Defects in Nonceramic Insulators: Can They be Detected in a Timely Manner?

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Abstract: This paper is a continuation of the work reported during the 2004 Daycor users meeting. The electric field measurement method has been explored to determine its potential for timely detection of defects in nonceramic insulators. Various types of defects were simulated and the external electric field was computed. It is shown that the electric field method used presently is not sensitive enough to permit early detection of defective. There is a need for an improved method, perhaps periodic corona inspection could be the answer.

Introduction: There are a multitude of designs, materials, formulations, and manufacturing processes that are used presently for nonceramic insulators. While this beneficial in terms of offering choices for the users, this also means that in case of problems, failure patterns could be different. It is fairly well known that most problems in NCI result originate from interfaces. The critical interfaces in this type of insulator are between the rod and housing, between hardware-rod-housing and different sheds of housing if unit is not manufactured in a single piece.

Fig.1: NCI Line Post that was removed from service in Southern USA

The presence of corona at the interfaces leads to sheath damage exposing the fiberglass rod, tracking the rod, thereby leading to insulator failure through interfacial flashover, rod burning and brittle fracture. Also, the presence of any contamination like water, salts, and dirt can intensify the field at those locations. Fig. 1 shows a picture of a failed NCI. It can be seen that the first few sheds have suffered corona cutting. Some degradation in the form of tracking and erosion is also visible. If the damage to the insulator is not in the line of sight, then this may not be identified as a problem during routine line inspection by road or helicopter patrols until the unit fails. The challenge is to identify such insulators at an early stage of degradation whe n there is still time to act.

Understanding the electric field distribution plays a vital role in insulator design and also can be useful for detecting internal defects. In ceramic insulators the voltage distribution is relatively more linear due to the presence of intermediate metal parts. The material does not degrade with corona, hence corona is not usually a problem in ceramic insulators. However in NCI's the voltage distribution is highly non-uniform as shown in Fig. 2, and can give rise to corona. Corona rings are normally used for NCI at voltages above 230 kV in order to reduce the electric field near the line end.

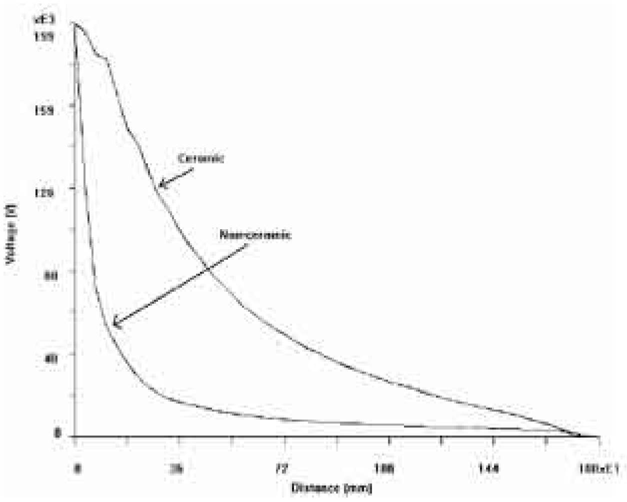

Fig.2: Significant difference in the voltage distribution exists between ceramic and NCI due to differences in construction. The insulator modeled is a 345 kV insulator

There have been several recent publications that concluded that there is no fool-proof method for early detection of defects in nonceramic insulators. Among the methods examined were partial discharge detection, infrared thermography, corona and audible noise detection, leakage current measurement and electric field measurement [1]. In the utility environment the electric field technique is being increasingly used as a diagnostic tool to ident ify defective porcelain units [2, 3]. Their use on nonceramic insulators appears to be the logical step. What types and degrees off defects can be detected by such a measurement? This study was undertaken to answer this question. The electric field distribution of a healthy insulator was taken as the reference.

Types of Defects Modeled: Several types of defects that can occur on a NCI were modeled. The various types of defects that are considered difficult to detect but critical are incorporated on to the healthy model and simulated. The size, position and conductivity of such defects are varied. The field values for locations close to the defect along the path of the probe are noted down. These values are then compared with the values obtained in the healthy cases. The presently used electric field probes are sensitive for field values above 2 kV/m [2]. Hence defects that produce a difference of 2 kV/m and above are considered detectable while others were considered undetectable. The differences in field values thus obtained are plotted as a function of the shed number. A logarithmic trend line is fitted to the above plot for a better perception of the defect detection possibilities.

Various types of defects such as those occurring on the shed, shank, interface, external tracks from end fittings and tracks occurring on the rod sheath interface were considered. Most of the external defects could be observed during careful visual inspection. However, defects that occur inside the housing are not visible. Hence such defects are modeled for electric field distortion studies to verify the possibility of detecting such defects using field probes as shown in Table 1. A defect that occurs for the distance between any two consecutive sheds is named as the single shed defect. A single shed defect will have the shape of a cylinder with a 9.2 cm height and 5 mm diameter. A diagrammatic representation of various types of single shed defects modeled is as shown in Fig. 3. Similarly two-shed and three shed defects are simulated and analyzed. Table 1: Various Defects Modeled in Non-Ceramic Insulators

Defect Type	Description
Single shed defect	Fully conductive defect at rod sheath interface
	100 mS/m conductive water defect at rod sheath interface

	Air void defect at rod sheath interface
Two shed defect	Fully conductive defect at rod sheath interface 100 mS/m conductive water defect at rod sheath interface Air void defect at rod sheath interface
Three shed defect	Fully conductive defect at rod sheath interface 100 mS/m conductive water defect at rod sheath interface Air void defect at rod sheath interface

Table 1: Various Defects Modeled in Non-Ceramic Insulators

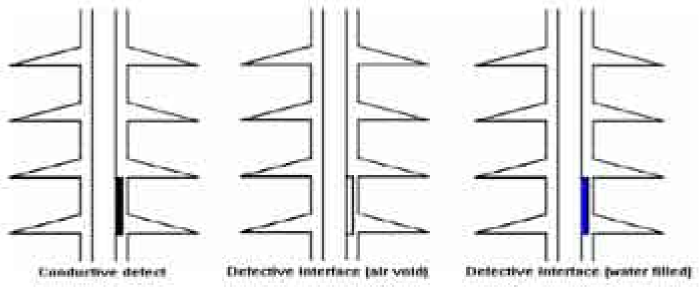

Fig.3: Diagrammatic representations of various types of defects modeled. A defect of 1 shed spacing is taken as the minimum length of the defect. The length of the defects were increased
to span 2 and 3 sheds

The field calculations are performed on the insulator along the axis as indicated by the path AB in Fig. 4. A distance of 2mm is assumed for the air gap in order to slide the probe on the insulator. The values obtained are compared with that of a healthy insulator and the change in field value is plotted against the shed number. The data for a defect of lengths equal to 1 shed spacing and 2 shed spacing are shown in Figs. 5 and 6.

It can be seen that the possibility of detecting defects in close proximity to the HV electrode is good, irrespective of the defect type. However, should the location be towards the middle of the insulator or towards the ground end, their chances of being detected is small or zero.

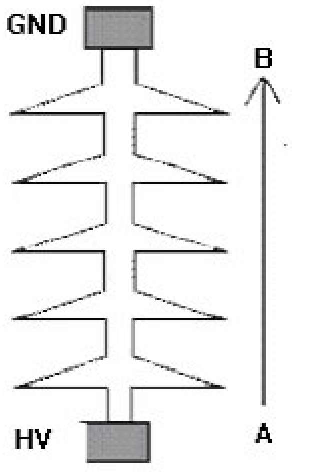

Fig.4: Measurement along insulator surface from location A to B. The line AB is about 2 mm away from the tip of the shed to permit probe movement

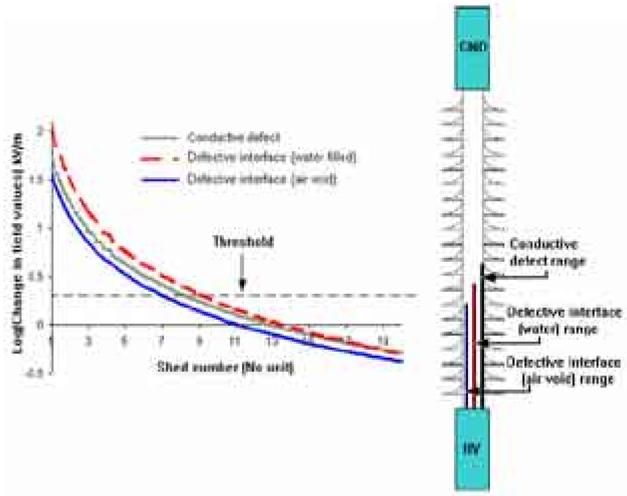

Fig.5: Range of detectability for defects that of length= 1 X shed spacing. Probe is assumed to me in the axial direction AB

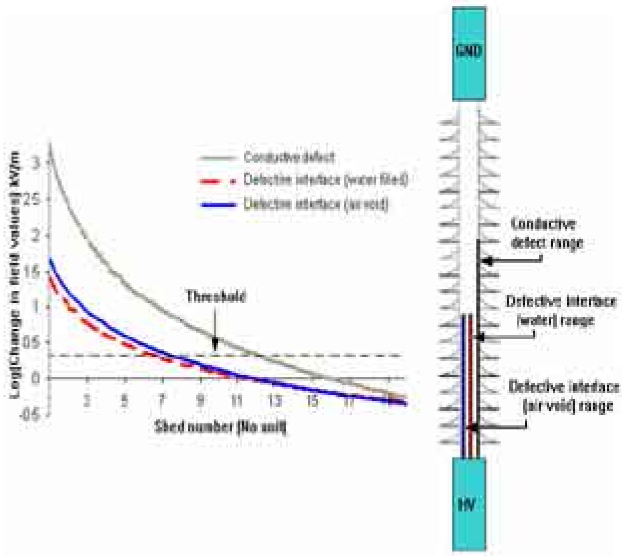

Fig. 6: Range of detectability for defects that of length= 2Xshed spacing. Probe is assumed to me in the axial direction AB

It is clear that in order to be able to detect any defect it is important to get as close as possible to the origin of the defect. As an illustration if it were to be possible to measure the electric field at the point C, Fig. 7, (2 mm away from the shank) then as is shown in Fig. 8, most defects can be detected irrespective of their location along the insulator. Can this be achieved in practice is a good question.

It is likely that corona cuts or any other deformities in the insulator will give rise to corona, especially under humid conditions. The work reported last year showed that a combination of location specifics and quantitative data like brightness can provide useful information on making decisions such as problematic corona or nonproblematic corona. This should be explored further.

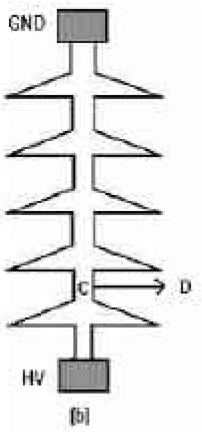

Fig.7: Measurement in radial direction from C to D. The point C is about 2 mm away from the sheath

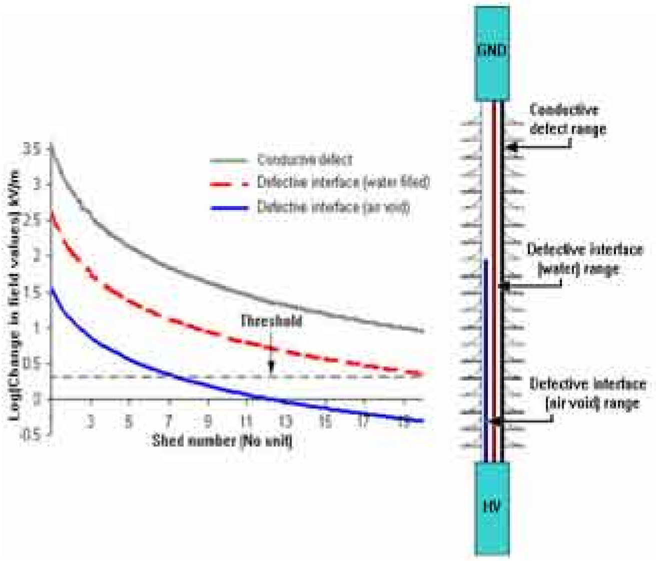

Fig.8: Range of detectability for defects that of length= 1 X shed spacing. Probe is assumed to me in the radial direction and is closest to point C

Conclusions:

The defect detection is position dependant and has the best possibility of being detected if it is closer to the high voltage electrode.

Larger and longer defects produce higher field changes hence they are more easily detected than the smaller ones.

The change in field value observed depends on the type of the defect. More conductive the defect is, greater is the possibility of detecting it.

The range of the field probe can be greatly enhanced if measurements are taken radially instead of conventional axial measurements.

References:

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