Indoor Switchboards

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 indoor switchboards in AusNet Services' Victorian electricity distribution network.

There are 80 indoor switchboard bus systems installed within the AusNet Services' Zone substations. The majority of the switchboards operate at 22kV and are air insulated type. The older first and second generation switchboards constitute approximately 36.3% of the total population. The third generation switchboards constitute approximately 31.2% of the population and the fourth generation switchboards built to latest AS and international Standard constitute approximately 32.5% of the population. The fourth generation are fully type tested switchgear for arc flash protection.

Condition assessment shows approximately 87.5% of the total switchboard population are either in a "very good condition" (C1), "good condition" (C2) or "average condition" (C3). Approximately 12.5% of the total population are either in "poor condition" (C4, 8.7 %) or "very poor condition" (C5, 3.8 %). The poor and very poor condition switchboards are mainly first generation switchboards which are also technically obsolete.

The consequence of a switchboard failure was assessed based on community impact due to outages, safety and collateral damage risks. A risk assessment for switchboards was performed using combined AWB / spreadsheet based on quantitative analysis. The economic analysis recommended for the period 2022-26, that risk be managed through proactive procurement of strategic spare switchboards.

The proactive management of switchboards inspection, condition monitoring and replacement practice is required to ensure that stakeholder expectations of cost, safety, reliability 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 specify fully internal arc fault contained compartmentalised indoor switchboards with external venting; consider motorised racking of vacuum circuit breakers for new installations.

1.1.2 Inspection

- Continue annual non-invasive condition monitoring scans ultrasonic and TEV /PD testing to evaluate any internal partial discharges in switchboards locations

1.1.3 Maintenance

- Continue with scheduled preventative maintenance as per specific Standard Maintenance Instructions for each indoor switchboard type.
- Continue planned inspection of bus chambers of all indoor switchboards as per PGI 02-01-04

1.1.4 Spares

- Maintain strategic spares holding for each indoor switchboard make and model

- Procure strategic spare transportable modular switchboards complete with building and protection panels for emergency response.

1.1.5 Refurbishment

- Review arc flash risks and mitigation methods to reduce safety risk
- Consider options - install arc flash relays in second and third generation switchboards,
- Consider options - Retrofit replacement of minimum oil indoor CBs with indoor vacuum CBs
- Consider options - motorised CB racking for first and second generation indoor switchboards

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 indoor switchboards 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 indoor switchboards operating at 22kV, 11kV and 6.6kV located in AusNet Services zone substations. The switchboard includes the busbar, cable entry, overall compartment and arc control design and isolation and earth switch facilities.

The following associated assets that's are installed in indoor switchboard are covered by other strategies;

Circuit Breakers - refer to AMS 20-54.
Instrument Transformers - refer to AMS 20-63

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

Indoor type switchboards are used as an alternative to outdoor medium voltage substation switchyards based on combination of factors such as economic, safety, environmental, aesthetic and availability of space in zone substations.

Metal enclosed switchgear is installed either in switch room buildings or modular indoor switch rooms along with the associated protection, control, and monitoring and communication equipment.

3.2 Asset Population

AusNet Services has a total of 80 indoor bus bar systems installed in 39 zone substations (2017 RIN Category Analysis). One bus typically has 4 to 8 cubicle bays.

Medium Voltage (MV) indoor switchboards are classified into 4 different age Generation categories of vintage as summarised below.

I. The First Generation Switchboards are those are installed prior to 1970s and were built to older British Standards and have the highest safety risk of arc flash protection. Circuit breakers are oil type and operation is mostly done in open switchgear with no external arc venting.

II. The Second Generation MV switchgear are those that are installed between the late 1970s and 1998 and built to older version of AS 2067 or AS 2068. They have medium safety risk of arc flash protection. Circuit breakers are typically minimum oil type, fully metal enclosed with external arc venting but CB isolation by racking in and out has to done with CB cubicle door in open position.

III. Third Generation MV Switchgear are installed between 1998 and 2008, built to IEC60298 (1998) standards. These switchboards arc fault contained to older standard although some boards vented into the room. CB are vacuum type and operation is generally with closed CB cubicle doors. They have comparatively lower safety risk to operators.

IV. The Fourth Generation are those that are built to the latest AS62771.200 (2005) standard and installed after 2008. These switchboards are fully arc fault contained, type tested with external arc venting and considered safe for operation with closed cubicle doors.

A summary of the indoor switchboard population by voltage, vintage type & voltage, vintage type & bus insulation and vintage type & Manufacturer / Model is shown in Figures 1 to 4 respectively.

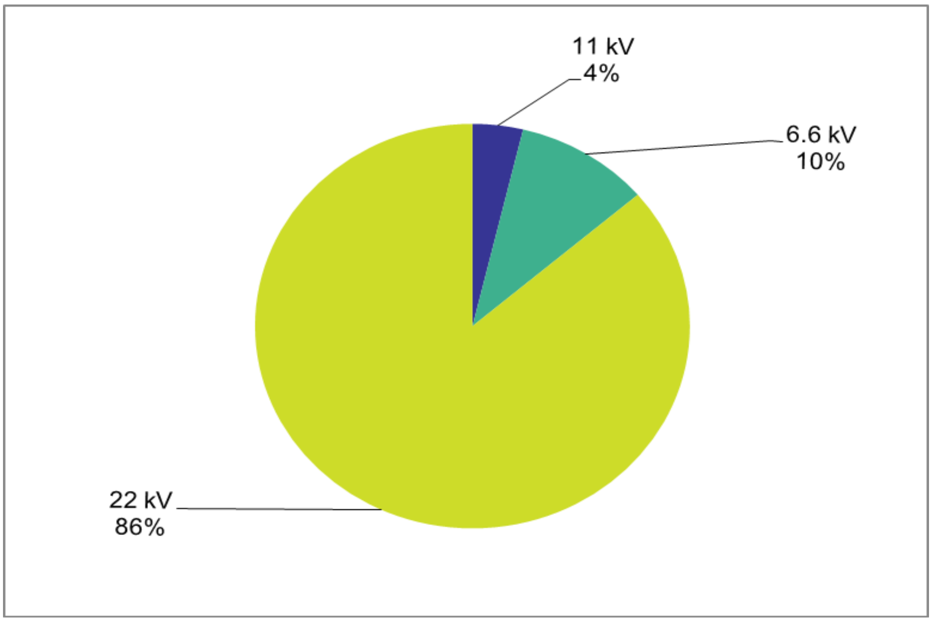

Figure 1 – Indoor switchboards by Service Voltage

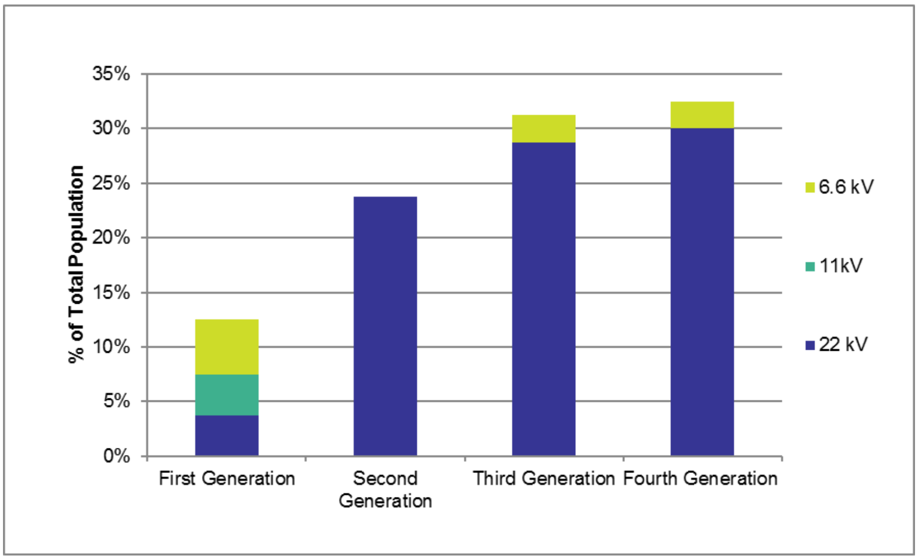

Figure 2 – Indoor switchboards by Vintage type and Service Voltage

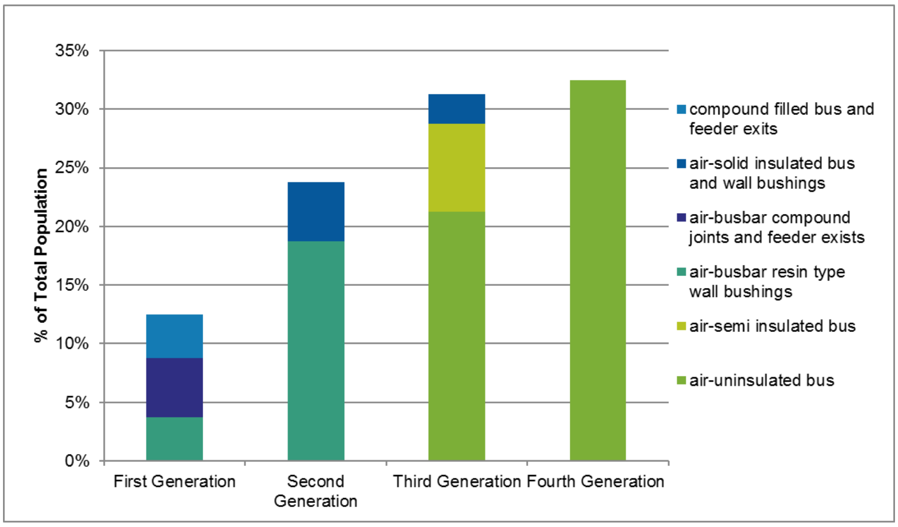

Figure 3 – Indoor switchboards by Vintage type and bus bar insulation

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3.3 Asset Age Profile

The average service age of indoor switchboard population is 21 years and the oldest being 68 years. Figure 5 & 6 shows the service age profile against service voltage and bus bar insulation type.

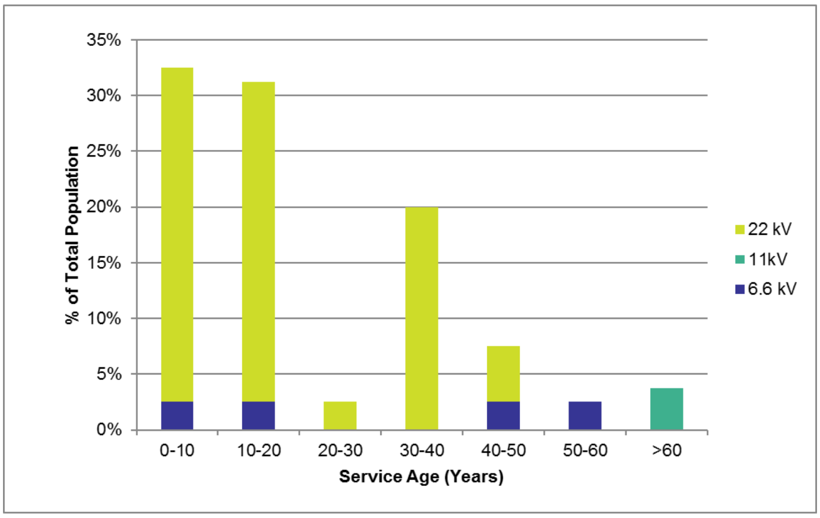

Figure 5 – Indoor switchboards Age Profile by Service Voltage

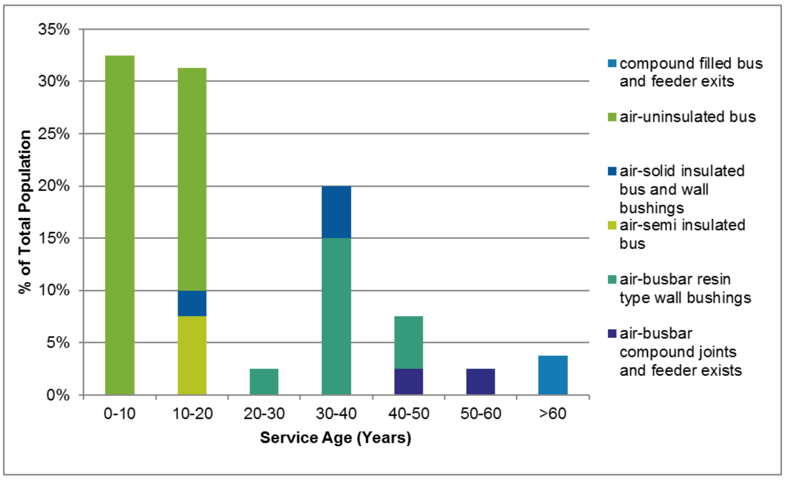

Figure 6 – Indoor switchboards Age Profile by bus bar insulation

The oldest indoor switchboard is located at MPS with compound filled bus bars and feeder exits and it is planned to be retired by 2019/20. The next oldest switchboards are located at open cut substations at MWN and YN substations. They are expected to be retired within the next 5-10 years.

All new indoor switchboards are of air uninsulated bus bar type while older types consist of mixture of either air or solid insulation of resin or compound filled types. It is noted that resin and compound filled insulation type switchboards have had major insulation failures in first generation type switchboards namely LYS and MPS substations.

3.4 Asset Condition

An indoor switchboard Health Score has been assessed for each indoor switchboard in the electricity distribution network.

Indoor switchboard Health Score are determined by considering the following factors.

I. Age
II. Observations
III. Bus bar insulation
IV. Building design
V. Measured condition (IR, PD, HV tests)
VI. Reliability factors

Indoor Switchboards

Asset Indices Methodology used by Distribution Network Operators in UK and NIE1 was used as a guidance to develop various factors to determine the Condition Score of Circuit Breakers in service.

Details on condition scoring methodology is given in Excel Work Book "ZSS Indoor Switchboard Condition Model".

The Table 1 provides a definition of the various condition scores and recommended action.

Condition Scoring Methodology			
Condition Score	**Condition Description**	**Summary of condition score**	**Remaining Life**
C1	Excellent	These SWBDs are generally less than 10 years old with air insulated bus bars and cable terminations built to the latest switchboard design. They are in good operating condition with no past history of defects or failures in enclosures, heating /dehumidification. Manufacturer support and spares are readily available. Fully compliant to current standards. Routine maintenance and continued condition monitoring is recommended.	>95%
C2	Very Good	This category includes SWBDs which are in better than average condition with air insulated bus bars and cable terminations for its service age and technology type. They may have some minor issues in enclosure heating failures and CB racking. They do not require intervention between scheduled maintenance nor do they show any trends of serious deterioration of condition. Manufacturer support and spares are available.	70%
C3	Good/ Average	This category includes SWBDs which are with an average condition for its respective service age and technology type. They may have developed few issues/ few minor failures due to in service related deterioration. These boards typically require increased maintenance. Spares are being used to replace damaged components such as bus bar and feeder insulator spouts and manufacturer support is just sufficient but deteriorating. These SWBDs are showing signs of deterioration in condition.	45%
C4	Below Average	This category includes SWBDs which are in worse than average condition. They may have developed an increasing number of CB racking in and out issues, arcing damage to insulation and condensation issues due to poor switchboard and building design. They may also have a history of failures occurring such as internal bushing failures, bus bar insulation failures. Local manufacturer support and spares are very limited and reverse engineering, salvaging parts from retired equipment or in situ repair are becoming the most practical solution. Specialist targeted maintenance is required to manage specific known defects.	25%
C5	Poor/ Bad	This category includes first generation SWBDs with pitch or compound filled busbars and cable compartments which are typically maintenance intensive. These SWBDs are approaching the end of economic life. The maintenance that can be performed to restore the condition is very limited due to its design. Lack of spare parts and experience and skill required to maintain these assets are very limited and not cost effective. They are no longer supported by the manufacturers. Obvious signs of deterioration or internal insulation PD / had major failures/ and may be operability & safety compliance issues.	< 15%

Table 1- Condition Score definition and recommended action

Condition profile of indoor switchboards by service voltage and vintage type are shown in Figure 7 and 8 respectively.

[1] DNO Common Network Asset indices Methodology Framework of 30-01-2017 of UK & NIE

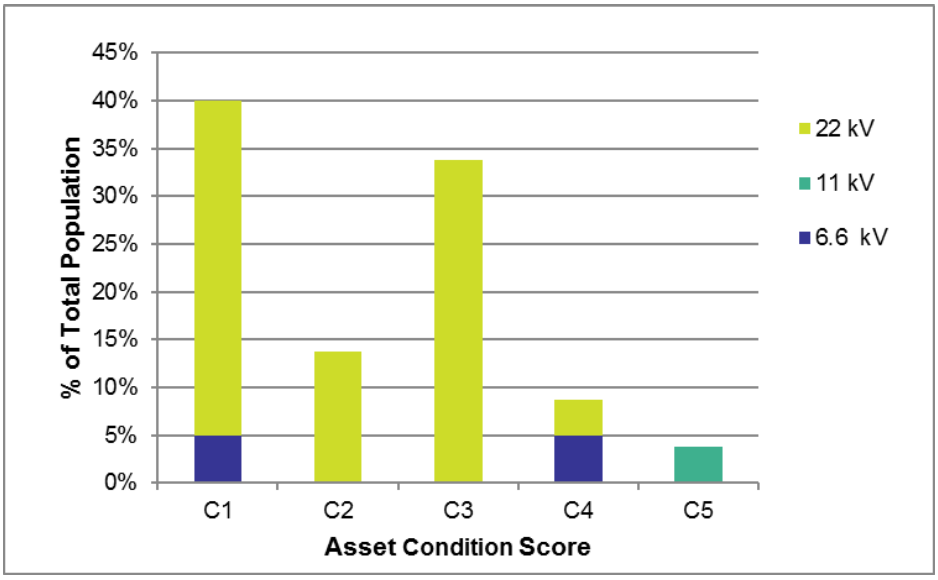

Figure 7 – Condition Profile of ZSS indoor switchboards by Service Voltage

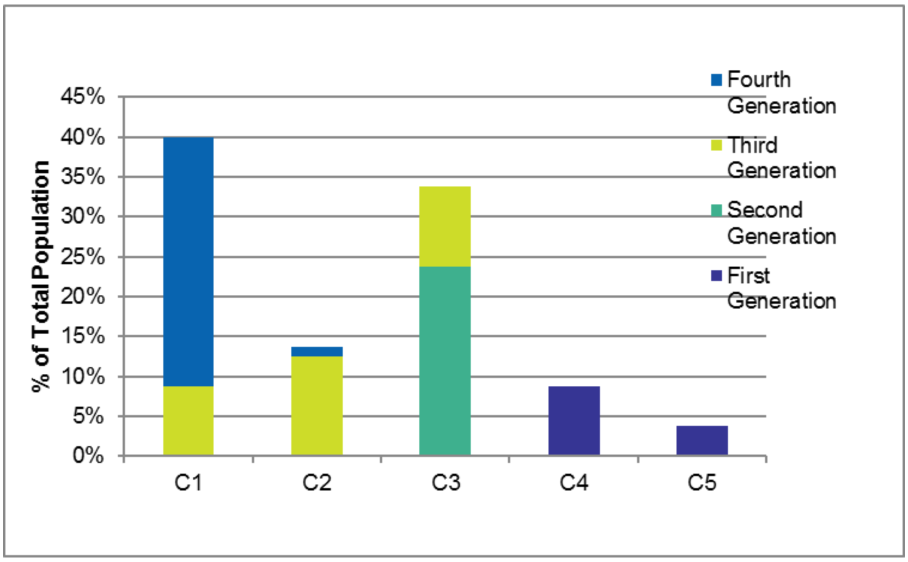

Figure 8 – Condition Profile of ZSS indoor switchboards by vintage type

All first generation indoor switchboards are either in 'very poor condition' (C5) or in 'poor condition' (C4). First generation switchboards have a high risk of safety against arc flash injury due to their inherent open design of racking and out circuit breakers and earth trucks and also the arc products are vented into the switch room. Because of their very poor condition (C5) or poor current condition (C4), the probability of a failure is higher and replacement or retirement is the best option.

Second generation indoor switchboards are in 'good /average condition' (C3).

Typical "very poor condition "(C5) and "poor condition" (C4) indoor switchboards are shown in Table 2 below.

Location	Switchboard Generation (vintage type)	Switchboard Make	Asset condition Score (C4/C5)
LYS	First Generation	C.I.C	C4
MPS	First Generation		C5
MWN	First Generation		C4
YN	First Generation		C4

Table 2 –Very Poor Condition (C5) & Poor Condition (C4) indoor switchboards

3.5 Asset Criticality

Asset Criticality, that is the consequences of failure, was determined by considering the following consequences of an indoor switchboard failure with the failure effects mentioned below.

I. Community impact due to outages (unserved energy)
II. Collateral damage,
III. Safety impact

Asset criticality is the severity of consequence in a major failure of indoor switchboard failure at a certain location due to above failure effects irrespective of the likelihood of the actual failure. This gives an idea of switchboard types, located critical locations which represent the total value of risk $.

Community impact due potential value of unserved energy is estimated based on a 24 hour outage for restoration of supply to customers by alternative means when alternative means are available.

Safety risk is highest for first generation indoor switchboards where there is open indoor switchgear involved. The recent installation of arc flash relays installed in first generation switchgear, and in some case de-energised racking in/out has significantly reduced safety risk.

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Collateral damage due to a bus bar failure has been assumed to be limited to damage only one complete bus compartment.

The Figure 9 shows the Relative asset criticality profile of indoor switchboards.

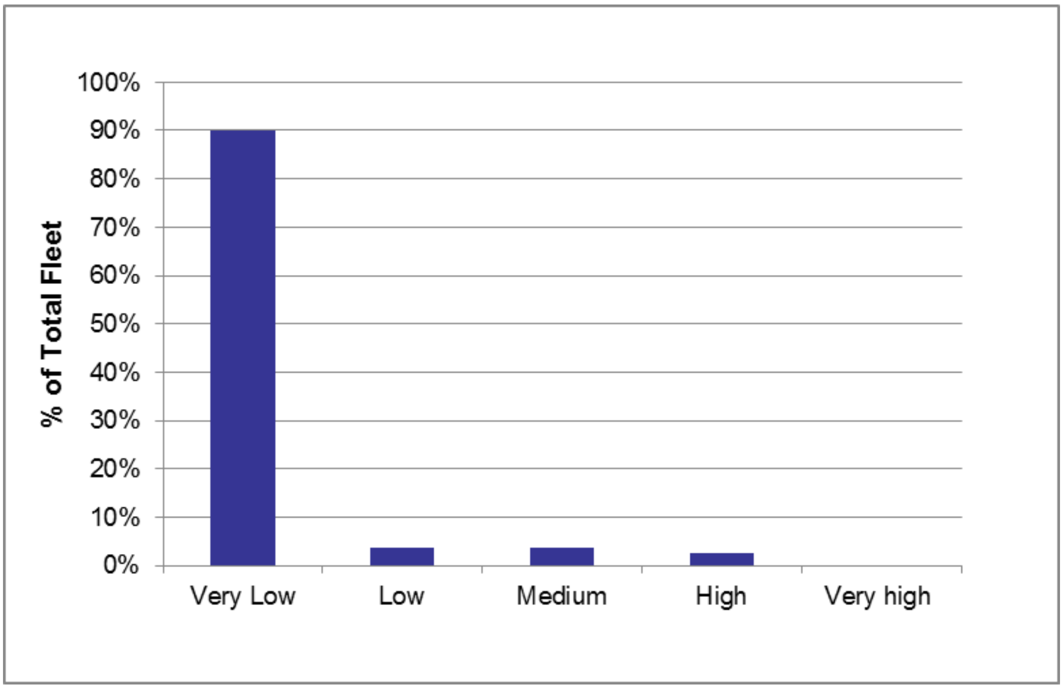

Figure 9 – Relative Base Criticality Profile

The applied interpretation of relative base criticality is shown in Table 3.

Relative Base Criticality	Criticality Banding	Economic Impact
Very low	1	Total failure effect cost < 0.3 times Replacement Cost
Low	2	Total Effect Cost is between 0.3 –1.0 times of replacement cost
Medium	3	Total Effect Cost is between 1.0 - 3 times of replacement cost
High	4	Total Effect Cost is between 3 -10 times of replacement cost
Very high	5	Total Effect Cost exceeds 10 times of replacement cost

Table 3 – Interpretation of Relative Base Criticality

Following observations are made on asset criticality:

- Approximately 90% of indoor switchboards have shown very low criticality.
- Criticality is low in most zone substations since they are provided with either two or three bus arrangements, main reason for low criticality is due to lower N-1 energy at risk.
- Very Low to high criticality is noted in stations with single bus switchboards, criticality is low due to low customer numbers and load transfer capability via distribution feeders in most zone substations.
- Medium and high criticality switchboards are at LLG, PHI, BWN, NRN and OFR stations.

3.6 Asset Performance

AusNet Services routinely analyses the root cause of unplanned work undertaken on indoor switchboards and investigates all major failures, and tracks customer outages due to switchboard failures.

3.6.1 Planned Inspections

All indoor switchboards are periodically inspected as part of the non – invasive inspection for electrical asset condition assessment on annual basis and corrective work is initiated based on observations and test results. Visual inspection of bus chambers are done periodically as per PGI-02-01-04.

3.6.2 Corrective Maintenance

Records of unplanned maintenance work undertaken on the indoor switchboards population are maintained in the Asset management system, SAP.

Work order Analysis in 2015 -2018 period show following typical type of component failures in indoor switchboards in Table 4 below.

Description of component failure	**2015**	**2016**	**2017**	**2018**
First generation				
Defective CB shutters	2			2
Defective Earth truck			1	
Second Generation				
Defective CB shutters		1	1	
Earth truck defect	1		1	
Moisture ingress		1	1	
Third generation				
Defective CB shutters				
Insulation spouts /Cones	1		2	
CB operating handle			1	
Cubicle door handle		1		
Moisture ingress	1			
Fourth generation				
Interlock failure		1		

Table 4 – Typical component failures in indoor switchboards

3.6.3 Major Asset Failures

Number of major defects and failures associated with indoor switchboards from 2008 -2018 is shown in Appendix 1.

It is noted that major asset failures during this period (2008-2018) were mainly due to:

I. instrument transformer failures (2),
II. underground cable terminations (1),
III. partial discharges due to moisture ingress (3),
IV. over voltages due to external faults (1),
V. insulation failures in compound filled termination boxes (2),
VI. wall bushing failures (1) ,
VII. poor connections in primary current path (2) ,
VIII. Catastrophic circuit breaker failures (3)

3.6.4 Catastrophic Failures

There were number of catastrophic failures of indoor switchboards reported in the period 2008-2018 shown in Table 5 below. Three of the incidents caused complete disposal of the smart switchboards whereas others caused significant damage to switchboard compartments.

Date	Station	Switchboard make	Description
01-02-2008 01-04-2008	Exeter Road 22kV smart switchboard (EXTB) Morris Road 22kV smart switchboard (MOSB)		Internal arc fault due to VT failure and catastrophic failure of switchboards
10-08-2008	CLN 22kV switchboard		Feeder chamber internal flashover collateral damage to feeder compartment
14-12-2008	Wodonga Terminal station 22kV switchboard		UG cable termination failure and collateral damage to feeder compartment
09 -03-2010	MWE 6.6kV switchboard	C.I.C	Compound filled feeder cable entry box failure and collateral damage to compound filled bus compartment
29-01-2012	Morris Road 22kV smart switchboard (MOSB)		Internal arc fault due to over voltage due to HV injection causing collateral damage to feeder compartment
04-06-2012	LGA 22kV MG customer switchboard		Damage to CB cluster contacts and associated bus spouts/insulating shrouds in feeder side and bus side
31-03-2016	WYK 22kV switchboard		Catastrophic CB failure causing collateral damage to CB compartment
22-02-2017	DRN 22kV switchboard		Damage to feeder CB and contacts due to poor connections causing collateral damage to feeder and bus spouts

Table 5 – Indoor switchboard catastrophic failures - 2008-2018

Except for EXSB, MOSB and MWE indoor switchboards (all replaced now), the arc flash was contained to the switchboard compartments and hence there was no safety impact during the faults since they were in normal operation with all compartment doors closed.

However there are now increasing safety concerns of possible arc flash due to the switchboard design of older boards when operating certain indoor switchboards. This resulted in issuing several safety grams recently, details given Table 6 below.

Safety Gram	**Description**	**Switchboard Make**	**Switchboard Vintage type**	**Station**
SG 2017023	Temporary access restriction due to ozone smell and detection of partial discharges inside switchboard due to moisture ingress		Third Generation	Lang Lang ZSS
SG2018023	Access restriction due to partial discharges detection during annual non-invasive asset inspection		Third Generation	Phillip Island ZSS
SG2018026	Access restriction due to elevated partial discharges detection during maintenance activities	C.I.C	First Generation	WMTS ZSS (similar type but not identical pitch filled bus bar switchboard at MPS)
SG2018029 SG2019001	Live bus CB racking in and out restriction after safety risk review where CB racking is required to be done with open doors or vented into room due to potential exposure to arc flash in the event of an incident.		First ,Second and some third Generation	Various sites with the associated switchboard vintage types under investigation

Table 6 – Indoor switchboard Safety Grams 2017-2019

4 Other Issues

4.1 Switch room building design

Modular Switch room building design has a major influence on the long term performance of indoor switchboards. Moisture condensation in internal insulating surfaces caused partial discharges and major insulation damage in some of the relatively newer switchboards (LLG, MJG). The switch room floor alignment is another factor which contributed to damages to CB, making contacts and interlocks while CB racking in and out during its life.

4.2 Higher Insulation Requirements for REFCL Areas

It is required higher than normal insulation requirements needed for indoor switchboards in service in REFCL project areas. Phase to ground insulation of 24.2 kV for a minimum duration of 8 minutes is required between all live components and earth. Older switchboard types may not been designed for this requirement requiring older switchboards to be tested for conformity (Partial discharge tests) and carry out modifications as required or replace indoor switchboard altogether.

4.3 Technical Obsolescence /Spares Management

Manufacturers generally cease to formally support when switchboards are older and could not normally obtain OEM spares parts beyond 30 years.

Although serviceability can be improved midway through asset operational life, by increasing the level of spares held in stores just before the OEM ceases manufacture stores holding will deplete to the point that salvaging components and reverse engineering become the only means of supporting a fleet. As the switchboards become older, wear of parts of CB and earth trucks, malfunctioning of CB shutters, interlocks, damage or weakened parts of insulated components do occur. Poor HV and secondary insulation had been noticed in some first generation switchboards. Also reused components cannot economically extend asset lives further and at this point it will become technically obsolete.

In regard to indoor minimum oil circuit breakers, mainly [C.I.C]

circuit breakers located in first and second generation indoor switchboards are now technically obsolete and no manufacturer support is available and the availability of spares is very limited.

Retrofitting these circuit breakers with indoor vacuum circuit breakers is an option but the retrofit solution needs customisation to match the existing switchboard technical requirements including further safety improvements are necessary.

4.4 Managing safety of older switchboards

Modern switchboards are fully type tested for required internal arc fault classification (IFC) and given a full Internal Arc Classification of safety based on the IEC standards. This is not the case for older switchboards where there was no defined AS/ IEC requirements. Although there are cost effective solutions available in the industry such as arc flash relays, retrofits ,CB remote racking ,needs customisation and testing prior to implementation.

Some access restrictions to older switchboards on their operation have to be imposed for safety of operators. (See section 3.6.4, safety grams issued)

5 Risk and Option Analysis

The key drivers of this program are supply risk and collateral damage.

Table 7 provide an assessment of the risk based on the condition of the assets and the monetised consequence of failure.

Effect Cost / Replacement Cost Ratio	C1	C2	C3	C4	C5
5	0	0	0	0	0
4	2	0	0	0	2
3	0	2	1	0	0
2	0	1	2	0	0
1	30	7	23	7	3

Table 7 – Relative Base Criticality for indoor switchboards

High Energy at risk at LLG switchboard warrant replacement during the EDPR period 2022-2026 due to its very poor condition and very high failure rate. Internal insulation flashovers caused replacement of bus Bar and CB insulation entirely almost annual basis and the switchboard including circuit breakers are fast deteriorating becoming unfit for service needing early replacement.

Further, purchase of at two spare indoor switchboard modular bus is justifiable due to following reasons.

1. There are five single busbar Air insulated indoor switchboards at PHI, BWA, BWN, NRN and OFR where a major failure of a switchboard can cause a considerable energy at risk. All these switchboards are in good condition (C1 or C2) except PHI switchboard where the condition is assessed as C3. Corrosion and moisture ingress has developed in PHI switchboard due to its poor design and construction and found to be slowly deteriorating with time. Keeping a spare can reduce the energy at risk due to reduced Mean Time to Repair (MTTR).

2. The possibility of multiple failures at one station results in N-2 supply risk. This can be significantly reduced by the holding of a spare which reduces the MTTR as well as the probability of having subsequent failures before an initial failed unit has been replaced.
   Note that second generation type switchboards pose a high risk of multiple failures due to its age; oldest being 41 years. Oldest first generation switchboard in service is 67 years.

3. Benefit / Cost modelling on several high risk two bus indoor switchboards shows that keeping a spare modular switchboard to mitigate N-2 supply risk is the most economical option.

C.I.C

Figure 10 below provides the graph showing the additional cost of different options of keeping a spare and replacement options vs NPV benefit. The straight line in red colour shows the optimum expenditure line compared against keeping a spare switchboard and combination of replacement options taking BGE in average condition as an example. Highest 45 degree line identifies the greatest NPV (optimal) option.

C.I.C

Based on N-2 risk, there are four stations, namely BGE, CLN, FTR and WYK where it is economical to keep a spare in the EDPR 2022-26 regulatory period. It is optimal to keep two spare switchboards in the next regulatory period.

Need for an indoor switchboard is a new concept and require detail design and development of primary and secondary interfaces, study space and access requirement at prospective zone substation sites to facilitate easy connections for shorter restoration times in the event of a switchboard failure.

Hence, it is recommended at this stage to proactively purchase two spare modular type 22kV indoor switchboard bus and develop a fast connecting indoor switchboard solution during the EDPR 2022-26 period and review further requirements in the following EDPR period.

6 Asset Strategies

6.1 New Assets

- Continue to specify fully internal arc fault contained compartmentalised indoor switchboards with external venting; consider motorised racking of vacuum circuit breakers for new installations.

6.2 Inspection

- Continue annual non-invasive condition monitoring scans ultrasonic and TEV /PD testing to evaluate any internal partial discharges in switchboards locations

6.3 Maintenance

- Continue with scheduled preventative maintenance as per specific Standard Maintenance Instructions for each indoor switchboard type.
- Continue planned inspection of bus chambers of all indoor switchboards as per PGI 02-01-04

6.4 Spares

- Maintain strategic spares holding for each indoor switchboard Make
- Procure strategic spare transportable modular switchboards complete with building and protection panels for emergency response.

6.5 Refurbishment

- Review arc flash risks and mitigation methods to reduce safety risk
- Consider options - install arc flash relays in second and third generation switchboards,
- Consider options - Retrofit replacement of minimum oil indoor CBs with indoor vacuum CBs
- Consider options - motorised CB racking for first and second generation indoor switchboards

Appendix 1 – Major Indoor Switchboard Failures 2008 – 2018

Location	Installed Year	Year of Failure	Age at failure	Switchboard Make	Switchboard Type	Switchboard Generation	Description of failure	Additional Comments
Exeter Road (EXSB) ,Morris Road (MOSB) smart switchboard	2005	2008	3	C.I.C		Third generation type	Non arc fault contained. Epoxy resin bus insulation. Epoxy VT failures at EXSB and MOSB. And HV injection at MOSB causing insulation failure	Both removed from service. Poor Board design
WOTS 22kV switchboard	1982	2008	26			Second generation type	UG cable termination failure and collateral damage to feeder compartment	
CLN 22kV switchboard	2006	2008	2			Third generation	Feeder chamber internal flashover collateral damage to feeder compartment after a cable fault.	Suspected over voltage
FGY 22KV switchboard	2007	2009	2			Third generation	Inadequate contact resistance due to use of less number of tightening bolts between CT and CB connections causing thermal connection failure and arc damage	Poor Workmanship
MWE 6.6kV switchboard	1930	2010	80			First generation type	Compound filled feeder cable entry box failure and collateral damage to associated bus chamber.	Replaced with new AIS switchboard
LYS 22kV switchboard	1979	2011	32			First generation type	Internal resin type wall bushing failure	
LGA 22kV switchboard	2000	2012	12			Third generation type	Damage to CB cluster contacts and associated bus spouts/insulating shrouds in feeder side and bus side	Alignment issues
MJG 22kV switchboard	2000	2012 & 2014	12			Third generation type	Poor switch room design resulting in condensation issues , severe PD damage to insulation	Switchboard now replaced with outdoor CB
LLG 22kV switchboard	2007	2013	6			Third generation	Condensation issues resulting in partial discharges in internal feeder and bus side CB insulation failure	Poor building design
MPS 11kV switchboard	1950	2016	66			First generation type	Internal compound insulation failure in feeder and associated bus chamber.	Arc flash relays installed
WYK 22kV switchboard	1979	2016	37			Second generation type	Catastrophic CB failure causing collateral damage to CB compartment	Retrofit with vacuum CBs
DRN 22kV switchboard	2014	2017	3			Fourth Generation	Damage to feeder CB and contacts due to poor connections causing collateral damage to feeder and bus spouts	Installation and poor workmanship
LLG 22kV switchboard	2007	2017	10			Third generation	Condensation issues resulting in partial discharges in internal feeder and bus side CB insulation failure	Poor building design
LLG 22kV switchboard	2007	2019	12			Third generation	Condensation issues resulting in partial discharges in internal feeder and bus side CB insulation failure	Poor building design