POSITRON

HIGH VOLTAGE INSULATOR TESTING BASED ON ELECTRIC FIELD METHOD

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Introduction

The condition of insulators on transmission and distribution power systems is of prime importance for the successful operation of a power grid. Particularly since a damaged or electrically deficient insulator(s) can lead to costly system outages, serious injury, or loss of life.

The measured results obtained from periodic checks on insulator strings can be systematically downloaded and stored to provide a diagnostic data base. This data base can be used to determine compromised insulators or defects and may also be used to predict degradation over time based on quantifiable data collected.

This paper will also describe how the electric field measurement technique can instantly alert a user to a dangerous situation on live lines with a visual and audible alarm, a "GO/NO-GO" (safe to work on the line or not).

Long lifetime and low maintenance are generally associated with suspension insulators. However it is useful to undertake preventative maintenance steps in order to detect degraded or failed insulators before they cause significant problems. These techniques range from simple visual inspection to procedures using test equipment and have varying degrees of ease of use and reliability.

Insulator failures can be divided into three categories: surface contamination, internal leakage over time or puncture damage, and vandalism. The first is often reversible by cleaning, the second and third are permanent. Each failure mode alters the electrical behaviour of the insulators by increasing the conductivity. This allows the detection of degradation of insulators and strings by the Electric Field method. Note that in a string of porcelain insulators, the failure of a single insulator need not result in a loss of electrical integrity for the string as a whole.

Porcelain insulator strings with metal interconnects capacitively grade the Electric Field along the string. Long Composite (Polymer) insulators with fibreglass cores have current levels measured in micro amps (if in good condition) and have relatively minor effects on the grading of the nearby fields. Consequently, the Electric Field intensity is much higher on both ends of a Composite insulator in comparison with a Porcelain insulator string. Change in Electric Field distribution along an insulator has been proven to be effective in detecting degradation of all types of insulators including Porcelain and Composite insulators.

Composite Insulator Testing using the Electric Field Method

Methodology

Suspension insulators are used in overhead power transmission lines to mechanically support high voltage conductors while providing adequate insulation to withstand switching and lightning overvoltages. Since the useful service life of individual insulators is hard to predict, they must be verified periodically to insure that adequate line reliability is maintained at all times.

Over the years many testing methods have been used for this purpose, each one with its distinct advantages and disadvantages.

There is a definite need for a reliable and safe insulator testing technique:

- that would not require short-circuiting of an insulator (Buzz method),
- that would instantly alert linepersons of any conductive defect that is dangerous with an audible and visual alarm (safe or not to work on the line),
- That would be very lightweight, fast and easy to perform a scan,
- that would include automatic counting of the insulators and record the measurements and defects and their locations automatically,
- that would not rely on the human judgement of the lineperson for detection of defects,
- that would improve efficiency and productivity of linepersons and be a useful maintenance tool,
- that would be safe to operate on an energized power line,
- that could be used to obtain statistics on performance and degradation of installed Porcelain and Composite insulators.

A definite advantage of the Electric Field Measurement method is its ability to measure a value proportional to a voltage differential without the necessity to make a metallic connection to the insulator.

The insulator tester consists of a specially designed Electric Field sensor which is transversally mounted on a high impact ABS sled which is moved along the insulator by means of a hot stick. The tester includes a data logger.

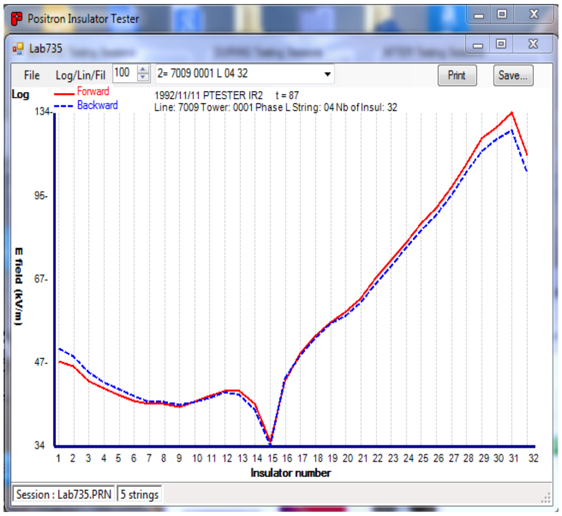
This Electric Field Measurement method can be used for Porcelain, Composite and Glass insulators.

A) Porcelain Insulator string testing

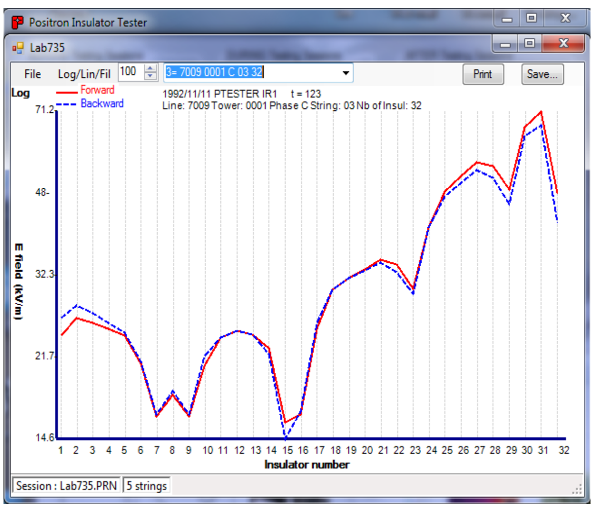
The Porcelain (or Glass) disc consists of two metallic parts (Cap and pin) insulated by a Porcelain (or Glass) material. A string of insulators consists of 3 to 35 discs. The line voltage to ground is distributed among these discs. When a Glass disc punctures, its glass portion breaks apart, making it easy to identify by visual inspection. Punctured Porcelain insulator discs cannot be identified visually. However, the voltage across the Cap and the Pin is reduced substantially. Since the Electric Field near the disc is nearly proportional to the voltage between its cap and pin, a drop on the graphic (E-field vs insulator number) will be noticeable at the location of the punctured disc.

Porcelain Insulator Tester

Electrical field measurements of a string of Porcelain insulators:



Porcelain disc #15 is punctured



Porcelain disc #7, 9, 15, 16, 23 and 29 are punctured

B) Composite Insulator Testing

Unlike the Porcelain Insulator, the Composite Insulator doesn't have metallic parts inside the insulation gap. The length of the insulation gap is equal to the length of the Composite insulator, excluding the end-fittings. Any conductive material (Carbon tracking, moisture ingress, contamination, etc.) inside the insulation gap will have an impact on the distribution of the Electric Field along the length of the insulator.

A reading of the Electric Field is taken at the edge of each shed. A single defect will usually span over more than one shed. A defect region (conductive region) can be connected or floating. Most defects are known to occur near the extremities under service conditions due to carbonization facilitated by the strong Electric Field which is present there. These defects are usually connected to the High Voltage end-fitting and grow toward the Grounded end-fitting. Conductive defects are not always visible to naked eyes and constitute the most dangerous type for proximity workers. These defects usually occur at the interface between the fiberglass rod and the covering material (Polymer). Discharges due to the Electric Field occur and carbonize the rod. This weakens the rod mechanically by burning the fibers. The carbonization also progresses gradually along the rod thus reducing the total effective insulating length of the insulator.

Composite Insulator Tester

The Composite Insulator Tester uses the same method as the Porcelain Tester, however, its sled and probe size is smaller to accommodate smaller sheds diameter than that of porcelain insulators.

The curves can be interpreted by the user downloading by Bluetooth or direct connection to a laptop PC. Automated interpretation for instantaneous danger alerting is performed by the built-in microprocessor inside the probe (GO/NO_GO feature). Deviation from a typical curve in the Electric Field distribution along the insulator is an indication of the presence of conductive material in the Composite insulator.

According to extensive activity carried out in Italy by CESI [1], "*A conservative approach can be adopted, for which insulators showing a maximum deviation lower than 10% are to be considered as defect-free, while insulators showing deviations higher than 30% should be considered as critical for a safe, reliable and prolonged service life and are to be removed from service for further, deeper checks*". This dangerous condition can be caused by a growing defect inside the insulator. It can also be caused by the presence of severe contamination.

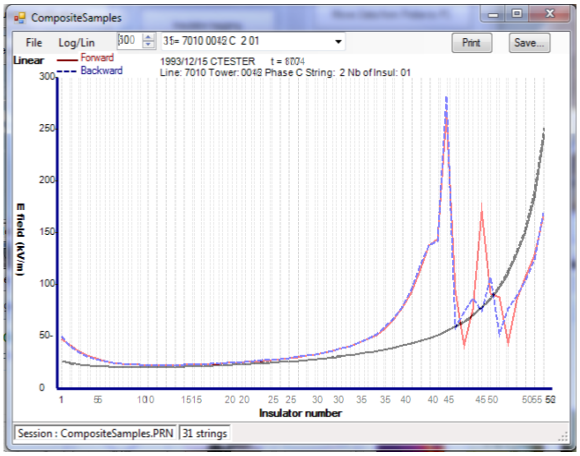
It has been proven in the laboratory [1] that defects of different nature having a length up to 25% of the insulator length are not critical for the dielectric performances of the line, with particular reference to safe live line working conditions.

Critical defects can be systematically pointed out with this method.

The sensitivity of this system is so high it will record and show the presence of minor (very short) defects in addition to critical or dangerous defects.

"On dry, and even on wet clean composite insulators, the Electric Field method provides a good estimate of the percentage of the total insulation affected by a defect or by contamination. Its use on energized lines should help to improve the safety of workers performing live line tests." [2]

Electrical field measurements of Composite insulators:



Colored curves: Dangerous insulator,
Black curve: Reference

C) Post, Bushing & Lightning Arrestor testing

The Electric Field measurement method is also used for testing many types of insulators in the field or in the laboratory. The sensor design remains the same, except that the sled is removed and replaced by an isolating ABS tab. A slight pressure is applied on the tab to trigger a reading. The insulator body can have various shapes and is not limited by the size of the tester's sled. Deviation from a typical curve constitutes the preferred interpretation technique.

Universal Tester

Conclusion

The Electric Field Distribution measurement method has a long record of reliable results and safe operation. The method can be used on many different types of insulators. Systematic investigation has been carried out focusing on its ability to point out critical defects and its sensitivity to different types of damage.

Extensive testing in electric utility high voltage labs and on live lines have been performed at voltage levels up to 1 Megavolt, with various types and numbers of insulator defects has shown that all defects are detected and recorded.

The programs and algorithms in the built-in processor enable the device to instantly and accurately report and provide an audible and visual alarm if there exists a situation (conductive defect or combination of defects) that make it dangerous for personnel to work on the live line.

In addition to preventative maintenance and defect detection, the Electric Field methodology enables this device to be used as an important safety tool.

References

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