Study on Tracking Time of Epoxy Resin Insulating Material under Artificial Accelerated Aging

Abdul Syakur, Hermawan
Department of Electrical Engineering
Diponegoro University
Semarang, 50271, Indonesia
email: syakur@elektro.undip.ac.id

Heri Sutanto
Department of Physics
Diponegoro University
Semarang, 50271, Indonesia
e-mail: herisutanto@gmail.com

***Abstract*— An insulator installation in tropical climate and high rainfall areas could cause a problem. Humidity and rain take an essential role in filling insulator wet surface which produces contaminant and leakage current flowing on it. Besides, continuous ultraviolet radiation will accelerate the aging and degradation process on the insulator surface which also make electrical current easy to flow. This research discussed the effects of ultraviolet radiation and fly ash addition as a filler material toward contact angle, tracking time, and the average leakage current value of high voltage insulation of epoxy resin materials. This research was done on a laboratory scale using epoxy resin polymer materials (DGEBA and MPDA) mixed with silicone rubber and fly ash with filler composition variation of 20%, 30%, and 40%. Samples were flowed by rainwater contaminant with conductivity of 196 µS/cm, NH4Cl with resistivity of 3,95 ± 0,05 Ωm and it also were already given ultraviolet radiation in 0, 24, 48, 72, and 96 hours. Leakage current values was obtained by conducting several tests using Inclined-Plane Tracking method (IEC standard 587 : 1984) and high voltage injection of 3.5 kV. The results indicated that filler material composition of epoxy resin and ultraviolet radiation completely affected the contact angle magnitude, the average of leakage current value, and the tracking time needed. From the whole parameter measured, the data of before and after treatments of ultraviolet radiation showed that RTV23 sample was the best sample compared to RTV22 and RTV24.**

Keywords*— *polymer insulation, ultraviolet radiation, leakage current, tracking time, contact angle.

I. Introduction

Polymer materials have been widely used in the distribution and transmission line for their good dielectric properties, light weight and compact, when compared to the porcelain or glass insulators [1-3]. However, polymer outdoor insulator shows degradation due to climate stresses such as ultraviolet in sunlight, moisture, temperature, humidity and other contaminants so that surface discharge, tracking, and erosion can occur, and degradation may reduce the performance. Actually, this reduction is result from chemical and physical changes taking place on the surface of polymer [4].

Most of insulator materials used in Indonesian eletrical power system are made of porcelain/ceramic and glasses. This kind of insulator is beneficial because it is more economical than polymer insulator, possessing a pulling power of 400-900 kg/cm2, resistant to various environmental conditions so it is not easy to experience degradation and possessing good dielectric power and thermal characteristic. However, this insulator has several weaknesses such as heavy in size, fragile, and easy to absorb water on its surface (hygroscopic) which makes the leakage current easier to occur on the surface and leads to an insulation failure.

One of the alternative ways to cope with porcelain and glass weaknesses is utilizing polymer insulator. Eventhough polymer insulator is more expensive than those two materials, it has several benefits such as being resistant to various environmental condition, so it is not easy to experience degradation, possessing better dielectric power and thermal characteristic, lighter construction, and relatively faster in manufacturing process. Nowadays, polymer insulator has been wider in using on transmission channel and distribution with higher voltage, and it has been massively marketed [5].

II. Experimental Set-Up

A. Material Composition and Dimension

The composition of testing sample alloys could be seen in table 1. The total of the testing samples were 60 pieces, comprising of five variation of ultraviolet radiation treatments, three variation of filler material compositions, and two variation of contaminants in which each measurement variation was done twice on a different testing sample.

TABLE I. THE COMPOSITION OF TESTING SAMPLES

Filler material composition	Fly ash mass (grams)	Silane mass (grams)	DGEBA mass (grams)	MPDA mass (grams)	Sample code
20%	10	10	40	40	RTV22
30%	15	15	35	35	RTV23
40%	20	20	30	30	RTV24

Testing samples used on this research were shaped in rectangle in size of 120 mm x 50 mm with a thickness of 5 mm. Testing samples must be drilled as Fig. 1 to place electrodes.

978-1-5386-0945-3/17/$31.00 ©2017 IEEE

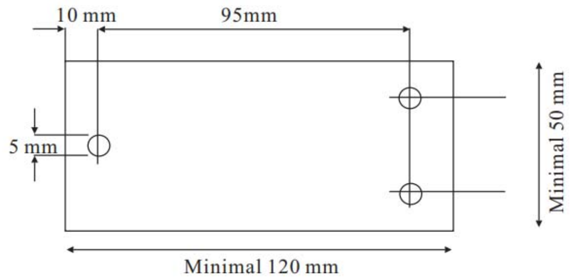

Fig. 1. Testing sample dimension [6]

B. Measurement of Contact Angle

Contact angle measurement was intended to find hydrophobic characteristic of testing samples surface. This characteristic could be revealed by measuring contact angle between testing samples and distilled water dropped into the surface (IEC standard 62073). The bigger the contact angle, the bigger the possibility of a material to have hydrophobic characteristic. The more hydrophobic a material surface, the bigger the material strength to resist water from getting into it.

Contact angle measurement was done on several samples which had already been given UV rays with radiation variation in 0 hour, 24 hours, 48 hours, 72 hours, and 96 hours. The contact angle measurement was presented in Fig.2.

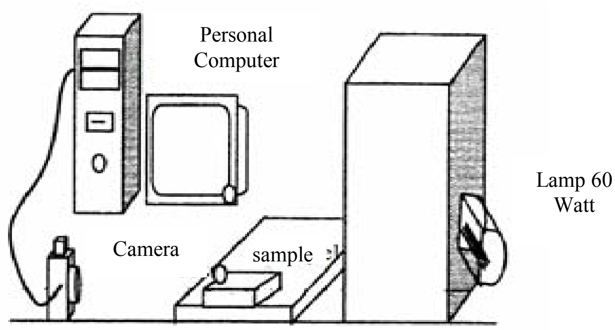

Fig. 2. Contact Angle Testing [10]

C. Artificial Accelerated Aging

Ultraviolet radiation effects toward epoxy resin insulation material could be revealed by conducting radiation tests in 0 hour, 24 hours, 48 hours, 72 hours, and 96 hours equipped with a 15 watt UV TL lamp which functioned to accelerate aging process 30 times from tropical climate (IEC standard 1109:1992).

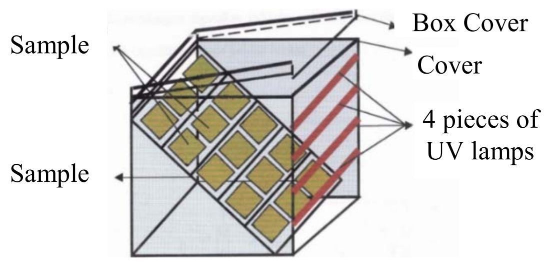

Fig. 3. UV Radiation Box [4,10]

The radiation was done in a room sized 50 cm x 50 cm x 50 cm with a tilt of 45° (ASTM standard 2303). This room was made of wood covered by aluminum foil on the inside to optimize the ultraviolet rays and avoid ultraviolet leakage out of the box. The box could accomodate 15 pieces testing samples. Ultraviolet radiation was shown in Fig. 3.

D. Measurement of Leakage Current

In this research, leakage current measurement used one of the methods to measure leakage current on insulation, that was Inclined-Plane Tracking (IPT) method which was regulated in IEC 587:1984.

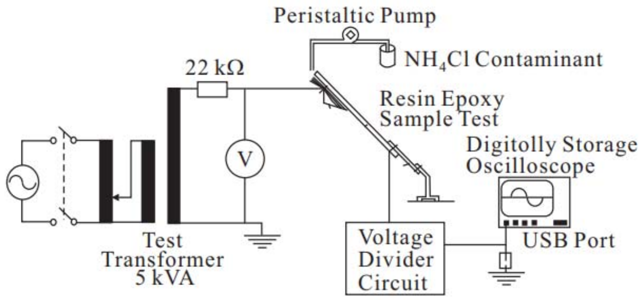

Fig. 4. Leakage Current Measurement Series [7]

Multisim's ability is able to model various circuit designs, test a circuit with possible components, check the properties of the whole circuit by performing AC/DC or transient analysis. With the completeness of a number of existing components we can make a combination of almost unlimited circuit design [6]. Display the multisim form as shown in Fig.5.

TABLE II. RESISTANCE VALUES OF SERIES RESISTOR OF IEC STANDARD 587 :1984

Testing Voltage (kV)	Recommended Voltage (kV)	Pollutant Flowing Speed (ml/min)	Resistance of Series Resistor (kΩ)
1,0 – 1,75	-	0,075	1
2,0 – 2,75	2,5	0,15	10
3,0 – 3,75	3,5	0,30	22
4,0 – 4,75	4,5	0,60	33
5,0 – 5,75	-	0,90	33

This study applied a voltage of 3,5 kV. Thus, the pollutant flowing speed was 0.3 ml/min and resistor resistance applied 22 kΩ.

Leakage current measurement was equipped with oscilloscope. Yet, the maximum voltage read by oscilloscope was 400 Volt. As a consequence, it required a voltage circuit divider which displayed in Fig.6.

According to the series in Fig.6, a calculation to find out I_1 value was obtained by using below equation:

$$I_1 = 0{,}025679\ V_{CF} \qquad (1)$$

Where I_1 was leakage current value flowing on the sample, and V_{CF} indicated effective voltage (V_{RMS}) read by oscilloscope.

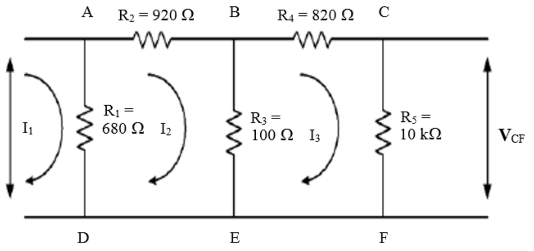

Fig. 5. Divider Series

III. Results and Discussion

A. Contact Angle of Hydrophobic

The way to measure contact angle of fly ash silicone rubber epoxy resin insulation with contaminant droplets could be seen in Fig.6.

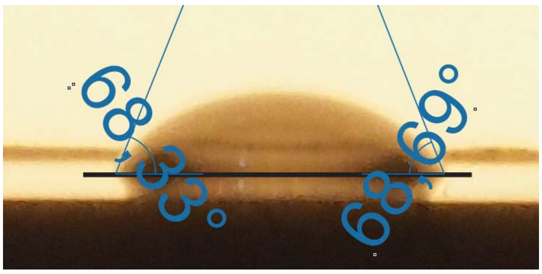

Fig. 6. Contact angle of testing samples surface

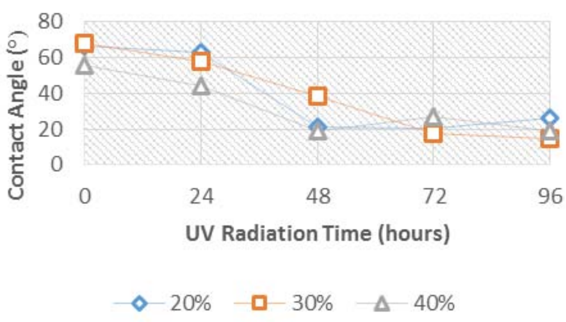

Fig. 7. Chart Showing Correlation Between Ultraviolet Radiation Time Towards the Average Contact Angle Contaminated by NH4Cl

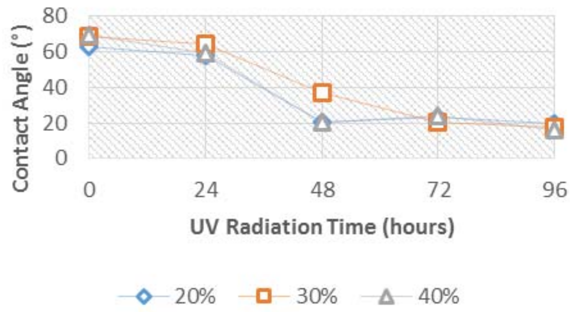

Fig. 8. Chart Showing Correlation Between Ultraviolet Radiation Time Towards the Average Contact Angle Contaminated by Rainwater

Fig. 7 and 8 showed that ultraviolet radiation resulted in decreasing of contact angle values. In additon, fly ash addition influenced the hydrophobic characteristic of testing samples. The more the addition of fly ash composition, the faster the contact angle declining process at the time of UV radiation was given. It was proven by contact angle of NH_4Cl which was formed in 0 hour UV radiation in which RTV_{24} sample had 55,616°. This value was lower than RTV_{22} and RTV_{23} samples which obtained 66,578° and 66,988° respectively. However, RTV_{23} sample experienced a significant decline as shown in figure 8. It occured because RTV_{23} sample was the most ideal sample, so that the composition had nothing to do with the hydrophobic characteristic of silicone rubber [8].

B. Characteristic of Leakage Current

a) Characteristic of Leakage Current with Rain Contaminant

After conducting all measurements, the average leakage current values could be observed in Fig.9.

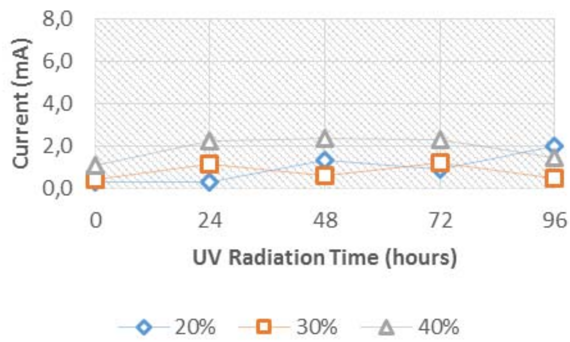

Fig. 9. Chart of the average leakage current value contaminated by rainwater

The measurement results indicated that the longer the ultraviolet radiation given on samples, the bigger the average of leakage current values. Fig.9 showed that the graph was inconstant because of the inhomogeneity samples making caused by limited material printing devices. Inhomogeneity samples making resulted in emerging of air cavity in stirring process so there was such different quality of testing samples. During the ultraviolet radiation, there were heating and oxidation processes which caused the occurence of chemical reaction on samples that affected its characteristics. New atomic cluster had different physical and chemical characteristics from its former atom. This atom cluster appeared when there was an occurence of termination process of functional group bond by energy photons absorbed by testing samples so it affected its characteristics.

The addition of filler material also affected the average of leakage current values. The average leakage current of RTV_{23} sample in UV Radiation of 48 hours was 0,598 mA. It was the lowest value of all samples, in which RTV_{22} and RTV_{24} got 1,354 mA and 2,371 mA respectively. The addition of filler material functioned to fix the characteristic of epoxy resin from hydrophilic to become hydrophobic, but the excessive addition would result in a declining of hydrophobic characteristic of testing samples surface. The more hydrophobic a material, the higher the resistivity. Testing material resistivity influenced the current flowing on the surface because the current only flowed on the parts with low resistance.

b) Characteristic of Leakage Current with NH_4Cl Contaminant

After conducting measurements, leakage current values of testing samples were presented in Fig.10.

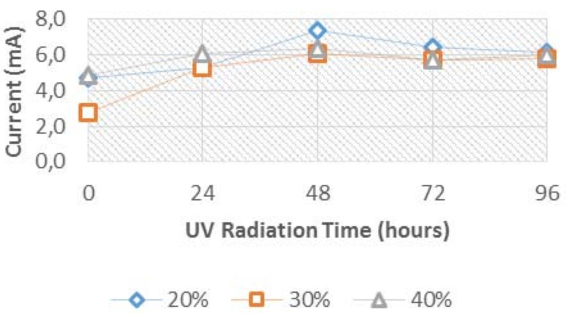

Fig. 10. Chart of the average leakage current values with NH_4Cl contaminant

Analysis of first discharge leakage current revealed that material performance showed the same phenomena. RTV_{23} sample obtained 2,746 mA in 0 hour UV radiation, got 5,266 mA in 24 hours UV radiation, had 6,111 mA in 48 hours UV radiation, gained 5,703 mA in 72 hours UV radiation, and had 5,822 mA in 96 hours UV radiation. It indicated that the longer the ultraviolet radiation time, the bigger the leakage current values on the testing sample surface. Fig.11 proved that the longer the samples aging process, the bigger the average values of its leakage current.

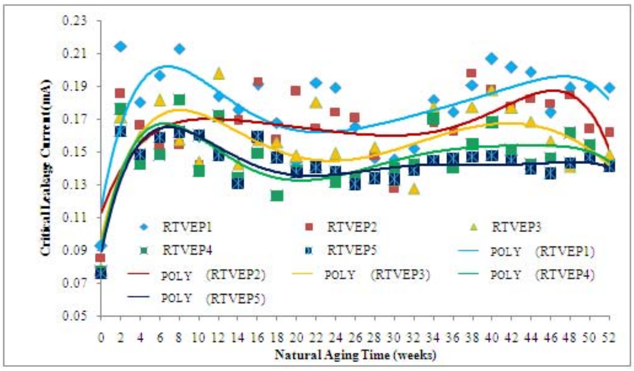

Fig. 11. Critical leakage current on insulator surface with filler composition variation in a natural aging of 52 weeks [11]

This research also discussed the time needed to form such tracking on 25 mm testing samples. The data obtained was displayed in Fig.12.

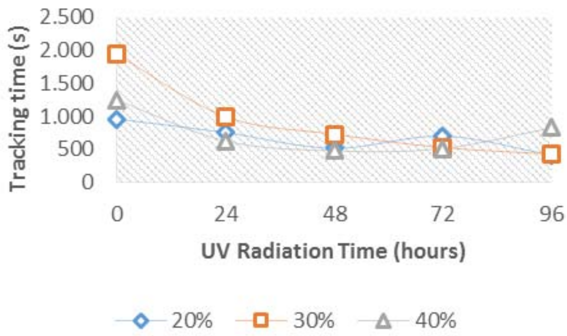

Fig. 12. Chart of time tracking for 25 mm at a voltage of 3,5 kV

Fig.12 informed that the longer the ultraviolet radiation on testing samples, the faster the tracking time for 25 mm. The effect of ultraviolet radiation was the occurence of degradation on the testing samples surface so that there would be such cracks which shorten samples' strength. The results of RTV_{23} showed that it required 1,941 seconds for tracking under the 0 hour UV radiation, 1,001 seconds under the 24 hours UV radiation and 731 seconds under 48 hours UV radiation. Meanwhile, samples with 72 and 96 hours UV radiation took 530 seconds and 432 seconds for tracking.

C. Comparative Analysis Using Different Conductivity

Correlation between contaminant and leakage current was the higher the conductivity value of the contaminant given, the faster the tracking time.

Leakage current measurement on the insulation surface only used the data without ultraviolet radiation. It was because the radiation intensity was stronger when samples were given 24 hours or more UV radiation so that it had already destroyed the samples surface.

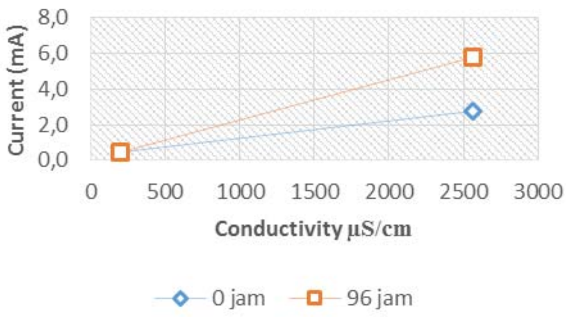

Fig. 13. The influence of rising voltage towards tracking time

Fig.13 displayed RTV_{23} sample with 0 hour and 96 hours UV variation. It showed that the bigger the conductivity given, the faster the time needed to reach tracking for 25 mm on the testing samples surface.

Thus, it proved that conductivity could influence the time when insulation failure occured. Meanwhile, figure 14 proved that the increase of conductivity and tracking time was inversely proportional.

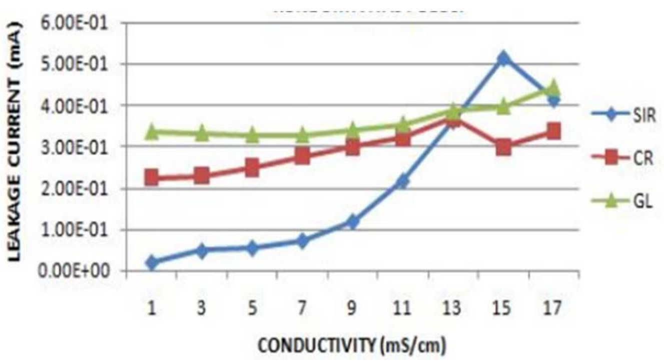

Fig. 14. Leakage current curve of SIR polymer insulator under the influence of salt conductivity [9]

IV. Conclusion

After considering contact angle values, tracking time for 25 mm, and leakage current of first discharge in maximum limit of 100 mA, RTV_{23} sample had the biggest contact angle value, the smallest leakage current, and the longest tracking time. Thus, the composition of fly ash silicone rubber epoxy resin polymer insulation was comprised of 35 grams DGEBA, hardening material which was 35 grams MPDA, 15 grams silicone rubber glue, and 15 grams fly ash filler material. This composition was considered feasible as insulation material of high voltage insulator which had the most optimum performance.

In testing sample making there were many voids appeared as a consequence of the inhomogeneity testing sample mixing. Therefore, a testing sample making which was free from voids was done to improve the accuracy of research data. In addition, samples examining must be done immediately after the samples got UV treatment radiation. It was because the samples were able to experience a recovery that could reach 23% within a period of 2 days so that it affected the data accuracy level.

Acknowledgment

The first author would like to thank to ministry of research of higher education, Republic of Indonesia; and Head of high voltage laboratory; and Adhitya Fauzan Hidayat and Diah Monica as research assistants who helped the research in laboratory.

References

[1] Gorur, Outdoor Insulators [M]. Phoenix, Arizona, USA: Ravi S. Gorur, Inc, 1999.
[2] Amin M, Akbar M, Salman M. Composite insulators and their aging: an overview[J]. Science in China Seri E Technology Science, 2007, 50 (6): 697-713.
[3] Md Afendi Md piah, Ahmad Darus, Azman Hassan. Effect of ATH filler on electrical tracking and erosion properties of natural rubber-LLDPE blends under wet contaminated conditions[J]. Journal of Industrial Technology, 2004, 13 (1):27-40.
[4] Berahim H, Sirait K.T, Soesianto F, et al. A new performance of RTV epoxy resin insulation material in tropical cilamte [C] // Proceedings of the 7th International Conference on Properties and Applications of Dielectric Materials, Nagoya, Japan: [s.n.] . 2003:607.
[5] Hackam R., "Outdoor High Voltage Polymeric Insulators," in Proceedings of 1998 International Symposium on Electrical Insulating Materials, Toyohashi, Japan, 1998, pp. 1–12.
[6] BS 5604:1986, IEC 587:1984, "Methods for Evaluating Resistance to Tracking and Erosion of Electrical Insulating Materials Used Under Severe Ambient Conditions", British Standards Institution, British Standard (BS).
[7] Syakur, Abdul, Hamzah Berahim, Tumiran, Rochmadi, Experimental Investigation on Electrical Tracking of Epoxy Resin Compound with Silicon Rubber, High Voltage Engineering, Vol. 37, No. 11, 2011.
[8] Kitta, Ikhlas, Salama Manjang, Wihardi Tjaronge, Ritta Irmawaty, Effect of Coal Fly Ash Filler in Silicone Rubber and Epoxy Resin as Insulating Material in Wet Environmental Conditions, International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol:16 No:02, 2016.
[9] Mustamin, S. Manjang, 2010, Characteristics of high voltage polymer insulators under pressure aging accelerated artificial tropical climate, Jurnal Media Elektrik, Volume 5, No. 2, December 2010.
[10] Hermawan, Abdul Syakur, Tommy Perdana, "The surface leakage currents analysis of epoxy resin-silane with silica sand filler insulators in the artificial ageing conditions", Power Engineering Conference (AUPEC), 2012 22nd Australasian Universities.
[11] Jaya, Arif, Hamzah Berahim, Tumiran, Rochmadi, "The Performance of High Voltage Insulator Based on Epoxy-Polysiloxane and Rice Husk Ash Compound in Tropical Climate Area", Electrical and Electronic Engineering, pp. 208-216, Vol. 2(4), 2012.
[12] Amin Muhammad, Amin Salman, Ali Muhammad, 2007, "Monitoring of Leakage Current for Composite Insulator and Electrical Device", UET Taxila, Pakistan.