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DETERMINATION OF THE CAPACITANCE OF LONG TRANSFORMER OIL GAPS WITH INSULATING BARRIERS

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Abstract: This work is aimed at the effect of insulating barriers on the variation of the capacitance of long transformer oil gap systems submitted to AC Voltage. The tests are carried out in point-plane electrode arrangement by considering the influence of the parameters of barriers such as its position with respect to the electrodes and its thickness. The capacitances of the system with barrier and that one without barrier are compared. It's shown that the evolution of the pre-breakdown charge versus the applied voltage has a capacitive behavior. The insertion of barrier increases the capacitance of the system resulting in a decrease of the impedance of the system. The determination of the capacitance provides a correlation between the electrical charge and the dielectric strength.

1 INTRODUCTION

It is well known that the dielectric strength of divergent long oil gaps is significantly increased by the insertion of an insulating solid material into the electrodes gaps [1-8]. This is due to the fact that the barrier acts as a geometrical obstacle for the disruptive discharge by extending the discharge trajectory [1, 2, 4 - 6]. The efficiency of barrier (i.e., the improvement degree) depends on many parameters. And the physicochemical mechanisms responsible of this improvement are far from being understood. The understanding of these mechanisms passes through the understanding of the pre-breakdown phase and the parameters characterizing it.

This paper deals with the influence of the insulating barrier on the pre-breakdown charge and the capacitance of long oil point-plane gaps. The main investigated parameters are the effects of applied voltage, the electrodes gap, the barrier position and its thickness. The capacitances of the system with barrier to that one without the barrier are also analyzed; and the equivalent impedance of the system without barrier is also deduced.

2 Experimental Set Up

The experimental set up consists of a high voltage test transformer 300kV/50kVA/50Hz, a capacitive voltage divider and a transparent test cell of 175 litres volume (Figure 1). The test cell is made of Plexiglas (700mm×500mm×500mm). It contains a point-plane electrode arrangement mounted horizontally (Figure 2). The point electrode is made up of brass and has a radius of curvature of 6 mm.



Figure 1: photograph of test cell

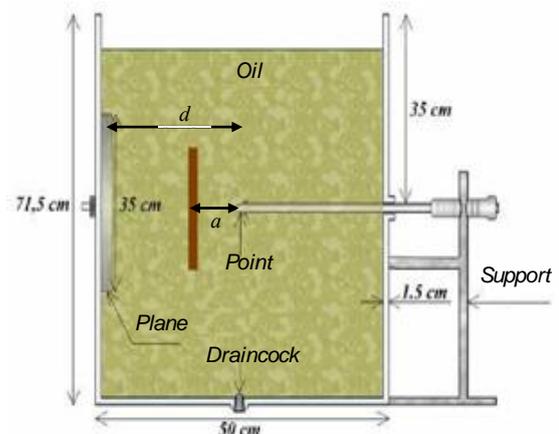


Figure 2: Test cell

The plane electrode is made up of steel and has a circular shape of 35 cm diameter. The electrode gap varies between 1 and 12 cm. The insulating barriers have a circular shape and are made of

Presspahn ($\epsilon_r=3$) (Figure3). Two thicknesses (2 and 4 mm) of barrier are considered. The barrier is mounted vertically between the electrodes and sustained by thin insulating threads. The barrier surface is cleaned with isopropyl alcohol. The mineral oil we used is of naphthenic type; it is subjected to rigorous conditions of storage in sealed drums for protection against degradation and humidity environment. The pre-breakdown charge is measured through a capacitance of $0.02 \mu\text{F}$, inserted between the plane electrode and the earth; it is connected to a storage oscilloscope. The value of the pre-breakdown charge reported on the different curves represents an average value on a series of six measurements. The position of the barrier is defined by the ratio a/d (Figure 2) where 'a' is the point-barrier distance and "d" is the point-plane gap.

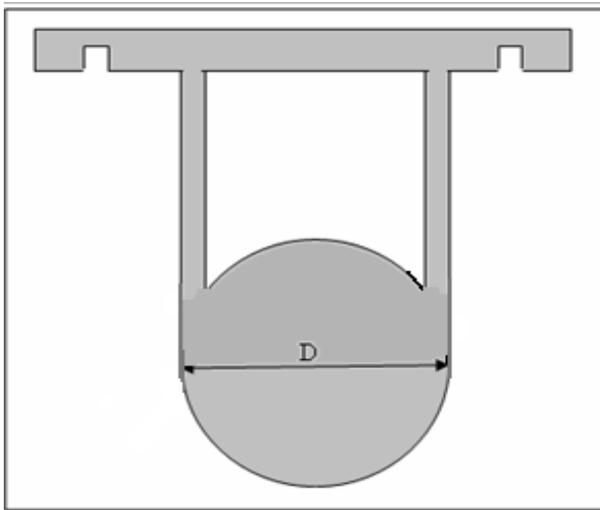


Figure 3: Scheme of barrier

3 Experimental results and discussion

Figures 4 and 5 show the effect of insulating barrier on pre-breakdown charge for different position of the barrier. For a given electrode gap and diameter of barrier, the pre-breakdown charge increases with applied voltage for all position of the barrier. This evolution of charge shows that the oil gap has a capacitive behavior. Therefore, the position of the barrier in the oil gaps does not influence the pre-breakdown charge, except for the position $a/d = 0$, where the barrier is in contact with the electrode point. In this case, the pre-breakdown charge is higher than those ones for other positions especially when the applied voltage is higher than 15kV . This fact can be explained by the accumulation of a large amount of charge on the surface of the barrier [9].

The capacitance of the point-barrier-plane gap length is deduced from the charge-applied voltage characteristics. It is observed that the capacitance is practically constant for all position of the barrier except when the barrier is very close to the point electrode (Figures 6 to 9). This result may relate to the structure of the material of the barrier.

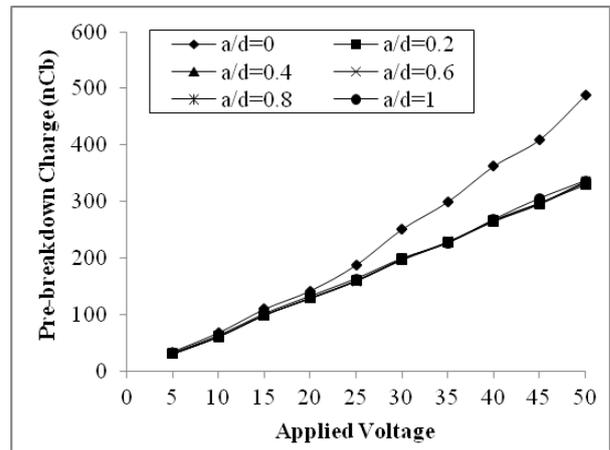


Figure 4: Pre-breakdown charge vs. the applied voltage for different positions of the barrier; $d=12\text{cm}$, $e=2\text{mm}$, $D=20\text{cm}$

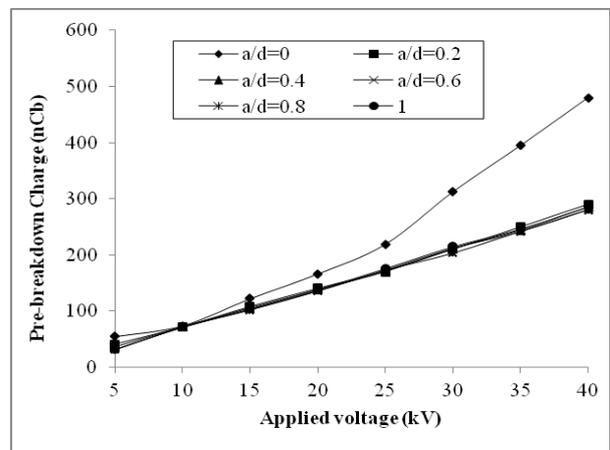


Figure 5: Pre-breakdown charge vs. the applied voltage for different positions of the barrier; $d=12\text{cm}$, $e=4\text{mm}$, $D=20\text{cm}$

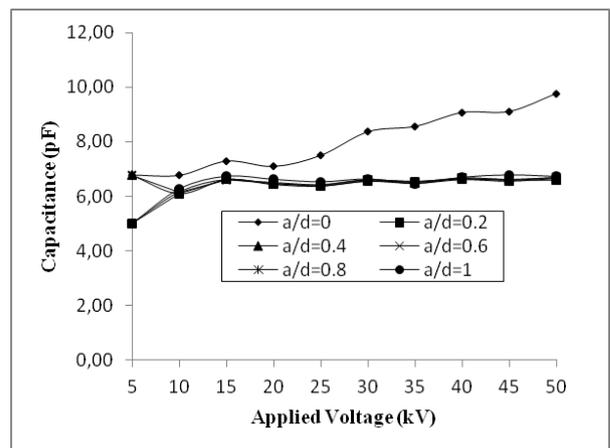


Figure 6: Variation of the capacitance vs. the applied voltage for different positions of the barrier; $D=20\text{cm}$, $d=12\text{cm}$, $e=2\text{mm}$

Figures 10 and 11 show the variation of the capacitance versus the electrode gaps for different positions of the barrier. It appears from these curves that the capacitance of the system decreases when the electrode gaps increase. The higher value of the capacitance is obtained at

$a/d=0$; this indicates an increase of the charge amount.

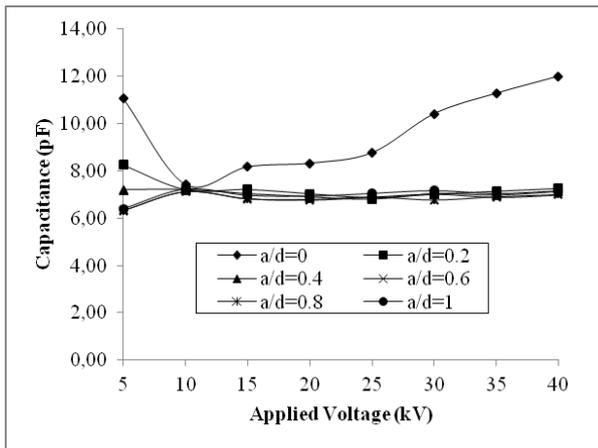


Figure 7: Variation of the capacitance vs. the applied voltage for different positions of the barrier, $D=20\text{cm}$, $d=12\text{cm}$, $e=4\text{mm}$

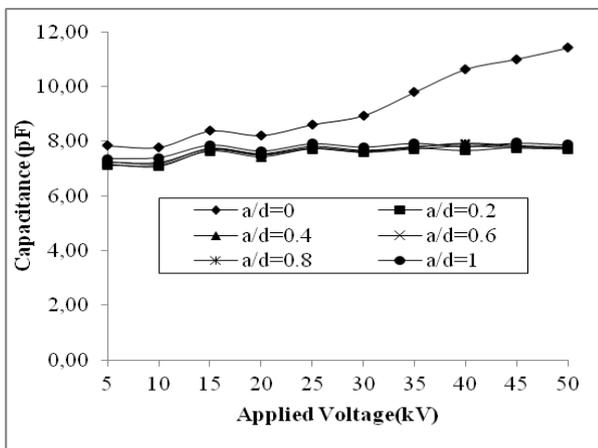


Figure 8: Variation of the capacitance vs. the applied voltage for different positions of the barrier, $D=20\text{cm}$, $d=8\text{cm}$, $e=2\text{mm}$

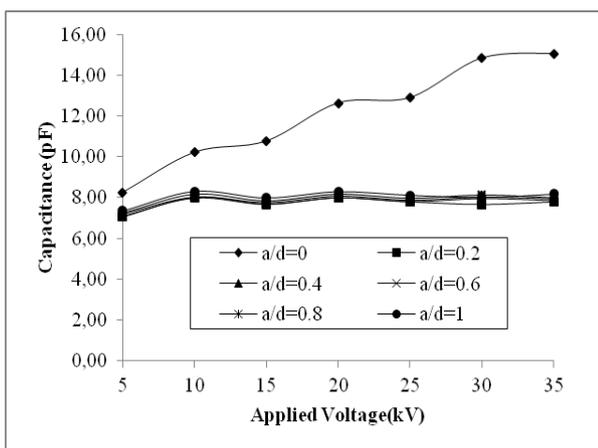


Figure 9: Variation of the capacitance vs. the applied voltage for different positions of the barrier, $D=20\text{cm}$, $d=8\text{cm}$, $e=4\text{mm}$

As shown in Figures 12 and 13, the variation of the barrier thickness leads to the increase of the capacitance of the point-barrier-plane, thereby to the decrease of the impedance (Figure 14). The

maximum value appears at the smallest the electrodes gap. As a result, the increase of the presspahn thickness strongly depends upon the surface charge accumulation [10].

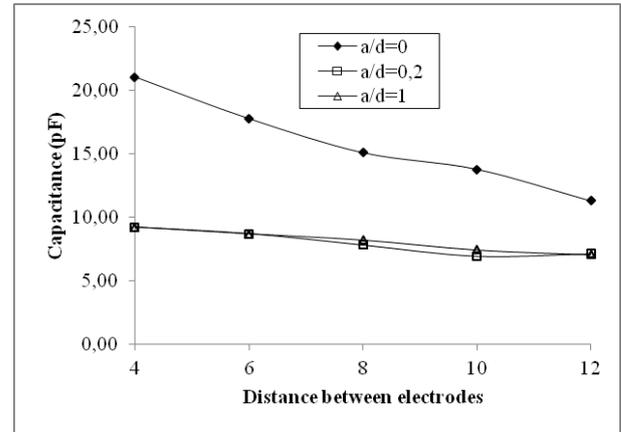


Figure 10: Variation of the capacitance vs. the electrodes gap for different positions of the barrier, $D=20\text{cm}$, $U=35\text{k}$, $e=4\text{mm}$

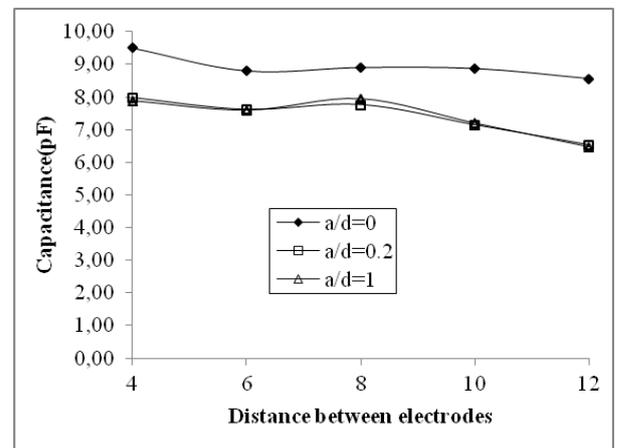


Figure 11: Variation of the capacitance vs. the electrodes gap for different positions of the barrier, $D=20\text{cm}$, $U=35\text{kV}$, $e=2\text{mm}$

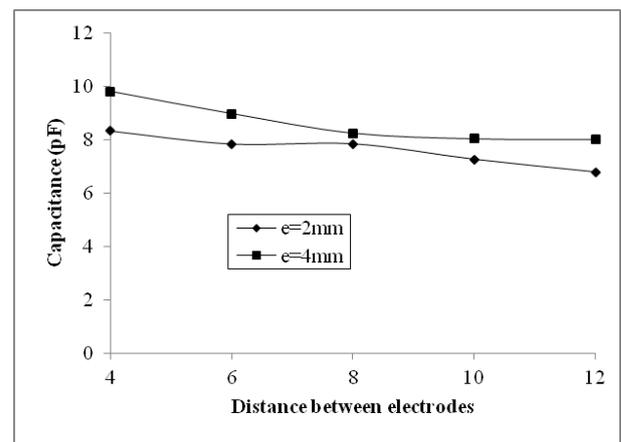


Figure 12: Variation of the capacitance vs. the electrodes gap for two different thickness, $D=20\text{cm}$, $U=5\text{kV}$, $a/d=0$.

A comparison between the system with barrier and that one without barrier has been performed. Figure 15 depicts the variation of the capacitance

versus the applied voltage for both systems. The insertion of the barrier in a point-plane electrode arrangement increases the impedance of the system resulting in a decrease of the capacitance of the system.

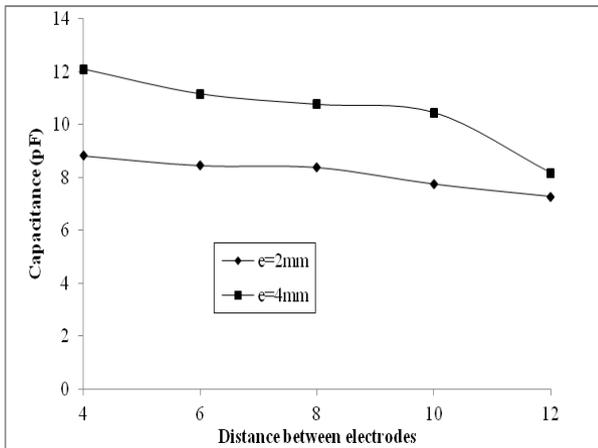


Figure 13: Variation of the capacitance vs. the electrodes gap for two different thicknesses; $D=20\text{cm}$, $U=15\text{kV}$, $a/d=0$

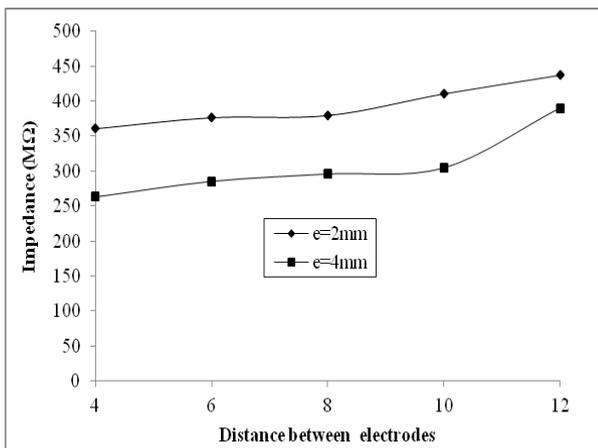


Figure 14: Variation of the impedance vs. the electrodes gap for two different thicknesses; $D=20\text{cm}$, $a/d=0$, $U=15\text{kV}$

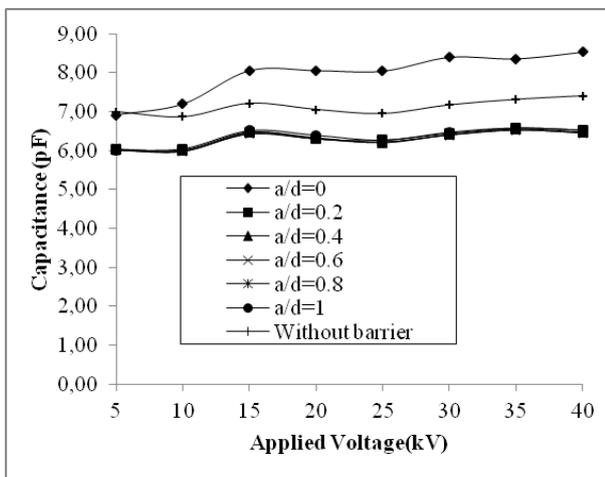


Figure 15: variation of the capacitance vs. the applied voltage for system with and without barrier, $e=2\text{mm}$, $d=12\text{cm}$, $D=10\text{cm}$

4 Conclusion

This work shows that the insertion of an insulating barrier in divergent oil gaps decreases significantly the pre-breakdown charge. This decrease depends on the applied voltage and the barrier thickness. On the other hand, the evolution of the charge versus the applied voltage for both systems with and without barrier shows that the oil gap has a capacitive behavior. The insertion of the barrier increases significantly the impedance and decreases the capacitance of the system. This is of interest for electrical insulation design.

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