Electric Field Distribution, Failure Detection, Maintenance and Safety Related To Porcelain Insulators

Figure 1 below shows the concept of how the electric field varies around a porcelain insulator string. It is important to note that the electric field completely surrounds the insulator. The Positron electric field sensor on Positron's high voltage live line testers detects a variation in the electric field. This variation is detectable from any position around the circumference of the insulator.

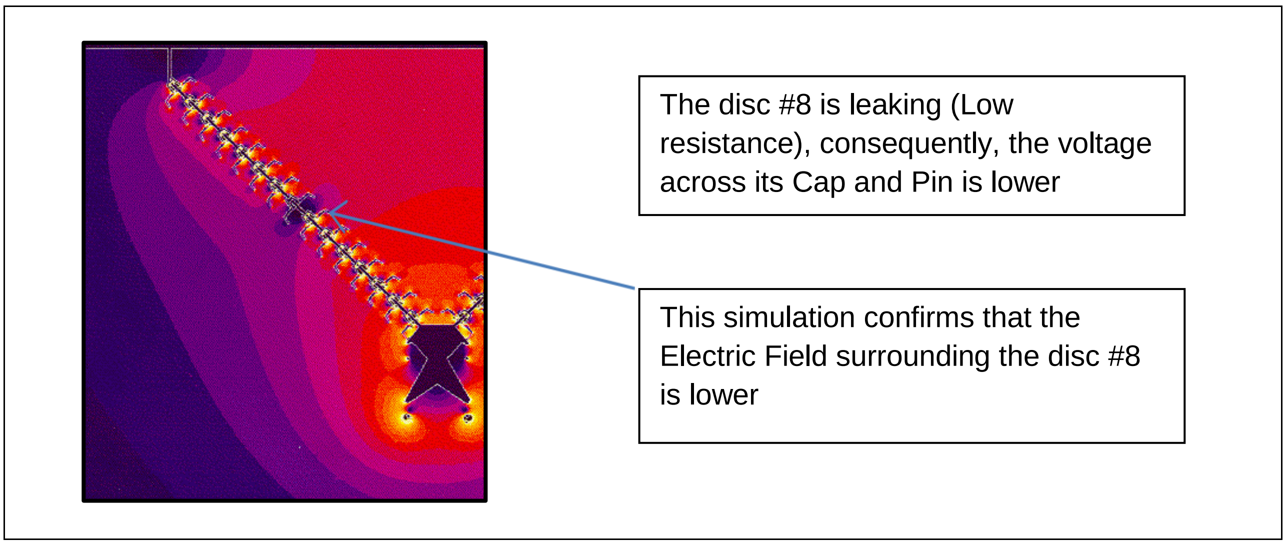


Figure 1: Electric Field Distribution

A conductive defect reduces the voltage between the cap and the pin of the insulator disc. This in turn reduces the electric filed surrounding the insulator disc. This is illustrated in the first slide which shows the location of a defective disc.

The Positron insulator tester does not make any electrical contact with the insulators, does not influence the electric field and is safe to use.

Figures 2 and 3 below show the typical construction of a ceramic insulator. The voltage exists between the Socket cap and the Pin of each porcelain insulator. Every porcelain insulator has a porcelain shell and cement between the cap and the pin. In typical failures that occur naturally, the primary failure is degradation of the cement. After a period of time, and expansion and contraction due to temperature changes, overvoltage exposures and mechanical tension, changes of the insulator string, cracks, pinholes or fissures occur in the porcelain shell. Water or humidity can penetrate these fissures and accelerate the deterioration.

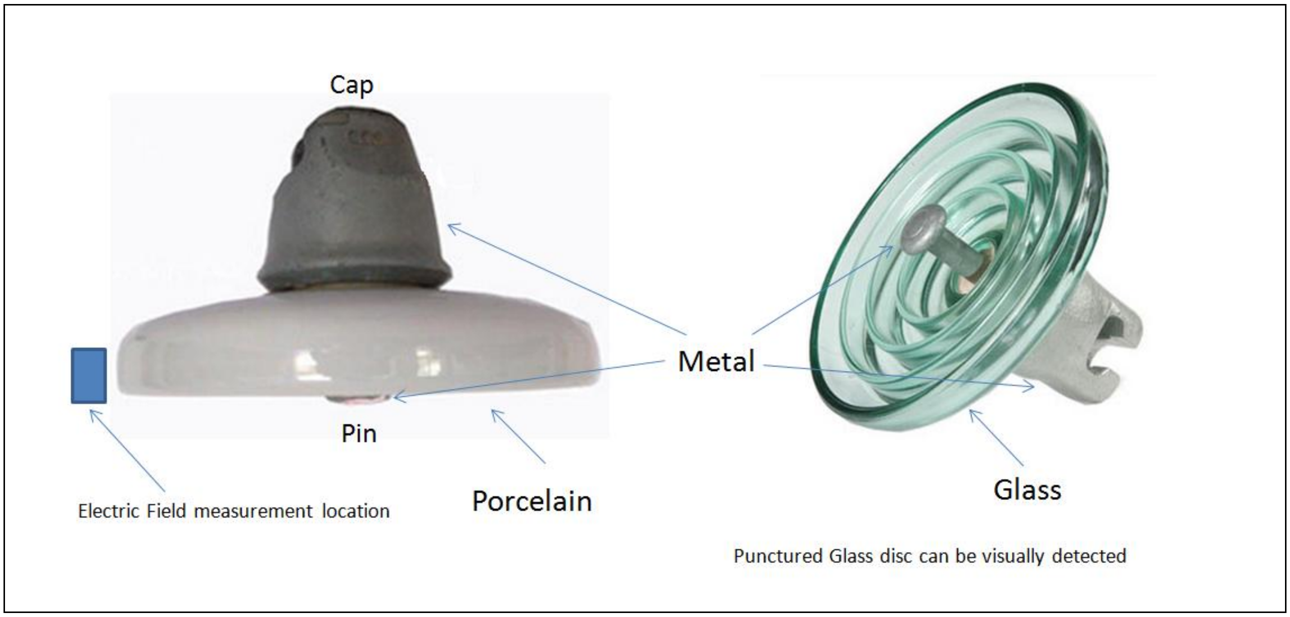


Figure 2: Porcelain & Glass Insulator

Once deterioration starts, it continues more rapidly. This decreases the effective gap between the pin and the cap. The leakage current increases over time until total failure of the insulator disc occur. Early detection prevents failures. It is highly recommended to change defective discs as soon as possible.

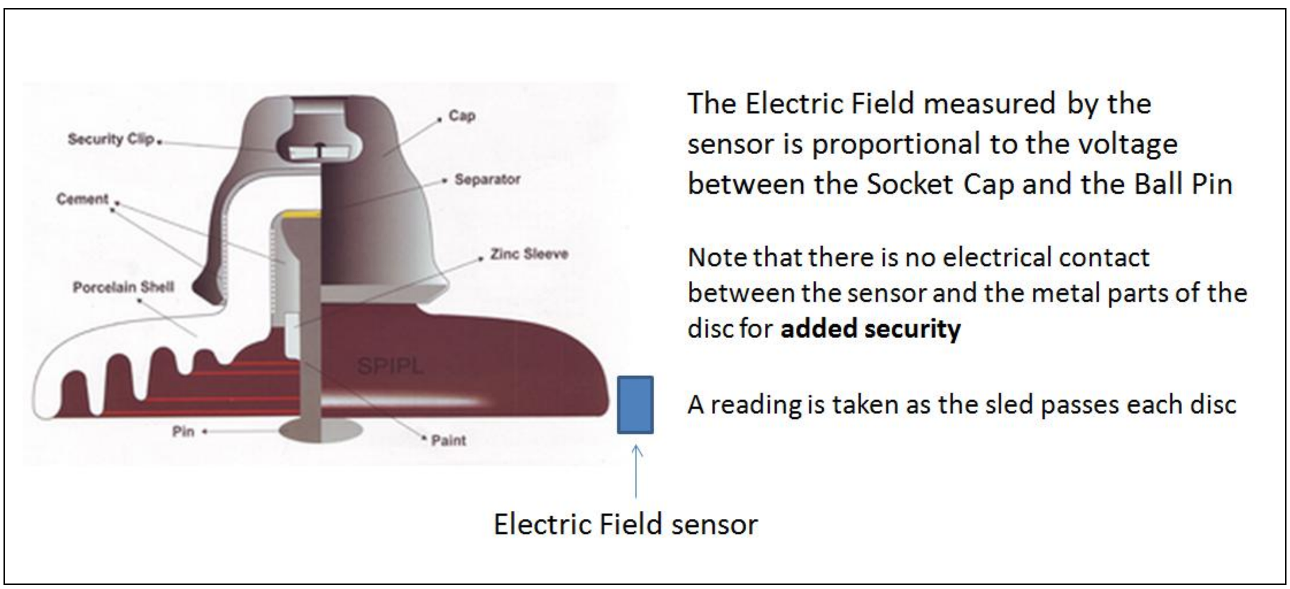


Figure 3: Electric Field Measurement

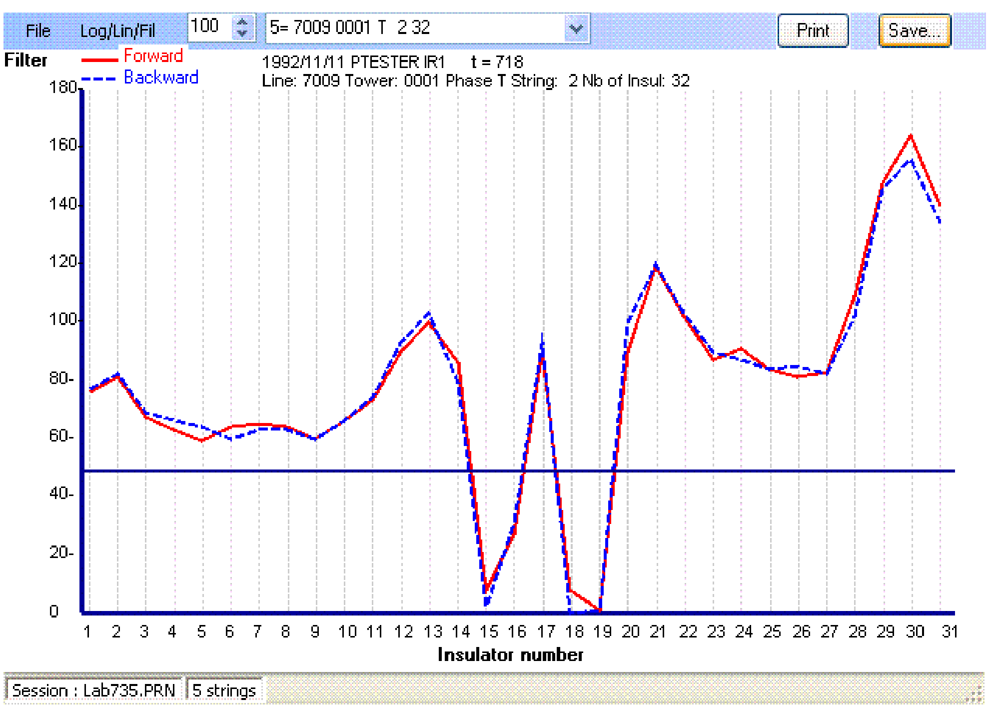
Positron's testers allow these defects to be instantly detected. The electric utility has the choice of immediately changing the defective insulator on the spot to save a costly extra truck roll (the cost of the time of the truck use and several men) and/or, the results can be stored and downloaded later for future analysis and scheduling of maintenance trips.

Positron's testers are early-detection instruments. A very small reduction or breakdown of insulation (1% voltage drop across a disc) will be detected and visible on the graphic display on a PC. All the results of the testing are downloaded to easily retrievable tables. This also allows the utility to evaluate deterioration over time. Some regions may be more susceptible to faster deterioration of insulators than others.

The "degree of defect" is clearly visible in the graph. One can see both small defects and major defects. The degree of defect is readily seen by the amplitude of the dip in the curve. (See graph 1).

The IEEE standards consider a porcelain insulator to be "shorted" if the insulator has 25% or less of the voltage across it between the pin and the cap compared to normal healthy insulator discs. Positron has conducted many tests with hundreds of defective strings working closely with Hydro Quebec. After years of work and scans we established the setting of this threshold using the electric field method. The Positron testers are shipped with the software factory set at this value. This threshold level is seen as a horizontal line on the graph (See graph1). Dips in the curve associated with specific insulator discs that dip below this line are readily seen. This does not mean that one should wait until the defect is severe before changing the insulator disc.

Graph 1 represents an example of the graphics produced by the Positron tester on the PC screen, which allows evaluation of the degree of defect on Porcelain discs. (Note: the red curve is the forward scan of the insulator string and the blue curve is the backward scan using Positron's tester. Although only one scan is necessary, the fact that both scans align with each other demonstrated that the scan was properly done.)



Graph 1: Discs #15, 16, 18 and 19 are below the blue line and are defective.

The rate of deterioration of porcelain insulators may vary from manufacturer to manufacturer and is also impacted by humidity, temperature conditions, pollution and mechanical tension in the insulator string, overvoltage occurrences (p.u. exposures) and the stresses it was subjected to. There is no published data on rates of deterioration.

Another important factor to safety and continuous operation is the number of defective discs in a porcelain string. The greater the number of defective discs, the greater is the danger of a catastrophic failure, loss of service, and danger to personnel. The smaller the number of insulator discs in a string, the greater the impact and danger of defective discs because failed discs would constitute a greater percentage of the length of the string.

We have attached a copy of an IEEE paper (IEEE Transactions on Power Delivery, Vol. 17, No. 3, July 2002) on the Minimum Number of Good (Healthy) Porcelain (or Glass) Insulators in a String For Live Line Work.

This document is based on the fact that live working should be performed under the following conditions:

- No rain conditions
- No lightning in the work area
- Circuit breaker re-closing equipment is disabled.
- (It is safe to work in humid conditions.)

Note: A disc is considered dangerously defective if the insulation of the insulator disc has deteriorated to 25% of the original dielectric strength. (i.e., the degree of the defect is such that the voltage between the pin and the cap of the insulator is 25% of the voltage that would appear on a good (healthy) insulator.

This document states that the minimum number of good discs in a string for safe operation is a function of:

- The number of discs in the string
- Size of discs (146 mm X 254 mm is used as the base)
- Location of defective discs in the string
- Altitude
- Maximum anticipated overvoltage as per installed surge arresters and protective air gaps on the power line
- Transient overvoltage wave shape
- Contamination

The maximum anticipated overvoltage depends on the installed overvoltage control devices. It is expressed in terms of p.u. The p.u. is the nominal voltage of the line. For example a p.u. of 2 means that the voltage on the line may reach 200% of the nominal voltage in a worst case condition. Typically p.u. varies from 1.7 to 3 p.u. depending on the installed overvoltage control devices.

A table is given and values are a function of:

- Maximum System Voltage (from 121 kV to 800 kV, phase to phase)
- Number of insulators (from 7 to 34)
- Maximum of anticipated voltage rise (from 1.7 p.u. to 3.0 p.u.)

Typically the number of defective porcelain insulators on a string for safe live line work is established by the number of insulators, the brand of insulator, the voltage on the line, the number of insulators and the size of the insulators. The safe acceptable percentage of defective discs in a string varies from utility to utility.

For preventative maintenance, Positron recommends the replacement of all defective discs even if the insulator string is still considered safe. This can be done on live lines before they become dangerous to work on.

SAFETY: Positron has incorporated an "instant reporting" feature with its software algorithms and internal microprocessor to determine the number of defective porcelain insulators (that do not meet the threshold) to immediately alert the user with a red flashing light on the tester which reports the number of defective insulators. No human judgement or PC is needed. The information is immediately available.

FREQUENCY OF INSULATOR TESTING FOR MAINTENANCE PURPOSES:

There is no established standard for determining the rate of decay of a porcelain insulator. The Positron insulator tester can determine the degree of defect in each porcelain insulator disc using the electric field measuring and detecting technique. This information can be used to see the amount of degradation and therefore which insulators require attention. It can also help the utility to monitor degradation and establish its own standards for preventative maintenance.

Obviously if a line has frequent tripping, breakdowns or faults reported, those lines should receive priority and more frequent attention. The same should also apply to transmission lines from major power stations or important establishments of national importance, large cities and important industrial pockets.

Frequency of testing is also impacted by the quality of insulators, the proper tension in insulator strings, for installations more than 5 years old and a greater frequency in areas where there is poor tower earthing (grounding).

Typically if the insulators are of good quality and conditions are good, testing is done at 5 year intervals. This interval should be much less in areas where troubles frequently occur, for critical infrastructure areas and on towers which have porcelain insulators which have been detected and recorded to have defects by Positron's testers. In such cases, intervals have occasionally been as short as 6-12 months.