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CHUBU Electric Power

YUKA Industries Co.,Ltd.

Study Committee D1

Materials and Emerging Test Techniques

Paper D1-PS1-10647

The Evaluation Method of Static Electrification in Aged Power Transformers Using Cellulose Fibers Suspended in Insulating Oil

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Motivation

- Static electrification occurs at the interface between insulating oil and the surface of solid insulators in a power transformer.

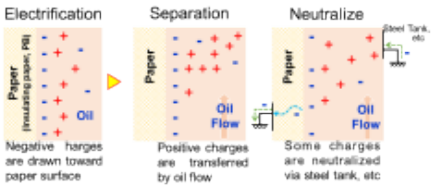

Figure 1 - Schematic illustration of static electrification

- If the electric potential on the surface of solid insulators becomes high due to static electrification, a dielectric breakdown may occur such as figure 2.

Figure 2 - Discharge mark caused by static electrification

- Ideal method for evaluating static electrification

Ideal method for evaluating Static Electrification

Gap

Conventional experimental method
e.g. Electrostatic charging tendency tester, Accumulation charge density measuring method

It is ideal for using degraded solid insulators and oil in actual transformer as samples for evaluating static electrification.

However, taking out degraded solid insulators from inside of an actual running transformer is not realistic.

Because of this, new paper or new pressboard is used for test samples in conventional methods.

Figure 3 - Motivation of our paper

Method

- The authors developed a method of evaluating static electrification **using cellulose fibers** that peel off from the surface of solid insulators (PBs and insulating papers) and insulating oil in an actual transformer to reproduce the static electrification phenomenon in an actual transformer.

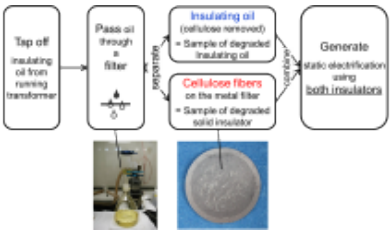

Figure 4 - Concept of the new test method for evaluating static electrification

Experimental setup

Electrification cell

- An electrification cell consists of a metal filter and filter holder. Cellulose fibers are clamped with the metal filter in the electrification cell.

Oil pump

- Oil flow velocity was controlled by an oil pump.

Pico-ammeter

- The amount of charge generated through the electrification cell can be measured with a pico-ammeter. The measured generated charge was standardized by dividing the value by the surface area of the cellulose fiber. It is defined as the "generated charge density" .

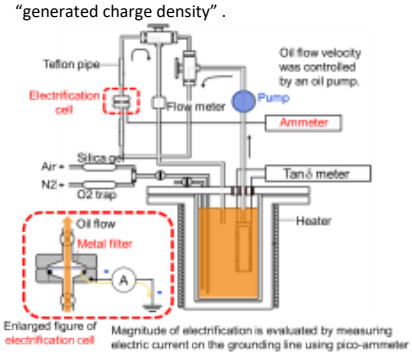

Figure 5 - Testing apparatus

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Basic study of the streaming current measurement using cellulose fibers

- This chapter will describe an investigation into the influence that the quantity of the cellulose fibers, oil flow rate, and oil temperature have on the streaming current intensity. In this examination, a new PB's cellulose fibers and forcibly degraded insulating oil were used.
- Test results are shown below.

✓ Streaming current increased with an increase in the amount of cellulose fibers.

✓ There was a trend in which the streaming current increased with an increase in the oil flow velocity, and the oil temperature also influenced the streaming current intensity.

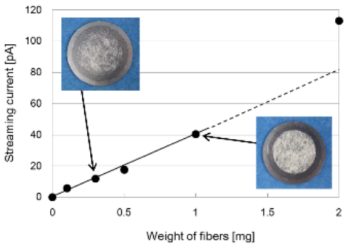

Figure 6 - Relationship between weight of cellulose fibers and streaming current

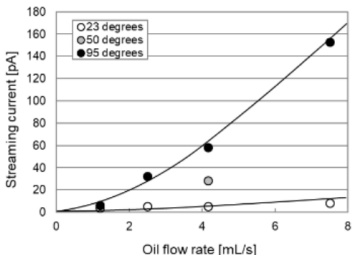

Figure 7 - Influence of flow rate and temperature

Streaming current measurement simulated actual power transformer

- In this chapter, the influence that degradation of a cellulose fiber has on streaming current is discussed.
- Figure 8 shows the relationship between the generated charge density and degradation level of insulating oil / cellulose fibers. There was a trend which the generated charge density increased as the degradation level of cellulose fibers became higher.

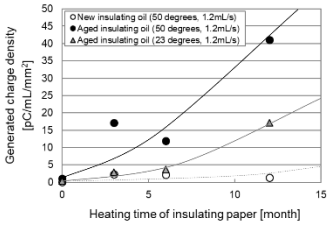

Figure 8 - Generated charge density under different degraded oil and cellulose fiber conditions

Streaming current measurement using cellulose fibers in an actual power transformer

- Nine transformers with different operating years were investigated to evaluate the tendency for the generated charge density to increase with respect to the operating years of the transformers.

Figure 9 - Amplification value of generated charge density

- The generated charge density tends to increase with the number of years of operation when the transformer has been in operation for about 30 to 40 years, but conversely, it tends to decrease beyond that.
- This feature is in agreement with another paper which is reported that the increase in static electrification traces a convex curve with respect to the aging of the transformer, and the peak number of years is approximately 40.

Conclusion

- By the method of evaluating static electrification using cellulose fibers in insulating oil, the tendency of the generated charge density to increase with the operating years of the transformer was evaluated.

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Additional Research

It is known that ions and polar substances in insulation oil are involved in static electrification. However, it remains unclear the effect of ions and polar substances in the insulating oil on the static electrification.

- The state of ions and polar substances in insulating oil is considered to vary depending on the degree of degradation, temperature, and other factors.
- However, there is no method to acquire data on characteristics of substances that affect static electrification such as the amount of ions or polar substances contained in insulating oil.

Evaluating the dynamic charge generation characteristic

- The authors developed a method to evaluate the characteristics of substances that affect static electrification by applying a DC voltage to the flowing insulating oil, utilizing the aforementioned testing apparatus (Figure 10).
- A DC voltage was applied to electrodes in the oil vessel, and at the same time, the temporal change in the ECT value of the electrification cell was investigated.
- Sample oil

  (A) New insulating oil

  (B) Sample oil that contains enough ions
  (New insulating oil + copper (II) oleate)

  (C) Sample oil that contains enough peroxide and oxide as polar substances
  (Sample(B)) + Peroxide + Oxide (Oil heated to 80°C))

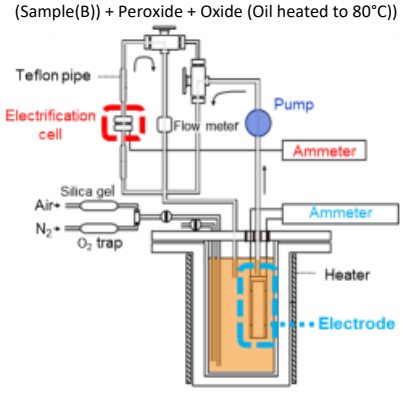

Figure 10 - Electrode location in the testing apparatus

Result of applying an electric field

- Figure 11-13 shows the temporal change in the electric charge tendency (ECT) value when DC 1 kV was applied to the electrodes. The ECT value changed in various patterns depending on the type of oil.

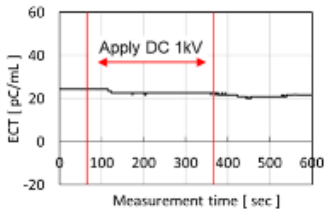

Figure 11 - Sample(A) New insulating oil

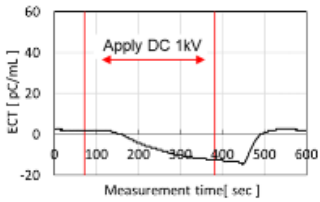

Figure 12 - Sample(B) Ion-rich oil

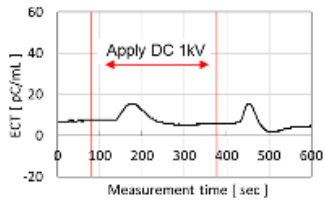

Figure 13 - Sample(C) Polar substances-rich oil

Consideration

- When voltage applied to the electrodes, the positive and negative ions in insulating oil are attracted to the opposite polarity electrodes depending on the electric field and some existing ions disappear. At the same time, charge dissociation occurred from oil molecules caused by electric field. It is assumed that the differences in temporal change in the ECT value caused by differences in the ion species.

Conclusion

- Evaluating the temporal change in ECT value when an electric field is applied to test oil has a possibility to evaluate the characteristics of substances that affect static electrification.