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Araştırma Makalesi - Research Article

Manyetik Alan Etkisi Altinda Polimerik İzolatör Performans Testi

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ÖZ

Çevresel ve elektriksel zorlayıcı etkiler enerji iletim dağıtım hattında yaygın olarak kullanılan silikon izolatörlerin yaşlanmasına sebep olurlar ve dielektrik performanslarını azaltırlar. Mekanik olarak taşıma kolaylığı, esnekliği ve hafifliği ile öne çıkan silikon izolatörler aynı zamanda yüksek elektrik direncine de sahiptir. Bu yalıtkanların yapısındaki herhangi bir bozulma, elektrik kesintilerine neden olarak ciddi finansal kayıplara yol açabilir. Enerji iletim-dağıtım hattı boyunca izolatörlerde, tellerden geçen akımın ürettiği manyetik alanın etkisi vardır. Bu alan, yalıtkan üzerindeki çalışma performansını değiştirecek bir etkiye neden olabilir. Bu çalışmada, silikon izolatörlerin çalışma performansını etkileyen AC manyetik alan, eğik düzlem testinde IEC 60587 ve ASTM 2303 standartlarına göre incelenmiştir. Ek olarak, üretilen bir elektrik alan ve kapasitif etki test edilmiştir. Numunelerin test süreleri, yalıtkan yüzeyinde üst elektrottan toprak elektroduna akan kaçak akım ve yüzey koşulları incelenmiş ve sonuçlar karşılaştırılmıştır.

Anahtar Kelimeler- Mineral Yağ, Pressboard, Kısmi Deşarj, Dielektrik, Yüzey Bozulması.

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Polymerıc Insulator Performance Test Under Magnetıc Fıeld Effect

ABSTRACT

The environmental and electrical stresses age silicone insulators commonly used in energy transmission-distribution line and reduce their performance. Silicon insulators, which stand out mechanically with their ease of transportation, flexibility and light weight, have high electrical resistance as well. Any deterioration in the structure of these insulators can lead to power outages, causing serious financial loss. On the insulators along the energy transmission-distribution line there is the effect of the magnetic field generated by the current passing through the wires. This field can cause such an effect that will change the working performance on the insulator. In this study, AC magnetic field effecting the working performance of silicon insulators was examined in inclined plane test according to IEC 60587 and ASTM 2303 standards. In addition, an electric field generated and the capacitive effect were tested. Test times of samples, leakage current which flows on the surface of insulator from top electrode to the earth electrode, and surface conditions were examined and results were compared.

***Keywords*- Mineral Oil, Pressboard, Partial Discharge, Dielectric, Surface Degradation.**

I. INTRODUCTION

Economic developments and the necessities in social life raise the problem of the cheap and reliable transmission of electrical energy. The renewal of transmission lines for the countries that have completed the industrial development is vital while that is the expansion of the transmission line network for the developing countries thereby the electrical engineers focus on these important issues.

The insulating materials used in the electrical industry are divided into five groups. These are gases, vacuum, liquids, solids and composites. Solid insulating materials are widely used in electrical power systems. Insulators which have been widely used since the beginning of this century are made of glass, ceramic and porcelain, while today, polymeric solid insulators join to these solid insulators and have taken their place in the electrical insulation industry. Silicone insulators are one of the commonly used polymeric insulators. Silicone insulators are more preferred than other solid insulators due to their flexible physical structure, high mechanical strength, electrical resistance to arcing and light weight. [1-2]. Although it is very light and flexible material, when it is subjected to long-term stresses, the formation of electrical conductive bridge and surface erosion in silicone insulation materials accelerate. [3-4].

Silicone insulator degradation is widely studied for understanding discharge behavior. Joseph Vimal Vas and M. Joy Thomas discussed how positive and negative dc coronas affect the surface degradation process of silicon rubber nanocomposites. [5]. In their study they have concluded that positive dc corona is less hazardous to silicon rubber sample insulator performance when compared to negative dc corona. Rakesh Kumar and Nandini Gupta investigated how silicone rubber filled with Barium Titanate ($BaTiO3$) influences surface deterioration and tracking failure for the silicone rubber interface [6]. They observed that the surface roughness of the non-filled silicone rubber was higher than that of barium titanate filled silicone rubber. Therefore, non-filled silicone rubber showed bad performance during surface discharge and erosion tests. T. Tokoro evaluated the effects of temperature and surface roughness on the hydrophobic properties of silicone rubber samples filled with different values of alumina trihydrate and silica [7]. When the surface temperature of the silicone rubber increases, the hydrophobic indexes are developed according to Tokoro's work. Fatin Liyana Muhamedin et al. conducted a simulation study by using Finite Element Method for investigation effect of electric field on polymer insulator dielectric performance. It is applied four different voltage stresses for 2.5 kV, 3.5 kV, 4.5 kV and 6.0 kV, respectively. It can be seen in the study that the shape of the contaminant liquid path affects the leakage current density and electric field distribution on the insulator’s surface [13].

In this study, it is examined the influence of magnetic field effect on the silicone rubber insulators by the help of inclined plane experimental test. The tests were carried out in accordance with the Inclined Plane Tracking Test Method Standard (IEC 587). During the experiments, samples were first tested under without magnetic field and electric field. Then, the samples were tested under only magnetic field and at last electric field effect added to magnetic field. The deterioration characteristics of the silicone insulator sample under different conditions were investigated.

In this study, silicone rubber was used to represent polymeric insulators because of its ease of production and cheapness. In order to determine the deterioration characteristics of the material under artificially created external factors during the studies, the tests were carried out in accordance with the test method on the inclined plane surface.

The studies were conducted under three different conditions. In the first, all samples were prepared in the same conditions without any electrical or magnetic field effect, and the aging effect on the silicone material was examined by keeping all external factors constant in the test. In the second step of the studies, the silicon material was investigated under the effect of magnetic field. Finally, the sample was examined under the influence of together of magnetic field and electric field.

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II. EXPERIMENTAL SET-UP

Silicone insulation materials are affected adversely by various aging mechanisms throughout their service life [8]. Many factors damage the dielectric property of the structure of insulator and result in breakdown. The time of concluded with breakdown may take a long time, it is difficult to reach a conclusion about the quality of the material by observing insulator case during its working life. In order to solve such problems, accelerated test methods were performed under laboratory conditions [9].

A. Inclined Plane Test

The Inclined Plane Test was first performed in 1961 and the ASTM D2303 standard was announced in the USA to determine these test conditions in 1964. In the following years, a new standard was developed as named the IEC 587 standard. Although there are small differences between ASTM and IEC tests, they are basically based on the same theory [10-12]. All tests performed in this study were performed in Inclined Plane Test. It is examined at the end of the test whether the insulator which is under high voltage electrical stresses is suitable for using in terms of dielectric performance or not [14,15]. Hence, according to the test results a good insulator provide a strong dielectric capacity to high voltage transmission and distribution system for outdoor application [16]. Because this is the key factor for power reliability which indicates sustainable energy transmission.

Figure 1 shows the placement of the insulator in the experimental setup that we used to examine the aging process of the samples in this study. It is regulated in accordance with IEC 587 standards [10]. All electrodes used on the test sample are stainless steel and have corrosion resistant. An eight-ply Vatman-type filter paper is used to ensure a steady flow of pollutant liquid along on the surface between the high-voltage and the earth electrode. The high voltage electrode is on the top and the earth electrode is on the bottom. A pre-resistor at a resistance level of 33 kΩ is used before the high-voltage electrode. High voltage transformer is supplied with an auto transformer called variac that it can be changed its value gradually.

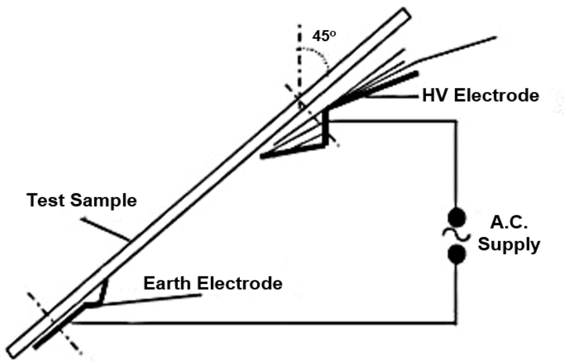

Figure 1. Test Sample Placement

The rate of pollutant liquid flowing over the test sample was set to 36 ml / h. 0.1 ± 0.002% NH4Cl (Ammonium Chloride) and 0.2 ± 0.002% Triton-X100 are added to the pure water used. Since the test specimen is at an angle of 45º to the vertical, the Triton-X substance is incorporated into the solution to allow the liquid flow throughout the entire surface. By placing two 47 kΩ (2x100 watt) resistances before the earth electrode, the leakage current caused by discharges on the surface of the test sample is prevented. Schematic representation of the test setup is given in Figure 2.

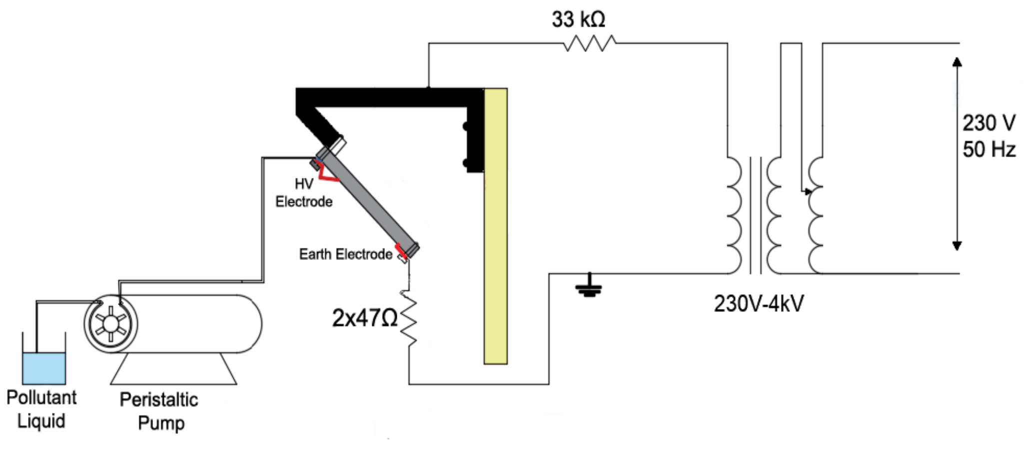

Figure 2. Schematic Representation of Experimental Setup

The grid voltage is adjusted between 0-220 V with the help of variac and the high voltage transformer with 220/40000 V turn ratio is supplied. Thus, the high voltage value of 4 kV is get by the help of transformer. The transformer output has a high voltage resistance of 33 kΩ. After this step, voltage is applied to the electrodes on the silicon test sample. Two 47kΩ (2x100watt) resistors were added to the test device to prevent sudden spikes caused by discharges on the surface of the test specimen.

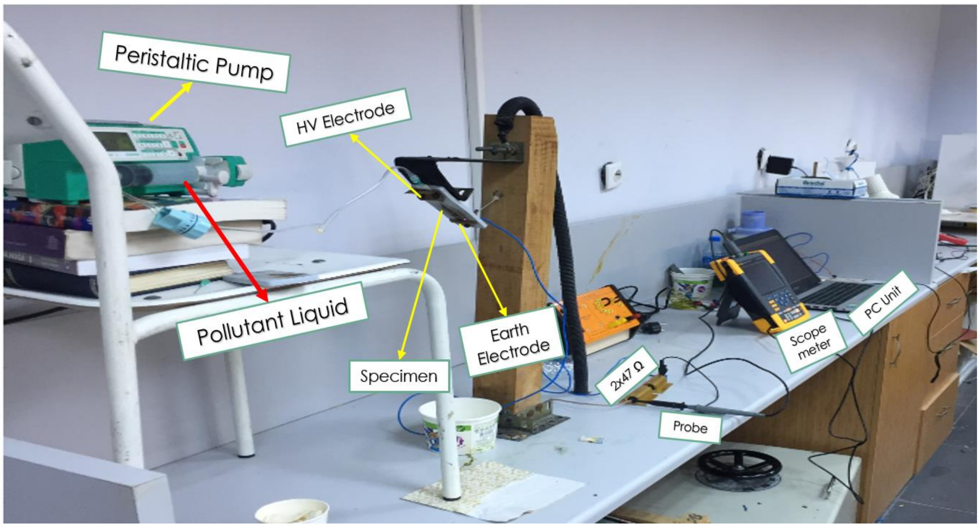

Figure 3. Test Set-up

As shown in Figure 3, current signals are taken over the resistor and read from Fluke 190-504S 500MHz oscilloscope channel. The read signals are transmitted to the computer simultaneously. In addition to the magnetic field effect, the electric field effect was also investigated. Figure 4 shows a photograph of this device.

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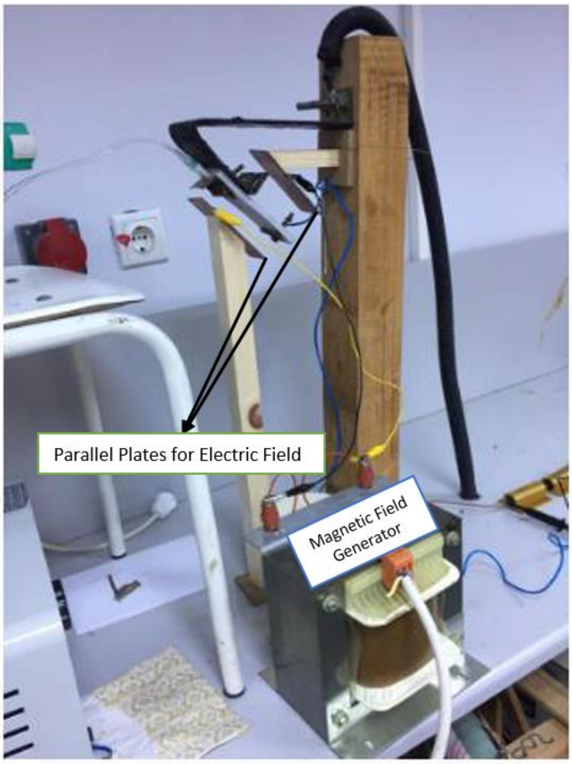

Figure 4. Magnetic and Electric Field Generator

As shown in Figure 4, the magnetic field is generated by a different transformer. The magnetic field was obtained from a measuring transformer placed near the test apparatus with a turn ratio of 220/1000 V and a power of 1 kVA. The magnetic field affecting on the samples was measured with the EXTECH 480826 electromagnetic measurement device. The measured value was recorded as 110mG. This value was measured exactly from the point closest to the surface area of the sample. The electric field is get by applying 1 kV voltage to two parallel copper plates with the dimension of 50x200x1 mm. The sample is between these two copper parallel plates during the last section of experiment.

III. RESULTS

Experimental studies were carried out in the laboratory environment in accordance with IEC 587 test standards on the inclined plane test set-up. Experiments were conducted in three different conditions.

1. Experiments without any external effects
2. Experiments under the influence of magnetic field
3. Experiments conducted under the influence of both magnetic field and electric field

The insulation properties of the material were evaluated according to the criteria determined by the standard. The test results are based on the following two criteria.

Criterion.1-The leakage current passing over the sample exceeds 60 mA for 25 ms.

Criterion.2-The length of the tracking between the two electrodes on the sample reaches or exceeds 25 mm from the ground electrode.

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A. Experiments without Any External Effects

In this part of the study, all external factors on the samples and in the laboratory environment were kept constant when there are not exist any magnetic and electric field. The times of tracking formation on the sample was determined by using 4 kV voltage level and 36 ml / hour pollutant liquid flow rate. The ambient temperature was measured as 23 ° C under laboratory conditions. Figure 5 shows a photograph of the surface condition of the sample after the experiment.

Figure 5. Tracking Formation without Any External Effect

Sample 1 was tested for 4 hours and 16 minutes on inclined plane test set-up under 4 kV voltage level condition. During the first 2-hour test period, the sample surface was darkened and carbonized. The leakage current value was 38 mA when the sample was under test. Based on the criteria of standard, it is considered successful in terms of criteria-1 but unsuccessful in terms of criteria-2. As a result, this sample failed for test. More than 25 mm tracking length is observed the sample surface. The sample mass was 45.74 grams before the test and 42.9 grams at the end of the test. Total eroded mass was calculated as 2.84 grams. The best and the worst points respectively in dielectric performance for two minutes of the leakage current of sample 1 measured by oscilloscope are shown in Figure 6.

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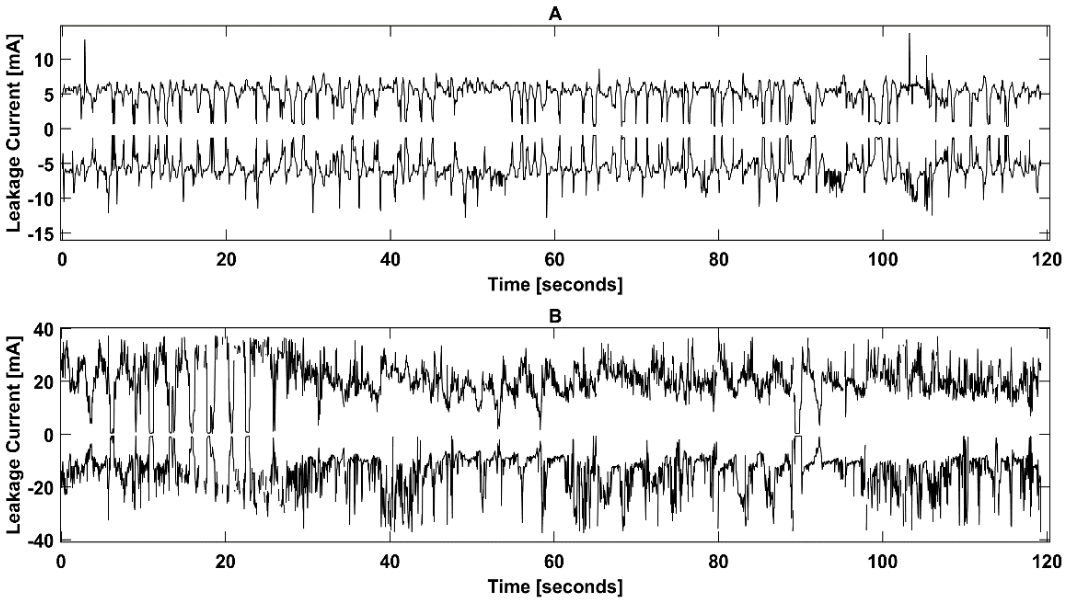

Figure 6. Leakage Current of Sample 1, A: Best Performance Ranges, B: Worst Performance Ranges

As the test time progresses, the leakage current gradually increases due to the deterioration of the surface that means the dielectric property of the surface decreases. As seen in Figure 6 (B), the leakage current value increased to 38 mA levels.

B. Experiments Under the Influence of Magnetic Field

The magnetic field value of 110 mG was kept constant on the sample under the influence of magnetic field. Sample 2 was tested under the influence of a magnetic field on the inclined plane test for 4 hours and 8 minutes. The leakage current value reached 41mA while the sample was under test. Based on the criteria, it is considered successful in terms of criteria-1 while unsuccessful in terms of criteria-2. As a consequence, the sample failed under this test set-up. The mass of sample before the test was 44.45 grams and 42.3 grams at the end of the test. Total eroded mass was calculated as 2.15 grams. In Figure 7, photograph of sample 2 are given after test.

Figure 7. Tracking Formation with Under the Influence of Magnetic Field

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The best and the worst points respectively in dielectric performance for two minutes of the leakage current of sample 2 are shown in Figure 8.

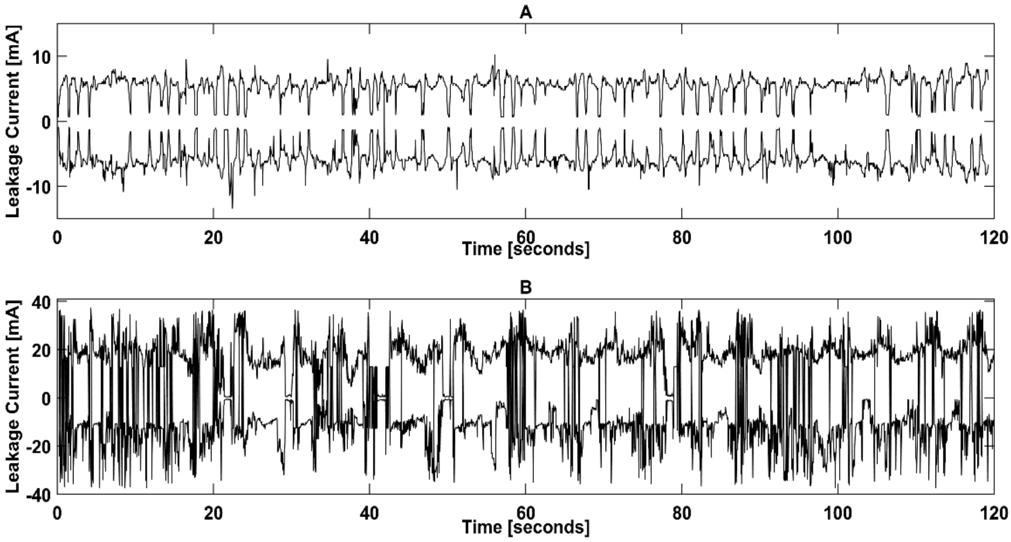

Figure 8. Leakage Current of Sample 2, A: Best Performance Ranges, B: Worst Performance Ranges

Under only the magnetic field, the leakage current signal more distorted when compared to the any without effect as shown in Figure 8 (B).

C. Experiments Conducted Under the Influence of Both Magnetic Field and Electric Field

In the test apparatus, the distance between two parallel plates was set to 10 cm to create electric field. A voltage at 1 kV was applied to the one of the parallel plates and the other was held at earth voltage. From the reference of E = V / d formulation, the electric field value between the two electrodes was calculated as 100 V / cm. The magnetic field on the sample is 110 mG as in the previous experiment. The sample was tested under these conditions. Figure 9 is a schematic representation of this test apparatus. Figure 10 shows a photograph taken during the experiment.

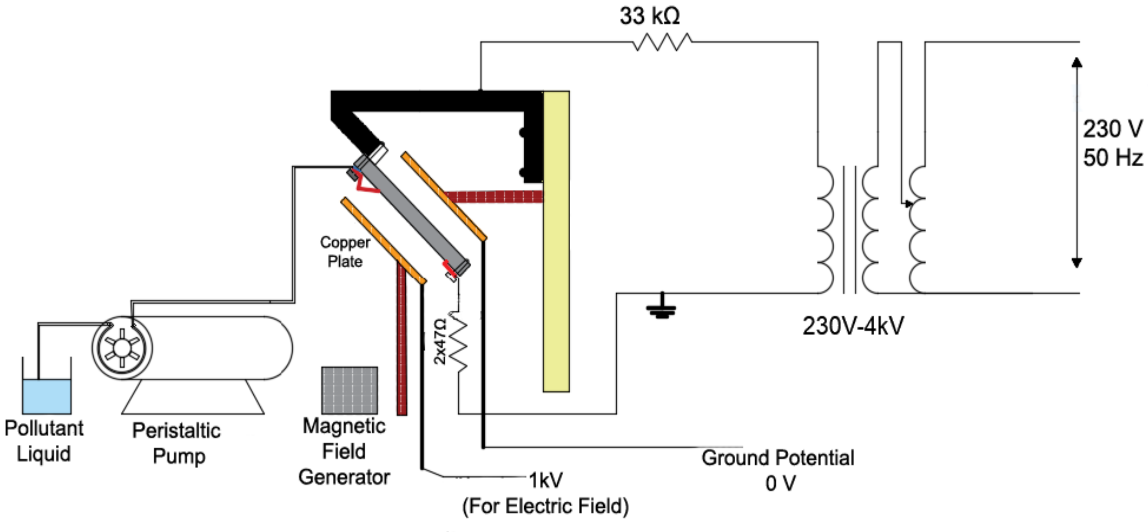

Figure 9. Schematic Representation of the Experimental Setup Under the Influence of Magnetic Field and Electric Field

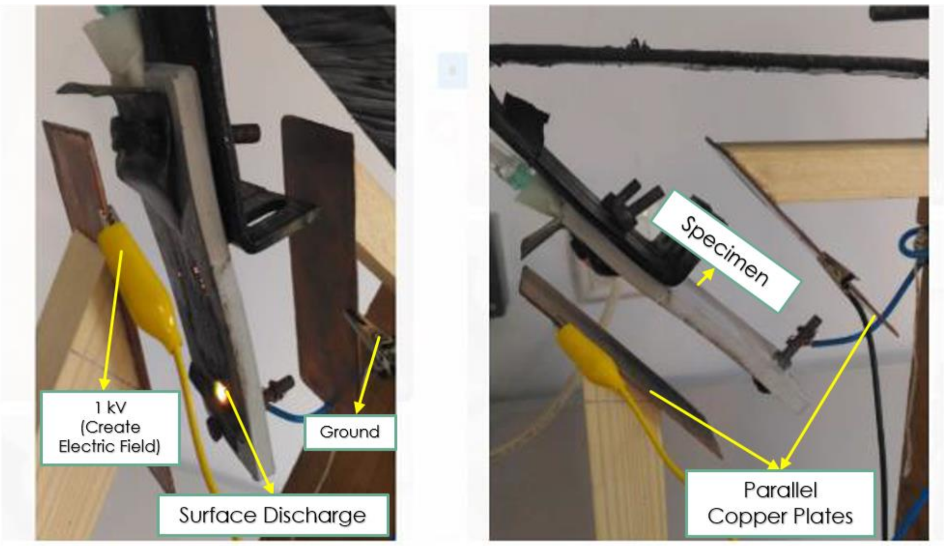

Figure 10. Experimental Set-up Under the Influence of Magnetic Field and Electric Field

Sample 3 was tested under the influence of electric field and magnetic field on the inclined plane test for 5 hours and 6 minutes. The leakage current value was measured as 39 mA while the sample was under test. Figure 11 shows the surface condition of the sample 3 after this test.

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Figure 11. Tracking Formation on Silicon Sample Surface Under the Influence of Electric Field and Magnetic Field

Based on the criteria, it is considered successful in terms of criteria-1 and unsuccessful in terms of criteria-2. As a result, the sample failed under test. The mass before the test was 44.5 grams and 42.4 grams at the end of the test. The eroded mass was calculated as 2.1 grams.

The leakage current signals of sample 3 are shown in Figure 12 when it has of the smallest and highest values for two minutes.

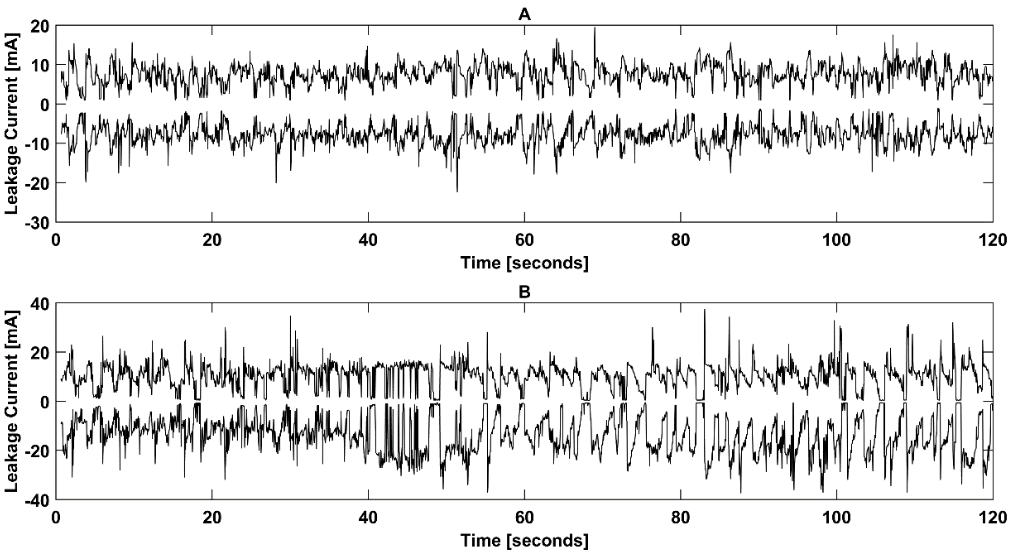

Figure 12. Leakage Current of Sample 3, A: Best Performance Ranges, B: Worst Performance Ranges

A graph showing the comparison of eroded mass, test time and tracking length of the samples is given in Figure 13.

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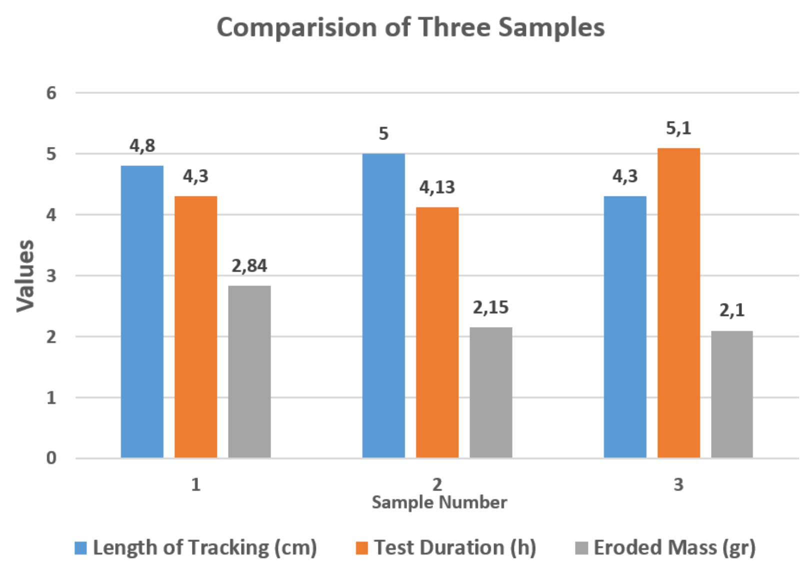

Figure 13. Comparison of Eroded Mass, Test Time and Tracking Length of the Samples

As can be clearly seen in the Figure 13, only the magnetic field effect has changed the parameters in the figure above. Also, changes were observed when the electric field effect was included.

IV. CONCLUSION

In the experiment conducted under the influence of electric field and magnetic field, the formation of carbonized pits on the surface of the insulating material is wider than the samples of other experiments, but the cavities on the surface are less deep. The lifetime of the silicone material decreased with the effect of magnetic field. When electric field is included in external influences; even if the electric field makes the energy flow more uniform on the surface and prolongs its service life, the overall life of the material is shortened. When the insulating materials are compared the lower mass loss is resulted the less depth cavities. It is observed that the uniform electric field makes the energy flow on the insulator more balanced based on the surface darkening. Unlike previous experiments, surface tracking formation took a rectangular shape. The shape of surface tracking is also an observer for electric field distribution on the insulator's surface. This is the future work of us for determining the performance of insulator by examining the electric field distribution.

Hence, it should be observed carefully while the performance of an insulating material is evaluating under what kind of electric and magnetic field. Especially in view of high voltage and high current cables are get underground, the effects of these cables on each other will be tried to put forward in future Works.

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