Comparative Analysis of Ceramic Insulator Performance with The Application of Silicone Rubber Coating and Nano-Ceramic Coating

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Abstract. Insulators are components that isolate between voltage components and other components. insulators are very important in the distribution of electrical energy. If the quality of the insulator is poor, it can cause interference with the power system. The quality of the insulator is determined by the standard value of insulation resistance, leakage current and contact angle. These values are influenced by environmental influences, one of which is rainfall. Therefore, the quality of the insulator needs to be improved so that it can work in wet conditions. The quality of the insulator can be improved by coating method. Coating is a technique of coating the insulator surface with a certain material. In this study, ceramic insulators were tested before coating, after coating nano ceramic and after coating silicone rubber. Ceramic insulators before coating and after coating are injected with voltages varying from 1 kV, 2.5 kV, 5 kV, 10 kV, and 15 kV in dry conditions and wet conditions. The result is to determine the insulation resistance and leakage current. Furthermore, the surface of each insulator will be dripped with rainwater to determine the contact angle value. The results showed that the insulation resistance value of dry conditions is greater than wet conditions while the leakage current of wet conditions is greater than dry conditions. The order of the best insulator quality based on the value of dry and wet condition insulation resistance is nano ceramic coating insulator, silicone rubber insulator, and non-coating insulator. The best insulator quality based on the value of leakage current in dry and wet conditions are nano ceramic insulators, silicone rubber insulators, and non-coating insulators. The best insulator quality based on contact angle is nano ceramic insulator (hydrophobic), silicone rubber (hydrophilic), and before coating (hydrophilic).

Keywords: Insulator, Insulator Quality, Insulation Resistance, Leakage Current, Contact Angle, Coating, Nano Ceramic, Silicone Rubber.

1. Introduction

Insulators are electrical components that work to isolate the part that is in voltage with other components in the power system. Insulators are used as insulation or insulators between

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conducting components that are in voltage with another electrical component. Mechanically, the insulator withstands the voltage load so that there is no leakage current and in a high field gradient, an electric jump occurs either through flashover or sparkover [1].

The ability of the insulating material is referred to as dielectric strength and is very important in determining the quality of insulators used in electric power systems (Fauziah et al., 2017). High dielectric strength is needed especially for high-voltage electrical equipment so that insulation failure does not occur (can cause interference with power delivery and large power losses in the power system) [2].

According to the installation, insulators are classified into 2, namely external insulators and internal insulators, while according to the type of insulation material used, namely solid, liquid and gas. Based on its function, insulators can be classified into: (1) support / hanging (solid support), which is a solid insulator material, for example ceramic insulators, wood insulators, polymers, glass, etc., (2) filling media, which is a liquid or gas isolator material, such as oil, bitumen, various gases and air, (3) covering material, which is an insulator material that is usually found on the outside, in the form of solid or liquid materials, such as mica, varnish or enamel [3] [4].

The functions of insulators or insulating materials include isolating between a conductor and another conductor, having the ability to maintain mechanical forces due to current flowing on the conductor and having the ability to withstand pressure due to the heat of chemical reactions [5].

The performance of the insulator is greatly affected by environmental conditions, such as high rainfall and the presence of pollutants. Rainfall and pollutants can affect the moisture content of the surface and cause changes in surface conductivity [6].

One of the proposals to improve the performance of an insulator is by coating. Coating is a method used to improve the quality of insulator performance, namely by coating the insulator with certain materials. The coating method to overcome contaminants in the form of pollutants on the surface of the insulator is to utilize silicone rubber coating materials and also nano-technology coating techniques [7].

Silicone rubber is a polymer composed of silicon and alternative oxygen where silicon atoms are joined by groups. Silicone rubber has an unusual molecular structure between silicon and oxygen. This relationship is also found in quartz, so silicone has superior heat resistance compared to other elastomers [8]

Nanoceramic coating is one of the applications of nanotechnology. Nanotechnology refers to technology at the nanoscale and has real-world applications. The references made are two polymeric materials, namely polyethylene-co-vinyl acetate (EVA) and polypropylene (PP) which are widely used as electrical insulation for cablers and insulators [5].

The coating uses a ceramic chemical liquid with silica material that has a high molecular density than other types of coatings [9]. The material can enter into small nano-sized gaps. Later the coating results will form a thin layer like glass that has no pores.

Insulators are said to perform well if they are hydrophobic and poorly if they are hydrophilic. The influence of pollutants on the surface of the insulator, can cause the surface of the insulator to be hydrophilic [7]. The reason for choosing silicone rubber as one of the coating materials on the insulator is because the material has improved insulator performance based on research. The selection of nano-ceramic coating material is because the material is able to create an excellent hydrophobic effect on vehicle paint. Research on nano-ceramic for hydrophobicity has been quite good while the parameters of leakage current, insulation resistance have not had specific research [10].

Therefore, based on this information, this research will use a research modification to determine the performance or quality of the insulator from the parameters of insulation resistance, contact angle (hydrophobicity), leakage current with dry conditions and wet conditions [9].

2. Research Method

2.1. Research Flowchart

In the experiment, the steps of the research implementation can be seen in the figure 1.

2.2. Testing Tools

The equipment used consists of equipment to measure insulation resistance, leakage current, hydrophobicity or contact angle used during the study.

Megger MIT 1525

In Megger 1525 there are instrument controls and indicators that will be used in testing. Instrument control and indicators are obtained through the Megger MIT1525 manual book which is available in the box when purchased.

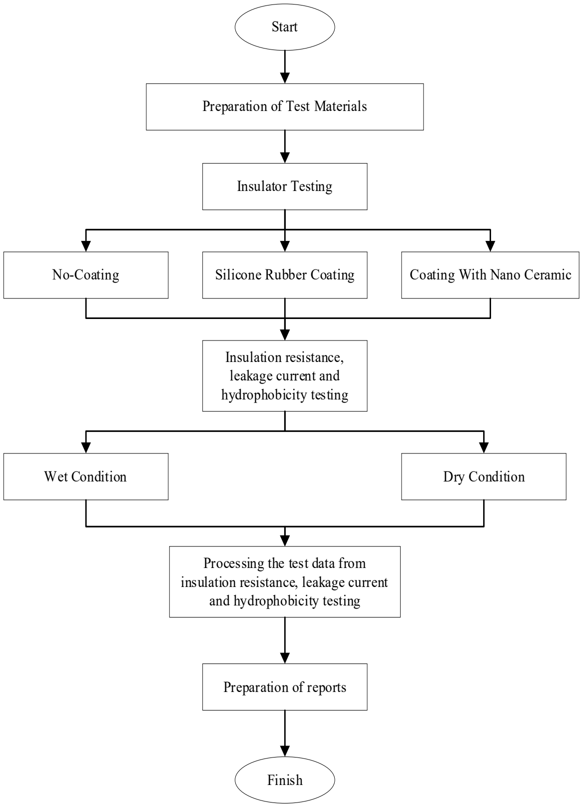

Fig 1. Research flowchart.

Fig 2. Megger MIT 1525.

Computers and Software

The software used is Power DB and ImageJ software.

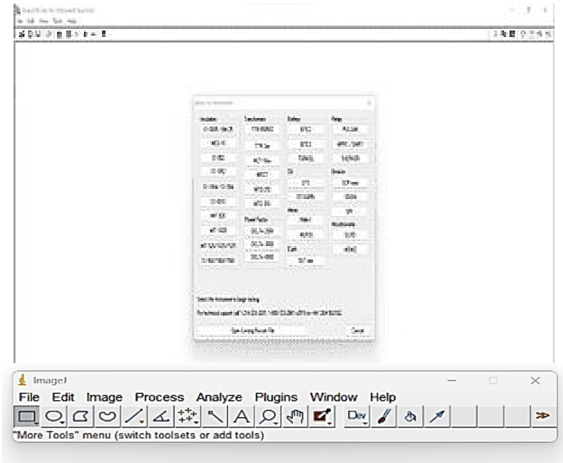

Fig 3. Power DB and ImageJ software.

2.3 Testing Materials

The test materials used in this study are;

1. Ceramic insulator

Fig 4. Ceramic Insulators

2. Coating materials are nanoceramic and silicone rubber

Fig 5. Coating nano ceramic

Fig 6. Coating silicone rubber

3. Rainwater

Fig 7. Conductivity of rainwater

2.4 Testing Steps

Testing Insulation Resistance and Leakage Current

This test is carried out in 2 conditions, namely dry conditions and wet conditions. The test steps carried out in dry conditions are as follows:

1. Prepare testing tools and materials.
2. Erect the isolator on the table to make the test more effective.
3. Position the red jumper (positive terminal) at the top and the black jumper (negative terminal) at the bottom.
4. Select one of the voltage variations to be injected into the isolator based on the expected test (1 kV, 2.5 kV, 5 kV, 10 kV, and 15 kV).
5. Select a test method. In this study, one method was used, namely IR(t) or PI with a total time of 10 minutes for 1 test.
6. Connect the Megger MIT1525 with a laptop/computer with a USB cable so that data can be saved directly to the computer.
7. On the computer screen open powerDB (adjust to how to operate powerDB), right-click on the data and select live stream to get the data in real time.
8. After the on-screen message appears, press the TEST button.
9. The test will last for 10 minutes. Data will be automatically collected into the PowerDB software.
10. Save the data and ground the insulators and jumper cables.
11. Repeat steps 4 to 10 for each variation up to 5 variations.
12. Clean the insulator then repeat steps 1-11 on the insulator before coating, nano ceramic coating, and silicone rubber coating.

The test steps carried out in wet conditions are as follows:

1. Prepare testing tools and materials.
2. Dipping the insulator into rainwater then straightening the insulator on the table to make the test more effective.
3. Position the red jumper (positive terminal) at the top and the black jumper (negative terminal) at the bottom.

4. Select one of the voltage variations to be injected into the isolator based on the expected test (1 kV, 2.5 kV, 5 kV, 10 kV, and 15 kV).
5. Select a test method. In this study, one method was used, namely IR(t) or PI with a total time of 10 minutes for 1 test.
6. Connect the Megger MIT1525 with a laptop/computer with a USB cable so that data can be saved directly to the computer.
7. On the computer screen open powerDB (adjust to how to operate powerDB), right-click on the data and select live stream to get the data in real time.
8. After the on-screen message appears, press the TEST button.
9. At the time of testing spray rainwater randomly to the insulator. this is done as a simulation of rainfall to determine the effect of rainfall on the quality of the insulator.
10. The test will last for 10 minutes. Data will be automatically collected into the PowerDB software.
11. Save the data and ground the insulators and jumper cables.
12. Repeat steps 4 to 10 for each variation up to 5 variations.
13. After that, dry the insulator then test steps 1-12 of the insulator before coating, nano ceramic coating, and silicone rubber coating.

Contact Angle Testing

Measurement of the contact angle on the insulator is done with the following steps:

1. Preparation of tools and materials for contact angle or hydrophobicity testing. Tools and materials are dropper, rainwater, cellphone camera, and laptop/pc with imageJ image processing application.
2. Drip rainwater on the surface of the insulator using a dropper.
3. Photograph the shape of the droplets on the insulator surface with a mobile phone camera. Use an additional light so that the droplets can be seen more clearly.
4. The photo is uploaded to a pc/laptop. Then do image processing with the application to measure the right angle and left angle on the photographed water droplets.
5. The results of measuring the left angle and right angle with an image processing application are recorded and then calculated with the formula.

6. Perform steps 1-5 for insulators before coating, after coating nano-ceramic coating and silicone rubber.

3. Research Results

3.1. Insulation Resistance Testing

Isolator Quality Standard

The standard value of the insulation resistance measurement results to determine the standard value of the insulation resistance measurement results can use the following equation, namely:

$$R = \frac{1000\,U^2}{\mathrm{E}} \times \frac{2{,}5}{10^6}\ (M) \tag{1}$$

The working voltage is 11.547 kV. E for each experiment is 1000V, 2500 V, 5000 V, 10,000 V, and 15000 V. From the formula, the standard value of insulator resistance based on the injection voltage E can be seen in table 1 below.

Table 1. Standard values of insulation resistance based on injection voltage

Injection Voltage E (V)	Insulation Resistance Standard R ($M\Omega$)
1000	333.33
2500	133.33
5000	66.67
10000	33.33
15000	22.22

Average Value of Insulation Resistance Testing Wet and Dry Conditions

Comparison of Average Value of Insulation Resistance of Dry Condition

The average value of insulation resistance after voltage injection experiments of 1 kV, 2.5 kV, 5 kV, 10 kV, and 15 kV for 10 minutes in dry conditions can be seen in the following table.

Table 2. Average value of insulation resistance under dry conditions

Voltage (kV)	Insulation Resistance *Non-Coating* (*M*Ω)	Insulation Resistance *Nano Ceramic* (*M*Ω)	Insulation Resistance *Silicone Rubber* (*M*Ω)
1	855050	2000000	2000000
2,5	910800	4310500	4290000
5	805550	3351000	2855250
10	632850	2226500	1661100
15	513600	1188100	740250

From table 2, a graphical representation of the test results can be formed as follows:

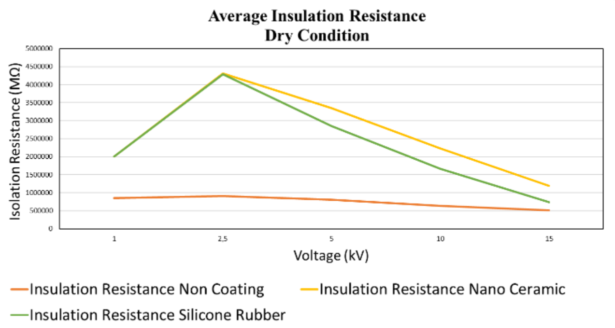

Fig 8. Comparison chart of average insulation resistance in dry conditions.

Figure 8 shows the average dry condition insulation resistance seen at 1 kV, insulators with silicone rubber coatings are the same value as nano ceramic coatings but greater than non-coatings. The same value is due to the Megger measurement limit can only reach 2000000 MΩ.

In the graph, the average insulation resistance when the test voltage is 2.5 kV, 5 kV, 10 kV and 15 kV, the average insulation resistance is greatest for insulators coated with nano ceramic followed by insulators with silicone rubber coating and non-coating insulators. The best insulator quality based on the insulation resistance value in dry conditions are insulators with nano ceramic coating, silicone rubber coating, and non-coating. In addition, from this test it can be seen that the greater the test voltage applied to the insulator, the smaller the insulation resistance.

Comparison of Average Value of Insulation Resistance in Wet Condition

The average value of insulation resistance after voltage injection experiments of 1 kV, 2.5 kV, 5 kV, 10 kV, and 15 kV for 10 minutes in wet conditions can be seen in the following figures and tables.

Table 3. Average value of wet condition insulation resistance

Voltage (kV)	Insulation Resistance *Non-Coating* ($M\Omega$)	Insulation Resistance *Nano Ceramic* ($M\Omega$)	Insulation Resistance *Silicone Rubber* ($M\Omega$)
1	65766	1262750	1653484
2,5	60000	937450	730295
5	53555	810750	626940
10	35766	673150	387899
15	23590	496160	203144

From table 3, a comparison graph can be formed between the insulation resistance of non-coating, nano ceramic coating, and silicone rubber coating in figure 9 below:

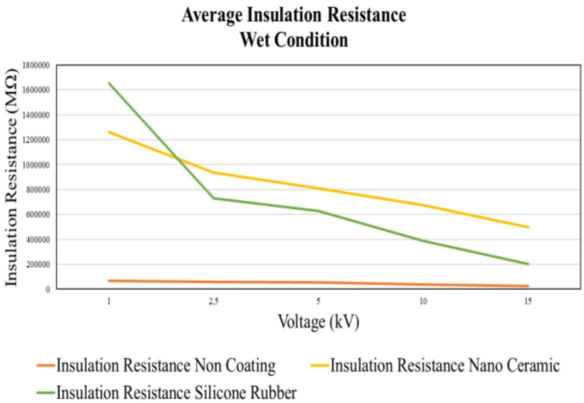

Fig 9. Comparison graph of average insulation resistance in wet conditions

Figure 9 shows the average graph of insulation resistance before and after coating wet conditions, it can be seen that the insulation resistance after coating is greater than before coating. At a test voltage of 1 kV, the insulator with silicone rubber coating is greater than nano ceramic coating and before coating. At test voltages of 2.5 kV, 5 kV, 10 kV, and 15 kV, insulators with nano ceramic coating are greater than those with silicone rubber coating and before coating. Overall, the best quality insulators based on the average insulation resistance value are insulators with nano ceramic insulation resistance, silicone rubber insulation resistance, and before coating, respectively.

Comparison of Insulation Resistance Testing Before and After Coating with Insulation Resistance Standards

Comparison of Average Value of Insulation Resistance in Dry Condition

The average value of dry condition insulation resistance Table 2 compared with Table 1 can be formed as follows:

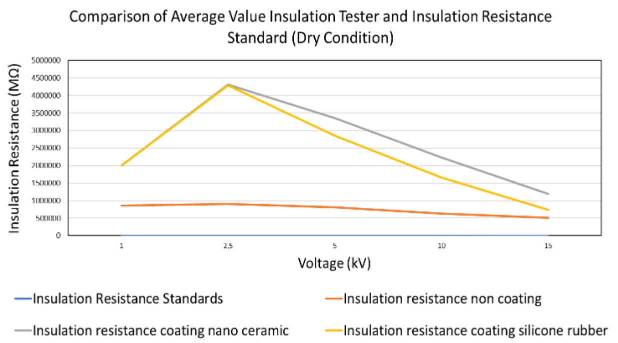

Fig 10. Comparison graph of the average insulation resistance against the dry condition test standard

The value of insulation resistance in non-coated insulators, nano ceramic coatings, and silicone rubber coatings in dry conditions has passed the standard value of insulation resistance based on the voltage injected into the insulator.

Comparison of Average Value of Insulation Resistance in Wet Condition

The average value of wet condition insulation resistance in Table 3 compared to Table 1 can be formed as follows:

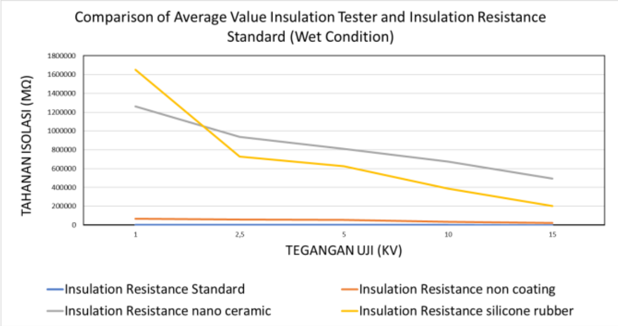

Fig 11. Comparison chart of average insulation resistance against wet condition test standards

The value of insulation resistance in non-coated insulators, nano ceramic coatings, and silicone rubber coatings in wet conditions has passed the standard value of insulation resistance based on the voltage injected into the insulator.

Comparison of Dry and Wet Condition Insulation Resistance Testing

Non-Coating Insulator

The value of the insulation resistance of non-coated insulators from table 2 and table 3 can be represented in the form of a graph as follows

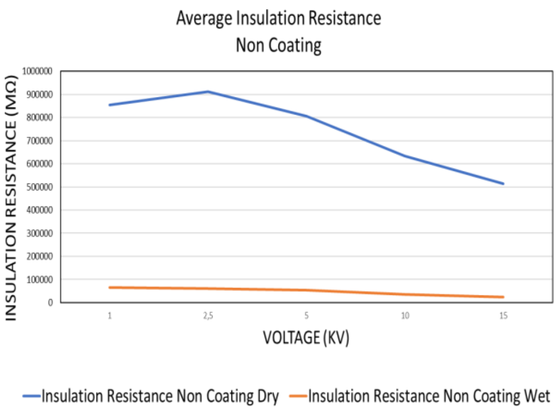

Fig 12. Comparison graph of the average insulation resistance of dry and wet conditions of non coating insulators

The insulation resistance value of the dry condition non coating insulator is greater than the wet condition due to rainwater which has a conductivity value that makes the insulator resistance decrease.

Nano Ceramic Insulator

The value of insulation resistance of nano ceramic coating insulators from table 2 and table 3 can be represented in the form of graphs as follows

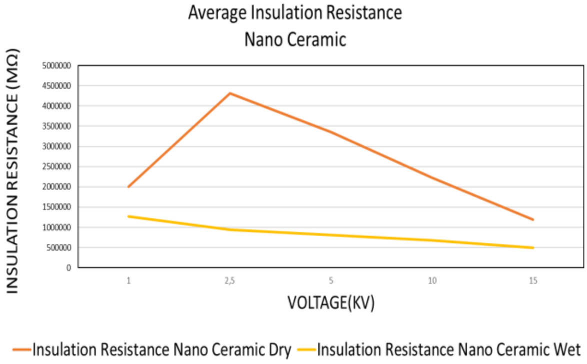

Fig 13. Comparison graph of the average insulation resistance of dry and wet conditions of nano ceramic coating insulators

The insulation resistance value of insulators with nano ceramic coating in dry conditions is greater than wet conditions due to rainwater which has a conductivity value that makes the insulator resistance decrease.

Silicone Rubber Insulator

The value of the insulation resistance of the silicone rubber coating insulator from table 2 and table 3 can be represented in the form of a graph as follows

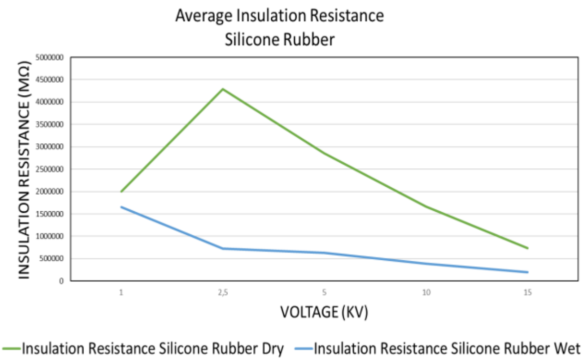

Fig 14. Comparison graph of the average insulation resistance of dry and wet conditions of silicone rubber coating insulators

The insulation resistance value of insulators with silicone rubber coating in dry conditions is greater than wet conditions due to rainwater which has a conductivity value that makes the insulator resistance decrease.

3.2. Leakage Current Testing

Average Value of Leakage Current Testing

Comparison of Average Leakage Current Values of Dry Condition

Leakage current testing by applying test voltages of 1 kV, 2.5 kV, 5 kV, 10 kV and 15 kV for 10 minutes on non-coated insulators, nano ceramic coatings, and silicone rubber coatings. The values are averaged and summarized in table 4 below.

Table 4. Average value of leakage current in dry condition

Test voltage (kV)	Leakage Current *Non-Coating* (µA)	Leakage Current *Nano Ceramic* (µA)	Leakage Current *Silicone Rubber* (µA)
1	0.0012055	0.0001915	0.000094
2,5	0.0028195	0.0005845	0.0006385
5	0.006356	0.001572	0.00203
10	0.016218461	0.004684	0.006838
15	0.02996594	0.013205	0.021375

From Table 4, a comparison graph of the average value of leakage current on the insulator can be formed in figure 15 below

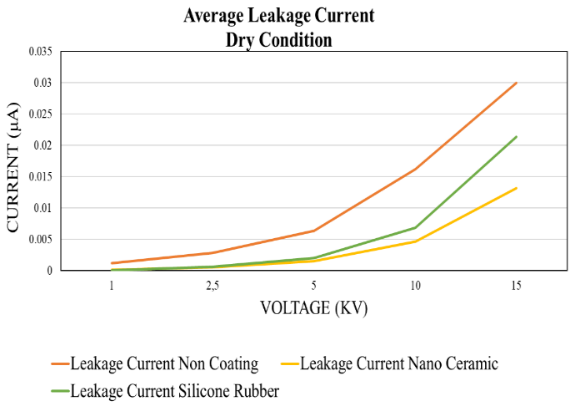

Fig 15. Comparison chart of average leakage current in dry conditions

Good insulator quality is when the leakage current value is small because the leakage current is very dangerous to propagate to other components. The smallest to the largest average value of leakage current in order based on Figure 15 is the insulator with nano ceramic coating, silicone rubber coating, and non coating. So based on this, the best quality insulators in dry conditions are insulators with nano ceramic coating, silicone rubber coating, and non coating.

Comparison of Average Value of Leakage Current of Wet Condition

Leakage current testing by applying test voltages of 1 kV, 2.5 kV, 5 kV, 10 kV and 15 kV for 10 minutes on non-coated insulators, nano ceramic coatings, and silicone rubber coatings. The values are averaged and summarized in table 5 below.

Table 5. Average value of leakage current in wet condition

Test voltage (kV)	Leakage Current *Non-Coating* (µA)	Leakage Current *Nano Ceramic* (µA)	Leakage Current *Silicone Rubber* (µA)
1	0.019524	0.000956	0.0005465
2,5	0.044030001	0.0028255	0.005511
5	0.099699999	0.006583	0.0109615
10	0.3521	0.016055	0.031955
15	0.90455001	0.03469	0.08329

From table 5, a comparison graph of the average value of leakage current on the insulator can be formed in the following figure 16

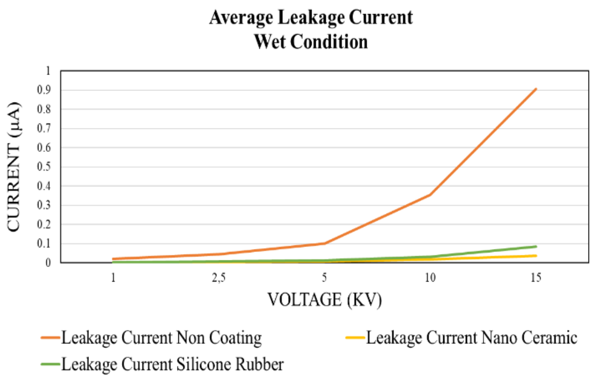

Fig 16. Comparison graph of average leakage current in wet conditions

The quality of a good insulator is when the leakage current value is small because the leakage current is very dangerous to propagate to other components. The smallest to the largest average value of leakage current in order based on Figure 16 is the insulator with nano ceramic coating, silicone rubber coating, and non coating. So based on this, the best quality insulators in wet conditions are insulators with nano ceramic coating, silicone rubber coating, and non coating.

Comparison of Average Leakage Current Values of Dry and Wet Conditions

Non-Coating

The average value of leakage current in dry and wet conditions on non-coated insulators can be seen in Table 4 and Table 5. The value is represented in the graph as follows

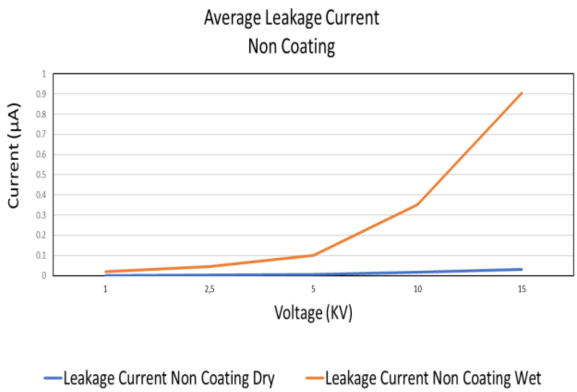

Fig 17. Comparison graph of the average leakage current of dry and wet conditions of non-coated insulators

The leakage current value of non-coated insulators in wet conditions is greater than dry conditions for each test voltage variation. This is due to the rainwater used to increase the conductivity of the insulator resulting in reduced insulation resistance and greater leakage current passing through the surface.

Nano Ceramic

The average value of leakage current in dry and wet conditions on nano ceramic insulators is seen in table 4 and table 5. The value is represented in the graph as follows

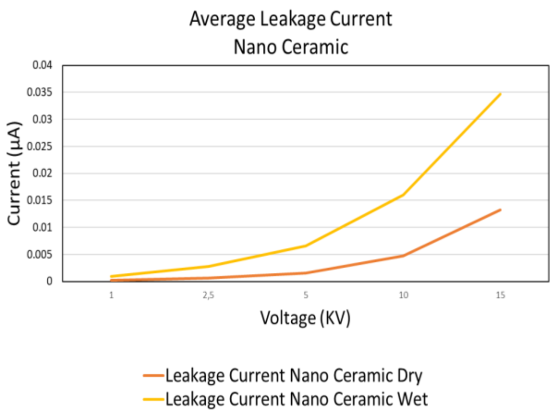

Fig 18. Comparison graph of the average leakage current of dry and wet conditions of nano ceramic coating insulators

Similar to previous research, the leakage current value of nano ceramic coating insulators in wet conditions is greater than dry conditions for each test voltage variation [8]. This is due to the rainwater used to increase the conductivity of the insulator resulting in reduced insulation resistance and greater leakage current passing through the surface.

Silicone Rubber

The average value of leakage current in dry and wet conditions on silicone rubber insulators is seen in table 4 and table 5. The value is represented in the graph as follows

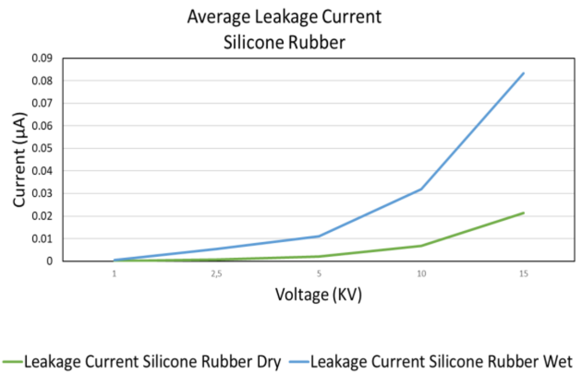

Fig 19. Comparison graph of average leakage current dry and wet conditions silicone rubber coating insulator

The leakage current value of silicone rubber coating insulators in wet conditions is greater than dry conditions for each test voltage variation. This is due to the rainwater used to increase the conductivity of the insulator resulting in reduced insulation resistance and greater leakage current passing through the surface. The existence of a silicon rubber layer is water-repellent so that it can keep the insulator surface clean and reduce the electrical conductivity of the insulator surface [8].

3.3. Contact Angle Testing

Contact Angle of Non-coated Insulator

Fig 20. Raindrops on a non-coated insulator

Figure 20 shows raindrops on an uncoated insulator. To determine the contact angle of the droplet, it is necessary to measure the angle of the droplet on the right and left. Using computer software, the droplet angles can be processed and the value of each angle can be determined. The droplet angles can be seen in Figure 21 and Figure 22 as follows.

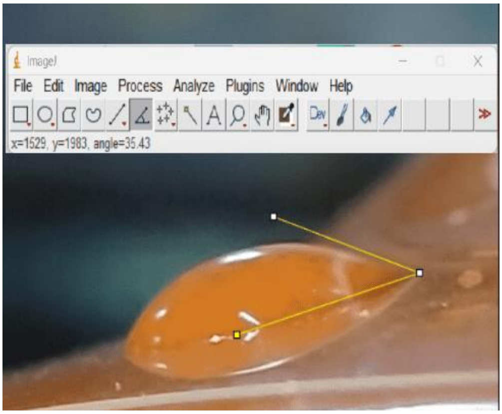

Fig 21. Droplet angle to the right of the non-coated insulator

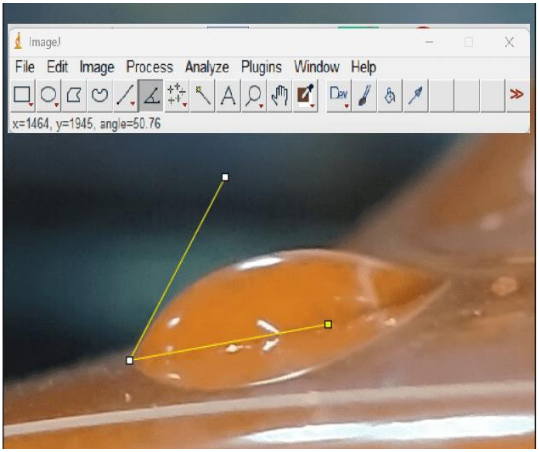

Fig 22. Left hand droplet angle of non-coated insulator.

Figure 21 shows the angle of the right droplet is 35.43° and Figure 22 the angle on the left is 50.76° so that the advancing angle (θa) is 50.76° and the receding angle (θr) is 35.43°. To calculate the contact angle using the equation

$$Contact\ Angle = \frac{\theta a + \theta r}{2} \tag{2}$$

So, the results of measuring droplets before coating are

$$Contact\ Angle = \frac{50{,}76 + 35{,}43}{2} \tag{3}$$

$$Contact\ Angle = \frac{86{,}19}{2}$$

$$Contact\ Angle = 43{,}095$$

The contact angle value is 43.095°. Based on the contact angle standard, if the contact angle of the raindrop is 0° < Contact Angle < 90°, then the contact angle is categorized as hydrophilic.

Nano Ceramic Coating Insulator Contact Angle

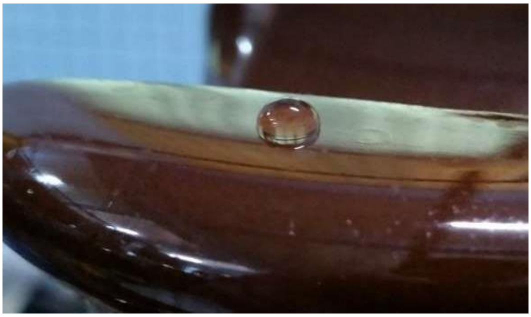

Fig 23. Droplets on the surface of nano ceramic coating insulator

Figure 23 shows the raindrops on the insulator after nano ceramic coating. To determine the contact angle of the droplet, it is necessary to measure the angle of the droplet on the right and left to obtain the advancing angle (θa) and the receding angle (θr). By using computer software, the droplet angles can be processed and the value of each angle can be determined. The droplet angles can be seen in Figure 24 and Figure 25 as follows.

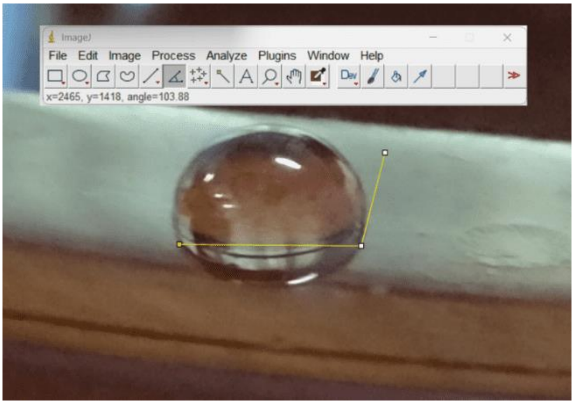

Fig 24. Right hand droplet angle of nano ceramic coating insulator

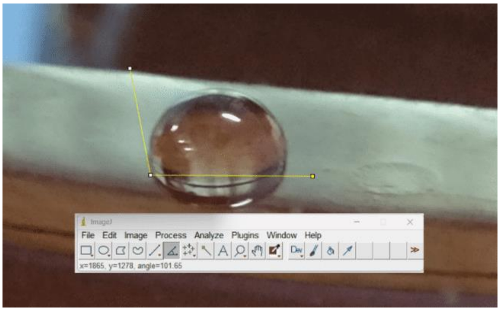

Fig 25. Left droplet angle of nano ceramic coating insulator.

Figure 24 shows the angle of the droplet on the right is 103.88° and Figure 25 shows the angle of the droplet on the left is 101.65° so that the advancing angle (θa) is 103.88° and the receding angle (θr) is 101.65°. To calculate the contact angle using the Equation (2). So, the results of measuring droplets before coating are

$$Contact\ Angle = \frac{103{,}88 + 101{,}65}{2} \tag{4}$$

$$Contact\ Angle = \frac{205{,}53}{2}$$

$$Contact\ Angle = 102{,}765$$

The contact angle value is 102,765°. Based on the contact angle standard, if the contact angle of the raindrop is 90° < Contact Angle < 120°, then the contact angle is categorized as hydrophobic.

Contact Angle of Silicone Rubber Coating Insulator

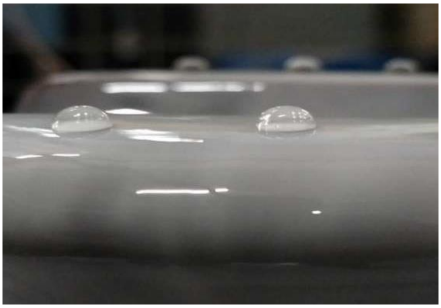

Fig 26. Droplets on the surface of the silicone rubber coating insulator.

Figure 26 shows raindrops on the insulator after silicone rubber coating. To determine the contact angle of the droplet, it is necessary to measure the angle of the droplet on the right and left to obtain the advancing angle (θa) and receding angle (θr). By using computer software, the droplet angle can be processed and the value of each angle can be determined. The droplet angles can be seen in Figure 27 and Figure 28 as follows.

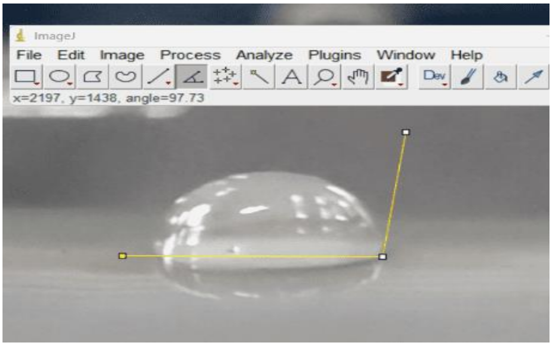

Fig 27. Drip angle to the right of the silicone rubber coating insulator

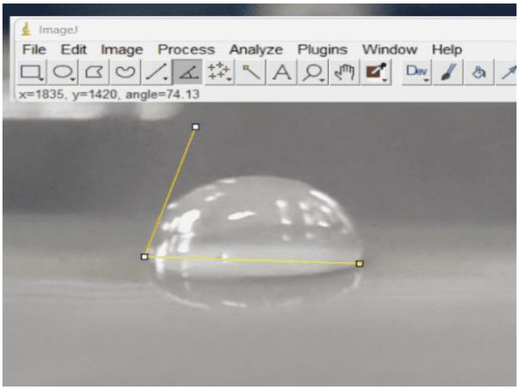

Fig 28. Left-hand drip angle of silicone rubber coating insulator

Figure 27 shows the angle of the droplet on the right is 97.73° and Figure 28 shows the angle of the droplet on the left is 74.13° so that the advancing angle (θa) is 97.73° and the receding angle (θr) is 74.13°. To calculate the contact angle using the Equation (2). So, the results of measuring droplets before coating are

Contact Angle = (97,73+74,13)/2

Contact Angle = 171,86/2

Contact Angle = 85,93

The contact angle value is 85.93°. Based on the contact angle standard, if the contact angle of the raindrop is 0° < Contact Angle < 90°, then the contact angle is categorized as hydrophilic.

Comparison of Contact Angle Values of Non-Coating, Nano Ceramic, and Silicone Rubber

Table 6. Comparison of contact angle values between insulators

	Advanc-ing angle (θa)	Reced-ing angle (θr)	Contact Angle Value	Nature
Non-Coating	50,76°	35,43	43,095°	Hydrophilic
Nano ceramic	103,88°	101,65°	102,765°	Hydrophobic
Silicone rubber	97,73°	74,13°	85,93°	hydrophilic

Table 6 shows the contact angle values of insulators before coating, nano ceramic coating and silicone rubber coating. Based on these values, the best quality insulator is the insulator coated with nano ceramic with a contact angle value of 102.765° which is hydrophobic than the contact angle value of silicone rubber insulator which is 85.93° which is hydrophilic and non-coating insulator is 43.095° which is hydrophilic. In addition, the quality of the insulator based on the contact angle value becomes better after nano ceramic coating and silicone rubber coating than the insulator before coating (non-coating).

4. Conclusion

This research has several conclusions, among others:

1. In dry conditions, the quality of the insulator is judged by the value of the largest insulation resistance. The largest to smallest value of insulation resistance is nano ceramic coating insulator, silicone rubber insulator and non-coating insulator. The best quality is nano ceramic insulator.

2. In wet conditions, the best insulator quality based on the largest to smallest insulation resistance value is nano ceramic coating insulator, silicone rubber coating insulator, and non-coating. In wet conditions, the best quality insulator is nano ceramic coating insulator.

3. In dry conditions, the quality of insulators based on leakage current based on this research is insulators with nano ceramic coating, silicone rubber coating, and before coating.
4. In wet conditions, the quality of insulators based on leakage current based on this research is insulators with nano ceramic coating, silicone rubber coating, and before coating.
5. Rainfall will affect the insulation resistance and leakage current. The test shows that high rainfall (increased water discharge) will cause the insulation resistance to decrease and the leakage current will increase.
6. The quality of the insulator based on the contact angle in order is insulator with nano ceramic coating with a contact angle of 102.765 ° is hydrophobic, insulator with silicone rubber coating with a contact angle of 85.93 ° is hydrophilic, and before coating with a contact angle value of 43.095 ° is hydrophilic.
7. The best insulator quality based on the value of insulation resistance, leakage current, and contact angle in dry and wet conditions is nano ceramic coating insulator.
8. The quality of the insulator will be better after the coating process so that the performance of the insulator becomes more optimal.

Authors' Contributions

Authors 1: Conceptualization, Methodology, Coating, Testing material, Adjusting, Visualization, Formal analysis, Writing – original draft, Writing – Report, Writing – review & editing, Finalization, Presentation. Authors 2: Conceptualization, Methodology, Validation, Review, Writing – review & editing, Supervision, Accepting. Authors 3: Conceptualization, Methodology, Review, Writing – review & editing, Supervision, Accepting.

Conflicts of Interest

The authors declare they have no conflicts of interest.

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