Voltage Detection and Indication by Electric Field Measurement

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Abstract

Reliably detecting and measuring high voltage on distribution and transmission voltage power lines is vitally important to the jobs performed by electric utility linemen. These jobs get done more quickly and safely when the voltage detection and measurement equipment is also convenient and easy to use. The most convenient equipment is usually a single terminal device which operates without a direct connection to ground. These single terminal voltage detectors and indicators are now more reliable and more accurate thanks to advances in electric field measurement.

Keywords

Voltage, accuracy, field, single terminal, detection, indication, ground

Introduction

Detecting and measuring voltage on distribution and transmission voltage power lines is one of the most basic and important tasks in the daily work of an electric utility lineman. Safety awareness and ongoing safety reviews of live line work practices are part of the job for those who daily go to work in close vicinity to potentially lethal voltages. Recognizing that the safest work practices are often those that are easiest to implement, recent emphasis has been placed on convenience and ease of use by both those who work on power lines and the voltage detection equipment providers.

Generations of electric utility linemen have become familiar with hot stick type voltage detectors and voltmeters. These devices started out as simple voltage indicators with neon glow tubes in series with current limiting high voltage resistors in the sticks. Later, ruggedized electromechanical meters provided not just an indication of voltage but a measure of the voltage. More recently, digital types provide a wide range of increasingly accurate voltage measurements that now encompass everything from secondary voltages up to transmission voltages. All of these types of devices share a need to establish and maintain two independent connections for either line to ground or line to line measurements. This is not always easy or convenient to do when measurement points are separated or when a long ground conductor can compromise safety. Work rule requirements can add to this inconvenience when two workers are required to use two stick devices.

A new generation of single terminal devices that do not require a ground connection is now available and in use. While single terminal voltage detectors have been around for a long time, recent improvements make these devices easier to use while providing more accurate voltage information. These newer devices also provide a wider range of detection and indication from low secondary voltages up to the highest AC transmission voltages.

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Electric Field Basics

Electric fields surround every energized conductor. All things being equal, electric field strength is directly proportional to voltage magnitude. The higher the voltage, the stronger the field and the greater distance from which it can be detected. The measure of an electric field is in voltage over a unit if distance, typically volts/meter. For a typical overhead distribution line at 7,200 volts and 12.2 meters (40 ft) up in the air, the average electric field strength beneath the line would be 7,200 volts / 12.2 meters or about 590 volts/meter. This is an average field strength however and electric fields are generally not uniform in strength over their distance. In this case, as shown in figure 1, the local field would be much stronger directly adjacent to the conductor but would fall off rapidly with distance and be barely detectable down near the ground. For line conductors suspended above ground, an inverse relationship generally prevails; twice the distance from the conductor results in one half of the electric field strength. This can also be illustrated as equipotential lines as shown in figure 2. In a typical underground URD cable, the electric field is contained completely within the cable between the inner conductor and the outer shield. The very high electric field inside the cable is not detectable outside the cable however due to the outer grounded shield.

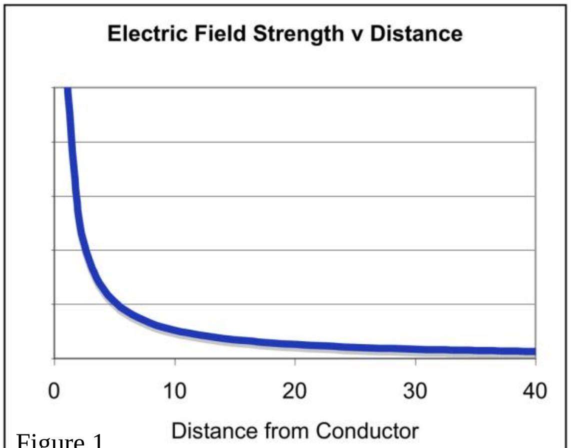

Figure 1

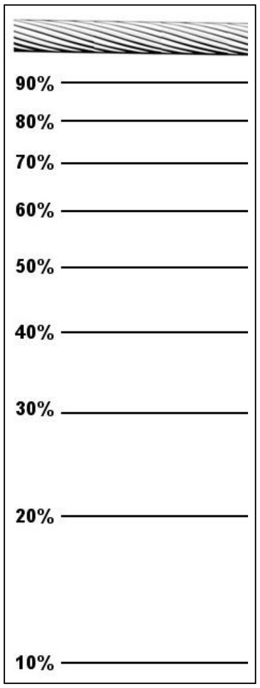

Figure 2

Weak Field Measurements

Weak electric fields are in the range of magnitude from a few volts/meter to tens of volts/meter. These weak fields exist either a short distance from a low voltage source or a long distance from a higher voltage source. Both situations have application in voltage detection tools.

Recent emphasis on what is frequently called urban stray voltage has placed a premium on the ability to easily detect voltages in the range of 6 to 10 volts on objects in the public right of way. Light poles, traffic signal controls, power pedestals, manhole covers, etc. are all subject to the scrutiny of inspectors looking for low AC voltage, usually caused by compromised insulation and/or defective grounds. A compact voltage detector with a single point of contact and a reliable detection threshold allows for quick and efficient inspections.

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Such a detector is shown here in figure 3. Designed to make direct contact with the metallic tip to equipment to be tested, it indicates the presence of voltage with visual and/or tactile alarms. The hand of the user forms a virtual ground around the handle of the device and collapses the electric field into the small distance between this hand and an inner electrode. Collapsing the very weak electric field in this manner increases the field strength and allows for a high degree of sensitivity and the detection of very small voltages including those resulting from equipment that is intact and working properly but simply ungrounded.

Figure 3

A second application for weak electric field measurement is in personal voltage detectors. These devices, typically worn on the body of the user, detect very weak electric fields as an indication of the presence of distribution voltage conductors in the general area of the wearer. Following storms or other accidents, downed medium voltage conductors are a persistent hazard to inspectors and work crews making repairs. A warning of the presence of nearby downed energized conductors can be helpful and even life saving but only if that warning is a useful indication of a potential hazard and not simply another reminder of known live conductors such as intact overhead lines.

Devices such as that shown in figure 4 are highly directional to the electric field vector with strong preference given to optimum sensitivity in the direction forward from the wearer and reduced sensitivity in the directions of the rear, far sides and overhead. Internal sensing electrodes exactly parallel to the plane of the body of the wearer result in optimum sensitivity in the direction of both work and movement of the user. Further shaping of these electrodes fine tunes sensitivity where it is desired and attenuates sensitivity in directions where it is not as shown in figure 5. The concentric ovals signify three distinct warning levels.

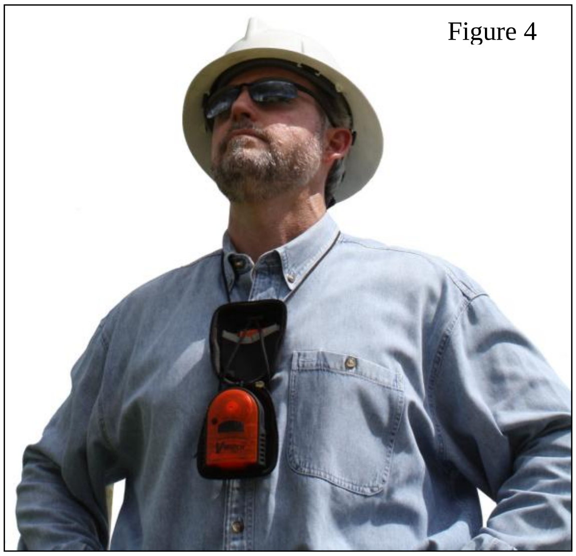

Figure 4

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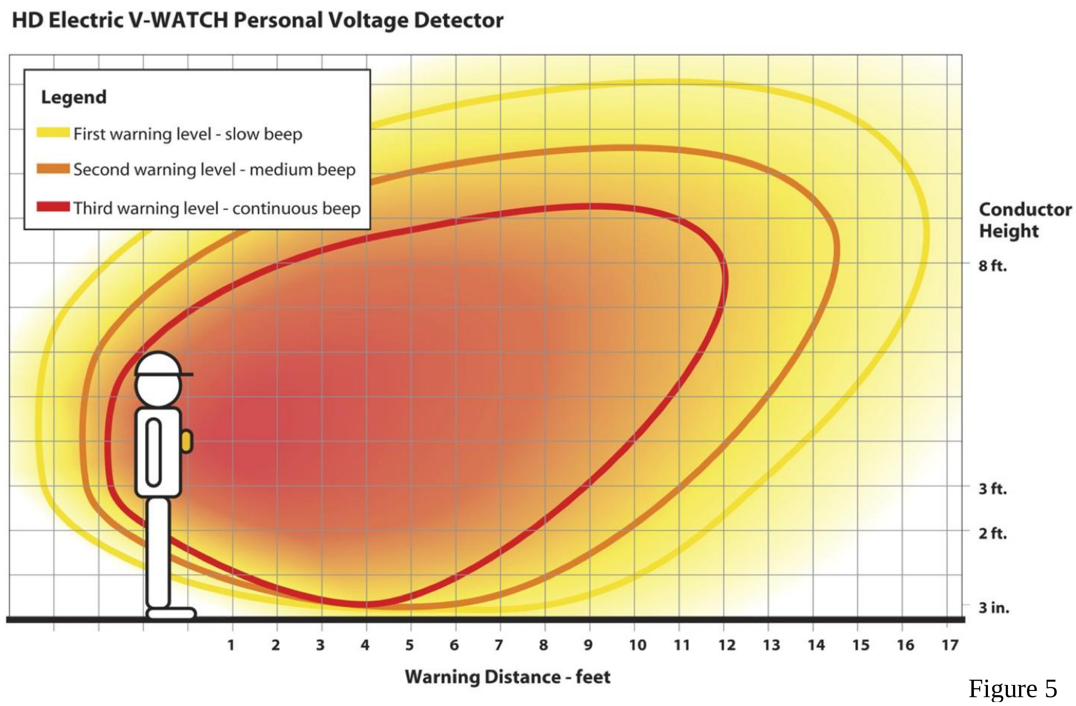

Figure 5

The presence of live conductors in the zone of optimum sensitivity will provide an audible and visual warning to the user from a distance of 2 to 5 meters (6.5 to 16 feet).

Medium Field Measurements

Medium strength electric fields in the range of hundreds of volts/meter to thousands of volts/meter are found in the general vicinity of energized distribution and transmission voltage conductors. Measurement of medium strength fields has application in a wide variety of voltage detectors and indicators.

While the original live line detector was a pair of pliers or wire cutters used in a gloved hand to touch or "fuzz" the line as a crude indication of the presence of voltage, OSHA and other regulations now require a detector with both audible and visual indications of voltage.

Direct contact voltage detectors are those designed to make direct electrical contact to an energized conductor and to indicate the presence of AC voltage on that conductor. Often, these devices have a fixed or variable voltage threshold setting allowing the user to selectively detect only voltages of interest.

Proximity voltage detectors are those designed to indicate the presence of AC voltage on a nearby conductor from a short distance away, generally within one half meter distance. Like their direct contact cousins, these devices have a fixed or variable voltage threshold setting allowing the user to selectively detect only voltages of interest.

Most important to the mission of these devices is their ability to discriminate directionally. The typical work environment does not always consist of only a single conductor as shown in figure 6. Multiple three phase feeders often with intersecting overbuilds or underbuilds make for an electrically complex environment. An electric field detector that can discriminate

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directionally will be able to determine which conductor among the many is the energized one.

Whether the voltage detector is of the direct contact type or the proximity type, the design principles are the same. For either type, the voltage detector is in the near field of the energized conductor and is measuring voltage between two electrodes. For a direct contact detector, one of these electrodes is the contact tip whereas for a proximity type there is an internal electrode near the forward end. A second internal electrode acts as a reference and is placed further from the energized conductor.

Figure 6

More sophisticated types of detectors have more sophisticated sensing electrodes and sensing circuitry to measure the electric field strength in more than one direction. These multiple measurements in combination with a well designed algorithm can make the detector respond differently to different conductor geometry. The purpose of this increased sophistication is to make the voltage detector more likely to detect voltage on conductor configurations that are harder to test with simpler detectors.

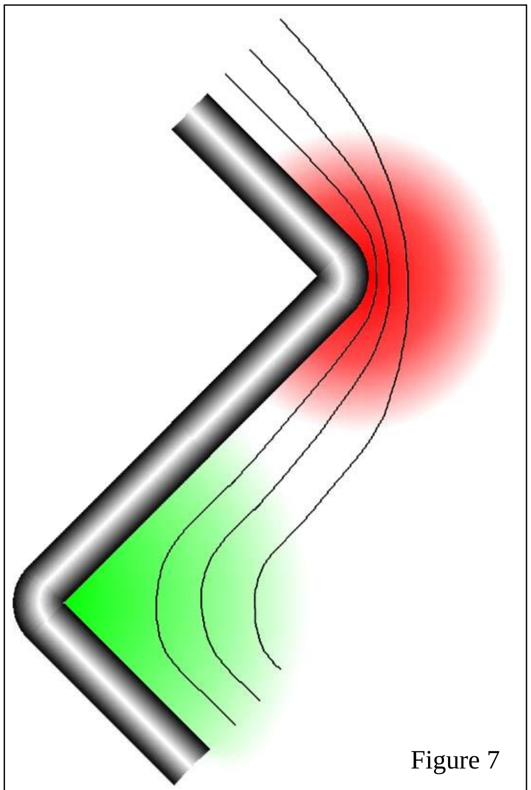

Figure 7

Bends and corners in stranded conductors and buss bars result in significant electric field changes as shown by the equipotential lines in figure 7. Outside corners concentrate electric fields while inside corners spread them out. The result is a change in electric field strength for a given voltage that can challenge voltage detectors to provide consistent results. Detectors that make multiple electric field measurements will be able to detect these unusual field gradients and make adjustments in sensitivity accordingly.

Strong Field and Other Measurements
Electric field measurements in the close vicinity to transmission voltage conductors provide special challenges. At the upper range of transmission voltages the conductor diameter increases to minimize discharge and these larger diameter conductors result in different electric field gradients for a given voltage. The electric field near the surface of a 138kV buss bar of 2 in. diameter will mimic the electric field near the

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surface of a 345kV buss bar of 4 in. diameter and an unsophisticated voltage detector will not know the difference. Further, at voltages of 345kV and up intense ionization at the surface of the conductor breaks down the surrounding air thus increasing the effective electrical diameter of the conductor.

Fortunately, it is difficult to fail to recognize that a conductor is energized at a transmission voltage. Proximity to these conductors, even well outside the minimum working distance, results in tingly skin and unmistakable audible discharges. The frequent challenge at these higher voltages is to distinguish conductors energized at nominal line voltage from those that are deenergized but ungrounded. Crowded and long transmission corridors can result in substantial voltages on conductors that are not intentionally energized but are simply left ungrounded. These voltages, though well below nominal voltage, can still be lethal. Projects such as reconductoring or other line maintenance place a premium on knowing the difference between energized lines and those running parallel with resultant induced voltages.

Figure 8

Accurate measurement of electric fields in combination with intelligent compensation for the transmission voltage effects mentioned above allows not just detection of voltage but a display of the measure of the voltage. Seen in figure 8, this new ability in a tool with a single point of contact allows users to easily distinguish nominal line voltage from induced voltage and to do so on systems up to 765kV.

Electric field measurements in a device of this type undergo further digital processing to compensate for conductor diameter, local ionization and other corona effects. The displayed number gives the user far more information than voltage detection alone, does so with ease and convenience and improves safety by providing a clearer picture of the status of the circuit being tested.

Conclusion
More sophisticated electric field measurement when combined with digital processing can provide new capabilities for voltage detection and indication. More sophisticated field measurements include sensing in multiple directions, field gradient testing and compensating for geometry and other high voltage field effects. Users reap the benefits of these advances with a new generation of tools that is smaller, lighter, more accurate and easy to use.

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