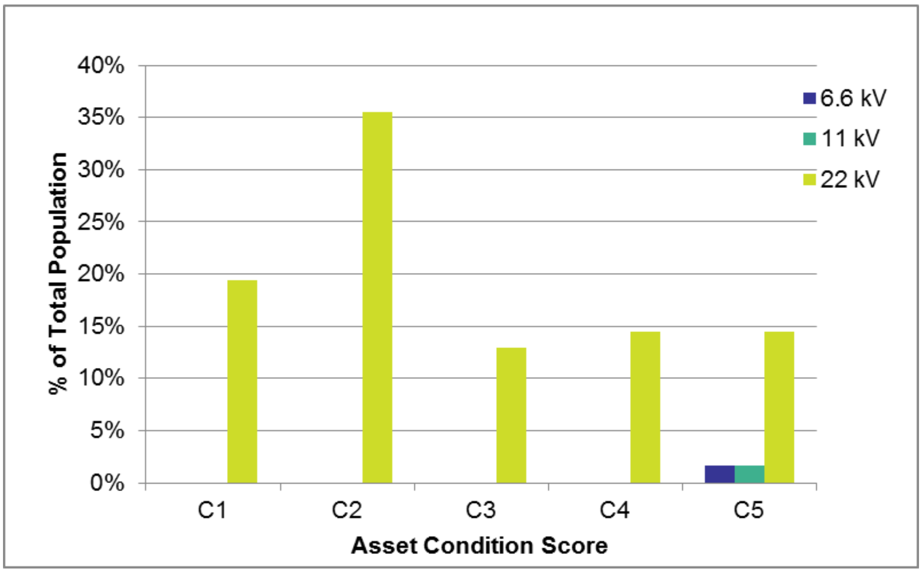

Figure 7 – Condition Profile of Capacitor banks

Approximately 14.5% and 17.7% of capacitor banks in zone substations are either in C4 and C5 asset condition respectively. These capacitor banks include the 6.6kV and 11kV capacitor banks at YN and YPS 11kV switchyard. These capacitor banks have poor condition: [C-I-C].

3.5 Asset Criticality

Asset Criticality of zone substation capacitor banks is lower than other assets types due to lower direct community impact, safety impact, and collateral damage impact . Malfunction or non-functioning of a capacitor bank affects mainly customer power quality and increase in power losses of the network. A few capacitor banks mentioned below become important during certain time of the year to maintain the voltage quality of customers but typically their average criticality level is low. Capacitor bank criticality is often re-assessed as part of detailed system studies for station major replacement and redevelopment projects.

The most common type of capacitor bank failure is failure of a capacitor can or cans or a series reactor failure. This causes the capacitor bank to be out of service till the cans are replaced as protection systems are unable to cope with the imbalance in phase currents. During this time the voltage support provided by the capacitor bank would not be available and as a result power factor will not be optimised and thus electrical losses will be higher. The stations that have capacity constraints in the event of a failure of a respective capacitor bank and at times of peak demand are Phillip Island (PHI), Wonthaggi (WGI), LGA, Warragul (WGL) and Seymour (SMR).

3.6 Asset Performance

AusNet Services routinely analyses the root cause of unplanned work undertaken on capacitor banks and investigates all major failures, and tracks their effects on reliability and power quality to the customers.

3.6.1 Corrective Maintenance

All zone substation capacitor banks are subjected to routine maintenance in accordance with PGI 02-01-04 and relevant standard maintenance instructions (SMI).

Typical defects found during planned & unplanned maintenance inspections carried out in capacitor banks during the period 2015 -2018 are shown in Appendix 1.

- There are 37 defects found in capacitor banks during the period 2015 -2018 which is 0.15 failures /defects per yr /capacitor bank.
- Approximately 43.2% of the defects during the period 2015 -2018 are capacitor can related: Capacitor can failures (18.9%), neutral unbalance (2.7%), [C-I-C] capacitor can fuse failures (21.6%).
- Capacitor bank controller failures - 18.9%.
- [C-I-C] reactor failures - 5.4%.
- Step switch and other failures - 32.5%

4 Other Issues

4.1 Monitoring Capacitor Cans

Capacitor cans deteriorate with age, utilisation and voltage surges. This causes random out-of-balance alarms and, in some cases, tripping of the capacitor bank. In either event, measurement of capacitance and rebalancing between phases is required. Recently it was found another factor of increased capacitor can failures due to defective step switches, ex: PHI capacitor bank

Prior to the event, it is difficult to detect or prevent these failures without substantial investment (in routine capacitance testing, for example) or by over-design of the capacitor units. Corrective action is needed when capacitor banks trip on unbalance (normally due to the failure of packets within cans). Corrective work is sometimes needed due to flashovers caused by birds or small animals.

4.2 Indoor Capacitor Banks

Indoor capacitor banks have different issues compared to outdoor capacitor banks. The modern modular approach to capacitor bank design means more indoor capacitor banks are being offered by suppliers.

Due to the need for more compact devices, iron cored reactors are typically used. Experience has shown that this results in greater audible noise, and potential customer complaints, if not factored into station designs. Iron cored devices also produce extra vibration and have induced other asset failures Greater compactness results in higher electric stresses and magnetic fields and as such dust and surface cleanliness can becomes much more important than outdoors. The enclosed environment also reduces rate of heat loss and thermal stress of components is more evident.

4.3 REFCL

REFCL requires the neutral point of the 22kV capacitor banks to be isolated from earth. In older capacitor banks this is not possible without replacement of the capacitor bank. A number of capacitor banks are being replaced due to this reason at Myrtleford (MYT) Moe (MOE) and Wonthaggi (WGI), Benalla (BN) ,Bairnsdale (BDL), Belgrave (BGE), Eltham (ELM), Lilydale (LDL), Moe (MOE), Rubicon A (RUBA) , Sale (SLE), Wangaratta (WN) .

5 Risk and Option Analysis

The key drivers of this program are capacity constraints, supply power quality, reliability and safety and collateral damage risk to other components in capacitor banks.

Replacement of poor condition capacitor banks are economical when detailed studies have identified if the capacitor banks are critical. These studies off failure risks against total replacement costs are undertaken during station augmentation / major project redevelopment when capacity constraints, network stability risks and other constraints are considered in detail by network planners.

As such several poor condition capacitor banks will be replaced under station major redevelopment projects in 2021-25 due to poor condition and criticality considerations.

- Capacitor banks at Maffra (MFA), Watsonia (WT), Traralgon (TGN) and Warrigal (WGL)

For non-critical capacitor banks, most economic option is to hold adequate spares to attend random failures and by carrying out smaller condition based component replacement.

Analysis indicates proactive replacement of capacitor cans and series reactors based on “Very Poor” condition (mainly [C-I-C] can types and cracked series reactors of make [C-I-C] can at following capacitor banks is recommended under the EDPR 2021-25 program:

- Selective replacement of up to 10 capacitor cans and three series reactors in poor condition at capacitors banks at BWN,FTR, FGY, PHI, TT, PHM, BRA, LGA , CYN, EPG

6 Asset Strategies

6.1 New Assets

- Continue to purchase capacitor banks to the latest specification with capacitors internally fused and capacitor bank detuned against harmonic resonance.

6.2 Maintenance

- Continue maintaining capacitor banks in accordance with PGI 02-01-04.
- Monitor and review settings of capacitor bank neutral unbalance , auto operation in order to minimise nuisance tripping and mal operations
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- Maintain strategic spares holding of capacitor cans and series reactors as per spare holding policies

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Appendix 1 – Zone Substation Capacitor Bank Defects/Failures - 2015- 2018

C-I-C