

Induced Voltage on Electric Fences

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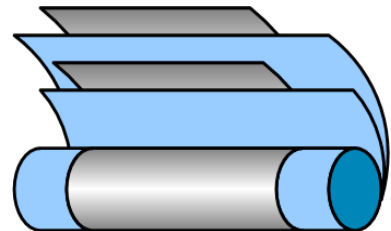
This presentation describes the phenomenon of induced voltage between the earth and electric fences (and other insulated objects) located near transmission lines.

The following materials are available upon request:

1. A Mathcad worksheet that will calculate the induced voltage on a fence paralleling a transmission line. This file is also available as a .pdf file for those who do not have the Mathcad software but want to study the calculations.
2. A .pdf file of the presentation slides
3. A .pdf file of this handout

Capacitance

Any two conductive objects that are insulated from each other will form a capacitor. Most of the time, this has no impact on us and goes unnoticed. Occasionally however, when one of the conductive objects is something like an insulated fence wire or a vehicle, and the other is a nearby high voltage transmission line, this unintentional capacitance can result in noticeable, and even painful shocks when someone standing on the earth touches the object.



The capacitance between two objects depends on their size, spacing, and the dielectric between them. Increasing their size or reducing their spacing will increase the total capacitance, and vice versa. These capacitances can be calculated. The transmission line and fence form a capacitor, as do the fence and the earth. In general, the capacitance between a fence wire and the earth will be much larger than the capacitance between the fence wire and a phase wire of the transmission line. Voltage will divide across these series capacitors, with most of the voltage between the earth and the transmission line conductors appearing between the fence and the transmission line. A small fraction of the total L-G transmission line voltage will appear between the earth and the insulated fence wire. The voltage between the earth and the fence wire is the voltage that someone comes in contact with.

To calculate the theoretical maximum voltage between the fence and the earth, only the conductor locations with respect to each other and the earth are needed. To calculate the actual capacitance values, the length that the fence and transmission line parallel each other is needed. Although the initial contact voltage may be more than 1000-volts, the capacitances involved are typically so small that this voltage all but collapses when the fence is contacted by a person. For those familiar with stray voltage investigations and terminology, the *source resistance* for the voltage between the fence and the earth is typically 100s of thousands of ohms, or even a few mega-ohms.

Example values:

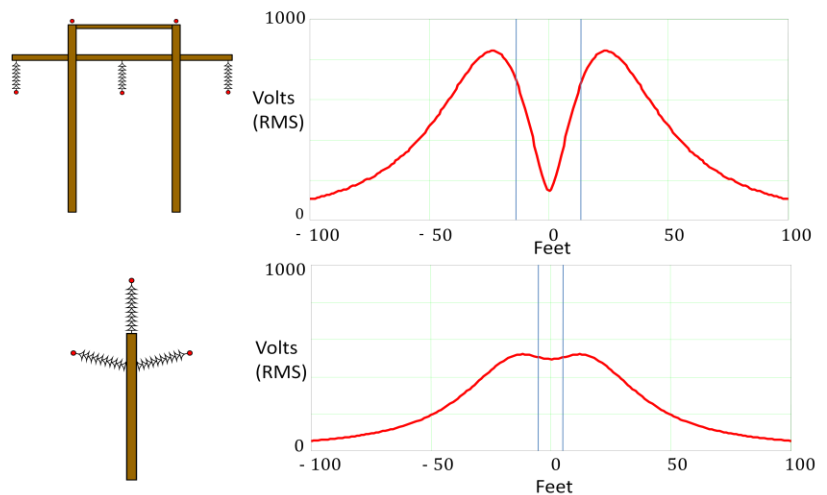
An insulated fence wire is 3-feet above the ground and 12-feet beyond the outside conductor of a 138-kV transmission line with conductors 35-feet above the ground spaced 13.5-feet apart. The fence parallels the transmission line for 2000 feet.

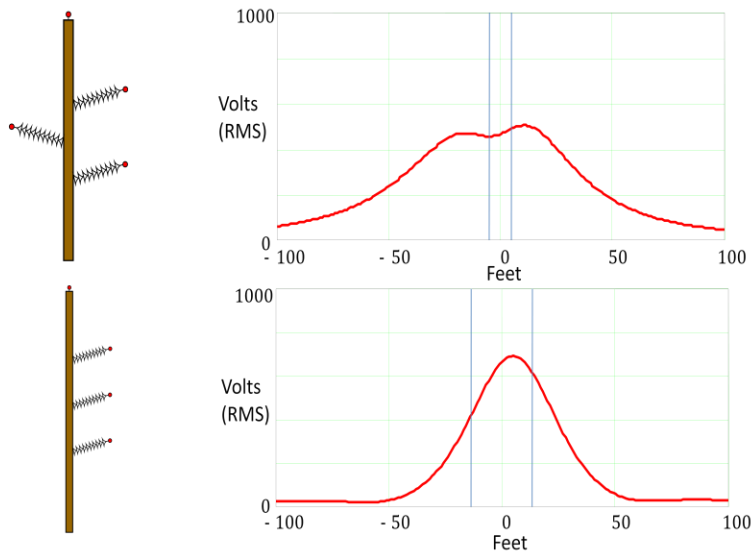
Calculated open-circuit voltage (fence to earth):	838V (RMS)
Measured open-circuit voltage:	790V (RMS)
Measured voltage across 500-ohms:	0.69V (RMS)

Notice how the internal impedance of the voltmeter (10M-ohm) resulted in a lower measured voltage than the calculated value. The voltage measured across the 500-ohm resistor is extremely low compared to the open circuit voltage. This large drop in the measured voltage when the 500-ohm resistor is used helps us recognize that the voltage being measured is induced rather than conducted.

Induced Voltage Profiles

138kV transmission lines with the lowest conductor 35 feet above the ground. The fence used in these models was 3 feet above the ground.





Hazards

When a person stands on the earth and touches an insulated fence near a transmission line, current will flow between the earth and the fence through the person. The person may experience a shock upon initial contact with the fence. This shock is due to the short time it takes for the capacitor formed by the fence and the earth to “discharge” through the person. This happens very rapidly, typically in a few microseconds. The shock a person experiences in this situation may be painful but is not likely to present a genuine safety hazard.

If the standards that are in place are followed, a person is extremely unlikely to experience an electrical injury as a result of this induced voltage. Specifically, the National Electrical Safety Code requires that the short-circuit current that would flow between the earth and an insulated object if the object were grounded shall not exceed 5mA RMS steady-state. In the example used above, the fence would have to parallel the transmission line for more than 1.36 miles for this to occur.

In general, if the voltage measured between the earth and an insulated object is less than 2.5V AC-RMS when measured across a 500-ohm resistor, the NESC requirement is being met at the time of measurement. Satisfying this criterion does not ensure that contacting the fence will not result in an unpleasant or painful shock, but the shock is unlikely to be harmful.

Mitigation

The author recommends that unless a device such as a fence is intentionally energized, it should be solidly grounded. A single-point ground may reduce the voltage between a fence and the earth due to capacitive-coupling, however, this creates a situation where a person at a distance from the grounding point could contact the fence and create a path for induced current to flow. To minimize the loop area for induced current, multiple grounds are recommended, especially near work areas.

For electric fences in the vicinity of transmission lines, the voltage between the fence and the earth should be measured with the fence charger turned off. If the measured voltage across a 500 or 1000-ohm resistor exceeds 2.5V or 5V respectively, mitigation may be necessary.

In cases where an electric fence is found to not meet the 5mA NESC criterion, one or more fence-filters can be installed on the fence. A fence-filter is a low-pass filter that provides a low impedance to 60Hz current but a high impedance to the short, fast pulse produced by the electric fence charger. Fence filters are available from ISSPRO Inc. (800)888-8065

Other mitigation options include reconfiguring the fence to reduce the parallel length, reduce the fence's capacitance to earth, or both. The fence could also be replaced with a grounded fence such as a barbed wire fence.