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Influence of the environment to the pollution performance of RTV Silicone Rubber coatings in Crete

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Abstract: The influence of the environmental factors on the pollution performance of RTV SIR Coatings of High Voltage Outdoor Insulation is presented in this paper, with special reference on the case of HV Substations of the island of Crete. In Crete the application of RTV SIR Coatings started in 1998 and until today it has been proved successful. This performance is directly correlated with the environment and the way that it influences the pollution phenomenon and the hydrophobicity of SIR. The environmental parameters that consist the above influence are correlated with the power outages for the case of Crete and based on this approach the performance of RTV SIR Coatings in Crete is evaluated.

1. Introduction

In cases where Outdoor Insulation pollution problems must be faced only with minor changes on the High Voltage equipment, the application of SIR for the Outdoor Insulation is increasingly adopted by Power Utilities. This is due to the improved pollution performance based on a hydrophobic surface and due to the satisfactory aging endurance, in comparison with other composite materials, as a result of the existence in the formulation of a very strong Si-O bond. [1-3]

Additionally RTV SIR Coatings give an efficient solution in the case of High Voltage Substations, where there are ceramic housings with various geometries and on the other hand the availability of composite housings in the market is limited.

In Crete the application of SIR started in the form of RTV Coatings in 1998 at Substations with severe pollution problems. Until today the performance of the installed coatings has been proved satisfactory, something that is correlated with the combination of the environmental parameters, that constitutes the pollution problem in Crete.

2. The pollution problem in Crete

Pollution related Power Outages

The pollution phenomenon is one of the most common sources of power outages for the Cretan Transmission System. Out of 777 reported incidents since 1969, 43% are ascribed to pollution. These outages refer to ceramic materials and took place mainly during the same period for each year, which as it can be seen in Figure 1, starts from August until October. The reason for the accumulation of power outages during this period is the combination of the parameters that influence the pollution phenomenon, which in the case of Crete are wind, precipitation, temperature and humidity.

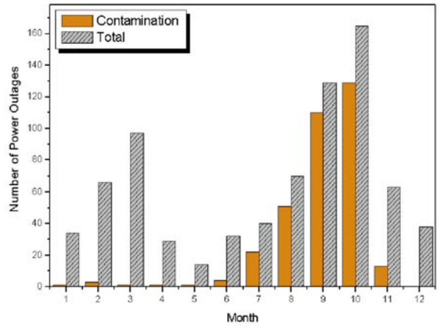

Figure 1. Monthly distribution of power outages due to contamination and due to any reason (total) from 1969 to 2000

It is also important to notice that during this period outages take place mainly during the night and early in the morning as it can be seen in figure 2.

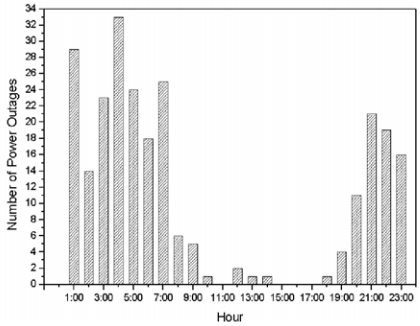

Figure 2. Hourly distribution of power outages due to contamination for the period August to October from 1969 to 2000

Influence of the Environment

Wind: The main source of contamination in the case of Crete is the sea. The coastal economical development of the island resulted to a Transmission System mainly located near the coast. Consequently months of increased wind activity may be considered as months of high accumulation of contaminants on the surface of electrical insulation. In figure 3 the average wind speed (m/s) for each month for one year cycle is shown. It can be seen that the average speed for each month exceeds 3m/s, which is considered as the minimum speed that can cause waves. Additionally the summer period (from June to August) is a period of increased wind speeds. In other words accumulation is possible all around the year and in the period from June to August in more intense.[4,6,7]

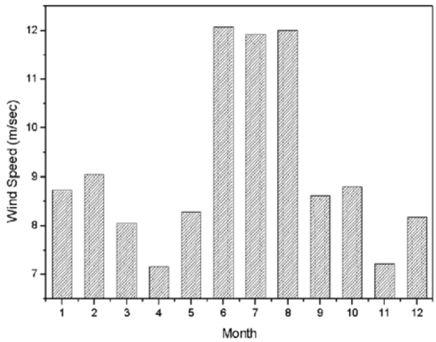

Figure 3. Average monthly wind speed at the eastern Crete (Period 1995- 1998)

Precipitation: The second parameter that will indicate the contaminants accumulation degree is precipitation, which influences the phenomenon as a cleaning factor. In figure 4 the average monthly precipitation is shown, where it is evident that the period from June to August is a period of low precipitation.

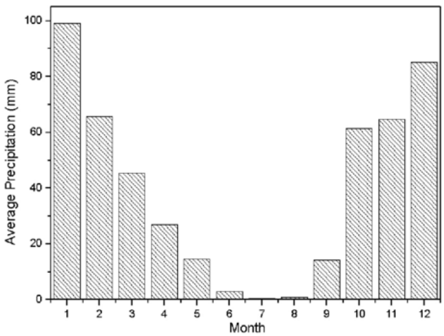

Figure 4. Average monthly precipitation at the eastern Crete for the period 1977 -1998

Consequently, combining the wind activity and the precipitation distribution round the year (figures 3 and 4 respectively) it can be concluded that the period from June to August is a period of intense contaminants accumulation on the surface of electrical insulation. [4,7]

Temperature: The period from June to August is also a period when the highest temperatures of the year are observed. In figure 5 the frequency distributions of temperature observations for typical months of the year are shown.

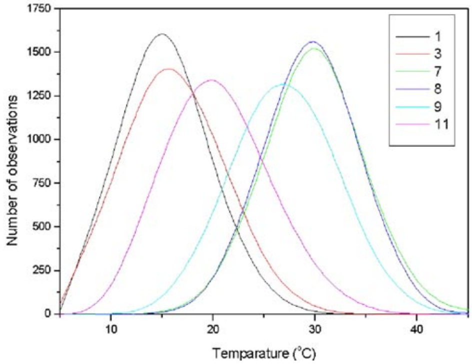

Figure 5. Frequency distribution of temperature for typical months of the year for the period 1994 - 1998

The influence of temperature is also important. In the case of ceramic materials, the already humid contamination that is deposited by the wind is dried on the insulation surface and on the other hand high environmental temperatures support the LMW hydrophobicity recovery mechanism of SIR.[8]

Relative Humidity: Relative Humidity completes the pollution phenomenon puzzle, since it is the wetting factor that will transform the initial contaminants layer to a conductive film [4]. Starting from August until the beginning of the rain season (usually November) and during calm (no winds) nights without clouds, RH exceeds the limit of 75%. This is a result of the surface cooling (and the air close to it) that takes place due to the radiation of energy to the atmosphere. [9]
In figure 6 the probability for RH of exceeding 75% is shown. It is important to notice that during August and September the probability is greater than 20%, although precipitation in the same period is low.

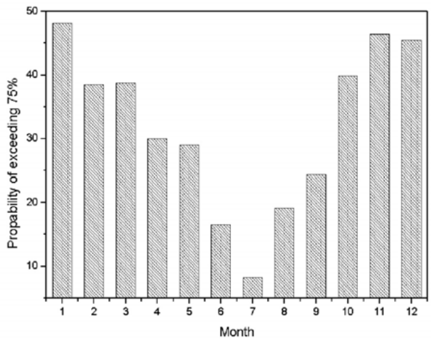

Figure 6. Probability of exceeding 75% for RH for the period 1994 - 1998.

Correlation of the Power Outages with the environmental influence

The monthly distribution of Power Outages in figure 1 comes in agreement with the combination of the above environmental parameters. The period from July to October, when most of the contamination related outages take place (92%), is a period of intense contaminants accumulation (strong winds and low precipitation). Additionally in the same period wetting of the contaminants layer is possible through the condensation mechanism, during the night and early in the morning. Therefore intense surface activity is observed during these hours, something that is reflected in figure 2.

Additionally two characteristics of the wetting mechanism are also worth mentioning. The first is that condensation takes place only during nights with no wind activity. Therefore there is a time gap between contaminants accumulation and wetting and the second is that this mechanism has the capability of transforming the initial contaminants layer to a conductive film, without cleaning the insulator (such as in the case of rain). Therefore surface activity can be also observed during the rest of the year. However due to precipitation is usually kept in low levels

3. Leakage Current Measurements

Test Setup

In order to evaluate the performance of RTV SIR Coatings in the Cretan Environment, the leakage current of six post type 150kV porcelain insulators is monitored. These insulators are installed in a 150kV/20kV Substation located in Heraklion (Urban Area) at a distance less than 1km from the sea. Four of these insulators are covered with RTV SIR Coatings using the brush method.

Leakage current in the case of porcelain: Porcelain insulators represent the reference, since the purpose of these measurements is to evaluate the performance of RTV SIR in comparison to porcelain and glass. In figure 7 the Accumulated Energy (kJoule) dissipated in a period of each month for the porcelain insulators is shown.

As it can be seen the period from August to October is a period of intense surface activity. This is reflected to the dissipated surface energy, where the difference between the above period and the rest of the year is remarkable. This comes in agreement with the correlation of the power outages in Crete with the environmental profile of the island.

It is also important to notice that there is a decrease in surface activity from August to October; although September and October are months with high value of observed outages (figure 1). The reason for this decrease is the washing activities of ceramic insulators, which in this period take place once in August and one in September. Also the observed wind activity is lower in September in comparison to August (figure 3). Therefore accumulation is also observed in lower levels.

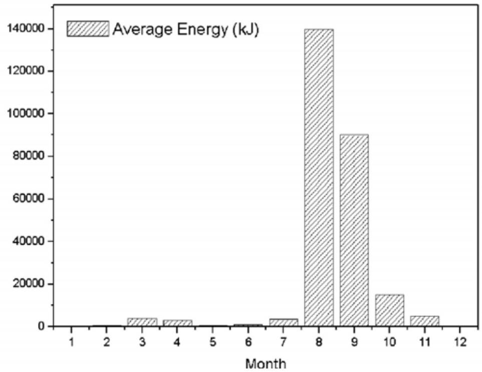

Figure 7. Accumulated Energy in kJ for each month in 2001 in the case of porcelain insulators.

Leakage current in the case of RTV SIR:

In figure 8 a comparison is shown in the case of porcelain insulators with and without coatings, for the period from July to October, when the surface activity is intense.

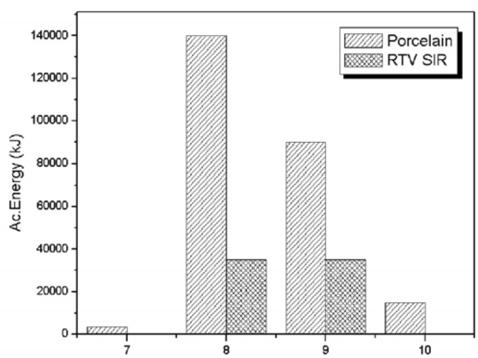

Figure 8. Accumulated Energy in kJ for the period of July to October of 2001, in the case of porcelain insulators with and without coatings.

As it can be seen there is a significant increase in the dissipated energy both in the case of porcelain and coated porcelain insulators for August and September. This increase indicates that there is surface activity in both cases and thus there are periods for the coating where hydrophobicity is lost. However in the case of the RTV coated insulators, the amount of the dissipated energy is significantly less in comparison to the uncoated insulators. Therefore it can be concluded that the coating hydrophobicity recovers and finally manages to suppress the surface activity.

4. Discussion

The performance of the coating is directly correlated with the interaction of the surface hydrophobicity recovery procedure with the environment. In the case of RTV SIR two mechanisms of recovery are considered dominant. The first is the reorientation of the side methyl groups and the second is a migration mechanism of LMW SIR Molecules from the bulk to the surface. [10-14]

Among them the second is more important in this case, since the coating surface is covered by a contaminants layer. Therefore the reorientation of the methyl groups has no significant influence to the final surface hydrophobicity and the mechanism of recovery is the migration of LMW molecules. It is important to notice that since this mechanism is based on the movement of molecules, it needs time to develop and this time is crucial for the application efficiency.

In the case of Crete there is a time gap between deposition and the onset of surface activity. Deposition takes place during the day, when wind activity is observed and on the other hand wetting and thus surface activity take place during calm nights. Additionally this time gap is extended since one day wind activity is not enough to accumulate a crucial amount of contaminants. This is something that can be verified by the need of washing during this period, which takes place once in August and once in September. Therefore there is time for the mechanism to develop which by the way is accelerated by the increased environmental temperature. [8]

This consideration is verified by the daily distribution of the surface activity. In figure 9 the Accumulated Resulting Charge (sum of the positive and absolute negative charge) for September 2001 is shown.

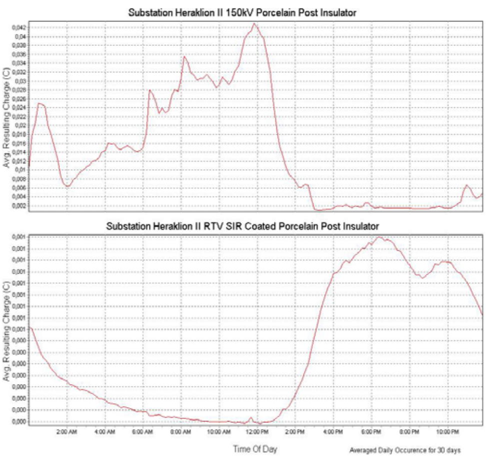

Figure 9. Average Resulting Charge in Coulomb for September 2001, in the case of porcelain insulators with and without coatings.

As it can be seen in the case of uncoated porcelain, surface activity is observed during the night and in the morning, something that is expected considering the wetting mechanism. On the other hand in the case of RTV SIR surface activity is observed during the day, when wind activity is observed. This stands because the contamination that is transferred form the sea is already humid at the time of deposition. Thus until the recovery of hydrophobicity there is a conductive film on the surface of the coating and activity is observed.

5. Conclusions

In Crete the problem of High Voltage Insulators Pollution is one of the main sources of power outages. The problem is more intense in the summer period and especially from August to October when the combination of the environmental parameters is most severe. During this period the performance of RTV SIR Coatings is satisfactory since although there is an increase of the surface activity, the material manages to suppress the activity. This is a result of the migration mechanism of LMW molecules and the time gap that is available between deposition and onset of surface activity, for the recovery to develop.

6. References

[1] R.S. Gorur, E.A. Cherney, J.T. Burnham, *Outdoor Insulators*

[2] E.A. Cherney, R.S. Gorur, *RTV Silicone Rubber Coatings for Outdoor Insulators*", IEEE Trans on DEIS ,Vol 6,No 5, October 1999

[3] K.T. Eldridge, *Evaluating Silicone High Voltage Insulator Coatings*, Midsun Documents

[4] CIGRE WG 33-04, Taskforce 01, *Polluted Insulators, A Review of the current knowledge.*

[5] J. Stefanakis, E. Thalassinakis, K.Siderakis, D.Agoris, E. Dialynas, *Fighting pollution in the Cretan Transmission System- 25 years of experience*, Contamination Issues on High Voltage Installations (CIHVI), Conf, Heraklion Crete, Greece, April 2001

[6] Robert H. Stewart, *Introduction to Physical Oceanography*, Dept.of Oceanography, Texas A & M University

[7] A. Tsanakas, G. Papaefthimiou, D. Agoris, *An approach to the effect of rainfall on the pollution performance of insulators in island networks,* 11th ISH, August 1999, London UK

[8] K.O.Papailiou,F.Schmuck,Y.Voyatzakis, *Silicone Rubber performance in respect to Mediterranean environment*, CIHVI, Conf, Heraklion Crete, Greece, April 2001.

[9] Gerard Guyot, *Physics of the environment and Climate*, John Wiley and Sons, 1998

[10] J. Kim, K. Chaudhury, M.J. Owen, *Hydrophobicity loss and recovery of Silicone HV Insulation*, IEEE Trans on DEIS,Vol 6,No 5, October 1999

[11] H.Hilborg, U.W. Gedde, *Hydrophobicity Changes in Silicone Rubber*,IEEE Trans on DEIS ,Vol 6,No 5, October 1999

[12] J. M. Seifert, W. Hubl, *Hydrophobicity effect of silicone housed composite insulators and its transfer to pollution layers – Design and environmental parameters influencing the hydrophobic surface behaviour*, CIHVI, Conf, Heraklion Crete, Greece, April 2001

[13] S.M. Gubanski, A.E.Vlastos," Wettability of naturally aged Silicone and EPDM composite insulators", IEEE Trans on Power Delivery,Vol 5,No3,July 1990

[14] Hui Deng, R. Hackam, *Low molecular weight Silicone fluid in RTV Silicone Rubber Coatings*, IEEE Trans on DEIS,Vol 0, No 1, February 2000.