Performance investigation of composite and RTV SIR coated insulators at a coastal test station

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***Abstract*-The field performance of four high voltage insulators, in a coastal test station is investigated in this paper. Two of the monitored insulators are composite and the other two are glass insulators, coated with Room Temperature Vulcanized Silicone Rubber. All four insulators demonstrate the same creepage distance and were monitored simultaneously for the same time period. The primary evaluation parameter employed is leakage current. The experienced performance indicates considerable differences in the surface activity developed indicating the importance of parameters such as the geometry of the insulator in reference to the experienced service conditions.**

***Index Terms*—Composite insulator, field testing, leakage current, RTV SIR coated.**

I. Introduction

The performance of outdoor insulators in coastal high voltage installations is significantly influenced by marine pollution [1,2]. The deposition on the insulation surface of contamination, either conductive or capable of becoming conductive, with the participation of a wetting mechanism, can considerably degrade the insulation performance and ultimately result to a flashover. In an effort to improve the performance of high voltage networks, exposed to such mechanisms, the use of composite materials has been introduced [3, 4]. The use of such material results to improved insulation performance since the development of surface conductivity is suppressed due to their hydrophobic surface behavior. However, surface behavior can change, due to the stresses experienced and material ageing [5-7]. Further, cycles of hydrophobicity loss and recovery appear. Consequently, the application success is strongly correlated to the material capability of maintaining the surface hydrophobicity under field conditions.

A well established monitoring technique [8, 9], capable of collecting the necessary information, for the investigation of surface electrical activity, is the measurement of leakage current. Leakage current monitoring can be implemented in the field and offers the ability of continuous and simultaneous monitoring of several ceramic and non-ceramic insulators. In this paper, the performance of four insulators installed at a coastal test station, which is constructed right next to the coast and therefore suffers from severe marine pollution, is investigated. Two of the monitored insulators are glass insulators coated with an RTV Silicone Rubber coating and the other two are HTV Silicone Rubber composite insulators.

All four insulators are new and leakage current flowing on their surface has been continuously monitored for a period of two months. However, the measurements performed revealed that that the two insulator types demonstrated quite different surface activity, although that all insulators have the same creepage distance, have a hydrophobic surface and were subjected to identical stress. Surface activity and leakage current measurements are further investigated in order to determine additional parameters that influence the experienced behavior.

II. Experimental Set Up

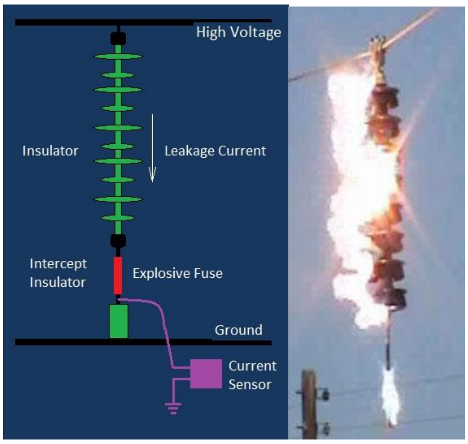
A. Insulator test station

The insulator test station of the Greek Public Power Corporation has been constructed in Crete, a Greek island in the Aegean, with intense pollution problems. Located at the north side of the island, in a considerably small distance from the sea coast, is exposed to the action of the sea and the dominant north winds, which actually are the cause of the problem for the high voltage installations of the island [10]. In addition industrial pollution is also present, since the test station has been built within the premises of Linoperamata Power Station. A view of the test station location from Google earth is illustrated in figure 1, were the small distance from the coast is evident.

Fig. 1. A satellite view of the test station location from Google earth

The test station is supplied by a dedicated 20kV transmission line, from the neighboring 150kV/20kV Linoperamata substation. There are three testing bays, one for the level of 20kV, supplied directly from the supplying line through cut off fuses and two 150kV bays for post and suspension insulators. The generation of the 150kV level is possible by a 25MVA 20kV/150kV power transformer. The test station specifications are similar to the specifications of a 150kV/20kV power substation, including grounding, safety and protection systems.

In addition, considering that flashovers will be often, in an effort to achieve continuous operation of the test station, each insulator is equipped with an explosive fuse [11]. Thus in the case of a flashover, the operation of this fuse will disconnect the considered insulator from the power supply and the reclosing feature of the employed circuit breakers will ensure the station operation. In the pictures of figure 2 the connection of the explosive fuse to an insulator under test (figure 2a) and the fuse operation in a case of a flashover are illustrated (figure 2b).



(a) (b)

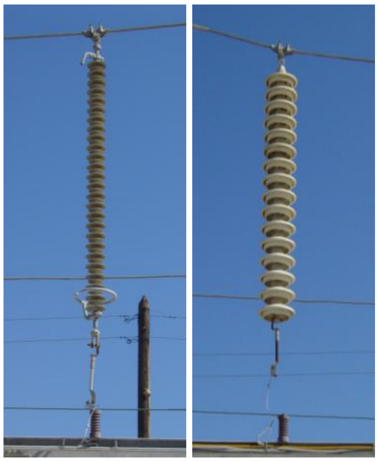
Fig. 2. (a) Installation set up including the connection of the explosive fuse (b) operation of the explosive fuse in the case of a flashover.

B. *Insulators under test*

The insulators included in this test are used in the 150kV transmission system of Crete, on the same transmission poles. Both provide hydrophobic surface behavior and thus improved pollution performance but also the coated ceramic insulator is employed in an effort to reduce the insulator axial length for the same leakage distance. The insulators tested are illustrated in figure 3 and their features are included in table 1.

TABLE I
INSULATORS UNDER TEST

No	Material	Creepage Distance. (mm)	Geometry
1	HTV SIR	6255	Aerodynamic
3	Glass -RTV SIR	6240	Fog



(a) (b)

Fig. 3. Insulators under test: (a) Composite HTV Silicone Rubber insulator and (b) RTV Silicone Rubber coated glass insulator.

C. *Leakage current measurement system*

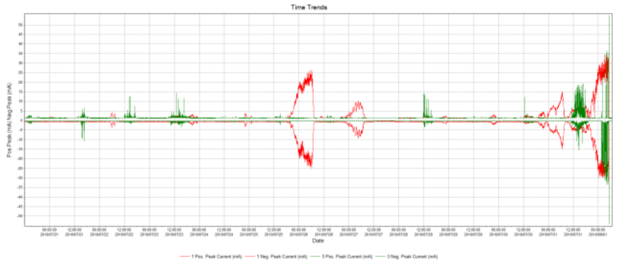
The primary evaluation parameter for the performance of the insulators under test is the surface leakage current. In this direction an appropriate data acquisition system has been employed, capable of simultaneous monitoring up to nine insulators and also the applied voltage and environmental parameters[12]. The current measurement is possible through hall sensors installed at the grounded insulator side and a sampling rate of 2kHz has been employed. Further parameters such as the positive and negative peak value of the leakage current, the positive and negative charge and the RMS value of leakage current are continuously monitored. In addition, a snapshot of 480ms of the leakage current and voltage waveform, as long as the waveforms of the environmental parameters is stored per user selected intervals [12].

III. Leakage Current Measurements

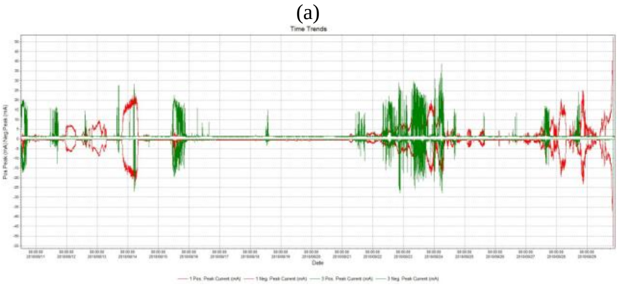
A. *Peak values of leakage current*

The data included in this paper correspond to a 60 days test, during July and August, two months with intense pollution problems for Crete. The measurements are presented in two periods, period A and B, which are in time sequence and a small maintenance period is interpolated between them. The peak values of leakage current, for the periods demonstrating activity within the test and for the insulator with the maximum activity (of each type), are illustrated in figures 4a and 4b respectively.

Incidents of activity have been recorded on both insulator types. The levels of current peaks are similar for both insulators. However the incidents of activity are not always simultaneous and the type of activity appears to be different. In the case of the composite insulators, surface activity appears to be continuous, while on the RTV SIR coated ceramic a train of intermittent current peaks has been recorded. This is evident in both periods, even in cases where the levels of activity on the coated insulator are higher that on the composite. Such an incident is illustrated in figure 5a. In addition in figure 5b the surface charge, calculated from the time interval of the current of figure 5a is illustrated.



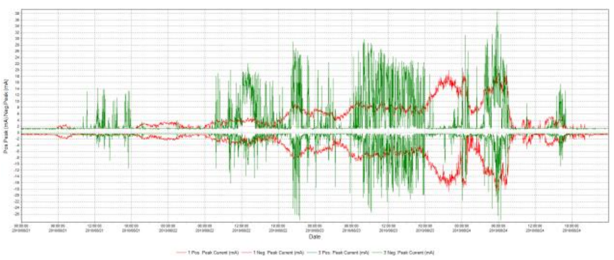
(a)



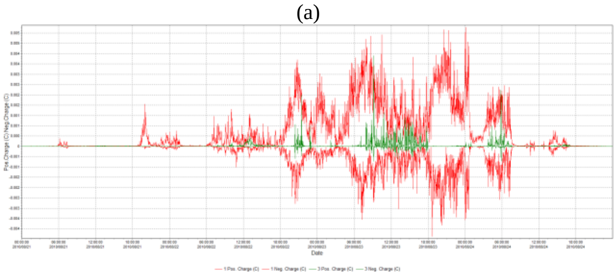
(b)

Fig. 4. Peak values of leakage current during (a) Period A and (b) Period B.(red line: composite insulator and green line RTV SIR coated glass)

The comparison of figures 5a and 5b reveals that although the peak values of leakage current indicate increased levels of activity on the ceramic insulator, the calculated surface charge reverses this indication and the activity appears to be more intense on the composite insulator. This is evident for the majority of the activity incidents recorded within the test, as illustrated in figures 6a and 6b, where the surface charge for the two time periods is presented.

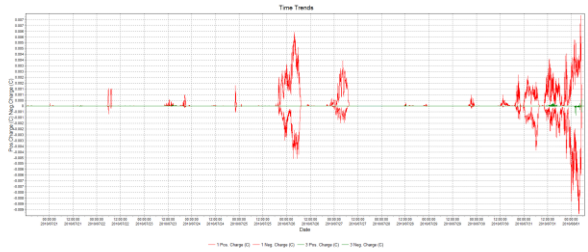


(a)

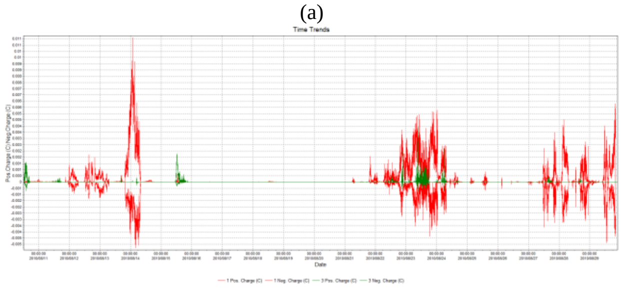


(b)

Fig. 5. (a) Peak values of leakage current during an incident of intense activity. (b)calculation of the surface charge for the waveforms of (a). (red line: composite insulator and green line RTV SIR coated glass)



(a)



(b)

Fig. 6. Calculation of the surface charge for the periods of activity in (a) figure 4a and (b) figure 4b.

B. Leakage current waveforms

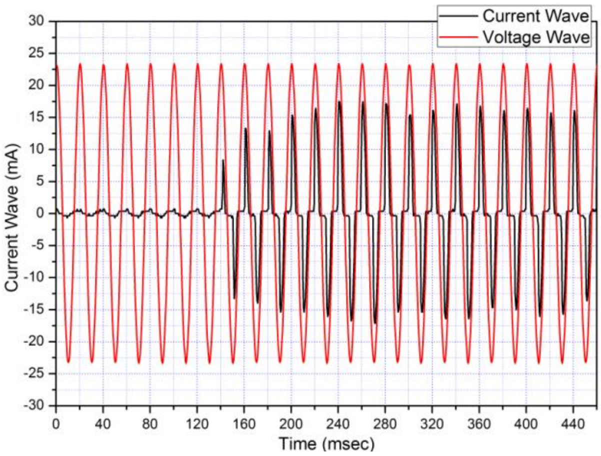
Two typical leakage current waveforms, one for each insulator type are illustrated in the following figures. They have been recorded within the incident of figure 5 and for each FFT analysis and the corresponding voltage current diagram have also been calculated. Figure 7 (a-c) are the waveforms and the corresponding diagrams for the composite insulator and figure 8 (a-c) for the coated ceramic insulator.

The activity illustrated in figure 8a is similar to the activity experienced on a ceramic insulator. The FFT analysis verifies the non linear character of the current and the size of the third and fifth harmonic [13, 14]. Also the V-I character reveals the presence of a gas discharge along the current path [15]. Similar findings can be reported from the corresponding figures for the coated insulator (figures 8a-8c). In this case however the FFT spectrum is not clearly distinct as in the case of the composite insulator and the energy supplied to the discharge is less as it can be estimated from the area included within the hysteresis curve of the V-I diagram.

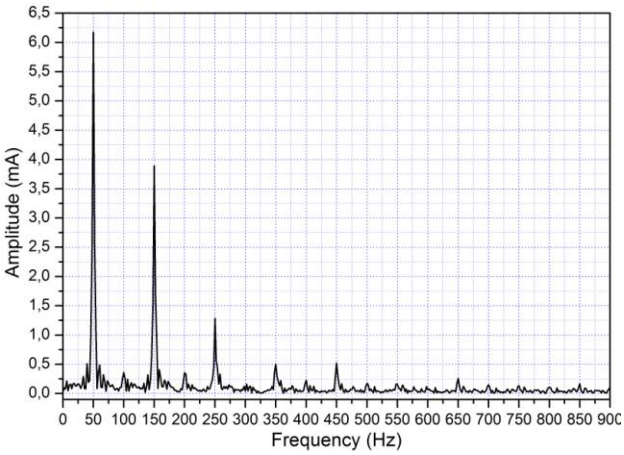
IV. Discussion

The investigated insulators were put in test in the same conditions for the same time period, starting from the same initial condition. The parameters that compose the surface activity, i.e. pollution deposition, wetting and surface behavior must be investigated in an effort to determine the reasons of the differences observed.

For the time of the test, the environmental conditions experienced are typical for the considered location [16, 17]. The first parameter is precipitation which may act both as a wetting and cleaning mechanism.



(a)



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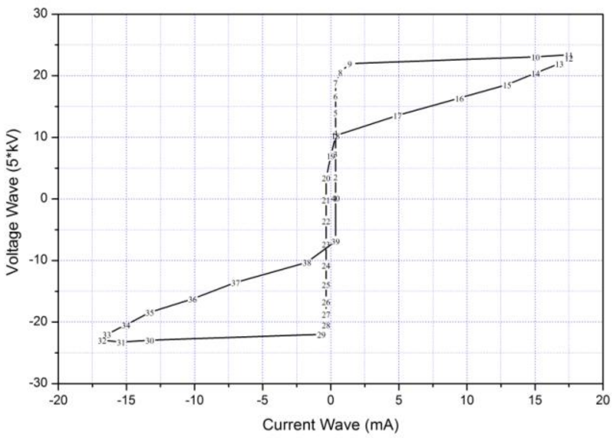
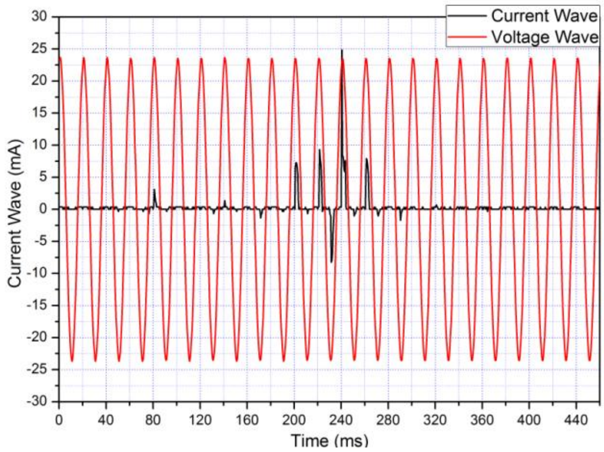
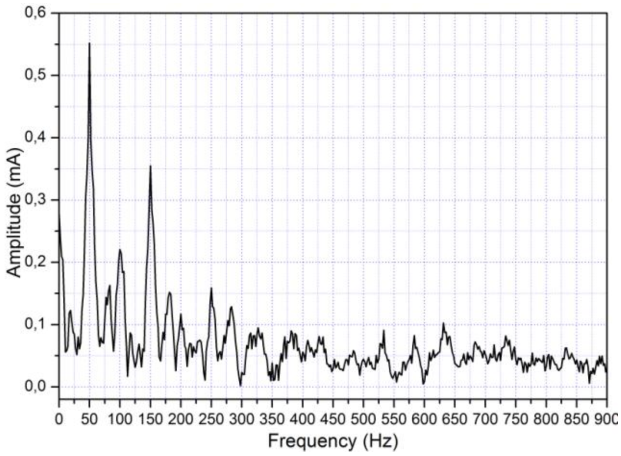


(c)

Fig. 7. Typical leakage current waveform on the composite insulator in the case of intense activity, (a) Leakage current and voltage waveform (b) FFT spectrum of the leakage current and (c) Voltage current characteristic for the period with the highest value of leakage current within the activity of (a).



(a)



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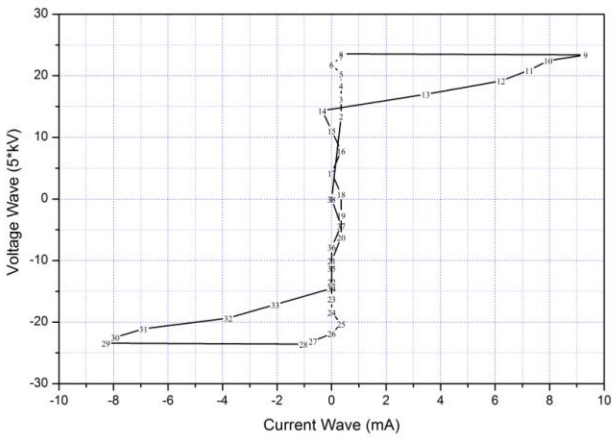

(c)

Fig. 8. Typical leakage current waveform on the RTV SIR coated glass insulator in the case of intense activity, (a) Leakage current and voltage waveform (b) FFT spectrum of the leakage current and (c) Voltage current characteristic for the period with the highest value of leakage current within the activity of (a).

The wind activity on the other hand was quite intense, resulting to the transfer of large amounts of contamination. Of course the amount finally found on the surface is determined by the geometry. The composite housing is fully exposed to the action of the wind and similar levels of pollution deposition along the creepage path can be expected. On the other hand, the ceramic insulator demonstrates a fog profile, which influences the pollutants deposition and larger amounts can be found under the insulator ribs due to its aerodynamic profile.

Further, there are two wetting mechanisms present. The first is the transfer of water by the wind from the sea, along with the salt pollution and the second is condensation wetting. In the first case the open profile of the composite insulator is fully exposed to the action of the sea and therefore uniform or almost uniform wetting along the leakage path is possible. This can support the development of surface activity, until the recovery of hydrophobicity is achieved. On the other hand in the case of the RTV SIR coated insulator, there are parts of the insulator that are protected from the deposition of water and thus the development of surface conductivity is more difficult. This may be the reason for the incidents of surface activity on the composite insulator and the corresponding absence of activity on the coated insulator.

Condensation wetting is the second wetting mechanism present. In this case the transient heat behavior of each insulator has a dominant role to play, since wetting in this case is possible due to the insulator cooling. Both insulators are exposed to the same ambient conditions, but their cooling features may differ [18]. The coated insulator has been reported [18] to have slower heat transfer features and thus cool slower. This corresponds to lower levels of surface wetting and thus less surface conductivity.

Consequently the development of surface activity for the ceramic coated insulator appears to be more difficult, although being exposed to the same ambient conditions, either due to the pollutants distribution along the creepage distance or due to the corresponding wetting distribution. This difficulty can be the reason for the differences between the peak leakage current values and the surface charge. The leakage current waveforms recorded and investigated, indicate that the same conductivity components, i.e. gas discharges and surface salt solution conductivity are present in both cases. The conditions for the onset of a discharge are also similar, resulting to the same levels of peak leakage current, but the energy supplied, as revealed from the surface charge, is less, probably due to higher resistance levels of the wetted part.

Further investigation is required in order to draw safer conclusions. The amount of contamination on each insulator type and the distribution achieved along the leakage path are parameters that have to be investigated as well as the cooling behavior. However, it can be stated that, at this point, the RTV SIR coated insulator demonstrated an improved performance in comparison to the composite insulator, although the creepage distance is the same for both. Of course this conclusion needs to be verified by long term monitoring, because the accumulation of contamination on the ceramic insulator is expected to be higher. As a result the long term performance cannot be predicted according to the measurements performed in this test.

V. Conclusions

The performance of four high voltage insulators, in a coastal field test station, for a two months period, is presented and investigated in this paper. Two of these insulators are composite with a HTV SIR housing and identical features. The other two are glass insulators with a RTV SIR coating. All of them have been selected to have the same creepage distance.

The performance experienced and recorded by leakage current measurements reveal that although they have been tested simultaneously, for the same time period and under the same conditions, they exhibit considerable differences in the surface activity. The recorded values of peak leakage current are at the same levels but the surface charge and the energy supplied to conductivity formed is quite different, with the RTV SIR coated insulator demonstrating the lower levels.

This behavior is initially attributed to the influence of insulator features, such as geometry and transient heat behavior, to the formation of surface conductivity. However further investigation is required to verify this hypothesis.

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