# Performances of Long-term Coastal Field Aged Silicone-coated Ceramic Insulators under Clean and Salt Fog Conditions

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***Abstract*—Ceramic insulator is a kind of insulator that is used most widely especially in Indonesia. It has good property in both electrical and mechanical strength but has hydrophilic behavior that susceptible for leakage current flowed on the surface of insulator. Based on previous research, leakage current can be a good indicator to diagnose insulator surface condition. This paper presents leakage current performance of a long-term field aged ceramic insulator with and without RTV silicone rubber coating under clean fog and salt fog condition. The insulators have been installed in the coastal field for 5 years and 4 months. The insulators were investigated in laboratory to know the effect of voltage rise to the aged insulator condition under clean fog and salt fog condition. Monitored parameters are magnitude and THD of leakage current. The result has shown that with voltage rise, coated insulator has better performance in both clean fog and salt fog condition especially to increase the flashover voltage of aged ceramic insulator.**

***Keywords—leakage current; ceramic insulator; RTV silicone rubber coating; long term aging; clean fog; salt fog***

## I. INTRODUCTION

There are a large amount of ceramic outdoor insulators located at coastal areas with high salt pollution, especially in Indonesia. The salt pollution can accumulate on the insulator's surface and make a layer that can decrease insulator resistivity until it becomes susceptible to leakage current flow, particularly if the insulator is exposed to high humidity. The leakage current may degrade the insulator surface leading to the failure of the insulators [1]. Leakage current can be used as a signature of the insulators because it represents the surface condition of insulators and can be an accurate diagnostic tool for flashover warning [2-4].

One of the solutions to improve ceramic insulator performance was by coating insulator surface with Room Temperature Vulcanization (RTV) silicone rubber. Previous research has reported that RTV silicone rubber coating for ceramic insulator can improve its performance because it has hydrophobic behavior [5-8] and the coating also improves surface smoothness of ceramic insulator [9].

This paper reports long-term coastal aged ceramic insulator with and without RTV silicone rubber coating testing under clean and salt fog condition to know both insulators condition with rise of voltage.

## II. EXPERIMENTS

Experiment was conducted to know the insulator's performance after exposed to natural coastal aging in Pangandaran beach along 5 years and 4 months. The aging was experienced in heavily salt polluted area which powered continuously by voltage 11 kV without any maintenance. Insulators were tested in laboratory by exposed voltage rise from 11 kV to 50 kV in clean fog condition, and then 11 kV until flashover occurs in salt fog condition with monitored parameters were magnitude and THD of leakage current.

### A. Samples

Samples used in the experiment were 20 kV class pin-post type ceramic insulators. 1 sample was uncoated and 1 sample was coated with RTV silicone rubber by using high pressure nozzle with surface thickness of 0,3 ± 0,05 mm. The insulators has creepage distance of 500 mm and widely used in Indonesian State Electricity Corporation (PT. PLN) network.

a. Coated insulator b. Uncoated insulator

Fig 1. Coated and uncoated insulator conditions after 5 years and 4 months aging in the field

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Fig 2. Configuration of insulators aging at coastal area

Fig 1 shows coated and uncoated insulator conditions after 5 years and 4 months aging that used as tested samples in laboratory, while Fig 2 shows configuration of insulators where aging was conducted along 5 years and 4 months.

### *B. Experimental Set up*

The insulators were tested in laboratory by exposed voltage rise from 11 kV to 50 kV in clean fog condition, and then 11 kV until flashover occurs in salt fog condition. The testing was conducted in a chamber which made from aluminum panel with dimension of 900 x 900 x 1200 mm$^3$ to simulate pollution to the samples. The front opening of the test chamber was made from acrylic to facilitate observation on the sample surface.

Clean fog was made by clean water (nonconductive water) to expose light condition to the insulator while salt fog was made by Pangandaran sea water with conductivity 51 mS/cm to expose severe condition. From both experiments, we can see the performance of coated and uncoated insulators when the same condition occurred in the field.

### *C. Leakage current measurement*

The leakage current flowed on the insulator surface was measured by measuring the voltage across a series resistance in variable resistor using a Digital Oscilloscope with digitizer of 8 bit, bandwidth of 100 MHz, and the maximum sampling rate of 1 GS/s. The circuit of leakage current measurement is as follow.

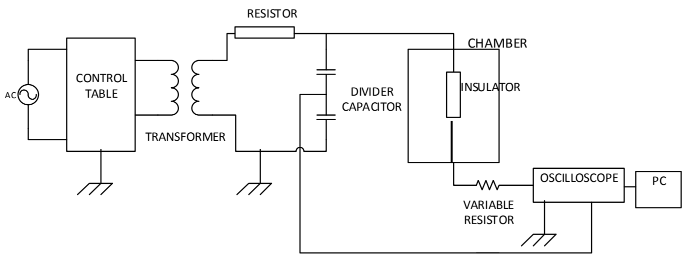



Fig 3. Leakage current measurement circuit

Fig 3 shows one line diagram of leakage current measurement. The tested insulator was placed in the chamber along measurement. Leakage current waveforms including low and high frequency components were obtained. The digital data was transferred to a personal computer through a GPIB for further analysis.

FFT was conducted in order to know harmonic content and calculate Total Harmonic Distortion (THD) of leakage current so the condition of leakage current wave can be diagnosed. The THD is defined as the total ratio of the harmonic components and the fundamental which can be expressed as follow.

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} I_n{}^2}}{I_1} \tag{1}$$

Where $I_1$ = 1$^{st}$ harmonic (fundamental)
$I_n$ = nth harmonic for n = 2, 3, 4, ….

## III. EXPERIMENTAL RESULT

The main purpose of the research was to test insulator performance after 5 years and 4 months aging with voltage rise under clean and salt fog condition with leakage current parameter.

### *A. Leakage current Magnitude and THD*

Leakage current magnitude and THD were an important parameter to know insulator condition. From the experiment, we can reveal RTV silicone coating impact to ceramic insulator performance under clean and salt fog condition with voltage rise. Comparison of the parameters under both conditions are as follows.

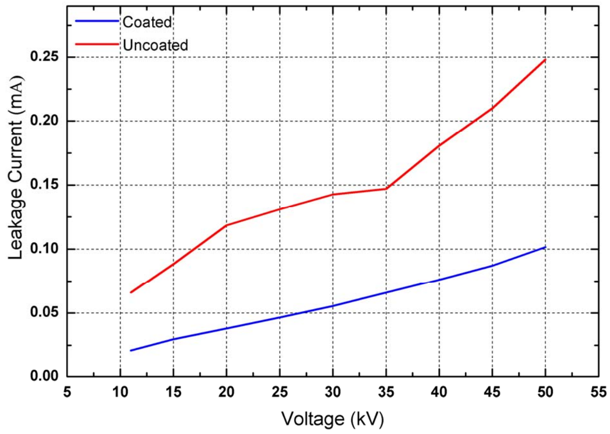



Fig 4. Dependences of leakage current magnitude of coated and uncoated insulators on applied voltage under clean fog condition

Fig 4 shows comparison of leakage current magnitude of coated and uncoated insulators under clean fog condition. Under clean fog condition, leakage current magnitude of both coated and uncoated insulators increased linearly in which uncoated insulator has higher magnitude. It shows that the coating can suppress leakage current under clean fog condition when applied voltages are 11-50 kV.

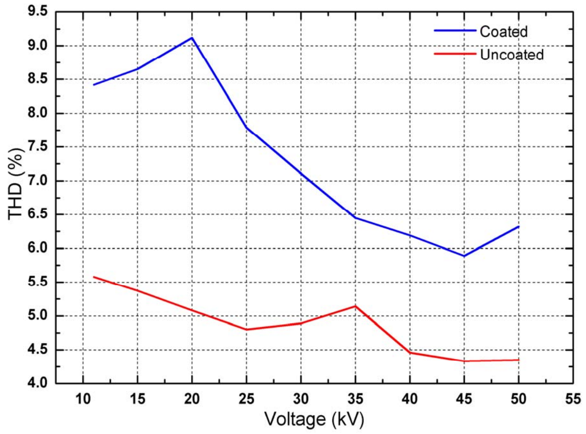



Fig 5. Dependences of leakage current THD of coated and uncoated insulators on applied voltage under clean fog condition

Fig 5 shows comparison of leakage current THD of coated and uncoated insulators under clean fog condition. THD of leakage current has the opposite trend with the magnitude. The higher voltage given, THD was decrease because rise of harmonic content slower than fundamental magnitude so ratio of them was smaller.

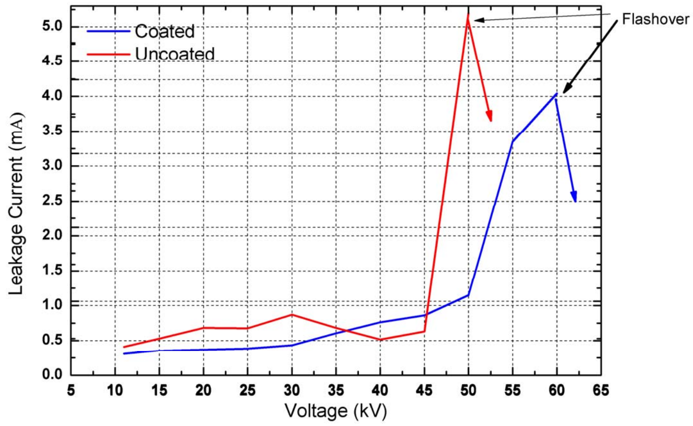



Fig 6. Dependences of leakage current magnitude of coated and uncoated insulators on applied voltage under salt fog condition

Fig 6 shows comparison of leakage current magnitude of coated and uncoated insulators under salt fog condition. Leakage current magnitude of coated insulator under salt fog condition was increased continously until flashover occurs at 60 kV while uncoated insulator was flashover at 50 kV with fluctuative leakage current magnitude especially when magnitude decrease at voltage 35 kV and increase at 45 kV.

Under fog condition, leakage current magnitude increase with fog conductivity. Compared to the leakage current magnitude under clean fog, the leakage current magnitude under salt fog was much higher than those from clean fog. At clean fog condition, the leakage current magnitude increased linearly with the applied voltage while at high fog conductivity the oscillation behaviour of leakage current magnitude dependence on applied voltage was observed due to the wetting effect of sample surface by the fog and drying effect caused by the higher leakage current [10]. The high magnitude of leakage current in turn will heat the insulator surface and may promote the degradation of the insulator.

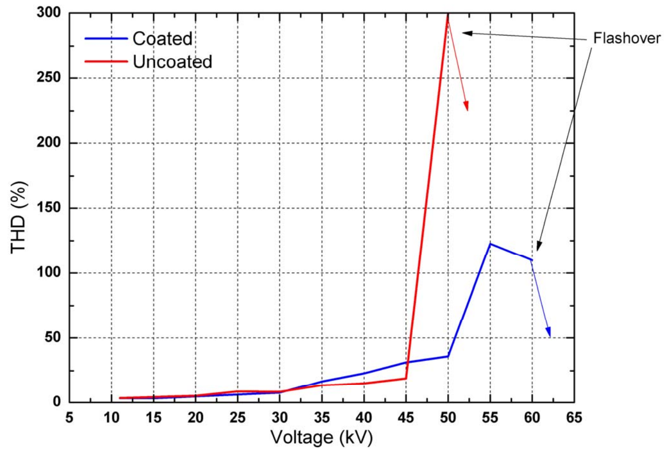



Fig 7. Dependences of leakage current THD of coated and uncoated insulators on applied voltage under salt fog condition

Fig 7 shows comparison of leakage current THD of coated and uncoated insulators under salt fog condition. THD of leakage current under salt fog condition has the same trend with the magnitude which THD of coated and uncoated insulator increased continously until flahover occurred. But when applied voltage was 60 kV for coated insulator, the THD decreased before flashover because the magnitude was very high while harmonic content increase not so high so ratio of them was smaller at that condition.

## *B. Leakage current Waveform*

Based on previous research, leakage current waveform strongly correlated with insulator condition [11]. Leakage current waveforms analysis under clean and salt fog condition with voltage rise are as follows.

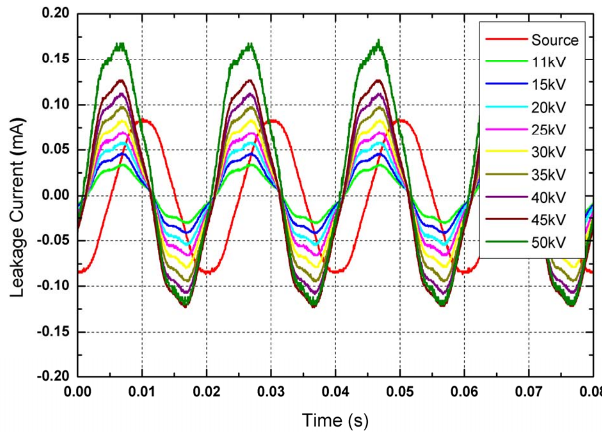



Fig 8. Dependences of leakage current waveform of coated insulator on applied voltage under clean fog condition

Fig 8 shows leakage current waveforms of coated insulator under clean fog condition with voltage 11-50 kV. The leakage current has low magnitude and low THD with almost sinusoidal waveform. Based on [11], it concluded as normal condition because no discharge was observed.

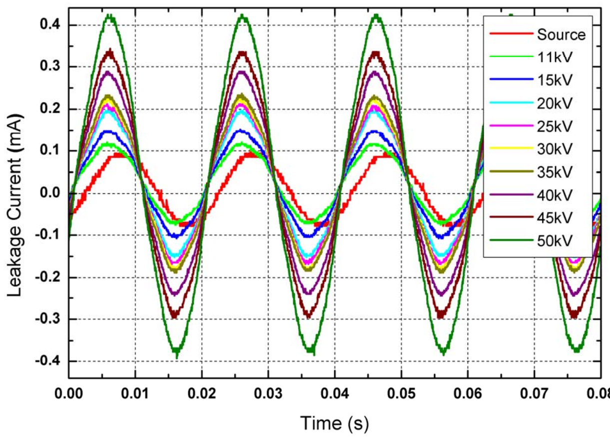



Fig 9. Dependences of leakage current waveform of uncoated insulator on applied voltage under clean fog condition

Fig 9 shows leakage current waveform of uncoated insulator under clean fog condition with voltage 11-50 kV. Under clean fog condition no discharge was observed at leakage current waveforms both coated and uncoated insulators. Uncoated insulator has more sinusoidal waveform with phase angle closer to the phase of source voltage. The result also showed that the leakage current magnitude of uncoated insulator was higher than coated insulator. Based on [11], under clean fog condition uncoated insulator has high surface conductance and high electric field.

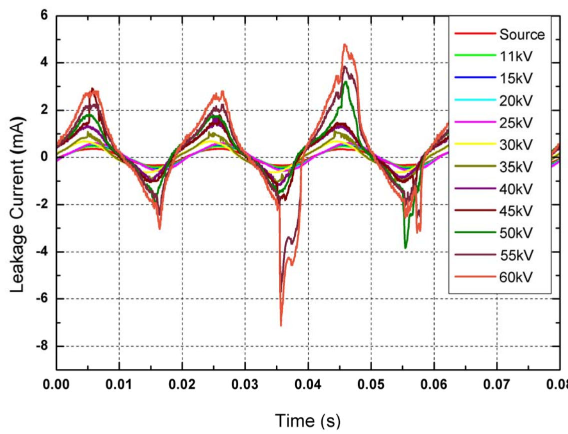



Fig 10. Dependences of leakage current waveform of coated insulator on applied voltage under salt fog condition

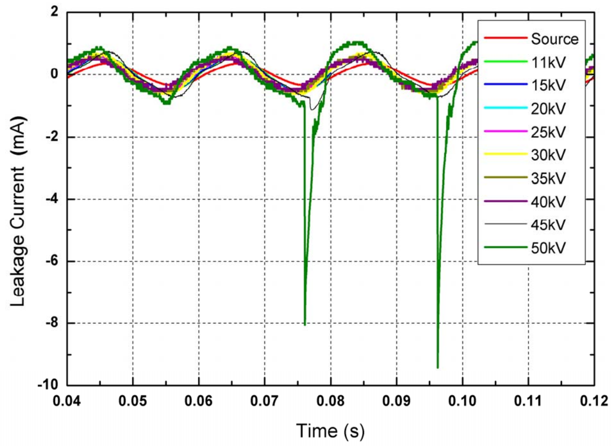



Fig 11. Dependences of leakage current waveform of uncoated insulator on applied voltage under salt fog condition

Fig 10 and Fig 11 shows leakage current waveform of coated and uncoated insulators under salt fog condition with voltage 11 kV until flashover. Under salt fog condition, discharge was observed in coated insulator since voltage 45 kV and the discharge was increased until flashover occurrs at 60 kV. When pre flashover condition occurred, the discharge was high in both positive and negative cycle. While in uncoated insulator discharge was observed at voltage 45 kV and flashover occurred at 50 kV with asymmetrical leakage current waveform where discharge was dominant in negative cycle.

As applied voltage increase, the ionization may take place on the insulator surface. Electric discharge may take place if initial charge of electron is available and instantaneous applied voltage exceeding a certain threshold value. This phenomenon could cause asymmetrical leakage current waveform. At positive dominant waveform distortion, the initial electrons were ejected from the fog side. At uncoated insulator, when flashover occurs larger distortion of leakage current waveforms were observed at negative half cycles. This means that the discharges were initiated from sample side insulator surface was very conductive at that condition. [10].

### *C. Condition Diagnosis of Insulators*

Based on previous research, each of leakage current magnitude and THD were good indicators of insulator surface. But cross product of magnitude and THD was more reliable because it gives better correlation to insulator surface condition [11]. In order to know the condition, cross product between magnitude and THD was used.

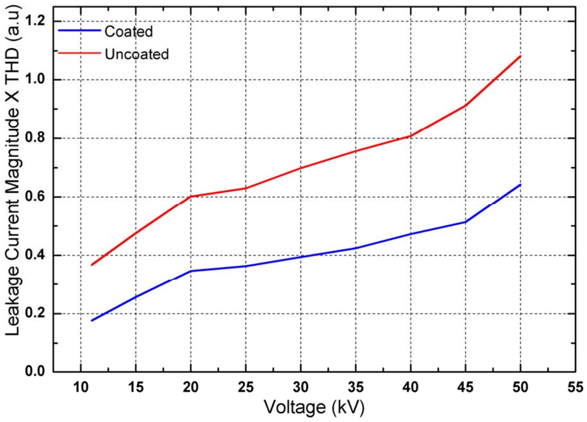



Fig 12. Dependences of cross product of leakage current magnitude and THD of coated and uncoated insulators on applied voltage under clean fog condition

Fig 12 shows cross product of leakage current of coated and uncoated insulator under clean fog condition. Under clean fog, cross product of leakage current magnitude and THD showed linear increase with uncoated insulator was higher. It shows that based on leakage current parameter under clean fog condition coated insulator has better performance.

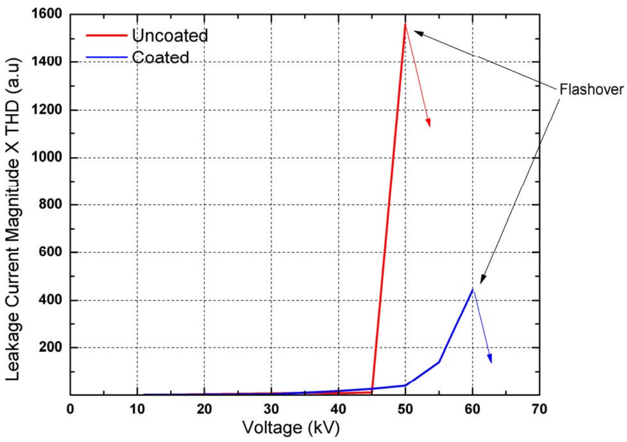
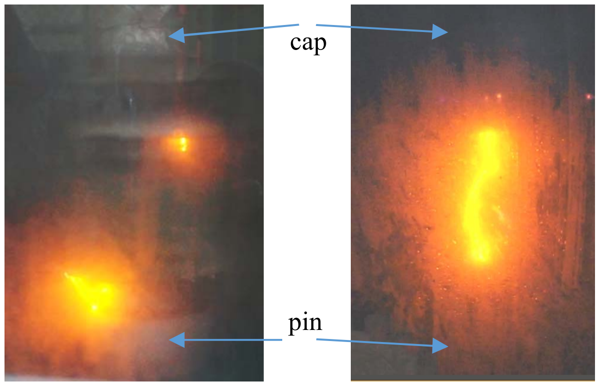



Fig 13. Dependences of cross product of leakage current magnitude and THD of coated and uncoated insulator on applied voltage under salt fog condition

Fig 13 shows cross product of leakage current of coated and uncoated insulator under salt fog condition. Under salt fog, both of insulators exposed to flashover with coated insulator has higher flashover voltage that uncoated insulator. From Fig 13 we can see that coating can improve ceramic insulator performance when it exposed to severe condition with high humidity and high fog conductivity. The flashover occurence showed in Fig 14. Coated insulator exposed to flashover at voltage 60 kV while uncoated insulator at 50 kV.




a. Coated insulator (flashover at 60 kV)

b. Uncoated insulator (flashover at 50 kV)

Fig 14. Insulator condition while flashover occurs

## IV. CONCLUSION

RTV silicone rubber coating can improve ceramic insulator performance under clean fog and salt fog condition with leakage current and flashover voltage indicators. By cross product of leakage current magnitude and THD, we can diagnose insulator surface condition more reliable because it includes both leakage current parameters in one analysis which each of parameter was an important indicator that can't be used separately.

At salt fog condition with conductivity 51 mS/cm, uncoated insulator flashover at voltage 50 kV while coated insulator flashover at voltage 60 kV. It shows that with RTV silicone rubber coating, flashover voltage of field aged ceramic insulator was increased, so it can be a good recommendation to use the coating for ceramic insulator which applied in coastal area with high pollution and high humidity condition.

## REFERENCES

[1] Suwarno and J. Parhusip, “Effects of humidity and fog conductivity on the leakage current waveforms of ceramics for outdoor insulators”, WSEAS Transactions on Systems Vol 9. No. 4, pp. 442-452, 2010.

[2] Wang, C., et al, “Study of Composite Insulator Leakage current Characteristics in Contamination and Humidity Conditions”, IEEE Annual Report Conference on Electrical Insulation and Dielectric Phenomena, 2014.

[3] Liu, et al, “Analysis of Leakage current of Long String Insulators of High-Altitude Artificial Contamination Test”, IEEE Annual Report Conference on Electrical Insulation and Dielectric Phenomena 2014.

[4] Banik, A., Dalai, S., and Chatterjee, B, “Condition Monitoring of Overhead line Insulator By measuring Surface Leakage current”, Annual IEEE India Conference (INDICON), 2014.

[5] Suwarno, Basuki, A., Lendy, F., and Sumedi, “Improving outdoor Insulator performances installed at coastal area using Silicone Rubber Coating”, IEEE International Conference on Condition Monitoring and Diagnosis 2012.

[6] Suwarno & Wibowo, AB, “Increasing the performances of various Types Outdoor Insulators by using RTV Silicone Rubber Coating”, International Journal on Electrical Engineering Informatics, Vol 4, No. 4, December 2012.

[7] Suwarno, and Prastomosiwi, F, “Application of RTV Silicone Rubber

Coating for Improving Performances of Ceramic Outdoor Insulator under Polluted Condition", International Conference on Electrical Engineering and Informatics 2009.

[8] Suwarno, "Leakage current Waveforms of Outdoor Polymeric Insulators and Possibility of Application for Diagnostics of Insulator Conditions", Journal of Electrical Engineering & Technology, Vol. 1, No. 1, pp. 114~119, 2006.

[9] Prastomosiwi, F., and Suwarno, "Performance Improvement of the Ceramic Outdoor Insulators Located at Highly Polluted Environment Using Room Temperature Vulcanized Sillicone Rubber Coating", International Journal on Electrical Engineering Informatics, Vol 2, No. 1, December 2012.

[10] Suwarno and J. Parhusip, "Effects of humidity and fog conductivity on the leakage current waveforms of ceramics for outdoor insulators", WSEAS Transactions on Sistems Vol 9. No. 4, pp. 442-452, 2010.

[11] Suwarno. "Leakage current Waveforms of Outdoor Polymeric Insulators and Possibility of Application for Diagnostics of Insulator Conditions". KIEE Journal of Electrical Engineering and Technology. Vol. 1, pp. 114-119, 2006.