Step and Touch Potential Awareness:

Improving Transmission Line Crew Safety

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Introduction

Step and Touch Potential resulting from ground potential rise (GPR) is well understood as a safety hazard in many situations involving energized power sources. What is not as well understood is that GPR and the associated step and touch potential can arise from de-energized lines due to electromagnetic coupling from parallel live lines. This paper explains why this is becoming a daily danger for transmission line workers and presents new and improved methods to increase worker safety by continuously monitoring and alarming when dangerous voltages are present.

Objectives

The objectives of this paper are to cover these four topics:

- What is meant by Step and Touch Potential?
- How does this apply to work on de-energized transmission lines?
- How is this safety issue handled now?
- What can be done to improve line crew safety?

What is meant by Step and Touch Potential?

OSHA [1] defines "Step potential" as the voltage between the feet of a person standing near an energized grounded object. It is equal to the difference in voltage, given by the voltage distribution curve, between two points at different distances from the "electrode". A person could be at risk of injury during a fault simply by standing near the grounding point.

"Touch potential" is the voltage between the energized object and the feet of a person in contact with the object. It is equal to the difference in voltage between the object (which is at a distance of 0 feet) and a point some distance away. It should be noted that the touch potential could be nearly the full phase to ground voltage across the grounded object if that object is grounded at a point remote from the place where the person is in contact with it. For example, a crane that was grounded to the system neutral and that contacted an energized line would expose any person in contact with the crane or its uninsulated load line to a touch potential nearly equal to the full fault voltage. (See Figure 1).

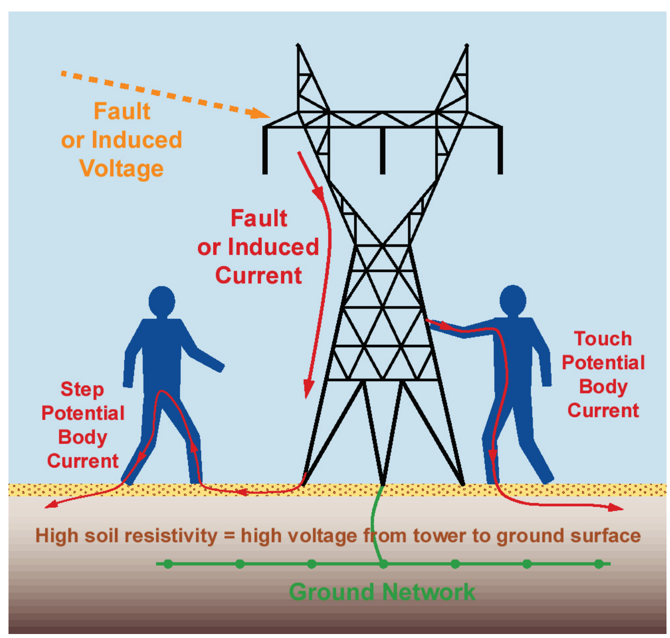

Figure 1: Step and Touch Potentials

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How does Step and Touch Potential hazard apply to work on de-energized transmission lines?

It may seem that Step and Touch shock hazard would not apply to transmission line workers when they are working on a de-energized line that is connected to a grounded tower. However, de-energized lines can build up lethal voltages due to induced energy (electromagnetic induction) from a parallel energized transmission line, and the chances of this happening are increasing due to the changing work environment, as will be explained below. In addition, the ground system at the tower is not always reliable, since ground resistances vary greatly depending on the soil type and environmental conditions and can change quickly as the soil dries out.

There are many factors that contribute to the increased danger of Step and Touch Potential hazards from induced voltages. Increased and varying energy use along with energy generation facilities that are often located far away from the areas of highest energy use have resulted in heavily loaded lines in congested power corridors. Existing rights-of-way are often used to support multiple transmission lines and existing structures are often used to carry additional cable under the main lines. (See figure 2). As has been noted in recent publications [2], these physical changes, along with increasingly restrictive utility shutdown policies are resulting in more incidences of dangerous induced voltages. In some cases, workers may be servicing one set of de-energized lines on a tower while other sets of lines on the same tower are still energized.

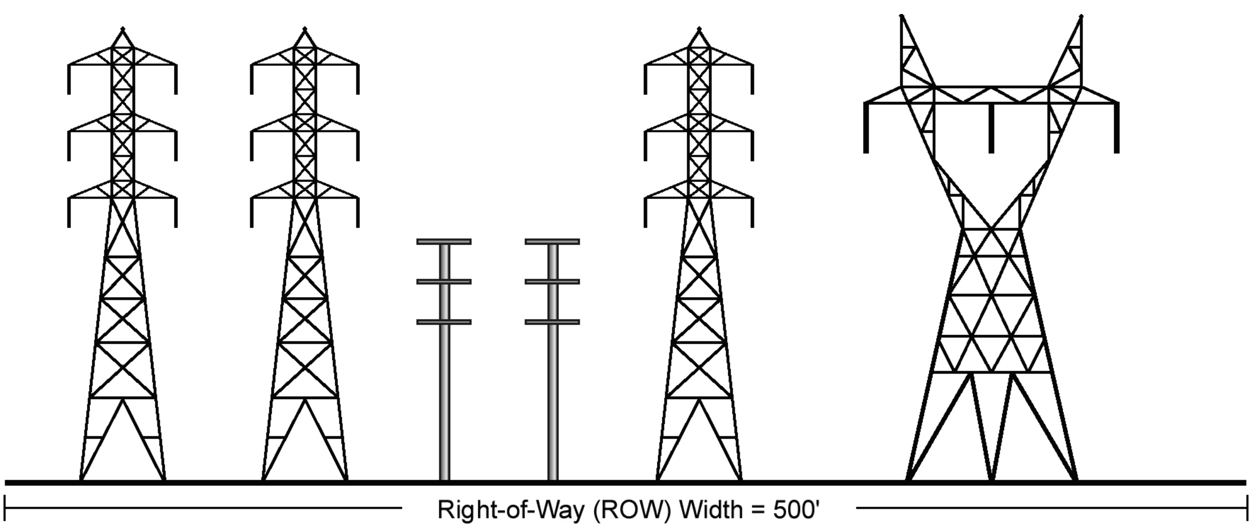

Figure 2: An example of a crowded power right-of-way [similar to ROWs in reference 3]

The Bonneville Power Administration (BPA) publication "Living and Working Safely around High-voltage Power Lines" [4] discusses the concerns for barbed wire and woven metal fences assuming an induced voltage when located near power lines. The BPA identifies potential concerns for a fence that is within 125 feet of the lines and more than 150 feet long. In a power system right-of-way, it is not unusual to have power lines within 125 feet (even on the same tower) that may run together for many miles [3].

So it is no longer adequate just to protect workers from the possibility that the line they are working on may become accidentally energized or from accidental contact with an energized line—it is also imperative to protect workers from induced voltages on grounded lines.

The Step and Touch Potential hazard would not be so severe if it was possible to assume that every tower work site had a very good earth ground connection. Unfortunately, this is not the case—particularly in areas where the soil may be volcanic or otherwise rocky. As studies have shown [5], the quality of ground connection varies dramatically depending on the soil:

Type of soil	Soil resistivity (Ohm-m)
Moist humus soil	30
Farmland, loamy and clay soils	100
Sandy clay soil	150
Moist sandy soil	300
Moist gravel	500
Dry sandy or gravel soil	1000
Rocky ground	30,000

Table 1: Typical soil resistivity values [5]

Because of the high resistivity of certain soils, a severe shock hazard could be created even with a very small induced current. Actual workplace measurements in Wyoming [5] have found resistances of 500 ohms or higher, which would only require 1 Amp of current to create a 500 V potential. Even higher resistances have been reported in British Columbia and elsewhere.

Since moisture content is a major factor affecting soil resistivity, a ground that tests adequate one day may be significantly higher resistance at another time when moisture content is lower. In fact, the normal drying out of soils during a day can mean that a safe environment during the morning may no longer be safe by afternoon.

Another condition that can create very high voltages at worksites is due to circulating currents resulting from more than one ground point. (For example, this can happen when more than one crew is working on a given line—a common situation given the pressure to reduce power downtime). This causes induced currents to circulate through any available grounds at any point along the line. As the adjacent lines induce currents into the sections between the grounds the currents created flow to the grounds and add to each other reaching high levels. Some linemen have seen as high as 2,300 V and 35 Amps—very lethal conditions!

How is this this safety issue handled currently?

In order to create a safe work site, it is common practice for transmission line workers to create a single-point work site ground and install ground cables connecting all conductive objects. This will provide adequate protection in most cases. Under the worst-case scenario of the line becoming accidentally energized, very high step-and-touch voltages can result, but this is very rare and usually for only a short period of time. Conventional wisdom is that this is best dealt with by training workers to avoid unnecessary contact with vehicles and other equipment connected to the ground.

Dealing with voltages caused by electromagnetic induction from parallel lines is a more difficult problem. Unlike accidental energization which is extremely rare, induced voltages are a continuous problem. And the chances of having a dangerous voltage at any given time depends on a large number of factors including the length of parallel lines and the type of soil at the site.

The use of insulating gloves and other protective equipment are mitigation measures required depending on the voltages anticipated. In some cases, it is desirable to add additional ground rods to the site. However, since the magnitude of the induced current and the actual resistance of the ground rod are unknown, the actual step and touch voltages are also unknown.

The practice of connecting all conductive objects with ground cables has ramifications, as well. For example, bonding a vehicle to a tower that has induced voltage present will cause the vehicle to become energized; and due the natural voltage gradient through the soil, will create the largest touch potential on the side of the vehicle that is farthest from the tower.

What else can be done to improve line crew safety?

A more certain technique to determine Step and Touch Potential is to measure it directly. This has commonly been done using a standard voltmeter equipped with a high voltage probe. A ground rod is driven in some distance from the tower (approximately 15 feet), and the negative probe is connected to this ground reference point. The high voltage probe is then touched to the tower and the voltage from tower to ground is measured. Since the meter draws very little current, it is not necessary to have a low ground resistance in order to get a useable reading. For practical reasons, this is typically done only once at the beginning of the shift.

Although this technique is a significant improvement over not measuring the voltage, it fails to account for the fact that conditions can change during the shift. These changes can be due to the soil drying out causing the ground resistance to become much higher rather quickly. Or the changes can be even more abrupt—perhaps the current on a parallel line is suddenly ramped up dramatically to compensate for a change in power generation or requirements. So, simply checking once at the beginning of a shift may provide a false sense of security.

Fortunately, special Step and Touch Instruments [6] are now available that address these limitations. These instruments are connected to the tower ground for the entire period of work, and continuously monitor the voltage on the tower. In addition, if a hazardous voltage is detected, the instrument warns the crew using light and sound—high intensity LEDs flash together with a piercing audible alarm. In typical field use, one crew member is assigned to keep an eye on the instrument, and make sure that everyone is always working under safe conditions.

Fig. 3: SNT Step and Touch Monitor

For example, the SNT-02 Step and Touch Instrument displays the actual voltage and provides a response based on the voltage range detected:

Range	Instrument Actions	Crew Actions (typical)
0-100V	Green LEDs Flash	Work with normal precautions
101-499V	Yellow LEDs flash, beeps once per second	Work with protective equipment
500V +	Red LEDs flash rapidly, beeps rapidly	Stop work

To make the use of this instrument easy and convenient for the line crews, it comes as a SNT-02 Step and Touch kit which includes a ground rod, a high voltage cable, a magnetic probe for steel towers and a clamp probe for aluminum towers, both of which can be attached with a standard "hot stick". The SNT is battery operated and comes with both an AC charger and a vehicle charger.

Figure 4: SNT-02 Kit

Summary

The Step and Touch potential hazard exists when a person approaches an electrified object. This has become an increasing problem for transmission line crews working on de-energized lines that are connected to a grounded tower. As power transmission corridors become more crowded and transmission systems more complicated, there is an increasing likelihood of significant power being coupled onto the de-energized line from a parallel line due to electromagnetic induction. Circulating currents caused by multiple grounds (e.g. from multiple crews working on the same line) can be very high. These conditions, in combination with a relatively high-resistance ground can cause dangerous ground potential rise voltages. Moreover, these voltages can vary both slowly and quickly as conditions change during the work period, making this a daily step and touch hazard for transmission line crews.

Step and Touch Instruments are now available to directly address the danger of injury to transmission line crew members, providing continuous monitoring of step and touch voltages and both visual and audible alarming. These instruments increase worker safety and are becoming standard equipment for workers at an increasing number of utilities. Existing users have found multiple times per year where crews have been prompted to mitigate or change work methods when alerted by the SNT to a rise in voltage during the work shift (often due to the soil drying out or a grounding change at another point on the line). Using older methods, crews would have been unaware of this potentially dangerous change in conditions.

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References

[1] Occupational Safety and Health Standards - Special Industries - Appendix C to §1910.269 -- Protection from Step and Touch Potentials - http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9871&p_table=STANDARDS

[2] Nothing's Shocking – Establishing an equipotential job site - Paragraph 2 – May 2007 - http://www.ecmag.com/?articleID=7560&fa=article

[3] Transmission Line Safety and Nuisance 6.14 - Page 10 – Induced Current and Voltages, and Figure 9: Typical ROW example – February, 2007 http://www.energy.ca.gov/sitingcases/victorville2/documents/applicant/afc/6.14%20TLSN.pdf

[4] Bonneville Power Administration - Living and Working Safely around High-voltage Power Lines – October, 2007 - http://www.bpa.gov/corporate/pubs/public_service/livingandworking.pdf

[5] Western Measures Step Touch Potential – Page 1 – Electromagnetic Induction, Tables 1 and 2 – February, 2007 – http://tdworld.com/mag/power_western_measures_steptouch/

[6] Step and Touch Instrument - http://stepandtouch.com/

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