A Safety Review of Overhead Disconnects and Switches on a Distribution Network

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Abstract

Overhead disconnects and switches are fundamental to a distribution network, facilitating isolation and hastening the restoration of supply.

A recent product approval workshop highlighted several issues relating to the operation and installation practices for overhead disconnects and switches. The requirement for earthing was questioned with the benefits extolled for hook stick operated switches over those with handles at ground level.

Extensive site audits further revealed that some switches had handles and operator positions impeded by metal fences, and that hook stick switches had been installed with no formal earthing despite being attached to conductive poles.

This paper takes a back to basics look at the reasons for earthing a switch and seeks to help nudge the industry towards a standardised best practice approach.

It looks at the industry practice to create an equipotential zone around the operator using an operator pad or grading ring and the previous regulatory requirement to earth all switches and handles (where not isolated from the operator). It extends these principles to hook stick switches and to sealed (vacuum and SF6) switches, to assess if the operator is truly isolated from a switch and if a tested earth is indeed considered an enduring requirement.

It explores the mechanisms and risks of mechanical failure that could liven switch frames, conductive poles and the associated earths. It suggests new practices to protect switch earths and provides examples to demonstrate the variability of current practice across the industry.

It also looks at various advantages and disadvantages of hook stick and handle operated switches and survey's lines mechanics and operators on their issues and preferences.

Introduction

Since the commencement of the wider provisions of the Health and Safety at Work Act (HSWA) in April 2016, there has been a documented industry wide reduction in the level of live line work and an increase in the requirement for switching for isolation. It is therefore seen as vitally important that switching assets are installed and maintained in a safe and operable condition, with consistent practices across a network and wider industry.

This paper first looks at the installation issues found during a recent audit of network switches and then seeks to suggest improved practices. Whilst other maintenance issues were also found during the audit these are not the focus of this paper.

This paper concentrates on the predominant issue found during the audit: that of incorrect or inconsistent earthing or issues relating to the earthing.

Background

During a product approval workshop in 2016, several issues were raised relating to the earthing requirements for Overhead Disconnects. It was questioned whether an earth was required for hook stick operated switches. It was also raised that other networks did not earth hook stick switches including disconnects, SF6 and vacuum switches.

Given the diverse views and understanding expressed at the workshop it was seen as important to document practices (current and historic) and best practice requirements. This was carried out by way of an extensive audit across Aurora Energy's Central network during March and April 2017.

Overview of Network Switches and Audit

There are close to 470 overhead distribution switches operating at or below 11kV on Aurora Energy's Central network[1]. Of these, 74 sites or 16% were audited as well as an additional 6 targeted sites with hook stick operated switches (80 switches in the extended sample). Despite a degree of geographical bias due to logistical efficiency, the sample (n=74) is considered to be representative, as switch installation practices have been relatively consistent across the Central Network.

[1] 32 operating at 6.6kV in the Clyde-Earnscleugh Area.

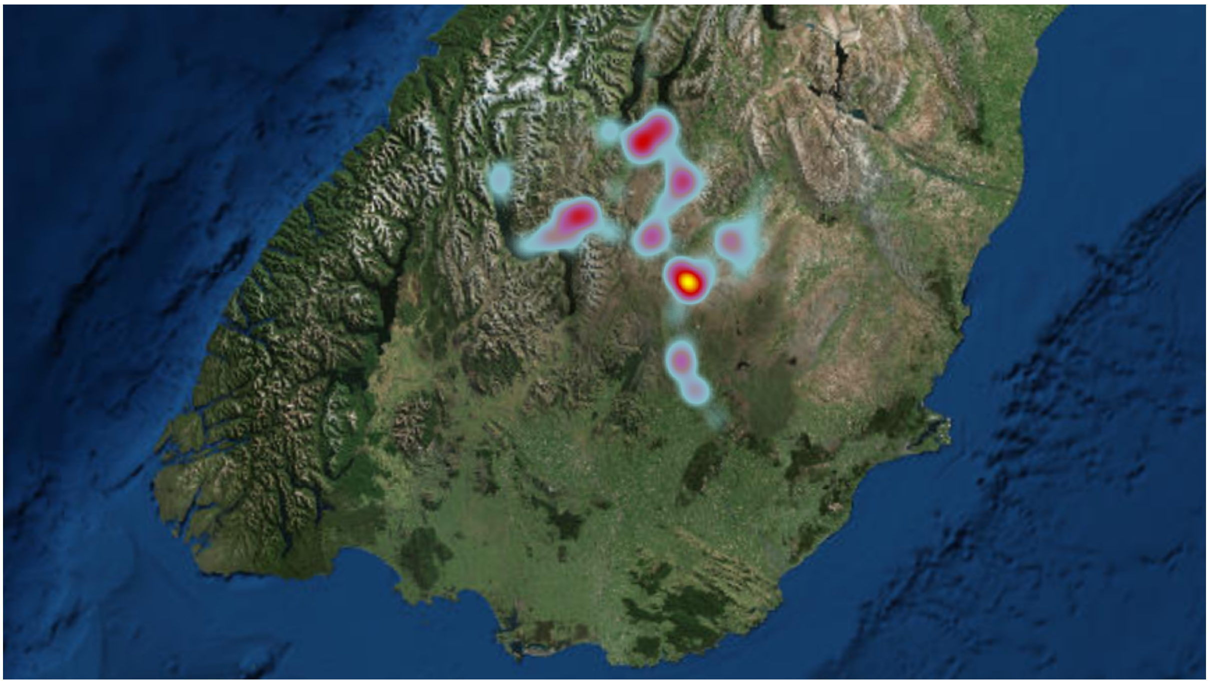

Figure 1: Population Area Heat Map of the 469 – 6.6/11kV Switches on the Central Network

The sample included:

1. 5 - Stick operated switches (10 extended sample)
2. 69 - Handle operated switches
3. 4 - Drop-out combination switches (handle operated)
4. 5 - 6-Pin legacy switches (handle operated)

Examples: Installation Issues Identified During Audit

The three main issues that were found during the audit can be summarised as follows:

1. Wire fence encroaching on operator position (7)
2. Compromised use of fibre glass isolation rod (11)
3. Hook stick switches attached to conductive pole and not earthed (7, 70%)

These are each looked at in turn below with background and discussion.

Metallic Fence Encroachment Issues

Two examples of where a wire fence was found to encroach on the operator position are shown in Figure 2. Whilst the operator position is also impeded, the main issue is one of earthing safety: should an earth fault occur at the switch whilst it is being operated, the switch, frame, earthing system and any conductive pole (metal or concrete) will become alive. The presence of the metal fence introduces a remote earth into the area with which the

operator can make contact. Whilst gloves are universally used across the industry, dielectric boots are not, it is therefore very likely that the earth potential rise (EPR) levels around the pole and earthing system will be transferred to the operator so creating a significant touch and step potential hazards.

Even in instances where the switch handle is successfully isolated from the switch the presence of an earth still creates an EPR issue close to the pole with the associated hazardous voltage risks.

Figure 2: Metallic Fence Encroachment - SW2012 (Left) and SW207 (Right)

Compromised Isolation - Use of Fibre Glass Isolation Rod

Figure 3 shows an example of where it has been attempted to isolate the operator handle from switch. As can be seen the switch handle is not formally earthed, but is earthed via the concrete pole. The fibre glass rod is compromised by the test block and earth lead in contact with the concrete pole.

Figure 3: Operator Not Isolated from Switch or Handle

Hook Stick Switches Attached to Conductive Poles and not Earthed

Figure 4 shows two examples of where hook stick switches have not been *formally* earthed. They both have an *informal* connection to earth via the concrete pole and the metal mounting bracket. This is not ideal for the following reasons:

1. A mechanical failure of the switch could lead to an earth fault that is not cleared by upstream protection due to a high resistance earth path and low fault current.
2. The operator is not isolated from the switch by way of the conductive pole and surrounding EPR.

The construction of hook operated switches is essentially the same as that of handle operated switches, with the chances of electrical failure being the same (all else being equal).

In the example on the left the switch informally shares a *tested earth* with a cable termination, the switch on the right is afforded a poor earth through the concrete pole to ground which is, in this case unlikely to operate feeder protection. It is seen as practicable to have formally earth both switches in the examples; it should therefore have been done *to ensure, the effective operation of protection fittings in the event of earth fault currents; (see clause 42* of the *Electricity (Safety) Regulations (ESR)).*

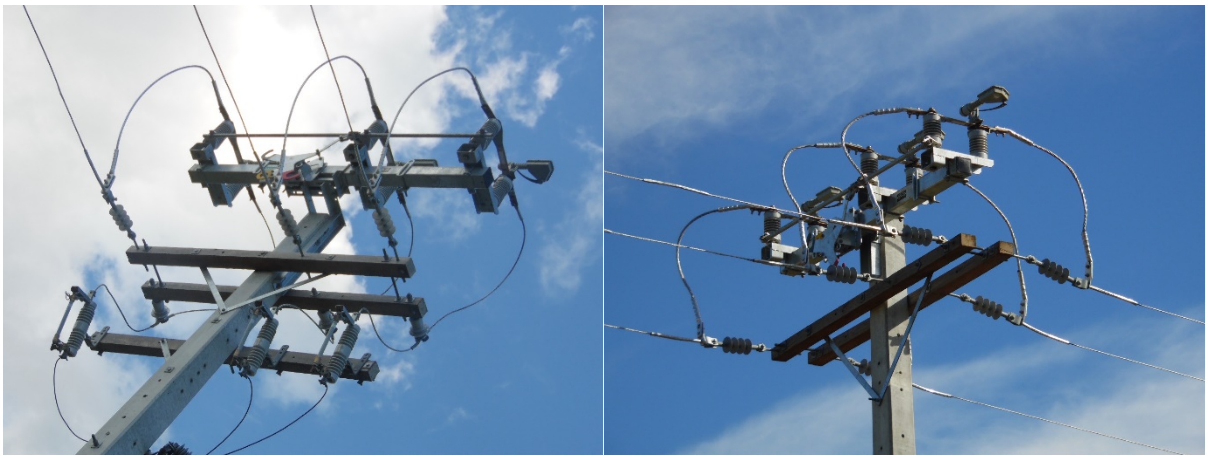

Figure 4: 'Unearthed' hook stick operated switches

Earthing Requirements for Switches

It has been industry practice to earth all switches and handles (where not isolated from the operator) [1-2][4-7] and for some networks and in most zone-substations to create an equipotential zone around the operator using an operator pad or grading ring, the assumption presumably being that there is a real risk that the mechanical operation of an overhead switch can lead to an earth fault that could liven switch frames, concrete poles and the associated earths. There have been many documented examples of broken leads and mechanical failure of switches, including hook stick switches (see associated presentation). This reinforces the need to consider the earthing risks and requirements.

While historically the earthing of switch handles was mandatory up until 1993 (where not isolated from the operator) it has become discretionary since the introduction of NZECP 35 [7], with it becoming a means of compliance only. Today, many approaches can be taken, provided that it can be shown that the asset is *Electrically Safe* and that all practicable steps have been taken to ensure this [4].

Minimum Operator Clearances (Egress & Hazardous Touch Voltages)

Clearly several of the switches had an operator position that was encroached on by a fence. There are two issues here; one of protecting the operator against hazardous voltages and the other of the operator not having adequate egress.

It is considered that the requirements of NZ ECP 34, for metal clad switchgear, would be a good starting point for minimum distances. This would give an *unobstructed passageway* of at least 1 m wide in front of the switch to any barrier not remotely earth. Obviously this would be beyond the handle radius as it could be considered an obstruction (see Figure 5).

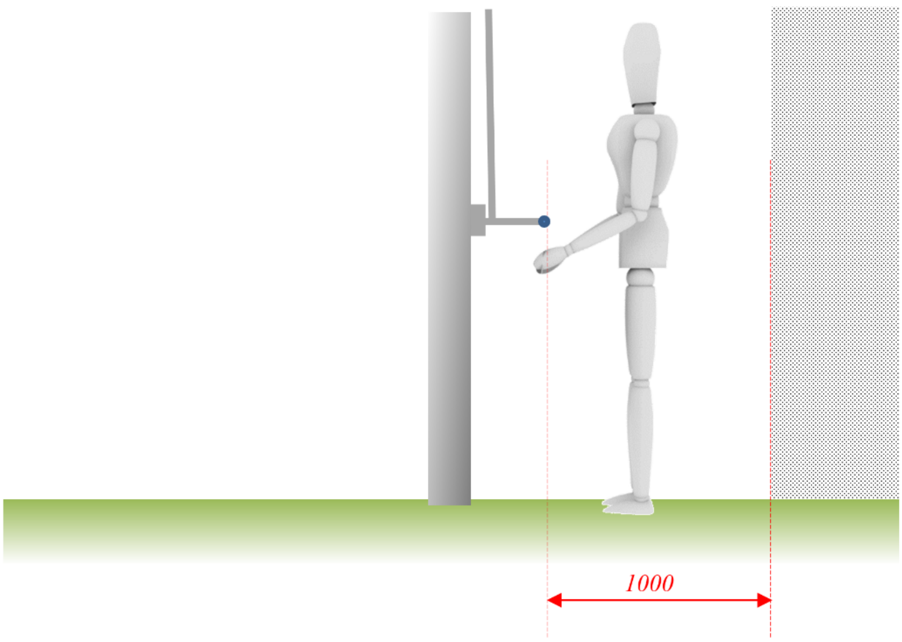

Figure 5: Suggested Clearance in Front of Switch (Aligning with NZ ECP 34

To protect the operator from hazardous bridgeable voltages, it is considered that a span distance of 2 metres be used and maintained (see Figure 6). This aligns with EEA Earthing Guide and is close to 99th percentile in terms of male span [9].

The bonding of switch earths to conductive fences and the installation of wooden (non-bridgeable) fence sections is seen as not ideal as ongoing inspection and maintenance is required (along with good record keeping). Our experience is that such mitigation measures tend to become compromised over time.

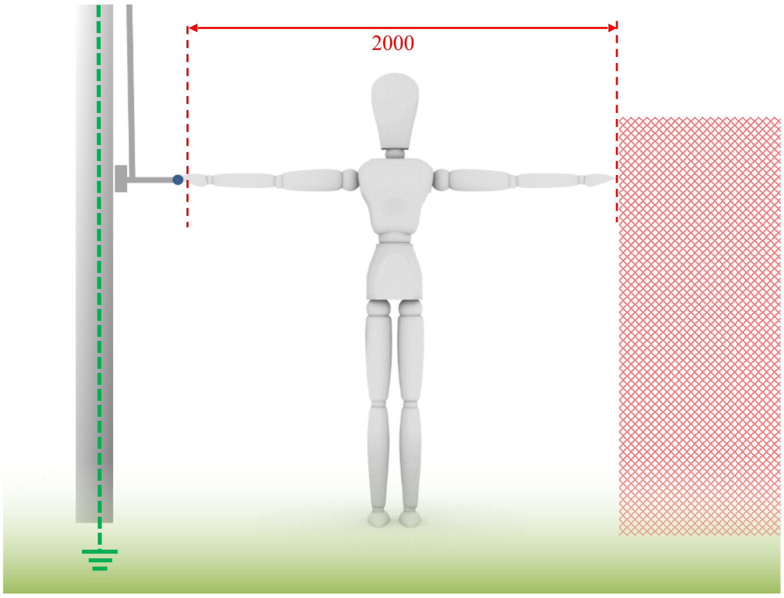

Figure 6: Suggested Clearance to Remote Earth (Red) – Max Bridging Span - Aligning with EEA Guide [2]

Operator Pads and Grading Rings for Handle Operated Switches

Grading rings (or gradient control conductor) are an important tool used to mitigate and control hazardous earth grid voltage rise (EGVR). They however must be used correctly and with caution. Table 6 in the EEA Earthing Guide [2] summarises the typical reduction in touch potential (as a percentage of EGVR) from installing grading rings around poles and kiosks. As can be seen touch potentials can be typically halved by such measures.

Operator pads, however, positioned on the surface in front of switches and bonded to the main earth and handle can control touch voltages much more effectively. Safe, deterministic, touch voltages levels can be achieved for the operator.

During the audit it was virtually impossible to determine if grading had been installed for the operator. Operating positions were more than often overgrown or have been significantly disturbed.

Relying on gradient control conductors below the surface is not recommended as they are hard to record, inspect and maintain. It is recommended that operator pads should be installed on the surface, so that they are clearly visible and maintainable; this could be done with a concrete pad or metal plate.

Protecting Earthing Systems (Earths)

Earths typically give many decades of useful life, they are usually only replaced when they fail a routine test or when their associated equipment is upgraded or replaced. Given this long life it very important to record and protect them.

Extensive shallow earths are typically hard to record and protect, and have a high degree of seasonal variability, as the ground moisture levels change. They can also spread hazardous transferred potentials wider, so increasing exposure. It is recommended by the authors that only compact deep driven electrodes be installed.

It is also suggested that the associated earthing for a switch should be deep driven and be installed within a 5 metre radius of the pole with a minimum covering of at least 750 mm; this aligns with the excavation (ground disturbance) protection afforded by NZECP 34. Such an earth is not in itself considered injurious and does not require an easement when installed on private land. Such an arrangement is considered more effective than purely relying on an easement or marking tape.

Advantages of Tested Earths

The benefits of having a tested earth available when earthing and isolating lines is seen as becoming increasingly important.

Temporary driven earths may not have a low enough resistance to operate upstream feeder protection (not *effectively connected to the general mass of the earth* – see definitions). This coupled, with earthing cluster leads, increases the hazards associated with accidental livening, especially during single phase livening where all three phases are livened through the cluster.

Even if a switch is not earthed, it would be advisable to have a tested earth for the application of the temporary earths at the isolation point. It is likely that the isolation point will become the preferred position for *issuer* applied earths (where practicable). Remember that SM-EI rule 3.602 para f, requires that switchgear with no visible break should be earthed at the disconnector, unless not practicable. This requirement is because there is generally an established earthing system at the disconnector, but if there is no established earth present then the recommendation is to earth at an established earth site.

Hook Stick Operated Switches

The hook stick operated switches shown in Figure 4 are not isolated from their conductive supporting poles with the operator potentially exposed to hazardous potentials. The operator position is not defined and is relatively flexible; this makes hazardous voltages difficult to control and mitigate.

Of the ten hook stick switch installations visited during the audit only one was found to be isolated from the operator; this was installed on a hardwood pole without an earth.

Given that most hook stick operated switches are likely to be installed on concrete or steel poles, it is seen as prudent by the authors to earth them by default. That is of course unless

the switch can be successfully isolated from the operator; such isolation could be achieved by design or via operating procedures.

Where a switch is installed, and is deemed to be isolated from the operator, the site should be clearly marked and recorded to ensure the operator is informed and that future maintenance will not compromise this isolation.

It is also considered prudent that that all hook stick operated switches that are not isolated have operator pads installed, to ensure the operator position can be controlled.

The issue of the hook switch levels, shown in Figure 4, being mounted above the high voltage line is noted. Its will be discussed further in the presentation.

Vacuum and SF_6 Switches

Vacuum and SF_6 switches have advantages over traditional disconnects; being more compact and often deemed maintenance free. If true isolation can be achieved from the operator or if they are remotely operated then an earth may not be considered necessary. But in such a case it should be clearly marked and recorded to ensure the operator is informed and that future maintenance will not compromise this isolation.

However from the variable earthing installation and design practices that were seen on the audit, it is considered very important to have a consistent approach to the earthing of switches. Field staff must be made aware that a switch has been designed to be connected <u>or</u> isolated from earth and informed as to the reasons why. It is better to be consistent than to try to manage the exceptions.

Given the benefit of a consistent approach and the increasing importance and advantages of tested earths (over untested temporary ones) it is recommended that all vacuum and SF_6 switches be earthed.

Summary of Suggested Practices

1. All overhead high voltage switches (including hook, vacuum and SF_6) should be earthed. They shall be provided with a distinct earth that will facilitate minimum practicable operating times on upstream protection, should the metal earthed frame of the switch become live.
2. An operator pad should be provided in front of the pole to define the operator position to control clearances and hazardous voltages.
3. Only compact deep driven electrodes be installed for switches within a 5 metre radius of the pole so as to be protected by NZ ECP 34.
4. Networks should, where practicable, move to use tested earths and not temporary earths.

Conclusion

It is vitally important that switching assets are installed and maintained in a safe and operable condition, with consistent practices across a network and wider industry.

Definitions

Earthed (ESR)**:** means effectively connected to the general mass of earth.

Earthed (EEA Guide)**:** means electrically connected to the general mass of earth

Earth Grid Voltage Rise (EGVR) [2]: – means the voltage rise to remote earth on a metallic structure connected to an earthing system during an earth fault.

Earth Potential Rise (EPR) [2] – means a rise in potential on the earth surface relative to reference earth.

References

1. EEA Submission to Worksafe 29/5/2016 w.r.t NZECP 35.
2. Guide to Power System Earthing Practice, EEA 2009.
3. Health and Safety at Work Act 2015.
4. Electricity (Safety) Regulations 2010.
5. Electricity Regulations 1935.
6. Electricity Regulations 1984.
7. NZ ECP35: New Zealand Electrical Code of Practice for Power System Earthing.
8. NZ ECP34: New Zealand Electrical Code of Practice for Electrically Safe Distances.
9. US Marine Corps - https://tinyurl.com/h6g8w8e

Acknowledgements

10. Mannequin Images: Raúl Ruano Ruiz - Own work, CC BY-SA 3.0, (https://commons.wikimedia.org/wiki/File:Silla014.png) - modified
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