International Journal of Engineering and Science Applications

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ISSN: 2406-9833 @2016 PPs-UNHAS

Impact of Water Absorptionon Dielectric Properties and Breakdown Voltage of Polymer Epoxy and Xlpe

S. Manjang[1], M. Arief[1], G. Duma[1], Syafaruddin[1], T. Waris[1]

[1]Department of Electrical Engineering, Hasanuddin University
Jalan Perintis Kemerdekaan Km.10 Tamalanrea, Makassar 90245

salamamanjang@unhas.ac.id; salamamanjang@gmail.com

ABSTRACT

Polymers have become an alternative option replaces the high voltage insulation materials made of ceramic and glass. The research aims to determine the dielectric characteristics of polymer insulation after water immersion for a certain period of time. The testing was conducted on two types of polymer insulation, namely the epoxy resin and the cross-linked polyethylene cable. The materials were soaked in water with the temperature of 50^{o}C and the measurements were taken every 24 hours for 38 days. The measurements were taken from the mass materials, the relative permittivity and the contact angle. Then, the breakdown voltage measurement and the analysis of the chemical structure of the polymer insulation material were measured when the material had reached saturation state. The research results indicate an increase in the value of the mass and the relative permittivity of the material after the immersion. Such increase level is due to the absorption of the water through the filler in the polymer insulating material. The contact angle value of the epoxy resin material ranged from 56^{o}-80^{o}, which was classified in the category of partially wet. The XLPE material has the value of the average contact angle of above 90^{o} and in the category of hydrophobic. The breakdown voltage value has decreased by 50% in average from the voltage limit before the immersion. The water absorption process has an effect on the decrease of the dielectric strength of the insulating polymer material.

Keywords: polymer insulator, dielectric characteristics, breakdown voltage, water absorption.

Article history: Received 2 May 2016, last received in revised 20 May 2016

1. INTRODUCTION

Insulators in electric power systems play an important role as a separation device between parts of system voltage and no voltage as well as retaining and supporting the cable line [1]. In general, insulators that is used in electrical power systems in Indonesia ranging from medium voltage, high voltage and extra-high is made of ceramic and glass insulators [1].

Various studies have revealed that in general the failure of insulators causes high losses in power systems. The losses can be in two aspects, namely surface aspect which leads to the emergence of leakage current surface and bulk aspects with lower dielectric properties that make it easy the insulator breakdown after lightning strikes or through switching process [2]. The bulk aspect of insulators which is commonly made of ceramic and glass is quite stable against aging, but its surface might be wetted by fog, dew or rain because they have high surface energy. The nature of the insulator surface is easily wet (hydrophilic) for ceramic insulator/glass. This

might be disadvantageous when this type of insulator is installed at high humidity and polluted areas, such as industrial site, urban area and coastal location. The potency of corrosive material is high and it increases leakage current that trigger the flashover on insulator surface [3].

However, recently there is fast change and development of insulating materials as the outside post insulators for high voltage equipment. The emergence of polymeric materials in high voltage insulation technology has replaced the traditional insulation material made of ceramic and glass. These conventional materials are increasingly unprofitable usage due to the high mass density of ceramic and glass, fragile and the losses getting bigger that cause high cost of construction and maintenance in electric power network [4].

Unlike the traditional insulator materials, the polymer insulator has advantages in dielectric properties, resistivity volume, thermal properties, mechanical strength and also lightweight [5]. In addition, the polymer insulator has a water-repellent (hydrophobic). Even it has capability in recovery and transfer to the hydrophobic nature of the pollution layer to be hydrophobic layer [6]. Hydrophobic properties and transfer capability of pollution layer is the most important property of polymer insulation for outdoor installation where the weathers are identified with moist, wet or rain. The insulator property will not give any chances to forming the continued water layer so that the conductivity of insulator surface remains low [7].

Despite the various advantages of polymer insulator, the composed material is a synthetic material that is generally susceptible to climate, pollution and exposure to high electric field. The influence of high humidity and rainfall could lead to erosive surface of the polymer insulator. Partial pressure difference between the materials and environmental conditions allows the absorption process [8]. The amount of water is absorbed and the speed of absorption depends on the outside air humidity and ambient temperature [9]. In addition, the decrease in surface properties can be seen by the disappearance of hydrophobicity, the occurrence of intense cracks and erosion in insulator surface. These phenomena are followed by the increase in the surface leakage current which can shorten the life time of the insulator material.

For these reasons, the study aims to determine the dielectric characteristics of the insulating polymer in a particular time frame. The methodology is focused on soaking the material in water with temperature of 50°C. The field measurements were taken every 24 hours for 38 days.

2. RESEARCH METHODOLOGY

The research was conducted in two laboratories, i.e. the laboratory of physical chemistry, Department of Chemistry, Faculty of Science, Hasanuddin University. In this laboratory, water contaminant of material sample is reduced before soaking the material and laboratory of high voltage engineering, Department of Electrical Engineering

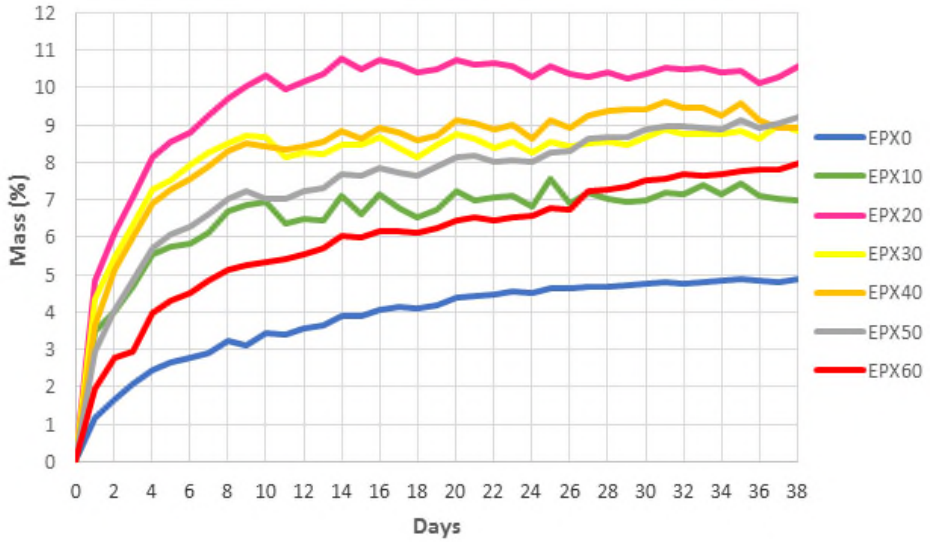

Fig. 1. Water absorption on epoxy resin

Hasanuddin University to conduct the immersion and breakdown voltage testing.

The laboratory experiment is conducted to investigate the effect of water absorption on the insulating polymer dielectric properties and breakdown voltage testing after immersion insulating polymer. Both testing are carried out with the direct measurement of the insulating polymer during the immersion process. The sample type of insulation polymer is silicone rubber, epoxy resin, and cable XLPE (cross-linked polyethylene) of which two are made in the laboratory by using room temperature vulcanizing (RTV). Samples were soaked in distilled water of 50^{o}C where each sample is inserted into different containers. Then, the measurement of mass, capacitance and the contact angle are taken for each sample every 24 hours. The process of data collection was conducted for 38 days.

3. RESULTS OF EXPERIMENT

From the experiment results regarding the water absorption of polymer insulator with different epoxy resin composition of the fly ash, it can be seen that the minimum water absorption on the pure composition of fly ash is equal to 4.8268%. Meanwhile, the maximum water absorption occurred in the 20% composition of the fly ash to the weight of the epoxy resin is amounted to 10.4435%. In general, the addition of fly ash into the epoxy resin will increase the water absorption on epoxy resin insulator (Fig. 1).

The testing result of the water absorption on 20kV XLPE cable shows the percentage of the highest water diffusion is equal to 0.3029% which is much lower than the epoxy resin polymer. It is due to the sample insulator has the good quality standard specified by the manufacturer. The measurement result can be seen in Fig. 2.

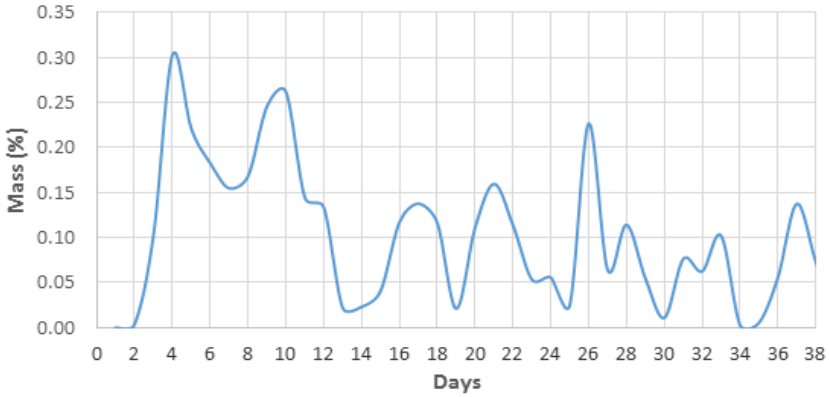

Fig. 2. Water absorption on XLPE polymer insulator

The contact angle measurements have been conducted in this experiment. From 7 types of samples, the epoxy resin insulator material has an average contact angle with the range from 56^{o} to 80^{o}. It can be concluded that all samples are in the category of partially wet. Meanwhile, the contact angle values XLPE polymer obtained before immersion is equal to 105.20. However, after soaking for 38 days, the value of the contact angle of XLPE polymer decreased to 77.30. In this respect, the results of contact angle measurements indicate that the XLPE sample is also in the category partially wet.

The relative permittivity of epoxy resin material relationship with the filler concentration shows the linear average value. The experiment is demonstrated by taking samples with having an average value of the relative low permittivity EPX0 of 7.0661and samples having the average value highest relative permittivity EPX60 of 12.7976. During the 38 days of immersion, it is obtained that the increase in permittivity level due to the influence of a much larger percentage of water absorption in the material so that on average each test sample reaches the maximum value of permittivity percentage (Fig. 3).

Measurement of relative permittivity on XLPE material insulator is conducted on XLPE samples for the medium-voltage underground cables. Before soaking, the first

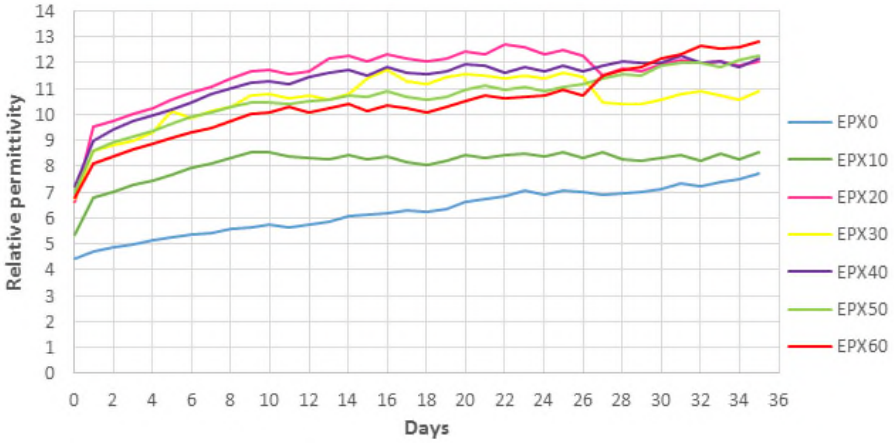

Fig. 3. Relative permittivity of polymer epoxy resin insulator.

measurement of capacitance values of testing materials is performed and it was obtained the average value of 0.67. When compared with the sample mixture of EPX0 without fillers, the relative permittivity value XLPE0 much smaller. Fig. 4 indicates that the XLPE polymer has a dielectric constant better than epoxy polymer.

Finally, the breakdown voltage test is conducted on the 7 samples of epoxy resin. From the obtained data measurements, the level of breakdown voltage decreases significantly after soaking the material for 38 days. The decrease in the breakdown voltage level is greatest during the experiment with the fly ash filler percentage of 60% contained on the insulator. The result proves that the addition of fly ash into the polymer insulator will decrease the dielectric strength of the insulation material as shown in Figure 5.

4. DISCUSSION

The research results show that the polymer epoxy resin insulator with different composition of the fly ash cause to increase in weight and the relative permittivity of material after immersion for 38 days. However, the breakdown voltage level experiences significant reduction of the voltage value before the immersion. Meanwhile, the water absorption does not affect the weight change and the relative permittivity of the material, in the case of XLPE insulation.

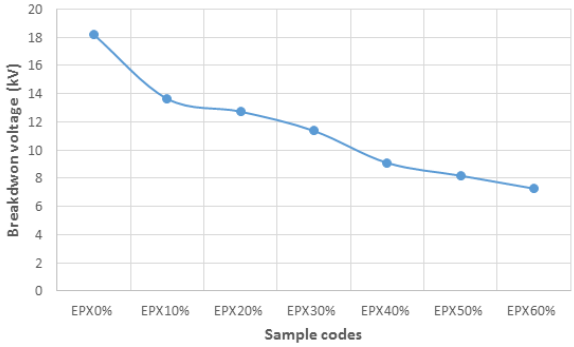

Fig. 5. Measurement of breakdown voltage of epoxy resin insulator after 38 days immersion.

5. CONCLUSION

The overall results of the research show that the water absorption water is the important parameter that influencing the dielectric properties of the polymer insulator. It is

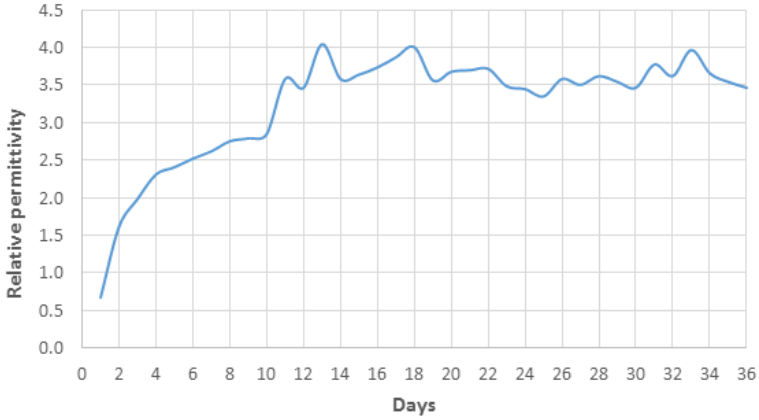

Fig. 2. Water absorption on XLPE polymer insulator

indicated by the change in the value of relative permittivity of epoxy polymer and XLPE insulators which increasing due to the water contaminant in the material. Suggestions for further research are in the process of measurement where it should consider the temperature and humidity conditions in order to obtain the accurate data, such as adding the temperature control (thermostat) of the room.

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