ESDD MEASUREMENTS IN THE POWER SYSTEM OF CRETE

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Abstract: *Insulator pollution is a significant issue for the operation of power networks as it may lead to flashovers and thus excessive outages. Therefore, determining a Site's Pollution Severity (SPS) is an important aspect of the procedures behind improved insulator selection, installation and maintenance. Specially designed measurements such as the Equivalent Salt Deposit Density (ESDD) are employed to determine SPS. In this paper, ESDD measurements conducted in 35 different towers located in 150kV Transmission Lines, in the island of Crete are presented and discussed in combination with previous network experience and environmental data. Crete is a Greek island located in the Mediterranean sea and portrays increased interest due to its particulate climate and development.*

Keywords: *high voltage, insulator, ESDD, pollution, SPS, transmission line*

1. Introduction

Pollution deposited on outdoor insulation is a significant problem for power networks as it can compromise their performance even to the point of a flashover [1, 2]. Deposits may be conductive or, more usually, may become conductive when wetted, thus permitting the flow of leakage current. This current causes uneven heating and drying and thus dry bands are formed, corrupting the current's flow. Under favorable conditions, discharges may bridge the bands and extend, ultimately leading to a flashover [1-3]. To suppress the phenomenon several actions can be taken such as cleaning, extending the length of insulators, using hydrophobic materials etc [1-3]. Therefore, defining the pollution level experienced on different parts of the network is a valuable piece of information for power companies as it can be used for network planning, insulator selection, maintenance, replacement etc [1-3].

A primary pollution source is the sea as the salt deposited on the insulators' surface becomes conductive when diluted in water (rain, fog drizzle etc) [1]. Thus, the distance from the sea is a key factor for the assessment of the pollution level, along with other geographical and environmental data [1-3]. The power network of the Greek island of Crete suffers intense marine pollution due to various factors such as the island's shape, the climate and the coastal development of the network [4-10]. Therefore, several remedies have been employed by the Greek Public Power Corporation in order to cope with the problem [4-12]. Further, several projects have been issued over the years to investigate and suppress the phenomenon's impact, in collaboration with Greek universities and institutes, with the latest step being the construction of TALOS High Voltage Test Station [13].

Among the actions taken was measuring the Equivalent Salt Deposit Density (ESDD) in different locations of the network. The ESDD measurement relies on collecting the pollution deposited on the surface of off-line insulators in certain intervals, diluting it in water and measuring the conductivity and temperature in order to define the equivalent amount of salt in mg per cm^2 of the insulator's surface [2]. It produces accurate results, takes into consideration the insulator's profile and it is a rather low cost technique. On the other hand, it demands that some off-line insulators are mounted and unmounted frequently, a procedure difficultly applied on a large scale. Therefore, and considering the local climate and previous experience, the procedure was slightly modified in order to be employed in a selection of 35 towers operating in different transmission lines of the Cretan system, over a 3 years time span. Results are presented and further discussed in this paper along with network and environmental data.

2. Landscape and climate

Crete is a Greek island located in the Mediterranean basin, as shown in Figure 1. It has a rather elongated shape and its coastline exceeds 1000 km in length.

Fig. 1 A map of Europe with the island of Crete shown in black

Crete is a mountainous island with three main mountain formations along the 260 km of length from east to west, as shown in Figure 2. Due to this, the most populated areas are near the coast and especially at the north side of the island, which faces the Aegean Sea. In addition, the usual wind direction is north northwest, which means that the salt deposition is more severe on the north side [5-8]. Wind in general is rather strong in Crete and this can be seen in the penetration of wind generated power which is probably the highest worldwide reaching 20% [12, 14]

Another important factor is the long dry period that usually starts in April and lasts until the end of October [5-12]. Strong winds also occur during the summer months resulting to highest deposition during this period [7]. Towards the end of the dry period, the deposited contamination gets exposed to increased levels of humidity thus resulting to a worst-case scenario regarding pollution [5-12].

Further, a significant difference between the west and the east part of the island should be noted. Not only are the winds stronger in the east part but rainfall is also considerably less. In fact, rainfalls in the west part are almost twice the ones in the east part [6]. These factors significantly suppress the pollution problem in the west part. This was obvious in the faults recorded in the transmission lines before the installation of composite insulators in the eastern part, which helped evening out the numbers. From 1978 to 1993, the number of faults per km was ten times more in the east part compared to the west part, even though eastern lines were cleaned twice each summer and were also overinsulated compared to the west [5].

2. Transmission Lines and ESDD measurements

The power network followed the island's development, and thus most substations and transmission lines are placed near the coast [4-12]. The position of all 150 kV Transmission towers (and thus, also the route of 150 kV transmission lines) is shown in Figure 2. The selected towers where ESDD measurements were conducted are shown in Figure 3 (figures created using Google Fusion Tables).

Fig. 2 The 150 kV transmission towers in Crete

Fig. 3 The towers where ESDD measurements were conducted

For the selection of towers, past experience from the operation of the network, environmental conditions as well as location issues were considered. Therefore, more measurements were conducted on the north and east part of the island and especially around the city of Heraklion, where a combination of severe marine and industrial pollution is recorded [9].

3. Set Up - Measurements

Strings of insulators were hanged (offline) from the metal structure of 150 kV Transmission towers as shown in Figure 4. They were placed in a slightly lower height compared to live insulators, in order to be easily and safely reached by the crew. Porcelain insulators were selected due to their superior endurance, as the measuring period should exceed at least one year. Cap and pin insulators of both disc and fog profile were placed as both profiles are used in the island’s transmission lines.


Fig. 4 A string of insulators (fog profile-porcelain) hanged (offline) from the metal structure of a 150 kV tower

Solutions of standard conductivity were employed in order to verify the measurements and to calibrate the conductivity meter, as shown in Figure 5. Measurements were recorded on site as shown in Figure 6.

Fig. 5 Calibration and accuracy verification using a solution of standard conductivity


Fig. 6 Measuring ESDD on site

Considering the above mentioned dry period, measurements were conducted once a year, towards the end of the dry period and before the rainfall period starts. Although standard procedure is to measure ESDD in smaller intervals, this was highly impractical in this case, due to the large number of measuring points and also considering the local environmental data. In fact, smaller intervals would be redundant during the dry period and the measured pollution would inevitably be lower after rainfalls starts due to their cleaning effect. It should also be noted that in order to cut costs, the measurements were conducted by the transmission line crew when the opportunity of other works in the area arose.

4. Results, Discussion and Future Work

The maximum ESDD value recorded over 3 years, was considered for each tower. To determine the Site's Pollution Severity (SPS) slightly different limits have been proposed by IEEE [15] and CIGRE [16], as shown in Table 1.

Table 1. SPS and ESDD values

SPS	ESDD value (mg/cm^2) (IEEE) [15]	ESDD value (mg/cm^2) (CIGRE) [16]
light	<0.06	<0.06
medium	0.06-0.10	0.06-0.12
heavy	>0.10	>0.12

A visualization of the results is portrayed in Figures 7 and 8. As shown, heavy pollution was recorded near larger cities located in the north and eastern part of the island (Heraklion, Rethimnon) but not near Chania which is the third larger city, but is located to the west. Further, lighter pollution was recorded to the areas that are located at the southern eastern part, however proximity to city pollution also seemed to make a difference in the case of Ierapetra (fourth largest city in Crete).

Comparing these figures some added remarks can be made. It can be seen that some measurements fell in the margin of 0.10 to 0.12 and therefore the corresponding SPS was considered "medium" in one case and "heavy" in the other. Further, neighboring towers produced results that fell in different SPS classes. This underlines the fact that such measurements should be considered as indications that are to be combined with past experience and objective data such as the distance from the sea or other pollution sources and environmental conditions.

Further investigation may optimize the results. For example, an important issue is the calculation of the area of the insulators' surface, which is used to calculate the final ESDD value in mg/cm^2. Several methods can be employed to calculate this value. In this paper, the area values were taken from the corporation's archives and they were calculated when the insulators were first purchased by dividing the insulator's area in minor parts. However, a new calculation of the insulators' area using computer aided design tools may improve the accuracy. Further, it should be noted that the measurements were conducted on both disc and fog cap and pin insulators. According to [17] a correction factor should be employed to correlate such measurements. However, the value of this factor has not been fully determined. Therefore, comparable ESDD measurements should be conducted on insulators of different profile, placed in the same location. For this purpose, suitable arrangements were recently made in TALOS High Voltage Test Station and concluding results are expected in 2015.

Fig. 7 Site Pollution Severity using the limits proposed by IEEE

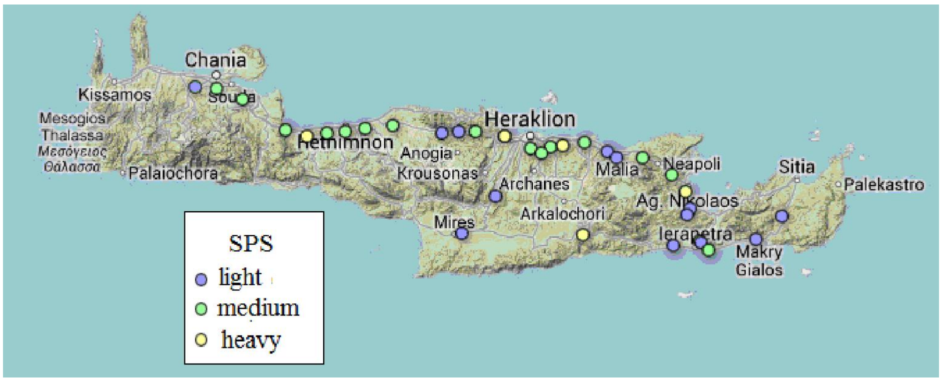

Fig. 8 Site Pollution Severity using the limits proposed by CIGRE

4. Conclusion

Mapping pollution is a complex procedure of significant interest to power companies. A Site's Pollution Severity (SPS) can provide valuable information to be exploited for insulator selection, maintenance and replacement. To determine SPS various factors should be considered such as proximity to pollution sources and local environmental conditions. The sea is considered a primary pollution source, as sea salt is carried by wind and deposited on insulators' surfaces. In locations where extended dry periods are recorded, contamination builds up during these periods which results to severe problems when wetting occurs. The Greek island of Crete provides an interesting site due to its peculiar climate and development. The power network is mainly coastal and suffers intense marine pollution. A dry period is recorded from April to October and there is also a diverse behavior between the northern and southern parts and also between the western and eastern part.

To cope with the problems the Greek Public Power Corporation S.A. and the Hellenic Electricity Distribution Network Operator S.A., have issued several remedies and also participated in several research projects. In this paper, ESDD measurements conducted on 35 different 150 kV Transmission Line towers are presented. Measurements were conducted through a 3 years period, using strings of insulators hanged offline from the metal structure of towers. The resulting SPS show a high correlation with the proximity from large cities, the coast and also with the weather experienced in different parts of the island, underlying the complexity of pollution mapping. The next research step would be to optimize the results using computer aided design and specially designed measurements conducted in TALOS High Voltage Test Station, constructed right next to the coast in Heraklion, Crete.

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