Modleing of Electric Tree Progression in the Presence of Barrier

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Abstract: Modeling of electric tree progression has been age old interest among the researchers and numerous works have been published. It is known that barriers included in the dielectric improves the breakdown voltage, breakdown time and overall performance of the dielectric. This work elaborates the tree progression under various field conditions and predicts the tree profile in the presence of barriers. Tree progression is simulated for different materials as well to study the effect of barrier materials. It is found that the barriers improve the breakdown time and could predict the nature of tree progression, which may be helpful to cable designers to have better and long life time design of cables and insulating materials.

Keywords: **Treeing, Barrier, simulation, breakdown time .**

I. INTRODUCTION

Electrical Treeing is one of the important mechanisms that cause degradation of solid insulating materials. Various models, both stochastic and deterministic ones were developed by researchers [1] to study the factors that influence tree progression. Researchers have investigated the effect of barriers [2-6] by simulating the tree structures with and without the barriers. Experimental research shows that treeing is a process that associates with partial discharge (PD) activity within the tree channels [7–9]. A PD is a complex process to model in its entirety, and attempt has been made [9] to approximate its effects in various ways and simulated the tree structures under various field conditions. The authors have made an attempt to use this model and simulated the tree progression to study the degradation of insulating materials with and without barriers.

The barrier effect was found in 1930's [10]. The barrier material would have the dielectric constant higher than the normal insulator [2]. The advantage of using the barrier is that it would increase the breakdown time, breakdown voltage, etc of the system. On introducing a barrier the breakdown voltage will depend primarily on the position of the barrier. The standard treeing process is halted by inclusion of the barrier in needle-plane electrode configuration. The treeing phenomenon is also found to be dependant of the density of the barrier. The treeing initiation and growth is reduced. Also the sample lifetime is drastically increased. The tree growth will spread along the surface of the barrier. But the final breakdown might even crack the insulator or degrade it thermally [12]. The adhesion between the barrier and the epoxy resin (bulk dielectric) also plays a major role in determining the resistance the barrier could offer to the tree growth. The internal strain introduced by the barrier into resin determines tree resistance [10].

II. SIMULATION

The presence of the barrier in between the dielectric will increase the life time of the insulator as a hole. In this modeling, above statement is proved. Also the characteristic of the breakdown is also analyzed based of changing various parameters of the insulator (especially of the barrier). The field at the needle tip is calculated using the Mason's formula.

$$E = \frac{2V}{[r\ln(1 + 4d/r)]}$$

Where,

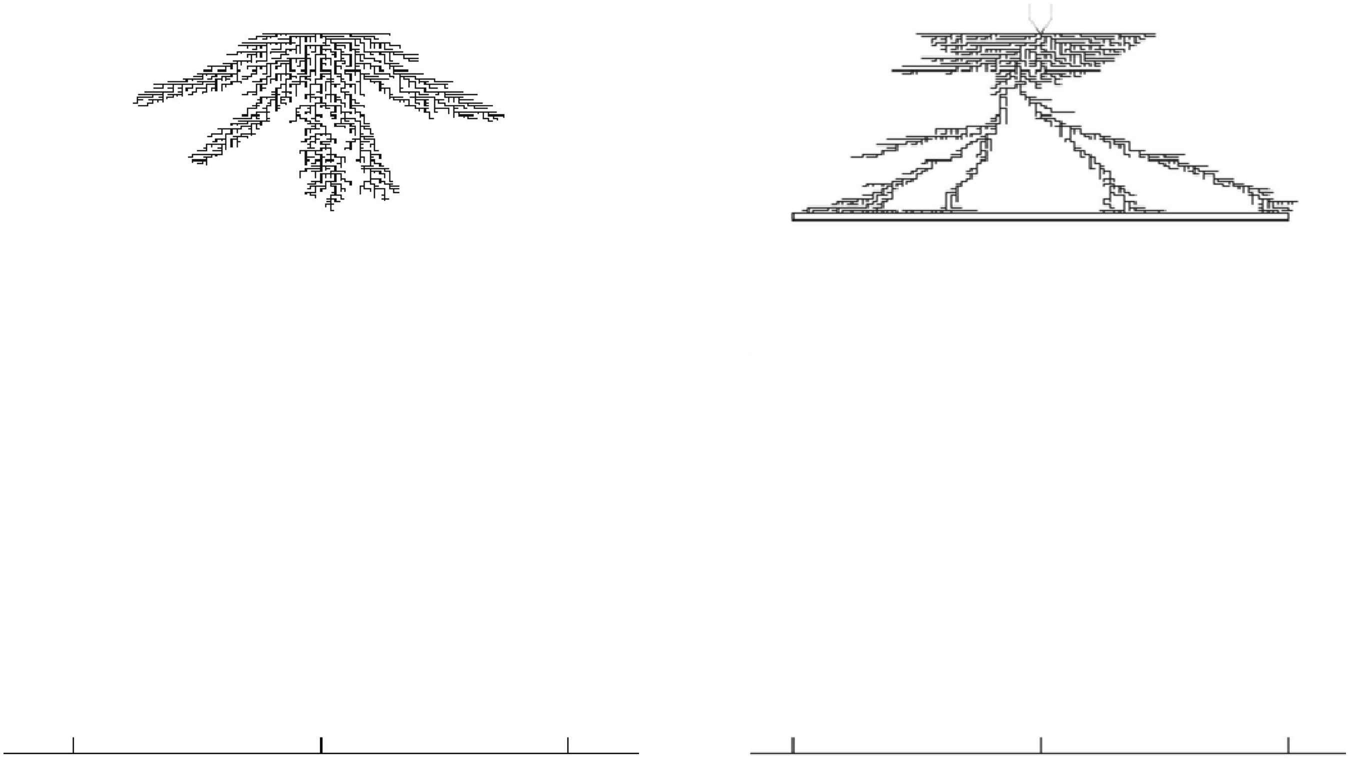
r- radius of the needle tip

d- tip-plane separation

The parameters analyzed are position of the barrier (ξ), width of the barrier, material used as barrier. ξ is the ratio of distance between the needle tip to barrier to the distance between needle tip to the ground electrode

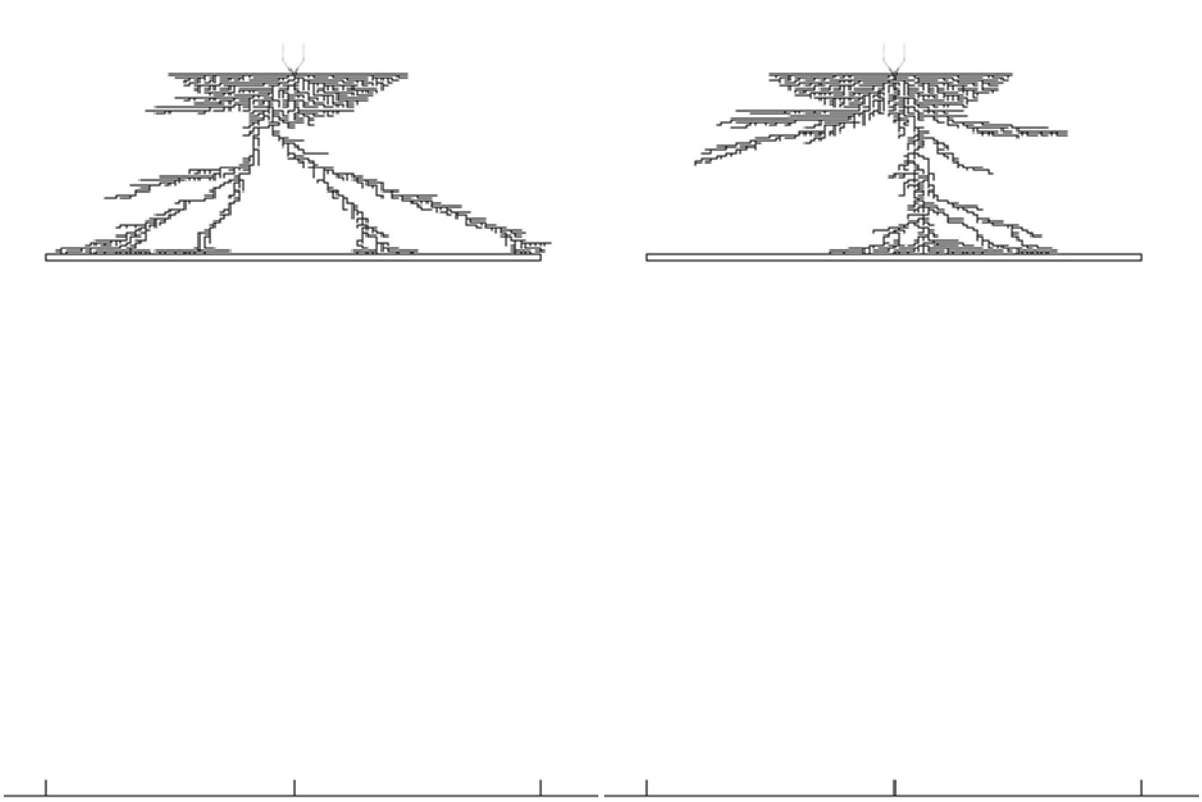
The relative permittivity of the bulk dielectric is 3.5 and the relative permittivity of the barrier is taken as 7. Figure 1 shows the simulated tree with and without barrier for $\xi = 0.25$. The very presence of barrier and also because of the high permittivity, the resistance to tree progression is obviously seen that the tree channels tend to propagate along horizontal direction. However few branches were attracted to barrier and wade along the surface. The tree spreading along the surface of the barrier is found. It is seen that the simulation without barrier has 1627 steps. The tree shape for both with and without barrier is found to be bushy near the needle tip.

. There are four categories of field available in literature. The position of the barrier is analysed for all the four field conditions. Based on the changing of field inside the insulator material, a reason for the breakdown is also given. The four types of fields are high field, moderately high field, moderately low field and low field. The values for this field are given in [11]. Tree pattern for with and without barrier at different field conditions are shown below.

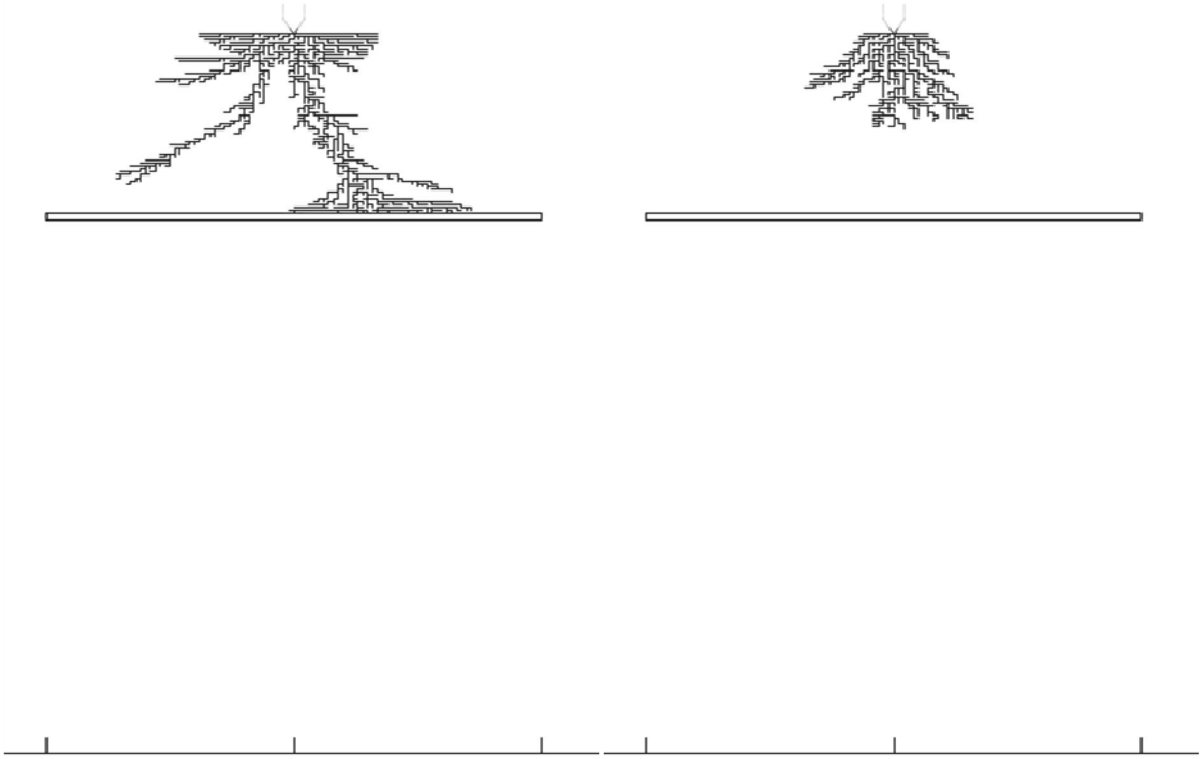


(a) Without Barrier, Steps =1627 (b) With Barrier, Steps = 1385

Fig 1. Comparing Tree progression Without and With Barrier



(a) High Field (b) Moderately High Field



(c) Moderately Low Field (d) Low Field

Fig. 2. Comparing Results at different field condition

A. Comparing Results at Different Field Conditions

Figure 2 shows the tree simulated under various field conditions. It is found that the number of steps in which the tree progression stops is reduced in high field and low field because of the field difference. This may be attributed to reduce space charge under low field and the presence of barrier as well. Though moderately high field has more number of steps compared to without barrier case, it shows the propensity to propagate horizontally. The number of steps for moderately high field case is 2544 and is bush-branch.
Moderately-low field condition in branchy type. This ran for 1423 steps. Low field condition bush type tree. Results ran for 1140 steps. The results shows that the tree could not penetrate the barrier but it spreads along the surface of the barrier. The value of ξ in this case is 0.25.

B. Comparing Different Material as Barrier

Figure 3 shows tree progression comparing different barrier material. When material with high permittivity value i.e glass used shows the tree progression time is increased (670 steps). So glass has good performance as a barrier compared to mica which took 537 steps to reach ground electrode. The barrier width is taken as 4 mm here. The value of ξ in this case is 0.5.

III. CONCLUSION

Modeled electric tree progression under different field condition proved the dependence of various boundary conditions and robustness of the model. This helped to* Study the structure of tree progression under various field conditions. *It is reiterated that barriers included in the dielectric improves the breakdown voltage, breakdown time and overall performance of the dielectric. This work elucidates the tree progression under various field conditions and predicts the tree profile in the presence of barriers. It is found that the barriers improve the breakdown time and could predict the nature of tree progression..

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a): Using glass as barrier (b): Using Mica as barrier

Fig 3 Comparing Different Material as Barrier

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