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RESEARCH ARTICLE

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THE EFFECT OF NEARBY GROUNDED OBJECTS ON PARTIAL DISCHARGE MEASUREMENTS USING FEM SIMULATION

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ABSTRACT

Partial discharge (PD) measurement is an important diagnostic to determine the performance of insulation systems in high voltage (HV) apparatuses. In line with this, PD measurements must be capable to acquire the genuine signals for quality data detection. Without proper PD measurement, the presence of grounded or ungrounded objects nearby interferes with the level of PD detected and it might cause the capacitance to increase. In this study, the HV laboratory is modelled and simulated using SLIM finite element software. The distance between the electrode and a grounded object is used as test object. The simulation results show that the presence of nearby objects can causes extra capacitance and hence charges to be accumulated on test objects. The result also was found that the capacitances between the high voltage electrode and nearby objects tend to reduce when the laboratory size is increased.

Key Words—Partial Discharge, Partial Discharge Measurements, Finite Element Method.

I. INTRODUCTION

PARTIAL discharge (PD) is a localized electrical discharge resulting from transient gaseous ionization in an insulation system when the voltage stress exceeds a critical value [1]. The generation of partial discharges may due to electrical, mechanical, thermal or chemical and environment conditions [2]. The progressive deterioration increases the probability of breakdown and decreases the breakdown strength of the insulation system [3-5]. Thus, it is essential to acquire the suitable technique to detect the deterioration of insulating systems.

PD measurement is the most recognized tool to predicting the condition of insulation systems in medium to high voltage apparatuses. It has been performed in miscellaneous IEEE standard or IEC 60270 standards [6]. Therefore, the genuine signals from PD measurements are vitally important to detect the presence of PD in insulation system.

Therefore, it is necessary to take into consideration the effects of imperfectly grounded or ungrounded objects, electromagnetic radiation, contact noise or loosely connection in the area of the high voltage while measuring the PD [7].

More significant for this work is to study the effect of grounded object in the area of the high voltage. This is to ensure, the electromagnetic fields or noise level produced by nearby objects does not influence PD signals. A better understanding of PD signal may be gained from modeling a nearby object on PD measurement using computer simulation [8].

Generally, the finite element method (FEM) is significant to solve problems in many fields including electromagnetic field [9-10]. With modern technology, the computational tool is becoming more popular and easy to analyze the finite element method. SLIM is the software module that provides facilities for the generation and solution of electromagnetic finite element models. The mesh concept in the SLIM uses much basic finite element method principles.

In this work, the effects of grounding objects on PD measurements in HV laboratory was modeled using SLIM finite element simulation software package. There were five main model configurations illustrated by Model A, Model B, Model C, Model D and Model E. The distance and height between the electrode and a grounded object are reported. The simulation results obtained are analyzed and discussed in order to understand in detail the effects of distant discharges on partial discharge transducers.

II. MODELING THE MODEL

The layout of HV laboratory represented by wall, floor, ceiling, crane and any metal objects in HV laboratory can be seen in Fig. 1. The value of the capacitance between the high voltage electrode and nearby objects was calculated within the finite element program by applying unit potential to the high voltage electrode and zero potential to all grounded objects. Computer simulation categorized into five model configurations which are (A) HV laboratory with actual size (20.73 meter height, 20.27 meter width), (B) crane nearby to HV laboratory's wall where the distance between the electrode and a grounded object which is the crane is kept constant; the height between the crane and the electrode is changed, (C) crane nearby to HV laboratory's ceiling where the height between the crane and the electrode is kept constant; the distance between the electrode and the crane is changed, (D) another grounded objects are added into HV laboratory and (E) HV laboratory with double size (height x width = 41.46 meter x 40.54 meter). Model A is used as reference model.

The capacitance between the high voltage electrode and all grounded objects was calculated by measuring the charges, Q over the surface of the high voltage electrode, as in (1). The unit for capacitance is Farad per meter (F/m).

$$C = \frac{Q}{V} \tag{1}$$

III. RESULT AND DISCUSSIONS

A. The HV laboratory with actual size.

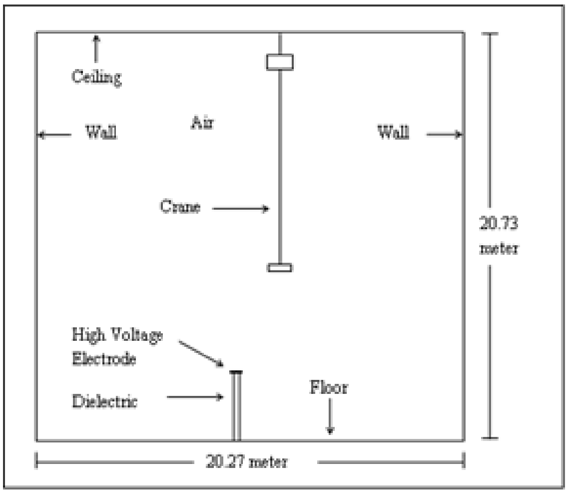
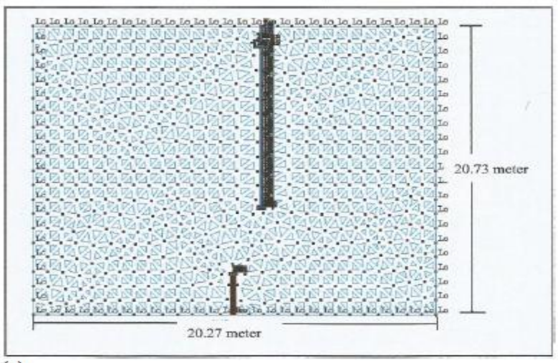


Fig. 1. Variation of the nearby grounded objects in the HV laboratory

Model A is illustrates in Fig. 2(a). The simulation results presented in Fig. 2(b) and 2(c) are shown the distribution of electric flux density and contour of charges, Q, respectively.

The contour in Fig. 2(c) used as the line reference. Then, by integrating the flux density over the surface of the high voltage electrode, the value of the charges was computed to give 4.09 x 10^{-12} *C/m*. Refer to (1), the capacitance between the high voltage electrode and surrounding grounded objects is 4.09 pF/m.



(a)

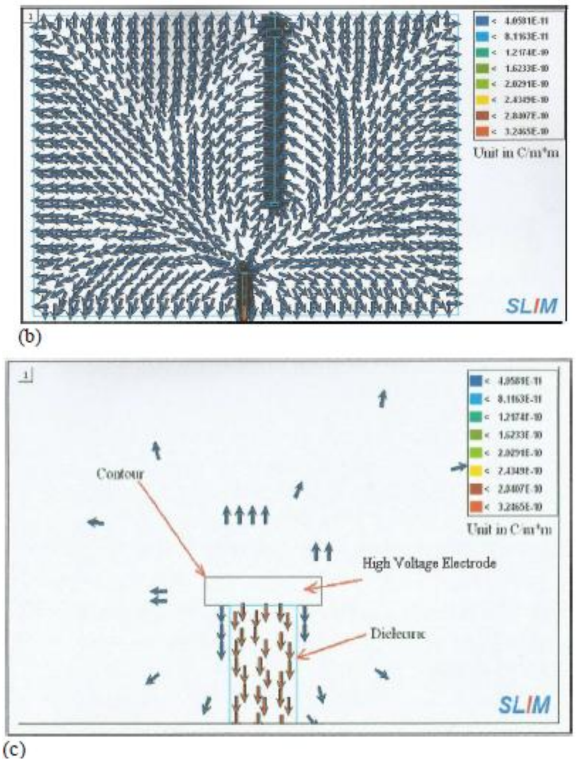


Fig. 2.The (a) model A, (b) flux density distributions, and (c) contour on the high voltage electrode of HV laboratory generated by FEM SLIM.

B. The crane was moved along the x and y-axes

The crane was moved away from the high voltage electrode step by step to new positions along the x and y-axes as represents in Fig. 3 (a) and (b). For every position of the crane, the value of charges was measured.

Both x-axis and y-axis movement are shows a decrement in capacitance value. The capacitance decreased to 3.88 pF/m if the crane moved to the wall, whereas it is reduced from 4.09 pF/m to 3.87 pF/m when the crane moved to HV laboratory ceiling. The variations of the capacitance with distance and height have some influence on PD measurements in the laboratory since some charges or capacitive effects related to the objects. Therefore, to reduce the additional capacitance that produced by the nearby objects, the crane need to moves far away from the high voltage electrode.

C. Another grounded objects added into HV laboratory's

To study the effects of the grounded objects and their distances, more grounded nearby objects are added in the laboratory as shown in Fig. 4. The capacitance between the high voltage electrode and all grounded objects is climbed to 5.22x10-12 F/m.

D. HV laboratory with double size.

For further simulation, the size of HV laboratory was double and the distribution of electric flux density vectors are demonstrates in Fig. 5 (a) and (b).

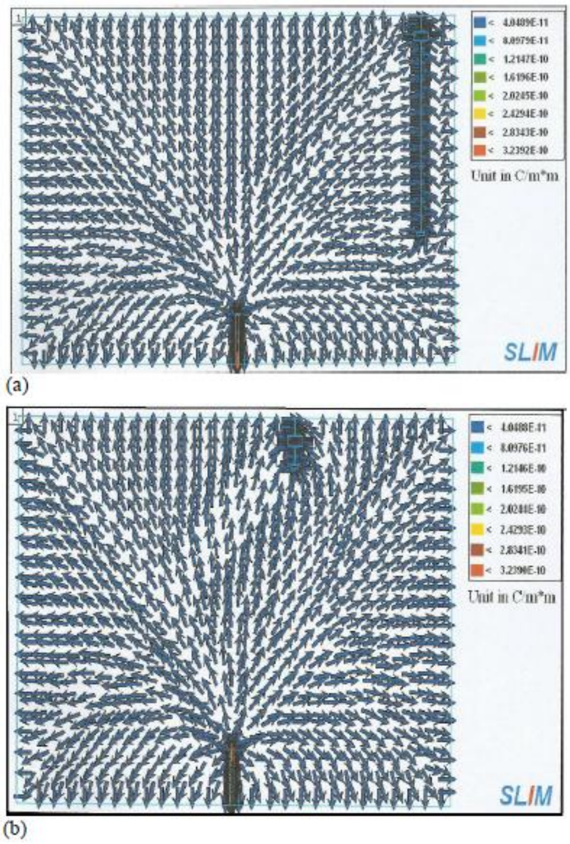


Fig. 3.The flux density distributions when (a) crane is near to the wall, and (b) crane is near to the ceiling corresponding to model B and C.

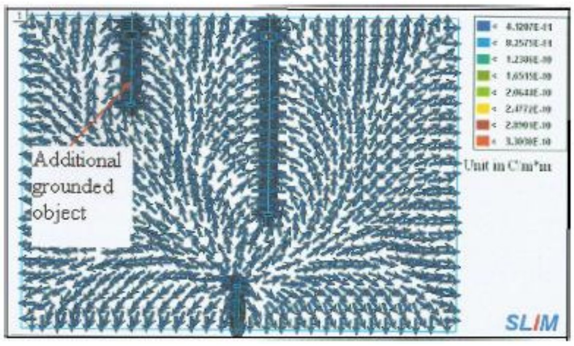


Fig. 4.The distributions of flux density corresponding to model D.

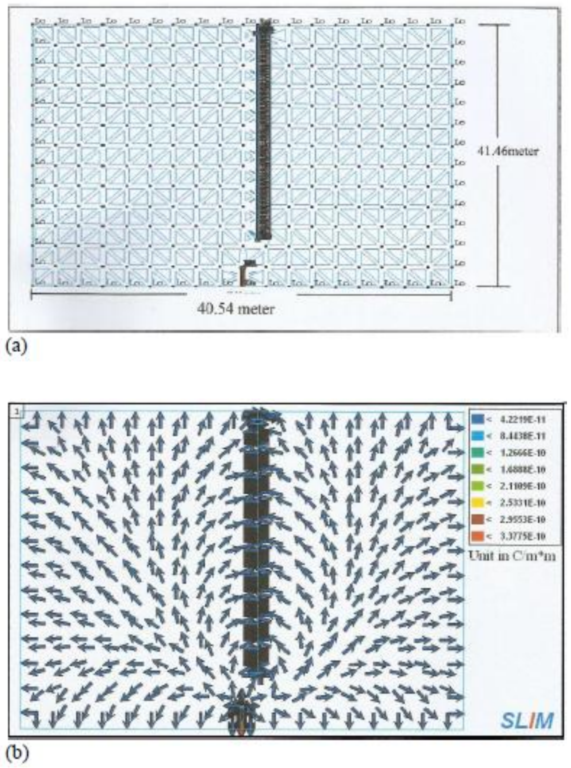


Fig. 5.The (a) model and (b) flux density distribution corresponding to model configuration E.

TABLE I; SUMMARY OF THE SIMULATION RESULTS

Model	Configuration	Capacitance to ground (pF/m)
A	HV laboratory with actual size	4.09
B	Crane nearby to HV laboratory's wall	3.88
C	Crane nearby to HV laboratory's ceiling	3.87
D	Another grounded objects added into HV laboratory's model	5.22
E	HV laboratory with double size	2.54

TABLE 2: Summary of the simulation results in term of percent increase and decrease.

Model	Configuration	Increase (%)	Decrease (%)
A	HV laboratory with actual size	Reference	Reference
B	HV laboratory with double size		37.9
C	Crane nearby to HV laboratory's wall		5.14
D	Crane nearby to HV laboratory's ceiling		5.38
E	Another grounded objects added into HV laboratory's model	27.63	

IV. CONCLUSION

HV laboratory was modeled and simulated using SLIM Electromagnetic Engineering Software (FEM) program. The presence of the grounded nearby objects on the PD measurement are restricted effects the accuracies of PD signal. The distance and height between the nearby grounded objects and the high voltage electrode produced additional effective capacitance. The capacitance tends to decreases about 2.54x10-12 F/m from 4.09x10-12 F/m or 37.9% with the increases in laboratory's size. As predicted, the capacitance increased by 27.63% with any additional of nearby objects into the laboratory. It seems that every nearby object even if it is grounded can have some influence on the PD measurements in the laboratory since some charges or capacitive effects related to the objects.

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A Brief Bio of authors

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