AMS – Victorian Electricity Transmission Network

Disconnectors and Earth Switches (PUBLIC VERSION)

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1 Executive Summary

AusNet Services has approximately 2,526 air-insulated disconnectors and 1,463 earth switches installed on the Victorian electricity transmission network.

After a circuit breaker has interrupted the relevant electrical current, a disconnector is used to create a physical separation between selected equipment and each source of electrical energy. A disconnector is an off-load switching device that electrically isolates selected equipment to permit safe inspection or maintenance.

Earth switches are closed (or portable earth leads are attached) to electrically connect selected isolated equipment to the general mass of earth via the station earth grid. The combined use of disconnectors and earth switches creates a safe working environment for inspection or maintenance, by preventing the formation of an electrical potential on the selected equipment.

Forty per cent of disconnectors and 18% of earth switches on the Victorian electricity transmission network have provided over 40 years of service. Three percent of earth switches are in C5 (very poor) condition while 57% are either in C1 (very good) or C2 (good) conditions.

As significant proportions of each fleet of disconnectors (29% of ≤ 66 kV, 8% of 220 kV, 24% of 330 kV and 26% of 500 kV) have been assessed as in C5 (very poor condition), disconnector replacement will continue to be a significant component of the scope of circuit breaker and station refurbishment projects through the planning period. With fewer station refurbishment projects forecasted in future, standalone switch replacement projects will be required to replace assets in "very poor" condition which pose a significant safety risk to workers.

Design defects in the 220 kV [C.I.C] disconnectors and earth switches are generating high manual operating effort creating occupational health and safety risks, as well as a performance risk of an outage caused by a switch that is unable to be opened. Design modifications to these switches need to be continued to eliminate the health and safety risk and improve performance.

The other types that need special intervention are: 500 kV [C.I.C], 220 kV, 330 kV & 500 kV [C.I.C], 220 kV [C.I.C], 66 kV and below [C.I.C] made switches and 66 kV and below fused isolators with cap and pin insulators (mainly [C.I.C] pre 1971 types). These types have developed problems in the operating mechanism, current path, control system (remote controlled switches) and support insulators.

Key asset management strategies for Disconnectors and Earth Switches include:

New installations

- Install 22 kV and 66 kV rotating double-break design isolators in new installations.
- Review station service transformer supply design to minimise future use of fused isolators.
- Install earth switches instead of earth receptacles at 220 kV and above for future earthing installations.
- Install motorised rotary double break disconnectors to 220 kV and above new disconnector installations.

Inspection

- Develop an inspection regime for disconnectors and earth switches by 2018.
- Continue annual non-invasive inspection of disconnectors with particular attention paid to heavily loaded circuits.

Maintenance

- Review maintenance regime with a focus on the selection of lubricants for disconnectors and earth switches
- Review and update specifications for disconnectors and earth switches to extend the maintenance intervals to better match that of new SF6 switchgear.

Refurbishment

- Continue to implement design modifications of the 220 kV [C.I.C] earth switches
- Where economic refurbish or replace 22 kV and 66 kV high-risk fused isolators and underslung isolators in C5 condition.
- Where economic refurbish or replace 220 kV and above high-risk disconnectors and earth switches which are in C5 condition.

Replacement

- Replace disconnectors and earth switches if their thermal or short circuit rating is exceeded.
- Where economic, include disconnector replacement in the scope of circuit breaker replacement and station refurbishment projects.

2 Introduction

2.1 Purpose

The purpose of this Asset Management Strategy (AMS) is to set-out and explain economic inspection, maintenance, refurbishment and replacement strategies to manage the performance of Disconnectors and Earth Switches in the Victorian electricity transmission network throughout their life cycle.

2.2 Scope

This AMS applies to AusNet Services' Disconnectors and Earth Switches installed in the terminal stations of the Victorian electricity transmission network.

Portable earth leads and associated receptacles are not included in this document. Disconnectors and earth switches installed in GIS and metal enclosed indoor switchboards are excluded from this asset management strategy. Refer to AMS 10-62 for information on disconnectors and earth switches installed in GIS bays in the Victorian electricity transmission network.

The strategies in this document are limited to maintaining design capabilities in terms of equipment performance and rating. Improvements in quality or capacity of supply are not included in the scope of this document.

3 Asset Summary

Disconnectors are used in the Victorian electricity transmission network 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; fault current ratings and fault make ratings but do not have the load breaking ratings or fault interruption ratings.

Earth switches in the closed position provide a direct connection of selected isolated equipment to general mass of earth via the terminal station grid. This is to create a safe working environment for equipment inspection or maintenance. Combined use of disconnectors and earth switches are provided by means of integrated disconnector – earth switch unit or as separate standalone units.

3.1 Population

3.1.1 Disconnectors

AusNet Services has approximately 2,526 air-insulated disconnectors (three-phase units) installed on the transmission network. A majority of the disconnectors in the transmission network (42%) operate at 66 kV followed by 220 kV (32%). There are a very few disconnectors operating at 275 kV, 11 kV and 6.6 kV voltages in the terminal stations. Figure 1 provides an overview of the disconnector fleet by their operating voltage.

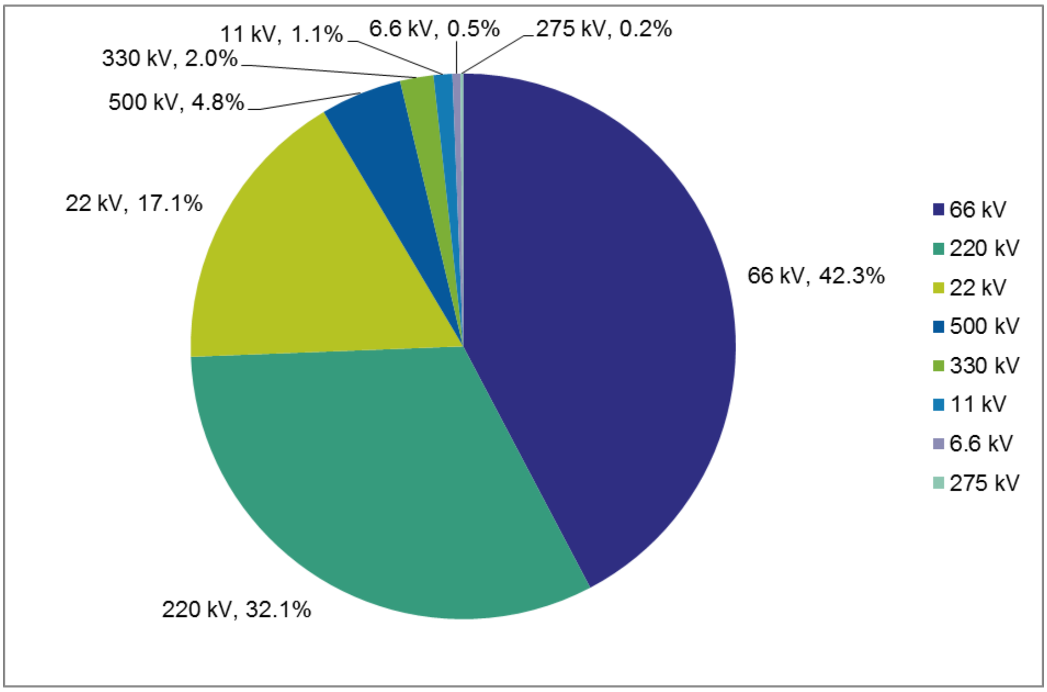

Figure 1 – Disconnectors by Voltage

Error! Reference source not found. below demonstrates the population of disconnectors used in the transmission network by their manufacturer. More than 25 different manufacturers have supplied disconnector units across the fleet. A majority of disconnectors were manufactured by Stanger (24%) and have an average service age of 36 years followed by [C.I.C] disconnectors (16%) with an average service age of six years. About 9% of [C.I.C] type disconnectors remain in the transmission network with average service age close to 50 years. More than 70 [C.I.C] disconnectors have provided more than 50 years of service. Generally these units are approaching the end of their useful lives.

[C.I.C]

3.1.2 Earth Switches

Approximately 1,463 air insulated earth switches are installed on the transmission network. Around 15 different manufacturers have supplied earth switches in this the fleet. The majority of earth switches are of [C.I.C] manufacture (28%) followed by [C.I.C] (21%) and [C.I.C] (16%). Figure 2 and **Error! Reference source not found.** provide an overview of the fleet.

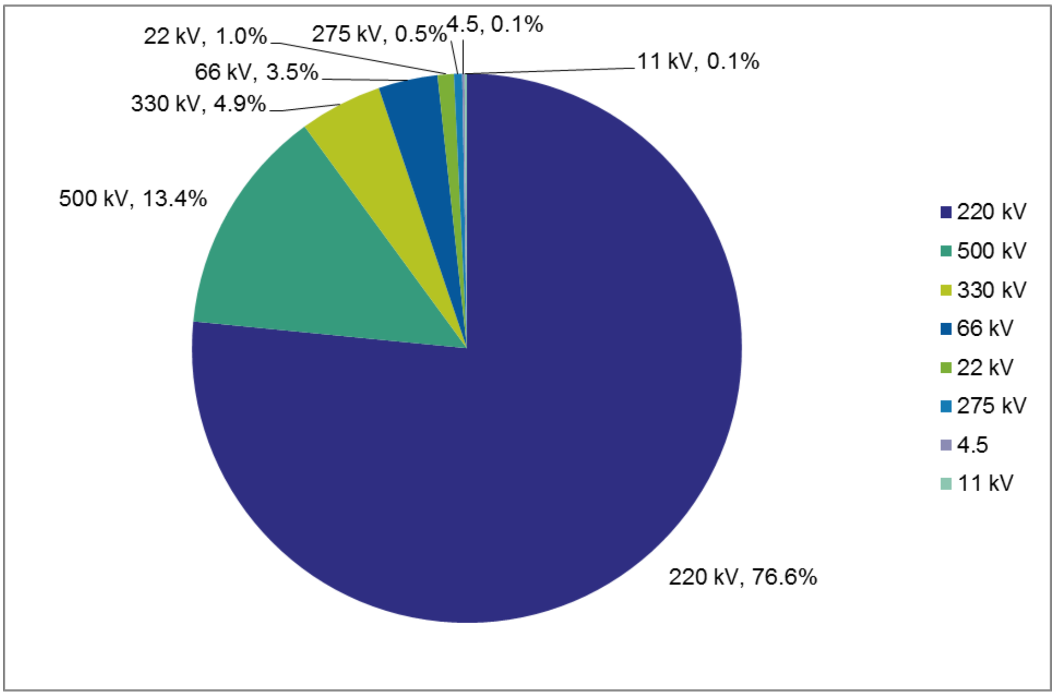

Figure 2 – Air Insulated Earth Switches by Voltage

[C.I.C]

Air-insulated earth switches are manually operated and are of a lighter construction than the disconnectors they serve. However, with a few minor exceptions, these switches have the same through-fault current rating.

3.2 Age Profile

3.2.1 Disconnectors

The average service age of the air-insulated disconnector fleet is 27 years, with the majority of disconnectors dating from the installation of the plant that they serve. Most disconnectors achieve an economic life of approximately 40 years.

Voltage (kV)	Average Service Age (years)
< 66	36
66	30
220	18
275	26
330	33
500	27
All Units	27

Table 1 – Average Ages

AusNet Services has a relatively old fleet of disconnectors, with approximately 40% of disconnector fleet having provided over 40 years of service. The 2013 ITOMS[1] results for disconnectors over 200 kV confirm that AusNet Services' fleet of disconnectors rank tenth oldest in the survey group of 25 transmission companies. The average age of disconnectors below 100 kV is even higher but the 2013 ITOMS provides no comparison of age data below 100 kV disconnectors. Figure 3 displays the service age profiles of the air insulated disconnector fleet.

[1] Practices report – ITOMS (International Transmission Operations and Maintenance Study) 2013 Report

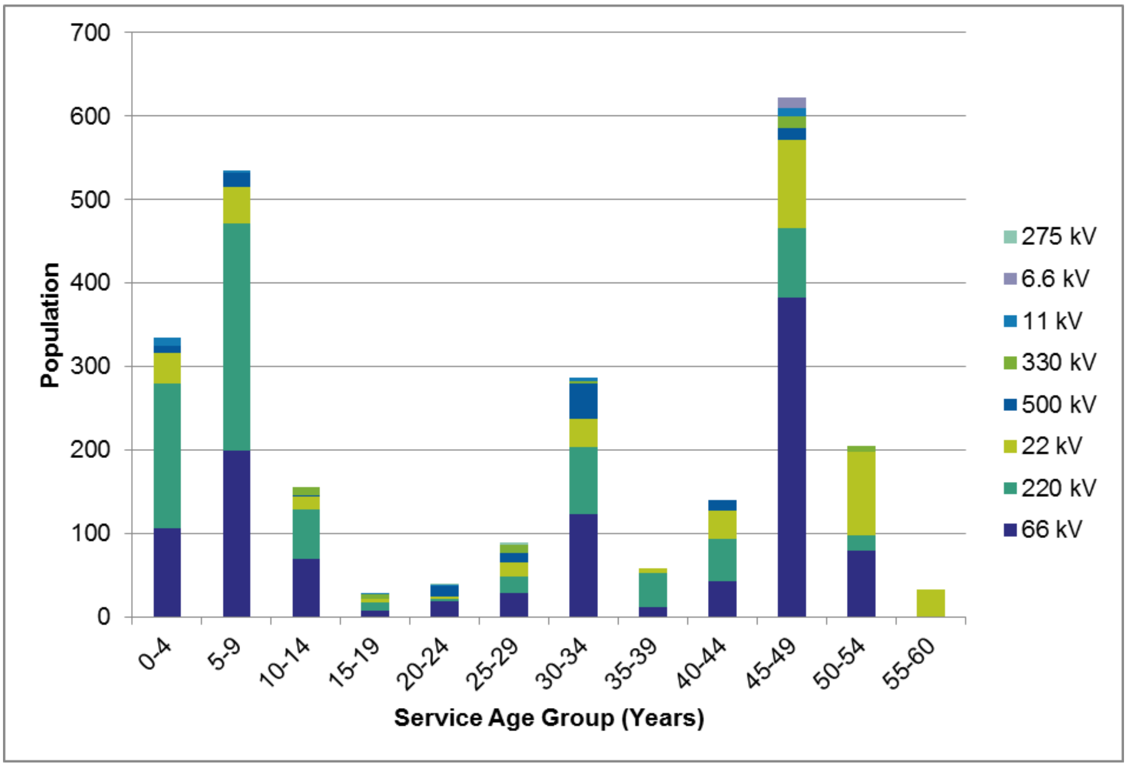

Figure 3 – Age Profile of Air-Insulated Disconnectors

A significant portion of disconnectors (25%) in the 45-49 service age group will move to over 50 service age group during next five years upon which deterioration is expected to accelerate. At present approximately 238 air-insulated disconnectors have provided over 50 years of service. This includes 80 disconnectors operating at 66 kV and 133 disconnectors at 22 kV. More than 46% of these were manufactured by the [C.I.C] and spares and technical support is no-longer available. Other elderly disconnectors still in service are of [C.I.C] manufacture.

It is also evident from the above graph that approximately 55% of the 220 kV disconnector fleet is less than 10 years old as a result of significant 220 kV asset replacements over the last decade.

3.2.2 Earth Switches

The average service age of the earth switch fleet is 20 years. Most earth switches will provide economic life of approximately 40 years.

Significant 220 kV disconnector replacements have contributed to a relatively young fleet of earth switches, with only 18% aged over 40 years and 46% aged less than 10 years. Approximately 57% of 220 kV earth switches are less than 10 years old. It can also be seen that more than 45% of 330 kV earth switches are now over 45 years old. The earth switches that are older than 45 years are of [C.I.C] manufacture.

Figure 4 displays the service age profiles of the earth switch fleet.

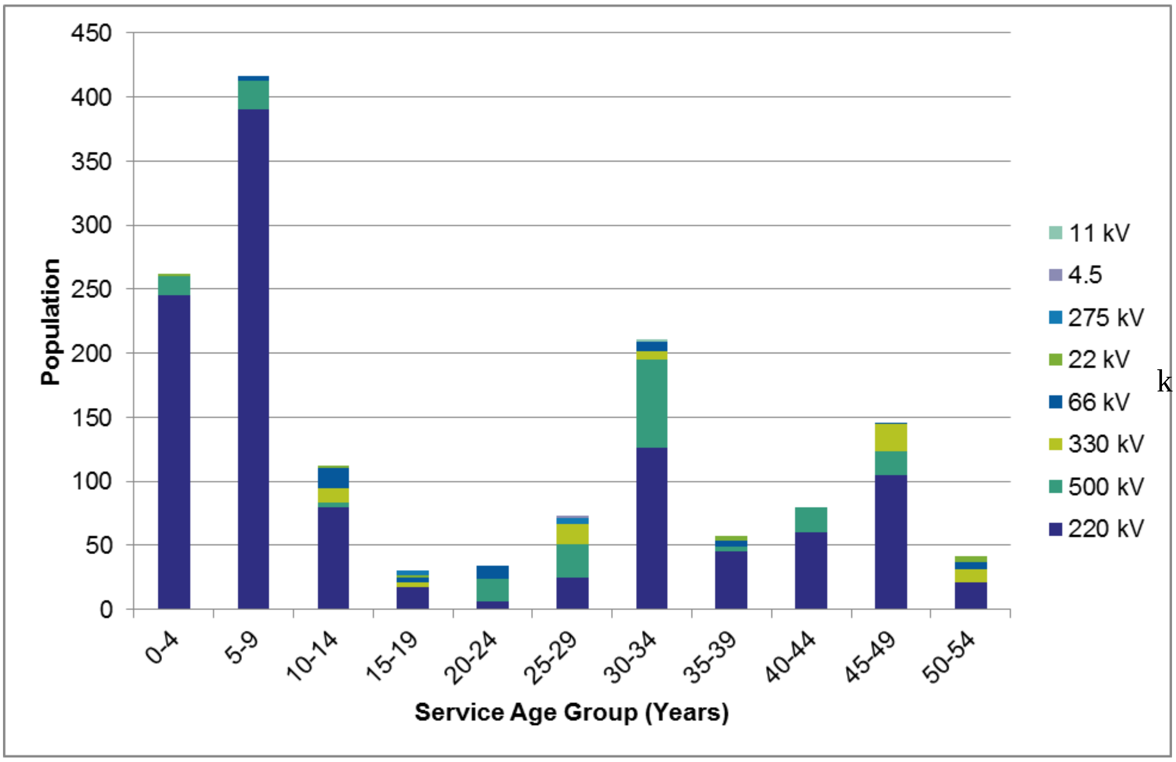

Figure 4 – Age Profile of Air Insulated Earth Switches

3.3 Key Issues

3.3.1 Binding Contacts

Due to design deficiencies, a lack of operation and the hardening of lubricating greases, the fixed and moving contacts of some earth switches are binding together. This presents both an OH&S risk to the operators, due to the increased operating force required, as well as a performance risk of an outage caused by a switch that is unable to be opened.

3.3.2 Disconnector Thermal and Short Circuit Ratings

Nominal currents and fault levels on the network have increased over time. Initial disconnector type tests demonstrate that in most cases the fault current withstand ratings of disconnectors purchased from the 1960s onward cannot be extended.

There are a small number of disconnectors on the network which are now exposed to currents which exceed their rated thermal and short circuit duties. Whilst these are still capable of providing an operational service to the network they need to be prioritised for replacement in the coming years.

3.3.3 Motorised Disconnectors

The use of SF_6 insulated CBs; in particular GIS or dead tank CBs requires that the CB can be isolated within a short space of time. Accordingly, during station refurbishment, the disconnectors would be motorised or replaced. While almost all designs of existing EHV disconnectors have the provision for motorised operation, changes in designs and manufacturers mean that the motorised drive units may only be available from a 'reverse engineering' process. It is questionable whether motorising old disconnectors is economic, unless they are in very good condition and have adequate future normal current and fault withstand ratings. For 66kV and below operating voltages, selective replacement is considered based on economic viability, health and safety, and technical requirements. Defective motors contributes to more than 3% of the unplanned work orders, majority of them are associated with the motors in 500 kV switches.

3.3.4 Tagged Switches

As disconnectors and earth switches are meant to be operated de-energised, the chance of causing a system incident by its own is very remote. Most of the time, defects are observed during planned maintenance inspections and during operation of switches. Operation of switches is required during a system incident for isolation and earthing of plant, and also for isolation when plant maintenance is carried out.

Some defects cannot be resolved during the planned outage. When switch function is impaired due to a defect they cannot be remotely operated and they are tagged as inoperable for safety. A Tag is usually associated with a comment on the problem of the switch. Tags remain in place until the defects are addressed. Due to difficulty in obtaining an outage to repair a tagged switch in the transmission network, sometimes a tagged switch remains tagged and unavailable for remote operation for a significant time. Most tagged switches are those which operate at higher voltages.

3.3.5 Spares Availability

As explained in earlier sections more than 34% disconnectors and more than 18% earth switches of the fleet have provided over 45 years of service. The condition of almost all of these switches is either “very poor” or “poor”. Most of them are at the end of their useful lives. For the aged assets it is very difficult to find spare parts as manufacturers’ support is not available for some models. In most of the cases, parts from already retired units are used as spares. However this is not a sustainable solution and these switches needs to be gradually phased out. These switches are technically obsolete.

3.3.6 22 kV and 66 kV Fused Isolators and Underslung Isolators

22 kV and 66 kV fused isolators and underslung isolators are opened and closed by hook sticks which are operated manually by field operators. They are operated in the vicinity of the switch location and if a switch is defective, the operator is prone to get injured due to falling parts or electrocuted due to entangling with live conductors. Several 22 kV fused isolators and underslung isolators failures occurred during the period 2005 - 2014.

Five safety grams have been issued warning operators to visually inspect isolators prior to operating them. In 2013 a safety gram (SG 2013039) was issued to cease operation of fuse units where conductors do not have a second point of attachment or support and could fall to ground in the instance of an insulator failure.

The root cause of failure of the 22 kV fused cap and pin type isolators was mechanical failure resulting from excessive mechanical operating loads during operation and static stresses imposed by cement growth on the porcelain insulator. Cement growth is a known failure mode of cap and pin insulators and an American research paper[2] on the subject suggests it can lead to insulator failure after 25 years.

Failures in 22 kV and 66 kV underslung isolators were due to a combination of cement growth, higher force required to operate due to stiffness and latching problems resulting in mechanical failure as they age.

With deterioration of these types of isolators, it is becoming difficult to use them for isolating the associated equipment for regular plant maintenance due to increasing safety risks and eventually they are tagged as inoperative.

3.3.7 Maintenance Inspection Intervals

Traditionally preventive maintenance inspections were based on manufacturer recommended intervals ranging from four to eight years. With the grouping of assets to match the maintenance intervals of associated

[2] [1] Failure Analysis of Brittle Materials by Van Derck Frechette. Published September 1st 1990 by American Ceramic Society.

[2] US Department of Interior, Bureau of Reclamation: Facilities Instructions, Standards & Techniques; Failures Of Pedestal-Type (Pin And Cap) Insulators(http://www.usbr.gov/power/data/fist/fist_vol_3/vol3-26.pdf)

equipment (circuit breakers, busbars) AusNet Services has optimised the inspection and maintenance intervals for disconnectors and earth switches to occur every 8 years in line with industry best practice.

Lubricants traditionally used on these types of isolators have progressively been phased out by the lubricant manufacturers which have forced utilities to investigate and trial suitable alternatives. Selecting suitable lubricants for the desired application and maintenance interval is being discussed with manufacturers along with other Australian utilities through industry working groups.

For older switches which are technically obsolete and have no manufacturer support, third party manufacturers have been approached to remanufacture specialist spare parts to support the ageing fleet. When supply agreements have been set in place the effective condition of the equipment can be reassessed.

All new disconnectors and earth switches purchased will be designed to meet a minimum eight year maintenance interval standard.

3.3.8 Type Issues

Key issues of particular disconnector and earth switch types that need special intervention are given in the table below. Table 2 provides the key issues found on those types.

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 Disconnector s and Earth switches	• Stiffness, Mechanism seizures, corrosion, drive rod failures, mechanism failures, alignment issues. • Frequent contact resistance issues due to wear and tear. • Control circuit failures and switches not operating electrically.
220 kV [C.I.C] 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.
66 kV and below [C.I.C] make switches 66 kV and below Cap and Pin type fused isolators (mainly [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.

Table 2 – Disconnector and Earth switch Type Issues

3.4 Condition

This section discusses the condition of the air insulated disconnector and earth switch fleets.

3.4.1 Condition Assessment

A condition rating has been assessed for each air-insulated disconnector and earth switch in the network. A final condition score is assigned based on the scale of C1 to C5, C1 being “Very Good” with 95% expected life remaining and C5 being “Very Poor” with 15% expected life remaining.

A fleet based condition score was assessed considering the corrective maintenance (CM) work orders raised during the period 1992 to mid-2014 against key components including; current path, operating drive, electrical control, and support insulators. An individual score was then derived from the fleet based score, technical obsolescence and major failures experienced in certain asset types into account. The technical obsolescence includes factors such as obsolescence of design, availability of manufacturer support and spares availability[3].

The following table provides the condition scoring matrix used to evaluate the condition of air insulated disconnectors and earth switches in the transmission network.

Condition Score	Condition Description	Summary of details of condition score	Expected Remaining Life
C1	Very Good	Generally less than 10 years old and in good operating condition with no past history of defects or failures. Manufacturer support and spares are readily available for routine maintenance. Routine maintenance and continued condition monitoring is recommended.	95%
C2	Good	This category is in better than average condition for service age and technology type. They have not developed recurrent defects but occasionally show signs of emerging defects in the component parts. Very rarely require intervention between scheduled maintenance and do not show trends of serious deterioration in condition or performance. Manufacturer support and spares are available.	70%
C3	Average	This category is in an average condition for its respective service age and technology type. (Some DS/ES may have some component parts replaced already and by doing so condition had improved to average level. They may have developed corrosion of some parts, wear of operating drive, current path overheating and electrical control system issues. These DS/ES may require increased maintenance. Spare parts are being used to replace defective components and manufacturer support is becoming limited.	45%
C4	Poor	This category is in worse than average condition. They generally have an increasing number of defects due to the effects of ageing, duty cycle and events. Manufacturer support and spares are typically not available: salvaged parts from retired equipment or in situ repair are becoming the most practical solution.	25%
C5	Very Poor	This category includes DS/ES which are maintenance intensive and have history of recurrent and widespread faults in component parts. These DS/ES are approaching the end of economic life. The defects develop within the maintenance inspection period and lack of spare parts is a major concern. Some types have developed defects due to poor design and recurrent repairs are becoming uneconomical to maintain the expected reliability. Salvaged components from retired equipment are used. Manufacturer support is very limited /or not available.	**15%**

Table 3 – Condition Scoring Framework for Disconnectors and Earth Switches

[3] Refer AHR 10-59 for further information.

3.4.2 Disconnectors

Figure 5 below depicts the condition profile of air-insulated disconnectors in the Victorian transmission network.

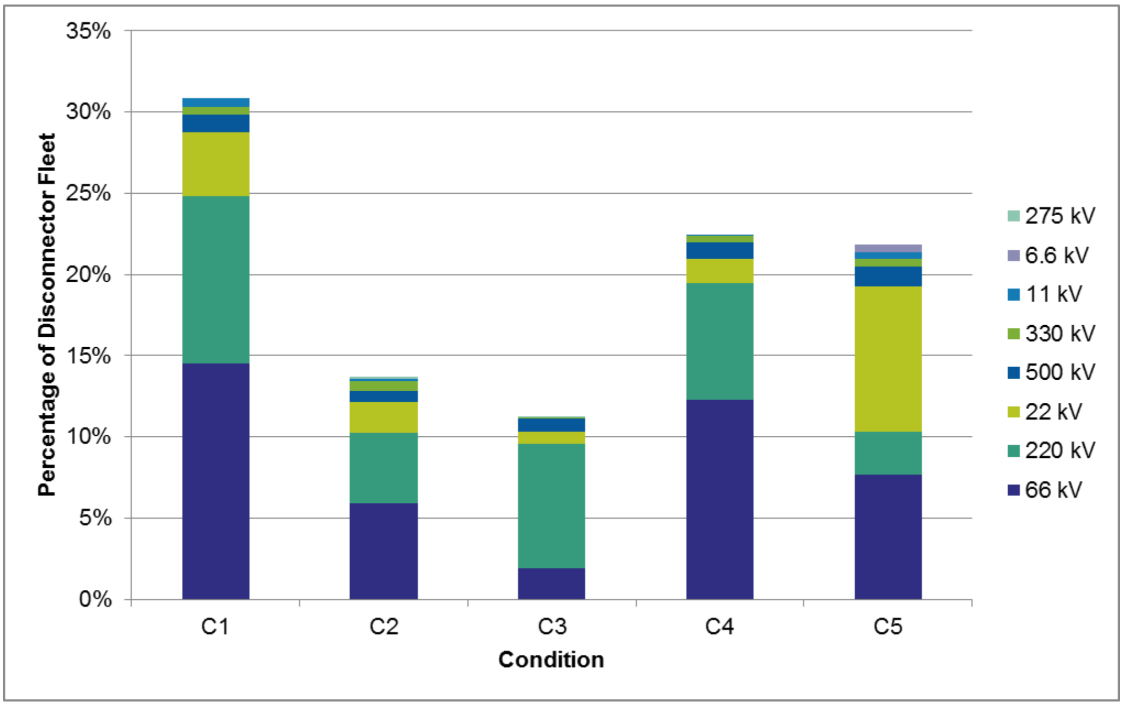

Figure 5 – Disconnector Condition Profile

It is evident from the above figure that 22% of AusNet Services' disconnectors are in "Very Poor" (C5) condition. Another 22% are in "Poor" (C4) condition and will move to C5 condition within the next 5 to 10 years if remedial action is not taken.

As a result of recent 220 kV asset replacements most of the 220 kV disconnectors are in a better condition. There are only 8% of 220 kV disconnectors in "very poor" condition and 45% are in either "very good" (C1) or "good" (C2) conditions. Approximately 24% of 330 kV disconnectors are in "very poor" condition while another 20% are in "poor" condition. All these disconnectors are at Dederang (DDTS) and South Morang terminal stations (SMTS) and most of them are either [C.I.C] type or [C.I.C] type disconnectors installed before 1969. More than 26% of 500 kV disconnectors are in "very poor" condition and they are either [C.I.C] type installed before 1970 or [C.I.C] type.

More than 28% of disconnectors operating at 66 kV or below are in "very poor" condition while another 23% in "poor" condition and are expected to approach "very poor" condition within next 5 to 10 years. More than 94% of these disconnectors in "very poor" condition are of [C.I.C] manufacture and were installed before 1970.

3.4.3 Earth Switches

The Earth Switch population is in a better shape compared to the disconnector population. Only 3% of the earth switch fleet is in "very poor" condition and 14% is in "poor" condition. Approximately 57% of earth switches are in either "very good" or "good" condition.

Figure 6 below demonstrates the condition profile of the air-insulated earth switch fleet.

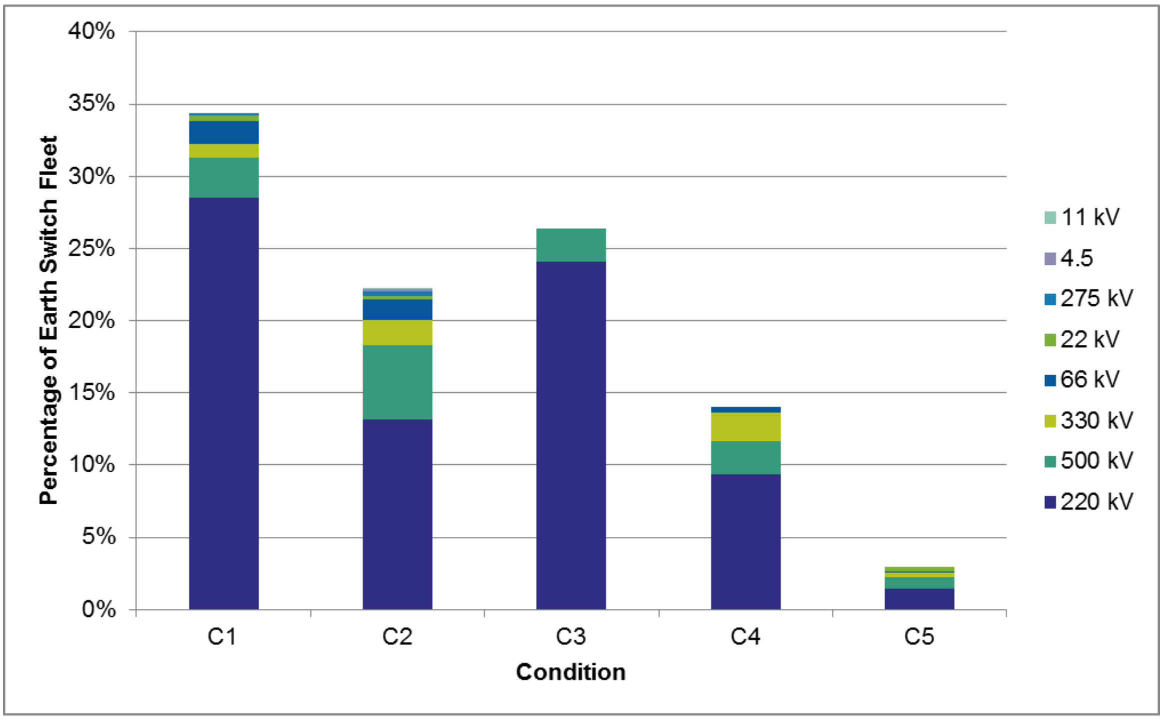

Figure 6 – Earth Switch Condition Profile

Of 1,120 earth switches operating at 220 kV voltage level only 21 switches are in “very poor” condition. This is only 2% of the 220 kV population. A majority of these earth switches are either [C.I.C] type or [C.I.C] type installed in late 1960’s. Another 12% are in “poor” condition demanding higher maintenance requirements. There are 12 earth switches operating at 500 kV that are in “very poor” condition. This is 6% of the 500 kV earth switch population. These earth switches are mostly [C.I.C] type installed in late 1960’s at Hazelwood terminal station (HWTS) and [C.I.C] type earth switches installed in early 1980’s at Moorabool terminal station (MLTS). Another 17% of 500 kV earth switches are in “poor” condition.

There are 16 earth switches operating at 330 kV at DDTS in either “very poor” or “poor” condition. They are either [C.I.C] type or [C.I.C] type installed in early 1960’s. Most of them have provided more than 50 years of service. SMTS has 16 [C.I.C] types earth switches installed in late 1960’s that are in “poor” condition. In summary 6% of 330 kV earth switches are in “very poor” condition and another 39% in “poor” condition approaching “very poor” condition over the next decade. All these earth switches are either at DDTS or SMTS and have provided more than 45 years of service. There are seven 66 kV and five 22 kV earth switches in “very poor” and “poor” conditions and all of them are [C.I.C] type earth switches installed in 1960’s.

3.5 Performance

This section describes the historic performance of the of the Disconnectors and Earth Switches fleet.

3.5.1 Disconnectors

In the period from 2005 to 2014, the network’s Disconnectors have experienced a mean of approximately 63 suspended failures annually, as shown in Figure 7. Suspended failures are relatively minor in nature and have not impacted on the reliability of the electricity transmission network. Suspended failures include OMU (O&M Maintenance Unscheduled) and OME (O&M Maintenance Emergency) work orders. Typical failures include replacing hot contacts, replacing defective insulators and repairing faulty drive motors and gearboxes on remote operated units.

Figure 7 depicts the overall number of unplanned work orders issued per annum for the period between 2005 and 2014.

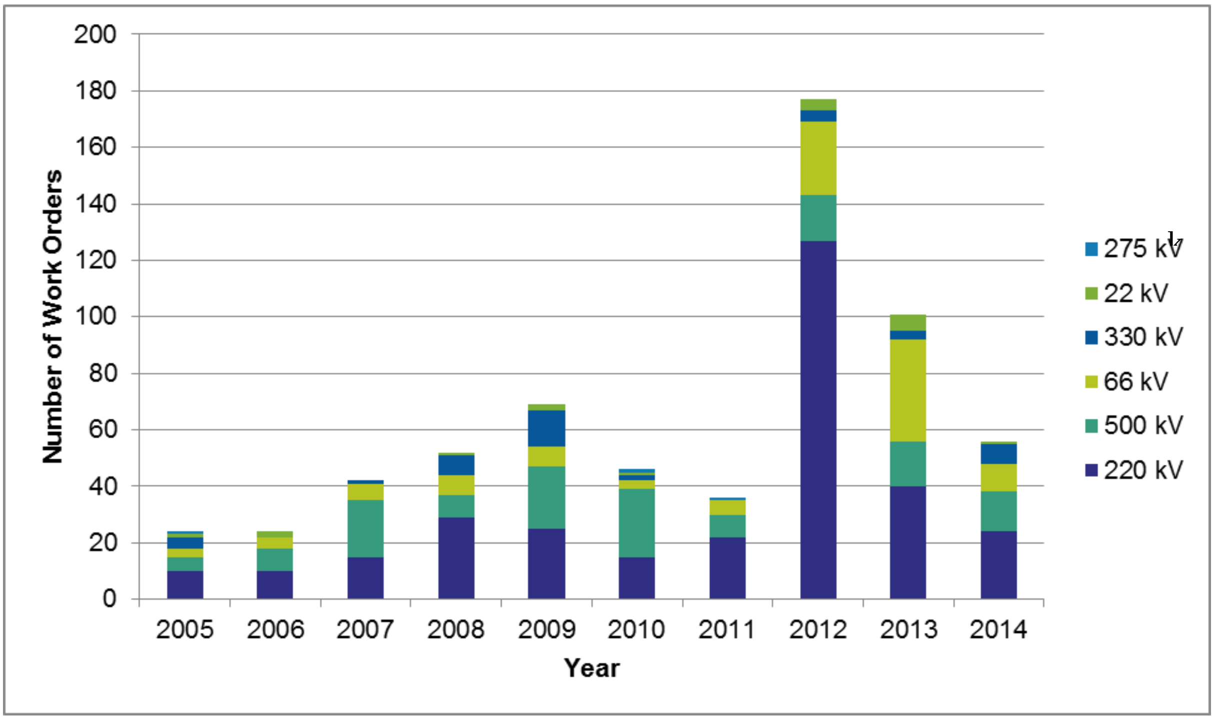

Figure 7 – Unplanned Disconnector Work Orders from 2005 to 2014

The 2012 peak in unplanned disconnector work orders, as shown in Figure 7 above, was because of the need to replace broken blade rotation collars on each 220 kV [C.I.C] disconnector in the fleet. Due to quality issues experienced with the construction materials used, failures and cracks of this component were detected at several stations, prompting the need for their type based refurbishment.

3.5.2 Earth Switches

In the period from 2005 to 2014, the network's Earth Switches have experience a mean of approximately 14 suspended failures annually, as shown in Figure 8. Suspended failures are relatively minor in nature and have not impacted on the reliability of the electricity transmission network. Typical failures include lubrication requirements, contact penetration adjustments and blade and gearbox repairs.

Figure 8 depicts the overall number of unplanned work orders issued per annum for the period between 2005 and 2014.

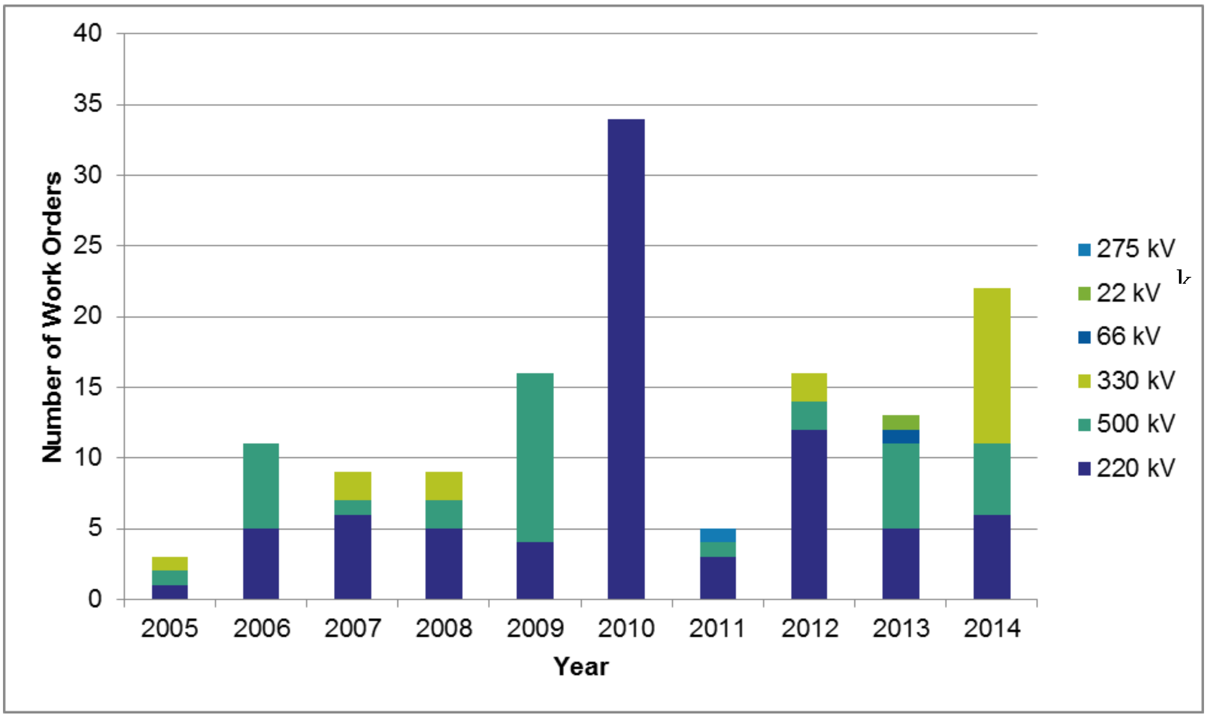

Figure 8 – Unplanned Earth Switch Work Orders from 2005 to 2014

The 2010 peak in suspended failures, as shown in Figure 8, was largely to lubricate and adjust the 220 kV [C.I.C] earth switches at Geelong (GTS), Bendigo (BTS), Terang (TGTS) and Ballarat (BATS) terminal stations.

4 Failure Mode, Effects and Criticality Analysis (FMECA)

FMECA is a technique for analysing and evaluating a life-cycle strategy to ensure that the function of an asset has the desired reliability characteristics by obviating critical failure modes through redundancy, maintenance, refurbishment or replacement. FMECA includes a criticality analysis, which charts the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

4.1 General Failure Modes

4.1.1 High Resistance Contacts and Connections

The wedge type contacts of disconnectors are held together in the closed position by spring compression. The contact pressure starts to relax due to thermal expansion and contraction with each duty cycle. The contact surface and the hinged area can also deteriorate due to corrosion. Subsequently these areas of the disconnectors can develop high resistance to the current path and high operating temperatures when they are subjected to high load currents. Because of their unsophisticated design and exposure to weathering, hot connections commonly occur.

Disconnector contacts in terminal stations are routinely checked by non-intrusive infrared thermal imaging to identify any hot spots within the switchyard and any temperature differential between different phases of disconnectors. About 34% of reported corrective maintenance work (CM) between 2005 – 2014 is due to issues associated with current path of the disconnectors. A majority of current path issues related to high resistance contacts and connections that can be rectified without significant work. If not detected in early stages, contacts can weld together and the disconnector cannot be opened when needed resulting in long outage durations.

4.1.2 Blade Mis-alignment

Some disconnector contacts are force closed or opened manually and some disconnectors by rotation or vertical shift of an operating handle. With duty cycles and weathering, the fixed and moving contact assembly can shift either vertically or laterally from each other so once opened, they cannot be reclosed. Other contacts are found to have jammed in closed position and cannot be opened. In attempting to work loose jammed disconnector contacts, the operator can try to force a switch closed or open, drawing extended arc and potential risk of flashover. The repair varies from simple lubrication, adjustment of the disconnectors to complete disassembly and replacement.

4.1.3 Defective Operating Drive

Defects in the operating drive are the most frequent failure mode of earth switches in the transmission system. More than 41% of CM work orders raised between 2005 and 2014 refer to defects in the operating drive of the switch. Of the recorded causes of operating drive failures, most common causes include defective collars, stiffness of the mechanism, defective motors, operating drive latching problems, gear box failures, corrosion, interlocking issues and moisture ingress.

4.1.4 Insulator Damage

Most of the disconnectors fitted with cap and pin type insulators have been in service for over 40 years. They are made from porcelain sheds cemented over a steel pin at its base and a steel cap on top. With age, the cement cracks and water and contaminant lodging in the gap leads to cracking of the porcelain. This can result in a flashover, with consequent network fault and loss of supply to customers.

Units for the highest currents and voltages are large in size and the forces created by their operating conditions frequently break castings and linkages, particularly if corrosion has caused pivot points to swell and stiffen.

There is also a related safety issue as most of the disconnectors are still manually operated. When opening the disconnector the porcelain shed can break and dislodge from its mounting support and the operator can be stuck holding the porcelain and a piece of live conductor at the end of the operating stick. During the past few years several insulator damage cases have been reported. About 2% of the CM work orders raised during 2005 to 2014 relate to insulator issues.

4.2 Failure Effects

Disconnectors and earth switches are operated de-energised for isolation purposes. The majority of earth switches still don't have remote operation capability. An operator needs to manually operate the switch locally. Therefore health and safety risks are paramount among the failure effects of disconnectors and earth switches.

Some of the disconnector failures listed below occurred in the distribution network but are relevant to the transmission network as both networks use similar types for 66 kV and below operating voltages.

On 6th February 2014, while preparing for access permit, the station operator applied flexible earth to a 22 kV capacitor bank circuit breaker bus isolator when, without any warning, the supporting porcelain insulator failed on the hinged point of the single phase isolator (see Figure 9 below). The operator did not receive any injury.

Figure 9 – Insulator Failure of an Underslung Disconnector

On 29th October 2013, an operator suffered an electric shock subsequent to operating a 22 kV station service transformer fused isolator at Rowville Terminal Station (ROTS). The incident was caused due to the failure of the cap and pin type insulator, resulting in the overhead conductor coming in contact with the operator. The failed isolator is shown in Figure 10.

Figure 10 – ROTS 22 kV Station Service Transformer Fused Isolator Incident

On 18th December 2012, whilst operating an earth switch the handle came away from the earth switch drive causing the operator to feel a strain on the back.

On 1st June 2012, an external fault occurred on PHM12 line while restoring switching a flash over caused damage to the centre phase transfer bus isolator and insulators. The operator was uninjured.

On 29th March 2011, Wonthaggi zone substation (WGI) blue phase 22 kV hook stick operated WG124 CB underslung isolator failed during opening, causing the isolator and a hinged section including porcelain insulator to fall to ground. The falling parts struck the operator.

On 16th February 2010, on closing the bus-side earth switch, an operator experienced a twinge in the back. Later the earth switch handle was bent at its weakest point (where the bolt holes are located to enable the handle to be locked) when two operators attempted to complete the task.

On 9th February 2010, an operator suffered back strain while opening [C.I.C] earth switch due to earth switch contacts sticking upon opening.

On 15th July 2009, while undertaking operating duties and returning BLLY LINE No 4 BUS CB to service, the stiffness of the line side earth switch caused the operator a knee injury.

5 Risk Assessment

Risks associated with Disconnectors and Earth Switches can be assessed in terms of health and safety and performance.

5.1 Health and Safety Risk

5.1.1 Obligations

Statutory obligations relating to the safety of workers are set out in the *Electricity Safety Act 1998* (Vic) and the *Occupational Health and Safety Act 2004*. This legislation requires AusNet Services to (amongst other things) ensure that it identifies and minimises hazards and risks to the safety of its workers '*so far as is practicable*'.

When evaluating alternative remediation options, AusNet Services must have regard to the likelihood and harm and what is known, or should be known, about the safety hazards. Ways to eliminate or mitigate hazards and the availability and suitability of ways to eliminate or mitigate safety hazards must then be considered. AusNet Services is also obliged to have regard to the cost of removing or mitigating the safety hazard or risk.

5.1.2 Risks

Due to design deficiencies, a lack of operation and the hardening of lubricating greases, the fixed and moving contacts of some earth switches are binding together. For manually operated switches, this presents an occupational health and safety risk to the operators (particularly manual handling injuries), due to the increased operating force required.

In some instances, resolution of this binding issue would require any affected contacts to be replaced with re-designed contacts. In the meantime the risks have been mitigated by a modified lubricating regime for the affected earth switches. It has been trialled and proven that lubrication will prevent the contacts binding to each other.

In recent years a few cases of supporting insulator failures while operating were reported. Fortunately no operator was seriously injured in these incidents.

However there is a health and safety risk associated with some types of manually operated disconnectors. When opening the disconnector the porcelain shed can break and dislodge from its mounting support and operator can be stuck holding the porcelain and a piece of live conductor at the end of the operating stick.

5.2 Performance Risk

Due to design deficiencies, as well as a lack of operation, corrosion and the hardening of grease, disconnectors and earth switches may become stuck or unable to operate correctly. A costly outage, such as a bus outage, would thus be required in order to gain access to the defective switch. The Australian Energy Regulator (AER) imposes financial penalties on Transmission Network Service Providers (TNSP's) when equipment outages cause constraints on the shared transmission network. Penalties are incurred via the Service Target Performance Incentive Scheme (STPIS).

This performance risk is a significant driver for the maintenance of reliability. While reliability is generally high, maintenance is scheduled at four or six-yearly intervals in order to keep them in good condition and prevent deterioration reaching a state that cannot be easily reconditioned.

Figure 11 shows the current risk profile presented by 22 kV and 66 kV isolators. There were two near misses reported on 22 kV fused isolators during the last two years. Subsequent audits on similar switches identified many other similar type of 22 kV and 66 kV fused isolators and underslung isolators in worst condition that needs replacement.

During the period 2005 -2014, five safety grams issued for 22 kV fused isolators and underslung isolators. Four of them were reported as near misses while one incident (SG2013039) resulted in 22 kV electric shock and had minor entry and exit wounds to the operator's right hand and foot requiring medical treatment. If no action is taken to address the issues of these fused isolators and underslung isolators, they will continue to deteriorate rapidly as they are at the end of life phase. This may result in incidents with exponentially increasing failure rate and possible extensive injury to operators in the future. The health and safety risk corresponds with a risk rating II on AusNet Services' risk matrix as shown in Figure 11 below.

At operating voltages 220 kV and above, it is not practical to implement standalone switch replacement projects mainly due to difficulty in obtaining network outages. Most of the switch replacements are achieved in conjunction with the main asset replacements (ex: circuit breakers, instrument transformers, power transformers). Therefore it is more appropriate to have a combined risk assessment for switches operating in higher voltages associated with the group of other main asset replacements.

Consequences	A	B	C	D	E
5	II	II	I	I	I
4	III	II	II	I	I
3	III	III	II	II	I
2	IV	III	III	II	II
1	IV	IV	III	III	III
	Likelihood				

Figure 11 – Risk Profile for Fused Isolators and Underslung Isolators

6 Works

During the next five years approximately 130 deteriorated disconnectors and earth switches are planned for replacement or refurbishment of which about 60% are replacements. Most of these switches are in 66 kV and below operating voltages. In addition approximately 120 switches are planned for replacement under station refurbishment projects at Fishermans Bend (FBTS), Heywood (HYTS), Templestowe (TSTS), Ringwood (RWTS), Springvale (SVTS) and West Melbourne (WMTS) terminal stations.

7 Strategies

This section includes asset management strategies for Disconnectors and Earth Switches installed in the terminal stations of the Victorian electricity transmission network.

7.1 New installations

- Install 22 kV and 66 kV rotating double-break design isolators in new installations.
- Review station service transformer supply design to minimise future use of fused isolators.
- Install earth switches instead of earth receptacles at 220 kV and above for future earthing installations.
- Fit motorised disconnectors and earth switches to 220 kV and above new disconnector and earth switch installations.

7.2 Inspection

- Develop an inspection regime for disconnectors and earth switches by 2018.
- Continue annual non-invasive inspection of disconnectors with particular attention paid to heavily loaded circuits as per SMI -67-20-01.

7.3 Maintenance

- Review maintenance regime with a focus on the selection of lubricants for disconnectors and earth switches.
- Review and update specifications for disconnectors and earth switches to extend the maintenance intervals to better match that of new SF_6 switchgear where possible.

7.4 Refurbishment

- Continue to implement design modifications to the 220 kV [C.I.C] earth switches.
- Where economic refurbish or replace 22 kV and 66 kV high-risk fused isolators and underslung isolators in C5 condition.
- Where economic refurbish or replace 220 kV and above high-risk disconnectors and earth switches which are in C5 condition.
- Introduce a system to monitor the repair /refurbishment of tagged assets to minimise the out of order time duration.
- Research to introduce a system to monitor unusual operational behaviour of remote controlled switches to improve condition monitoring and attend to maintenance work before switch failure.

7.5 Replacement

- Replace disconnectors and earth switches if their thermal or short circuit rating is exceeded.
- Where economic, include disconnector replacement in the scope of circuit breaker replacement and station refurbishment projects.
- Continue the current trend of replacement maintaining the condition profile.
- With a fewer number of rebuild projects forecasted in future, develop standalone asset replacement programs to replace assets in “very poor” condition targeting those that pose significant safety risks.