

Early Fault Detection on Energized Substation Equipment

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SUMMARY

The electric field distribution measurement method has a long record of reliable results and safe operation. The method has been utilised on many different types of Porcelain and Composite insulators used on overhead power transmission lines up to 1 million Volts. The high sensitivity of this technique allows the early detection of all internal or external conductive defects, including floating defects on energised power network. This is the only device that can detect and record small floating defects on Composite insulators [1].

The readings from the Electric field (E-field) sensor are transmitted via a long-range Bluetooth transmitter to a touch-screen Windows Tablet for immediate interpretation. In addition to preventive maintenance and defect detection, the instantaneous graphical display of the E-field enables its use as an important safety tool.

The built-in historical data storage of the system is used to evaluate the degradation over time and to optimise the testing interval based on quantifiable data collected.

The same technology is now being used in substations for the early detection of defects in various Porcelain and Composite insulators such as Potential Transformer (PT), Current Transformer (CT), breakers and transformer bushings, cable termination, surge arrestors, etc. Deviation from a typical curve in the E-field distribution along the insulator is an indication of the presence of conductive material in the insulator. Part of the complexity of the design was dealing with all of the various shapes and sizes. The bushings may be cylindrical, conical or various other shapes.

For safety reason, there is no metallic or electrical contact with the insulator.

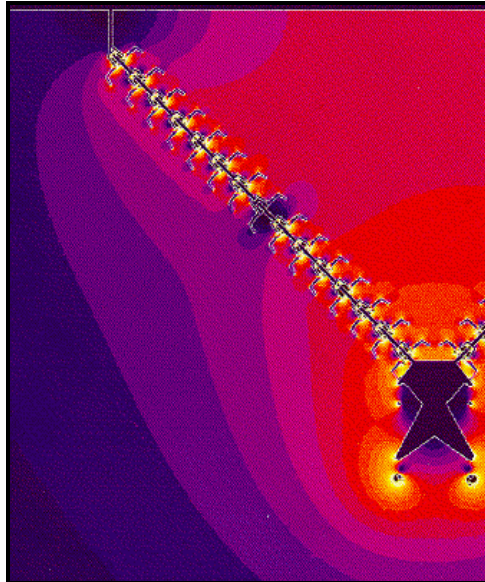
Various graphics of insulators found in a substation will be presented in this paper.

KEYWORDS

Diagnostics, Substation, Insulators, Bushings, Electric Field, Live Line Work, Safety, Contamination

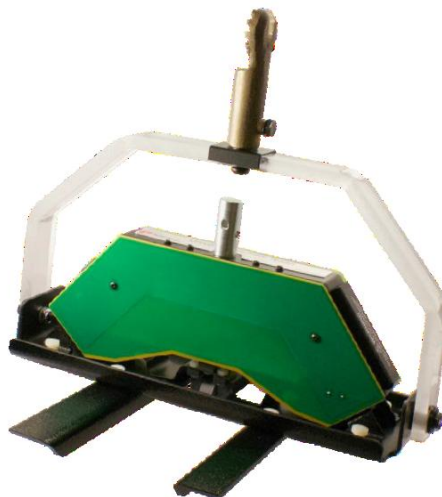
THE ELECTRIC FIELD METHOD

The equipment measures the AC electric field surrounding Porcelain and Composite insulators. The field is proportional to the voltage differential at any location along an insulator and drops at the location of a conductive defect. The electric field is read on each disc or skirt and stored in a database.



E-field computer simulation

THE ELECTRIC FIELD MEASUREMENT EQUIPMENT

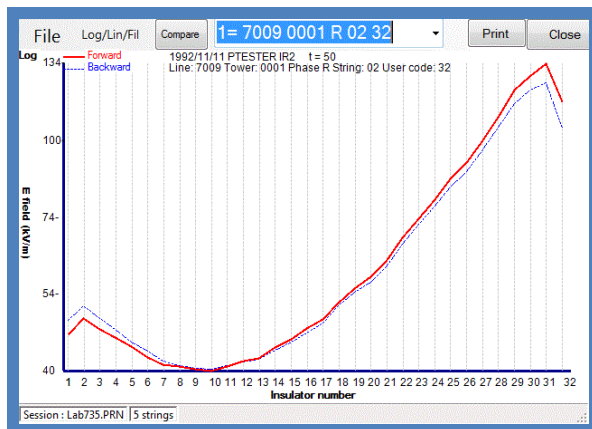


GRAPHICS INTERPRETATION

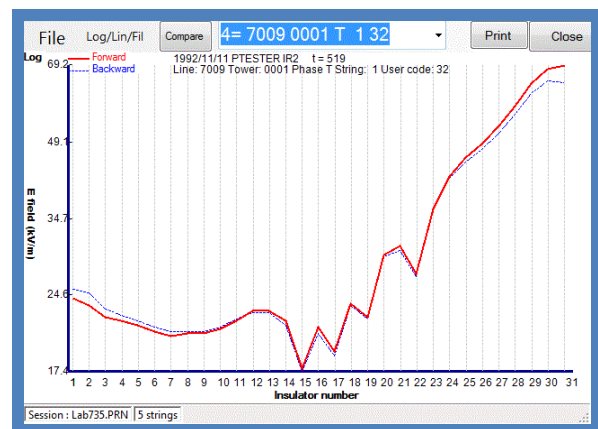
The reference U-shaped curve of the E-field is always the same in the case of insulators used on high voltage overhead transmission lines. A defect causes a discontinuity to the smoothness of the curve. In the case of insulators used in a substation, each type of apparatus has its own curve's shape (signature). The interpretation of the graphics consists in simply comparing the signatures obtained from all three phases of a given apparatus.

A) Overhead transmission line

The following pictures are typical graphics of **Porcelain insulator strings** used on a 735 kV overhead transmission line:

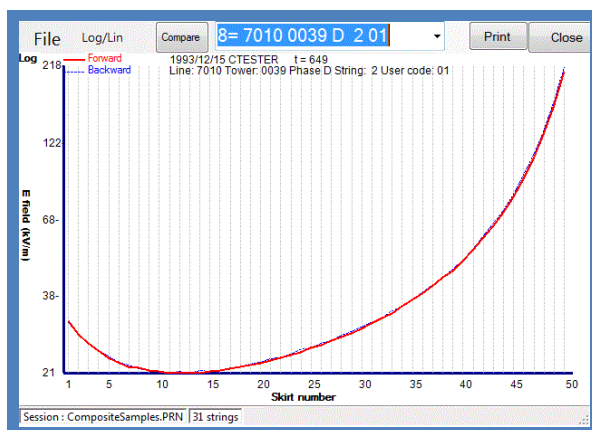


Good Porcelain insulator string

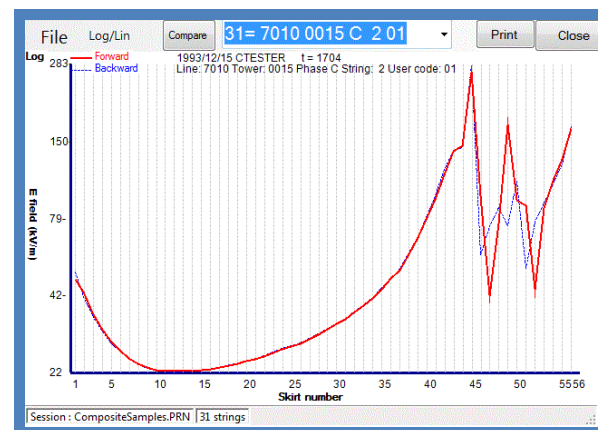


4 bad discs found in this string

The following pictures are typical graphics of **Composite insulators** used on a 735 kV overhead transmission line:



Good Composite insulator



Dangerous Composite insulator

B) Substation

Unlike the overhead transmission line application, in a substation, the shape of the curves (signature) depends on the apparatus being tested. In this case, the interpretation of the graphics consists in looking for a deviation from a reference signature or simply comparing the signatures obtained from all three phases of a given apparatus. The phase comparison constitutes the preferred interpretation technique.

Internal defects include carbon tracking, moisture ingress inside hollow posts, shorted grading capacitors inside bushings, leaking discs inside surge arresters, etc. A very small mechanical defect such as a crack or a leaking gasket may cause the moisture to get inside Potential Transformer (PT) or Current Transformer (CT) post and breaker hollow post. The E-field signature will be affected because the moisture deposited on the internal surface is conductive.

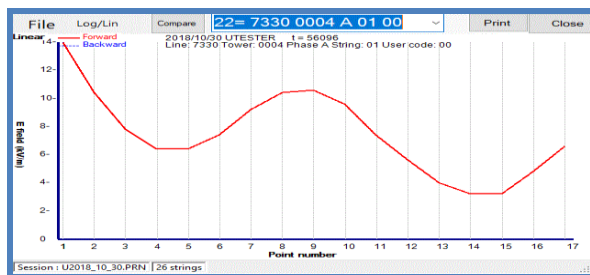
The material may be composite or ceramic. One testing device will work on all bushings of power transformers, PT, CT, circuit breakers, lightning arrestors, coupling capacitors, polymeric posts, cable terminations, ceramic hollow posts, etc.

The pictures on the next pages show various insulators found in a substation and their associated graphics.

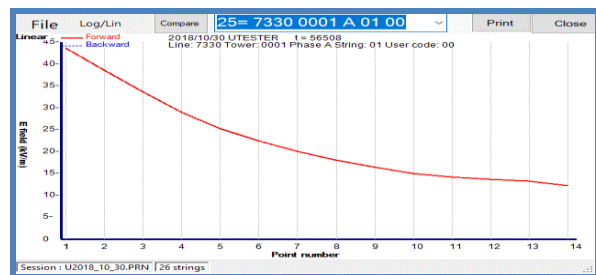


115 kV Oil Breakers in open circuit position

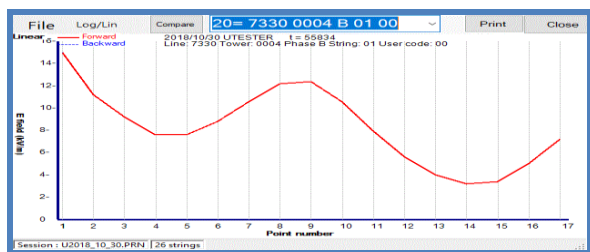
The three breakers consist of 2 sections: An upper section and a lower section. Each section has been scanned separately and a graphic has been produced for each section.



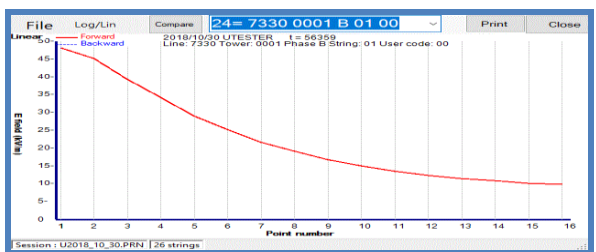
Phase A, upper section



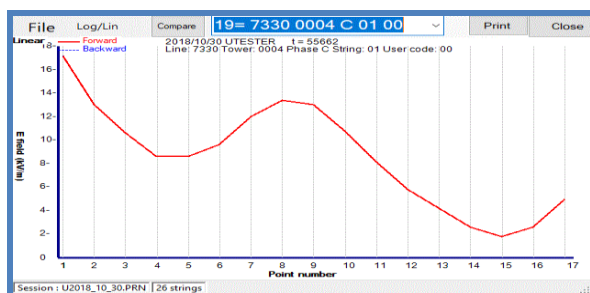
Phase A, lower section



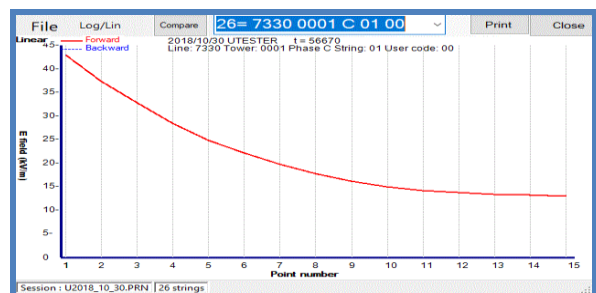
Phase B, upper section



Phase B, lower section



Phase C, upper section



Phase C, lower section

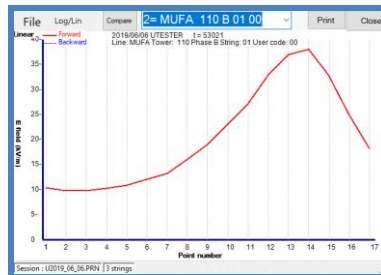
The graphics of phases A, B and C are identical. Consequently, all three oil breaker posts are good. If the graphic of one phase would have been different than the other phases, then the insulator on this phase would be defective.



110 kV Cable Terminations



Phase C



Phase B



Phase A

The three signatures of the three cable terminations are identical. Consequently, all three cable terminations are good.

Note: The signatures on the next page and the signatures on this page are different because the cable terminations come from a different manufacturer.



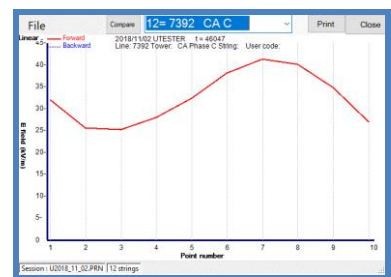
115 kV Cable Terminations



Phase A



Phase B



Phase C

The three signatures of the three cable terminations are identical. Consequently, all three cable terminations are good.

Note: The signatures on the previous page and the signatures on this page are different because the cable terminations come from a different manufacturer.



110 kV Surge Arresters



Phase R



Phase W

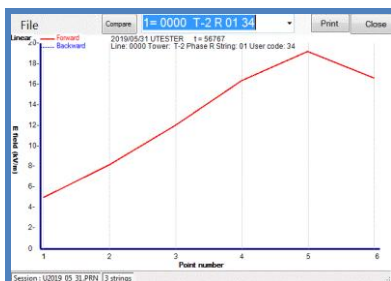


Phase B

The three signatures of the surge arresters are identical. Consequently, all three surge arresters are good.



34.5 kV Transformer Bushing



Phase R



Phase Y



Phase B

The three signatures of the transformer bushings are identical. Consequently, all three transformer bushings are good.



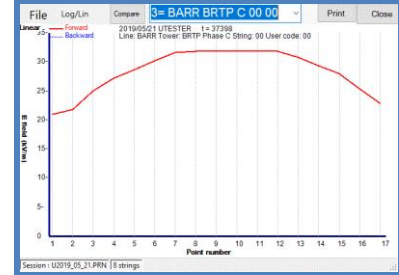
115 kV Potential Transformer (PT)



Phase A



Phase B

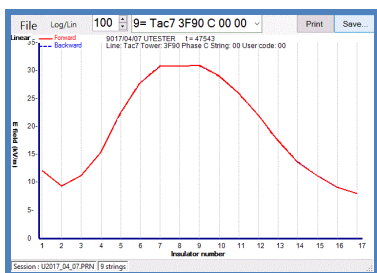


Phase C

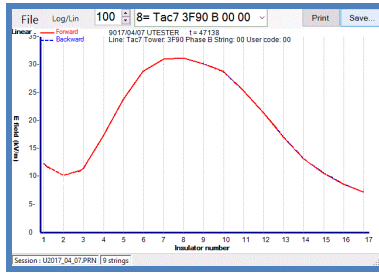
The three signatures of the Potential Transformers (PT) are identical. Consequently, all three PT bushings are good.



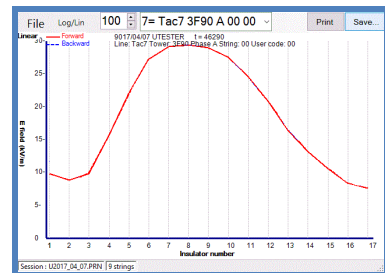
115 kV Current Transformer (CT)



Phase C



Phase B



Phase A

The three signatures of the Current Transformers (CT) are identical. Consequently, all three CT bushings are good.

CONCLUSION

Based on the above graphics, we can conclude the following:

- The graphics from the three phases of a given apparatus are repeatable and can be easily compared to identify defects
- The signatures for a given apparatus may be different depending on the manufacturer
- There is no need to disconnect power to diagnose a substation apparatus
- An insulator takes less than 30 seconds to scan by a light tool attached to a standard hot stick
- The tested insulators may have any shapes and sizes
- The data is stored for future reference

The high sensitivity of this testing technology allows the detection of small faults before it becomes too dangerous. This is the only method that can detect floating defects and small defects. The tester is completely safe to use and makes no electrical/metallic contact with the insulators. It is not sensitive to sound, wind, light or temperature. It is reliable and immediately alerts workers of a dangerous situation.

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