HV Switches, Disconnectors and Earth Switches

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 HV switches, Disconnectors and earth switches.

This strategy covers the 2349 switches installed within AusNet Services Zone substations. The majority are the hook stick operated underslung type (45% of the total population) and remainder 3 phase gang operated switches and disconnectors (9% of total population) and earth switches (32% of the entire population) and HV fused isolators.

Condition assessment shows that approximately 76% of the total population are in a good to average (C1-C3) condition and approximately 24% of the total population in "Poor" (C4) or "Very Poor" condition (C5). These are mainly the older Taplin, SECV, Switchgear and Duo roll make, which are technically obsolete now.

Asset criticality is lower compared to other asset types although as the majority are manually operated, a failure could pose a safety risk to the operator if they fail mechanically during the operation and especially those with cap and pin type insulators.

A risk based assessment has identified a proactive replacement program is recommended for disconnector and earth switch types, that use cap and pin insulators, for the 2022-26 period and some additional cap and pin bus support insulators.

Proactive management of HV switches, disconnectors and earth switches including condition based maintenance 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 purchase fully type tested isolators and earth switches to the latest specification

1.1.2 Maintenance

- Continue maintaining isolators and switches in accordance with PGI 02-01-04.
- Continue with annual thermo-vision scans of all disconnecting switches (as part of station scan and as per SMI 67-20-01).

1.1.3 Spares

- Maintain strategic spares holding of HV switches, disconnectors and earth switches as per spare holding policies

1.1.4 Replacement

- Replace "Very Poor" condition HV switches, disconnectors and earth switches under proposed major station rebuild programs and CB asset replacement programs under EDPR 2022-26

HV Switches, Disconnectors and Earth Switches

- Replace worst of the “Very Poor” condition underslung/fused isolators at those sites not included under major station projects (e.g. RWTS 22KV, CYN, WO, WN)
- Replacement of worst of the “Very Poor” condition Cap and Pin type insulators at eight zone substations that are not included under major station projects (e.g. BN, BRA, CYN, LDL, MBY, WGL, WN, WO)

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 High Voltage (HV) switches, disconnectors and earth switches 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 HV switches, disconnectors and earth switches associated with the AusNet Services electricity distribution network that operate at 66 kV, 22 kV, 11 kV and 6.6 kV in zone substations and power station switchyards.

The following assets are covered under other strategies:

MV fuse switch disconnectors refer to AMS 20-61

MV switches and ACRs refer to: AMS 20-60

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

HV switches are used at 66 kV, 22 kV, 11 kV and 6.6 kV in zone substations to manually energise and de-energise transformers and bus-tie circuits when carrying load current and also used for plant isolation.

Disconnectors are used for isolating major primary plant such as transformers, circuit breakers, reactors, instrument transformers, capacitors and lines for maintenance access, and for isolating faulty equipment from energised circuits. They have continuous current ratings and through fault current ratings but do not have the load breaking ratings or fault interruption ratings of HV switches.

Some HV switches/disconnectors are fitted with earthing switches and separate earth switches in capacitor banks to connect de-energised equipment to the general mass of earth and permit safe access for maintenance work.

3.2 Asset Population

AusNet Services has a total of 1581 Disconnectors, HV switches and 758 earth switches installed in AusNet services zone substations as at end 2017. Earth switches are typically gang operated and an integral part of a disconnector / earth switch in outdoor type earth switches. The majority of disconnectors are installed outdoors and most are manually operated.

There are also earth switches installed in third and fourth generation type indoor switchboards on the bus side and feeder side to provide earthing for the feeder exit cable and enable safe access for bus maintenance work.

Figure 1 below illustrates various types of switches, disconnectors and earth switches in service in zone substations in AusNet Services network. It is noted that single phase operated under slung isolators (45.1 %) are the key type of disconnecting device used in zone substations. Gang operated disconnecting devices consist of air break switches, rotary double break switches and vertical break switches together cntribute to about 19.2%.

Indoor and outdoor type earth switches contribute to about 32.4% of the total population of switches.

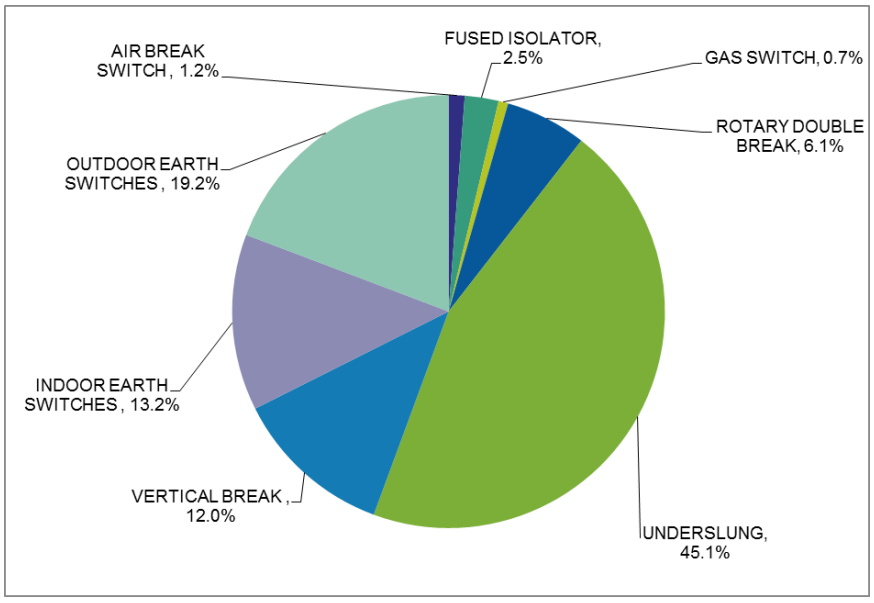


Figure 1 – Population of HV switches, disconnectors and earth switches as a percentage of total population

HV Switches, Disconnectors and Earth Switches

Figure 2 below illustrates various types of switches, disconnectors and earth switches by service voltage in zone substations in AusNet Services network. Larger population of under slung isolators are found in 22kV outdoor distribution network (31.1%) compared to 66kV voltage level (12.4%).

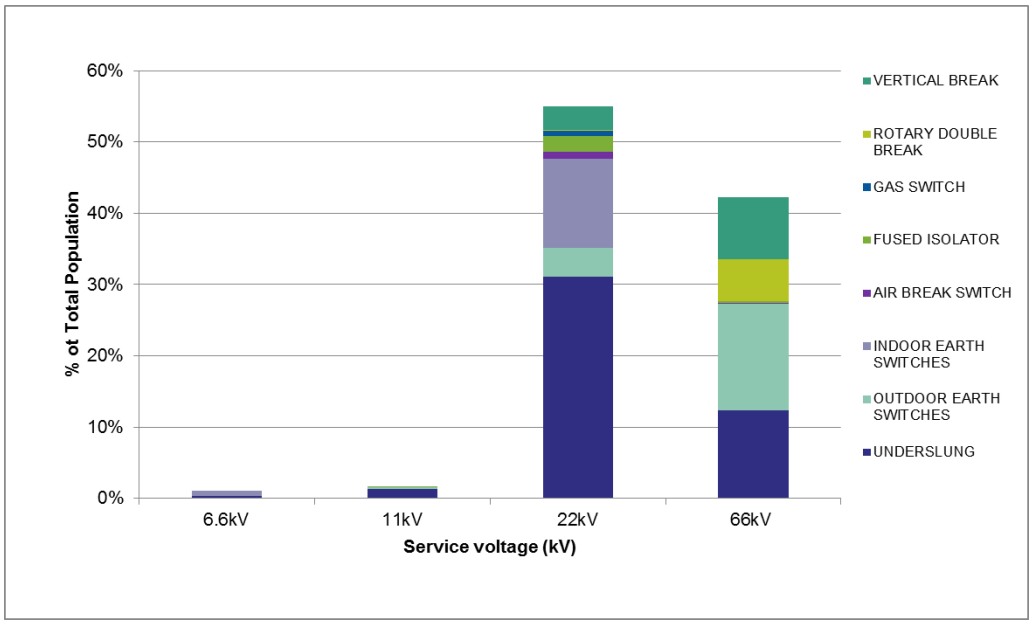


Figure 2 – Population of HV switches, Disconnectors and earth switches by service voltage and type

3.3 Asset Age Profile

The service age profile of zone substation isolators and earth switches by service voltage is shown in figure 3. About 29.7% of the total population of switches are older than 50 years old. Approximately 18.7% of those operate at 22kV and 11% operate at 66kV switches.

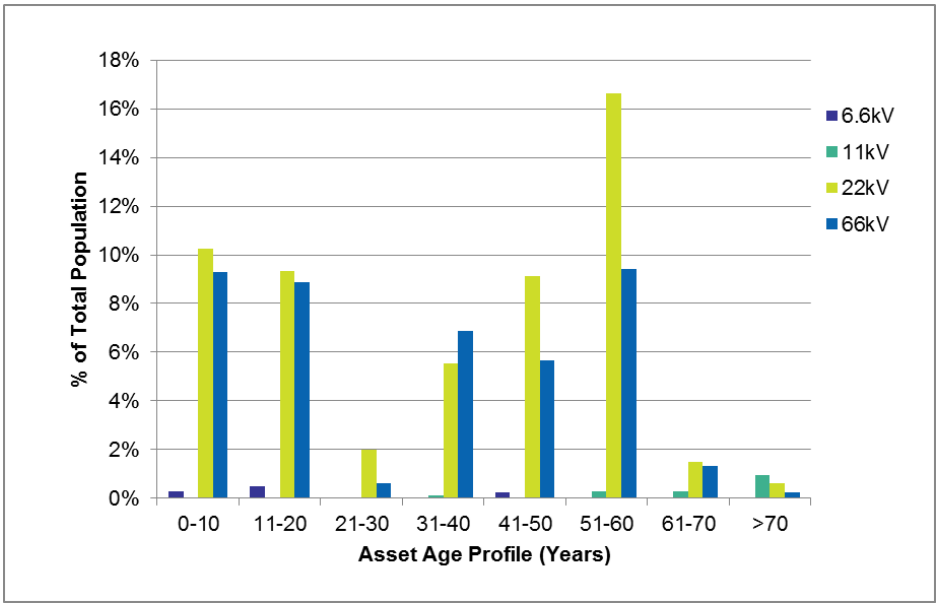


Figure 3 – Age Profile of HV switches, Disconnectors and Earth switches in zone substations

Figure 4 provides the service age profile of switches by type.

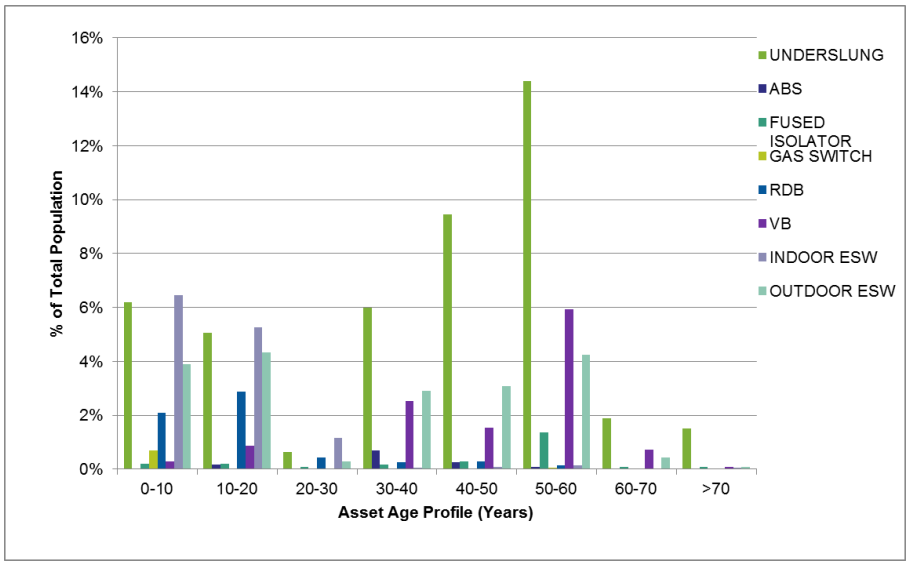


Figure 4 – Age Profile of HV Switches, Disconnectors and earth switches by Type

Following observations are made:

I. Approximately 17.8% of the total population are older than 50 years old and are the manually operated underslung type. From a type perspective, approximately 40% of underslung population are older than 50 years old. These are mainly [C.I.C] where the support insulators are mainly cap and pin type. Cap and pin type have a historical failure of insulators breaking away from the metal pin and posed operator safety risk during their operation during operation and maintenance activities.

II. Approximately 6.8% of the total population are older than 50 years old and ganged vertical break type switches. From a type perspective 57% of the total vertical break switch population are older than 50 years. These are mainly [C.I.C] roll types. Majority of these switches are used for transformer load switching and they are maintenance intensive.

3.4 Asset Condition

Table 1 provides the condition assessment criteria of HV switches, disconnectors and earth switches in zone substations.

HV Switches, Disconnectors and Earth Switches

Condition Description	Summary of details of condition score	Remaining Service Potential
Very Good	These switches are relatively new and in good operating condition with no past history of defects or failures. Manufacturer support is available. Routine maintenance and continued condition monitoring is recommended.	**95%**
Good	These are better than average condition . They may not have developed actual faults or defects but developing minor issues which require occasional minor maintenance. They do not require intervention between scheduled maintenance nor they show any trends of serious deterioration in condition. Manufacturer support is available. Routine maintenance and continued condition monitoring is recommended.	**70%**
Average	This category of switches which are with average condition. These units require increased maintenance inspections between schedule maintenance. Repair is only of minor in nature and does not result in long outages.	**45%**
Poor	This category of switches typically have brown cap and pin type support insulators and have older SECV, Switchgear, Taplin types and require frequent intervention between scheduled maintenence. Issues such as stiffness to operate, contact misalignment ,high contact resistance. Manufacturer support is generally not available and salvaged components from removed switches are commonly used for repairs. Operation and maintenance cost is high and advisable to replaced with opportunity.	**25%**
Very Poor	This category typically show signs of ageing condition, the blade will not open or close affecting network reliability and availability, insulator crack with potential to fall or flashover posing Health & Safety risk to personnel. Manufacturer support is not available. They are approaching end of economic life and replacement the best option.	**15%**

Table 1 – Condition Assessment Criteria

Asset Condition Profile of HV switches, Disconnectors and Earth switches by Service Voltage is given in Figure 5.

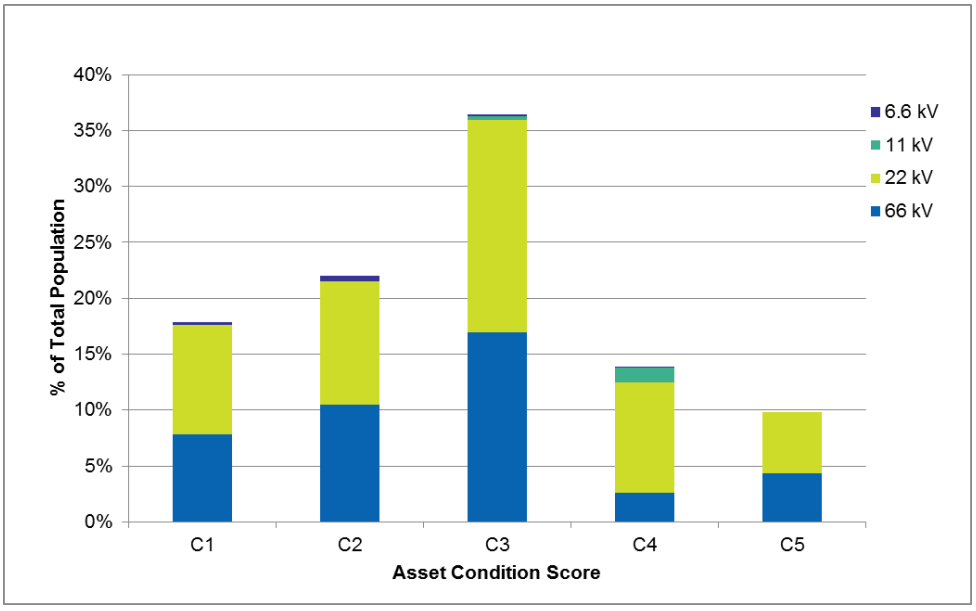


Figure 5 – Condition Profile of HV switches, Disconnectors and Earth Switches by Service Voltage

Approximately 15.3% of total population is 22kV and 6.9% of total population is 66kV Isolators and Earth switches in either C4 or C5 asset condition. This is about 22% of the total population of switches.

Asset Condition Profile of switches is given in Figure 6.

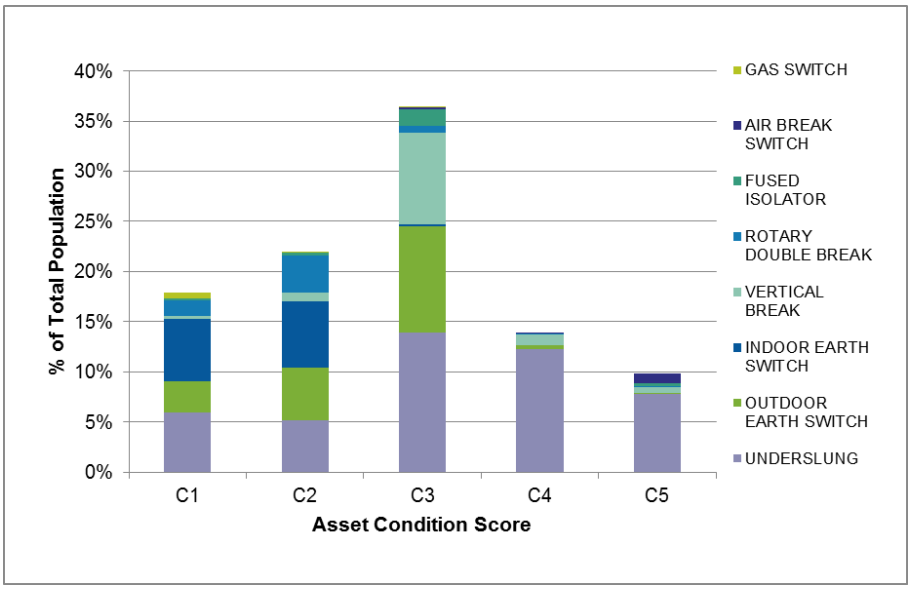


Figure 6 – Condition Profile of HV switches, Disconnectors and Earth Switches by Type

Approximately 20% of the total population is in C4 or C5 asset condition and mainly consists of underslung isolators. These are mainly [C.I.C]

Approximately 2% of the total population in C4 or C5 asset condition consist of vertical break switches. These are mainly [C.I.C] types. They are maintenance intensive due to the requirement of transformer and load switching where arcing contacts are required to be maintained to perform the required switching.

3.5 Asset Criticality

The consequence of a failure from a network reliability perspective, for HV switches, Disconnectors and earth switches are relatively low due to low direct community impact . Operator safety impact is the major driver of asset criticality.

There are operator safety risks associated with older hook stick operated fused isolators and underslung isolators and older rotary double break switches with brown cap and pin type insulators. During operation, the insulator may break away causing live connections to separate which can cause insulators and conductors to fall to the ground and pose safety risk to operators.

3.6 Asset Performance

AusNet Services routinely analyses the root cause of unplanned work undertaken on isolators and earth switches 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 HV switches, Disconnectors and earth switches are subjected to routine maintenance in accordance with PGI 02-01-04 and relevant standard maintenance instructions (SMI).

Analysis of corrective maintenance work carried out during 2015 -2018 period is shown in Figure 7.

HV Switches, Disconnectors and Earth Switches

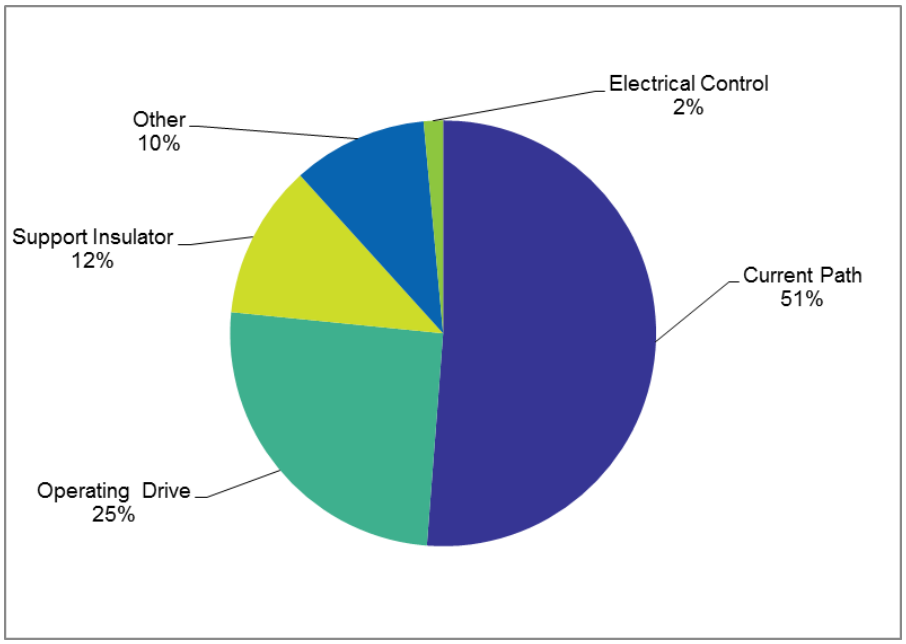


Figure 7 – Work Order Analysis of HV switches, Disconnectors and Earth Switches - 2015-2018 Period

Following observations were made:

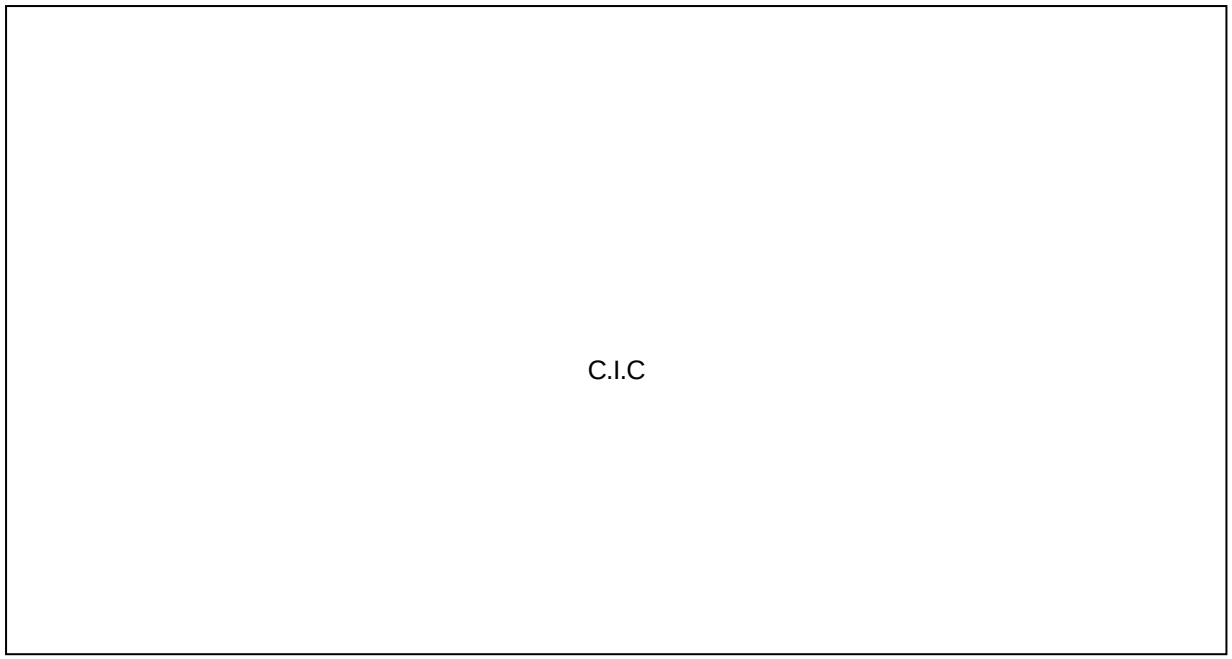
I. Current path issues contributed to 51% of the total work orders. These are mainly due to issues associated with current part; contact welding, contact misalignment, high resistance contacts/connections found during maintenance inspections or switching operations and also hot spots found during annual thermal scanning on switches
II. Operating derive issues (25%) are mainly due to stiff switches or seizures of switches due to contact welding.
III. Support Insulator failures (12%) are due to cracks, broken or arc flash damage.

Table 2 below shows the work order rate per switch type per year for the period 2015- 2018.

Corrective work orders	Current Path	Support Insulator	Operating Drive	Other	Electrical Control	Grand Total
Work Orders - Isolators	94	22	19	15	3	153
Work orders- Outdoor Earth Switches	11	2	33	5	0	51
Work orders- Indoor Earth Switches	0	0	0	1	0	1
Work orders / Isolator	0.059	0.014	0.012	0.009	0.002	0.097
Work orders /Isolator /yr	0.015	0.003	0.003	0.002	0.000	0.024
Work orders / Outdoor Earth Switch	0.024	0.004	0.073	0.011	0.000	0.113
Work orders /Outdoor Earth switch /yr	0.006	0.001	0.018	0.003	0.000	0.028
Work orders / Indoor Earth Switch	0.000	0.000	0.000	0.003	0.000	0.003
Work orders /Indoor Earth switch /yr	0.000	0.000	0.000	0.001	0.000	0.001

Table 2 – Work order Rate for HV switches, Disconnectors and earth switches -2015-2018

Figure 8 below shows the percentage work orders by Manufacturer.



[C.I.C] vertical break and under slung isolators have been found to be maintenance extensive. Other makes such as [C.I.C] vertical break types are becoming maintenance extensive. Key failure objects are associated with current path and operating drive issues.

3.6.2 Major Failures resulting in safety incidents

There had been three significant incidents reported during the period 2013 - 2018 of isolator and switches in Zone Substations and Terminal Stations. These incidents resulted in near misses of serious injury to operators while operating them.

In 2016, [C.I.C] old ganged 3 phase isolator failed at Mansfield ZSS (MSD) when performing switching duties. The fixed jaw assembly of one phase separated from the rotary switch insulator and fell onto the adjacent bus below, ending up suspended 1 meter from the ground resulting in a near miss. (IMS reference 225511). Safety gram SG 2016040 was issued.

The details of the two significant incidents reported at Terminal stations are as follows:

In 2013, a 22kV [C.I.C] fused isolator at Rowville Terminal station (ROTS) failed when attempting to open the isolator. This caused the top fuse bracket insulator breaking resulting in the conductor falling and swinging towards the Operator resulting in an electric shock. Energy Safe Victoria (ESV) attended to conduct an independent assessment. A Significant Incident Investigation was launched under reference IMS 210811. Safety gram SG 2013039 was issued.
In 2015, a 22kV [C.I.C] fused isolator at Richmond terminal station (RTS) failed when attempting to open the isolator during decommissioning of retired plant. The top of the failed insulator failed and broke away and remained suspended above ground. The ceramic fuse was retained on the operating stick and fortunately there were no injuries. (IMS reference 215324)

Mechanical failures in old fused isolator support insulators are a result of combination of mechanical operating loads imposed on an insulator that weakened due to cement growth of grouting compound, used on the cap and pin style insulator. Cement growth is a known failure mode of cap and pin insulators and usually starts to appear after 30 to 40 years in service.

4 Other Issues

4.1 Cap and Pin support insulator failures

Cap and pin type insulator types used in HV switches, Disconnectors are also used as bus bar support insulators in older zone substations. Although they are used as stand-off support insulators they tend to electrically fail due in pin corrosion similar to HV switches and Disconnectors, with insulator cracking of porcelain and insulation failure causing bus outages. Many of have them have reached end of life.

There were three incidents of 22kV bus outages caused due to cap and pin type insulator failures during the period 2015-2018 affecting number of customers. (MYT ZSS -2016, BWR -2018, TGN -2018)

4.2 Very low operation of switches

It is often found that switches that operate very rarely are often found with the difficulty to open or too hard or stiff to operate during network switching operations. This causes delays and extended outage time due to unforeseen unplanned work to be carried out in them. Exercising the switches by operating at regular time periods or consider reduced maintenance frequency are the alternatives available to overcome this issue.

4.3 Technical obsolescence and spares management

Manufacturers generally cease to formally support when switchgear 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. Also reused components cannot economically extend asset lives further and at this point it will become technically obsolete.

[C.I.C]are typical under slung isolators and [C.I.C] that are technically obsolete and the availability of new spares is very limited to maintain the fleets.

5 Risk and Option Analysis

The drivers of this program are supply reliability and operator health and safety risk where operator health and safety is the dominant driver.

Poor condition disconnectors, switches and bus insulators are normally replaced when detected during maintenance inspections reduces safety risk. However some failure do occur between planned maintenance intervals.

Refurbishment of older existing HV switches, Disconnectors and earth switches is not cost effective as in many instances parts required have to be re-engineered . Also type tested performance cannot be guaranteed with modified components in HV switches, Disconnectors without testing or proven as safe. Therefore replacement was considered as the technically feasible option for older types.

Proactive replacement of number of poor condition HV switches, Disconnectors and earth switches can be done efficiently in a cost effective manner if replacements are coordinated with the planned replacement of associated power transformers and switchgear.

“Very Poor” condition earth switches and cap and pin bus support insulators will be replaced under REFCL and proposed Station Rebuild projects as follows:

- Station Rebuilds (under EDPR 2022-26) : Bayswater (BWR) , Maffra (MFA), Watsonia (WT), Traralgon (TGN) and Warrigal (WGL) ,Numeralla(NLA) ,Thomastown (TT)
- REFCL Program (during current period) : Myrtleford (MYT) Moe (MOE) and Wonthaggi (WGI), Bairnsdale (BDL), Belgrave (BGE), Eltham (ELM), Lilydale (LDL), Moe (MOE), Rubicon A (RUBA) , Sale (SLE) ,Wangaratta (WN)

A proactive replacement of poor condition fused isolators and cap and pin type station post insulators are recommended under the EDPR 2022-26 program which are not covered under above programs:

- Replace ten sets of “Very Poor” condition underslung/fused isolators (e.g. RWTS 22KV YARD, CYN,WO ,WN)
- Replacement of “Very Poor” condition 22kV and 66kV Cap and Pin and Pin Post with station post insulators in eight zone substations (e.g. BN, BRA, CYN, LDL, MBY, WGL, WN, WO)

6 Asset Strategies

6.1 New Assets

- Continue to purchase fully type tested isolators and earth switches to the latest specification

6.2 Maintenance

- Continue maintaining isolators and switches in accordance with PGI 02-01-04.
- Continue with annual thermo-vision scans of all disconnecting switches (as part of station scan and as per SMI 67-20-01).

6.3 Spares

- Maintain strategic spares holding of HV switches, disconnectors and earth switches as per spare holding policies

6.4 Replacement

- Replace “Very Poor” condition HV switches, disconnectors and earth switches under proposed major station rebuild programs and CB asset replacement programs under EDPR 2022-26
- Replace worst of the “Very Poor” condition underslung/fused isolators at those sites not included under major station projects (e.g. RWTS 22KV, CYN, WO, WN)
- Replacement of worst of the “Very Poor” condition Cap and Pin type insulators at eight zone substations that are not included under major station projects (e.g. BN, BRA, CYN, LDL, MBY, WGL, WN, WO)