And., Intl.,J., Appl Sci., Eng., Tech, Vol 01, No 02, November 2021
e-ISSN: 2797-0442

Effect of humidity and contaminants on dry band formation in Outdoor Distribution Current Transformer 20 kV

Satia Zaputra
Department of Electrical Engineering
Kebangsaan University, Bandung Indonesia
Satiazaputra3107@gmail.com

Abstract— This study reports the effect of humidity and pollutants on the formation of dry band phenomena on the insulation surface of an outdoor 20 kV distribution current transformer. From the results of measurements at high humidity 95% and high conductivity 36 mS/cm at a working voltage of 2-20kV test there is a change in the curve of increasing the value of the leakage current which is very volatile. Wet layer of impurity will cause a drastic decrease in surface resistance resulting in a large increase in leakage current. At a high conductivity of 36 mS/cm, the results of the measurement of surface resistance at low humidity of 55% worth 30.2 giga ohms decreased to 2.1 giga ohms at high humidity of 95%. While the value of the leakage current curve is very fluctuating from the value of 206 - 678 A at high conductivity with heavy pollutants. This information confirms the hypothesis that the boundary region of the two air-solid dielectrics of the epoxy resin causes surface discharge problems in dry band formation due to an increase in the non-uniform local electric field in the impurity layer adhering to the surface of the distribution current transformer.

Keywords : leakage current, dry band, surface discharge, contaminants

1. Introduction

Epoxy resins with white cement fillers have begun to be widely used for solid insulation of outdoor distribution current transformers. The external pair current transformer in the distribution feeder located in the factory area is very prone to contaminants with dust pollutants attached to its surface. Distribution current transformers in polluted conditions are often reported to experience temporary disturbances, thereby reducing the performance of the distribution feeder. In our previous study it has been reported that environmental factors such as humidity and impurities contribute greatly to the increase in surface leakage current of the outer pair distribution current transformer [1-2].

Another researcher proposed two new methods to separate the leakage current of polymeric materials for outdoor polymer insulators into two components such as conductive current and dry band arc current. Leakage current was observed and analyzed using differential value and distortion factor of leakage current waveform. Furthermore, the differential technique has a better assessment of the distortion factor in the separation of this leakage current component.[2-3]. Furthermore, it was also reported that the corona discharge current (partial) and dry band arc discharge current had a significant effect on the deterioration of polymer samples. The increase in leakage current with increasing dry band gap length also gives a weak chemical change on the polymer surface after experiencing the aging effect due to environmental influences [5-6].

Other researchers reported experimental results on the LC characteristics of insulating epoxy resins. The sample used is an epoxy resin block with dimensions of 250 × 50 × 20 mm^3 . Samples were tested in a controlled artificial environment. The correlation between LC waveforms and dry band bending phenomena under various environmental conditions is described. The results of this study also reported that the leakage current (LC) can reduce the surface degradation of the insulator and in a long time can cause flash over [4-5].

Received: October 24, 2021, Revised: November 17, 2021, Accepted: November 19, 2021
https://doi.org/10.25077/aijaset.v1i1.7

https://doi.org/10.25077/aijaset.v1i1.7

Furthermore, other researchers observed the effect of dry band formation and its characteristics on HV insulators with different salt mixtures and varying thickness of the pollution layer. The non-uniform distribution of contaminants, wetting and drying processes cause the development and formation of several dry bands on the surface of the insulator. The deposition of a pollution layer on the surface of a high voltage insulator (HV) is the first stage of the phenomenon of the occurrence of an insulation failure (flashover) on a polluted insulator [7-8].

2. Dry band forming

The study of dry band formation on the insulator surface is strongly influenced by the non-uniformity of impurities and various variations of environmental factors such as location, temperature and humidity. Many research studies have made the surface of the insulator evenly stained using dust contaminants (kaolin) to observe the occurrence of this dry band formation principle. The increase in surface leakage current that occurs is closely related to the electric field and surface resistivity with the equation :

$$E_s=\rho_s . J_s \quad (1)$$

J_s is the surface current density which is as follows::

$$J_s = I/d \quad (2)$$

As we know that the surface conductivity (σ_s) is inversely proportional to the surface resistivity (ρ_s) thus:

$$\sigma_s = 1/\rho_s \quad (3)$$

Furthermore, the power dissipation per unit area can be expressed as :

$$P_s=\rho_s . J_s^2 \quad (4)$$

This dissipation power causes an increase in surface temperature, temperature transfer of the insulator to the environment and evaporation of water in the layer of impurities.

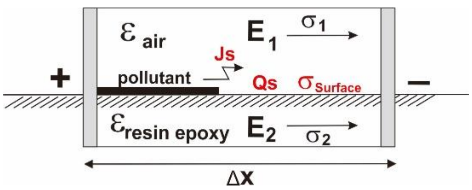

Figure 1. Relationship between leakage current and current density

From Figure 1, it can be seen that the surface current density J_s will be proportional to the given electric field. Meanwhile, the presence of pollutants can increase the increase in the distribution of the local electric field to be non-uniform so that the surface current density (J_s) becomes large because it makes it easier for the charge (Q_s) to be ionized in the air-solid dielectric boundary of the epoxy resin. This wet impurity also reduces the surface resistivity (ρ_s) so that the surface conductivity (Q_s) increases significantly [9-10].

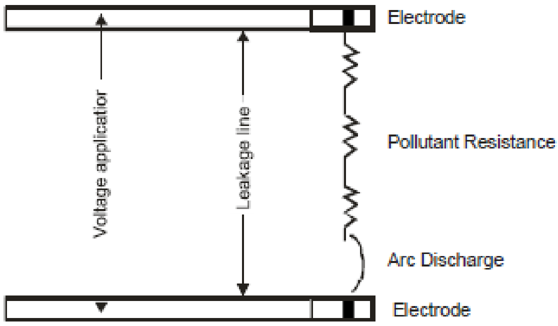

Figure 2. Dry band formation scheme

From Figure 2 , it can be seen that the heating caused by the leakage current of the impurity (pollutant resistance) increases the temperature of the coating. The difference in temperature of 2-3^{0}C from the ambient temperature is enough to make the process of evaporation of water. At a critical temperature condition (θ_C), the evaporation process of this water will cause an increase in the resistivity of the impurity surface layer. In a saturated condition, meaning that there is no further surface heating, the wet-dry process has stopped. At that time the initial formation of dry tape on the surface of the insulation. If the dry band distance is longer (Δ_X) on the surface of the distribution current transformer, the surface tracking process is taking place. The surface tracing process always begins with the discharge of charge (corona) in the impurity layer. This continuous dry band formation process eventually connects the anode to the insulating cathode so that an arc discharge will occur. This arc discharge causes the surface flashover mechanism (flashover) as an indication of the failure of the distribution current transformer isolation.

3. Experimental Section/Methods

Distribution current transformer installed location

The test object of polymer insulating material for the measurement of surface leakage current in an external pair distribution current transformer is shown in Figure 3 below. The distribution current transformer is located in the 20 kV distribution network feeder belonging to PT. PLN Distribution West Java which is prone to exposure to pollutants (pollutants) and the influence of temperature and humidity environments. At critical locations of distribution current transformers located in high polluted factory areas such as cement factories and high salt pollutants such as coastal areas, the phenomenon of dry band formation becomes an interesting case study of insulation failure to study.

Figure 3. Distribution current transformer installed in the 20 kV distribution feeder

Testing the leakage current of distribution current transformers under the influence of artificial environmental conditions

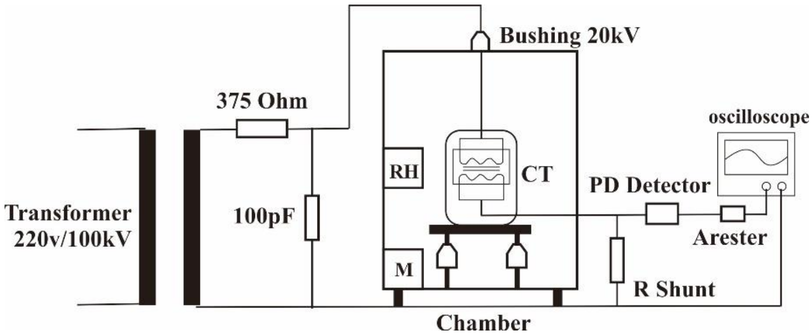

Figure 4. Leakage current test circuit

In Figure 4, a chamber box is used to create conditions for the influence of the artificial environment. The artificial condition that is set is that the distribution current transformer is exposed to light pollutants (4.6 mS/cm) and heavy pollutants (36 mS/cm) with the effect of low humidity (55% RH) and high (95%) close to wet. The results of the measurement of light pollutant leakage current compared to high pollutant conditions. The temporary hypothesis is that under heavy pollutant conditions, the phenomenon of dry band formation can be seen physically from changes in the layer of impurities on the surface of the current transformer (surface tracking). While the characteristics of changes in the leakage current curve can be analyzed to explain the process of evaporation of water in the impurity layer as the beginning of the formation of dry bands.

4. Result and Discussion

Figure 5 below is a characteristic of the leakage current under conditions of low humidity and light pollution. At low humidity (55%RH) it can be seen that the graph of the increase in leakage current increases linearly when given a working voltage of 2-20 kV. In the high pollutant condition 36 mS/cm has a higher leakage current value than the low pollutant condition 4.6 mS/cm.

Likewise on the conductivity graph of 4.6 mS/cm , it is clearly seen by using the histogram type (humidity 55% RH) the increase in leakage current approaches the liner. In wet conditions (95% RH humidity) has a higher leakage current value compared to low humidity 55% RH.

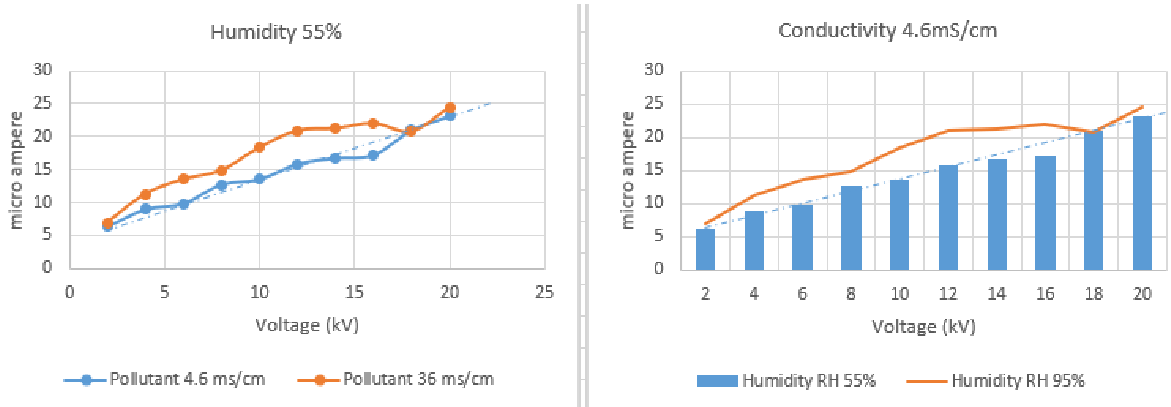

Figure 5. Graph of increase in leakage current at 55% RH humidity and 4.6 mS/cm . conductivity

From the appearance of two graphs of linear increase in leakage current in Figure 5 above, the process of evaporation of water in the impurity layer from wet to dry conditions due to heating of the leakage current has not occurred significantly. This means that in low pollutant conditions it explains that the process of forming dry bands has not occurred significantly.

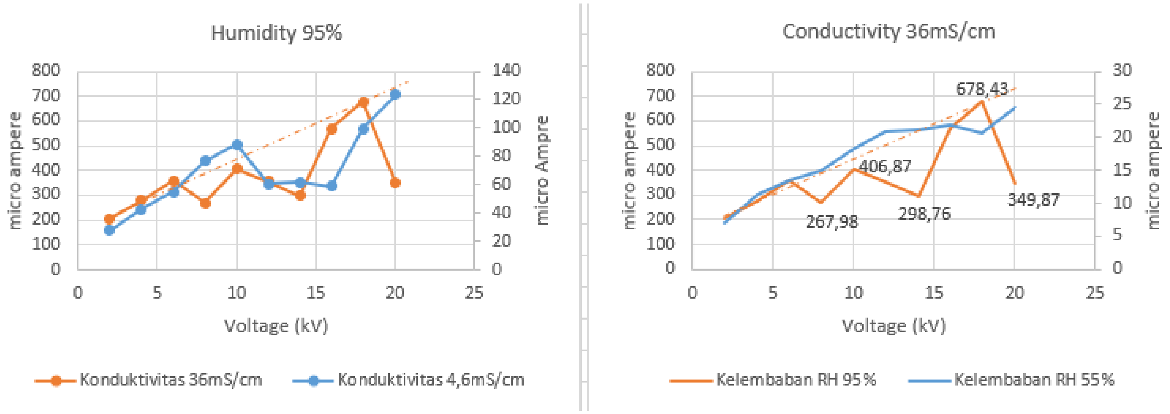

Figure 6. Graph of increase in leakage current at 95% RH humidity and 36 mS/cm . conductivity

In Figure 6 above, it is clearly seen that the large increase in the value of the leakage current in conditions of high humidity near wet (95% RH) and high pollutant (conductivity 36 mS/cm) has a very fluctuating increase characteristic which is inversely proportional to the nature of the increase in the liner in the figure. 5

In the high-polluting 36 mS/cm conductivity graph, it is clear that the increase in leakage current is very fluctuating, namely increasing the maximum value of 359 A (6 kV), 406 A (10 kV) , 678 A (18 kV) but also experiencing leakage current breakdown (minimum values) to 267 A (8 kV), 298 A (14 kV), and 349 A (20 kV). This means that the process of evaporation of water from wet conditions to dry conditions continuously occurs by changing the surface resistance value from low to high at the breakdown point of the partial discharge of the leakage current. This means that the process of evaporation of water in the impurity layer occurs continuously making the surface resistance low in wet conditions, then the leakage current increases significantly when the surface conductivity becomes high again, as a result the impurity layer becomes a good heat conductor and accelerates the process of increasing the surface temperature as a start. dry band formation.

In the case study, the test voltage was increased to 30 kV, this leakage current testing system had experienced a total breakdown, namely a flashover occurred in the flashover mechanism in the dry band on the surface of this external pair distribution current transformer. This confirms the hypothesis that the main problem at the boundary of the two air-solid dielectric (epoxy resin) is the surface discharge in the impurity layer attached to the surface of the distribution current transformer. The electric charge in the air is more easily ionized due to the increase in the local electric field that is not uniform as a trigger for partial discharge along the dry band conductive layer (impurities).

5. Conclusion

The study of the surface leakage current characteristics of the external pair distribution current transformer has been carried out in a high voltage laboratory. The main problem in the air-solid dielectric boundary is the surface discharge that occurs in the impurity layer on the surface of the distribution current transformer. This impurity layer triggers an increase in the local electric field distribution to become non-uniform so that the charge ionization process in the air around the impurity layer occurs more easily.

Especially the conditions of high humidity of 95% RH and high conductivity of 36 ms/cm have a very fluctuating increase in leakage current characteristics. This fluctuating nature explains the dry band formation process due to the conductive layer in the impurities adhering to the surface of the distribution current transformer. This dry band layer triggers the occurrence of surface discharge as an early indication of the failure of the isolation of this external pair distribution current transformer.

For further research, it is also very good to study the characteristics of the maximum and minimum partial discharges that occur in the distribution current transformer's impurity layer. From this partial discharge data, it can be proposed an effort to manufacture ion shielding to overcome the surface discharge in the air-solid dielectric boundary area of this epoxy resin.

Acknowledgment

The author expresses his gratitude for the assistance of three external pair distribution current transformers provided by PT. PLN West Java Distribution and the leakage current measurement facility in the current and high voltage laboratory of the electrical power engineering study program - School of Electrical Engineering and Informatics, Institut Teknologi Bandung.

.

References

[1] L. Wibowo, A. Syakur and T. Andromeda, "Design Of Temperature And Humidity Control Devices In The Leakage Current Test Chamber Of 20 kV Insulator," 2019 6th International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE), 2019, pp. 1-6.

[2] Taryo, A. Syakur and Hermawan, "Comparison Study on Leakage Current of 20 kV Silicon Rubber and Epoxy Resin Insulator Under Dry and Wet Condition," 2018 5th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE), 2018, pp. 260-263.

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

[4] S. Zaputra, "Leakage current and partial discharge characteristics of epoxy resin material of distribution current transformer in salt fog pollutant condition," 2017 International Conference on High Voltage Engineering and Power Systems (ICHVEPS), 2017, pp. 508-513.

[5] M. M. Hussain, S. Farokhi, S. G. McMeekin and M. Farzaneh, "Dry band formation on HV insulators polluted with different salt mixtures," 2015 IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP), 2015, pp. 201-204

[6] Suwarno and S. Ardianto, "Characteristics of leakage current and flashover on epoxy resin insulator," 2014 IEEE Workshop on Electronics, Computer and Applications, 2014, pp. 754-757.

[7] S. Manjang and I. Abduh, "Leakage Current Patterns on Artificially Polluted Porcelain and Polymer Insulator," 2006 IEEE 8th International Conference on Properties & applications of Dielectric Materials, 2006, pp. 443-446.

[8] N. Anami et al., "Evaluation of dry band arc on the polymeric insulator using differential technique and distortion factor of leakage current," 2003 Annual Report Conference on Electrical Insulation and Dielectric Phenomena, 2003, pp. 414-417

[9] N. Anami et al., "Proposal of separate technique using differential value of leakage current," Annual Report Conference on Electrical Insulation and Dielectric Phenomena, 2002, pp. 339-342.

[10] H. Homma, T. Kuroyagi, T. Takahashi, S. Ohtsuka and M. Hikita, "Algorithm for determining the surface leakage current on polymer insulating materials based on current waveform distortion," Annual Report Conference on Electrical Insulation and Dielectric Phenomena, 2002, pp. 676-679.