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Operational use of grounding switches within an HVDC converter station

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SUMMARY

Field experience has proven that installing a temporary portable grounds (TPG) in large high-voltage substations is not preferred. With the increased footprint & height, fault currents, and higher voltages, safety equipment and process to ensure safe work isolations and grounding techniques become more extensive, heavier and demanding for the employee to install. Including inclement weather, most employers now place their workers in a high-risk event that could pose a danger to their employees.

HVDC converter stations are some of the largest interconnected stations installed in a power transmission system. Using HVDC technology to move mass amounts of power from far-reaching locations effectively to load centers to be distributed on transmission networks throughout the region, operational concerns, safety of the workers & maintaining the effectiveness of the power system becomes paramount to all. Within HVDC converter stations, standard builds will include ground switches installed that is fully automated with sequencing from the control system that will effectively ground portions or complete stations with one click via the HMI. However, this does not make it safe for utility operations to now go to work as noted between different provincial jurisdictions, federally accepted standards & utility best practices.

Fully automated switch installations are not the norm for most utilities and with the onset of renewable energy, increased OPEX costs and higher risk to today's utility employees, more intelligent decisions about where and how to do work must be considered.

This paper calls to light the need for further discussion on the different aspects of operating systems that are similar and revising utility standards to help protect our workers.

KEYWORDS

HVDC, Ground Switch

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From all utilities participating in this document, the use of ground switches was relatively new in the context of a high-voltage converter station operation. Working together between different utilities over the years, discussions between different persons created a need to explore different manners of applying temporary portable grounds (TPG). The following paper is essentially years of discussion between the different parties involved in creating a standard practice for ground switch use.

Safety of workers

The principal reason for this topic of discussion is the safety of workers. Personnel performing grounding work methods are placed in a quasi-safe situation where equipment is isolated from sources yet not deemed safe to touch or work until accepted grounding techniques are applied per the operating authority's requirement. During the installation of these safety devices, it is noted that personnel are to maintain minimum approach distances as defined by the jurisdictional authority. While performing this task, the utility employee is placed in the line of fire of large, heavy TPG sets that become cumbersome to move and install. This hazard is compounded when we use minimum approach distances, creating safe distances between the equipment being worked on and the often person basket of an aerial work platform. It is important to remember that all locations discussed had the highest AC system voltage regionally, increasing the ergonomic distances required to maintain the minimum MAD clearance. It is noted that most utilities have 40-50ft of 2/0 temporary conductors used to ground a piece of equipment. Using MAD utility worker clearances up to 4200mm requires a large 16ft grip all stick to move TPG chains

Using these switches prevents persons from being in inclement weather and ensures they are subjected to less stress physically, which keeps the workers focused on high-stress tasks like station isolation and troubleshooting complex problems.

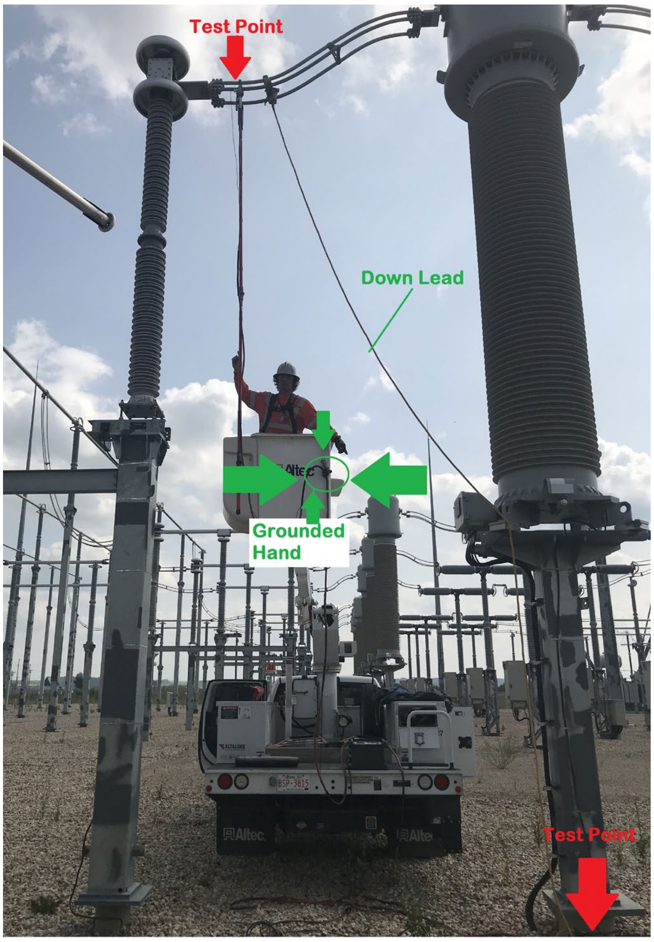

Figure #1 – worker testing TPG near the outdoor ground switch

Paper Cont'd

Cost-benefit – operational downtime vs maintenance.

Operational downtime for large power transmission stations is often a big concern. Stations with gigawatt transfer capabilities must operate and maintain minimal downtime and loss of production for the interconnected generation system or maintain forced and planned availability targets to their regulator. As sometimes both of these scenarios play into the operating utilities' overall operating strategy, it is always reflected and demonstrated in the design and operating philosophies incorporated with the installation of these large stations. Often, installations have a vast amount of redundancy in apparatus, control and protection schemes as the reliability of these stations must be paramount for the owner.

The increased costs associated with the operations of these complex, redundant and often remote interconnected sites are often considered during pre-planning and ongoing operations of the stations. Historically, these stations have more operational costs associated with the complex redundancy. In retrospect, downtime of the critical transmission infrastructure is often felt by most, if not all, customers on the inverter or load centers connected to the link.

Using these ground switches for grounding operations decreases the amount of installation time and has little effect on increasing outage times due to inclement weather. Most owner-operators think that if I can plan an outage during low transfer times, effectively performing maintenance in a planned environment decreases the operational risk and overall downtime during forced outages during sometimes inclement weather. In addition, the ability to quickly dispatch competent crews no matter what weather risks are posed to them promptly to sometimes quick maintenance routines to get the entire transmission asset back into service serves as high-cost savings. The asset owner can transmit power during peak demand or maintain their forced availability targets. Although, for some, the costs for this exercise are insignificant, some costs for having persons in the field are considerable, especially during winter, and effective snow clearing is required for sizeable aerial equipment to be installed in the working area.

Maintenance of switches vs costs

Historically, when looking at using these switches, most utilities did not have a preventative maintenance routine for ground switches. During the research of different utilities, only ones with generation assets interconnected within their transmission terminal stations would have these switches maintained to provide safe working clearance for the worker. as more discussion about maintenance costs arose. Although everyone's need to decrease operational spending is top of mind, the realization that these switches are installed, moving during automated sequencing and do need some maintenance was quickly realized before most instituting this procedure as failures of auxiliary devices on some of the ground switch motor operators were seen with some of the utilities. The consensus is that due to the criticality of these stations, performing zero maintenance was not acceptable for some due to the risk of having switch failures and creating extended outages to valve halls and the inability to return to reliable power transfer.

With these HVDC outdoor and indoor switches for safe isolation, all utilize an additional preventative maintenance procedure due to the intent of a guaranteed safety device. It was a common understanding that maintenance routines were required to be compliant if someone used the device as a safety device. As such, the common understanding is that every 2nd maintenance routine milestone would be when switches require a maintenance routine to confirm their integrity. After the maintenance/tests have been completed, a tag or visual verification indicating the integrity of the switch should be left somewhere on the switch, similar to testing calibration tags noted on most TPG ground sets.

Site & weather conditions

Often these stations are in remote locations or are exposed to harsh environmental conditions. All utilities are subject to harsh environmental conditions depending on their location within Canada. Some have regionally high winds with immense amounts of rain. Conditions on the other side of the HVDC line could have an extreme amount of snowfall. Coastal stations for this utility have been known to have multiple problems with salt spray and insulator contamination; therefore, creepage distances for these stations are increased significantly. All utilities have accounted for these items during the design phases of the installation, but the operations may need to consider more extensive, more expensive work platforms that can reach higher. As noted, higher, taller equipment requires more TPG to be effectively connected at a suitable bonded location to ensure an excellent connection to the earth is maintained.

With modern work practices following health and safety laws, employers must provide an increased level of safety when operating aerial work platforms and fall arrest systems with insulated tools. Additionally, as noted in other standards like CAN / ULC S801-14 (1) – inclement weather can cause many other difficulties by decreasing the clearances from possibly live apparatus to the worker. All of these points pose additional hazards to the worker as distances from considered live bus work to the ground are increased therefore adding incremental weight to grounding equipment and more hazard to the worker.

Other utilities, such as ones with incredible winds, use an indoor grounding procedure developed to allow safe isolation when wind speeds increase above 45km/hr or the wind speed limit of most aerial devices. In other locations of this utilities' infrastructure, large amounts of snow over 180cms can often be seen on site with incremental operating costs to remove in case of a forced outage. Maintenance of an item that piles up naturally with wind and then vanishes during summer months is not the utmost return on dollars spent for operations, and incredibly hard to justify spending money in case of a forced outage.

Figure #2 – Snow Accumulation near Control building entrance

Corona damage
Utilities have noted an increase of corona or conduct damage in sensitive areas like indoor valve halls. As a result, some utilities with installed converter stations historically only allowed grounding outside the valve halls due to the risk of corona or connector damage when applying a serrated clamp of the TPG. As a result, installing TPG sets increases the likelihood of possible damage and equipment failure over the asset's 40-year lifecycle.

With both of the above scenarios, small amounts of damage occur to the conductor. However, repairs to this conductor would require complete isolation, could not be done live and require specialized crews due to the current ratings and typically large spans. This risk is eliminated with the use of an already installed ground switch. It is essential that after testing, any imperfections are smoothed out before re-energizing.

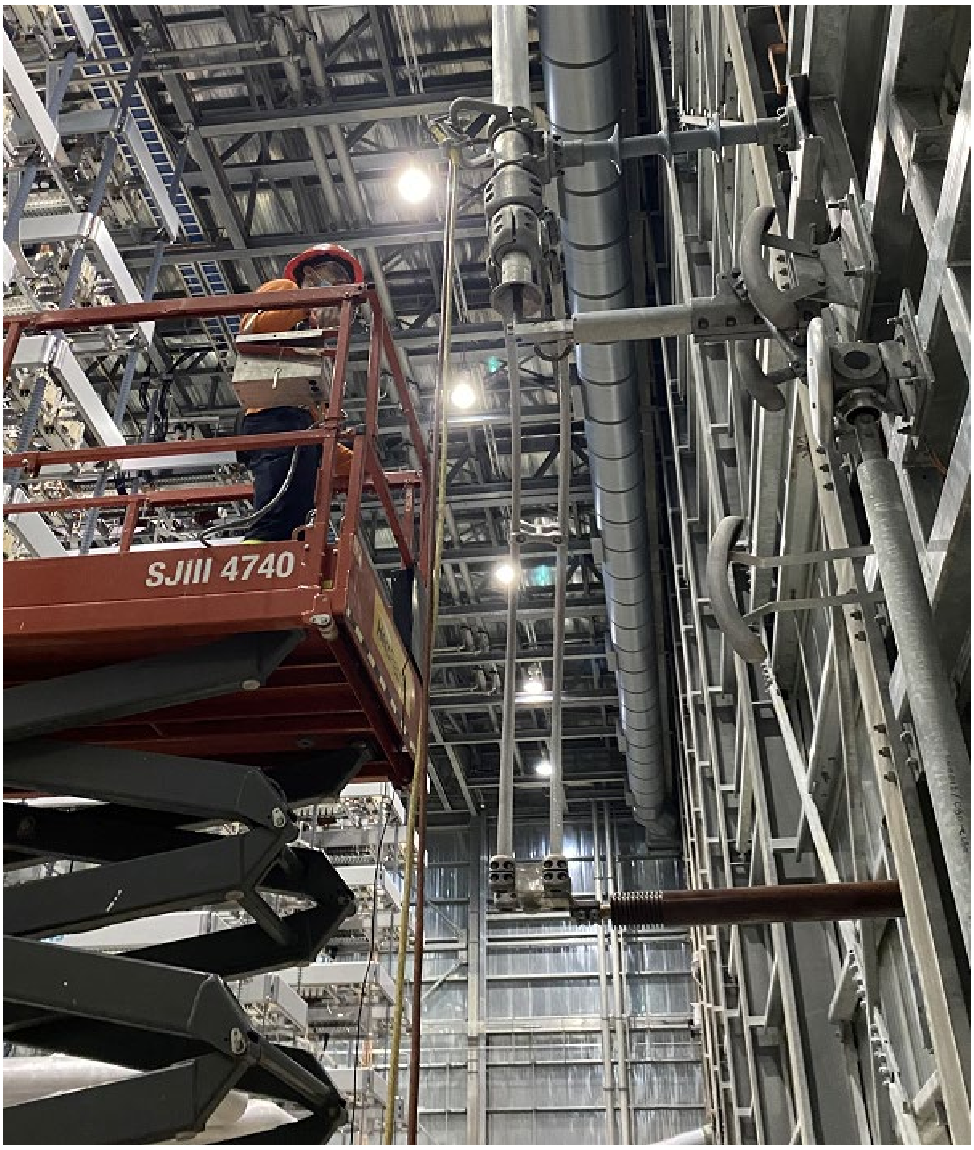

Figure #3 – worker performing LV ground switch maintenance within a valve hall

Complex interlocking decreases operational risk within the stations

Where HVDC controls act as the protection elements, and can quickly intervene and transfer power from different modes of operation, complex interlocking schemes using either mechanical or electrical interlocking are required for accurate and safe equipment status. Unfortunately, most installations have both types of interlocking installed due to these stations' complexity.

In contrast, complexity is not realized within a standard utilities' point of distribution substation with two to three lines interconnecting a step-down transformer as it increases costs for no real gain on investment operationally or safely. Using tried and true utility best practices work for most installations regarding isolation and grounding techniques.

Due to HVDC installations with complex and often redundant concepts, and physical and mental stresses imposed by these large stations with a critical nature, it may create some effects on personnel, increasing the risk of operating error or human risk when performing isolation and then grounding techniques.

A commissioned, engineered solution like interlocking can decrease this "human element" risk evident during forced outages and imposed on persons during high-stress faults or shutdowns. In addition, some utilities use these interlocking schemes with model permits to allow for safe isolation done consistently to ensure minimal errors are realized or create a hazard for the worker and prevent forgetfulness from leaving a ground chain installed on the high voltage equipment.

During the initial commissioning of these HVDC stations, it is noted that most operations staff know what is to be done for safe isolation, what steps are required and can effectively make this transmission asset safe to work quickly. In addition, it is noted that outages after initial commissioning are fewer, with sometimes years in between total outages that may create times of uncertainty, especially for newer, non-experienced staff hired after the initial commissioning phase. Hence the use of approved procedures, revised by the utility operations personnel to maintain that knowledge over time, during high-stress events or when staff are uncomfortable or not experienced with this act of isolation. An example of this would be documenting the correct position of the grounding switch and how to properly make it inoperable while it is being used as a grounding point. Again, it is vital for consistency and comfort for future staff.

Standards

When each utility was performing research on the operational use of these switches, most noted that maintenance standards regarding the use of these mechanical ground switches are not noted in most applicable industry standards. As such, most utilities tried to verify with vendors and manufacturers of these installed switches the maintenance routines required for safe work and isolation use of these switches – all gave mixed messages and unclear results.

A push for an industry standard to use ground switches with results from other utilities to verify their effectiveness will help create more understanding of environmental conditions that may affect the electrical resistance changes within equipment and create fewer workplace injuries.

Testing ground switches and results found

Further testing of these devices is to be trended by most utilities independently to ensure these switches still provide a safe and effective way to maintain a safe work area for employees. As most of these concepts are new and not trended with these utilities, some learnings must be made by each owner's respective switch – as each utility surveyed did not have the same type of grounding switch. However, maintenance and analysis of the switches' overall performance are within most of each operator's plans.

During the research, it was found that installations of grounding conductors, accessories like grounding stirrups and overall site installation of equipment differed between sites and locations. However, as noted, everyone agreed that these changes affected the ground switches' overall performance and could explain some differences between sites. For example, depending on the utility and type of switches installed, switches are typically 4 to 6 times less resistant than a TPG set. Also, different atmospheric conditions between different utilities were noted, creating a difference in resistance compared to others. For example, ground switches subjected to salt contamination near the ocean observed half the resistance compared to like switches in the prairies.

During testing, the worst-case scenario was considered the practical value, which is considered within each utility's pass-fail criteria. Generally, these switches cannot be less resistance than the TPG typically installed. Also, the switch is tested at its location of operation, giving staff a know resistance value to the ground for that work area. Another benefit of grounding switches is that they have minimal movement during a fault condition compared to TPGs.

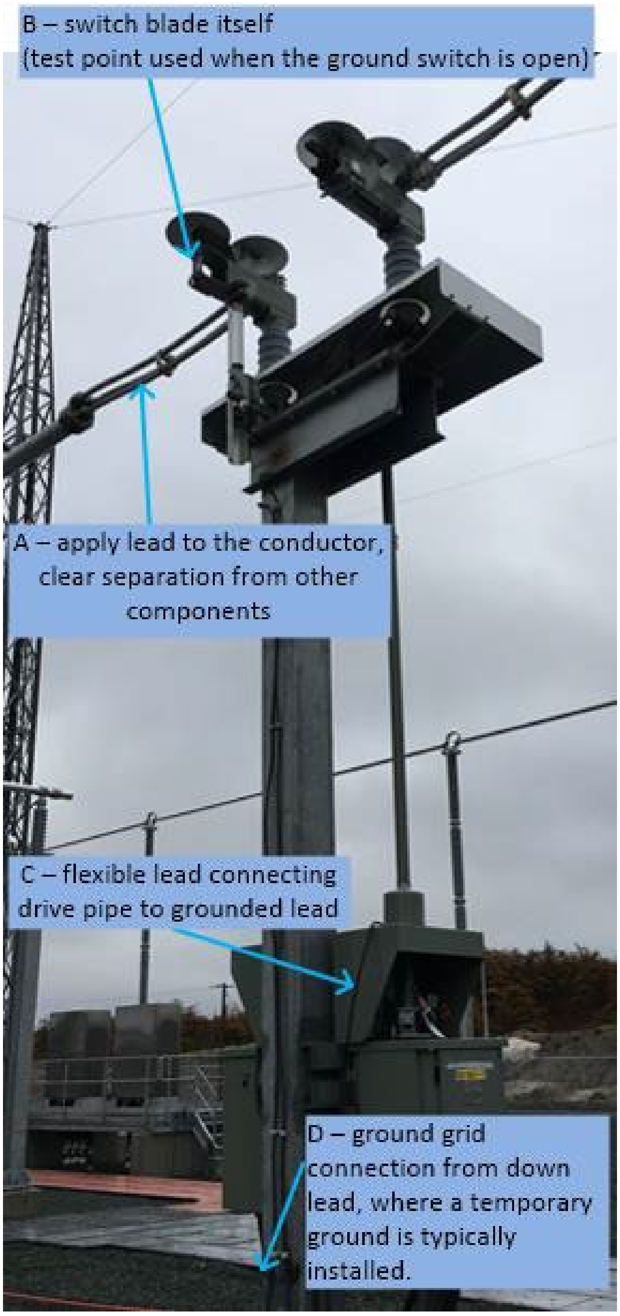

Figure #4 – centre break switch open with a ground switch closed with an explanation of the test

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BIBLIOGRAPHY

[1] CAN / ULC S801-14 – Standard on Electrical Utility Workplace Electrical Safety For Generation, Transmission and Distribution