Effect of Field Uniformity on Discharge and Breakdown Characteristics of Transformer Liquids under Lightning Impulse

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***Abstract*— This paper proposes a new method to deduce the transition field factor boundary between streamer initiation / propagation dominated breakdown. Meanwhile, the boundaries of three transformer liquids were deduced under negative lightning impulse, which is 9.6 for mineral oil, 7.3 for GTL oil and 42.0 for synthetic ester. Besides the studies on the effect of field uniformity, the breakdown characteristics of transformer liquids under the conditions close to practical insulation geometry is also investigated in this paper. Although the streamer propagation characteristics are different at varying gap distances, the effect of impulse polarity and liquid component on the breakdown voltages are limited. It is due to that the field uniformity of the practical insulation geometry is lower than the transition field factor boundaries, and the breakdown is dominated by the streamer initiation and irrelevant to the streamer propagation characteristics. Hence, the identification of transition field factor boundary can be used to explain the breakdown voltage difference between impulse polarities or among liquid components.**

Background & Main Results

As one of the most important power equipment, the safe and reliable operation of power transformers is vital for the power network. Streamer and breakdown characteristics of transformer liquids under lightning impulse have been widely studied in terms of varying field uniformity. Based on the comparison between streamer initiation voltage and breakdown voltage, the breakdown phenomenon can be classified into streamer initiation dominated breakdown and streamer propagation dominated breakdown. The field factor boundary between two breakdown mechanisms have been investigated under positive lightning impulse, which is 53.0 for mineral oil and 79.0 for synthetic ester. However, there is no such transition field factor boundary results under negative lightning impulse. This paper proposes a new method to deduce the transition field factor boundary, which is only based on the breakdown voltage measurements under different gap distances. The breakdown voltages of three transformer liquids were measured under negative lightning impulse with rod (tip radius of 0.5 mm) to plane electrode geometry at the increasing gap distance from 2 mm to 40 mm. Then, the transition field factor boundaries are deduced, which is 9.6 for mineral oil, 7.3 for GTL oil and 42.0 for synthetic ester. The identification of transition field factor boundary can be used to explain the breakdown voltage difference between impulse polarities or among liquid components.

Besides, the paper wrapped copper conductor from real transformer winding was employed to study the discharge and breakdown characteristics of the transformer liquids. The experimental setup is shown in Figure 1, which is composed a 170 L test cell with the designed lightning impulse withstand voltage of 500 kV. Although the streamer propagation characteristics are different at different gap distances, the breakdown voltages are comparable between two impulse polarities and among different transformer liquids. The reason can be explained by the breakdown mechanism of streamer initiation dominated breakdown.

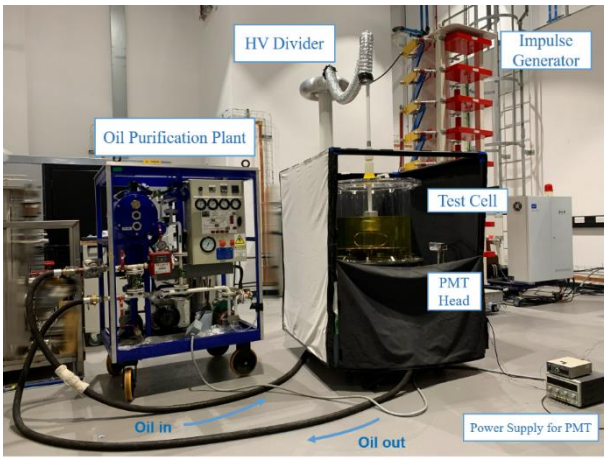

Figure 1: Experimental setup for discharge and breakdown measurement of transformer liquids.

Conclusions

The transition field factor boundary between streamer initiation dominated breakdown and streamer propagation dominated breakdown is deduced in this paper, based on which the breakdown voltage differences between two impulse polarities and among different transformer liquids can be explained. The breakdown characteristics of different transformer liquids are also investigated under the conditions close to practical insulation geometry, which can provide reference to the transformer insulation design.