Office of Health, Safety and Security
Safety Advisory

Contact with Overhead Lines and Ground Step Potential

2010-05 **August 2010**

PURPOSE

This Safety Advisory is issued to warn sites about the potential for serious electrical injury (potentially fatal) caused by ground step potential resulting from a phenomenon called ground gradient, which is produced when equipment comes in contact with energized overhead power lines.

BACKGROUND

On March 26, 2010, at the Hanford Site, an excavator (Figure 1) accidentally touched an energized 13.8-kV electrical power line. The actual voltage to ground was 7.96 kV because only one phase was in contact with the excavator. The burned power line is shown in Figure 2.

A Project Safety Representative (PSR) saw sparks underneath the excavator and inappropriately responded by driving his truck to approximately 13½ feet from the excavator. The PSR stepped out of his truck onto damp/wet ground and moved toward the excavator. Fortunately, the equipment operator had backed the excavator away from the power line before the PSR arrived.

Figure 1 - Excavator that touched energized power line

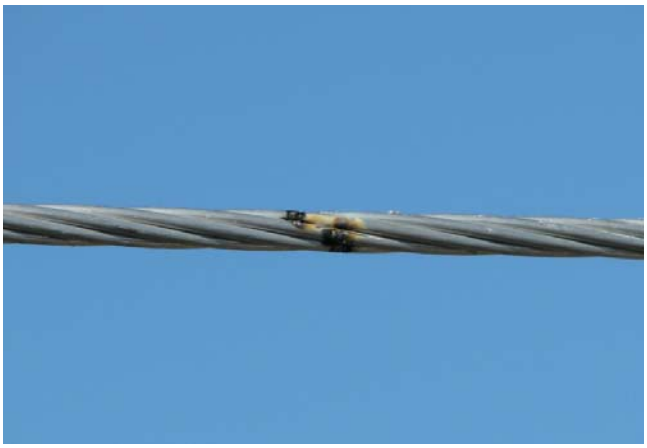

Figure 2 – Burned contact point on 13.8-kV power line

DISCUSSION

When an energized source of electricity (e.g., a downed power line) comes in contact with the ground, the electrical current can pass through the ground. The voltage is strongest at the point where ground contact is made and becomes weaker as it radiates out from the point of contact. This phenomenon is called “ground gradient,” and is much like a series of irregular concentric circles expanding outward (Figure 3). If you were to walk toward the point of contact, current could pass into and up one leg and down and out the other. This is known as “step potential,” or the flow of ground gradient electricity through the body from one area of electrical potential to another area of electrical potential between your feet. Each area between these lines of concentric circles has a different electrical potential. This danger might first be identified by a tingling sensation in the feet. The step potential becomes even more severe when the ground is damp or wet.

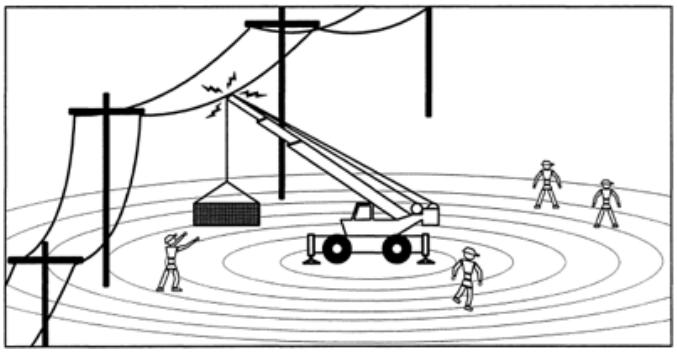

Figure 3 – Example of ground potential gradient

ANALYSIS

According to two technical documents (see references), the voltage gradient along the ground is reduced in half for every 2½ to 3 feet moved away from the energized source.

The Department of Energy, Richland Operations Office electrical subject matter expert interviewed Mr. Clayton King, an author of one of the references, and found that his conclusions regarding the voltage gradient were based upon multiple tests using 1.4-kV and 7.2-kV voltage sources. According to Mr. King, the resistivity of the soil used was 18 ohms-cubic centimeter. Considering an area covered by a size 12 shoe (0.0274 square meters), the ground resistance of the test soil would be 6.6×10^8 ohm-meter. Based upon IEEE Standard 80-2000, Table 7, "Typical Surface Material Resistivities," the test soil used as the basis of the rule-of-thumb described above conservatively represents most dry soil. Also based upon the data provided by this table, most wet soils have a resistivity that is reduced by 1,000 ohm-meter.

In the Hanford event, if the excavator had still been energized at 7.96 kV when the PSR stepped out of his truck onto damp/wet ground, the voltage potential would have been approximately 500 volts or more. On the PSR's first step toward the excavator, approximately the same voltage potential (or more) would have existed between his feet.

The PSR was extremely fortunate that the equipment operator took the initiative to back the excavator away and break contact with the energized conductor. If the excavator had still been in the circuit, the PSR would have been severely shocked and possibly killed with his first step.

ACTIONS

1. Equipment operators whose equipment contacts energized electrical lines must be aware that they, and the equipment, are at the same electrical potential as the power line. If possible, break contact by moving the equipment clear of the wires. This may not be feasible where contact has welded conductors to equipment. Do not attempt to exit the equipment. Warn others to remain clear. Unless other hazards are present (e.g., a fire), it is safer to stay inside the equipment until emergency responders or utility personnel have safely de-energized the power line and verified that it is safe to exit.
2. Emergency responders, and all other personnel who are in the immediate area, must be aware that a voltage gradient exists along the ground from the equipment that is touching the energized electrical source. Every effort should be made to move away to a safe distance where the ground potential is less than 50 volts. For example, using the gradient rule, for 13.8-kV phase-to-phase systems, a minimum safe distance would be at least 22 feet, and for a 230-kV phase-to-phase system, a safe distance would be at least 34 feet. For wet soils, this safe distance should be doubled to 70 feet.

THINGS TO REMEMBER

- Always consider power lines energized until confirmed to be de-energized. Even if the line is not sparking it can still be dangerous.
- Power lines could re-energize following a ground fault if the circuit is equipped with automatic reclosers that work off of time delay relays. Circuit breakers can reclose and energize the line if the fault has cleared. Even if you break contact with

the line it could re-energize.

- It is a myth that the tires protect you – the metal of the vehicle conducts electricity around you like a bird on a power line. You are safe inside the vehicle as long as you don't step out and touch the vehicle and ground at the same time. Remember, the electricity is not only traveling through the metal of the vehicle but it is also traveling in the ground around the area.

ADDITIONAL SOURCES OF INFORMATION

OE Summary 2005-14: The first article in this OE Summary, *"Be Aware of Overhead Electrical Lines when Operating Dump Trucks,"* provides considerations for drivers when operating equipment near power lines.

Appendix C to §1910.269: *Protection from Step and Touch Potentials*. This OSHA standard discusses the dissipation of voltage from the grounded end of an energized grounded object and the ground potential gradient.

REFERENCES

- *Why Proper Grounding is Vital for Worker Safety*, "Electrical World Magazine," November 1990, by Clayton C. King
- *Encyclopedia of Grounding for De-Energizing Construction & Maintenance*, Copyright 2008, Hubbell Power Systems, Inc.
- Lessons Learned 2010-RL-HNF-0035, *Contact with Overhead Lines and Ground Step Potential*

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Signed by

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