# FIELD MEASUREMENTS OF LEAKAGE CURRENT ON PORCELAIN AND RTV SILICONE RUBBER COATED INSULATORS


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## Abstract

RTV SIR Coatings represent an efficient solution for preventing pollution flashovers, in cases where composite housings are not available or the cost of replacement is remarkable. The advantage of hydrophobicity is also available in the case of coatings providing an improved performance in comparison to the uncoated insulators. However aging phenomena will limit the lifetime of the coating and surface activity will take place. Leakage current is a parameter that can provide information regarding the performance of the material. In this paper field measurements of leakage current on coated and uncoated insulators are presented and analyzed in respect to the wetting mechanism.



## Key Words
RTV SIR Coatings, leakage current, field measurements, frequency spectrum, wetting mechanism.


## 1. Introduction

The improved performance of composite materials for outdoor insulation resides on the hydrophobic surface behaviour. Hydrophobicity is blocking the formation of the contaminants conductive film, thus suppressing surface activity and consequently a possible flashover [1]. However, hydrophobicity in the case of outdoor insulation is a property that may change temporary due to the deposition of contaminants and the influence of the environment or permanently due to aging mechanisms [2-4]. Therefore, the improved outdoor performance of composite materials, including RTV SIR Coatings, is limited in time depending on the stress and the related aging mechanisms in each specific application.
Further a successful application of composite materials apart from the improved pollution performance includes also a sufficient lifetime or in other words the capability of early failure detection, before a flashover occurs. Consequently monitoring of the materials performance is necessary especially for the first application in a specific environment.
Leakage current is a parameter that may supply enough information about the performance of the material under study [5, 6]. The disadvantage of the method is the high application cost, especially due to the necessary equipment and also the need of specific conditions (humidity, contamination etc) in order to have measurements. On the other hand the measurement of leakage current is possible without changing the condition of the insulators surface, it can be used for simultaneous measurements of different materials (ceramic and non ceramic) and with the appropriate equipment continuous monitoring can be possible [7].
In this paper the performance of RTV SIR Coatings is evaluated, based on field measurements of leakage current. The recorded LC waveforms are compared to measurements of uncoated insulators and the influence of the wetting mechanism for each case is discussed

## 2. Field Measurements of Leakage Current

### 2.1 Measurements site

The evaluation of the performance of RTV SIR coatings is based on field measurements that take place in Crete. Crete is a Greek island at the eastern Mediterranean with intense pollution problems during the summer due to the sea influence and a long dry period that starts form late April until September and sometimes October. Many methods have been used in order to prevent pollution flashovers and especially in the case of High Voltage substations a large application of RTV SIR Coatings has taken place.
This was the first application of such materials in Greece. Therefore in order to monitor the performance of the coatings, two leakage current monitoring systems were installed in high voltage substations. 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. Then the measurement is 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)

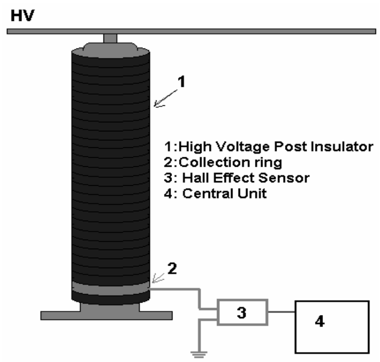



**Figure 1:** Measurements setup

The systems are installed at two substations in Crete. The first (site 1) called Heraklion II is a 150kV/15kV High Voltage Substation located at the east side of the city Heraklion, in an urban area, in a distance of about 1km from the sea. The second called Linoperamata Substation (site 2), is the step up substation of the Linoperamata power plant, located at the west side of the city, in a distance of less than 300m from the coast.

### 2.2 Performance of ceramic insulators

The pollution problem in the case of ceramic insulators is observed at the end of the summer until the onset of the rain period (August to October and sometimes November). During this period precipitation is absent (cleaning factor) and due to the sea influence contamination is accumulated on the surface of insulators. Thus at the end of the summer, after 3 to 4 months of accumulation the necessary wetting mechanism comes to surface. Atmosphere humidity during the night (condensation) transforms the contaminants layer to a conductive film and surface activity takes place. In figure 2 the distribution by month of the pollution related faults, observed in Transmission Lines (ceramic insulators) is shown.

The intensity of the problem during the above mentioned period may be verified by the rapid increase of the observed faults.

### 2.3 Leakage Current on RTV SIR Coatings

RTV SIR Coatings were installed in High Voltage Substations in order to suppress the surface activity during the pollution period. The application of the coatings resulted to a remarkable improvement of the insulators performance. The first proof of this improvement is the absence of activity sound and visual phenomena. Additionally it is verified by leakage current measurements.

In figure 3 the accumulated charge on two identical insulators, with and without a coating is shown, for three months of the pollution period (August, September and October). These insulators are installed in the same place, as it can be seen in figure 4 and when the measurements took place the coating was 1,5 years old. It must also be mentioned that the porcelain insulators are washed twice during this period.

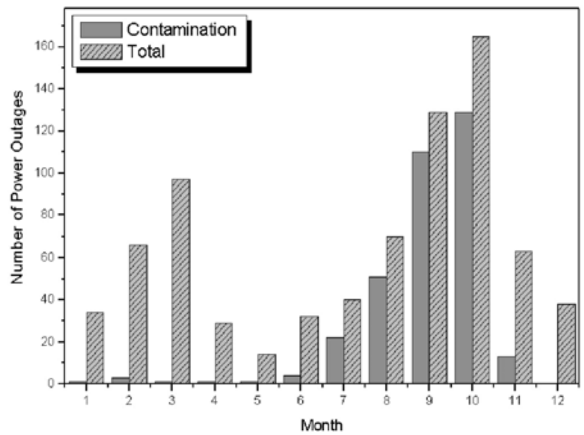



**Figure 2:** Monthly distribution of power outages (contamination and total) from 1969 to 2004

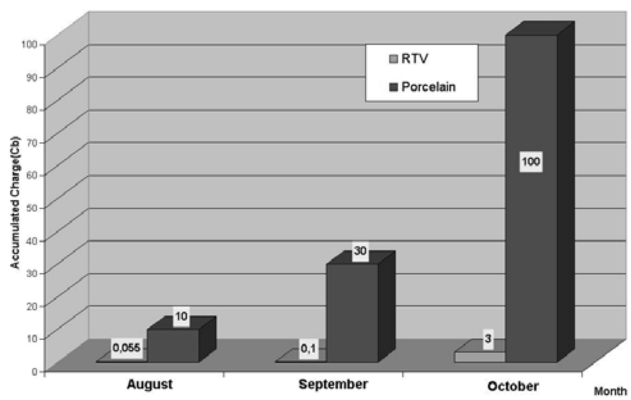



**Figure 3:** Accumulated charge on two identical insulators, with and without a RTV coating for the period from August to October (average values)

Thus as long as the coatings maintain a hydrophobic surface, the possibility of a flashover is minimized. However the continuous monitoring of LC around the year indicated that in the case of coatings intense activity is observed, but during a different time period. In figure 6 a monthly distribution of the average accumulated positive charge, from measurements at site 2 is shown.

Combining figure 5 with figure 6, where the monthly distribution of average precipitation at Heraklion is shown, it can be seen that the period of activity in the case of coatings, comes along with precipitation. This may be verified also in figure 7, where the simultaneous measurements of the peak positive and negative value of LC (in the case of a coated insulator), and precipitation are shown.

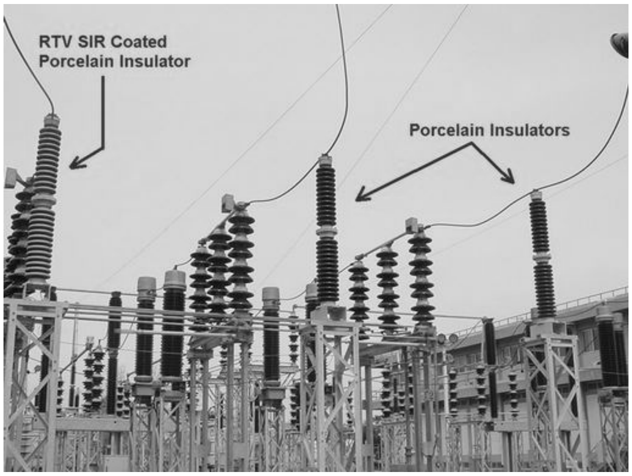



**Figure 4:** Monitored 150kV insulators at site 1. One of them is RTV coated and the other two uncoated.

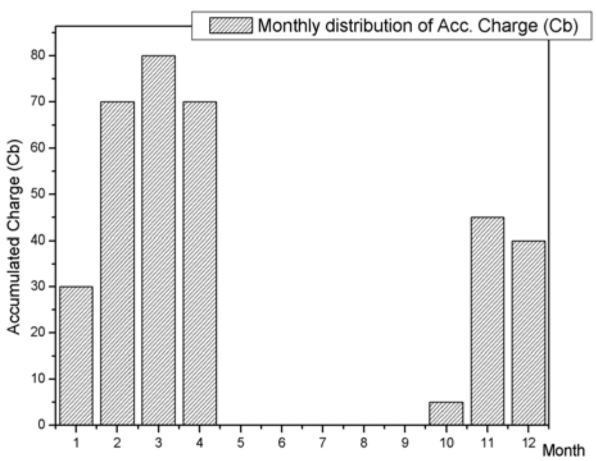



**Figure 5:** Accumulated charge on RTV SIR coatings (average value) by month for one year monitoring at site 2.

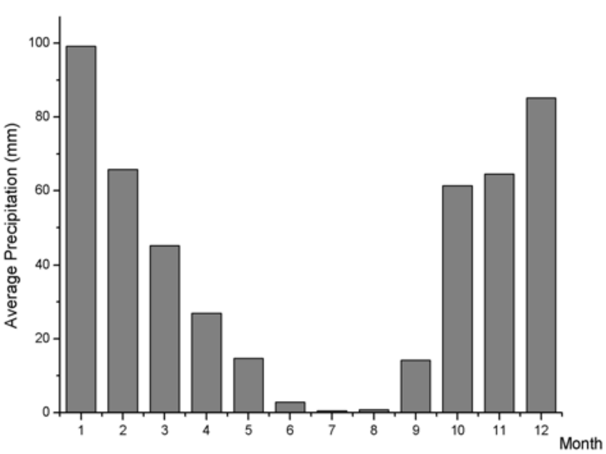



**Figure 6:** Average monthly precipitation at Heraklion (sites 1 and 2).

## 2.4 Leakage Current waveforms

The waveform of leakage current can reveal the surface condition regarding hydrophobicity. In the case of a hydrophobic surface, high values of surface resistance are expected. Thus LC is confined to low values and high frequencies in the case of water drop discharges.

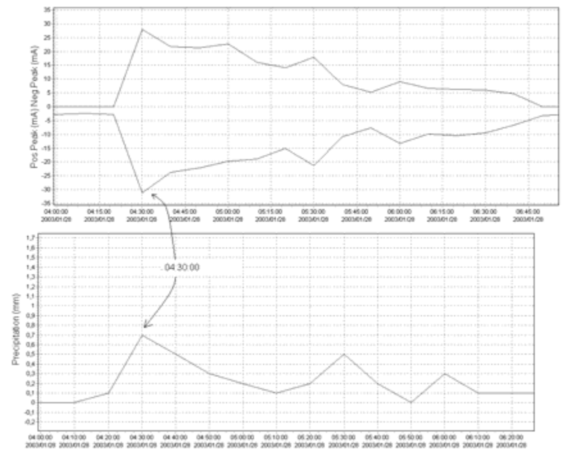
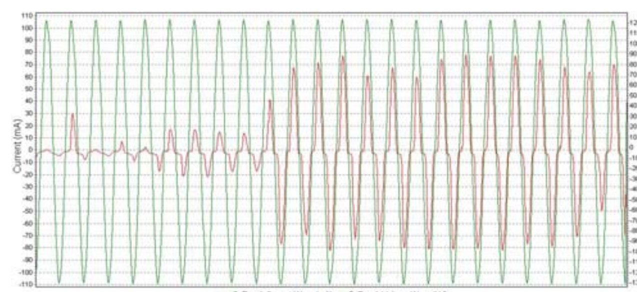
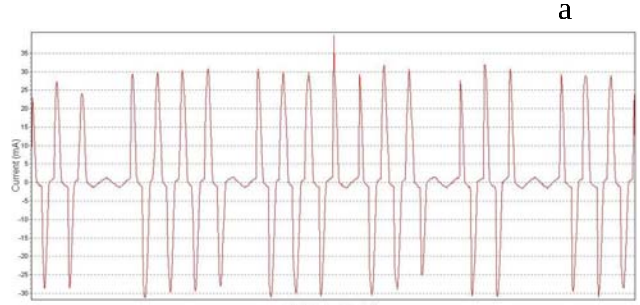



**Figure 7:** Peak positive and negative values of LC during light rain on an RTV SIR coated insulator at site 2.

On the other hand in the case of hydrophobicity loss the waveform of leakage current obtains higher values, especially in the case of a dry band discharge. Figure 8a is a typical measurement of LC on a porcelain insulator, in the case of a dry band discharge. Figure 8b is also a measurement of LC (dry band discharge) but in the case of an RTV coated insulator.



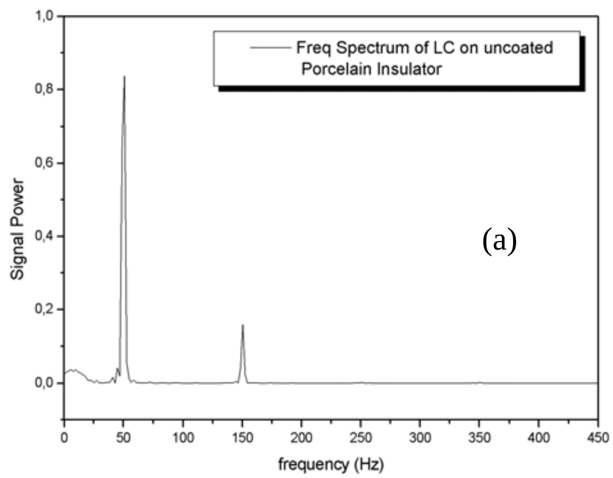
a



b

**Figure 8:** **(a)** Leakage current and voltage waveform on a 150kV porcelain post insulator at site 1,
**(b)** Leakage current waveform on a 150kV porcelain post insulator at site 2

The leakage current waveforms in both cases seem to be similar. The frequency spectrum (figures 9a and 9b respectively) indicates a large 50Hz frequency component and also a large component at 150Hz in both cases. This similarity occurs since the behaviour of the RTV coating in the case of a hydrophobicity loss is similar to porcelain. Therefore in this case an appropriate leakage path is necessary to ensure the suppression of surface activity.



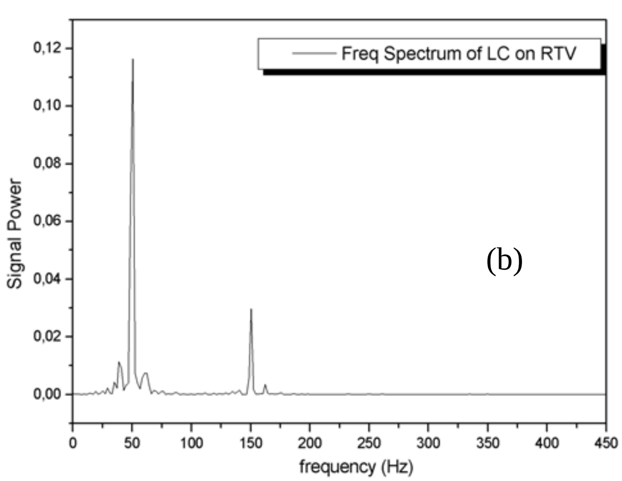




**Figure 9:** **(a)** Frequency spectrum of the Leakage current waveform on a 150kV porcelain post insulator at site 1, shown in fig 8a. **(b)** Frequency spectrum of the leakage current waveform on a 150kV porcelain post insulator at site 2, shown in fig 8b

It is also important to notice, especially in the case of figure 8a where the corresponding voltage is also shown, the dominant resistive component of LC, indicating the existence of a resistive conductive layer and therefore the dissipation of energy on the coating's surface. Additionally the presence of a non linearity in the leakage current (in both cases) also reveals the presence of an arc resistance in series. This non linearity can be seen in the frequency spectrum (150Hz component) and also in a Voltage versus Current diagram (figure 10).

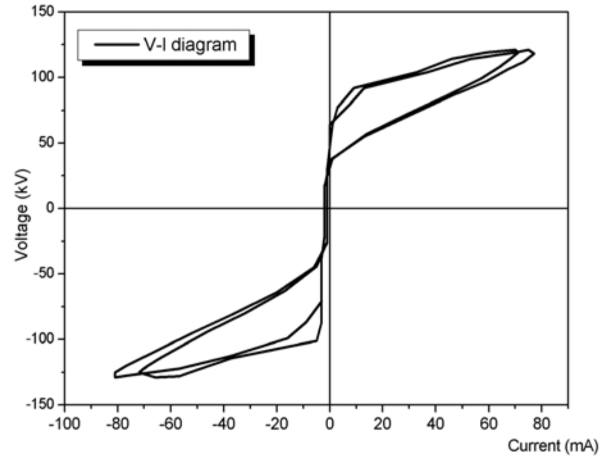



**Figure 10:** Voltage Current diagram for the waveforms of LC and Voltage in figure 8a.

### 2.5 Influence of the wetting mechanism

The deposition of contaminants, which is the first step of the pollution phenomenon, does not depend on the coating presence, but on the insulator geometry and orientation. Therefore the different performance is attributed to the development of the conductive film, thus the wetting procedure.

Many researchers have studied the influence of various wetting mechanisms such as mist, fog, condensation and rain [7]. Each mechanism requires special conditions to take place and results to an amount of water on the insulation surface. It is important to notice that the accumulated water may act in favour of the insulation performance, when it is enough to wash away the contaminants. On the other hand it can support efficiently the development of a surface conductive film, especially when it is not sufficient to clean the surface.

In the case of the coating, the hydrophobicity recovery mechanism must also be taken under consideration. The main component in this mechanism is a number of **L**ow **M**olecular **W**eight silicone rubber molecules. These molecules move from the coating volume to the surface and penetrate in the pollution layer, thus changing the initial hydrophilic behaviour (due to the contaminants layer) to hydrophobic [8]. In figure 11 a porcelain insulator coated with RTV SIR is shown. The insulator was installed near the coast, out of voltage and a contaminants film has been formed on the surface. As it can be seen despite the presence of contamination the surface is hydrophobic. Thus, even after the formation of a hydrophilic pollution layer, hydrophobicity can recover and the development of the conductive layer is postponed, since water forms droplets on the surface.

Unfortunately the achieved hydrophobicity can be lost since it is correlated to the presence of the LMW molecules, which are weakly bonded to the surface. Thus any mechanism that can wash away the LMW molecules is capable of altering the achieved hydrophobic behaviour.

In figure 12 the contaminants layer in the case of the insulator shown in figure 11 has been removed and as it can be seen the behaviour is hydrophilic. Of course it must be mentioned that in this case the energy supplied by the hand friction when removing the pollution also contributes to the loss of hydrophobicity by changing the orientation of the side methyl groups in the Silicone Rubber molecule (second hydrophobicity mechanism). However the reorientation will take place very fast after the excitation mechanism cease.

**Figure 11**: Hydrophobicity measurement on an RTV SIR coated porcelain insulator with a contamination layer.

**Figure 12**: Hydrophobicity measurement on an RTV SIR coated porcelain insulator. The contamination layer has been removed and a hydrophilic behaviour is observed.

Furthermore the wetting mechanism, due to its influence to the surface LMW molecules concentration, may determine the performance of the RTV SIR coatings. The key parameter is the amount of the accumulated water. In the case of mechanisms such as condensation, the amount of the formed water is not sufficient to support the development of the conductive film, since water will form droplets (hydrophobic surface).

On the other hand, mechanisms that can supply large amount of water, will cause the cleaning of the surface and thus hydrophobicity loss will be observed. However since the contaminants will also be washed away, surface activity will be suppressed. It must be mentioned that in the case of the RTV SIR and sea originated pollution, cleaning requires larger amounts of water in comparison to a ceramic surface. This is due to the sticky effect caused from the LMW molecules [9].

Finally mechanisms such as light rain can supply the optimum amount of water, sufficient to support the formation of a conductive film, but not enough to clean the surface. In this case it is possible to observe a surface behaviour similar to the case of porcelain and glass.

Therefore in the case of RTV SIR Coatings the period of high risk is observed during light precipitation, when the amount of water formed on the insulation surface is sufficient to dissolve the surface conductive film, without washing away the accumulated pollution.

For the environment of the Eastern Mediterranean Bay this periods are observed during the transition from autumn to winter and winter to spring. These are the periods when intense activity is observed on the RTV Coatings. On the other hand in the case of ceramic materials, the period of the intense flashover risk is observed at the end of the summer due to the absence of rain (cleaning) and the presence of humidity condensation during the night and early in the morning.

Consequently the application of the coatings has improved the system reliability during the period of high risk for the ceramic insulators, however in order to maintain the advantage round the year, the combination of the various wetting mechanisms present and the LMW recovery mechanism must be taken under consideration.

## 3. Conclusion

The pollution performance of ceramic insulators may be improved by the use of RTV SIR Coatings. The advantage in this case is a hydrophobic surface that postpones the development of a conductive surface film, suppressing in this way surface activity and thus a possible flashover.

However the advantage of hydrophobicity may be lost due to the influence of the wetting mechanism. In the case of condensation, the amount of the formed water is not enough to dissolve or wash away the pollution layer. Therefore in this case surface activity is limited in contrast to the uncoated insulators. However increased amounts of water, especially if not enough to clean the surface, may lead to intense surface activity.

Consequently in the case of ceramic insulators the use of RTV SIR Coatings may improve remarkably the pollution performance. However there are cases when surface activity appears due to the loss of hydrophobicity and appropriate insulator selection (leakage path) is necessary to retain fault free performance.

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