Influence of Tropical Environment on Electrical Properties of Electrical Insulation Materials

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Abstract. The development of optimal electrical insulation materials in the tropics continues. One of the development models is to look for fillers that allow it to be mixed with insulating materials (polymers, ceramics, and glass). This study aims to obtain the properties of electrical insulation materials in the form of polymeric materials (silicon rubber) which are filled with fly ash (coal-fired power plant waste) so that it can be used as a high-voltage electrical insulator. The activity that has been carried out was testing the performance of electrical insulating materials filled with fly ash under conditions under high electric fields and tropical environments. The research was conducted at the Electrical Engineering Building, Hasanuddin University, Makassar City, Indonesia. The performance evaluation of electrical insulation materials (silicon rubber plus fly ash) refers to the results of measurements of water diffusion characteristics and relative permittivity characteristics. The results of the study were in the form of information about the feasibility of coal-fired power plants to be used as fillers for electrical insulators in tropical environments. The results of this study are Fly ash added to silicone rubber to improve the electrical properties of the insulating material.

1. Introduction

Isolator is a material that is used with the aim to be able to separate the parts that are voltage with parts that are not voltage. Electrical insulators are widely used in almost all electrical equipment ranging from generators, transformers, electrical power distribution systems and even electronic devices. Generally, insulators that are often used in electricity networks in Indonesia are glass and porcelain ceramic insulators. This material has a disadvantage if it operates in humid conditions, because it has water absorbing properties, namely the contact angle of water is at a level less than 30°, this condition will get worse if it is in the field of work that is contaminated by natural conditions open as a seafront or industrial area, which results in a small amount of contact with the surface material and water droplets.

The phenomenon of the performance limitations of the insulating material referred to above, is very inviting the guts of high voltage equipment experts, so in the last few decades researchers have begun to develop types of insulators from polymer materials, such as Silicone Rubber (SIR). Silicone rubber material has the advantage of being able to resist water [1], besides that it can transform the hydrophobic nature of the material which is being affected by pollution due to the open natural conditions that it passes [2]. The ability of an insulator to function properly, depends greatly on the state of the surrounding environment (air pressure, humidity, temperature, rain and pollution) [3, 4].

Despite various advantages, until now the use of silicone rubber insulators in some countries is still limited, such as Indonesia because of the high production costs of silicone rubber insulators, so that
many researchers have optimized materials that can be mixed with silicone rubber, especially in the case of filler material concentrated on silica (SiO$_2$) and alumina (Al$_2$O$_3$) [5].

Currently looking for a source of filler is not easy, so technology is needed to get the filler. So the research continues on the search for possible filler sources. One source of filler material that can be utilized as an alternative filler in silicone rubber insulators is coal fly ash, where coal fly ash contains chemical elements such as silica (SiO$_2$) and alumina (Al$_2$O$_3$).

Indonesia is a tropical region. The use of silicone rubber as an insulating material must be resistant to exposure to various factors of high-intensity tropical climate such as UV (ultra violet) radiation from the sun around 12 hours during the day, air temperature between 16-35 °C, relative humidity close to 100% between early morning until morning and high annual rainfall between 40-500 mm. These factors will simultaneously hit the silicone rubber insulator that is installed outdoors. So that this paper contains the results of research in the form of experimental studies of silicone rubber performance filled with fly ash conditioned in the tropics.

2. Research Method

2.1. Types of research
This paper is based on the results of experimental studies to test and analyze the feasibility of fly ash as a filler of silicone rubber insulating materials, especially high voltage electrical insulators. The location of the study was carried out at the Electrical Engineering Department of the University of Hasanuddin High Voltage Engineering.

2.2. Raw material and test material making proses
The materials used in this research are coal fly ash, Silicon rubber RTV 683. Fly ash or coal fly ash is used as filler for silicone rubber insulation material. Fly ash is meant here is the residue from burning coal in a steam power plant (coal-fired power plant waste) in the form of smoke or dust that comes out through a gas exhaust pipe and deposited by electrostatic precipitators. The coal fly ash used in this study was taken directly from the silo of Tonasa coal-fired power plant. The content of silica (SiO$_2$) and alumina (Al$_2$O$_3$) was 59.64%. Silicone rubber used in this study is polydimethylsiloxane with type RTV (Room Temperature vulcanization). Silicone rubber branded silicone rubber RTV 683.

The test material is made in two types, namely silicon rubber test material without filler material called MATERIAL-0, and a test material in the form of a mixture of silicone rubber with fly ash called MATERIAL-30, where this composition fly ash 30%. The process of making material test material that will be tested consists of 4 stages, namely: mixing, air bubble repeating, printing of test materials, removal of water content in the test material.

2.3. Outdoor testing
The results of the manufacture of test materials will then be tested for performance under exposure to the natural tropical climate. Analyze and characterize its properties using various measurement methods as described in the previous section. Parameters are measured every day after being burdened with a natural tropical climate, which are sample weight and relative permittivity. This percentage of water diffusion measurement is intended to see the state of water absorption in the material, where the change in weight as a function of aging is an indicator of the amount of water absorbed by the test material based on the percentage of water absorption. While the measurement of dielectric constants is intended to give an overview of the behavior of the silicone rubber dielectric properties to the environmental conditions [6].

3. Result and Discussion

3.1. Meteorological data
Tropical climate data in the form of relative humidity, air temperature and UV radiation on the Hasanuddin University campus and its surroundings are presented in Figures 1 and 2. From the beginning to the 40th day there was a fluctuation in daily average humidity from 60.2% to 93.0 % as shown in Figure 1. Variations in daily average air temperature changes are shown in Figure 1. Minimum daily average air temperature is 24.8 °C and maximum is 32.7 °C. This change in temperature is caused as a result of the initial change of the rainy season to the dry season where the occurrence of a torrential rain is quite heavy.

![Figure 1. The relative humidity and air temperature of research location](image1)

In Figure 2 shows the intensity fluorescence curve of UV radiation from the sun in Makassar. From the first day of the study to the 40th day of the study, the recorded average daily UV radiation intensity fluctuated from 0.02 watt/m² to 5.9 watt/m². This condition is the beginning of the dry season, where the density of clouds is lower than the rainy season.

![Figure 2. The UV radiation of research location](image2)

### 3.2. Water diffusion measurement result in test material

Figure 3 shows the change pattern curve for the percentage value of water diffusion of Material-0 and Material-30 test materials. The first day of aging, the percentage value of MATERIAL-0 water diffusion of 0.75% and MATERIAL-30 of 0.36% showed an increase in weight due to water uptake in the test material. On the first day of aging, the weight increase of the MATERIAL-0 test material was slightly higher than that of the MATERIAL-30 test material. This increase is due to absorption of water by the test material from the humidity of the surrounding air and rain. The process of diffusion of water into the MATERIAL-0 test material and MATERIAL-30 until close to saturation in the open air only lasts less than one day. The speed of diffusion of water into silicone rubber until saturation matches the results of the research by soaking the silicone rubber test material into 50 °C water [6] until the increase reaches saturation weight which only takes 2 days. This illustrates that the water molecule does not get much free space in the test material.

On the second day of aging, the weight of the MATERIAL-0 test material decreased slowly until the 40th day, where the water diffusion percentage value of 0.75% decreased to -0.47% (the test material became lighter). This weight reduction when associated with climate factor curves (Figures 1
and 2) shows that from the first day to the 40th day the climate shifts to the dry season where the average temperature in the environment is around an average of 28.9 °C. This gives an indication that the water absorbed by the MATERIAL-30 might evaporate or deabsorb during this time. The process of absorption and deabsorption of water in polymeric materials has been proposed by several researchers as a physical process. The MATERIAL-0 weight change pattern curve does not appear to follow the climate curve pattern (humidity and temperature) that occurs. Weight loss in MATERIAL-0 was affected by exposure to UV radiation from the sun.

On the contrary the MATERIAL-30 test material undergoes heavy changes following the pattern of daily climate change, where the change in weight starts from the first day until the 40th day is almost constant. On the first day the percentage of water diffusion value of MATERIAL-30 was 0.36% and on the 40th day the percentage of water diffusion value of MATERIAL-30 was 0.43%. A slight increase in weight occurs in MATERIAL-30, this indicates that the MATERIAL-30 test material is not affected by UV exposure from the sun.

3.3. Relative permittivity measurement
The relative permittivity values of MATERIAL-0 and MATERIAL-30 test materials are presented in Figure 4. The relative permittivity of MATERIAL-0 and MATERIAL-30 after the first day (day 2) of aging showed a sharp increase (MATERIAL-0 = 1.81 and MATERIAL-30 = 2.09) where previously in the initial conditions, MATERIAL-0 was 0.37 and MATERIAL-30 was 0.70. After that, in the following days the relative permittivity value decreased until the 10th day ie MATERIAL-0 of 1.06 and MATERIAL-30 of 1.23. Furthermore, on the 11th day the relative permittivity values of both test materials increased, namely MATERIAL-0 of 1.44 and MATERIAL-30 of 1.43. On the 12th day the relative permittivity value of the MATERIAL-0 test material decreased again until the 13th day, where the MATERIAL-0 value was 1.18. The relative permittivity value of MATERIAL is 0 until 40th day (MATERIAL-0 = 1.10). For MATERIAL-30 which on the 10th day has a relative permittivity value of 1.23, it rises to a value of 1.46 on the 13th day. Next down and saturation until the 40th day (MATERIAL-30 = 1.28).

The influence of climate on the relative permittivity of test materials exposed to this natural tropical climate causes the relative permittivity curve to tend to follow the daily climate pattern. This can be seen in the pattern of daily humidity and daily temperature which is almost the same as the daily pattern of relative permittivity of MATERIAL-0 test material and MATERIAL-30. And, the effect of daily UV radiation exposure also dominates because of a decrease in the relative permittivity value at the beginning of the measurement.
4. Conclusion
The filler added to silicone rubber is to improve the electrical properties of tropical climate environmental stresses. In the natural tropical climate, the impact of filler on silicone rubber for weight changes (percentage of diffusion of water) is to maintain the weight of silicone rubber as shown in MATERIAL-30 which is not like non-filler silicone rubber (MATERIAL-0), where the weight is getting decreased due to exposure to UV radiation from the sun. For the relative permittivity parameter, the role of coal fly ash filler on silicone rubber is to maintain the relative permittivity value, this is evidenced by the formation of the same pattern and the almost close value with non-filler silicone rubber (MATERIAL-0). Changes in the relative permittivity value of the test material are strongly influenced by climate and UV radiation from the sun.

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