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Effect of Impulse Voltage on Partial Discharge of Oil and Paper - Oil Insulators Containing Air Cavity

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Abstract
In power systems, usually by lightning strikes or switching operation, impulse voltage is produced. This paper reviews the effect of high impulse voltage on the PD parameters. In recent years, numerous studies on PD in the insulation, under the impulse has been done. Despite the use of power equipment and tools, switching impulse is created in the system. So, studies on PD activity with the initiation and end voltage PD in insulators have been investigated. However, the combination of PD characteristics with AC and impulse has not been studied in many studies so far. Unlike previous studies, in this paper, along with the impulse voltage, the AC voltage effects are also considered. On the other hand, dielectric characteristics show the quality of insulation in terms of the soundness or deterioration of equipment over time. The deterioration and aging of equipment can be due to electrical stresses such as alternating current PDs or transient stresses or due to environmental pressures and temperature or mechanical pressures. At this point, the effect of the PD alternating current (AC) on paper combination insulation oil dielectric frequency response equipment is investigated. In this review, a brief history of the performance of insulation against partial electrical discharge is addressed, and the finite element method software (Maxwell) is used to simulate partial electrical discharge for objects that are particularly sharp.
Keywords: Partial electrical discharge, insulation, oil, oil paper, dielectric response

1. INTRODUCTION

Electrons and ions which have absorbed energy by partial discharge, locate on the surface of the insulating oil paper, that this energy is absorbed as a result of covalent gap and cell breakdown [1]- [5]. On the other hand, creating heat through PD cause thermal cell breakdown [1]- [5]. Hence, polymer free radicals that are charged electrically, gain energy in the PD process [1], [2]. As a result of free radicals incensement, specific conductivity of oil conductor become more

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than paper conductor and also carbon dependent on paper conductor increases step by step which cause incensement of paper special conductivity [1]. When free radicals stimulate further, the temperature of oil paper insolation increases and after that special conductivity of insolation increases. In general, special conductivity of oil is more than paper [6,7], or paper permittivity is more than oil. Hence, when it is exposed to electrical stresses, loads cross of oil phase better than paper phase. Hence, oil insulation response is different from paper and when insulation is oil-paper, the combination of answers is the response [1].

2. RESULTS OF TESTS AND SCRUTINY

2.1. PD Dielectric Spectroscopy Measuring System

A PD measuring system is shown in Fig. 1 and the schematic diagram of spectrometric measuring system is shown in Fig. 2.

Where the main components are,AC source of HV amplifier low pass filter, case of test, wave impedance Zs, monitoring insulator position, ICM system and a computer that is represented under its schematic diagram [8].

Table 1. ***Summary of the performed tests.***

Number of samples	Description	Study
1	PD measurement: Destructive effect of PD in highlighted periodic voltages in range of more that 5 hours	1
2	PD measurement: Effect of high tension impulses	2
3	PD measurement: Effect of a mixture of 4 high tension impuls and be destroyed because of PD under the influence of AC alternating voltages in range of 5 hours	3
1, 2,3	DS measurement: Safety of test sample for 2 different time (4samples) sample 1 (safety time and after test in first study) and samples 2 and 3 after test in 2 and 3 studies	4

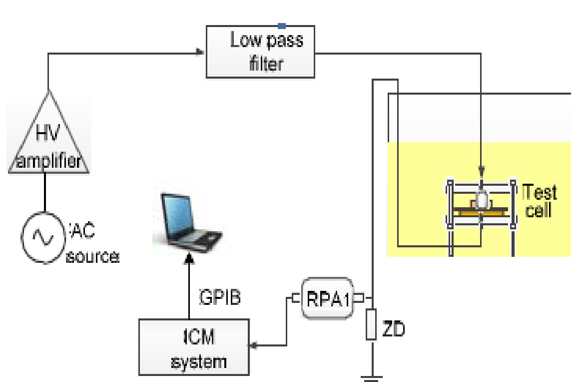


Fig. 1. Schematic diagram of PRPD measuring System.

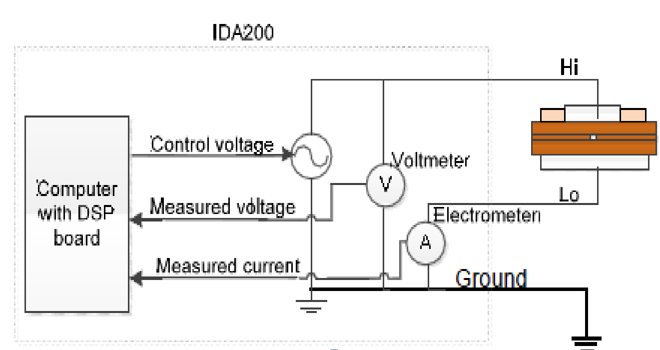


Fig. 2. Schematic diagram of spectrometric measuring system.

3. PD PARAMETERS VARIATION OF OIL PAPER INSULATION BY AIR CAVITY AT APPLYING AC VOLTAGE TIME AND IMPULS

3.1. Applying AC Voltage

The applied AC voltage has the pick value equal to 16 (KV[1]) that is used in period of 5 hours. Initial voltage of PD has 6 (KV) peak. System saves sample's PRPD measures every 5 minutes.

The average of PD numbers increases by damage in rate of equipment's oldness until reaches 180 minutes. Then, the average of PD numbers decreases.

3.2. Effect of HV Impulse Voltage on PD

In this study, a test sample is under four 1.2/50 (μs) impulse of 80 (KV) peak each. That PRPD[2] equipment records samples before and after every four times.

Fig 3 shows the PD parameters in period of applying AC voltage and Fig. 4 illustrates the PD parameters before and after applying impulse voltage. In spite of the first case that the amplitude of the PD parameters is in the same direction, in impulse voltage the amplitude of the PD parameters fluctuates between two impulses.

3.3. Combination of Applying AC Voltage

In this part by applying both AC and impulse voltages, the PD is studied. Fig. 5 shows the PD parameters before and after applying the AC voltage and the impulse as well.

It is seen that PD parameters after applying third impulse decrease a lot and till the end of test remain in that low value and constant level. After doing this test, the surface of cavity and inside it become carbon and black but in two previous tests it didn't happen [4].

3.4. Symmetry in PD

All recorded PD samples in half positive and negative cycles are symmetric. Image of PD, as an example, after 5 hours (see Fig. 6) and 18 hours (see Fig. 7) are represented. As clearly seen in Figs. 6- 7, in half positive and negative cycles, samples are symmetric, where PD samples symmetry in half positive and negative cycles show the beginning of insulation damage process. After 18 hours of PD process, a sign of PD creation in air cavity in the middle of oil paper insulation appears [22].

According to Fig. 8, after applying periodic PD in the range of low frequency, the amplitude of PD increases.

3.5. Parameters of Insulation Diagram after PD

The loss coefficient decreases by increasing frequency and after applying voltage and PD creation, the loss pick appears. Amplitude of loss coefficient by increasing time duration of applying voltage, especially for frequencies less than 100Hz, increase significantly.

Loss pick on the surface of oil paper insulation increases because the maximum insulation parameters difference (loss coefficient and permittivity) is the edge of these two insulation.

It is considered that sticky matter after applying voltage increases. Actually this chart is a standard for measuring the oil purity rate which is used in transformers. Fig. 11 shows the damage of equipment depends on applied voltage on it and Table. 2 writes the turbidity assessment of oil before and after voltage application.

The Inter Facial Tension (IFT) oil interfacial force tension is being used that is a standard for measuring the oil purity rate. The amount of existed acid in oil which is created

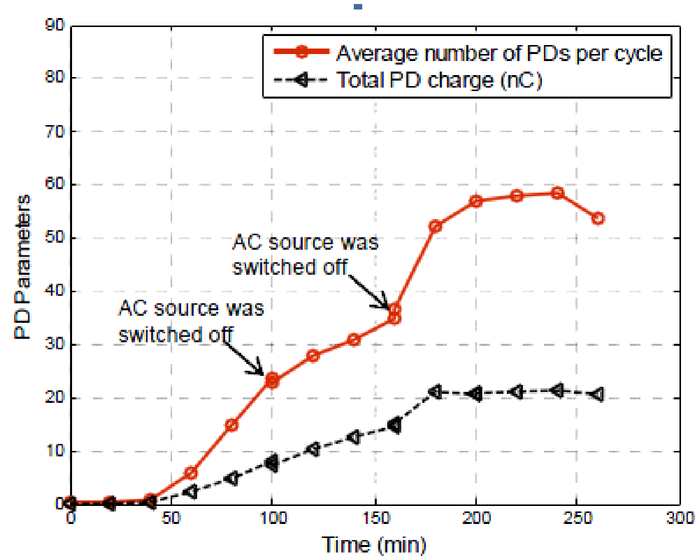


Fig. 3. PD parameters in period of applying AC voltage.

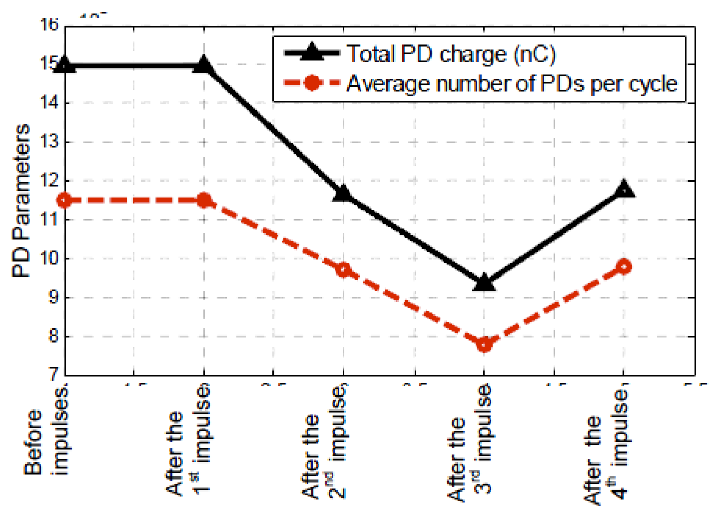


Fig. 4. PD parameters before and after applying impulse voltage.

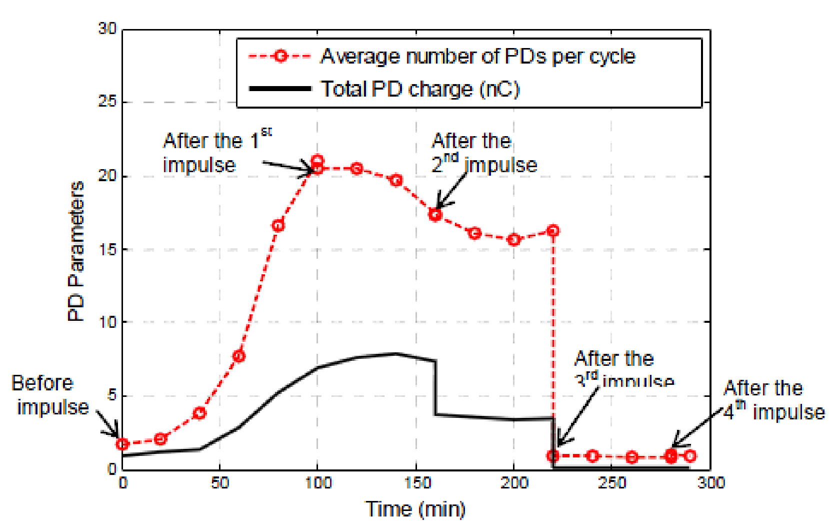


Fig. 5. PD parameters before and after applying AC voltage and impulse.

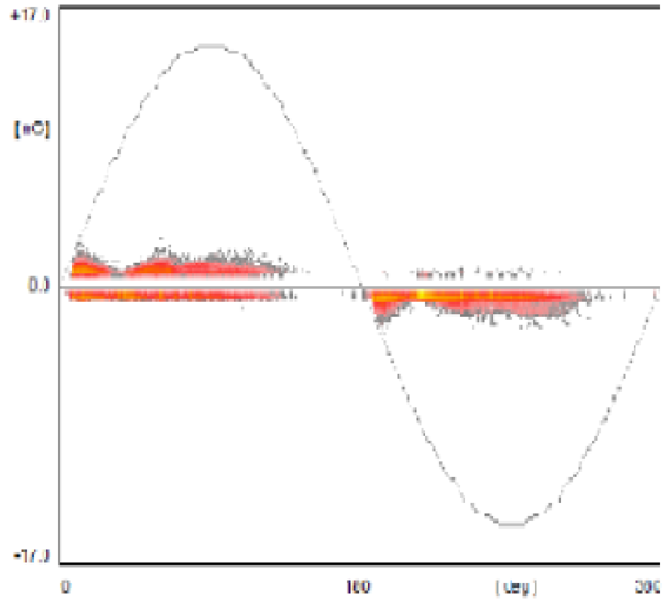


Fig. 6. PD after 5 hours.

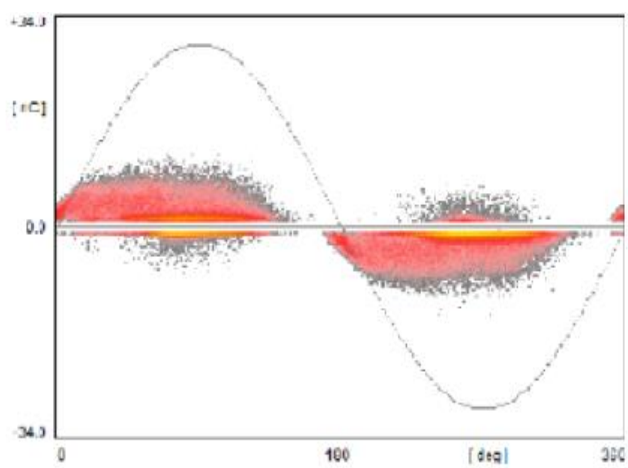


Fig. 7. PD after 18 hours.

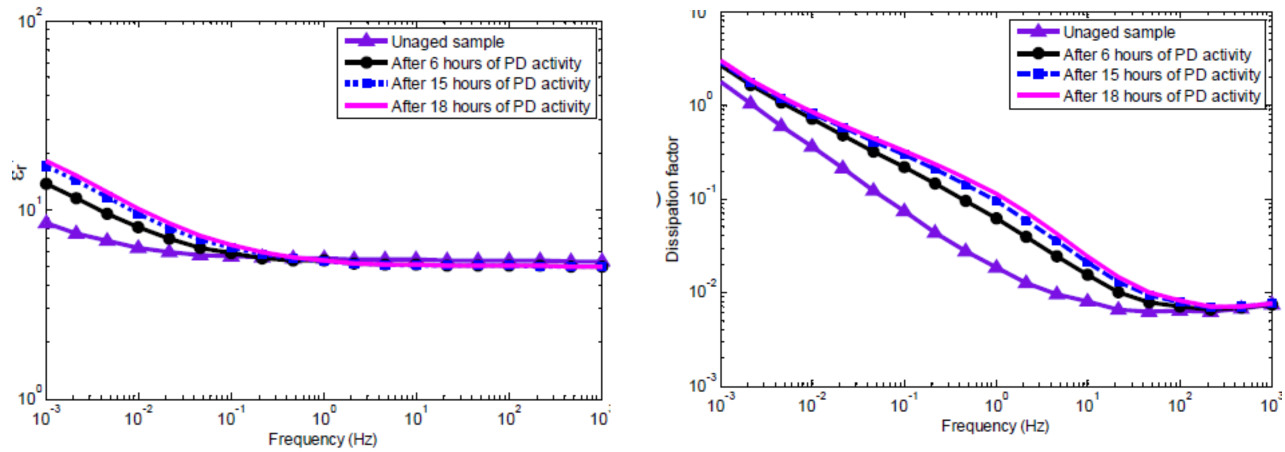
Table. 2. ***Turbidity assessment of oil before and after voltage application.***

		After Applying Voltages(kv)			
	Fresh oil	5	6.5	8	10
Turbidity (NTU)	0.49	0.65	1.08	1.34	1.47

by heat, which gradually creates sticky matter, is measured based on the standard and by applying voltage, this acidic matter increases. The rate of incensement in 10(KV) reaches 19.2(dynes/cm) that means the quality of the oil is not appropriate.

3.6. Effect of PD on Existed Oil in Transformer

By using the results of ASTM[1] test, it is possible to obtain dissipation dielectric factor (DDF) and special conductivity of insulation



(a) **(b)**

Fig. 8. The Dielectric Spectroscopy Results of oil- impregnated paper at the time of unaged and after applying AC voltage a) Real part of relative complex permittivity, b)dissipation factor.

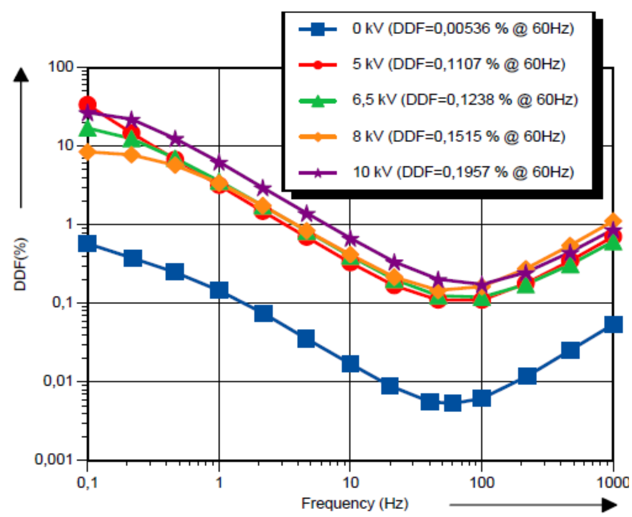


Fig. 9. Frequency scans of the DDF of the oil before and after applying voltages.

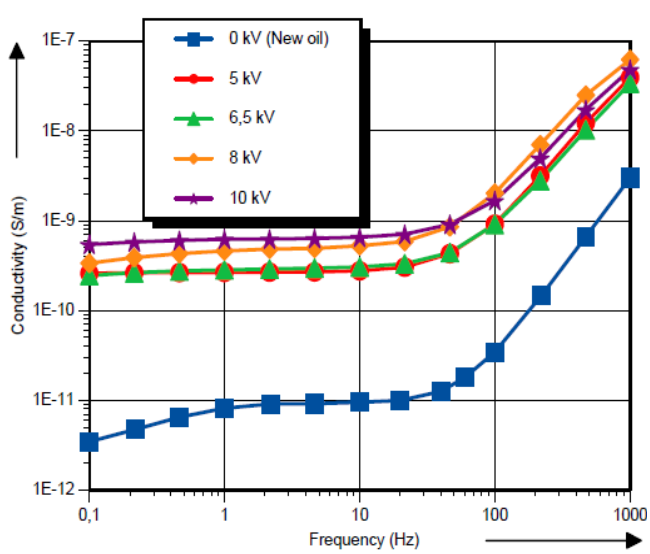


Fig. 10. Frequency scans of the conductivity scans of the oil before and after applying voltages.

matter by applying a voltage by frequency interval 0.1 to 1000Hz[2] that it is considered by applying voltage both properties increase, see Fig. 9.

As it is considered by increasing the free radicals the amount of DDP[3] increases [5], see Fig. 10. By air interring air to oil, oil becomes oxidized, so-called gassy and causes incensement in free radicals in the space around the cavity and causes creation of sticky matter in transformer oil containers.

However, this material prevents porous creation in paper prevents heat transmission and decreases heat transmission power and causes free radicals incensement and conductivity incensement and conducts the insulation.

4. SIMULATION USING FEM MODEL

In this part, oil paper system by finite element method is simulated. By using it, field variation, voltage and flux and even flux density can be obtained.

Since in this system, oil paper insulation is considered constant and no transmission is applied on it, a 2D (two-dimensional) system is used for simulation, see Fig. 12. Nevertheless by considering transmission and Transient type of analysis, 3D (three-dimensional) model should be used, but program performance would be time consuming.

Existed figure in reference [8] that is simulated by Comsol software, here is simulated by Maxwell:

1) First, the green rectangle (paper insulation) is designed by below dimension. (according to existed dimension in source [1]), Fig. 13.

2) Then, electrodes are drawn, Fig. 14. By dimension, Fig. 15.

3) In this step, as it is mentioned in the paper, the tip of electrodes should be Epoxy. Hence, epoxy of electrodes tip is drawn, Fig. 16.

4) Then, the empty cavity space full of air should be created. For this purpose, a rectangle with the mentioned below dimension should be created and reduce it from paper insulation space, Fig. 17.

As a result, a cavity is created in the center that is specified by star, Fig. 18.

5) In this step, excitations are created (1).

By specifying Setup and the type of solving problem analysis, the steps of designing are being checked.

By confirming all steps, now it's time to obtain voltage analysis and other parameters. Hence, select all spaces then right click and as the result according to the system analysis, in the voltage around 8(KV) PD happens in the cavity.

5. CONCLUSION

Partial electrical discharge can be easily analyzed by infinite element software (MAXWELL). By using the design tools, most of dangerous infinite discharges that happen and cause serious damages to expensive and structure complex equipment, can be simulated and analyzed in different regions of the model which has important sharpness or pointy that cause non-uniform fields. In this way, it is possible to resolve one of the fundamental problems of simulating infinite electrical discharge that was mentioned in [9], and also the speed and accuracy of analysis increase and the problems related to sensitive and sharp regions also can be resolved.

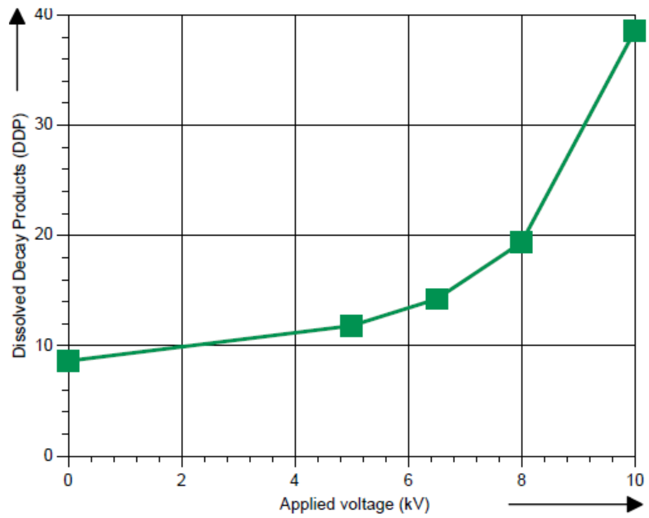


Fig. 11. Damage of equipment depends on applied voltage on it.

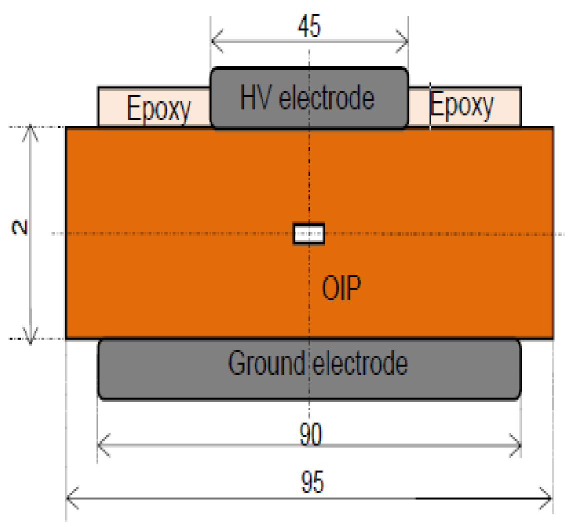


Fig. 12. Shown the HV and Ground electrode.

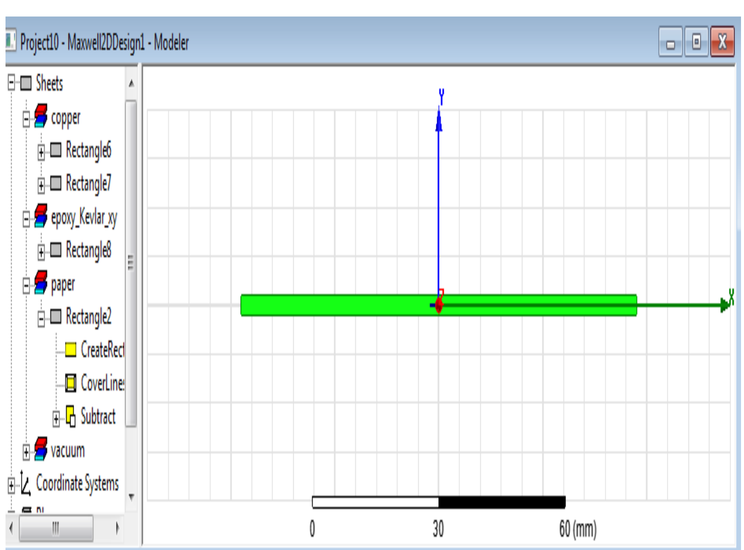


Fig. 13. Paper insulation.

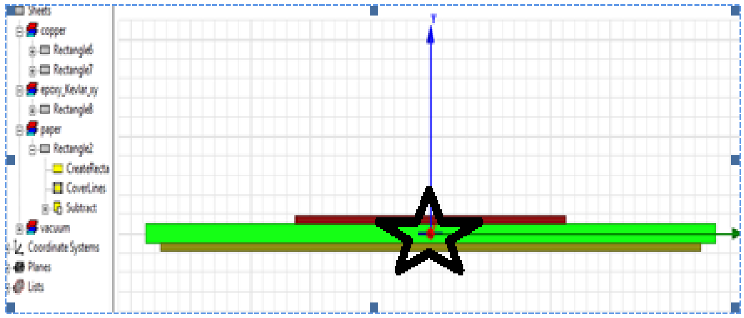


Fig14. Electrodes.

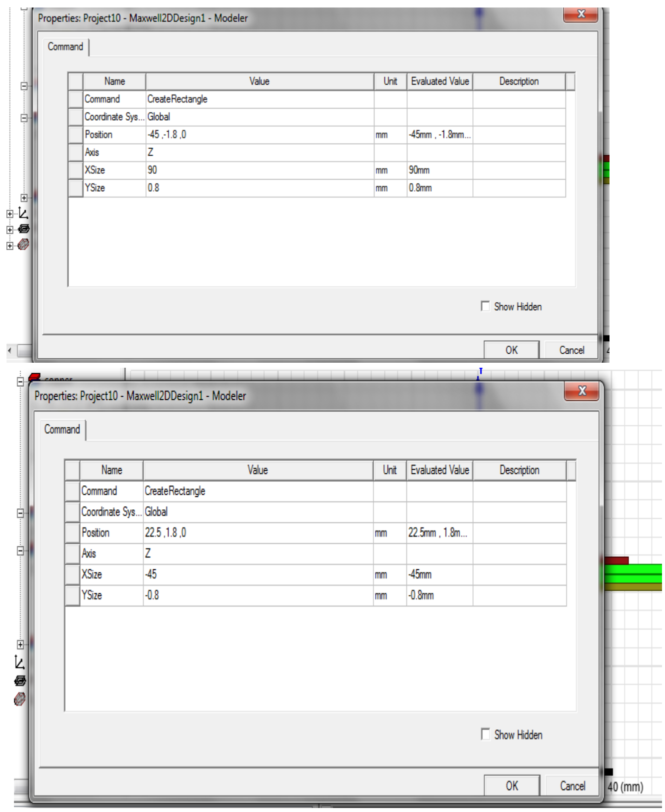


Fig. 15. Electrodes dimension.

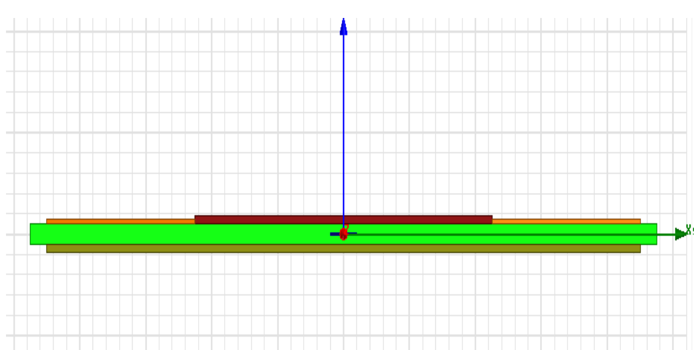


Fig. 16. Epoxies (orange).

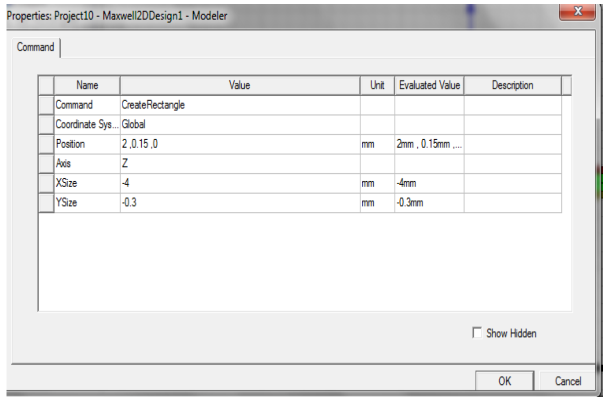


Fig. 17. Rectangle's dimension.

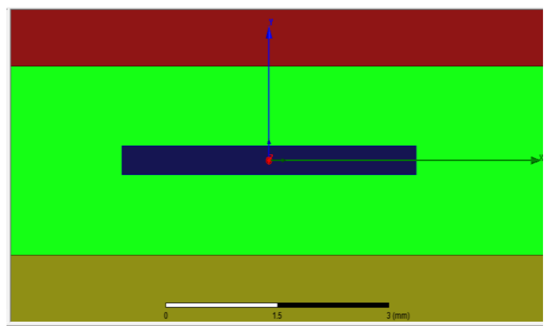


Fig. 18. Cavity.

REFERENCES

[1] C.Homgak, K. Mossner and T Leibfried, "Investigation on degradation of power transformer solid insulation material", IEEE 78, 2008.

[2] K.Dumke, H. Boris and E. Cockenbach, "Experimental investigation on the behavior of decomposition gases in insulation liquids caused by partial discharge and breakdown", Int'l. conf conduction and Breakdown, Dielectr. Liquids, Roma, pp. 436- 439, 1996.

[3] J. Yan, R. Liao, L. Yang, J. Li and B Liu "product analysis of partial discharge damage to oil – impregnated insulation paper". J. Appl, surface Sci, Vol, 257, pp. 5863-5870, 2011.

[4] Sbau and R Stokhuyzen, "the side effects of gasinng in transmission power transformers "IEEE, conf Electr. Insul. Dielectr. Phenomena (CEIDP), Victoria, BC, Vol. l, pp, 264-7267, 2000.

[5] J.S N'cho, T Aka – Ngnui, A Beroual and I. Fon Fofana "Effect of electrical discharge on oil decaying process.

[6] M. Kohtol, S Kaneko, S Okabe and T Amimoto "Aging effect on electrical characteristics of insulation oil in field transformer".

[7] SM. Gubanski, P. Boss, G. Csepes, V Der Houhanwsian" dielectric response method for diagnostics of power transformer".

[8] R. Clemen kiza, M. Ghaffarian Niasar, R. Nikjoo, X. Wang & H. Edin "The effect of partial discharge by – products of the dielectric frequency response of oil – paper insulation comprising of a small cavity"

[9] R. Clement Kiza, R. Nikjoo, M. Ghaffara Niasar, X. Wang &H Edn "effect of high

voltage impulse on partial discharge acivity in a cavity embedded in paper insulation”.

[10] jialu Cheng, Diego Robalino, peter Werelius, Matz ohlen” improvement of the transformer insulation XY model including effect of contamination”.

[11] M. Koch and T. Pre vost “Analysis of dielectric response measurement for condition assessment of oil – paper transformer insulation”, IEEE Trans. Dielectr. Electr. Insul, vol. 19. Pp. 1908-1915, 2012.

[12] M.Jaya, T.Leibrried and M. Koch “Information within the clielectric response of power transformers for wide frequency ranges” IEEE 2010.

[13] S.M.Gubnski, P.Boss, G.Csepes, V. Der Houhanesian, J.Rilippini, P.Guainic, U.Gafvert, V.Karius, J.Lapworth, G.urbanic, UL. Gafvert, V.Karius, J.Lapworth, G.Urbani, P. Werelius and W.Zaengle “Dielectric response methods for diagnostics of power transformer” IEEE 2003.

[14] j.Sabau and R.Stokhuyzen “The electroche mical stability of mineral insulating oils” Electricals Insulating Materials America Society of Testing and Materials, 2000.

[15] Astm 0971, Standard Tost Method for Interfacial Tension of Oil Against Water by the ring Method Vol.10.03.