Investigation of leakage Current on High Voltage Insulators Field Measurements

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Abstract: - Leakage current measurements can be used in order to investigate the performance of outdoor insulation. The advantage of the method is that it can provide information regarding the development of the surface activity, from the onset of current flow until the case of a flashover. This information is available from continuous monitoring that can take place in a lab but even more in the field. In the last case the study of the complete phenomenon is possible minimizing the influence of the lab simulation faults. In this paper the characteristics of leakage current from field measurements are investigated. These measurements took place on 150kV post porcelain insulators located at a high voltage substation of the Power System of Crete.

Key-Words: - Leakage current, field measurements, porcelain insulators, frequency analysis

1 Introduction

Surface activity on high voltage outdoor insulation, is the result of the environmental influence, in combination with the electric stress. The first step of the phenomenon is the accumulation of contaminants on the insulation surface. Then, in the presence of a wetting mechanism, the contaminants layer is transformed to a conductive film and the flow of current on the surface is permitted [1, 3]. This current reflects the development of surface activity and thus it provides plenty of information about phenomena, that follow after the onset of the current flow (dry band arcing) [1-4].

Therefore, leakage current monitoring is a method that can be used in order to study the pollution phenomenon. It can provide simultaneously and comparable measurements on different insulating materials (ceramic and composite). Additionally these measurements may take place in a laboratory or in field conditions.

The advantage of field measurements is that monitoring of the phenomenon in real condition is possible, avoiding the problems that occur during a laboratory simulation. On the other hand long term measurements are necessary for safe conclusions to come up, since the appearance of surface activity depends on the environment.

Field LC measurements may take place in specially designed installations for this purpose (Test stations) or on insulators that belong to a Transmission or Distribution system. In this paper the evaluation of field LC measurements on actual power system insulators is presented. These measurements took place at a High Voltage Substation in Crete, a Greek Mediterranean island.

2 Measurements Setup

Crete is a Greek island located at the eastern basin of the Mediterranean Sea. Due to the sea influence intense pollution problems have been observed in the Transmission and Distribution system of the island. In order to investigate the pollution phenomenon field measurements of LC take place.

For this purpose two specially designed LC monitoring systems where installed at two High

Voltage substations and one of them is used to monitor LC on porcelain insulators.
Each system is capable of simultaneous recording of 9 LC channels and 3 voltage channels. The measurement of leakage current is possible by inserting in the LC path a collection ring and a Hall sensor (Figure 1). Due to the low input impedance, the current is forced to go through the sensor on the way to earth and thus the measurement is accomplished. Then the data are transmitted to the central unit where it is processed and stored. The sampling frequency of each channel is 2 kHz and all the channels are simultaneously sampled.

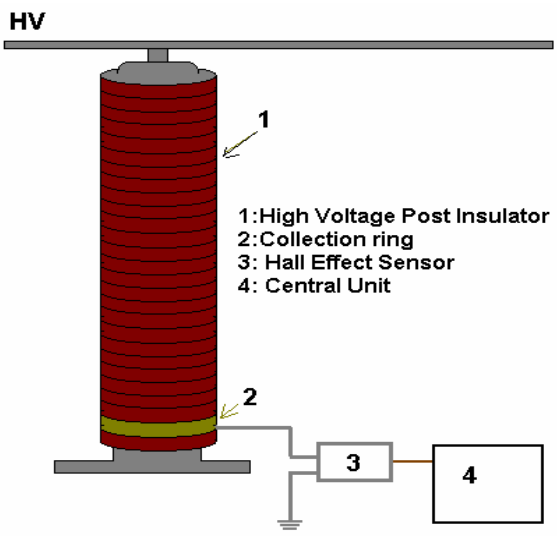

Figure 1: Measurements setup

The monitoring of the porcelain insulators takes place at a Substation called Heraklion II. It is Substation located at the east side of the city Heraklion, in an urban area, in a distance less than 1km from the sea.

3 LC on Porcelain Insulators

The flow of leakage current on the surface of a ceramic insulator results to the dissipation of energy due to the Joule law. Therefore, drying of the surface film should be expected and localized changes in the surface conductivity are observed. Where current density is increased, areas of higher resistance are formed (dry bands) and consequently the voltage distribution along the insulator is altered. As a result increased stress along the dry bands is observed and discharges appear (dry band discharges). Finally these discharges may lead to a complete flashover of the insulator.
Further, on the development to a complete flashover, three stages regarding the leakage current form are observed. In the first stage leakage current flows due to the application of the voltage across the surface conductive film (resistive behavior). During this stage, equilibrium is observed between heating due to the flow of current and wetting due to the influence of the environment.
However when drying becomes the dominant mechanism, the surface discharges that take place change the LC waveform (stage 2). Higher peak values are observed and non linear characteristics can be observed. During this stage LC is the result of the voltage application across a series combination of a resistance and an arc [5]. Finally the third stage is the flashover of the insulator where the arc is the dominant component.

3.1 Stage 1: Drying period

In figure 2 the waveform of leakage current at the end of the initial drying period is shown. As it can be seen, the current at this stage has a sinusoidal form, since surface conductivity is the dominant factor for the surface behavior.

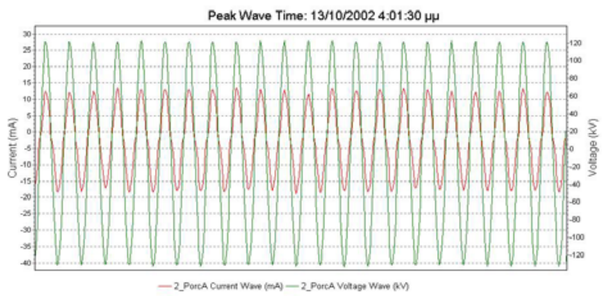

Figure 2: LC at the drying stage

Frequency analysis of the above waveform indicates that the principal frequency component present is the 50Hz fundamental. As it can be seen in figure 3 there is also a small 150Hz component.

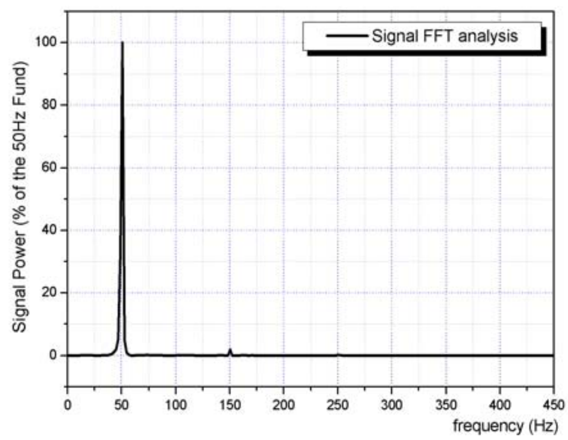

Figure 3: FFT Analysis of the LC in fig. 2

Due to this third harmonic the LC in figure 2 cannot be considered as perfectly linear. However as it can be seen in figure 4, in the I-V characteristic, the LC in figure 2 is not far from the linear behavior (I-V characteristic of a resistor).

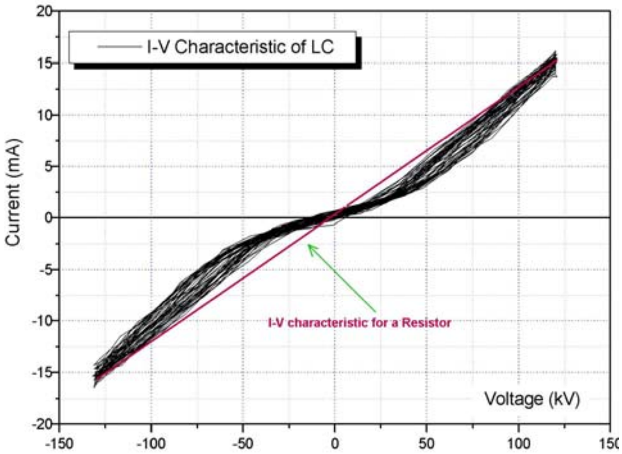

Figure 4:I-V Characteristic for the LC in figure 2

3.2 Stage 2: Dry band activity

During dry band activity higher values of leakage current can be observed. This is due to the discharges that appear on the surface, that result to higher surface conductivity. However the presence of a discharge influences the leakage current waveform, due to the non linear characteristics of the arc [6].

Two typical waveforms of LC during dry band activity are shown and analyzed in figures 4 and 9. In figure 4 the waveform of LC during a dry band discharge is shown. The duration of the discharge exceeds the time of 12 voltage periods and the peak current is 25mA.

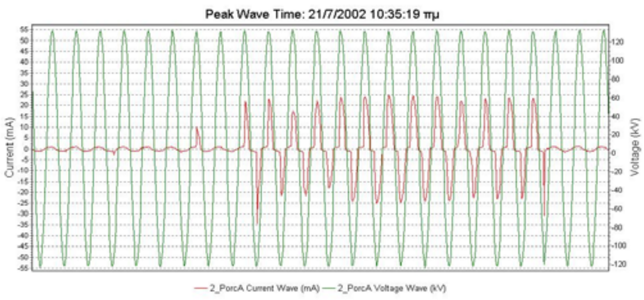

Figure 4: LC in the case of a dry-band discharge (early stage)

In figure 5 the frequency analysis of the leakage current in figure 4 is shown. The non linear behavior is indicated by the presence of a 150Hz component.

It is worth mentioning that the fundamental and the 150Hz components are the dominant in this case.

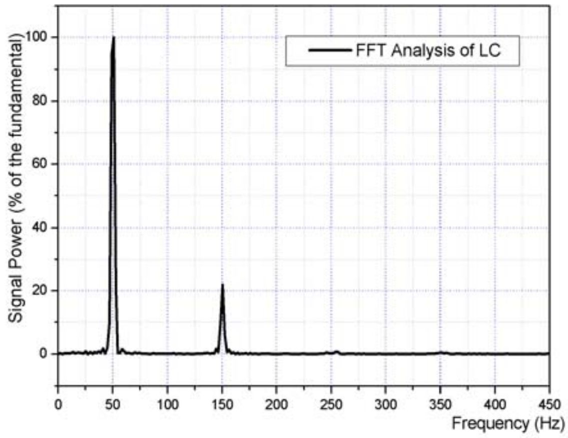

Figure 5: FFT Analysis of the LC waveform in fig. 4

The influence of the third harmonic can be evaluated also from the I-V characteristic in figure 6. As it can be seen, the characteristic in this case has obtained the form of a hysteresis curve, in agreement to the arc nature [6].

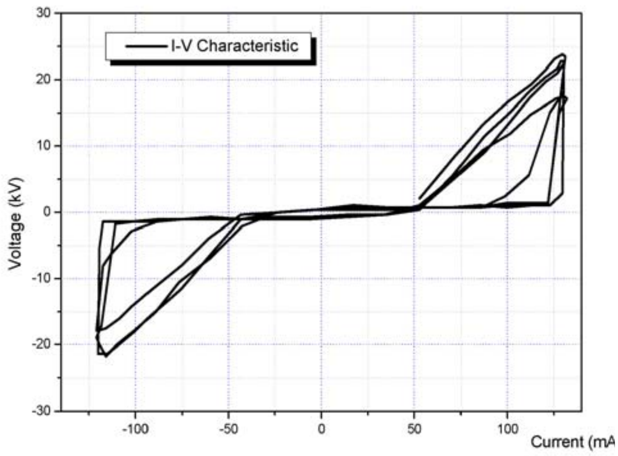

Figure 6: I-V Characteristic of the LC waveform in fig. 4

Under favorable for the phenomenon conditions more intense activity may be observed. The waveform in figure 7 is such a case. As it can be seen, subsequent discharges of probably the same dry band have been recorded. It is important to notice that the duration of each discharge is about seven voltage periods and the peak value of LC reaches 100mA.

In figures 8 and 9 the frequency analysis and the I-V characteristic are shown. The analysis of this waveform verifies that the third harmonic is the principal component that appears besides the 50Hz fundamental. Additionally, in this case the dissipation of energy is increased, something that is reflected to the I-V characteristic in figure 9.

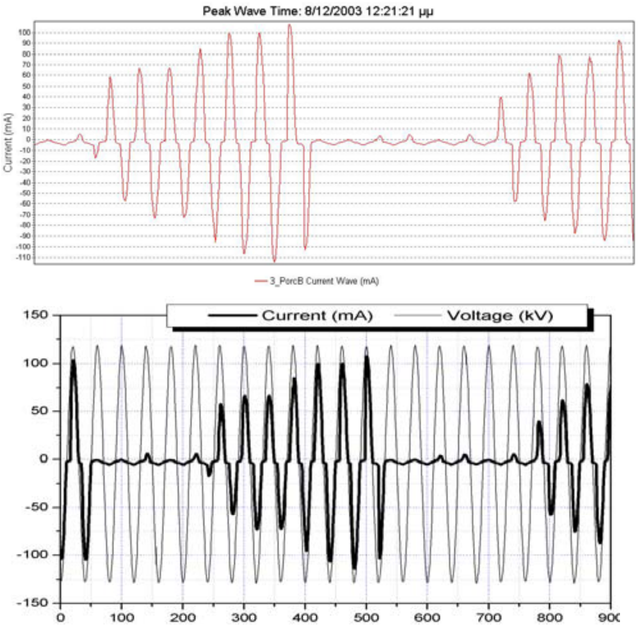

Figure 7: LC waveform in the case of intense activity (a. LC, b. LC and Voltage)

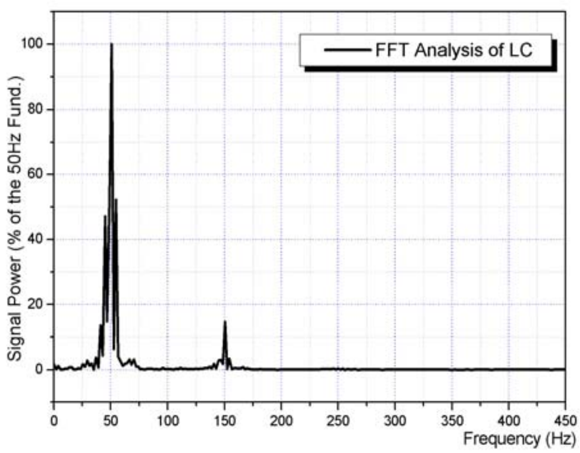

Figure 8: FFT Analysis of the LC waveform in fig. 7

4 Conclusion

The leakage current measurements shown above and the analysis that followed verify the first two stages, the drying period and the dry band activity period. During the drying period the observed current is sinusoidal, since the voltage is applied across a resistance, which is the surface contaminants film. It is important to notice that there is also a capacitive component, which however is too small comparable to the resistive. Thus the current during the dry period can be considered almost linear (figure 4) and resistive. It must be noticed that due to the small size of the 150Hz component in the first waveform, it can be considered that this case is the limit between stages 1 and 2.

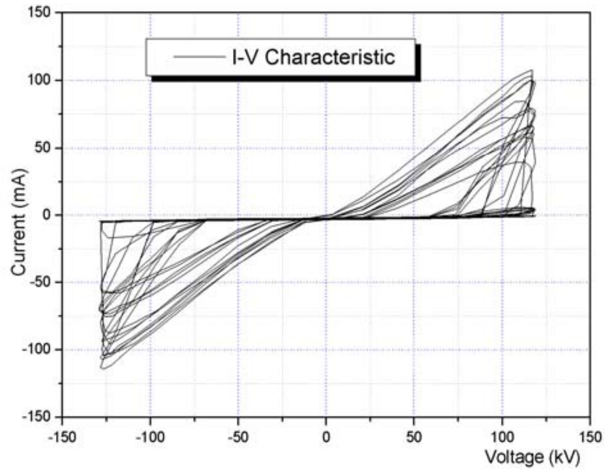

Figure 9: I-V Characteristic of the LC waveform in fig. 7

The onset of surface activity (discharges) changes the initial linear behavior. Due to the existence of a non linear arc in series with the surface resistance, a large third harmonic is present. The non linear behavior is also verified in I-V diagrams.

It is important to notice that the transition from the stage 1 to 2 is indicated by the presence of the 150Hz harmonic, which is the dominant non linear component.

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