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# Three Phase Distribution Transformer Modelling and the effect of Insulation Failure on Electric Field Distribution

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## ABSTRACT

***A transformer failure mostly arises because of insulation failure. Insulation failure in distribution transformer causes electrical and thermal disturbances. In order to decrease the effect of insulation failure on transformer the selection of best insulation material can be done. In this paper modeling of 25kva distribution transformer and effect of insulation failure on the electric field is done using ANSYS MAXWELL simulation program. Transformer model and electric field distribution of designed transformer using two materials under different condition are presented with simulation results. The electric field distribution is compared for OIP and Bakelite insulation material. This paper provides advantage for the research and engineer who do the transformer designing optimization study on electric field analysis using simulation program such as ANSYS. In future optimization study on transformer oil and location of partial discharge and thermal analysis will be done.***

*KEYWORDS: Transformer, Insulation failure, Electric Field Analysis, Simulation.*

## 1. INTRODUCTION:

Transformers are used to step up or step down the voltage level for transmission and distribution of energy in power system. Due to its high power efficiency it is one of the most important and expensive component. Therefore, effective design and modeling are required for transformer.

Distribution transformers encounter the load switching, lightning and other environmental stresses, which causes the worst impact on insulation. So electric field analysis of transformer under these kinds of stresses is important in order to protect the insulation and hence the transformer. The failure rate of distribution transformers in India is more compared to any other developed countries. The transformer failure result in loss, not only in terms of repair or replacement of failed transformer, but also has worst impact the economic condition to the utility in terms of power cut to the consumers. In order to improve reliability of the system and to reduce the risk of failure, it is necessary to bring down failure rates.

Lightning is meteorological processes that have adverse effects on power system. Lightning is one of major causes of power outage and has noticeable damage to power system and its components. This affects the power quality and the reliability of the system. As distribution transformer can be exposed to over voltages occurring due to lightning stroke [1].

Switching overvoltages are highly damped short duration overvoltages. They are 'temporary overvoltages' originate in fault clearing processes or during switching in the power system. With increase in transmission voltages, the overvoltages generated inside the system reached to the higher order and last for longer duration. Therefore, they are severe and more dangerous to the power system.

Lightning effect on the electric field and the potential distribution of a distribution transformer is simulated using Ansys Maxwell-2D software. Ansys Maxwell uses Finite Element Method (FEM) to simulate a geometrical model. A lightning impulse and overvoltage is applied on the secondary winding of a transformer and the effect on the insulation between LV and HV winding is considered for the study. Electric field analysis on the transformer in different condition like lightning, switching surges and because of presence of air gap in the insulation paper is simulated on the 3D ANSYS MAXWELL.

## 2. TRANSFORMER MODEL DESIGN

In this study, 25 kVA distribution transformer was modeled using ANSYS Maxwell simulation program and insulation failure caused by various factors like switching, lightning and manufacture defect in the insulation paper was simulated for two different insulation papers Bakelite and OIP(Kraft).

TABLE 1 TECHNICAL SPECIFICATION OF DESIGNED TRANSFORMER

| Element | Value/Feature |
|---|---|
| Power Rating | 25 KVA |
| Primary voltage | 11kV |
| Secondary voltage | 0.4kV |
| Core material | M15_027 |
| Winding material | Copper |

The 2D transformer model of designed oil type transformer is presented with front view in figure 1.

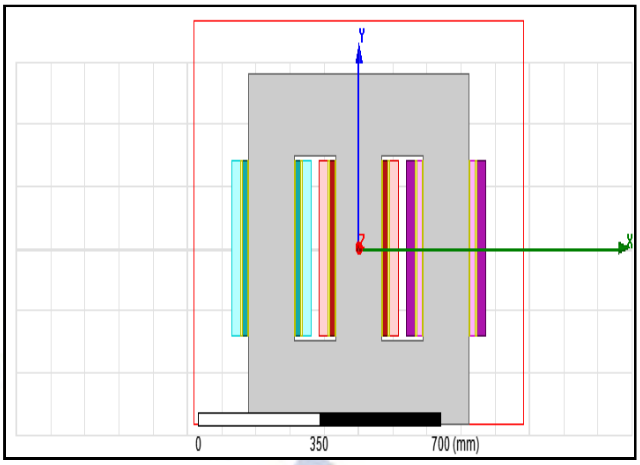


Fig.1. 2D model of distribution transformer

The 3D model of designed transformer include transformer core, primary and secondary windings, insulation papers between the core and windings and insulation oil inside the bounding box (such as transformer tank). Figure 2 and figure 3 represent the trimetric view and top view of designed transformer.

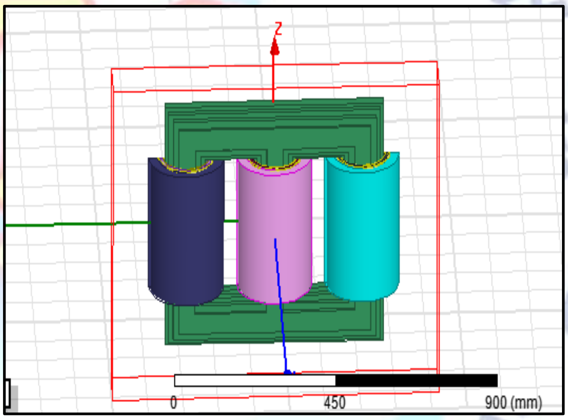


Fig.2. Trimetric view of designed transformer

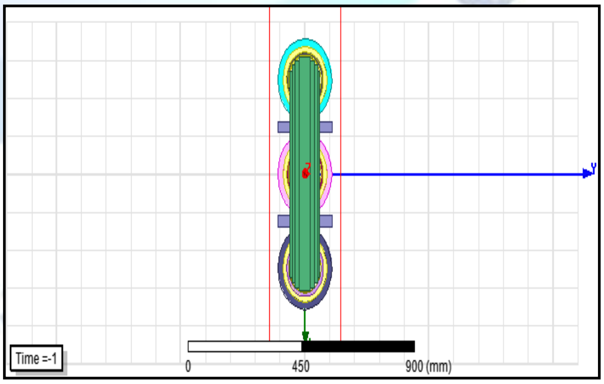


Fig.3. Top view of designed transformer

A 140kV lightning impulse is given to the secondary of the transformer. The maximum value of voltage is shown in fig 6.The simulation time is set to 100 microseconds and analyzed.

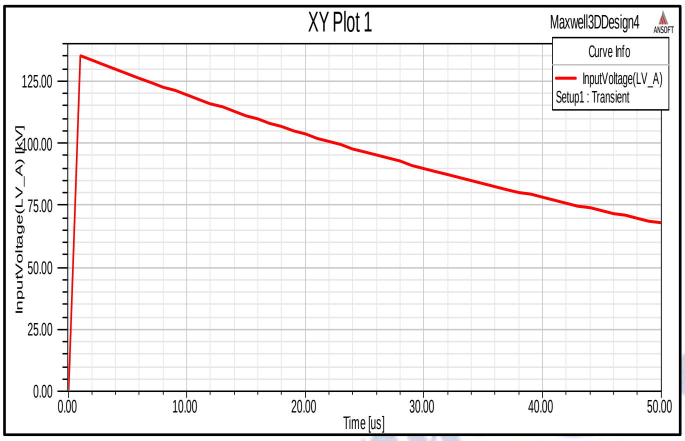


Fig.4. 140 KV lightning impulse voltage

The switching overvoltages were given to the transformer windings and simulation run time is set to 100ms with 1ms time step and analyzed in the electric transient solver with the excitations given to the transformer as shown in figure 5 and figure 6.

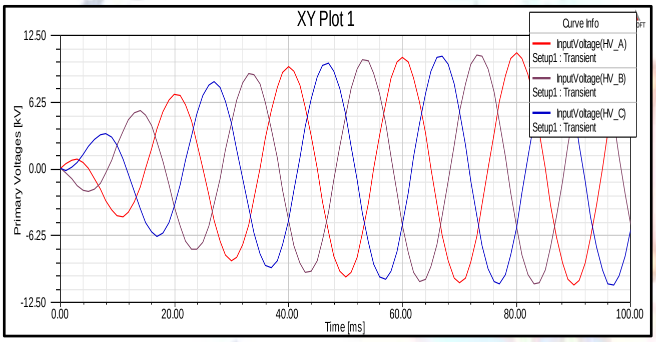


Fig.5. Voltage surges given to primary winding

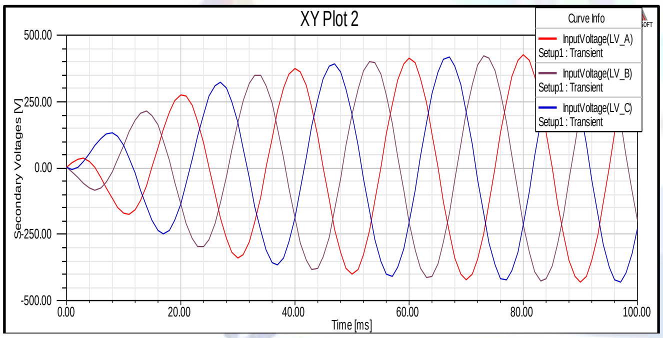


Fig.6. Voltage surges given to secondary winding

Distribution transformer is subjected to various electrical and thermal stresses which mainly disturb the coil or winding arrangement because transformer coils were subjected to electromagnetic forces which leads to coil deformation which then create the voids between the winding and insulation. The formation of air gap during manufacturing of insulation paper is also a reason for the partial discharge in the insulation. The air gap of 1mm radius is created in the insulation paper as shown in figure 7.

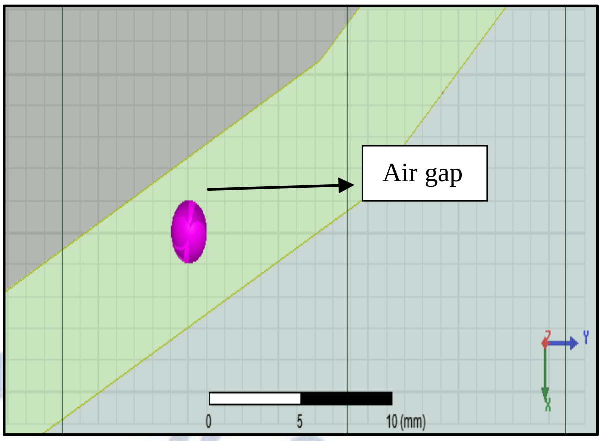


Fig.7. Insulation paper with air gap

The simulation run time is set to 100ms with 1ms time step and analysed in the electric transient solver with the excitations given to the transformer as shown in figure.

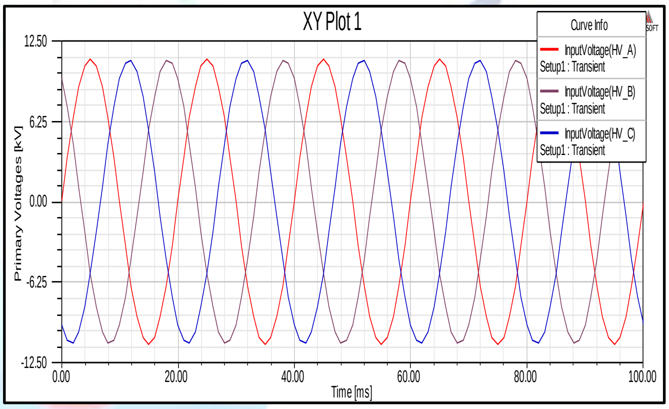


Fig.8.Primary voltage excitation to the transformer

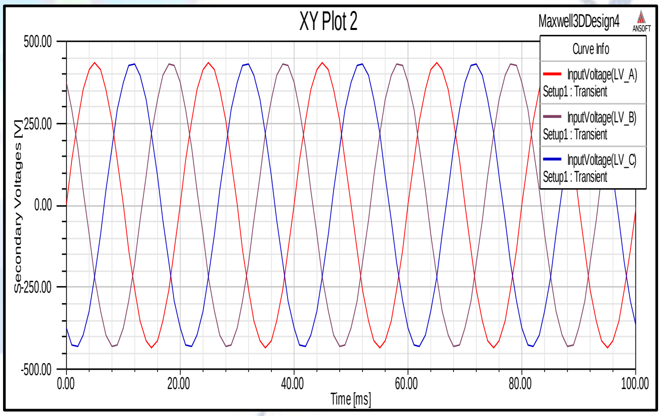


Fig.9. Secondary voltage excitation to the transformer

## 3. RESULTS

For lightning analysis of transformer is done with lightning impulse of 140kv excitation is applied on secondary winding. For this 2D model is used. Voltage distribution and electric field distribution on transformer is presented for lightning impulse in fig 10 and fig 11.

And the electric field distribution on the top of insulation paper is shown in fig 12.

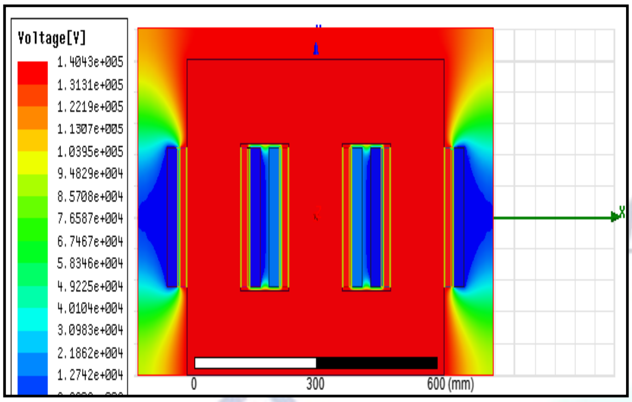


Fig.10. Voltage distribution on the transformer

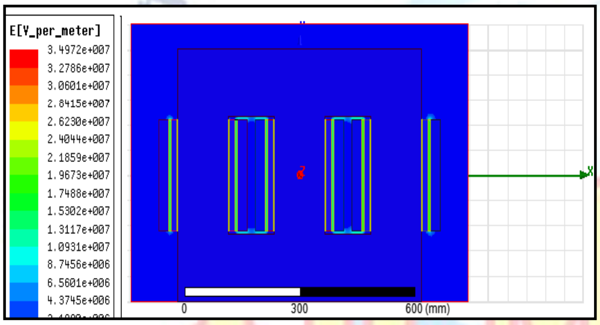


Fig.11. Electric field distribution on transformer

Meshed model of the transformer core is shown in fig 12.

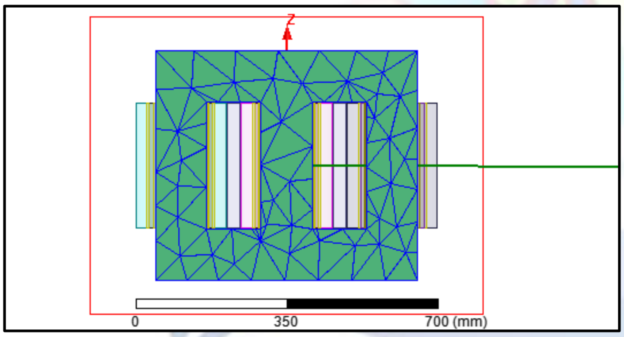


Fig.12. Meshed model of designed transformer

The simulation of 25kVA distribution transformer with 140kV lightning impulse is applied on the secondary winding and overvoltage is applied to the transformer windings. The electric field on 3D model of transformer is shown in figure 13 and figure 14 for case 1. The maximum electric field is increased from $1.1323 \times 10^7$ v per metre to $1.1386 \times 10^7$ v per metre by using an improved version of Kraft paper.

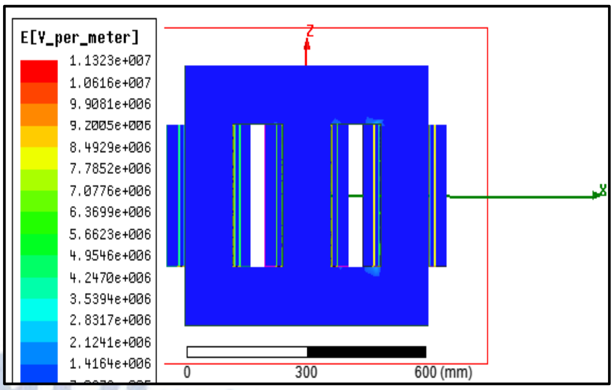


Fig.13.Lightning electric field distribution of transformer with Bakelised paper

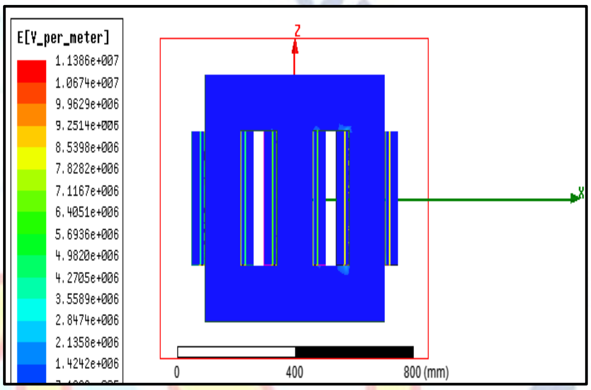


Fig.14.Lightning electric field distribution of transformer with OIP

The electric field distribution on the transformer when the switching surges applied to primary and secondary windings of the transformer are shown in figure 15 and figure 16.

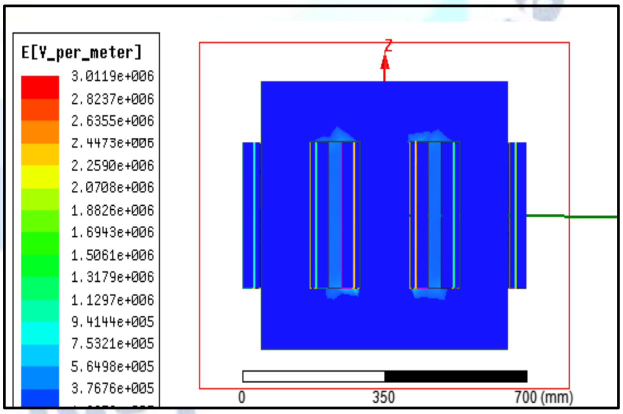


Fig.15.Eelectric field distribution of transformer with OIP during transient

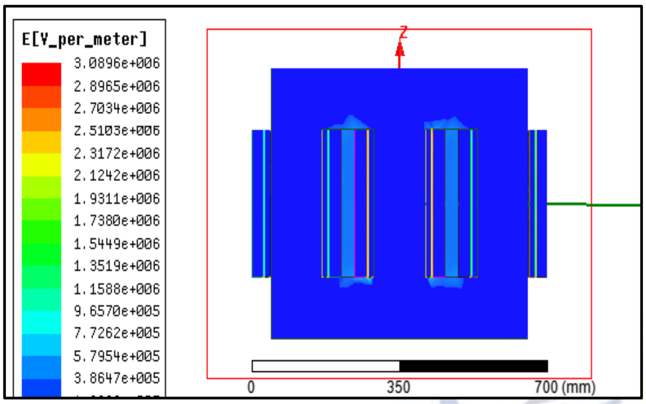


Fig.16.Eelectric field distribution of transformer with OIP during transient

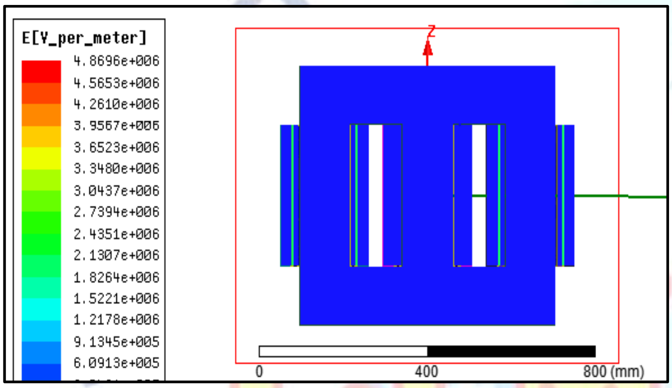


Fig.17.Eelectric field distribution of transformer with bakelised paper with the presence of air gap

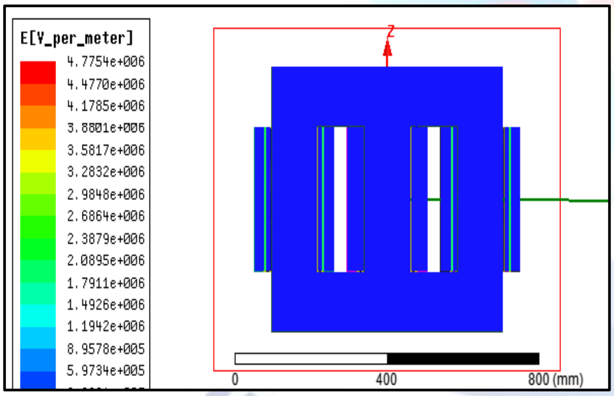


Fig.18.Eelectric field distribution of transformer with OIP with the presence of air gap

The insulating material between the primary and secondary winding is Bakelite and OIP were separately simulated and the maximum electric field produced during the lightning, switching and normal input voltage for the insulation with air gap is shown in figure 20, figure 21 and figure 22. The polyline1 is drawn across the insulation which is shown in figure 19, across which the electric field between the materials is compared.

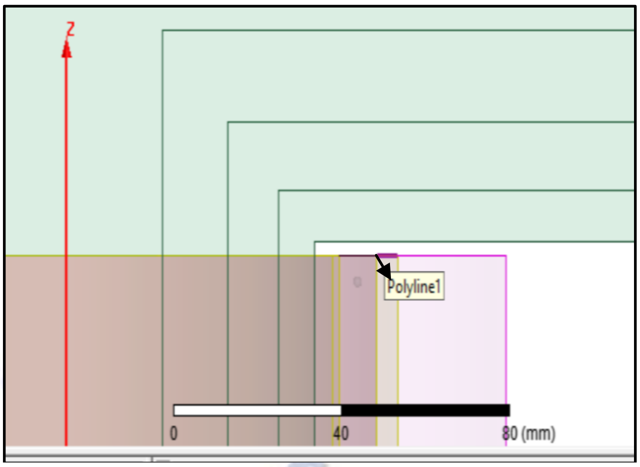


Fig.19. Polyline1 on top of insulation paper between low voltage and high voltage winding

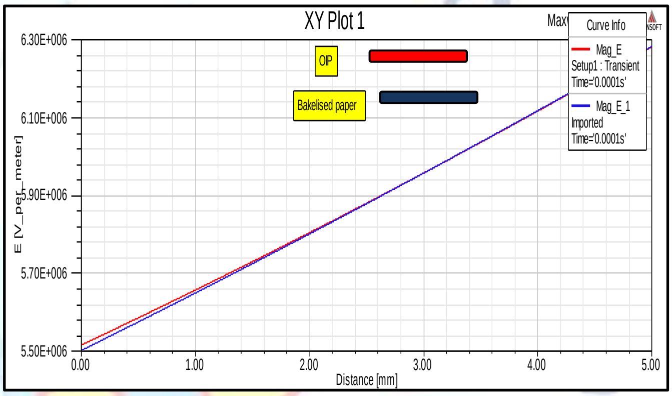


Fig.20.Maximum electric field across insulation paper during lightning for OIP and Bakelised paper

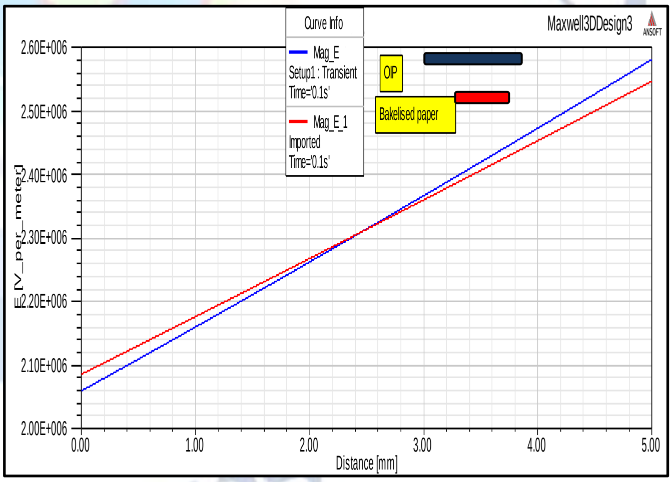


Fig.21.Maximum electric field across insulation paper during transient for OIP and Bakelised paper

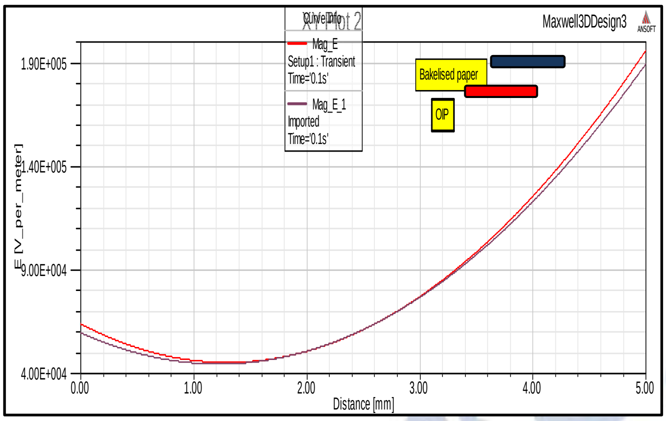


Fig.25.Maximum electric field across insulation paper with the presence of air gap for OIP and Bakelised paper

Results of input voltages are consistent with applied excitation values. Critical regions on the insulation materials between primary and secondary winding are shown. Electric field distribution on critical regions on insulation material of 3D model is shown for different conditions. The comparison of electric field distribution for Bakelised paper and OIP is also shown.

## 4. CONCLUSION

Insulation failure can cause transformer failure, which may lead to power quality problems in the power network. Thus, design and modeling of transformer and analysis of insulation failure of transformer is important in solution of such problem.

In this paper, three phase distribution transformer modeling and effect of insulation failure on the electric field distribution using ANSYS MAXWELL simulation program are proposed.

Voltage excitations were given to the designed transformer; voltage distribution and electric field distribution during these conditions are presented with simulation results. Electric field distribution on the insulation material of two-dimensional model is shown. Maximum Electric field distribution on the insulation material between primary and secondary winding is compared for Bakelite and OIP. Critical region on the transformer during these voltage excitation were shown.

This paper provides advantage for researchers and engineers for the design of transformer and for the selection of other insulation materials on a simulation program such as ANSYS. In future, optimization study for transformer oil and partial discharge localization will be done.

## Conflict of interest statement

Authors declare that they do not have any conflict of interest.

## REFERENCES


[1] J. Smajic et al., "Simulation and measurement of lightning-impulse voltage distributions over transformer windings," IEEE Transactions on Magnetics, vol. 50, no. 2, pp. 553-556, Feb. 2014, Art no. 7013604.

[2] Q. Yang, Y. Chen, W. Sima, H. Zhao, "Measurement and analysis of transient overvoltage distribution in transformer windings based on reduced-scale model", Electric Power Systems Research, vol. 140, 2016, pp. 70-77, ISSN 0378-7796.

[3] A. M. Miri, N. A. Riegel and A. Kuhner, "Finite element models for the computation of the transient potential and field distribution in the winding system of high voltage power transformers," 1999 Eleventh International Symposium on High Voltage Engineering, London, UK, 1999, pp. 39-42 vol.2.

[4] X. M. Lopez-Fernandez, C. Alvarez-Mariño, D. Couto, R. Lopes and A. Jacomo-Ramos, "Modeling and insulation design methodology in power transformer under fast transients," The XIX International Conference on Electrical Machines - ICEM 2010, Rome, 2010, pp. 1- 6.

[5] J. Smajic, R. Obrist, M. Rüegg, B. Cranganu-Cretu, C. Roy, B. Weber, E. Rahimpour, "Lightning impulse modeling and simulation of dry-type and oil immersed power- and distribution transformers", Journal of Energy, vol. 63, 2014, Special Issue, p. 235-243.

[6] M. Ostrenko and B. Andriienko, "Transformer impulse surges calculation by FEM coupled to circuit," in IEEE Transactions on Magnetics, vol. 53, no. 6, pp. 1-4, June 2017, Art no. 7401804.

[7] D. Constantin, P. Nicolae and C. Nitu, "3D Finite element analysis of a three phase power transformer," in Proc. of Eurocon 2013, Zagreb, 2013, pp. 1548-1552.

[8] C. Liao, J. Ruan, C. Liu, W. Wen and Z. Du, "3-D Coupled electromagnetic-fluid-thermal analysis of oil-immersed triangular wound core transformer," IEEE Transactions on Magnetics, vol. 50, no. 11, pp. 1-4, Nov. 2014, Art no. 8401904.

[9] A. Bakshi and S. V. Kulkarni, "Coupled electromagnetic-structural analysis of the spiraling phenomenon in a helical winding of a power transformer," IEEE Transactions on Power Delivery, vol. 29, no. 1, pp. 235-240, Feb. 2014.

[10] A. Q. Ma and Z. S. Zhang, "End insulation electric field analysis and design optimization of 500kV power transformer based on ANSYS", in Proc. of 2012 IEEE

Innov. Smart Grid Technol. - Asia, ISGT Asia, Tianjin, China, pp. 2-5, 2012.

[11] J. R. da Silva and J. P. A. Bastos, "Analysis of power transformer geometry simplifications on electromagnetic and thermodynamic simulations," IEEE Transactions on Magnetics, vol. 51, no. 3, pp. 1-4, March 2015, Art no. 8400404.

[12] P. M. Nicolae, D. Constantin and M. C. Nitu, "2D electromagnetic transient and thermal modeling of a three phase power transformer," in Proc. of 4th International Youth Conference on Energy (IYCE), Siófok, Hungary, 2013, pp. 1-5.

[13] H. R. Mirzaei, A. Akbari, E. Gockenbach, M. Zanjani and K. Miralikhani, "A novel method for ultra-high-frequency partial discharge localization in power transformers using the particle swarm optimization algorithm," IEEE Electrical Insulation Magazine, vol. 29, no. 2, pp. 26-39,