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DIAGNOSTIC OF NON-CERAMIC INSULATORS AGED IN A SALT FOG CHAMBER BY USING ELECTRIC FIELD SENSOR

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Abstract: The objective of this paper is to validate the electric field measurement technique for the diagnosis of non-ceramic insulators (NCI). To validate this technique, fifteen NCI were aged in a salt fog chamber by applying non-standard methods. Before ageing the NCI, the electric field distribution along each insulator was measured (sound field curve). When an insulator flashed over during the ageing test, the insulator was removed from the salt fog chamber and its electric field distribution was again measured (aged field curve). All the insulators that flashed over had visible defects and showed an electric field distribution different to that initially obtained. The comparison between the sound field and aged field curves for these insulators validated the location of the defects along the insulator. On the other hand, the electric field distribution measured on insulators which had no visible defects was similar to that initially obtained. This means that for these cases the flashover was only caused by the pollution phenomenon, and not by any defect. Furthermore, the electric field distribution measurements on all the insulators at the middle and at the end of the ageing test were performed, in order to mainly determine if some internal defect in the insulators, without visible defects, had occurred. According to the results, no-defects were found in the insulators without visible defects, being as those aged field curves equalized their sound field curves. It is concluded that this diagnostic technique may be used in service to evaluate the performance of non-ceramic insulators if the measurement methodology is systematically applied and the electric field detector is used in a proper way. The insulators that did not suffer damage during the ageing test show a good correspondence between the electric field curves measured before and after ageing.

INTRODUCTION

The main components whose deterioration could interrupt transmission line operation and to which can be applied on-line diagnostics, are conductors and insulators. The techniques used to detect damage in these components can be divided into three groups [1]: Optical, acoustic and electrical techniques. Electric techniques are the leakage current measurement and the electric field measurement along the insulator. By using electric field measurement, the defect is located where the typical electric field distribution changes in a way more or less abrupt.

Diagnostic techniques for non-ceramic insulators (NCI).

To determine ageing in NCI, simple and complicated techniques are used. A simple technique is the visual aid by using either binoculars or hydophobic visual observations [2]. A complicated technique is the measurement of the contact angle [3], which is difficult to apply in field. Other techniques used are the infrared thermography [4], the electric field distribution [5], the daylight corona discharge imager [6], the leakage current measurement [7] and the partial discharge measurements (PD).

In Mexico, as a test plan, NCI having different designs have been installed on several transmission lines of 115 kV, 230 kV and 400 kV. On some insulators, their leakage current is being monitored by a leakage current system developed in Mexico [8]. This is in order to apply the electric field technique in evaluating the state of the insulators and determine whether there is or not a relationship with the leakage current and the insulator ageing. To achieve this purpose the study developed is presented in this paper.

Test Method

Fifteen NCI from different manufacturers were aged in a salt fog chamber by applying both non-standard methods as well as the standard solid layer method [9]. First, the electric field distribution along each insulator to be aged in the fog chamber was measured, obtaining an average electric field curve for each insulator (sound field curve). Second, some NCI were polluted with different pollutants by the solid layer method, and then, the ageing test started. During the ageing test, the insulators were visually inspected. When damage was observed on the insulator surface and such damage caused three times a flashover on the insulator, the insulator was removed from test and left about 24 hours its surface to dry. The next step was to measure the electric field distribution on a damaged insulator and also to compare the field curve scanned with its sound field curve.

The device used to measure the electric field distribution along the insulators evaluated was developed by Hydro-Quebec (IREQ) [10] and at present is manufactured by the Positron Industries Inc.

The sensor installation should be mounted on a strong mechanical base, the conditions of the distance of the insulator-sensor and the sweeping velocity of the sensor are always repetitive; another condition is to have approximately an equal relative humidity for each measurement (lower than 80%). To obtain a graph, 5 tests on each sample were done and the average of the 5 sets of readings obtained are plotted. Besides the standard deviation for the 5 readings at each shed was calculated, being in most cases standard deviations smaller than 2%. Of the total readings performed for all the insulator sheds, 8.35% of all the readings had a greater...
standard deviation than 2% for which the repetitive of the method is right. Normally, in the readings having greater standard deviation involved the hot line sheds.

As in the circuit shows, the insulator is placed in a vertical position, at the lower sheds the connector of high tension is found, while the upper sheds are located at the ground. The UFP (universal field probe) is connected to a pole, which is installed in a manual mechanical crane (Fig. 1).

The sweeping of the insulator was done downward (side ground to hot side). The UFP takes a reading each time that the shed blocks the infrared rays (Fig. 2) for this reason the file should have equal number of data points as sheds. However, some insulators have alternate sheds (normally of two different sizes) and the UFP only records the value corresponding to the large shed leaving without recording all small sheds.

In agreement with theoretical analysis and calculations carried out using computer, the electric field distribution along an insulator has the form of "U" [11] the values of the electric field intensity in the final part of the curve are greater than the middle part.

**RESULTS**

During the test four insulators failed: The insulator # 2 contaminated with kaolin, the insulator # 0 contaminated with fertilizer, the insulator # 12 clean (without contaminant) and finally the insulator # 14 clean (without contaminant); at 1430, 1590, 2165 and 2464 hours respectively.

The electric distribution of field was measured energizing the insulators to 65 kVac five times. The curve A corresponds to new insulators (initial condition). The curve B corresponds to the electric field after 1670 hours ageing and the curve C corresponds to the test ending at 3277 hours (final condition).

**Insulators damaged during test.**

1) **Insulator # 2 contaminated with kaolin**

The Fig. 3 shows the electric field distribution and insulator physical condition when it failed during test (at 1430 hours). In curve B some variations are observed from shed 1 until shed 15. At this length, the insulator shows tracking formation and cracks in two insulator zones. One from shed 1 until shed 9 and another from shed 12 until shed 15. This damage corresponds with the electric field curves obtained.

This insulator after the fault occurred was not returned to the salt fog chamber. The curve C was recorded ending the evaluation the same for failed insulators as well as insulators that remained until the end of the test. In this curve, a similar behavior is observed when the insulator was removed by fault.

2) **Insulator # 0 contaminated with fertilizer**

This insulator failed and was removed from the salt fog chamber at 1590 hours. The electric field curves B and C...
show a deformation among sheds 6 and 12, in this section, besides erosion and chalking, the insulator shows large formations of tracking and cracks involving the rod and the sheds. Like insulator # 2, this unit did not return to the chamber and the curve C was also taken to the end of the test. Curve C shows a similar behavior to that of curve B.

3) Insulator # 12 clean
The insulator # 12 was aged previously in another test and until this time, the insulator had tracking (13 cm of length), which at the present evaluation was deepened and extended to 14.3 mm. This insulator was removed from the salt fog chamber after 2165 hours of test when it had accumulated 3 flashovers. The electric field distribution and the physical condition of the insulator are shown in figure 5. The UFP does not register the electric field when the insulator has alternate sheds, since the infrared sensor detects during sweeping the presence of the sheds. If they are of different diameter, the small ones are not detected.

Figure 5 - Electric field distribution and physical condition of insulator # 12.

The tracking among sheds 7 and 9 could not be detected in the electric field distribution curve, since the most severe damage was found in shed 8 and that is a smaller shed than the sheds 7 and 9.

The recommendation is to have provision that the UFP registers for each shed. In this case, the electric field curves would indicate that there was not any damage, because there is not a great variation among the curves A, B and C.

4) Insulator # 14 clean
This insulator was the fourth that failed. Its duration inside the chamber was 2464 hours. The electric field distribution along this insulator is shown in figure 6. For this insulator the variation of the electric field due to the damage suffered is very clear (curve C). Physically, it represents degradation by tracking with formation of cracks involving the rod and the sheds; the depth of the cracks propagate until the glass fibre bar.

The damaged zone is found among sheds 10 and 19 with a total length of 46.5 cm. In the graph a variation in the electric field is shown starting from shed 10, which is in agreement with the visual inspection. The maximum electric field maximum point was displaced until shed 13 due to damage that there was between this and the hot line side forming a conductive medium.

Figure 6 - Electric field distribution and physical condition of insulator # 14.

Insulators not damaged during the evaluation

1) Insulator # 1 contaminated with fertilizer.
The electric field distribution curve of this insulator is shown in figure 7. The three curves present the same behavior (the "U" shape), except at the end of the graph B where is observed a decrease in the electric field magnitude in shed 19, however, physically no abnormality was seen near this shed.

Figure 7 - Electric field distribution of insulator # 1.

2) Insulator # 3 clean.
This insulator and insulator # 6 consisted of two modular weatherhood housings with 16 sheds each, that cover the rod. These modules are mechanically bonded to the adjacent module by an external polymer collar. This insulator has 32 sheds; however, a similar arcing distance compared with the other insulators was considered (25 sheds). In curve B a small variation is observed among sheds 13 and 18 (the polymer collar is among sheds 16 and 17), but in the last curve (C) this variation is not observed (Fig. 8). Physically, only the insulator has erosion and chalking.

3) Other insulators that did not fail in the test

Insulator #4 with natural pollution, insulator #5 clean, insulator #6 contaminated with lime, insulator #7 contaminated with lime, insulator #8 contaminated with lime, insulator #9 contaminated with lime, insulator #10 clean, insulator #11 contaminated with lime and insulator #13 clean.

The main defects detected in the insulators were tracking and cracks in the moulding line, in the union triple, and in the rings or external polymer collar (used to join the modules that integrate the insulator). Too many hidden degradations were detected (tracking in the interface rod-sheath), which simple observation cannot detect.

In most cases analyzed, the worst insulators (more damaged) are the ones that produced greater current peaks with quantities in the range from 50 to 120 mA.

Regarding the systematic application of electric field methodology that was utilized during the evaluation, results obtained indicate that certain types of degradation of the insulating material of the insulators can be detected by means of the electric sensor UFP. This technique can be utilized with some modifications in field to detect damaged insulators that could cause a fault on the Mexican transmission lines.

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REFERENCES