Feasibility Study on Electrical Properties of 20 kV Polymeric Insulator Dry Test and Rainwater Test

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***Abstract*—Insulator is a very important equipment in an electric power system. Ceramic insulators have been widely used to support conductors in 20 kV power lines. The problem of ceramic insulators is that they are heavy, easily contaminated on the surface and require a lot of energy in the manufacturing process. Therefore, polymer insulators were developed. This paper presents the design of an epoxy resin polymer insulator with Titanium Dioxide (TiO2) as a nanofiller. The leakage current test was carried out in a high voltage laboratory by applying an AC high voltage of 50 Hz to the insulator dry conditions and the insulator wetted by rainwater contaminants. The results of the leakage current test in dry conditions are 487.6 µA, rainwater contaminated conditions are 594.93 µA, insulation resistance in dry conditions is 2.07 G-Ohms, and contaminated conditions are 1.41 G-Ohms. Based on the test results show that the insulator leakage current increases up to 22% when the surface of the insulator is contaminated with rainwater. Meanwhile, the insulation resistance decreased by up to 32% in conditions contaminated with rainwater. The value of leakage current and insulation resistance indicates that the epoxy resin insulator with TiO2 as filler is electrically feasible to use.**

Keywords: ***insulator, leakage current, resistance, contaminant, rainwater***

***Abstrak*—Isolator merupakan peralatan yang sangat penting dalam sistem tenaga listrik. Selama ini, isolator keramik telah digunakan secara luas untuk menyangga konduktor di jaringan listrik 20 kV. Permasalahan isolator keramik memiliki bobot yang berat, mudah terkontaminasi pada bagian permukaannya dan memerlukan energi yang besar pada proses pembuatannya. Oleh karena itu dikembangkan isolator polimer. Makalah ini mempresentasikan desain isolator polimer bahan Epoxy Resin dengan bahan pengisi nano Titanium Dioxide (TiO2). Uji arus bocor dilakukan di laboratorium tegangan tinggi, dengan menerapkan tegangan tinggi AC 50 Hz pada kondisi isolator kering dan isolator terbasahi kontaminan air hujan. Hasil pengujian arus bocor kondisi kering 487,6 µA, kondisi terkontaminasi air hujan 594,93 µA, tahanan isolasi kondisi kering 2,07 G-Ohm, dan kondisi terkontaminasi 1,41 G-Ohm. Berdasarkan hasil pengujian menunjukkan bahwa arus bocor isolator meningkat hingga 22% ketika permukaan isolator terkontaminasi air hujan. Sementara itu, tahanan isolasi menurun hingga 32% pada kondisi terkontaminasi air hujan. Nilai arus bocor dan tahanan isolasi menunjukkan bahwa isolator resin epoksi dengan bahan pengisi TiO2 secara kelistrikan layak untuk digunakan.**

Kata kunci: ***isolator, arus bocor, tahanan, kontaminan, air hujan***

I. Introduction

Insulator is one of the important equipment in the electric power system. The insulator serves to isolate the conductor from the tower body. Ceramic and glass insulators have been widely used. Currently, composite insulators are being developed for use in electric power transmission lines and distribution lines. Polymer materials that have been used as insulators are epoxy resin and silicon rubber. There are several advantages of using composite insulators compared to ceramic and glass insulators, including easy manufacturing process, easy installation, light weight, high dielectric strength and high insulating resistance [1]. Before insulator being used in electric power transmission lines, the insulator needs to be tested to determine its performance. Several insulator performance tests were carried out including the polluted condition insulator test [2], flashover test [3], foggy condition insulator test [4], contaminated condition [5], insulator test under dry and wet condition [6], and a comparison test between composite material and ceramic insulator performance [7]. To facilitate the analysis of the performance of the insulator, especially on electrical parameters, it can also be done using artificial simulations of the tropical climate in the room [8]. Insulators are generally installed in open areas so that they are very susceptible to environmental

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influences such as rain, so that their electrical performance is tested by flowing rain contaminants on the surface of the insulator [9], also the influence of environmental humidity conditions [10], even including the insulator test that is contaminated with the presence of plant life on the surface of the insulator [11]. This paper presents the comparison of electrical properties of the insulator in dry conditions with conditions contaminated with rainwater. The test was carried out in the HV research laboratory using a high voltage AC 50 Hz.

II. Research Study

Research on the performance of insulators has been carried out by many researchers in Indonesia and various countries. Researchers in Indonesia such as Taryo et.al [6] have investigated the comparison of leakage currents in Silicon Rubber and Epoxy Resin insulators. Utami et.al[8] have investigated the leakage current characteristics and resistivity of resin insulators with silicone rubber and alumina filler, Abdul Syakur et.al[9] have investigated the leakage current characteristics of insulators with varying fins using rainwater contaminants. Pertiwi et al[10] have investigated the characteristics of the leakage currents in epoxy resin insulators under varying humidity conditions, and Rachmawati et.al[12] have investigated the leakage current characteristics and electrical properties of uncoated ceramic insulators, compared with ceramic insulators coated with Silicone Rubber and coated with semiconductive glass.

Meanwhile, researchers from various countries abroad such as Bossi et.al [2] have investigated the performance of composite insulators under polluted conditions. Karaday [3] has investigated the flashover mechanism in non-ceramic insulators and composite insulators. The flashover mechanism is caused by the presence of contaminants flowing on the surface so that the surface becomes more conductive, the insulation resistance of the insulator surface decreases so that flashover occurs. Researcher A. De La [4] has carried out tests on non-ceramic insulators and compared them with porcelain insulators in clean and mist-free test conditions. A.C. Baker [5] has investigated insulators to be used in high voltage transmission lines with the influence of contamination. Another researcher K.R. Suri [7] has investigated the comparison of the performance of porcelain insulators with polymer insulators used in transmission lines, and M.N. Dinesh [11] has investigated the performance of composite insulators affected by bio-contaminants and without bio-contaminants. All studies related to these insulators were carried out to obtain excellent composite insulator performance.

III. Experimental Set Up

A. Polymeric Insulator

The polymeric insulator used in this study is a polymer insulator with the following constituent materials: 75% epoxy resin (EP), 15% silicon rubber (SiR) and 15% titanium dioxide (TiO_2). The insulator has 5 fins that have the same diameter. The shape of the test insulator is shown in Fig. 1.

Figure 1. The test insulator with 5 fins

B. Resistance Measurement

The measuring of insulator resistance was carried out in dry and wet conditions. The measuring instrument used to measure insulation resistance is the HV Insulation Tester. The insulation resistance measurement circuit is shown in Fig. 2.

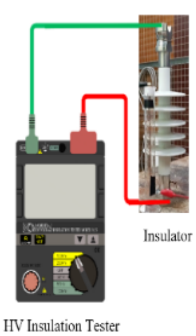

Figure 2. The measuring of insulator resistance

C. Leakage Current Measurement

The leakage current on the surface of the insulator is measured by applying a high voltage of 50 Hz AC to the insulator. Leakage current measurements were carried out in dry and wet conditions. The leakage current in this study is the result of a calculation between the resistance of the divider and the voltage measured on the oscilloscope. The leakage current measurement circuit is shown in Fig. 3.

D. Measurement of Rainwater parameter

The rainwater used in this study was obtained from rainwater in the Tembalang area of Semarang. Rainwater has been tested in the Environmental Engineering lab. The test results on the rainwater contaminant parameters are shown in Table 1.

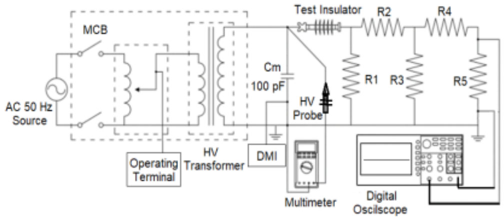

Figure 3. The circuit measuring of leakage current

Table 1. Parameter of rainwater

Test Parameter	Result test of rainwater contaminant		
	Unit	Test result	Method
pH	-	7.65	SNI 6989.11.2019
NH3	mg/L	0.066	SNI 6989.30.2005
DO	mg/L	7.04	SNI 6989.14.2004
Cl	mg/L	20.59	SNI 6989.19.2009
Nitrat	mg/L	0.174	APHA 4500-NO3 B:2017
Sulfat	mg/L	<0.01	SNI 6989.20.2019
Fe	mg/L	Nihil	SNI 6989.4.2009
Zn	mg/L	Nihil	SNI 6989.7.2009
Conductivity	µS	103.5	Used conductivity meter

IV. Results Experimental

The results of testing the electrical parameters of the insulator performance including insulation resistance and leakage current in dry conditions and contaminated with rainwater are explained respectively as follows:

A. Insulation Resistance

There are 3 conditions of measurement of insulation resistance, namely the measurement of insulation resistance in dry insulator conditions, wet conditions with H_2O liquid and it with rainwater contaminants. The measurement results of insulation resistance are shown in the Table 2.

In addition to testing the dry and wet conditions of rain contaminants, testing is also carried out in wet conditions using H_2O liquid. After measuring the conductivity of the H_2O liquid, the conductivity value is 2.7 µS.

B. Leakage Current

The results of the leakage current measurements under the three test conditions are shown in Table 3. There are three conditions for measuring leakage current, namely

Table 2. Result test of insulation resistance

Test Conditions	Insulation Resistance (GΩ)
Dry test Condition	2,07
Aquades contaminant	1,90
Rainwater contaminant	1,41

Table 3. Result of leakage current

Dry Test Condition		H2O Liquid Contaminant		Rainwater Contaminant	
Voltage Applied [kV]	Leakage Current [µA]	Voltage Applied [kV]	Leakage Current [µA]	Voltage Applied [kV]	Leakage Current [µA]
11,17	437,49	11,07	472,90	11,23	553,35
12,38	487,60	12,23	517,88	12,21	594,93
13,20	517,76	13,06	551,50	13,04	625,27

dry insulator conditions, wet insulator conditions with liquid H_2O contaminants and wet conditions with rainwater contaminants. To determine the characteristics of the leakage current in the insulator, the test was carried out with a voltage of 11 kV, 12 kV and 13 kV. The voltage variation is based on the consideration that the insulator will be used for a 20 kV system, so that the voltage for each phase is divided by the root of 3.

The analysis carried out in this paper is by looking at the test results on the electrical parameters of the insulator made of TiO_2 filler. The results of measurements of insulation resistance and leakage current in dry and wet conditions, it becomes important to know the performance of the insulator in the best and worst conditions. The results of this test are then compared with the composite insulator with other fillers. Thus, new discoveries of insulator performance will be obtained by observing electrical parameters, namely insulation resistance and leakage current in dry and wet conditions.

C. Effect of rainwater contaminant to Insulation Resistance

To analyze the insulation resistance of the composite insulator under various test conditions, a graph can be made based on the measurement data in table II. Based on the graph in Fig. 4, we can see that the insulation resistance of the insulator in the dry condition is the largest, namely 2.07 GΩ, and decreases when the wet test conditions use H_2O liquid, and further decreases to 1.41 GΩ when the wet test conditions use rainwater contaminants.

This decrease in insulation resistance is because on the surface of the insulator there are rainwater contaminants

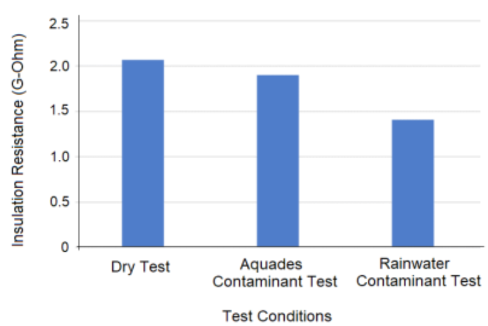

Figure 4. Graph of insulation resistance under various test conditions

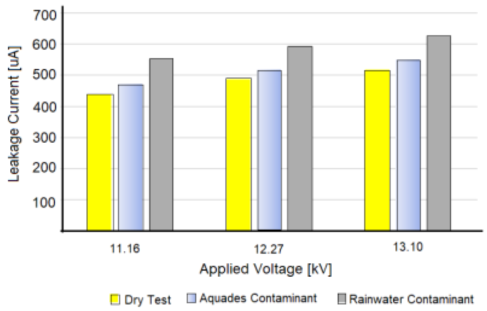

Figure 5. Graph of leakage current under various test conditions

which have a conductivity of 103.5 µS. In this rainwater contaminant there is also 20.59 mg/L of chlorine which is a conductor of electricity. Chlorine is a halogen element that will react to form salt when it meets a metal element such as sodium. The surface becomes more conductive when there are rainwater contaminants, and consequently the insulation resistance of the surface becomes smaller.

D. Effect of raintwater contaminant to Leakage Current

The effect of rainwater contaminants and applied voltage on the insulator surface leakage current is shown in Fig. 5. The easiest observation based on Figure 5 is that the test conditions affect the leakage current measurement results. In dry conditions with an applied voltage of 11 kV, the smallest current value is 437 µA, and the highest leakage current is 625.27 µA obtained from the measurement results by applying a voltage of 13 kV in wet conditions with rainwater contaminants.

The effect of rainwater contaminants that have a conductivity of 103.5 µS makes the surface of the insulator more conductive than in dry conditions. The element of chlorine of 20.59 mg/L contained in rainwater contaminants played a role in increasing the surface leakage current. Based on Fig. 5 we know that the greater the applied voltage on the insulator, the leakage current flowing on the surface of the insulator also increases. In this study, the test voltage range applied was from 11 kV to 13 kV. Taryo [6] has investigated the effect of contaminant conductivity on leakage current. The test was carried out on a silicon rubber insulator with an applied voltage of 15 kV in dry conditions and wet conditions with variations in contaminant conductivity from 10 mS to 14 mS. At an applied voltage of 15 kV in dry conditions, the leakage current value is 21,029 µA. Furthermore, in wet conditions with a contaminant conductivity of 10 mS, the leakage current increased to 28.75 µA, and when the contaminant conductivity was 14 mS, the leakage current was 29.72 µA. This shows that the higher the conductivity value of the contaminants, the higher the leakage current. Compared to the leakage current in the epoxy resin composite insulator, the leakage current appears to be larger because the conductivity of rainwater reaches 103.5 mS. Other researcher, Rahmawati [12] has investigated the effect

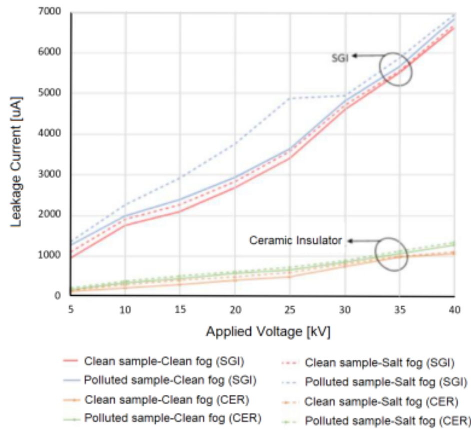

Figure 6. LC Magnitude comparison of ceramic insulator & SGI [12]

of applying voltage on the value of the leakage current in ceramic and semiconducting glazed insulator (SGI) as shown in Fig. 6. The applied voltage range used for testing is from 5 kV to 40 kV. Figure 6 clearly shows that the increase in LC increases as the applied voltage increases for each test sample under any environmental conditions. In addition, the Fig. 6 shows that the range of leakage current (LC) values for ceramic and SGI insulators is clearly different, where the maximum LC value of SGI can reach up to seven times the LC of ceramic insulators. With an applied voltage range of 5 to 40 kV, ceramic insulators have an LC of 130 – 1300 µA, while SGI has a magnitude of LC of 950 – 7000 µA.

By focusing the graph on Figure 7 when the application of a voltage up to 20 kV, we can see that the leakage current in the epoxy resin polymer insulator wetted by rain in this study is 625 µA (black arrow) at a voltage of 13 kV. While the ceramic insulator Rahmawati's research results are less than 500 µA (green arrow), and the leakage current in the SGI insulator is more than 2500 µA (blue arrow). The results of the leakage current study on ceramic insulators and SGI conducted by Rahmawati as additional information on the results of the leakage current and insulation resistance measurements carried out in this study.

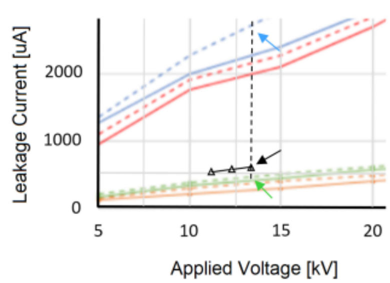

Figure 7. Graph focused on applied voltage up to 20 kV {12]

V. Conclussion

Based on the results of measurements on electrical parameters that have been carried out, the highest insulation resistance at epoxy resin insulator in dry conditions is 2,07 GΩ and the lowest is 1,41 GΩ contaminated with rainwater. For the leakage current, the highest value is obtained at dry conditions of 625,27 µA and the lowest leakage current is 437,39 µA. An epoxy resin polymer insulator with an insulation resistance value of 1.41 Giga Ohm and a leakage current of 625.27 µA under conditions of rainwater pollution is still suitable for use in a medium voltage network of 20 kV.

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References

[1] Kevin L. Richardson,, Insulators: Types, Properties and Uses (Electrical Engineering Developments: Physics Research and Techology), Nova Science Pub Inc, 2011.

[2] Bossi, S., Pigini, A., Fini, G.P, Study of the performance of composite insulators in polluted conditions, Cigré Report, pp. 33–104, 1994.

[3] G. G. Karaday, "Flashover mechanism of non-ceramic insulators", *IEEE Transactions on Dielectrics and Electrical Insulation*, vol. 6, no. 5, pp. 718–723, 1999.

[4] A. De La, R. S. Gorur and J. Chang, 1994 "AC Clean fog tests on Non-ceramic Insulating Materials and a Comparison with Porcelain", *IEEE Trans. Power Delivery*, vol. 9, no. 4, pp. 2000-2008.

[5] A. C. Baker, M. Farzaneh, R. S. Gorur, S. M. Gubanski, R. J. Hill, G. G. Karady, et al., "Insulator selection for AC overhead lines with respect to contamination", *IEEE Trans. Power Delivery*, vol. 24, no. 3, pp. 1633-1641, 2009.

[6] Taryo, A. Syakurr, Hermawan, "Comparison study on leakage current of 20 kV silicon rubber and epoxy resin insulator under dry and wet condition," in 2018 5th *International Conference on Information Technology, Computer, and Electrical Engineering* (ICITACEE), 2018, pp. 260-263.

[7] K. R. Suri, A. Gupta, Y. Anand and S. Anand, 2015, "Porcelain versus polymer insulators- a changing era in transmission lines", *International Journal of Advance Research and Innovation*, vol. 3, pp. 502-506, 2015.

[8] A.M.S. Utami, A. Syakur, H. Hermawan, "Analysis of leakage current and insulator resistivity for quality assurance of medium voltage network polymer insulators alumina - SiO_2 in tropical climate simulator room," *Jurnal TEKNIK*, vol. 42, no. 1, pp 10–19, 2021.

[9] A. Syakur, and Hermawan, "Leakage current characteristics at different shed of epoxy resin insulator under rain contaminants," in 2014 1st *International Conference on Information Technology Computer and Electrical Engineering* (ICITACEE), 2014, pp. 413-418.

[10] P. N. Utami; A. Syakur; and Hermawan, "Leakage Current Characteristics of 20 kV Epoxy Resin Insulators Under Variation Humidity," in 2018 5th *International Conference on Information Technology, Computer, and Electrical Engineering* (ICITACEE), 2018, pp. 264-267 .

[11] M. N. Dinesh, "Performance of composite insulators with and without bio contamination," in *International Conference on High Voltage Engineering and Application*, 2008, pp. 124-127.

[12] Rachmawat, N. Sartika, N. R. M. Putra, and Suwarno, "The Study on leakage current characteristics and electrical properties of uncoated ceramic, RTV silicon rubber coated ceramic, and semiconducting glazed outdoor insulators," *International Journal on Electrical Engineering and Informatics*, vol. 10, no. 2, pp. 318-336,2018.

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