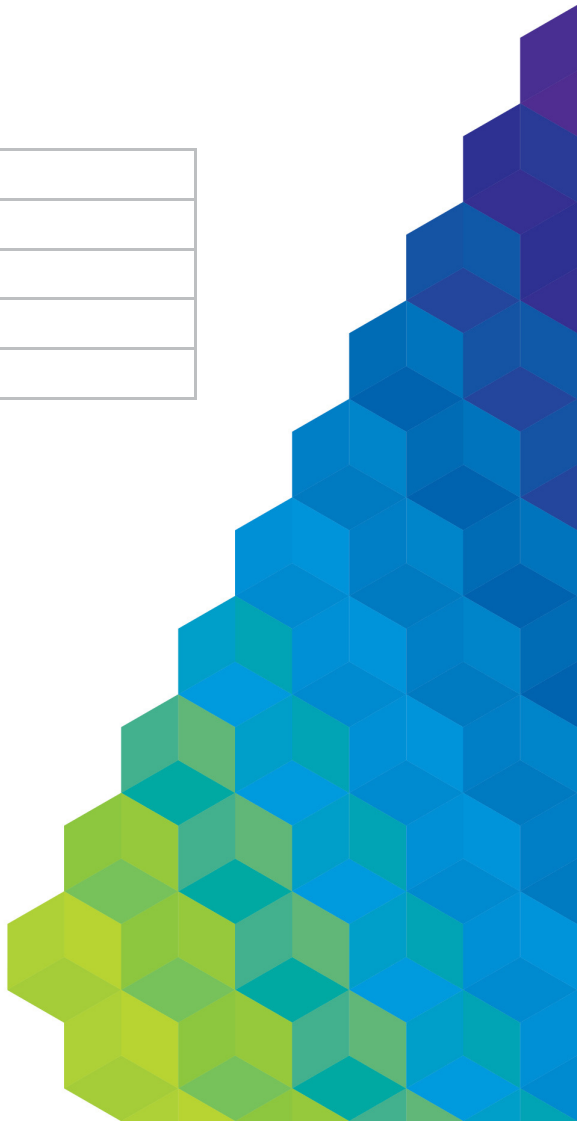
Program of Works

2017 – 2022

Disconnector and Earth Switch Replacement

Document number	N/A
Issue number	1
Status	Approved
Approver	S. Owens
Date of approval	01/06/2015



ISSUE/AMENDMENT STATUS

Issue Number	Date	Description	Author	Approved by
0.1	01/06/15	Draft document	N. Boteju	S. Owens
1.0	01/06/15	Initial Issue	N. Boteju	S. Owens

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1 Summary

PROGRAM	Disconnector and Earth Switch Capital Replacement Program 2017 – 2022
SERVICE DATE	On-going throughout period 2017 – 2022
LOCATION	Different Terminal Stations of Victorian Electricity Transmission Network
VALUE	$ 10.6M for the period 2017/18 – 2021/22

Table 1 – Program Overview

This works program document should be read in conjunction with AMS 10-59 Disconnectors and Earth Switches. It details the background and options analyses performed in order to determine most economical Disconnector and Earth Switch maintenance and replacement program for the period 2017 – 2022.

1.1 Program Scope

This program is to replace / refurbish 127 off deteriorated Disconnectors and Earth Switches at various Terminal Stations in Victorian electricity transmission network described below:

- 10 off 500kV Disconnectors;
- 7 off 330kV Disconnectors and Earth Switches;
- 13 off 220kV Disconnectors;
- 49 off 66kV fused isolators and underslung isolators;
- 48 off 11kV and 22kV fused isolators.

1.2 Program expenditure forecast

The Disconnector and Earth Switches Replacement works are planned to commence in the 2016/17 financial year and extend over the forecast regulatory period. Table 2 below shows the expenditure over the forecast regulatory period.

2017/18 ($k)	2018/19 ($k)	2019/20 ($k)	2020/21 ($k)	2021/22 ($k)	Total ($k)
848	2,440	2,440	2,440	2,440	10,608

Table 2 – Program timing and expenditure forecast

Forecast costs shown in Table 2 are $2014/15 P50 direct costs. These costs exclude overheads, finance charges and cost escalation. Unit costs are described in Appendix 4D: Unit Rates.

2 Obligations

The National Electricity Rules (clauses 6A.6.6 and 6A.6.7) require AusNet Services to forecast operating and capital expenditures to, amongst other objectives, *comply with all applicable regulatory obligations or requirements associated with the provision of prescribed transmission services;*

The Electricity Safety Act (clause 98) requires a major electricity company, such as AusNet Services to design, construct, operate, maintain and decommission its supply network to minimise as far as practicable:

a) the hazards and risks to the safety of any person arising from the supply network; and

b) the hazards and risks of damage to the property of any person arising from the supply network; and

c) the bushfire danger arising from the supply network.

In the definitions of this Act, the term 'practicable', means having regard to:

a) the severity of the hazard or risk in question; and

b) the state of knowledge about the hazard or risk and any ways of removing or mitigating the hazard or risk; and

c) the availability and suitability of ways to remove or mitigate the hazard or risk; and

d) the cost of removing or mitigating the hazard or risk;

This means "as low as reasonably practicable" which has been interpreted as until the safety related costs are (grossly) disproportionate to the safety related benefit.

The *Occupational Health and Safety Act 2004* (Vic) (**OHSA**) requires AusNet Services to:

> *as far as is reasonably practicable, provide and maintain for employees of the employer a working environment that is safe and without risks to health.*[1]

When determining what is (or what was, at a particular time), reasonably practicable in ensuring health and safety, the OHSA requires that regard be had to the following matters:

a) the likelihood of the hazard or risk concerned eventuating;
b) the degree of harm that would result if the hazard or risk eventuated;
c) what the person concerned knows, or ought reasonably to know, about the hazard or risk and any ways of eliminating or reducing the hazard or risk;
d) the availability and suitability of ways to eliminate or reduce the hazard or risk.[2]

[1] Section 21(1).

2 Occupational Health and Safety Act 2010, section 20(2).

3 Program Drivers

Network Reliability

- Major Defects in switches are encountered during planned maintenance inspections and switching operations associated with system incidents. Major failures of switches cause impairment of switching function. This results in unplanned outages, delays or cancellation of planned work on critical plant and equipment. This results in unintentional transmission penalties and market constraints.

Safety and Environment

- In 29 October 2013, a 22kV fused isolator at Rowille 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. The Operator fell to the ground and the conductor made contact with his right hand also 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[3]. Investigations revealed that the mechanical failure of the 22kV fused link insulator was mainly due to cement growth of grouting compound, used on the cap and pin type insulator. Health and Safety risk to operators due to falling broken parts off defective switches at heights and possible electrocution.
- Manual handling of defective switches could lead to back injuries to operators resulting in Loss Time incidents (LTI) / Medical Treatment incidents (MTIs). Excessive force is required to operate some switches due to stiffness and other mechanical defects.
- Safety Grams issued for Disconnectors and Earth switches during the period 2000-2014 is given in Table 3.
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Safety Gram Number	Date of accident	Disconnector / Isolator Type	Description
E 2005-19	07/05/2005	22kV Underslung Isolator	Mechanical failure of support insulator while operating.
2007-031	17/08/2007	22kV Underslung Isolator	Mechanical failure of support insulator while operating.
2009-006	13/02/2009	22kV Fused Isolator	Mechanical failure of support insulator while operating.
2009-028	14/05/2009	245kV Remote Operated Disconnector	Support Insulator Failure due to lower mechanical strength as a result of poor quality of manufacture.
2010 -012	30/03/2010	245kV Earth Switch	Back pain due to excessive force required to operate due to poor design.
SG2013039	30/10/2013	22kV Fused Isolator	Mechanical failure of support insulator while operating.
SG2014007	06/02/2014	22kV Fused Isolator	22kV Fused Isolator due to mechanical failure of support insulator.

Table 3 – Safety Grams on Disconnectors / Earth Switches

[3] \\cbdshare\asset\Plant and Equipment\Stations Group\General Team Information\Regulatory Resets\TRR\2017 - 2022\ Program of Works Documents \significant incident report ROTS 22kV Electric Shock - Insulator Failure.docx

The root cause for 22kV fused isolator failures was due to mechanical failure as a result of combination of mechanical operating loads, imposed on an insulator that was 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 American research papers on the subject[4] suggest it can lead to insulator failure after about 25 years. Failures in 22kV underslung isolators were due to combination of several factors such as cement growth, higher force required to operate due to stiffness and latching problems resulting in mechanical failure.

Financial Impacts

- Failure of the critical switches will result in high market impact costs;
- Financial penalties from incentive schemes;
- Increased costs associated with emergency replacements following major failure of switches;
- Costs associated with injuries / fatalities arisen to staff and contractors working on site;
- Delays or cancellation of planned work on critical plant and equipment resulting in other network risks and inefficiencies in delivery of planned maintenance work.

Regulatory Compliance

- To comply with all applicable regulatory obligations or requirements associated with the provision of prescribed transmission services.

Corporate Image

- To maintain the corporate reputation as a prudent asset manager by managing risk as low as practicable.

4 - US Department of Interior, Bureau of Reclamation: Facilities Instructions, Standards & Techniques; Failures Of Pedestal-Type (Pin And Cap) Insulators.

0(http://www.usbr.gov/power/data/fist/fist_vol_3/vol3-26.pdf).

-T&D World magazine (Feb 01, 2013): Don't Let Aging Insulators Inflict Substation Outages (http://tdworld.com/archive/dont-let-aging-insulators-inflict-substation-outages).

- Lapp Insulator Company (May 1990): Article SA-002 Station Post Replacements for Cap & Pin Insulators.

4 Overview

Disconnectors and Earth Switches are vital components for electrical isolation and earthing of key equipment in the electricity network. Together they provide safe access to equipment for inspection or maintenance and network operations. Major defects in disconnectors and earth switches cause impairment of their intended functions. Their correct operation is essential to enable operating and maintenance staff to work on plant and switchgear with electrical isolation at earth potential. Failures of some types of older switches are becoming common and many switches have been tagged as inoperable due to unreliability and health and safety concerns. Major failures in critical switches result in cancellations or delays in carrying out planned maintenance work leading to inefficient network operations.

4.1 Health and safety risks

When switch function is impaired due to a major defect, they cannot be operated and they are tagged by the Customer & Energy Operations Team (CEOT) for safety reasons. A Tag is usually associated with a comment on the problem of the switch. During the period 2003 -2014, there were 136 switches tagged as inoperable due to various reasons. It should be noted that 64 switches were tagged by the CEOT as inoperable since 2012 due to major defects. (2015 - 7 switches, 2014 – 27 switches, 2013 – 21 switches, 2012 – 9 switches).

Lack of operation and the hardening of lubricating greases contributes to the fixed and moving contacts of some disconnect and earth switches binding together. For manually operated switches, this presents an occupational health and safety risk to the operators, due to the increased operating force required. The health and safety risk, associated with a back injury to an operator, corresponds with a risk rating of II on the AusNet Services' risk matrix. This is shown in Figure 1 below. This risk rating indicates that an injury resulting in lost time or medical treatment could occur. Although such incidents are not common, the risk could increase if no action to replace or refurbish the very poor condition switches.

Ultimately, resolution of this binding issue would require any affected contacts to be replaced with re-designed contacts. In the meantime the risks are being mitigated by a modified lubricating regime for the affected switches. This modified lubricating regime is being trialled to prevent the contacts binding to each other.

In recent years a very few cases of supporting insulator failures while operating were reported. Fortunately no operator was injured in these incidents. The porcelain insulator can break and dislodge from its mounting support when operating switches with defective Supporting insulators. In such an event, the operator can be seriously injured with falling parts and also possible electric shock.

4.2 Performance Risks

Outdoor Disconnectors and Earth switches have developed problems associated with their key components such as Current Path, Operating Drive, Electrical Control and Support Insulators. Some of the issues are due to inherent design of the switch which causes problems in early asset life. The others are caused by environment due to lack of operation, dust and corrosion, and loss of contact lubrication and grease on mechanism parts. High ambient temperatures cause lubrication to dry out and hinder the operation of the switch. As a result, the switch may become stuck or unable to close properly. Wear and tear of the operating mechanism and contacts cause late life problems as they age. Technical obsolence, non-availability of manufacturer support and limited availability of spares make it increasingly difficult to maintain older switches.

Although a useful asset life of 45 years is expected, it is found that outdoor switches develop problems much earlier in life after 20-25 years due to above reasons. Major defects occurring in switches with increased failure rates result in increased operation costs as a result of urgent repairs and frequent interventions. A costly outage, such as a bus outage, would thus be required in order to gain access to a defective switch. Financial penalties are imposed on Transmission Network Service Providers (TNSP's) when equipment outages cause constraints on the shared transmission network.

The performance risk, associated with costly repairs and replacements with an outage required to fix a defective switch, corresponds to a risk rating of II on the AusNet Services' risk matrix, shown in Figure 1, below. This risk rating indicates that a negative financial impact, as a result of an outage, could occur. This poor performance risk is a significant driver for maintenance of reliability.

Disconnector and earth switch maintenance is generally integrated with the associated switchgear or group of switchgear to optimise costs. Presently, a maintenance interval of 8 years is adopted for switches considering the maintenance intervals of associated primary equipment. It is not feasible to rectify major defects especially in poor condition switches without major component replacements. These switches require either major refurbishment or total replacements which takes much more time than the standard time taken during planned inspection.

Apart from risks associated with health & safety consequences, defective disconnectors and earth switches affect network reliability and security causing cancellation or delays for projects and planned asset maintenance works.

5 Risk Matrix

Figure 1 shows the current risk profile presented by these disconnectors and earth switches for 22kV and 66kV isolators. There were two near misses reported on 22kV fused isolators during the last two years. Section 3 provides details safety grams issued during 2005-2014 period.

Subsequent audits on similar switches identified many other similar type of 22kV and 66kV fused isolators and underslung isolators in worst condition that needs replacement.

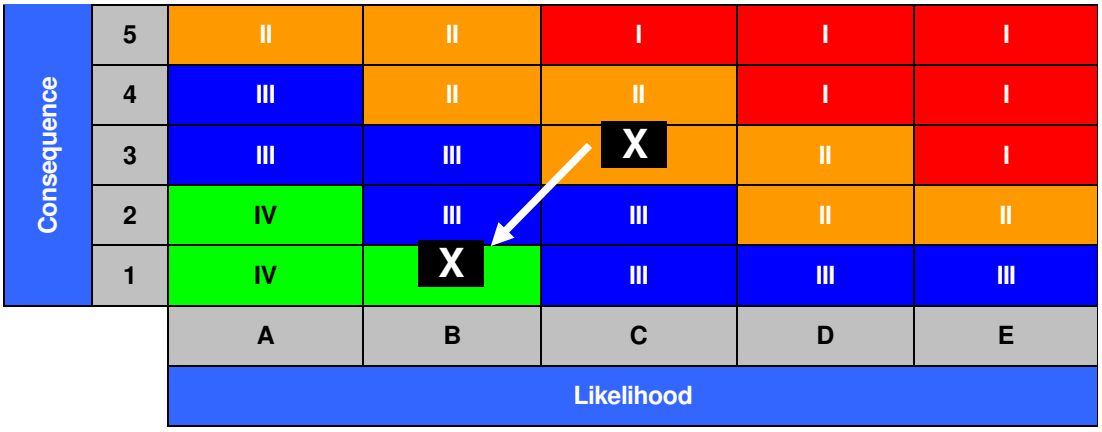

Figure 1 – Risk Matrix - Fused Isolators and Underslung Isolators

6 Option Analysis

The following options have been analysed.

Option 1 Do Nothing

Option 2 Replace 127 off condition 5 switches

Option 3 Replace 75 and refurbish 52 condition 5 switches

6.1 Option 1 – Do Nothing

The 'Do nothing' option involves routine inspection and maintenance but takes no action to refurbish or replace assets as they deteriorate and ultimately fail in service. In this option the functionality of the assets is progressively lost and service to consumers progressively declines and ultimately ceases.

In addition, this option presents increasing operational costs due to emergency repairs and replacements, and safety risks to workers.

This option does not address AusNet Services' obligations:

- under the National Electricity Rules to maintain the quality, reliability and security of supply of prescribed transmission services;
- under the requirements of the Electricity Safety Act to operate, maintain and decommission its supply network to minimise as far as practicable the hazards and risks to the safety of any person arising from the supply network.

This option is not consistent with AusNet Services' accepted Electricity Safety Management Scheme. This implies a very high risk to the business and it fails to address key business drivers listed above in Section 3.

This option is included for economic modelling purposes only. It has PV costs of $14M.

This option is inconsistent with AusNet Services' obligations under the National Electricity Rules. It is not consistent with the obligations of the Electricity Safety Act and with AusNet Services' approved Electricity Safety Management Scheme and asset management strategy for Disconnectors and earth switches and therefore the Do Nothing option is not recommended.

6.2 Option 2 – Replace 127 off condition 5 switches

This option involves proactively replacing 127 off deteriorated condition switches as per Section 1.1 – Program Scope. This option will allow AusNet Services to mitigate the risk of failure of disconnectors and earth switches by replacing the worst condition switches. It will also address the program drivers listed in Section 3 above.

However this is not the most economically feasible option due to high cost of replacement.

This option involves replacing all deteriorated switches instead of considering refurbishment of switches that could be done in an optimised manner.

It also has a disadvantage of longer outage requirement for complete replacement of all switches with a non-identical switch which involve design, installation, setting up, foundation and connection works for all switches.

It has a PV cost of $16.8M which is higher than the other two options considered and is therefore not recommended.

6.3 Option 3 – Replace 75 and refurbish 52 condition 5 switches

This option involves proactively replacing or refurbishing deteriorated disconnectors and earth switches in an optimised manner as per Section 1.1 – Program Scope. This option will allow AusNet Services to mitigate the risk of failure of disconnectors and earth switches. It will also address the program drivers listed in Section 3 above.

Choosing option 3 ensures that the risks and issues associated with these disconnectors and earth switches are addressed in the most economic manner.

Combined replacement / refurbishment option involves proactive refurbishment of switches with few identified issues instead of costly replacement. Refurbishment may extend the life of these switches by 20 years. The replacement of some assets will also produce some spare components from removed switches to maintain the remaining fleet of identical type of switches until they are gradually phased out.

This is the most economic option with a PV cost of $12.7M.

Therefore this option to replace 75 worst condition switches and refurbish another 52 switches in very poor condition is recommended.

7 Financial Analysis

All three options have been financially analysed using an NPV model[5]. As shown in Figure 2 - NPV Analysis Option 3 (Replace 75 off C5 conditions switches and refurbish 52 off switches) has a similar NPV to Option 2 but requires significantly less capital expenditure.

Economic Analysis of Options ($'000s)	PV Capital Cost	PV Opex Costs	PV Community Benefits	PV Proceeds From Sales	Total PV Cost	NPV including Reg Return
Do Nothing	-	(7,495)	(6,591)	-	(14,087)	**(214)**
Replace all 127 worst C5 condition switches	(13,717)	(1,445)	(1,681)	-	(16,843)	**480**
Replace 75 and Refurbish 52 C5 condition switches	(9,602)	(1,500)	(1,681)	-	(12,783)	**415**
	-	-	-	-	-	-
	-	-	-	-	-	-

All figures are in $000's unless otherwise stated.
(nominal and discounted)

Figure 2 - NPV Analysis

8 Recommended Action

The replacement and refurbishment of 127 off deteriorated disconnectors and earth switches, Option 3, is recommended.

This program scope is to replace/refurbish 10 off 500 kV, 7 off 330kV, 13 off 220kV, 49 off 66 kV and 48 off 22kV deteriorated switches in Victorian electricity transmission network as outlined in Section 1.1.

9 Reference Documents

- National Electricity Rules.
- Electricity Safety Act.
- Electricity Safety (Management) Regulations.
- Work Health & Safety Act (2011).
- AMS 10-01 – Victorian Electricity Transmission Network.
- AMS 10-59 – Disconnectors and Earth Switches.
- AHR 10-59 – Disconnectors and Earth Switches.