

Incident Summary (Reference #II-667666-2018)

SUPPORTING INFORMATION	Incident Date	March 4, 2018	
	Location	Fraser Valley, BC	
	Regulated industry sector	High Voltage Electrical System (greater than 750v)	
	Impact	Qty injuries	1
		Injury description	An electrical worker received an electrical shock which resulted in burns to his hands
		Injury rating	Minor
	Damage	Damage description	A high voltage underground termination elbow and termination junction were destroyed.
		Damage rating	Moderate
Incident rating	Moderate		
Incident overview	<p>An underground high voltage cable termination failed causing a partial power outage to a private utility servicing a mountainside resort and residential area.</p> <p>An electrical worker received a shock while trouble shooting the power outage on the underground high voltage distribution system. The electrician believed that the part of the system he was working on was de-energized when he made contact with an energized piece of equipment.</p>		
INVESTIGATION CONCLUSIONS	Site, system and components	<p>The high voltage system:</p> <ul style="list-style-type: none"> -The mountainside resort and residential area is serviced by a 25000/14400 volt three phase overhead and underground high voltage network consisting of poles, pole mounted high voltage switches, overhead lines, underground conduits, and high voltage in-ground vaults and pull boxes with cables installed in them. -The system is interconnected together with removable and interchangeable cable connections (high voltage termination elbows) located within the vaults. The underground network of conduits, cables, vaults and pull boxes are routinely subject to fluctuating water levels caused by mountain run off from rain and snow. -Drains in underground vaults and pull boxes are installed to keep water from rising to levels that will submerge cable terminations and can sometimes become blocked or plugged with debris and no longer work effectively. This can cause water levels to rise and contact the cable terminations. -The cables and termination elbows are designed for installation in underground locations where they are subject to moisture. However the termination elbows are not rated to be submerged in water so the vaults are designed so that the termination points are elevated in the in-ground vault. This is done to prevent the terminations from becoming submerged under water which can cause a failure of the terminations resulting in a fault to ground or a fault to one of the other phases. -Dirt and dust combined with moisture on the surface of high voltage termination elbows in some instances can cause high voltage tracking over the insulated parts which can also cause a failure of the terminations resulting in a fault to ground or a fault to one of the other phases. 	

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	<p>-Failing to properly maintain underground vault drainage can cause water and contaminants to infiltrate and damage equipment potentially causing the failure of terminations.</p> <p>The work procedure:</p> <p>-The termination elbows have a DC capacitive test port on them to provide a testing point for utility workers to test the cable voltage with a proximity tester to determine whether the cable is energized or de-energized prior to working on the system.</p> <p>-The proximity tester used has two different settings, a low setting (30V -1500V) and a high setting (1500V – 122,000V) -see Picture 4</p> <p>-In a typical troubleshooting scenario the distribution lines to the area would be de-energized, tested, locked out, grounded, and isolated for safety. This would allow the system to be worked on safely.</p> <p>-In addition to this, electrical workers use insulated tools such as ‘hot sticks’ to provide separation and isolation of the worker from potentially energized electrical equipment until it has been confirmed as de-energized and safe to work on.</p> <p>-Personal protective equipment (PPE) and clothing such as line gloves, boots, hard hats with arc-flash shields and fire resistant overalls is the last line of defense to protect workers against electrical shock hazards.</p> <p>-Failure to follow proper safe work procedures and use PPE can result in electrical workers being shocked or electrocuted.</p>
<p>Failure scenario(s)</p>	<p>The electrical worker shock:</p> <p>-The electrical worker received information indicating that a power outage had occurred from the private utility manager.</p> <p>-Approximately an hour later the electrician arrived at the site to trouble shoot and repair the system.</p> <p>-The electrical worker identified the “C” phase fuse located on the pole had opened as indicated by the dropped out fuse holder. He opened the main switch on the pole, replaced the fuse, and turned the switch on again. The fuse immediately opened again. This process was repeated again with the same result indicating the fault still remained on the system.</p> <p>-The switch remained on with the A&B phase fuses intact and the C phase fuse open.</p> <p>-The electrical worker then proceeded to one of the main in-ground vaults. He opened the vault, put on high voltage gloves, installed the proximity tester on the end of the hot stick, turned it on, and likely set the tester to “high” anticipating that if a voltage was present on the system it was over 1500V.</p> <p>-The electrical worker then proceeded to test the voltage on the cables within the vault by removing the high voltage elbow test caps from the capacitive test ports with a hot stick and bringing the proximity tester within range of the test ports.</p>

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- The electrical worker stated the proximity voltage tester did not indicate a voltage present on the “C” phase bus within the vault.
 - Phases “A & B” remained energized throughout the system and within the vault.
 - The electrical worker removed the ‘C’ phase cable termination elbow from the termination junction bushing and attempted to “park it” on the parking bushing at the left end of the termination junction.
 - The cable length and orientation of the cables within the vault prevented the electrician from being able to park the cable on the bushing with the hot stick because the cable was not long enough and it was located behind the other cables.
 - Thinking the termination was de-energized, the electrician removed his gloves, entered the vault, grabbed the termination elbow with his left hand while bracing himself on the ground with his right hand, and tried to force the cable onto the parking bushing.
 - The electrical worker received a sustained shock that prevented him from being able to let go of the cable.
 - A worker standing behind the electrician heard a zapping and crackling sound and noticed the electrician had stopped moving for a few seconds. He grabbed the electrician by the jacket at his shoulders and pulled him out of the vault and free from the energized cable.
 - The ‘C’ phase cable that was removed was not the de-energized cable coming from the open fuse but rather a cable that was being back fed AC voltage through the primary windings of several transformers connected to the still energized A & B phase primary lines of the system.
 - The cables and termination bus were not properly marked to identify which installation or portion of the installation they served.
 - The electrical worker did not anticipate a potential feedback through the primary windings of multiple transformers connected to the utility system. **-See Diagram 1**
 - The electrical worker likely received a shock from the DC capacitive test port on the high voltage elbow of unknown DC voltage. The voltage would have been relative to the AC voltage back fed through the cable (up to 10% of the AC voltage).
 - The tester may not have been set to the correct voltage setting to detect the range of voltage that may have been present on the cable. This may have been equal to or less than 1500V AC depending on the equipment and loads connected to the system which consisted of multiple transformers, motors, and other loads related to the resort and subdivision.
- The failed cable termination:**
- The failed cable termination was located in a different in-ground vault from where the electrical worker was shocked.
 - It’s likely the cable termination failed due to improper drainage within the in-ground vault which caused water to enter and/or fill the vault. Water combined with contamination such as dust and dirt within the termination elbow caused high voltage

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	<p>tracking, a fault to ground, and an overcurrent condition which opened the C phase fuse.</p>
<p>Facts and evidence</p>	<p>Timeline</p> <p>10:06am - power failure on 'C' phase 11:00am approx. – Call by resort/utility manager is made to Operating Permit electrical contractor requesting that he attend the site and repair outage. 12:15pm approx. – Electrical Worker (EW) arrived on site 3:00pm approx. – EW is shocked</p> <p>Witness Statements</p> <p>Operations and Maintenance Manager</p> <ul style="list-style-type: none"> - Was the only person with EW at the time of the incident. Everyone else assisting with snow clearing to locate the in ground vaults were at least 25' away. - When EW was unable to place the high voltage elbow on a grounding bushing with the hot stick he observed EW take of his high voltage (HV) gloves and jump into the vault and attempt to park the cable onto the bushing with his hand(s). - He observed EW go still for a few seconds and heard a 'buzzing or crackling' sound coming from where EW was standing. No spark or flash was noticed. - He instinctively grabbed EW by the jacket and pulled him out of the vault. - EW was still conscious. - He recalled that he was pretty sure rubber cap for capacitive DC voltage test port remained removed from the termination elbow while the EW was handling it. <p>Utilities Manager</p> <ul style="list-style-type: none"> - Observed EW change the fuse 2 or more times on the HV overhead line that was faulted prior to the shock incident. - Had a conversation with EW prior to the incident where it was discussed whether to disconnect all phases of the utility. EW stated that he was going to park the elbow and that it should be fine. <p>Electrical Worker</p> <ul style="list-style-type: none"> - Replaced fuse on 'C' phase overhead HV line but it blew instantly. - Picked an in-ground vault halfway up into the subdivision to troubleshoot direction of fault. This is where incident happened. - Used hot stick to test all phases in vault. Determined 'C' phase was de-energized. 3-4 elbows were installed on 'C' phase connector rack. Removed

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far left 'C' phase elbow with hot stick after using capacitive tester to test for voltage on capacitive test port. Was unable to park it onto grounding bushing.

- He took off his HV gloves, stepped into the vault and while standing on the energized and de-energized cables lying in the vault floor, used his left hand to grab the removed elbow and stabilized himself with his right hand by planting it in dirt outside the vault. No other parts of his body were touching anything to the best of his knowledge. The intention was to push it onto the grounding bushing. He was then shocked but never lost consciousness.
- Was unable to let go of elbow while he was being shocked prior to being pulled out by the jacket by Operations and Maintenance Manager.
- The EW and Operations and Maintenance Manager then drove to load break air switch on line side of overhead fuses and de-energized all phases.
- EW noticed minor burns forming on both hands. The left hand burn was noticeable by the wrist and on the right it was noticeable on the webbing between the thumb and forefinger.

Equipment

- Hot stick, voltage tester and HV gloves onsite the day of the incident as declared by the electrical contractor were provided for examination on April 25, 2018 and bore evidence of approval for use. The equipment appeared to be suitable for its intended use. **-See Picture 4**
- HV elbow that was the source of shock was visually observed to be dirty but under reasonable conditions of use and environment and displayed no evidence of being faulty. **-See Picture 3**
- The high voltage elbow that was the source of the fault that initially caused the 'C' phase fuse to open and the resulting power outage was visually observed to have suffered catastrophic failure. It's possible that due to high voltage tracking over moisture and contamination the resulting electrical arc pierced through the rubber insulation of the elbow leaving a hole and destroying the bushing mounted on the load-break junction. **-See Picture 6**

Observations

- While attending a shutdown of the private utility network after the incident for maintenance and investigatory reasons on April 25, 2018 the ESO's present observed the electrical worker that had received the shock testing and moving de-energized high voltage cables and elbows within a couple in-ground vaults. It was noticed that after removal of the rubber cap covering the capacitive test point and testing it with a voltage tester and hot stick that the rubber cap was not re-installed prior to commencing with work. This may have been the same procedure followed the day of the incident where the cap was left off after testing and contacted by the worker when he received the shock.

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	<ul style="list-style-type: none"> - The capacitive test point on the elbow is essentially a capacitive voltage divider which makes use of the elbows high voltage insulation between the HV conductor and a conductive plate to create a HV capacitor. Many variables such as size of the cable, thickness of material, dielectric constant, operating temperature of the dielectric, and size of the capacitive plate will affect the capacitive DC voltage present on the capacitive plate (port) used for testing but it is a ratio relative to the voltage present on the HV cable. The most significant variable would be the AC voltage present within the cable which was not known but may have been between 100s and 1000s of volts AC which would have imposed a DC voltage at the test point between 0 to 10% VDC of the present AC voltage of the cable.
<p>Causes and contributing factors</p>	<p>The cause of the failed high voltage cable connection in one of the in-ground vaults that caused the fault to ground and the C phase fuse to open was likely improperly functioning drainage inside the vault.</p> <p>A contributing factor would have been the dirt and dust within the vault creating a lower resistance path for high voltage tracking to occur.</p> <p>The cause of the shock to the electrician is very likely due to not following proper safe work procedures to de-energize and test all electrical equipment prior to performing work.</p> <p>Contributing factors include failure to recognize a potential feedback through the primary windings of the energized phases, lack of labeling cables within the in-ground vault, failure to ground and isolate the portion of the system being worked on, and failure to wear the proper PPE.</p>

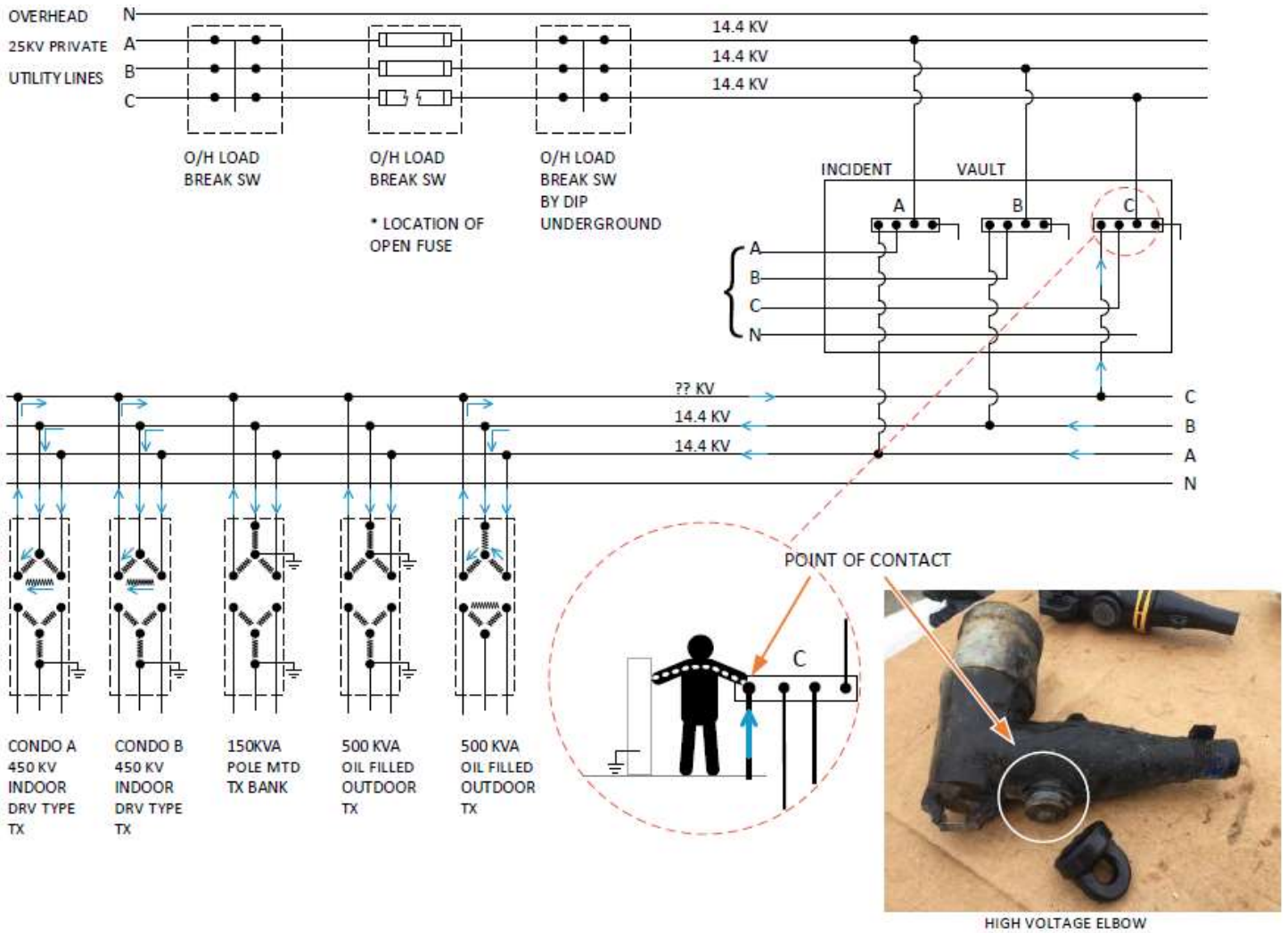


Diagram 1 – One-line diagram showing voltage potential, current flow, and the point of contact



Picture 1

Vault where electrical worker was shocked.



Picture 2

This group of high voltage elbow terminations is the 'C' phase in the in-ground vault. The worker attempted to remove and 'park' the far left elbow when he was shocked. Photo also shows standing water in the vault.



Pictures 3

Location of DC capacitive test point on the removed high voltage termination elbow which the worker was attempting to 'park' when he was shocked. Insulated cap is removed for photo.



Pictures 4

Proximity voltage sensor that the worker used to test the high voltage elbow prior to attempting to remove and 'park' the elbow. Notice the two voltage settings. The tester may not have been set to the correct voltage setting to detect the range of voltage that may have been present on the cable.



Picture 5

Downstream pull box opened to demonstrate the fluctuating water levels that may be present in below ground vaults. Improper drainage was observed in multiple in-ground vaults.



Pictures 6

Failed high voltage termination elbow and related damaged equipment at in-ground vault. The red arrow indicates the location of the high voltage fault to ground. The red oval shows the damaged junction termination port on the junction termination bus that was within the in-ground vault.