AMS 10-59 Disconnectors and Earth Switches

2023-27 Transmission Revenue Reset

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1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' electricity transmission network. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of terminal station Disconnectors and Earth switches.

The disconnecting switches, that are predominantly the single phase underslung type (32.2%), and three phase ganged type switches (27.9%) contribute to total population of 60.1%. Earth switches contribute to 39.9%. Approximately 6.8% of the disconnectors and 3.6% of earth switches are associated with Gas insulated switchgear (GIS).

Condition assessment shows that approximately 75.8% of the total population are either in a good /average (C1-C3) condition and approximately 24.2% of the total population in "poor" (C4) or "very poor condition" (C5). They are mainly of older [C-I-C] & [C-I-C], [C-I-C], [C-I-C], [C-I-C] roll make which are technically obsolete.

Asset criticality is lower compared to other assets although as some older switches are manually operated could pose a safety risk to operator if they fail mechanically during manual operation, especially those with cap and pin type insulators.

Most efficient program is to replace poor/very poor condition as integral part of the major station replacement programs during 2022-27. In addition, a modest proactive replacement program is recommended to generate strategic spares for those poor /very poor condition types not included in station replacement programs and no major spares assemblies exist.

Proactive management of 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 disconnector and earth switches to the latest specification

1.1.2 Maintenance

- Continue maintaining disconnectors and switches in accordance with PGI 02-01-02.
- 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 disconnectors and earth switches as per spare holding policies
- Replace selected types to generate spares, where no strategic spares exist and there is no manufacturer support.

1.1.4 Replacement

- Replace poor and very poor condition disconnectors and earth switches with their associated CB during the major station asset replacement programs during 2022-27.
- Replace selected types of the poor /very poor condition, technically obsolete disconnectors and earth switches, that are not included in major station programs, to generate strategic spares:
    - 2 off 220kV [C-I-C] type
    - 2 off 220kV [C-I-C] switch disconnector type
- Replacement of very poor condition Cap and Pin type insulators at terminal stations that are not included under major station projects

1.1.5 Refurbishment

- Complete implementation of the 220kV [C-I-C] manually operated earth switches redesign
- Continue investigating stiffness issue and solution with manufacturer of the 220kV [C-I-C] manually operated earth switch

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 disconnectors and earth switches installed in terminal stations in AusNet Services' Victorian electricity transmission 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 disconnectors and earth switches associated with the AusNet Services regulated asset base electricity transmission network that operate at 500kV, 330kV, 275kV, 220kV, 66kV, 22 kV, 11 kV and 6.6 kV in terminal stations.

The GIS disconnectors and earth switches assets are also covered under the other strategy:

Gas Insulated Switchgear AMS 10-62

2.3 Asset Management Objectives

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

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

As stated in *AMS 10-01 Asset Management Strategy -Transmission Network*, the electricity transmission network objectives are:

- Maintain top quartile benchmarking;
- Maintain reliability;
- Minimise market impact;
- Maximise network capability;
- Leverage advances in technology and data analytics;
- Minimise explosive failure risk.

3 Asset Description

3.1 Asset Function

Disconnectors and Earth Switches are used at 500kV, 330kV, 275kV, 220kV, 66 kV, 22 kV, 11 kV and 6.6 kV in terminal stations. Disconnectors are mainly 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.

Most ganged disconnectors are fitted with earthing switches and separate standalone earth switches are also provided for earthing of certain equipment as required by the design 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 4085 switches, as reported in 2018/19 RIN, comprised of 2386 Disconnectors and 1672 earth switches installed in AusNet services terminal stations. Most disconnectors are installed outdoors and either they are manually or automatically operated. Earth switches are typically gang operated and an integral part of a disconnector / earth switch or as a separate standalone earth switch outdoor type earth switches.

Figure 1 below illustrates various types of disconnectors and earth switches in service in terminal stations in AusNet Services regulated network. It is noted that single phase operated under slung disconnectors (ISOL) contribute to 32.3% of the disconnector population. Three phase gang operated disconnectors (ISOLGNGD & ISOLROTARY) contribute to about 21.1% of the total population of switches. Approximately 6.8% of the disconnectors and 3.6% of earth switches are associated with Gas insulated switchgear (GIS). Outdoor type earth switches contribute to about 36.3% of the total population of switches.

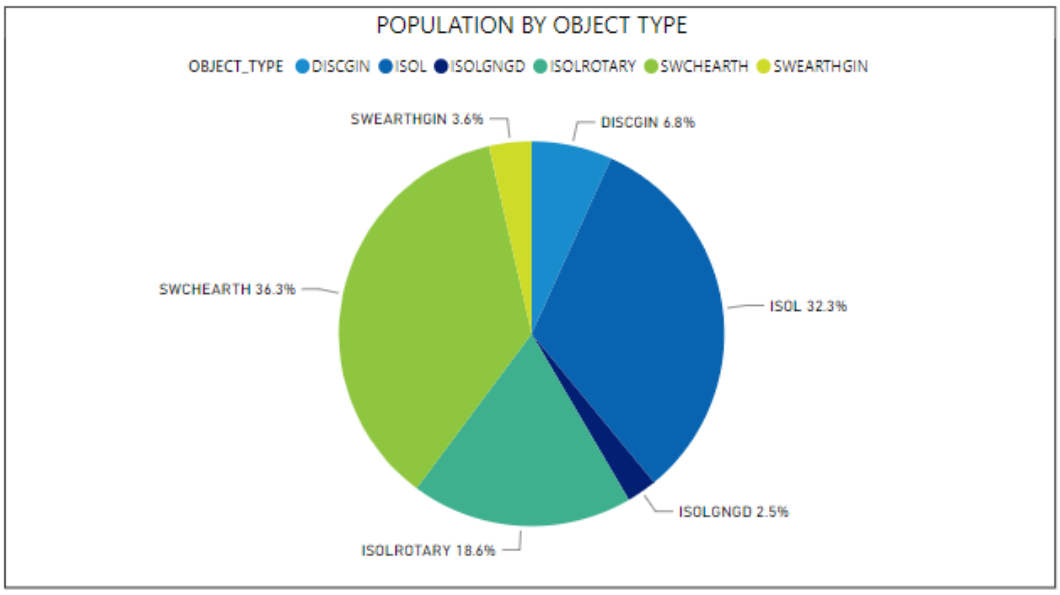

Figure 1 – Population of disconnectors and earth switches as a percentage of total population

Figure 2 below illustrates various types of disconnectors and earth switches by service voltage in terminal substations in AusNet Services network. The larger population of Switches are found in the 220kV Transmission network (approx. 47%) followed by 66kV transmission network (approx. 29%) together constitute 76% of the total population of disconnectors and earth switches.

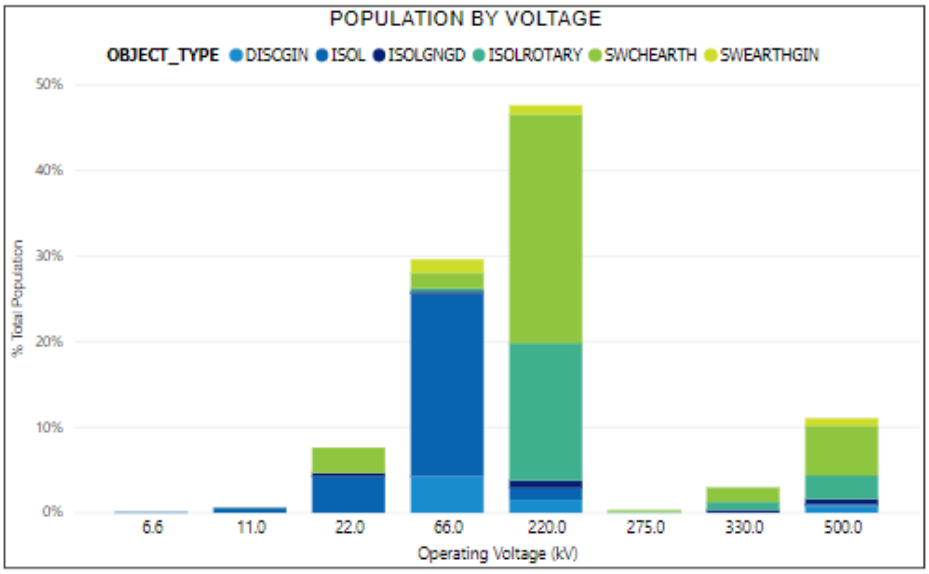

Figure 2 – Population of Disconnectors and earth switches by service voltage and type

3.3 Asset Age Profile

The service age profile of terminal station disconnectors and earth switches by service voltage is shown in figure 3.

About 16.9% of the total population of switches are older than 50 years old. Approximately 10.1% operate at 66kV & below while 6.8% operate at and above 220kV.

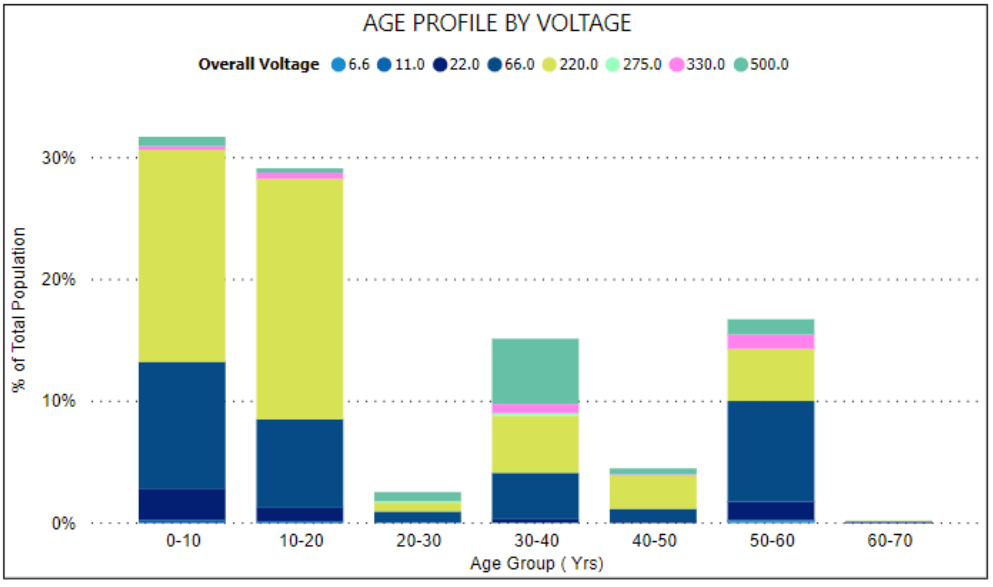

Figure 3 – Age Profile of Disconnectors and Earth switches

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

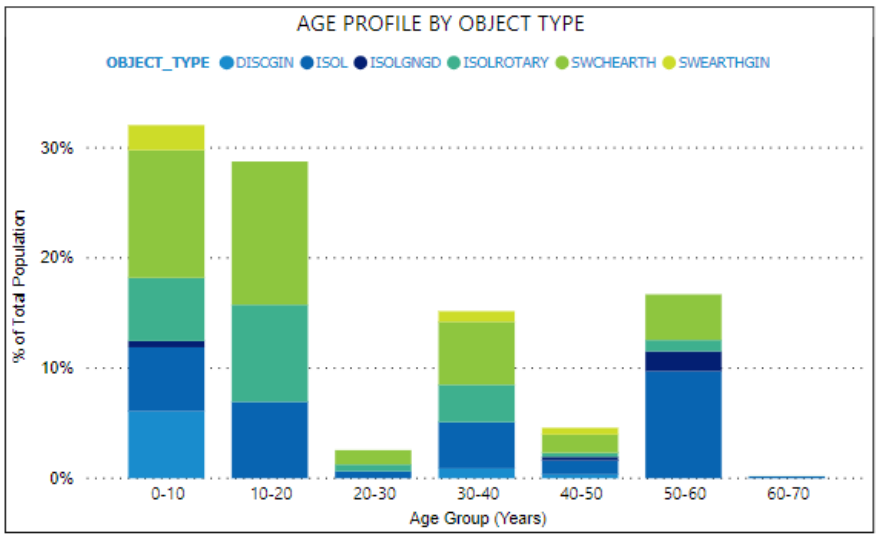

Figure 4 – Age Profile of disconnectors and earth switches by Type

Following observations are made:

I. Approximately 16.9% of the total population are older than 50 years old. From a type perspective, approximately 9.9% of total population in this age bracket are the single phase underslung type. These are mainly [C-I-C], [C-I-C] and switchgear IS2/4 and G1 make 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 2.9% of the total population in the older than 50 years age bracket are ganged horizontal and vertical break type switches. These are mainly [C-I-C] types. The remainder are their associated earth switches.

3.4 Asset Condition

Table 1 provides the condition assessment criteria of disconnectors and earth switches in terminal stations.

Disconnectors and Earth Switches

Table 1: Condition Assessment Criteria:

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%**

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

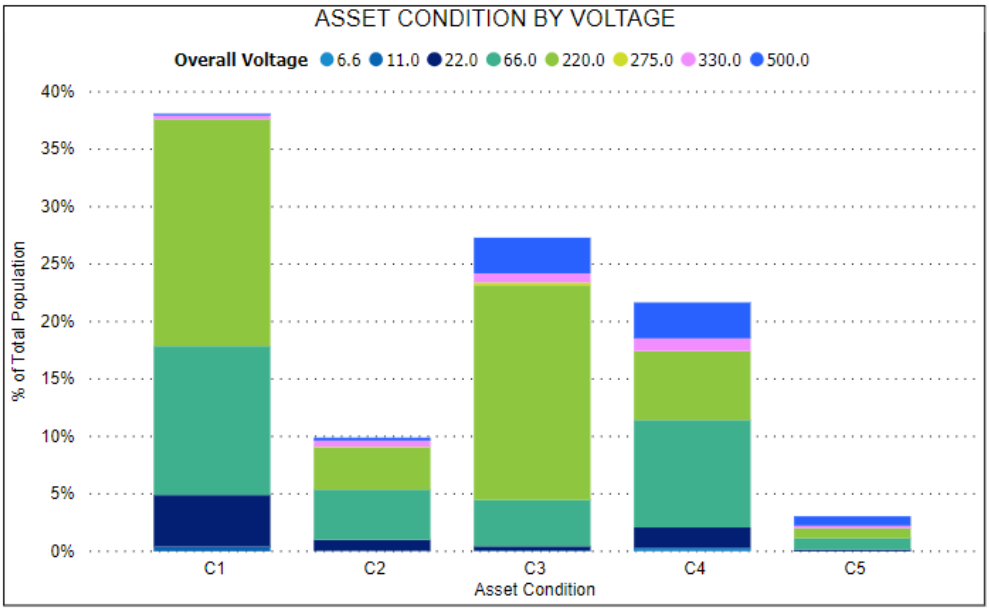

Figure 5 – Condition Profile of Disconnectors and Earth Switches by Service Voltage

Asset Condition Profile of Disconnectors and Earth switches by Type are given in Figure 6.

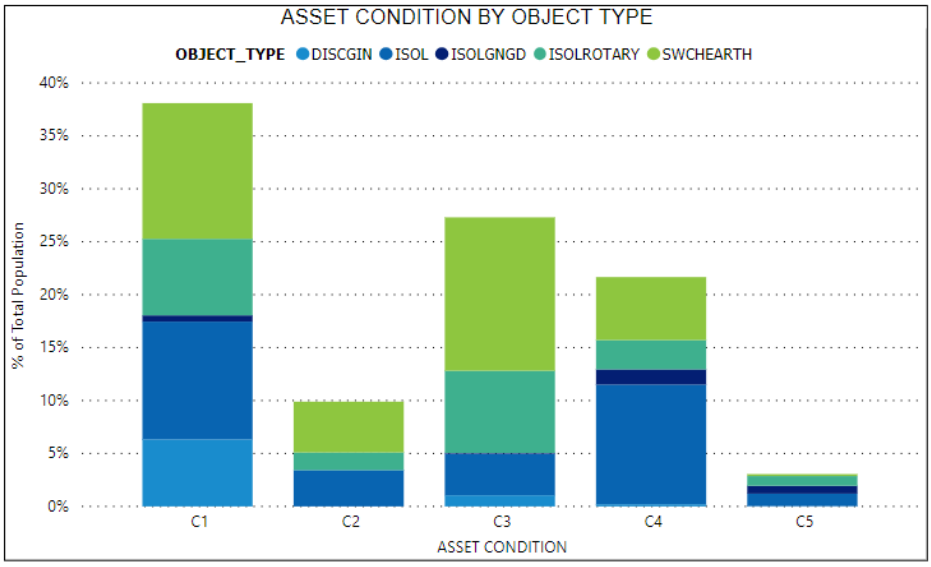

Figure 6 – Condition Profile of Disconnectors and Earth Switches by Type

Approximately 24.7% of the total population is in C4 or C5 asset condition and approximately half of the group consists of underslung disconnectors. These are mainly Taplin, SECV and Switchgear make.

3.5 Asset Criticality

The consequence of a failure from a network reliability perspective, for HV 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 disconnectors and underslung disconnectors and older rotary double break and vertical 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.

Similarly, most of the older ganged disconnectors and earth switches are manually operated, which as stiffen or maloperation can pose a safety risk to operators through manual handling injury risk, as well operators are in the drop zone of live equipment.

3.6 Asset Performance

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

Analysis of corrective maintenance work (ZA - condition based) carried out during 2015-2019 period is shown in Figure 7,8, 9 ,10 &11.

Disconnectors and Earth Switches

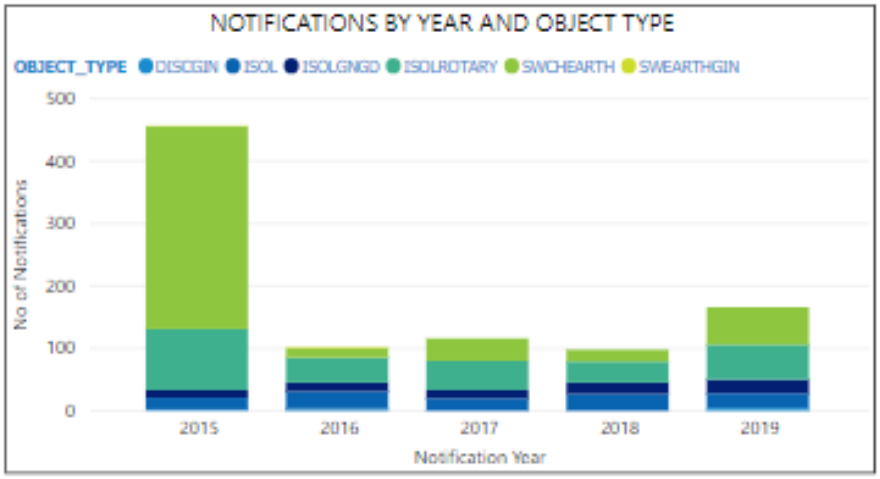

Figure 7 – ZA Notification analysis by object type of Switches - 2015-2019 Period

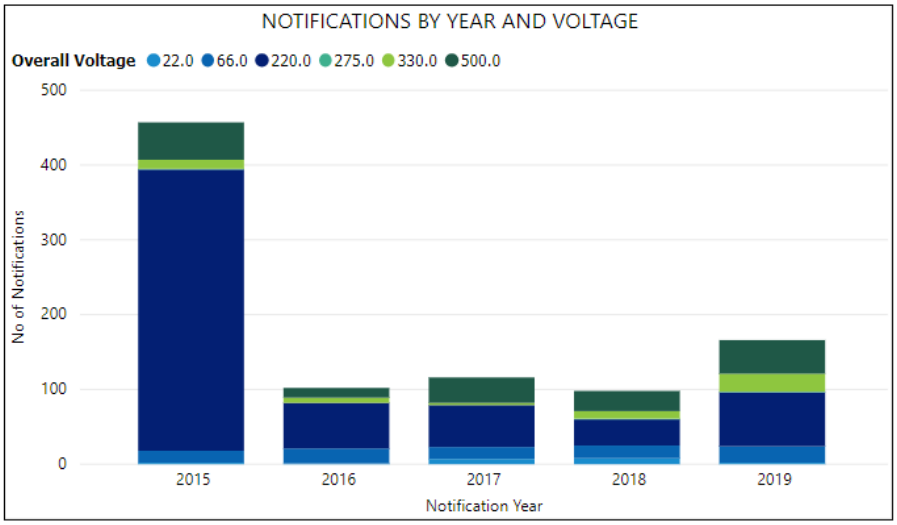

Figure 8 – ZA Notification analysis by operating voltage of Switches - 2015-2019 Period

[C-I-C]

Figure 9 – ZA Notification analysis by Manufacturer of Switches - 2015-2019 Period (top 10 by noti counts)

Disconnectors and Earth Switches

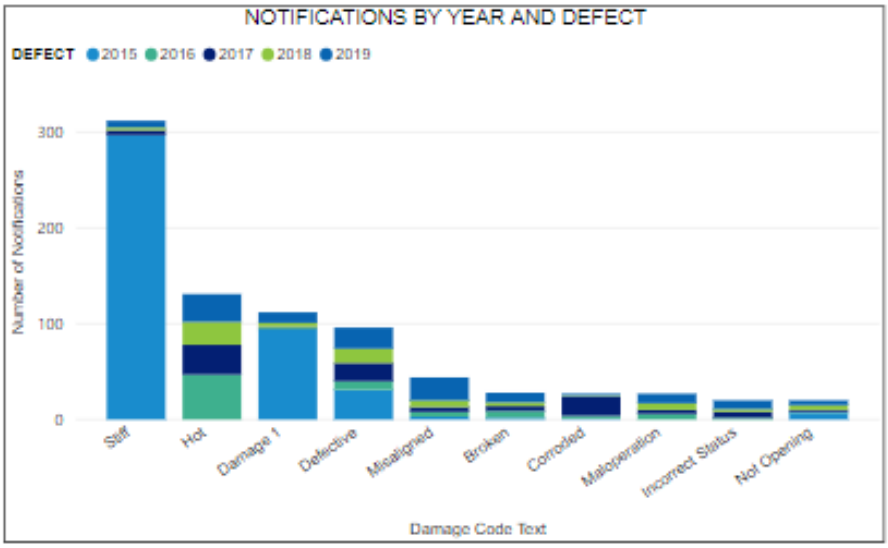

Figure 10 – ZA Notification analysis by Defect - 2015-2019 Period (top 10 by noti counts)

[C-I-C]

Figure 11 – ZA Notification analysis by Defect - 2015-2019 Period (top 10 manufacturer by noti counts and defects >10 noti counts)

Following observations were made based on figures 7,8 ,9 ,10 & 11.

1. Approximately 71.1% of the ZA notifications in the year 2015 were due to earth switches. Out of earth switch faults in the year 2015, 89.2% of the ZA notifications were due to 220kV [C-I-C] earth switches. The key issue found in [C-I-C] earth switch was stiffness of the switch to operate causing HSE risk to operators. Condition of [C-I-C] Earth switches improved after implementing the earth switch modification program in consultation with the manufacturer. Some [C-I-C] disconnectors integrated with the [C-I-C] Earth switch had blade rollover material breakages, due to inappropriate grade of material, and these were also resolved at the same time. Average age of these switches is about 12 yrs.

2. 500kV [C-I-C] switches recorded the second highest count of ZA notifications during the period 2005-2019, mainly due to effects of corrosion, misalignment, maloperation. Average age of these switches is about 35 yrs and needs frequent intervention and becoming maintenance extensive.

3. 220kV [C-I-C] recorded the third highest ZA notifications during the period 2015-2019, mainly due to corrosion, high resistance contacts, misalignment and latching problems. Average age of these switches is about 48.8 yrs and needs frequent intervention and becoming maintenance extensive.

4. 220kV [C-I-C] switches recorded the fourth highest count of ZA notifications during the period 2005-2019, mainly due to effects of corrosion, high resistance contacts, stiffness, misalignment, maloperation. Average age of these switches is about 51yrs had developing issues.

5. 66kV (& 22kV) [C-I-C] type under slung isolators recorded the next highest ZA notifications during the period 2005-2019, mainly due to high resistance contacts and latching problems. Average age of these isolators is about 39 and 31 years respectively. They are operated by hook sticks for equipment isolation during network operation & maintenance activities more frequently than typical 220kV and above ganged disconnectors and earth switches is the main cause for developing issues in midlife.

Table 2 below shows the Notification rate per switch type per year for the period 2015- 2019.

Table 2: Notification Rate for Disconnectors and earth switches -2015-2020

Object Type	Total Count of ZA Notifications 2015-2019	Count of Equipment	Average Notification Rate per object type	Average Notification Rate per object type per year
SWEARTHGIN	2	2	1.000	0.20
SWCHEARTH	443	401	1.105	0.22
ISOLROTARY	264	165	1.600	0.32
ISOLGNGD	75	40	1.875	0.38
ISOL	115	79	1.456	0.29
DISCGIN	10	7	1.429	0.29
Total	**909**	**694**	**1.310**	**0.26**

3.6.2 Major Failures resulting in safety incidents

There had been three significant incidents reported during the period 2013 - 2018 of disconnector 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] type rotary type old ganged 3 phase disconnectors 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] type fused disconnector at Rowville Terminal station (ROTS) failed when attempting to open the disconnector. 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] type fused disconnector at Richmond terminal station (RTS) failed when attempting to open the disconnector 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). A replacement program was initiated to replace all these types and in that design arrangement.

Mechanical failures in old fused disconnector 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 usually starts to appear after 30 to 40 years in service.

The 220kV [C-I-C] manually operated Earth switches, installed in the 2000's, had the fixed and moving contacts binding together resulting in need for excessive force to open presenting an OH & S risk to the operators. Safety gram 2010-012 was issued regarding operation of [C-I-C] earth switches. [C-I-C] subsequently proposed a modified blade with fixed and moving contacts to overcome this issue and it is being implemented at all sites.

Similar problems have occurred for 220kV[C-I-C] manually operated earth switches, installed between 2008 to 2013, some have had stiff operation issues that can results in excessive force having to be applied, and earth switches jamming closed. Once this occurs, access equipment is required to, manually force blade out of the jaws. This issue is under investigation with supplier. Since 2013 all EHV ganged disconnectors and their earth switches, at and greater than 220kV, are fully motorised.

3.6.3 Type Issues

Key issues of older disconnector and earth switch types that need special intervention are given in the table below Table 3. provides the key issues found on those types. Refer figure 11 for typical issues by manufacturer-model.

Disconnectors and Earth Switches

Table 3: Disconnector and Earth switch Type Issues

Description	Key issues
500 kV [C-I-C] make Disconnectors and Earth switches	• Major issues with operating drive, gearbox seizures. • Electrical control system failures or mal operations contribute ROI not operating electrically or remotely. • Moisture ingress into mechanism box.
220 kV,330 kV & 500 kV [C-I-C] make Disconnectors and Earth switches	• Stiffness, Mechanism seizures, corrosion, drive rod failures, mechanism failures, alignment issues. • Frequent contact resistance issues due to corrosion. • Control circuit failures and switches not operating electrically. • No support from manufacturer
220 kV [C-I-C] make [C-I-C] type Disconnectors and Earth switches	• Problems due to electrical control system issues such as auxiliary switch defects, incorrect status indication, alignment issues. • Damages to support insulators and one case of mechanism seizure reported. • Contact system failures and high resistance contacts, defective blades, and burnt contacts. • Drive rod failures, alignment issues and defective mechanisms. • Electrical control failures, failure to operate electrically or remotely. • No support from manufacturer
66 kV and below [C-I-C], Switchgear and [C-I-C] make switches 66 kV and below Cap and Pin type fused disconnectors (mainly [C-I-C], [C-I-C] pre-1971 types)	• Locking pin misalignment. • Wear and tear. • High resistance contacts. • Latching problems. • Brown cap and pin type support insulator failures due to pin corrosion. • No support from manufacturer

4 Other Issues

4.1 Cap and Pin support insulator failures

Cap and pin type insulator types used in older disconnectors and are also used as bus bar support insulators in older terminal stations. Cap and pin type insulator types eventually fail through cement growth causing insulator cracking or pin drop out, in turn causing insulation electrical failure or more insidious a lack of mechanical strength. Many of have them are approaching end of life.

4.2 Very low operation of switches

Switches that operate very rarely are often found to be difficult to open 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 completely cease support 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.

The 220kV to 500kV [C-I-C] make, the 220kV [C-I-C] and 66kV [C-I-C] underslung types, the 66kV [C-I-C] and [C-I-C]l Vertical Break switches and [C-I-C] Air Break Switches are all technically obsolete and the availability of new spares is particularly difficult to maintain these 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.

Refurbishment/part replacement of older existing Disconnectors and earth switches is not cost effective as in most instances parts are required to be re-engineered due to technical obsolescence. Type tested performance cannot be guaranteed with modified components in Disconnectors without testing or proven as safe. Nor can these easily be brought up to more modern safety standards, such as 220kV and above with fully motorised operation (no manual handling and less direct exposure during operation) and greater clearances for safer operational access. Therefore, replacement is considered as the economically feasible option for older types.

The majority of the poor and very poor condition disconnectors are associated with the poor/ very poor condition circuit breakers. Proactive replacement of number of poor condition Disconnectors and earth switches can be done efficiently in a cost-effective manner if replacements are coordinated with the planned station works /asset replacement of associated power transformers and switchgear.

The poor/very poor types proposed to be replaced under the Major station replacement programs include the majority of deteriorating types 500kV [C-I-C], 220kV [C-I-C] and 66kV [C-I-C] type.

There remains some deteriorating types, where no strategic spares exist, and that are not part of a bundled program of work during 2022-27. Replacement to generate spares of following very poor condition (C5), technically obsolete Disconnectors & Earth switches, that are not included under major projects are recommended to manage availability, HSE risk and repair times:

- 2 off 220kV [C-I-C] type
- 2 off 220kV [C-I-C] type

Spares for other types including the 500kV & 330kV [C-I-C] type are being generated in current TRR period.

It is also recommended to replace worst of the very poor condition Cap and Pin type bus insulators at terminal stations that are not included under major station projects.

6 Asset Strategies

6.1 New Assets

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

6.2 Maintenance

- Continue maintaining disconnectors and switches in accordance with PGI 02-01-02.
- 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 disconnectors and earth switches as per spare holding policies
- Replace selected types, where no strategic spares exist and have no manufacturer support.

6.4 Replacement

- Replace poor and very poor condition disconnectors and earth switches with their associated CB during the major station asset replacement programs during 2022-27.
- Replace selected types of the poor /very poor condition, technically obsolete disconnectors & earth switches, not included in major programs, to generate strategic spares:
  - 2 off 220kV [C-I-C] type
  - 2 off 220kV [C-I-C] switch disconnector type
- Replacement of very poor condition Cap and Pin type insulators at terminal stations that are not included under major station projects

6.5 Refurbishment

- Complete implementation of the 220kV [C-I-C] manually operated earth switches redesign
- Continue investigating stiffness issue and solution with manufacturer of the 220kV [C-I-C] manually operated earth switch