RECLAMATION *Managing Water in the West*

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Research and
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The Knowledge Stream

Research Update

Safe and Grounded

Ensuring deenergized equipment is adequately grounded while maintenance work is being performed

Bottom Line

The placement of temporary grounds with respect to the location of the electrical work being performed can greatly influence how effective grounding is at protecting workers from being shocked or killed during an accidental energization. This research examines various factors that influence grounding effectiveness and provides equations to calculate safer grounding placement.

Better, Faster, Cheaper

Providing more accurate methods to calculate the effectiveness of safety ground cables in limiting worker exposure voltage during an accidental energization is critical to safely protecting workers.

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Problem

Worker safety is paramount in hydropower and other utility work, particularly as work often times requires direct contact with deenergized high-voltage equipment and transmission lines. High-voltage equipment and transmission lines need to be deenergized, placed on a clearance, and safely grounded with temporary personal protective ground (PPG) cables prior to performing maintenance. But determining what constitutes a safe level of grounding and how ground cables should be configured is a difficult question.

Grounding deenergized high-voltage equipment and power lines during maintenance or construction activities is critical for worker safety. This is usually done by applying PPGs according to the utility's procedure to create a safe work zone. However, in practice, many of these procedures tend to underestimate the maximum voltage a worker would be exposed to during an accidental energization of the equipment.

Solution and Results

The Hydropower Diagnostics and SCADA Group in Reclamation's Technical Service Center (TSC) has been testing different grounding methods used in the electric industry. The research looked at measuring the actual voltages that a worker could be exposed to across a PPG during an accidental energization. The field tests involved installing PPGs on deenergized powerplant equipment or transmission lines. The PPGs were then intentionally energized and the resultant currents in the PPGs, and the resultant exposure voltages at locations where worker contact with energized equipment was probable, were monitored.

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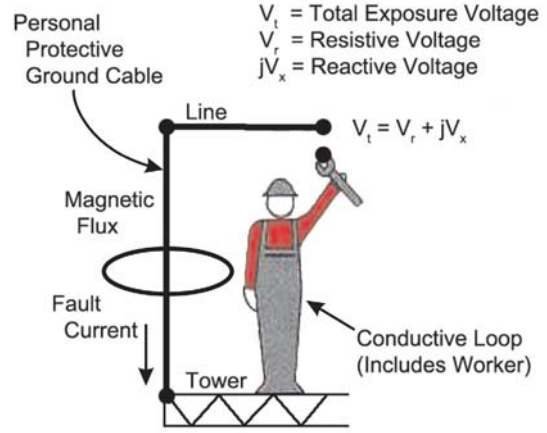
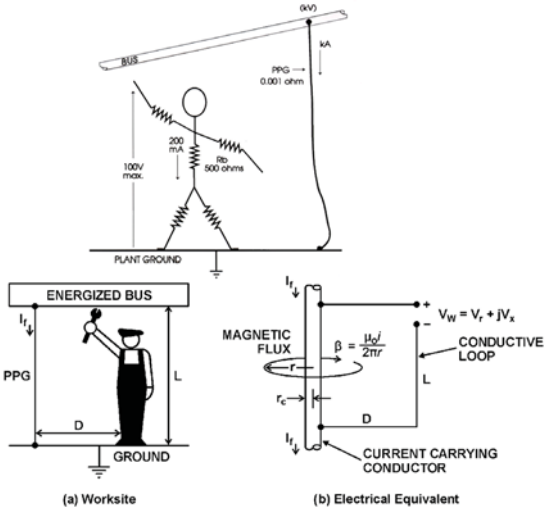


Inductive ground loop principle.



Reclamation's grounding principles.

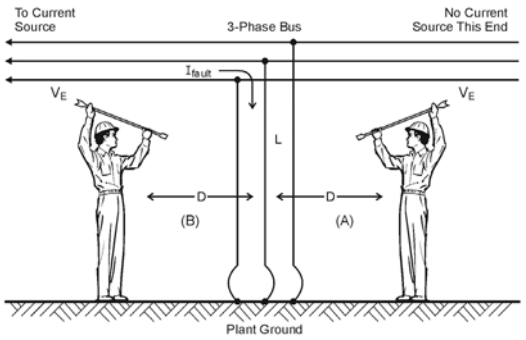


Illustration of worker relative to protective grounds.

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The field testing found that the exposure voltages were 2 to 3 times higher than what would be predicted by calculating the voltage drop just across the PPG. The additional voltage was the result of the geometry of the PPG in relationship to the position of the worker.

Historically, the PPG cable resistance was placed in parallel with the worker's body to calculate worker exposure touch voltage and the resultant current through the body if the grounded worksite was accidently energized. The PPG cable resistive voltage drop resulting from the power system fault current was the key factor in determining worker touch voltage.

However, the field testing demonstrated that the PPG cable reactive voltage drop often is a significant component of the worker touch voltage. Reactive voltage is developed due to the magnetic induction around the PPG that is produced by the flow of current in the PPG. This magnetic induction inherently produces a reactive voltage drop at the worksite due to the loop that is formed between the PPG cables and a worker. Therefore, the PPG cable resistance and reactance should both be considered for realistic worker exposure touch voltage evaluation.

Following these field test data, the recorded information was analyzed and the effect of the reactive voltage drop was then incorporated into Reclamation's Facility Instructions, Standards, and Techniques (FIST) manuals. FIST 5-1, *Personal Protective Grounding for Electric Power Facilities and Power Lines*, provides PPG procedures that enable Reclamation workers to perform their duties within a safe working environment.

To further expand on the field test data and to better predict expected worker exposure voltages, mathematical methods to calculate the worker exposure voltages were developed that include both the resistance and reactive components. Six temporary protective grounding scenarios were modeled to illustrate the effect that magnetic induction has on worker exposure voltage when a worksite is accidentally energized. The Hydropower Diagnostics and SCADA Group also participated with the Institute of Electrical and Electronic Engineers (IEEE) Standards Association to incorporate these findings into IEEE standards. The latest edition of IEEE Standard 1246, *IEEE Guide for Temporary Protective Grounding Systems Used in Substations* incorporates Reclamation's research findings.

Workers working on high power transformer lines.

"The primary purpose of personal protective grounding is to provide adequate protection against electric shock causing death or injury to personnel while working on deenergized lines or equipment. This is accomplished by limiting exposure voltages at the worksite to a safe value if the line or equipment is accidentally energized."

Phil Atwater
Electrical Engineer, retired
Reclamation employee

Collaborators

Reclamation:

- **Hoover Powerplant**
- **Grand Coulee Powerplant**

Western Area Power Administration

Future Plans

Continue to inform the power industry through guides such as IEEE Standard 1246 and through publishing additional papers on these new mathematical models to predict worker exposure voltages.

More information

www.usbr.gov/research/projects/detail.cfm?id=5446