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Partial Discharges in Bulk Oil and at Oil-pressboard Interface under Negative Lightning Impulse Voltages

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Introduction

The inter-phase oil-pressboard interface has been associated with creepage discharge failures in large power transformers. Creeping discharge or surface discharge is considered as a serious fault condition that can lead to catastrophic failure under normal operating conditions. The studies on this fault condition are normally on the inception and extinction voltage under AC voltages. Recently, there has been interest in the formation of white marks and measurement of leakage current during the surface discharges. Most studies related to creepage discharges under lightning impulse (LI) voltages are focused on pre-breakdown streamer propagation.

Propagation of streamers has been generally accepted as a key breakdown mechanism in dielectric liquids. There is general agreement that streamer propagation or creepage discharge at a solid-liquid interface due to impulse voltages has similar features to that of streamer propagation in the liquid bulk. However, the effect of the solid-liquid interface due to differences in liquid and solid dielectric properties and surface condition of the solid dielectric have highlighted the importance of the study of creepage discharge, as there is limited understanding of this failure mechanism. This work investigates partial discharge (PD) behaviour in the bulk oil and at the oil-pressboard interface from the accumulative effect of breakdown tests for different configurations of electrodes. Tests were also conducted using different moisture contents in oil-impregnated pressboard for comparison purposes.

The Experiment

- Oil bath with dimension of 600mm x 300mm x 150mm filled with 25 litres of old and untreated transformer oil contains approximately 18-22ppm moisture.
- Negative LI (1.2/50μs), tungsten needle (approx. tip radius 50 μm), needle tip (HV electrode and earth electrode gap was fixed to 10 mm.
- Electrode configurations (see Figure 1):
  1. Point-plane – bulk oil
  2. Needle-bar – Oil-pressboard interface
     - i. at an angle close to horizontal of the pressboard surface (Needle-bar 1)
     - ii. parallel to horizontal of the pressboard surface (Needle-bar 2)

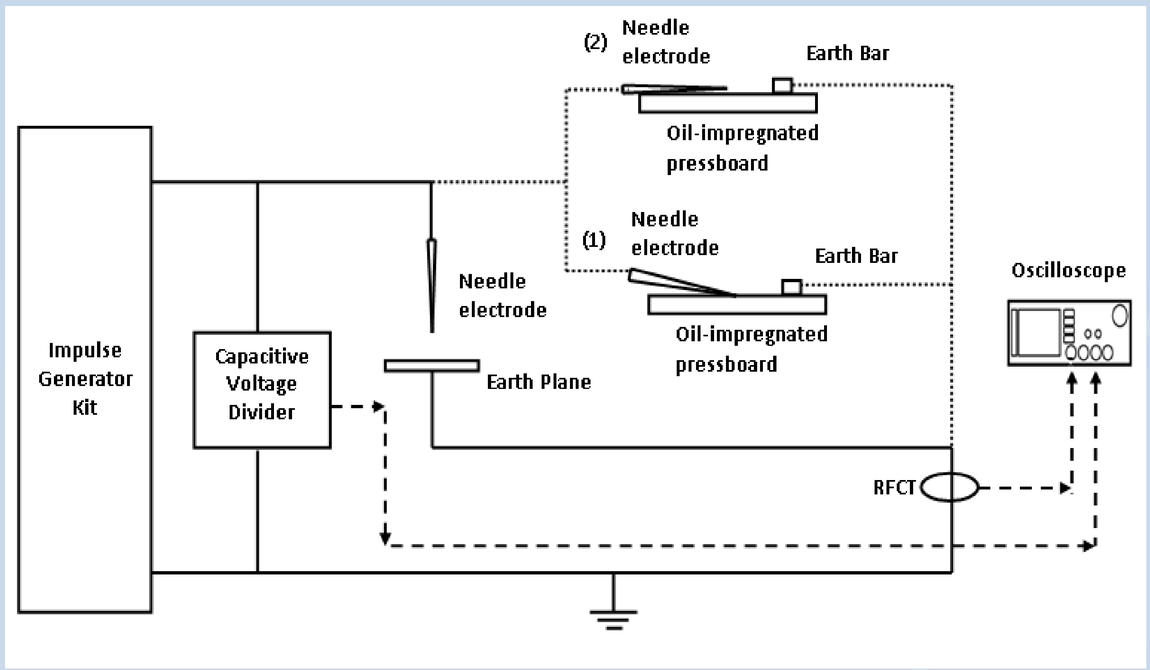

Figure 1: Experimental setup

- Four types of pressboard condition – dry pressboard (less than 0.5% moisture) and pressboard conditioned to 3%, 6% and 9% moisture.
- Multiple-level method test (IEC-60060-1)
  - to investigate PD behaviour by means of accumulative effect from the measurement of 50% breakdown voltage
  - 10 shots for each voltage level, time interval of 30s between two consecutive shots (ASTM D3300), test repeated 3 times.
  - Initial voltage of 25kV and 3kV increment (Negative voltage polarity)

Results and Discussions

- Effect of different electrode configurations (see Figure 2 and 3)
  - Breakdown voltage with the existence of oil-pressboard interface using needle-bar 2 configuration is slightly lower than the breakdown voltage from point-plane test in bulk oil except for 3% moisture pressboard.
  - Breakdown voltage using the needle-bar 1 configuration is always lower than the those obtained using the needle bar 2 configuration
- Effect of different moisture content within pressboard (see Figure 3)
  - No significant difference between dry, 6% and 9% moisture pressboard.
  - Significant reduction in breakdown voltage for 3% moisture pressboard

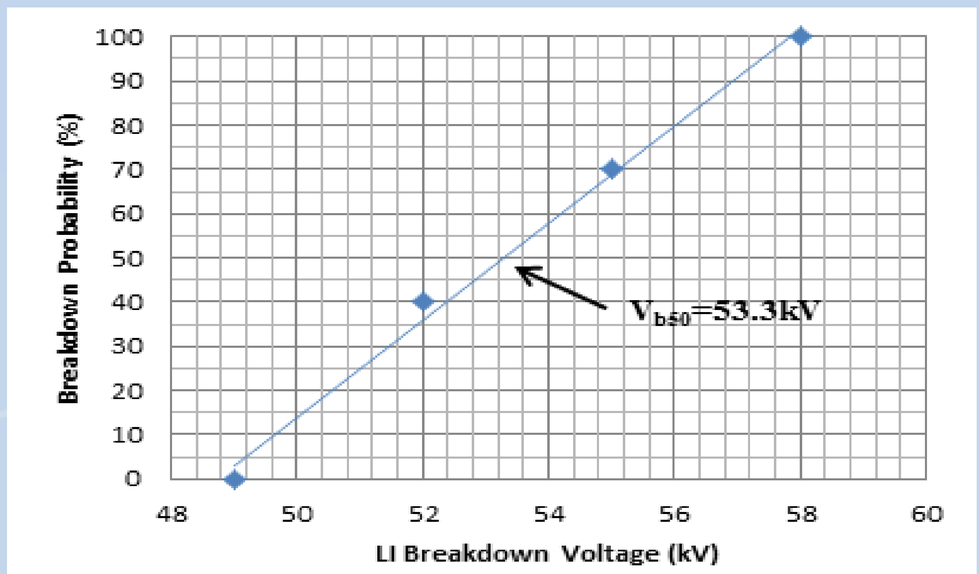

Figure 2: Breakdown voltage of the bulk oil

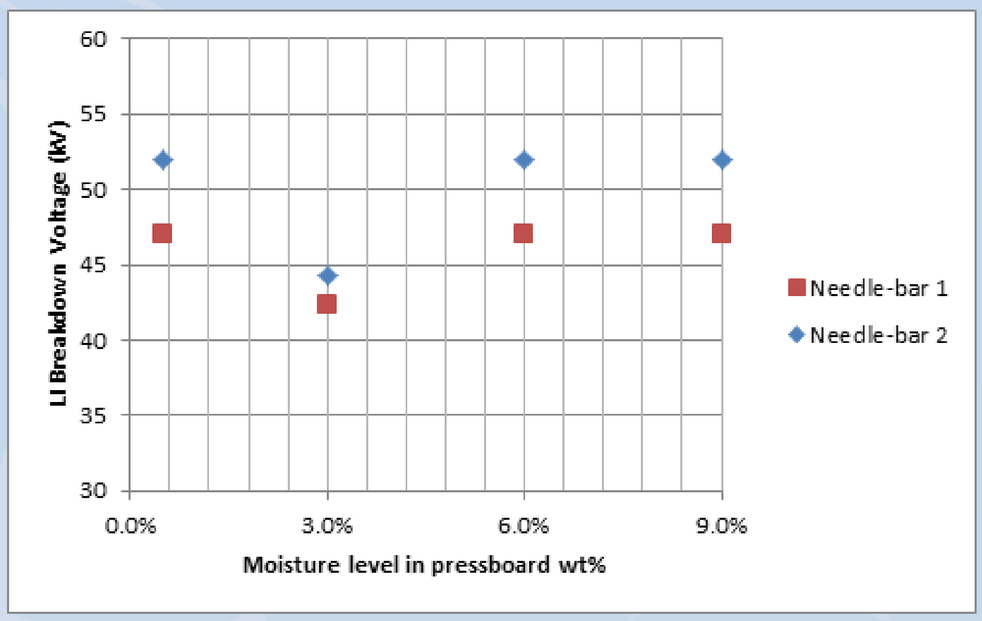

Figure 3: Breakdown voltage for oil-pressboard interface

- Reduction in breakdown voltage due to the presence of an oil-pressboard interface shows the accumulation effect due to PD events from streamer initiation and propagation at the oil-pressboard interface.
- It is appeared that these PD events might be caused by localised events during subsequent discharges that is sustainable until a certain streamer distance is reached and branching activity occurs from random local ionisation.
- Needle-bar 1 configuration leads to a larger space charge trap in the pressboard region of oil-pressboard interface, i.e. transition region. Whilst, for needle-bar 2 configuration, PD events can happen in the bulk oil side and at the oil-pressboard interface (very thin layer of oil and pressboard regions). Therefore, the latter configuration promotes some of the charges to disperse in the oil because there is no accumulation effect in bulk oil and this results in less charge accumulation during the breakdown test.
- If in the case where there are bubbles or gases generated due to PD due to negative streamers, the multiple shots from the breakdown experiment can enhance gaseous generation by creating gaseous channels in the pressboard pores towards the earth electrode.
- Significant reduction for both electrode configurations for 3% moisture pressboard compared to others is in agreement with a surface discharge experiment under AC voltages whereby 3% moisture pressboard requires the shortest time for the white marks to develop until the first appearance of a full discharge.
- The presence of moisture reduces the ionisation potential for a PD event. But, excessive levels of moisture requires greater heat energy from PD activities to remove any moisture in the pressboard pores before the development of gaseous by-products that develop towards the earth bar electrode over time.

Conclusions

- An experiment to study the effect of PD activities on creepage discharge at the oil-pressboard interface has been undertaken.
- The results suggest that the electrode configuration plays an important role in the study of accumulative effects as a result of PD activities under LI voltages at the oil-pressboard interface.
- Agreement between results from this multiple shot experiment under LI voltages and surface discharge experiments under AC voltages suggest that pressboard with a moisture content around 3% has the poorest performance in terms of resistance to creepage discharges.
- Further work will investigate the features of PD pulse current as a result of LI voltages.

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