Personal Protective Grounding
Think Electrically-Not Mechanically

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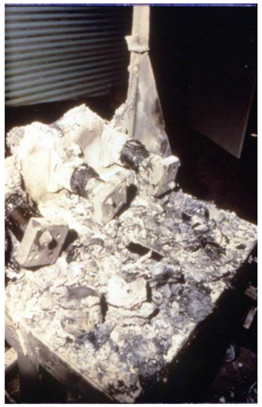
ELECTRICAL SAFETY CONSULTING

A Little about Me

Mike Bahr

- 50 Years in the industry
- Electrician
- Lineman
- Safety and Training

How did I become a "Safety Guy"



SIFs

- According to national lineman surveys and utility company data, 42 for every 100,000 lineman are killed on the job each year.
- This makes lineman jobs one of the most dangerous only behind loggers and manual laborers in agriculture.
- The number of job fatalities has declined since 1994, with utility companies reporting a decline in workplace injuries and illnesses.

SIFs

- Age group the suffers the most loss 25-34
- Line workers suffer the highest incident rate of any job classification at utilities.
- One of the 10 most hazardous occupations.
- Should we not have grown to the point that this is no longer the case?

Are jobs in our industry dangerous?

- We do not work in a dangerous environment; we work in a **hazardous environment** that we make dangerous by not following safety procedures and not wearing the proper PPE.
- Our industry is predictable, it is also very unforgiving.

Are jobs in our industry dangerous?

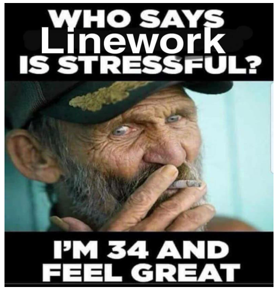
- Our industry suffers from a high level of “Optimism Bias”
- Knowing how common such accidents or mistakes are, many people — perhaps unconsciously — feel confident that such misfortune won’t happen to them.
- Until we believe an outcome is possible our arrogance won't allow or protective predictive system to mitigate the risk. (WM)
- When we only look at where we’ve been, it drives us to where we are heading, same ole road. (BJ)

Are jobs in our industry dangerous?

- Too often many times workers do not follow the rules with no negative consequences, the result is complacency.
- People make mistakes; But the mistakes that we make in our industry are very unforgiving, the consequences are high we’re not twisting ankles and getting slivers in our fingers, the mistakes we make will kill you, If your taking shortcuts your being selfish.

Are jobs in our industry dangerous?

- Current regulations if followed protects the utility worker in almost all situations?
- If an employee understands and follows all rules and regulations, they will be safe?



Are jobs in our industry dangerous?

- Line workers are intelligent and among the finest people on earth, caring, good values, they love their families, and their communities and no one, no one should go to work and be involved with an incident that ends their lives.
- Contact with live parts (this includes induction) make up most of the SIFs, how is it that a crew can know that they will be working on, or near, energized lines and equipment and not be able to establish a plan based on a hazard assessment that will effectively prevent contact with that energized conductor or part, contact with live parts are preventable.

Induction fatalities

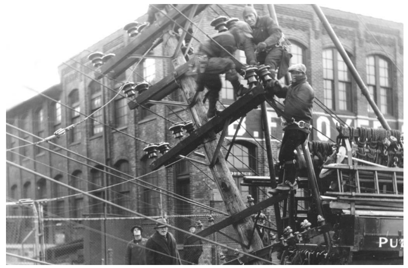
One area within the electric utility and utility construction area that we continue to see fatal accidents and injury involves line workers exposed to induced voltages on deenergized and grounded lines and equipment.

- Data from accidents due to ac induction in transmission lines and substations in the USA between 1985 and 2021 indicate (US Bureau of Labor Statistics) 81 accidents in transmission and distribution lines and substations. As a result, 93 people were involved in the accidents and 60 are deaths.

Grounding Requirements

When the earliest linemen first began to ground lines for worker protection, they attached a small chain – known as a ground chain – to the conductors, with the end dropped to the ground.

One of the “old timers” at a mid-west rural utility related that they used to cut a “fat green weed” to ground the line. Thankfully, the days of grounding with “fat green weeds” and grounding chains are long gone.



Grounding Requirements

Ever since enforcement of 29 CFR 1910.269 began in 1994, OSHA has required grounding practices that will protect employees in the event that the line or equipment on which they are working becomes re-energized or employees are exposed to the hazards of induced voltages.

Grounding Requirements

Does this Individual have possible exposure?

What if he's working between bracket grounds?

Common beliefs

Electricity takes the path of least resistance

True or False?

False, The statement is not correct. Current will take any path that is available to it.

Induced voltage can be dissipated by grounding

True or False?

False, The statement is not correct. Induced voltage is not a trapped or static charge and cannot be dissipated by grounding

Common beliefs

All ground sources are at the same electrical potential

True or False?

False, The electrical potential between ground sources is dependent upon the resistance between them.

Current Flow-Principles

Current flows in grounded systems the same way it flows in ungrounded circuits. Current in parallel systems takes every available path inversely proportional to the resistance of the path. This means interconnected systems will have current in every path, and low-resistance paths will have more current flowing than high-resistance paths.

Current Flow-Principles

It takes about 50 volts to break the electrical resistance of your skin. The voltage required to break the electrical resistance of your body increases when you don nonelectrical barriers like shoes or gloves. If you use rubber gloves, the required voltage increases substantially. (this is the key)

Current Flow-Principles

Charles Dalziel's empirical data from his experiments in the 1950s and 1960s showed us that a 155-pound line worker could withstand 91 milliamps for 3 seconds before ventricular fibrillation For that reason, it is widely accepted and used here that 50 milliamps of current is the threshold of exposure that rises to the level of a hazard to workers.

Current Flow-Principles

Grounds installed to trip a de-energized system during an inadvertent energizing will not protect a worker who is not at equal potential with the system path.

Grounds installed to trip the circuit, or tripping grounds, may also be used to protect the worker. However, unless they are arranged or installed to create a zone of equipotential, they will not protect the employee from injury either from inadvertent energizing or induction.

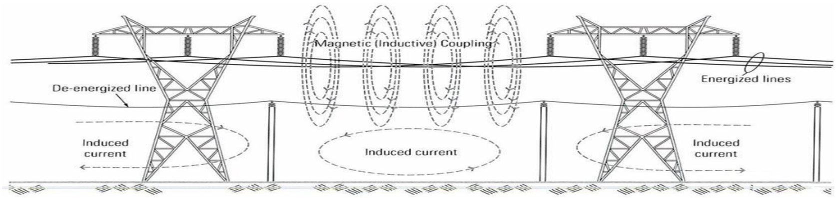
Induction Hazards

The dangers of induction are often underestimated. Induction can kill. With more lines being forced into corridors and operated at higher currents, induction sources must be considered and respected

Induction Hazards

Electromagnetically Coupled Voltage - i.e., Magnetic Field Induction

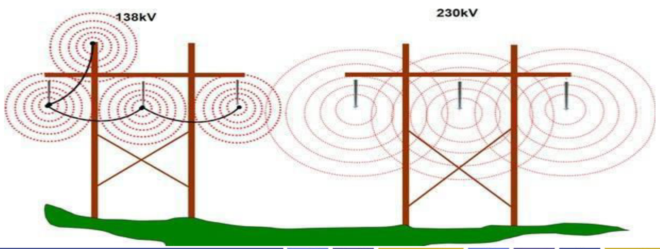
- Electromagnetically induced voltage is created by an action similar to what occurs in a transformer. When the primary winding in a transformer is energized, the secondary winding is energized automatically.



Induction Hazards

A parallel high voltage transmission line will energize other nearby lines. Circulating current will flow in all possible loops including flowing through the employees. Particular areas of concern include:

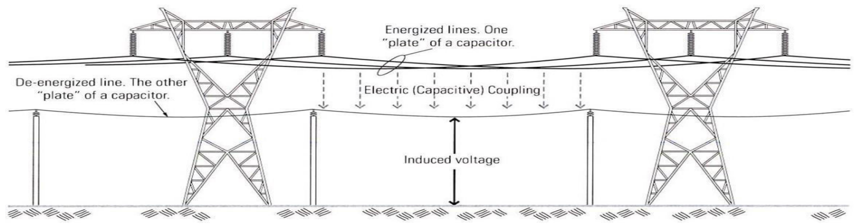
- Adjacent high-current carrying lines.
- Long parallel lines (i.e., miles).



Induction Hazards

Capacitive Coupled Voltage - i.e., Electric Field Induction

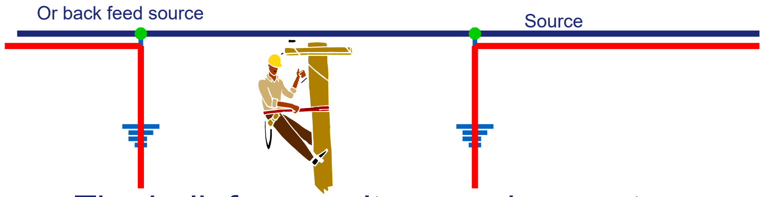
An energized conductor can act like one plate of a capacitor, while another line acts like the other plate of the capacitor. The air in between is the dielectric. Capacitive coupling between lines is similar to the exchange of energy between the plates in capacitors installed on conductors and in substations to improve the power factor. Capacitive induction creates voltages on de-energized lines.



Current Flow Principles

What did we once believe about grounding for worker protection?

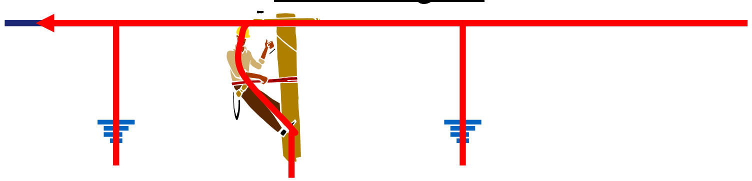
Its all about giving current a path, right?



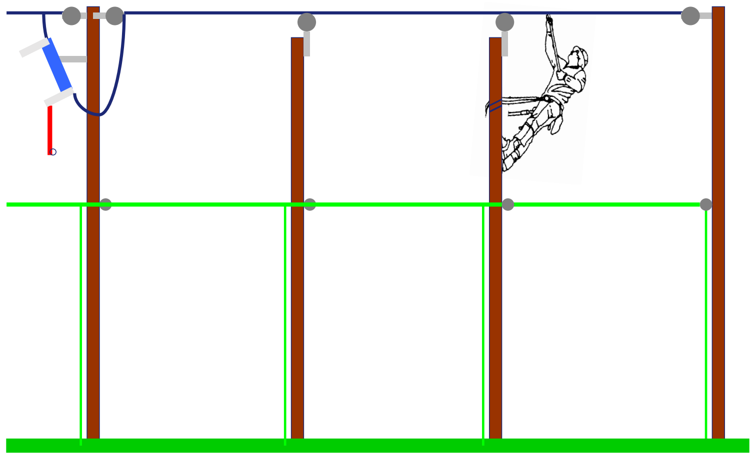
The belief was voltage and current would travel to the grounding location, Stop and Go to Earth!

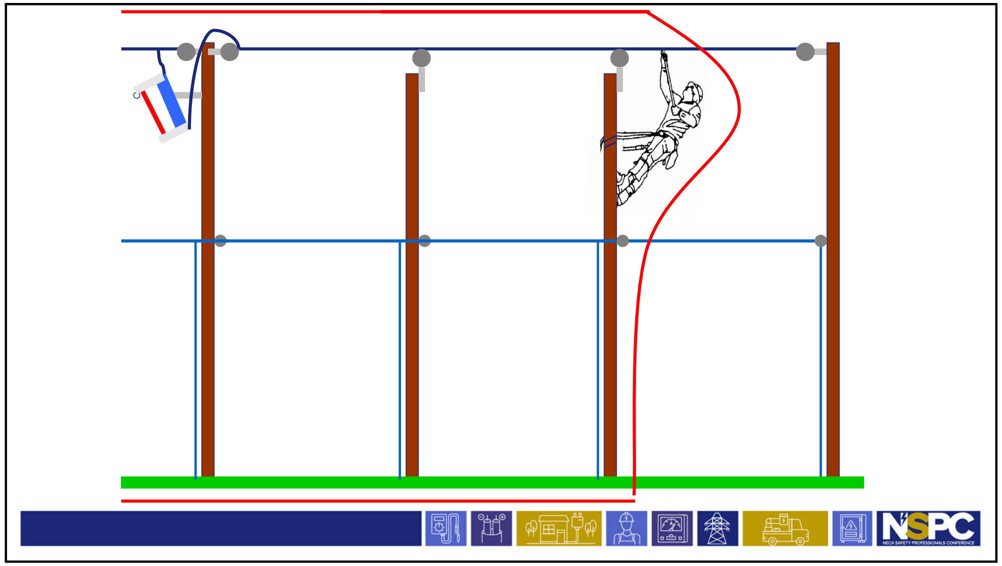
Long Before it Gets to US!

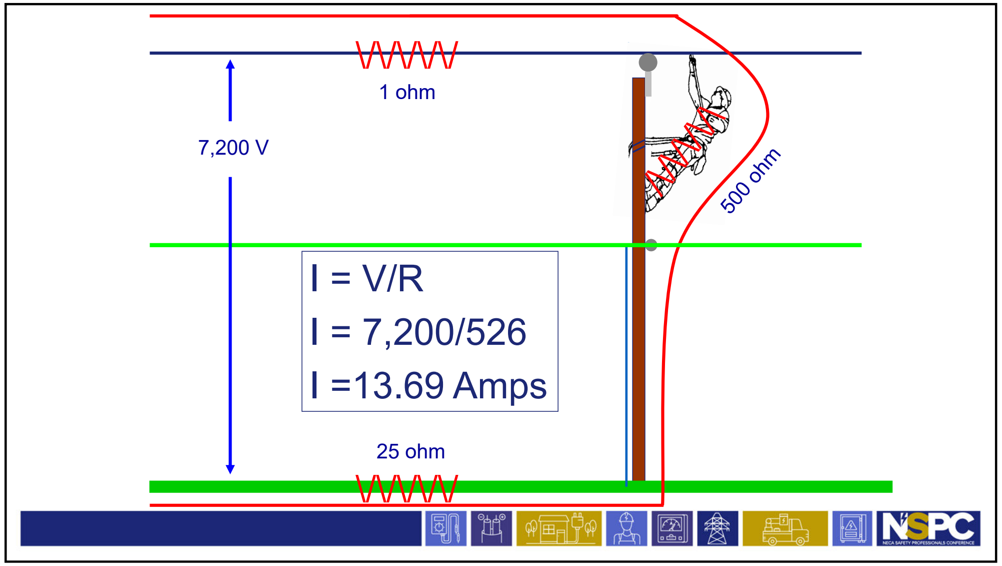
What Really Happens in Bracket Grounding???



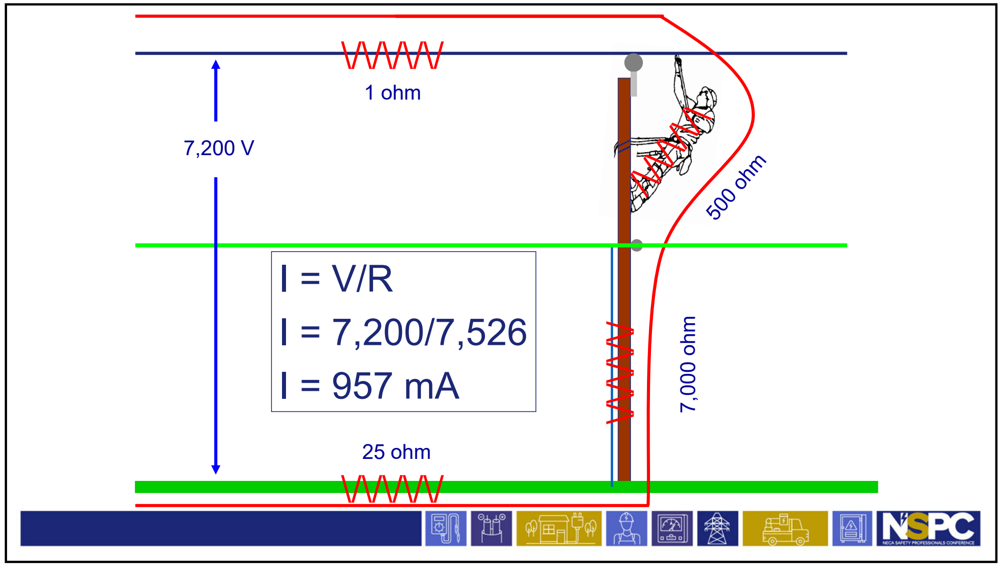
Current Takes ***ALL*** Paths to Ground!



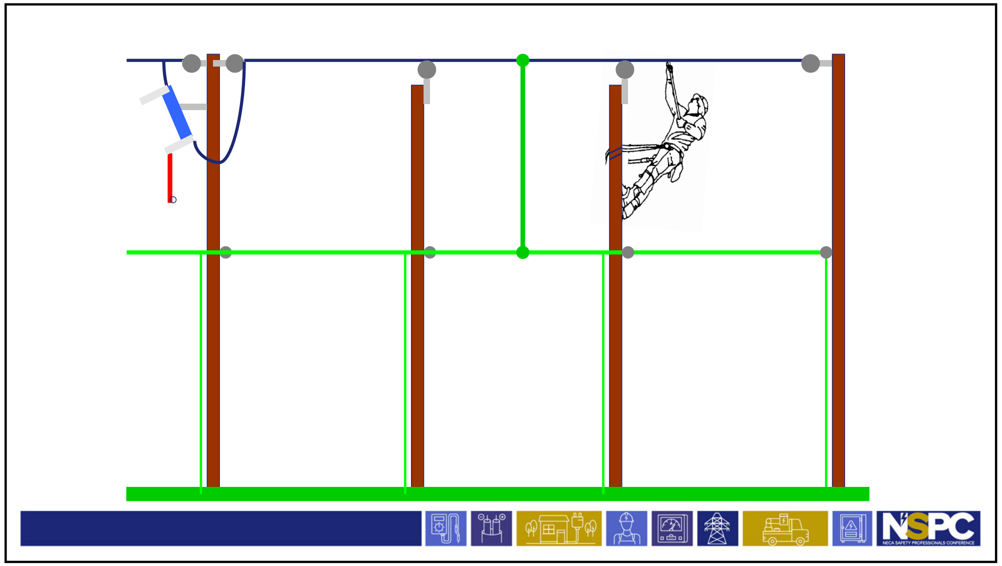


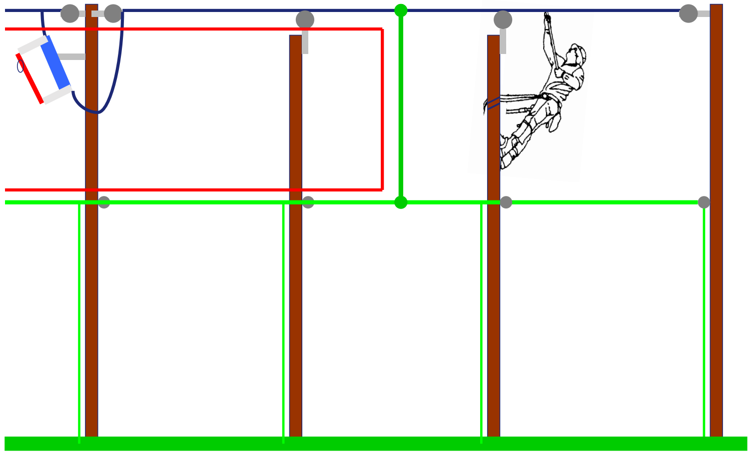


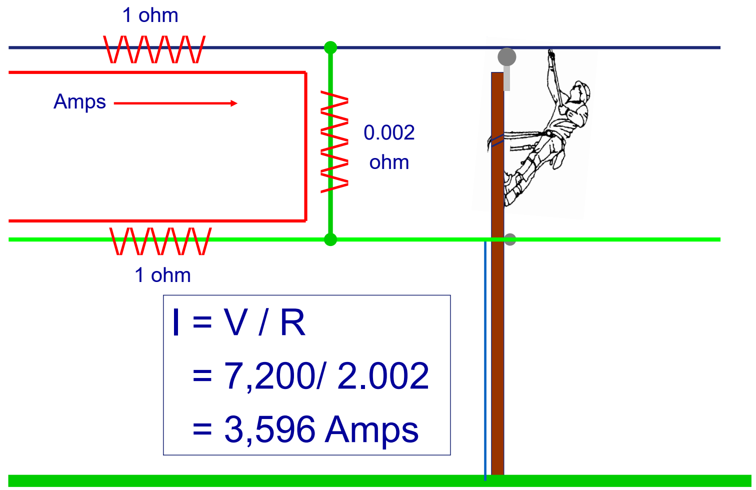
1 ohm
7,200 V
500 ohm
I = V/R
I = 7,200/526
I =13.69 Amps
25 ohm



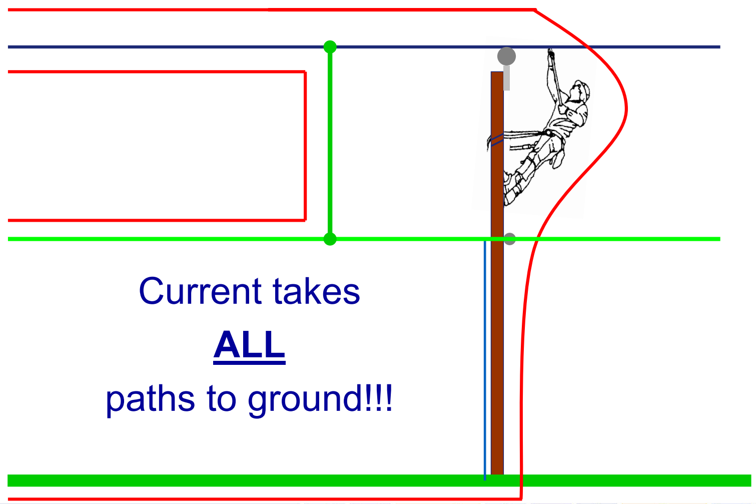
1 ohm
7,200 V
500 ohm
I = V/R
I = 7,200/7,526
I = 957 mA
7,000 ohm
25 ohm

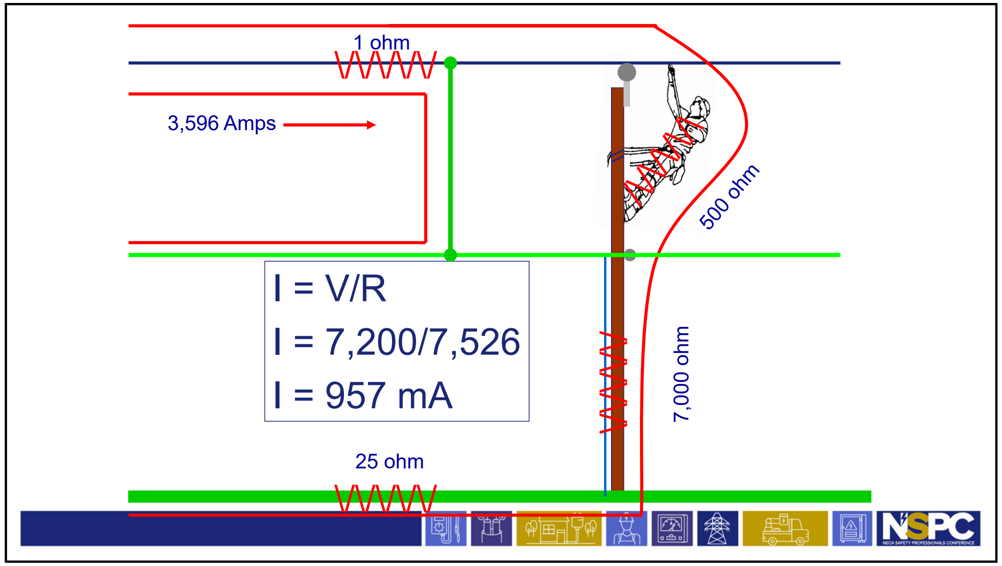


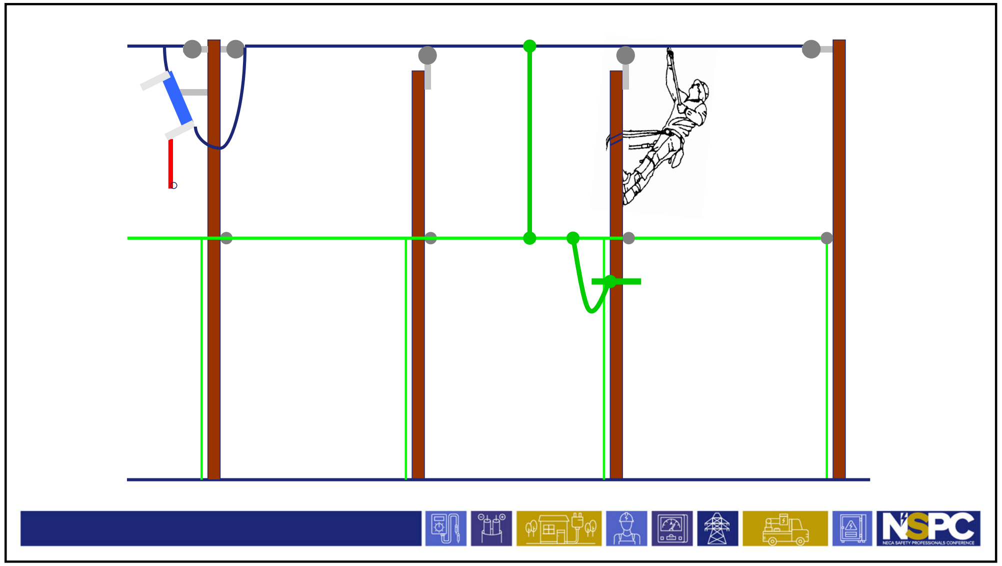


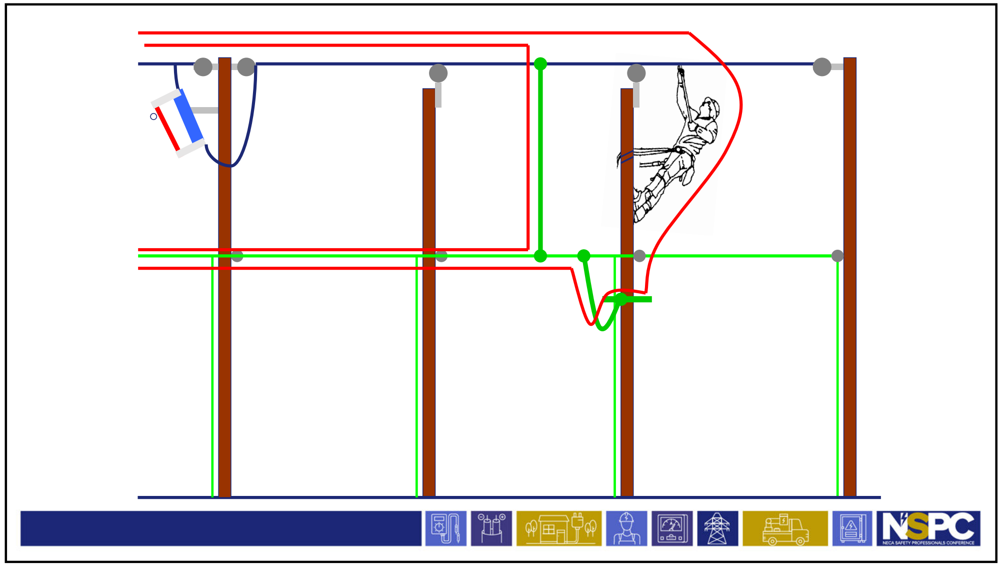


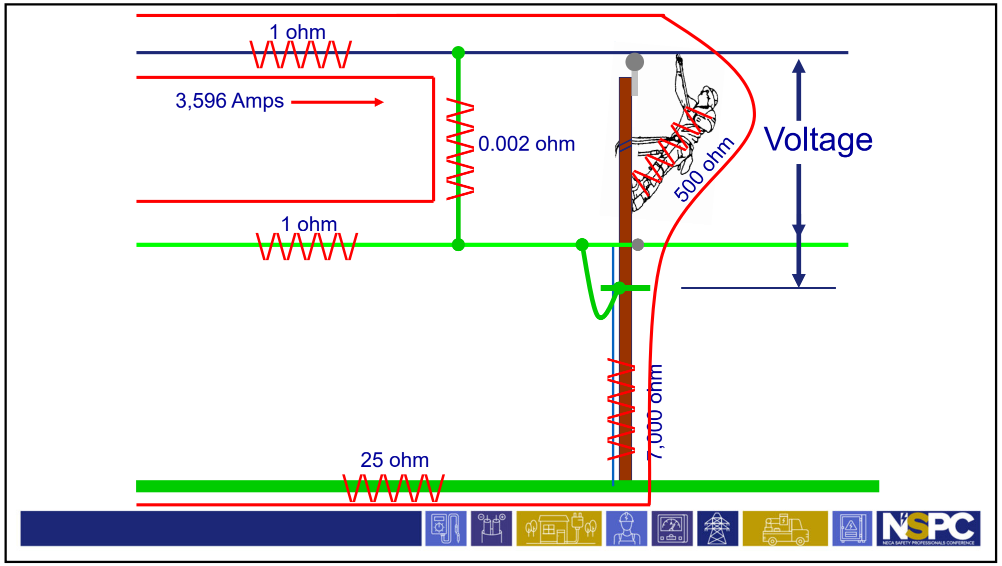
HOWEVER!!!
Current Takes
ALL
Paths to Ground!

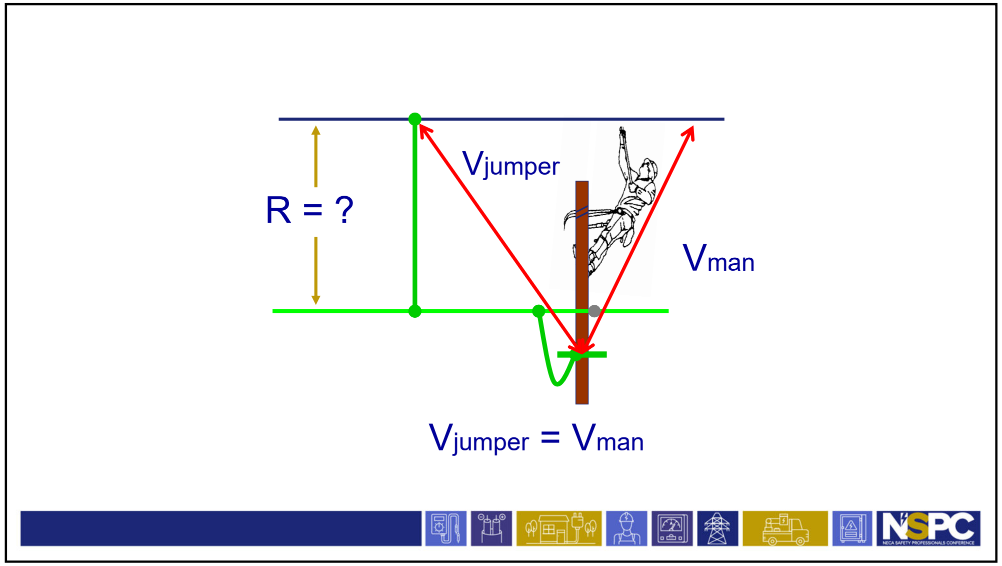


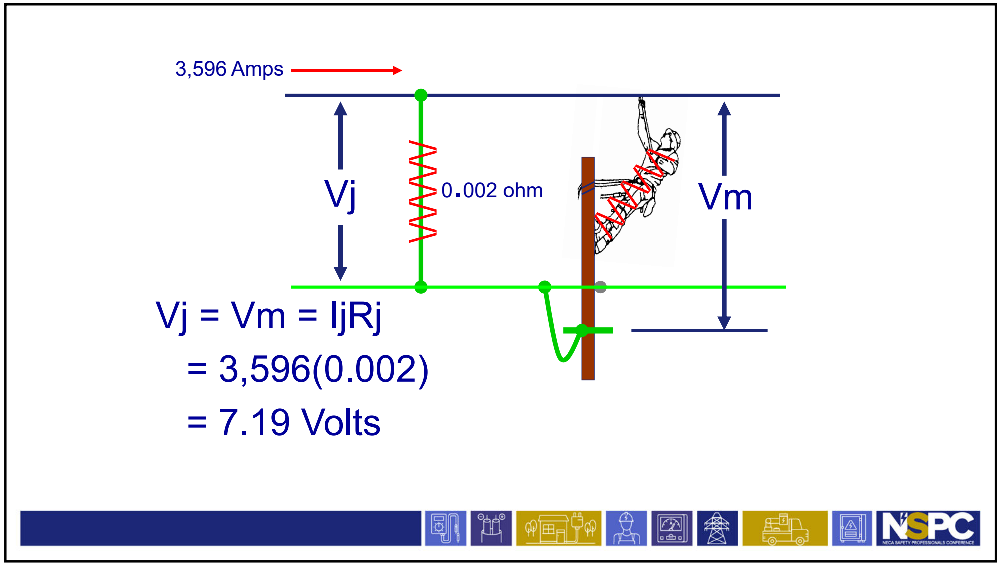

1 ohm
3,596 Amps
500 ohm
I = V/R
I = 7,200/7,526
I = 957 mA
7,000 ohm
25 ohm
NSPC

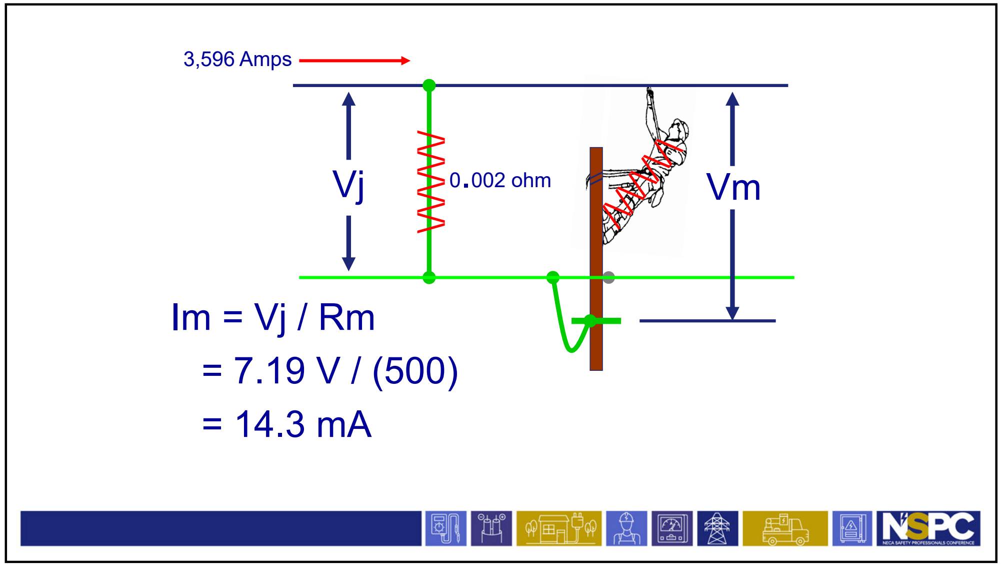

NSPC

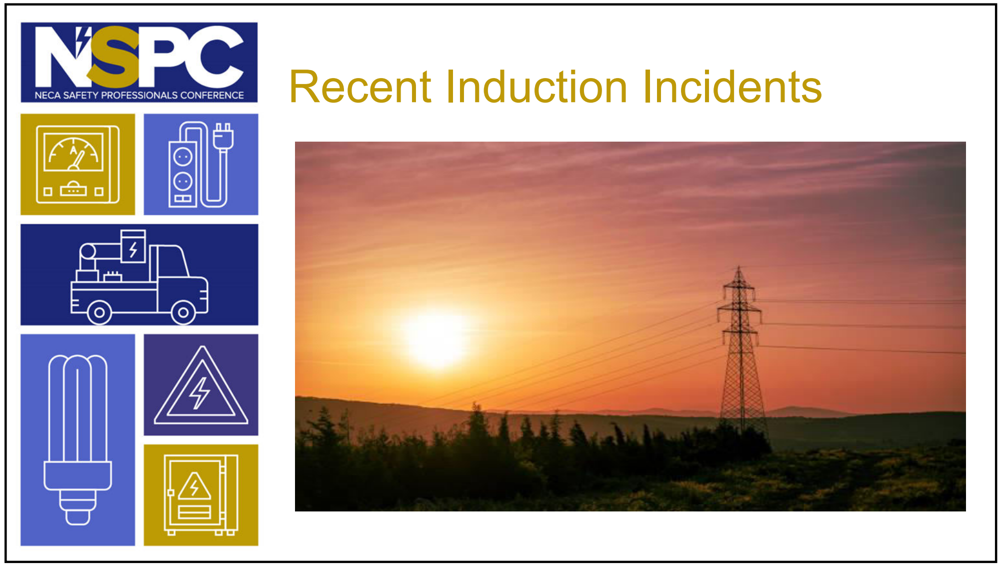

NSPC


1 ohm
3,596 Amps
0.002 ohm
Voltage
500 ohm
1 ohm
7,000 ohm
25 ohm
NSPC


R = ?
Vjumper
Vman
Vjumper = Vman


3,596 Amps
Vj
0.002 ohm
Vm
Vj = Vm = IjRj
= 3,596(0.002)
= 7.19 Volts

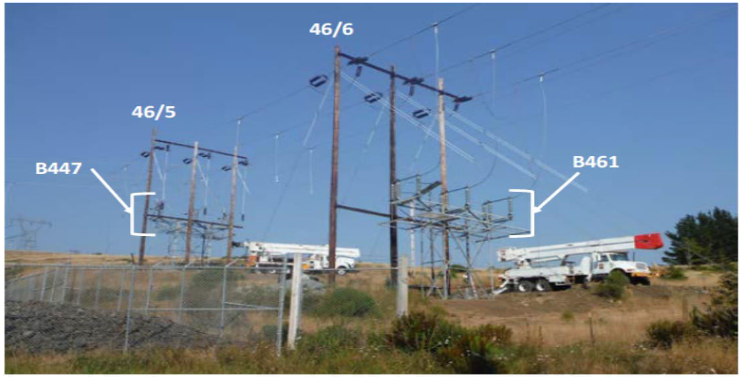

3,596 Amps
Vj
0.002 ohm
Vm
Im = Vj / Rm
= 7.19 V / (500)
= 14.3 mA


NECA SAFETY PROFESSIONALS CONFERENCE
Recent Induction Incidents

Induction incidents

- I wanted to make everyone aware of a fatality that occurred on xxxxx property on Wednesday of this week. We were made aware yesterday during our Safety Liaison meeting with XXX. We do not have a lot of information, but a 7th step apprentice was killed, and the incident was connected to grounding (removing grounds) and fall protection.
- Early indications appear that somehow the worker came into contact with induced voltage and also fell from a bucket due to not have his lanyard attached.
- As you all know, grounding incidents and fall protection are topics that we are all heavily involved in, and this will be another awful reminder that we will need to stay on top of these hazards.

Induction incidents



Induction incidents

- **Crew Foreman was fatally injured while preparing to remove a jumper from a sectionalizing disconnect switch on 115kV line.**
- The plan of the day was to relocate two 115kV sectionalizing disconnect switches.
- The Crew Foreman climbed up to the top of switch stand to attach lift slings suspended from the crane. Once the lift slings were placed and pulled up snug, he positioned himself to assist in the removal of the blade end sectionalizing jumper on B-phase.
- The foreman made contact with a difference of potential across the blade end insulator stack

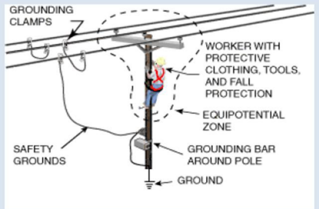
Induction incidents

- The on-site crew heard the foreman yell, and Equipment Operator saw an arc and noticed that the foreman had fallen back into his work positioning belt and harness. While 911 was called, other crew members began to initiate rescue operations.
- Using a bucket truck, the foreman was lowered to the ground. CPR was performed until the EMS personnel arrived on the scene.
- EMS's automated external defibrillator (AED) was used. Foreman was transported by ambulance at 1010 and pronounced dead at 1051

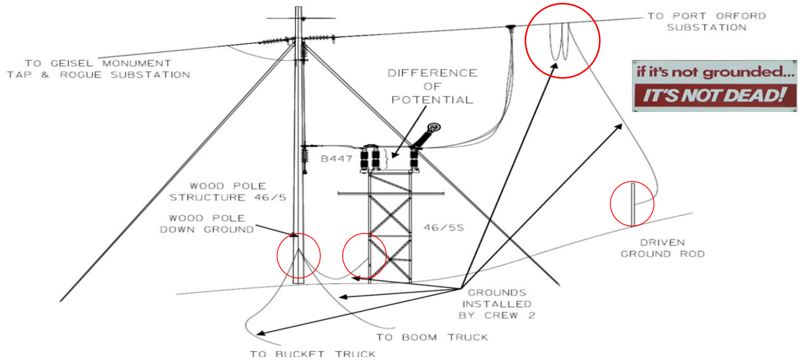
Induction incidents

- The Board concluded the **direct cause** of the accident was that the foreman made contact with a difference of potential across the blade end insulator stack.
- The Board concluded the **root cause** of the accident was **Crew failure to establish an equipotential zone (EPZ).**

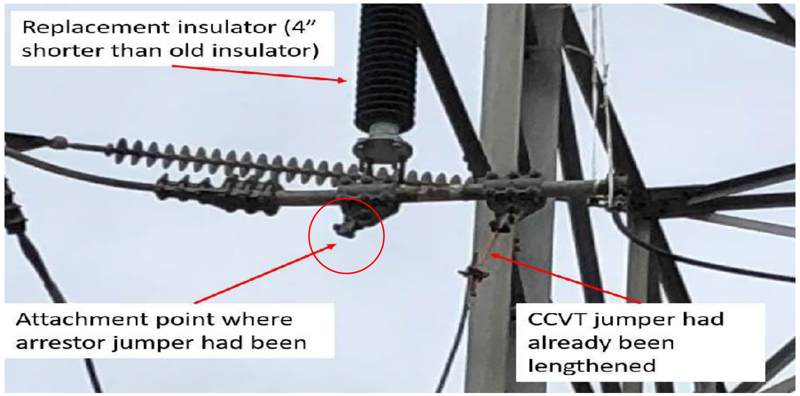
An equipotential zone is a work zone in which the worker is protected from electric shock from differences in electric potential between objects in the work area. These differences in potential can be caused by induced voltage, line re-energization, or lightning.



Induction incidents



Induction incidents



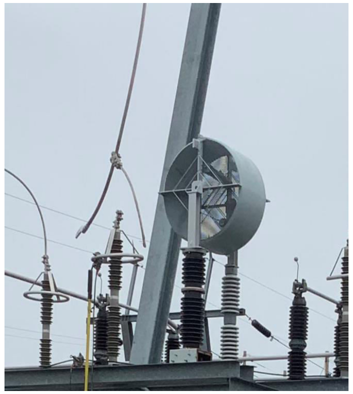
Induction incidents

What happened:

While changing out a wave trap on a de-energized line, a Substation Technician experienced an electrical contact. The technician had just disconnected the center phase from the grounded structure to start prepping the connection to the wave trap. At this point, the employee experienced the contact.

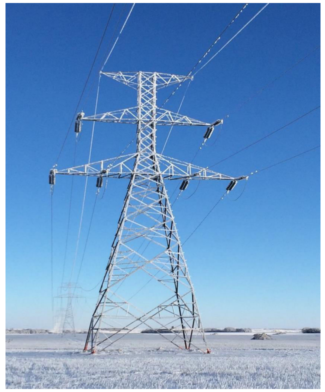
Induction incidents

Tragically, the result of the employee's injury was fatal.



Induction incidents

There was heavy hoar frost in the area

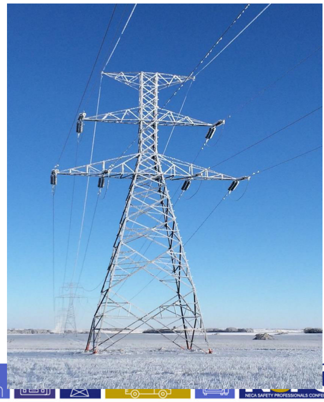


Induction incidents

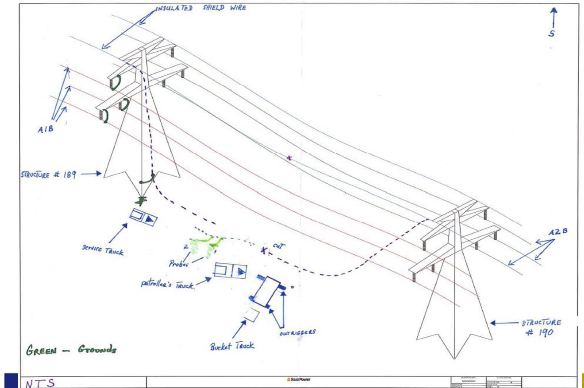
There was heavy hoar frost in the area

Outage
At 4:50 am a phase to ground trip resulted in an outage on the A1B line.

Patrollers 2 located a broken insulated shield wire on A1B line 30 miles from AB and 43 to BE at approximately 1030 am. A2B remained alive to maintain system integrity and was operating at 244 KV.

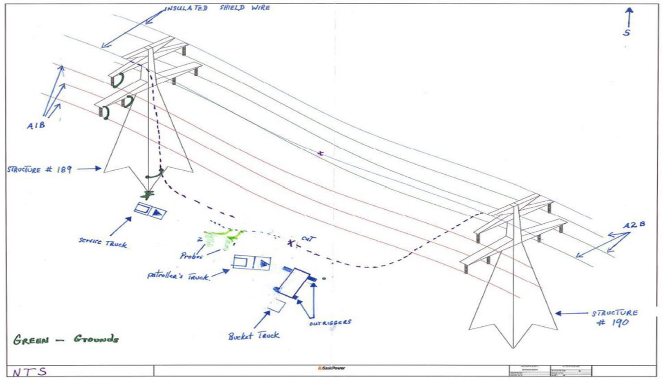


Induction incidents



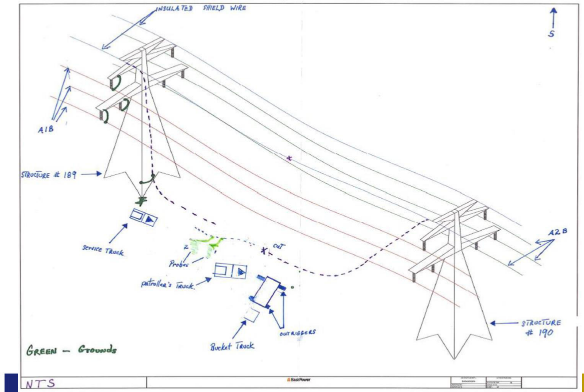
Position of Grounds and Equipment at Time of Incident

Induction incidents



Position of Grounds and Equipment at Time of Incident

Induction incidents



Position of Grounds and Equipment at Time of Incident

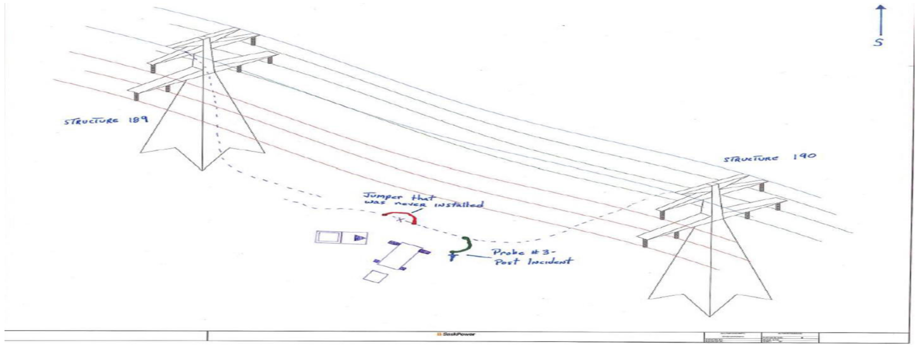
Plan B
At this point they realized their original job plan was not possible due to limitations of their eighty five foot bucket truck. A second plan was devised whereby they would add approximately forty five metres of additional wire to the shield wire at structure #189. This would move the splice to an area where a hill would add additional height advantage to the bucket truck. The change to the original job plan was discussed with all members of the crew but not documented.

After removing the dead end preform grip from the shield wire at structure #189, approximately forty five metres of conductor was added to the shield wire tail. The decision was made to remove approximately forty metres of excess shield wire that ran from structure #190. This would reduce the hazard of potentially contacting a live conductor when it was raised.

Once the location of the cut was determined, the APPLT anticipated the need for bolt cutters so he went to retrieve a pair he knew was located near structure #189. Supervisor also asked PLT to get bolt cutters from the bucket truck. Patroller 2 held the shield wire with both hands and was on his knees while the Supervisor taped the shield wire to prevent the strands from unravelling when it was cut. PLT retrieved a pair of bolt cutters and returned. Supervisor told PLT they would make the cut in the middle of the tape. **Supervisor then walked towards the bucket truck to retrieve a jumper.** Patroller 2, who was still on his knees and wearing leather gloves, extended the shield wire with both hands to PLT who was holding the bolt cutters. He made the cut in the middle of the tape.

Patroller 2 came into series with the electrostatically induced shield wire and was fatally electrocuted.

Induction incidents



Intended Position of Jumper that was Not Installed and Ground Probe 3 that was Installed Post Incident to Ensure Site Safety

Induction incidents

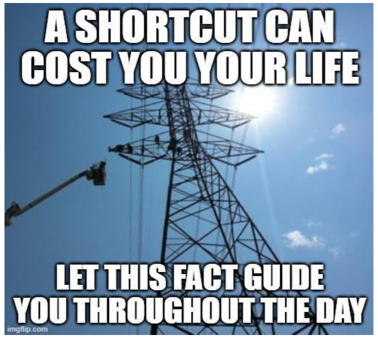
Then the sad thing about this was 6 days later the entire line was out due to extreme hoar frost that damaged the shield supports!

EPZ-Think Electrically, not Mechanically

Job Planning

Careful planning of work assures that the work is performed efficiently and safely, and a hazard analysis is a critical part of work planning.

A properly conducted pre-job briefing ensures the scope of work is understood, appropriate materials are available, all hazards including potential for induced voltage have been identified and protective measures have been established, and all affected employees understand what is expected of them.



EPZ-Think Electrically, not Mechanically

Once all hazards are identified the crew can better determine a way to keep people out of harm’s way.

Knowing a hazard of induced voltage may be present and not determining how to properly protect workers from it is not enough.

You must address how the hazard is to be mitigated and ensure everyone understands.

EPZ-Think Electrically, not Mechanically

Protective grounding of lines and equipment is fundamental to the safety of line workers. It is remarkable that the well-recognized concept of creating an equipotential work zone is not better accepted and established.

The fundamental purpose of the equipotential work zone is to minimize electric current flow across the worker's body. It is very simple and should be easily understood.

It has become clear that, standing alone, grounds installed on either side of the work location or bracketed grounds do not prevent potentially lethal current from reaching and flowing through the worker.

There is a conception that when working between grounds (bracketed grounds) somehow the bracketed grounds are going to stop the electric current from flowing through the worker and it simply doesn't happen. The current takes every path.

EPZ-Think Electrically, not Mechanically

As we train our workers in personal protective grounding methods, we must ensure that we teach them about the hazards of induced voltages and how to think of themselves as part of an electrical circuit, if they put themselves in series with a difference of potential or create a parallel path though them, there will be a voltage drop and a resulting current flow.

All conductive objects in the work area that can be reached by the workers must be electrically bonded to eliminate differences in potential that the worker may be exposed to.

Please complete the Online Evaluation

https://www.surveymonkey.com/r/2024NationalSafetyProfessionalsConference