INVESTIGATING AND OVERCOMING THE NOISE AND DATA SIZE PROBLEMS IN LONG TERM FIELD LEAKAGE CURRENT MONITORING

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Leakage current (LC) measurements are widely employed to monitor surface electrical activity, surface condition, site pollution and overall performance of insulators, which are all strongly correlated with local conditions. The advantage of field measurements is that they provide an actual view of the phenomena experienced during field service, under the specific service conditions. However, the required long term monitoring results to the accumulation of vast amounts of data. The extraction of several values from the LC waveform has been proposed by several researchers but a fully representative value is yet to be defined. Further, research is usually targeted on waveforms that portray actual electrical activity and the impact of noise is rarely considered. However, the noise problem is rather significant in the case of field measurements due to the nature of the task. In this paper, part of the obtained experience in field LC waveform monitoring is investigated. A number of 5000 LC waveforms recorded on porcelain and RTV SIR coated 150kV post insulators installed at a coastal HV Transmission Substation, are taken into consideration. Typical waveforms and their correlation to surface activity, are illustrated. Field related noise is investigated and three different types of noise are defined. Hardware applicable techniques are employed and evaluated towards addressing the noise and data size problems. Results presented in this paper can be incorporated in the development of improved field LC monitoring systems.

The main problem concerning outdoor insulation, which leads to a number of flashovers worldwide, is the pollution phenomenon, which is rather intense in areas located near the sea. The network in the Greek island of Crete suffers severe pollution since, due to the island's coastal development, the main part of the grid -including High Voltage (HV) Substations- is located in a proximity to the sea coast [21-22]. Therefore, a large monitoring project has been issued in order to investigate the performance of different insulator materials and types employed by the Greek Public Power Corporation. Part of the obtained experience, related to long term field LC waveform monitoring, is presented in this paper.

The monitoring site is the 150kV Transmission Substation of Linoperamata, which is located right next to the sea coast, in Heraklion, Crete. A total number of 5000 waveforms, recorded on 150 kV porcelain and RTV SIR coated post insulators that are part of the grid, are investigated. An equal number of waveforms has been selected for each material. In order to measure the leakage current, a collection ring is installed at the bottom side of each insulator, the current is driven through a Hall current sensor and the acquired data are transmitted to a central Data Acquisition System (DAS). The measuring system is shown in Figure 1.

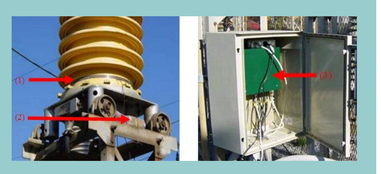

Figure 1: The measuring system: 1.collection ring 2.Hall sensor 3. the DAS

TYPICAL LC WAVEFORMS

The basic stages of activity and the corresponding LC waveform shapes have been well documented in the literature. The basic discrete stages of activity consist of: sinusoid waveforms due to the presence of a conductive film on the insulator surface, distorted sinusoid waveforms as an intermediate stage and dry band arcing that causes a time lag of current onset. Pulses due to local discharges may also superpose on waveforms at the maximum absolute value of half cycles. A large number of LC waveforms in agreement to the typical shapes suggested in the literature have been recorded in the considered site. The same basic stages are met on both materials, but it should be noted that surface activity is rarer on RTV SIR coated insulators and appears only during hydrophobicity loss periods [21-22]. Typical activity portraying waveforms are illustrated in Figure 2.

PROBLEM DESCRIPTION

Noise is a factor of significant influence in the case of field measurements. The monitored insulators and the measuring system are located in the field, subjected to various environmental stresses as well as to high voltage stress and various electrical events occurring during the operation of a HV substation (switching etc). Further, since monitored insulators are part of the grid, access to the measuring system is limited and sensor or cable faults can not be immediately addressed. Investigation of the recorded waveforms led to the identification of three different types of noise: typical noise, single point noise and dysfunction generated noise. Typical noise consists of a random amount of minor peaks of random but low amplitude (Figures 3A, 3B). Single point noise describes the recording of a single point far from the rest of the waveform (Figures 3C-3F). Such single points have been recorded superimposed on all types of waveforms: sinusoids (Figures 3D and 3E), dry band arcs (Figure 3F) and even typical noise (Figure 3C). Their time allocation is random (Figures 3D, 3E). It should be noted that recorded pulses (Figure 2C) are always consisted of more than one points. Temporary dysfunctions lead to chaotic shaped measurements (dysfunction generated noise) (Figure 4). It should also be noted that due to the digitization process, sinusoids of very low amplitude (<0.1752 mA) are portrayed as squares (Figure 5).

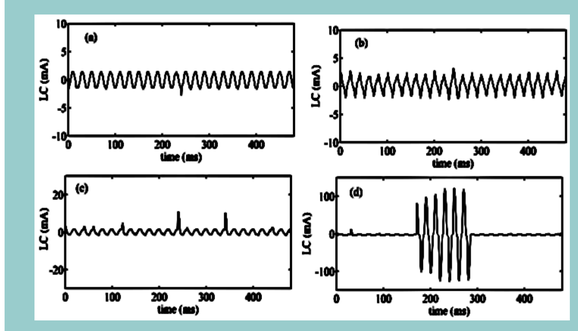

Figure 2: Field Measurements: typical waveform shapes: a) sinusoid b) distorted sinusoid c) pulses superimposed at the waveform crest d) dry band arcing

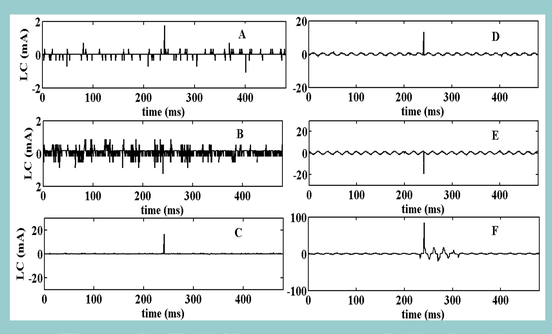

Figure 3: Field Measurements: field related noise: A-B: typical noise, C-F: single point noise

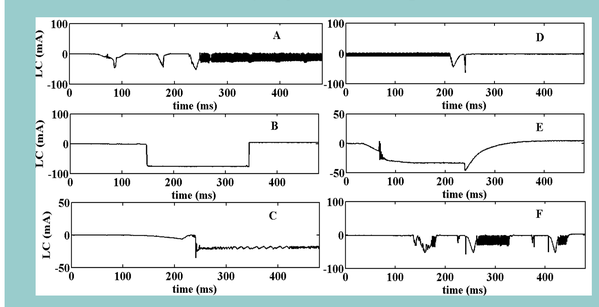

Figure 4: Field Measurements: field related noise: A-F: dysfunction generated noise

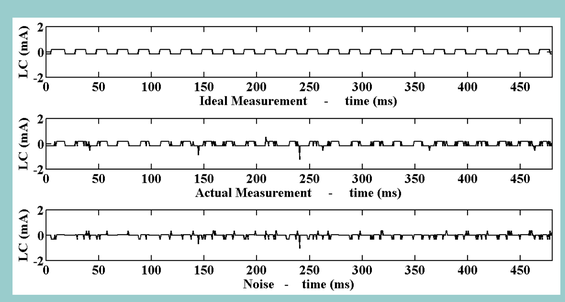

Figure 5: A LC measurement of low amplitude. The ideal (noise-free) measurement, the actual measurement and the extracted noise.

EVALUATED TECHNIQUES

The techniques incorporated in field LC monitoring systems should be fast and easily applied in hardware in order to be used online in the field. The **Time-Window (T.W.) technique** is a technique usually employed in long term field measurements [14, 25] to cope with the data size problem, and is incorporated in the DAS used in this paper. Further, three techniques are employed in this paper: the **Negligible Threshold (N.T.)** technique, the **Fundamental Frequency Criterion (F.F.C.)** technique and the **Maximum and Minimum Point Smoothing (M.M.P.S.)** technique. Using the N.T. technique, all waveforms that portray peak value under a predefined threshold are discarded, with the definition of the threshold value being an issue. Using the M.M.P.S. technique, the maximum and minimum points of the waveform are replaced by their neighboring point with the largest absolute value. Using the F.F.C. technique, all LC waveforms with a fundamental frequency other than 50 Hz are discarded. The N.T. technique is employed to cope with typical noise, the F.F.C. technique is employed to cope with dysfunction generated noise and the M.M.P.S. technique is employed to cope with single point noise.

RESULTS AND DISCUSSION

Investigation of the recorded waveforms showed that the majority portrayed low peak LC values. That was expected due to the nature of the phenomenon (rare short time periods of activity). Several different negligible thresholds in the range of 1 mA to 2.5 mA were applied and were also combined with the other techniques. Results are shown in Figures 7, 8. The number of waveforms portrayed in these figures is the number of waveforms that are not discarded after the application of each threshold value. It is shown that low threshold values do not offer an effective solution to the data size problem. The 1 mA threshold, proposed in the literature for similar test sites [26], is proved insufficient for the considered site. The value of 2.5 mA offers the best results and is less than half of the amplitude of the smallest recorded discharge, and therefore it is proposed in this paper as a threshold value. Further, it is shown that the efficiency of any negligible threshold value is enhanced with the application of the M.M.P.S. technique since a significant number of waveforms exceeded the predefined threshold by just a single point. The enhancement is rather significant in the case of 1 mA and 1.5 mA and smaller in the case of the 2.5 mA, which is another reason that the 2.5 mA is proposed as threshold. It should be noted that the proposed techniques are supplementary to each other as shown in Figures 10 and 11.

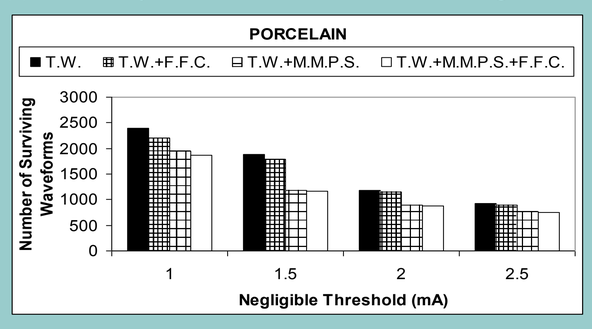

Figure 7 : Results for various N.T. values

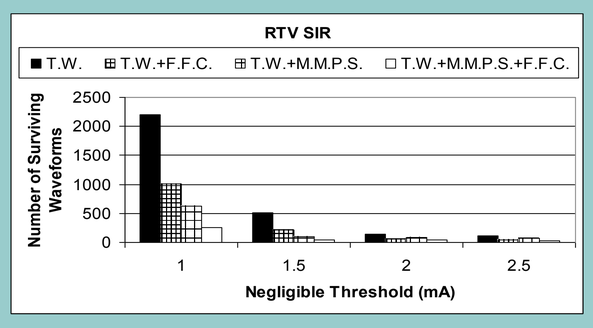

Figure 8: Results for various N.T. values

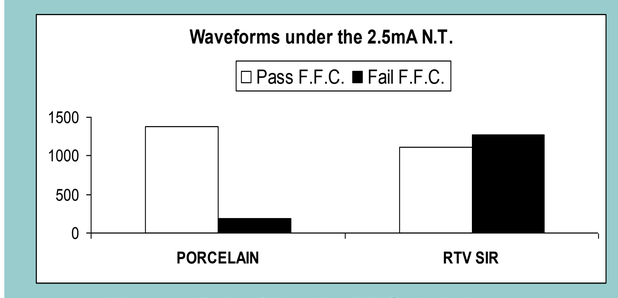

Figure 10: Applying the F.F.C. technique under the 2.5mA N.T.

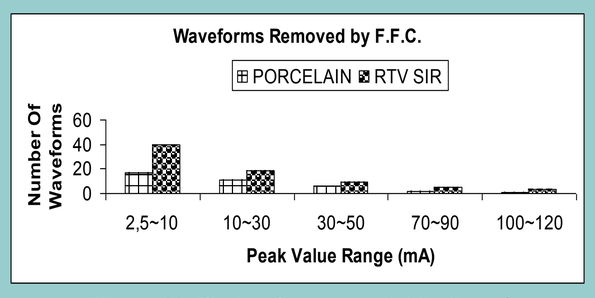

Figure 11: Peak value range distribution of waveforms discarded by F.F.C. application

Results show that the T.W. results to a data set mainly consisted by noise. The combined application of the other techniques may offer a significant improvement as shown in Figure 13. The three techniques proposed in this paper can either replace the T.W. technique, allowing a significantly more effective continuous recording, or be used in combination with the T.W. technique, allowing the setting of smaller time-windows and significantly more effective monitoring.

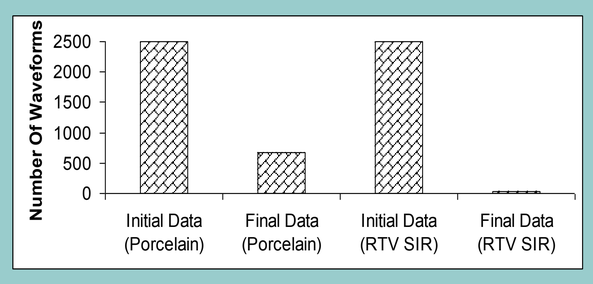

Figure 13: Addressing the data size problem

CONCLUSION

In this paper, a number of 5000 leakage current waveforms recorded in the field, during a period exceeding 5 years, are investigated in order to obtain an exact image of expected data and problems during long term field monitoring. Two problems emerged concerning the effectiveness of any field leakage current measuring system: the data size and the impact of field related noise. Simple and hardware applicable techniques are evaluated towards coping with the data size and noise problems. The results presented in this paper can be incorporated in advanced field LC monitoring systems.

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