PARTIAL DISCHARGE CHARACTERISTICS IN OIL OF DIFFERENT ELECTRODE ARRENGEMENTS

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Abstract: This paper represents the partial discharge characteristics in oil of different electrode arrangements. The test experiment is performed with various types of electrodes. The electric field strength of the electrode arrangements is simulated using the Finite Element Method Program ElecNet. The test experiment is set up according to IEC 60270. Three types of electrodes configurations for corona in oil, needle-rod, needle-sphere, and needle-plane, are investigated at specified gap distances under different oil conditions. Dry and humid oil at the room temperature are investigated. Rate of rise of voltage is 1 kV/s from zero to the partial discharge inception voltage, according to IEC 61294. The PDIV and PD activity are recorded and then the voltage is raised to a value up to the maximum of 1.3 times of the PDIV value. We maintained this voltage level for 5 minutes and then recorded PD activity. Electric field strength of each electrode system, PDIV, partial discharge values and partial discharge patterns obtained from the experiments are analyzed and presented in this paper. We can use each PD pattern as fingerprint to classify the type of PD obtained from practical research and the oil insulation system.

1. INTRODUCTION

Insulating liquids play an important role as an excellent electrical insulation for high voltage equipment. Besides, they are also outstanding in cooling properties. However their electrical properties will be distinctly deteriorated due to electrical stress, contamination, moisture, overheat and so on.

There are many standards which are introduced to verify the liquid insulation characteristics such as IEC 60156 [1], ASTM D 877 [2], or ASTM D1816 [3] and so on. Partial Discharge (PD) in oil especially corona discharge is an important problem which initiates the deterioration of the liquid insulation and may develop to the failure of high voltage apparatus. IEC 60270 [4] introduces the test procedure for PD measurement of high voltage equipment. In addition, Partial Discharge Inception Voltage (PDIV) is an alternatively important indicator that most researchers use for representing the integrity of the liquid insulation.

The PDIV measurement can be performed according to IEC 61294 [5]. However, some aspects of this PDIV test technique are doubtful, whether it is more sensitive to the changing of liquid insulation characteristics or not including the test method may be not practical. Parts of these questions are now verified by some research groups and they also propose the alternative ways for PDIV testing [6-8].

Even though many aspects of liquid characteristics have been investigated, but the findings and conclusion cannot be reconciled [9]. The findings sometimes lead to the contradiction of the theory development of liquid insulation. With this reason the research topics for the liquid insulation are still challenging the researchers up to now.

2. CORONA DISCHARGE IN LIQUID INSULATION

Partial Discharge is a localized electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to the conductor [4].

PD can be divided as corona discharge, surface discharge and internal discharge. It can occur in all types of insulation medium for example gas, liquid or solid insulation or even in the mix insulation system. Naturally corona discharge in oil is difficult to occur comparing with corona discharge in air, but it is less stable and less reproducible.

Corona discharge can be simulated in the laboratory with many types of electrode systems and insulating medium including the various types of testing procedures. Obviously the corona discharge characteristics obtained from tests are different. Both Partial Discharge Inception Voltage (PDIV) and Partial Discharge Extinction Voltage (PDEV) are the factors that represent the integrity of the liquid insulation but it seems that PDIV is better known parameter. IEC 61294 [5] defines the PDIV as the lowest voltage at which a partial discharge occurs of an apparent charge equal to or exceeding 100 pC when the sample is tested under the specified condition. However, some research groups define the PDIV as the voltage step at which incipiently one or more PD pulse burst are recorded over 10 minute time interval [10, 11].

3. TESTING EXPERIMENT

The experiment can be divided into 2 parts. The electric field simulation of the electrode systems simulated by ElecNet [12] is the first part of this study. Then, the experiment in the laboratory is carried out in the second part.

3.1 Electrode configuration

Examples of electrode configuration to produce corona discharges are shown in Figure 1. An aluminium hemispherical plane with a radius of 14 cm forms the ground electrode, whereas the needle with the tip radius of 1 mm is connected to high voltage. The transformer oil, Nynas, is used as the insulating medium. Corona will be produced due to the high electric field stress around the tip of the needle. Three types of electrodes, needle-rod, needle-sphere and needle-plane, are investigated at various gap distances under different oil conditions.

(a) (b) (c)

Figure 1: Electrode configuration (a) needle-rod electrodes, (b) needle-sphere and (c) needle-plane electrodes

3.2 Test set-up

Test circuit arrangement is shown in the Figure 2.

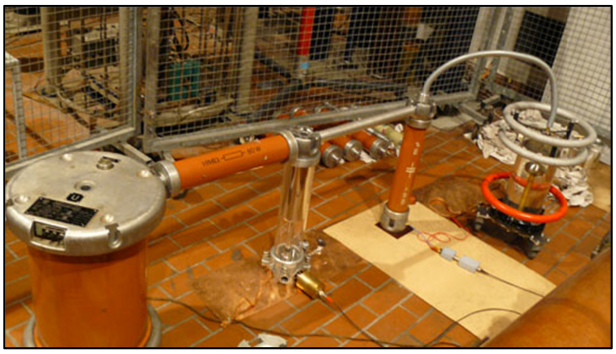


Figure 2: Test circuit set-up

Where: U: high-voltage supply 50 kV, R: current limiting resistor 10 MΩ, C1 and C2: capacitor voltage divider 100 kV, ratio 10000:1, Test cell: test object, Ck: coupling capacitor 100 kV, CD: coupling device, CC: connecting cable, MI: measuring instrument ICM.

3.3 Test Procedure

PD and PDIV measurement are performed conforming to IEC 60270 [4] and IEC 61294 [5] respectively. Rate of rise of voltage is 1 kV/s from zero to PDIV value. The PDIV and PD activity are recorded and then continue raises the voltage to a value up to the maximum of 1.3 times of the PDIV value. We maintain for 5 minutes at this voltage level and record PD activity. The test procedures is shown in Figure 3.

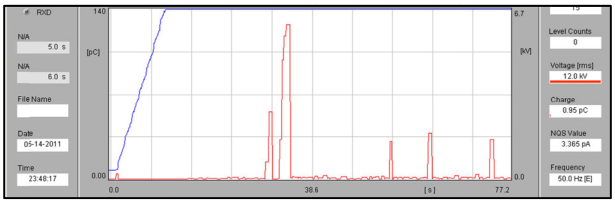
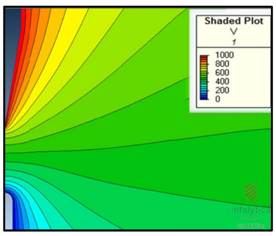


Figure 3: PDIV measurement test procedures; the blue line is the tested voltage raise and the red line is PD activity

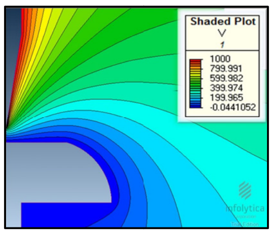
4. TEST RESULTS

4.1. Electric Field distribution

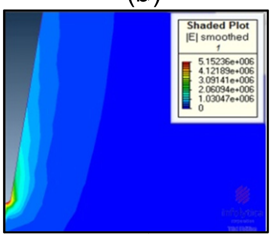
The patterns of electric field distributions of electrode systems were simulated in order to compare with the results from the laboratory experiment. Figure 4 and 5 show the example equipotential lines of the electrode system.



(a)

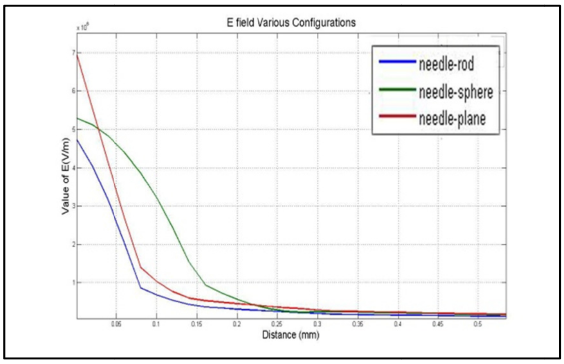


(b)

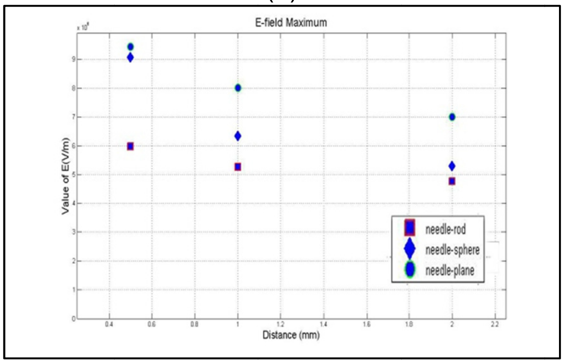


(c)

Figure 4: Equipotential lines for (a) needle-plane electrode, (b) needle-needle electrode and (c) electric field at the tip of the needle electrode



(a)



(b)

Figure 5: Electric field distributions of the electrode systems (a) Electric field between HV to ground electrode and (b) Maximum Electric field strength

4.2. Experiment test results

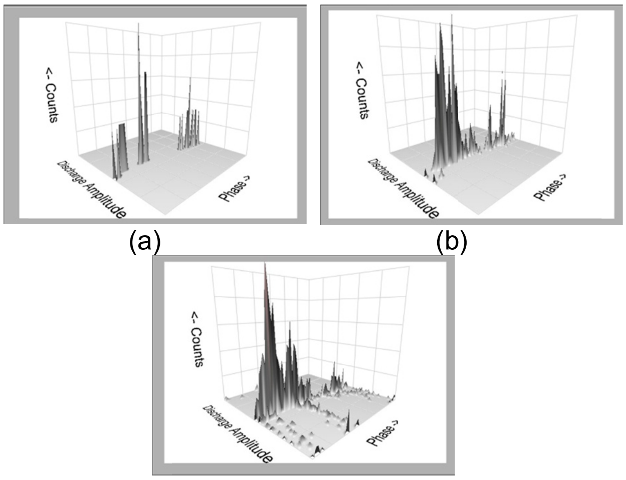
The PDIV values of the electrode systems are illustrated in Table 1 and 2 respectively. PD patterns obtained from the electrode system with the gap spacing of 2 mm for dry and humid oil conditions are depicted in Figure 6 and 7 respectively.

Table 1: PDIV test values of the electrode systems (various electrode configurations)

	Dry oil (water content upto 10 ppm)			Humid Oil (> 10 ppm)		
	Needle – Rod	Needle - Sphere	Needle - Plane	Needle – Rod	Needle - Sphere	Needle - Plane
PDIV (kV)	>45	36.3	29.2	>45	31.6	28.5

Table 2: PDIV test values of the electrode system (various gap distances)

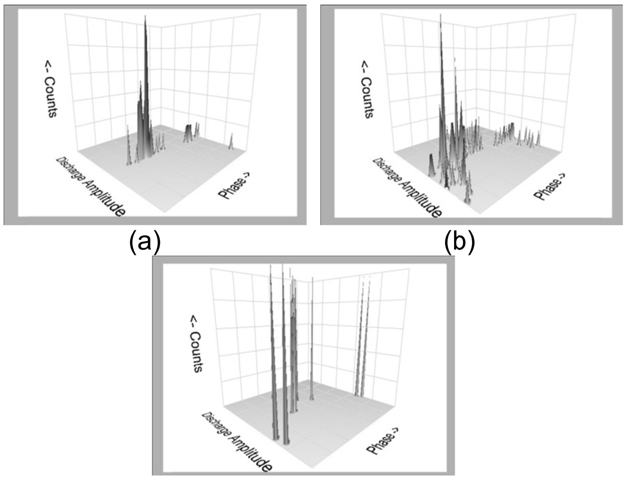
Needle-Rod	Gap Distances		
	0.5 cm	1 cm	2 cm
PDIV(kV)	31.8	37	>45



(a) (b)

(c)

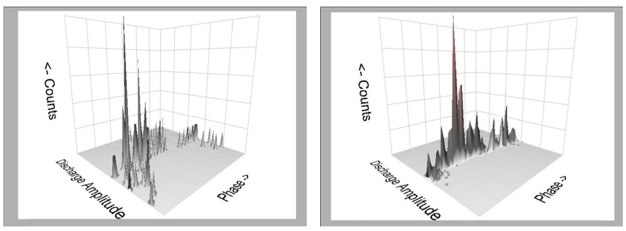
Figure 6: PD patterns for (a) needle-rod, (b) needle-sphere and (c) needle-plane with gap the spacing of 2 cm, dry oil condition



(a) (b)

(c)

Figure 7: PD patterns for (a) needle-rod, (b) needle-sphere and (c) needle-plane with gap the spacing of 2 cm, humid oil condition.



(a) **(b)**

Figure 8: PD patterns for the needle to plane at various times a) PDIV, t = 0 b) after PDIV occurs 5 minutes

The relation between PDIV and PD can be explained at least 3 ways. The first way, after the PDIV is detected the test voltage is raised. The PD activity, both, it's value and the repetition rate are higher before oil develop to breakdown. The second way, the PD activity, both, its value and the repetition rate are lower after PDIV is detected as shown in Figure 8. In this case it may be take times or need higher voltage for the electrode system before oil breakdown occur. The third way, breakdown in oil can occur directly at the suitable voltage level. In this case PDIV cannot be measured if PDIV is defined as the lowest voltage at which a partial discharge occurs of an apparent charge equal to or exceeding 100 pC. However, smaller PD values can be detected before oil breakdown.

5. CONCLUSIONS

According to the experiment, the PDIV values depend on electrode configurations, electrode geometry, gap distance and oil quality (moisture content in oil). The simulation results show the maximum electric field at the tip of each electrode configuration. The PDIV depends directly on the maximum field as we can see from the experiment results.

PD patterns from each electrode arrangement are not so much different. PDIV activities can be found approximately at the phase angle of 0-50 and 310-360 degree. Higher repetition rate of PD activities are found at the phase angle between 60-140 degree. From the experiment, the relation between PDIV and PD can be summarized in three ways. The first ways, PDIV can occur before oil breakdown. The second way, PDIV occurs after that the PD activity decrease. In this case, the insulation system need more time or higher voltage before breakdown occur. The third way, oil breakdown occur directly before PDIV can be detected.

This work is a preliminary study about PDIV and PD characteristics in oil. Other aspects about PDIV and PD characteristics will be carried out. Further work will include investigations of the influence of temperature as well as other different electrode arrangements.

Acknowledgment

Authors would like to express their thanks to Robert Eberhart and Thomas Berg who gave many invaluable suggestions.

6. REFERENCES

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