Effect of the Dielectric Inhomogeneity Factor's Range on the Electrical Tree Evolution in Solid Dielectrics

Hemza MEDOUKALI, Mossadek GUIBADJ, Boubaker ZEGNINI

Laboratoire d'Etude et Developpement des Materiaux Semi Conducteurs et Dielectriques, LEDMaScD, Amar Telidji University-Laghouat, BP 37G road of Ghardaia, Laghouat 03000, Algeria

hamzamedou@gmail.com, m.guibadj@lagh-univ.dz, b.zegnini@lagh-univ.dz

DOI: 10.15598/aeee.v14i5.1789

Abstract. *The main contribution of the presented paper is to investigate the influence of the Dielectric Inhomogeneity Factor on the electrical tree evolution in solid dielectrics using cellular automata. We have a sample of the XLPE which is located between needle-to-plane electrodes under DC voltage. The electrical tree emanates from the end of the needle in which the electric stress attains a dielectric strength of the material. At every time step, Laplace's equation is solved to calculate the potential distribution which changes according to electrical tree development. Dynamic simulations clearly demonstrate the influence of the range of the Dielectric Inhomogeneity Factor on the electrical tree growth. Simulation results confirm the published technical literature.*

Keywords

Cellular automata, cross-linked polyethylene, dielectric inhomogeneity factor, electrical tree, Laplace's equation.

1. Introduction

The Cross-linked Polyethylene (XLPE) is widely used in medium and high voltage cables due to its excellent characteristics such as high breakdown strength, low dielectric permittivity, and low dielectric loss [1] and [2].

Electrical treeing phenomenon is one of the principal reasons for failure and deterioration of the XLPE dielectric. In this area, trees initiate from the regions where the electric stress enhances due to many factors such as protrusions in the high voltage electrode, material inhomogeneity due to manufacturing defects and presence of conducting particles or gas-filled cavities. Therefore, inception and propagation of electrical tree are accompanied by the Partial Discharge (PD) activity within developing dendrites [3], [4], [5], [6] and [7]. The phenomenon of treeing is initiated by the formation of micro-channels and completed by electrical tree which deteriorates the cable.

To remind, the growth of electrical tree is a complex mechanism that took a great deal of researches and studies. In literature, many works are published to analyze and clarify this phenomenon experimentally, theoretically and by simulation. In this field, multiple studies investigated the influence of the temperature, distance between electrodes, impurities and frequency on the behavior of the electrical tree in XLPE samples using different experimental technics [2], [3], [4], [8], [9], [10], [11], [12], [13] and [14]. Other authors have analysed both initiation and propagation mechanisms of the electrical tree inside solid insulation from experiment to theory [5], [15] and [16].

Many models are proposed to explain the formation mechanism and structures of trees in solid dielectrics. The breakdown phenomenon based on the fractal dimension is analysed in [17]. A non-lattice three-dimensional model is created to simulate both electrical tree growth and Partial Discharges (PD) activity within the growing tree channels [16]. Other researchers have presented the model which termed Deterministic Discharge-Avalanche; which is deterministic in concept and associates the branching with local field fluctuations generated by the mechanism itself [18].

The propagation of the electrical tree in solid dielectrics is simulated in various cases with the aid of Cellular Automata: the presence of voids, the existence of conducting or insulating particles and the influence of spaces charges on the development of dendrites [19], [20], [21] and [22]. Unfortunately, these previous references do not discuss the effect of the Dielectric Inhomogeneity Factor's (DIF) range.

Taking advantage of this fact, this paper is focused on the effect of the DIF's range variation on the electrical tree formation inside the XLPE, which is located between needle-to-plane electrodes (see Fig. 1). The study is based on the inherent inhomogeneity of the dielectric which gives a significant fluctuation on the electric field value. Dynamical simulations (using Cellular Automata (CA)) are presented to demonstrate practical potential of the proposed approach.

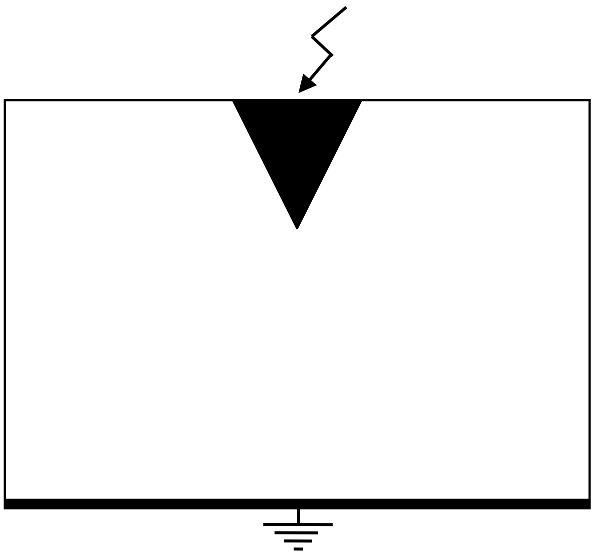


Fig. 1: The point/plane electrode arrangement, the white area corresponds to the solid dielectric and black areas correspond to the electrodes.

2. Cellular Automata

The behavior of a physical system is not determined only by macroscopic parameters. The important aspects of the microscopic laws of physics are a great challenge for anyone who tries to simulate physical system. Cellular Automata (CA) are an idealization of dynamic systems where space, time, and variables are discrete and interactions are only local [23] and [24]. CA are first introduced by John von Neumann in the late 1940s [25] and [26]. It has been used extensively to model natural phenomena and complex systems [27]. Despite the simplicity of its structure, it is able to describe the behavior of the complex physical system. Jon Conway in 1970, and Stephen Wolfram in the beginning of the 80's have developed architecture of CA, the former proposed what is called "Game of Life" and the latter studied in much detail a family of simple one-dimensional CA rules, known as: Wolfram rules [28].

More precisely, CA consists of a regular uniform n-dimensional matrix. At each site of the matrix (cell), a physical quantity takes values. This physical quantity is the global state of the CA, and the value of this quantity at each cell is the local state of this cell. Each cell is restricted only to local neighborhood interaction, and as a result, it is incapable of immediate global communication [23]. Figure 2 shows the neighborhood of the cell which is taken to be the cell itself and some or all of the immediately adjacent cells. The state of each cell is updated simultaneously at discrete time steps, based on the states in its neighborhood at the preceding time step. The algorithm which is used to compute its successor state is referred as the CA local rule. Usually, the same local rule is applied to all cells of the CA. The state of a cell at time step $(t+1)$ is affected by the states of all eight cells in its neighborhood at time step t and by its own state at time step t:

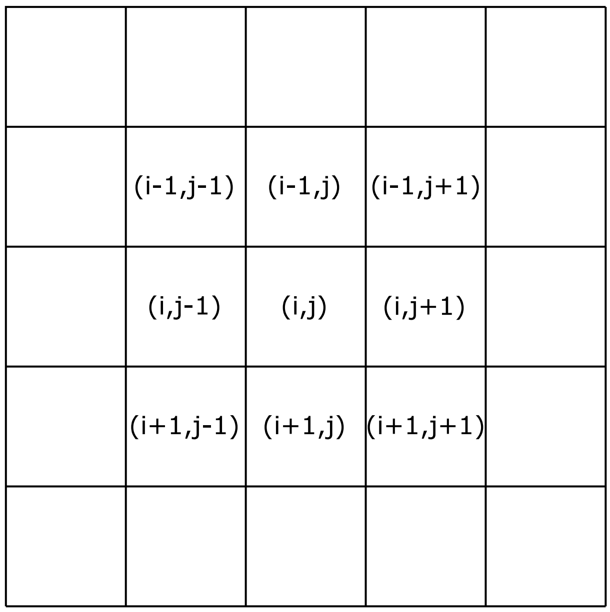


Fig. 2: The neighborhood of the (i,j) cell is formed by the (i,j) cell itself and the eight marked cells.

The CA local rule is given by:

$$S_{i,j}^{t+1} = F\begin{pmatrix} S_{i-1,j-1}^{t}, S_{i-1,j}^{t}, S_{i-1,j+1}^{t}, \\ S_{i,j-1}^{t}, S_{i,j}^{t}, S_{i,j+1}^{t}, \\ S_{i+1,j-1}^{t}, S_{i+1,j}^{t}, S_{i+1,j+1}^{t} \end{pmatrix}, \quad (1)$$

where $S_{i,j}^{t+1}$ and $S_{i,j}^{t}$ are the states of the (i,j) cell at time steps $(t+1)$ and t, respectively.

3. Simulation

Laplace's equation Eq. (2) is solved to calculate the potential distribution inside dielectric at every time step by Partial Differential Equation (PDE) Toolbox of Matlab:

$$\nabla^2 V = 0. \tag{2}$$

For the correct calculation of the potential distribution (see Fig. 3), the definition of the appropriate boundary conditions is crucial:

- Dirichlet boundary conditions at the interface between the needle electrode and XLPE, plane electrode and XLPE are expressed as follow:

$$h \cdot V = r, \tag{3}$$

  where V is the electrostatic potential value, h is the weight factor equation (normally $h = 1$) and r is the applied potential (at the needle $r = 80$ kV, at plane $r = 0$).

- Neumann boundary conditions between the dielectric sample and surrounding air are formulated as follow:

$$\vec{n} \cdot \varepsilon \cdot \vec{\nabla} V + q \cdot V = g, \tag{4}$$

  where $\vec{n}$ is the outward unit normal, q is the charge ($q = 0$), V is the electrostatic potential value, g is the surface charge ($g = 0$) and ε is the relative permittivity of the medium, for XLPE $\varepsilon = 2.3$.

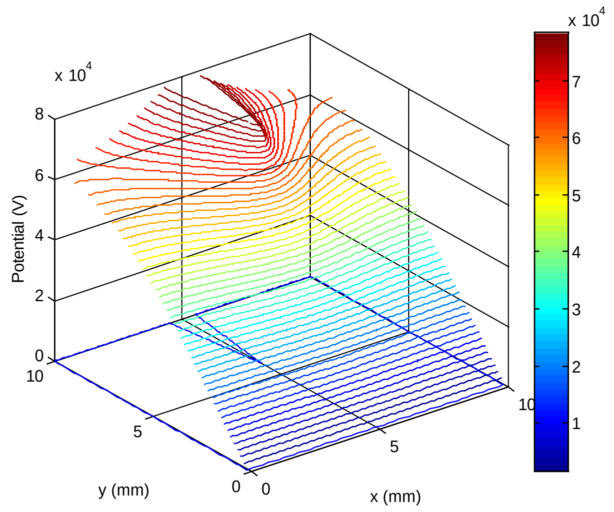


Fig. 3: Potential distribution at the needle-plane geometry; the applied voltage is $V_{ap} = 80$ kV at time step $t = 0$.

The potential values obtained from PDE Toolbox of Matlab are classified with the aid of a Matlab algorithm in a matrix of (100 × 100) cells in every time step.

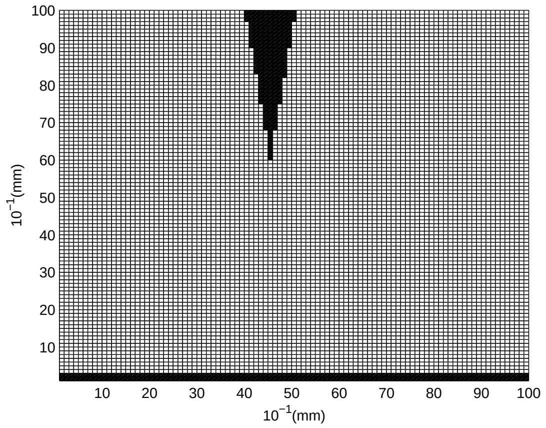


Fig. 4: CA representation of an XLPE dielectric with a needle-plane electrode arrangement.

The physical system with needle-plane electrodes is divided into a matrix of identical square cells (100 × 100), in which every cell has dimensions (0.1 × 0.1) mm. Thus, dimensions of XLPE sample are (10 × 10) mm (see Fig. 4). In this model, the internal state of each cell is defined by two parameters: the potential value V and the value of dielectric inhomogeneity factor g_{dif} which is generated randomly between two values.

Before simulation, the value of the electric stress $E_{\max}$ at the end of the needle tip is assumed by the formula [29]:

$$E_{\max} = \frac{2V}{r(\ln(1 + \frac{4s}{r}))}, \tag{5}$$

where V is the applied voltage, s is the electrode gap distance, and r is the radius of the needle tip.

If the Emax attains a dielectric strength $E_c = 40$ kV·mm^{-1} [29], the electrical tree initiates from the end of the needle electrode because the value of the electric stress is transferred into this latter [30] and [31], and consequently the state of the cell at the end of the needle tip at time step $t + 1$ is 1.

The common local rule (see Tab. 1) which is applied at every time step to all cells to simulate electrical tree evolution is:

Tab. 1: Local rule applied to simulate electrical tree evolution.

<table>
<tr><td rowspan="2"></td><th colspan="2">Time step</th><th rowspan="2">Conditions</th></tr>
<tr><th>t</th><th>t + 1</th></tr>
<tr><td rowspan="3">State of the (i, j) cell</td><td>1</td><td>1</td><td>/</td></tr>
<tr><td>0</td><td>0</td><td>None of its neighbor's state is 1.</td></tr>
<tr><td>0</td><td>1</td><td>One or more of its neighbor's state are 1 and $E/E_c > 1$.</td></tr>
</table>

The potential distribution gained from solving Laplace's equation with PDE of Matlab at every step

Tab. 2: Parameters of three simulations for the electrical tree evolution.

	Simulation 1.	Simulation 2.	Simulation 3.
Matrix dimensions	100×100	100×100	100×100
Cell dimensions (mm)	0.1×0.1	0.1×0.1	0.1×0.1
XLPE permittivity ϵ	2.3	2.3	2.3
Local dielectric strength ($\mathrm{kV \cdot mm^{-1}}$)	40	40	40
Applied voltage (kV)	80	80	80
DIF's range (g_{dif})	0.95–1.04	0.95–1	0.97–1

is used to calculate electric field E between every cell of the electrical tree and the eight surrounding cells by the following equation [14] and [32]:

$$E \rightarrow g_{dif} \frac{\Delta V}{\Delta x}, \tag{6}$$

where g_{dif} is the dielectric inhomogeneity factor of a cell (it is generated randomly), ΔV is the potential difference between the two neighboring cells (horizontal, vertical or diagonal) and Δx is the distance between centers of cells.

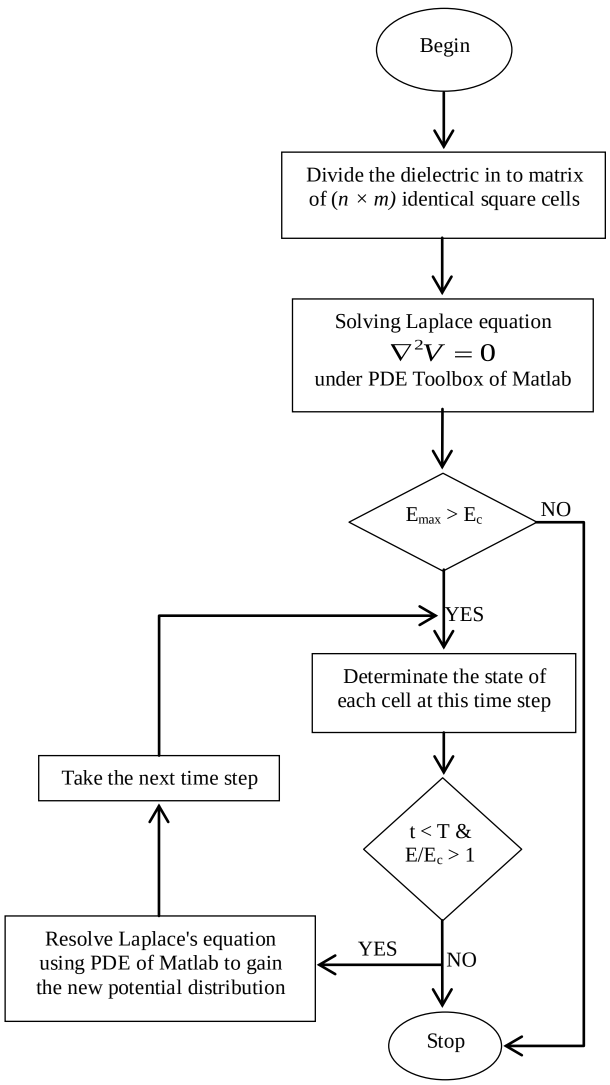


Fig. 5: Flow-chart of the dynamical simulation.

The algorithm checks in every step cells that can belong to an electrical tree by applying cellular automata rule (see Fig. 2). If the tree progresses, then its structure will change, which means new boundaries conditions are applied in the next step, and Laplace's equation is solved again to gain the new potential distribution.

The tree stops growing if:

- The electric field is less than local dielectric strength $E/E_c < 1$.
- The dendrites reach the plane electrode.

In this paper, three simulations are presented to display the influence of the Dielectric Inhomogeneity Factor's range on the tree propagation. In each case, the range variation of the g_{dif} is chosen.

Details of three simulations are included in the Tab. 2.

All stages of each simulation are summarized in the following flow-chart (see Fig. 5).

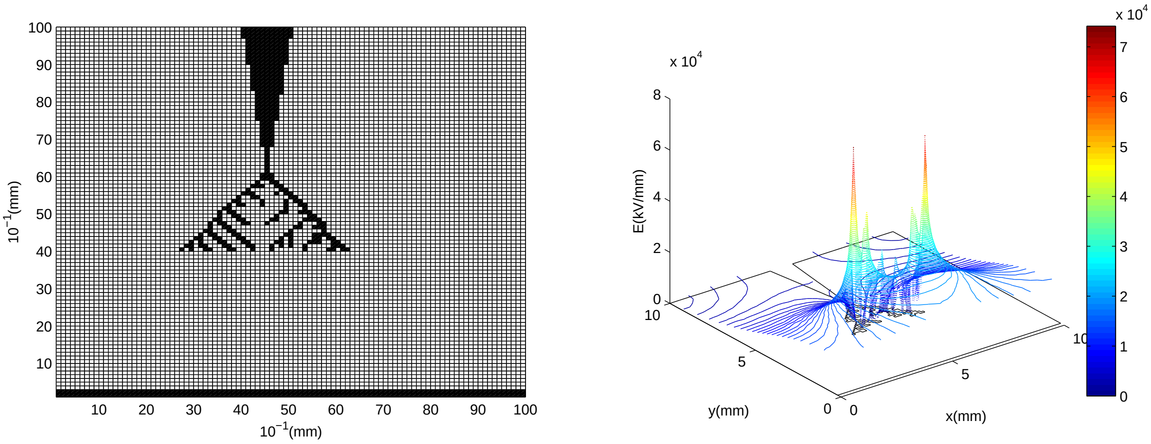
4. Results and Discussion

The effect of the DIF's range on the electrical tree evolution in XLPE is simulated in three different cases as shown in Fig. 6, Fig. 7 and Fig. 8. The applied voltage at the needle was taken to be equal to 80 kV and the distance between electrodes was chosen to be 6 mm.

The electrical tree initiates from the needle tip and advances toward the plane electrode. In every time step, the Laplace's equation is solved to calculate a new distribution of the potential due to the propagation of branches which means a change in boundary conditions.

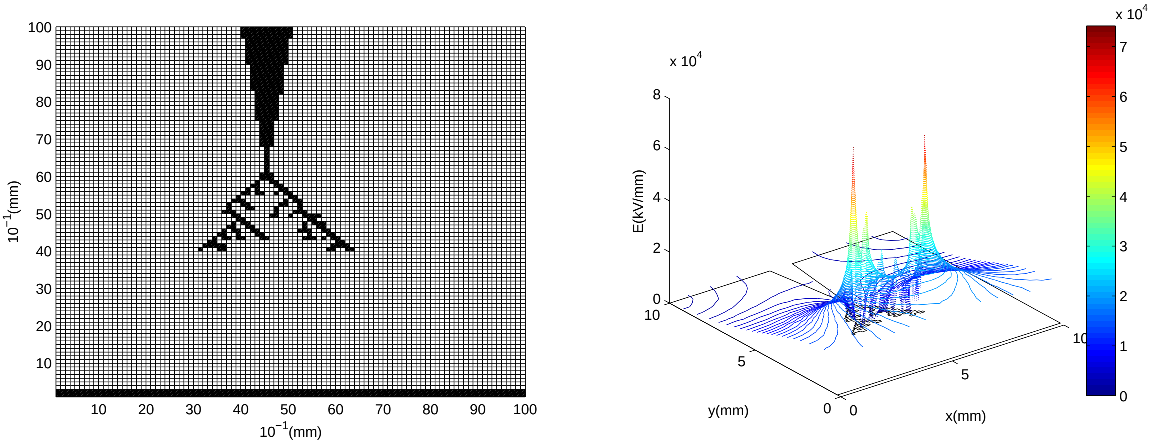
All simulations are identical regarding the sample of dielectric XLPE, the geometry, and the same applied voltage. However, the difference is only in the DIF's range variation which is randomly generated. In the case of Fig. 6 the g_{dif} is varied between 0.95–1.04, but in both cases Fig. 7 and Fig. 8; g_{dif} is varied between 0.95–1 and 0.97–1 respectively.

In these three cases, first, the tree emanates from the point electrode where the electric stress is higher



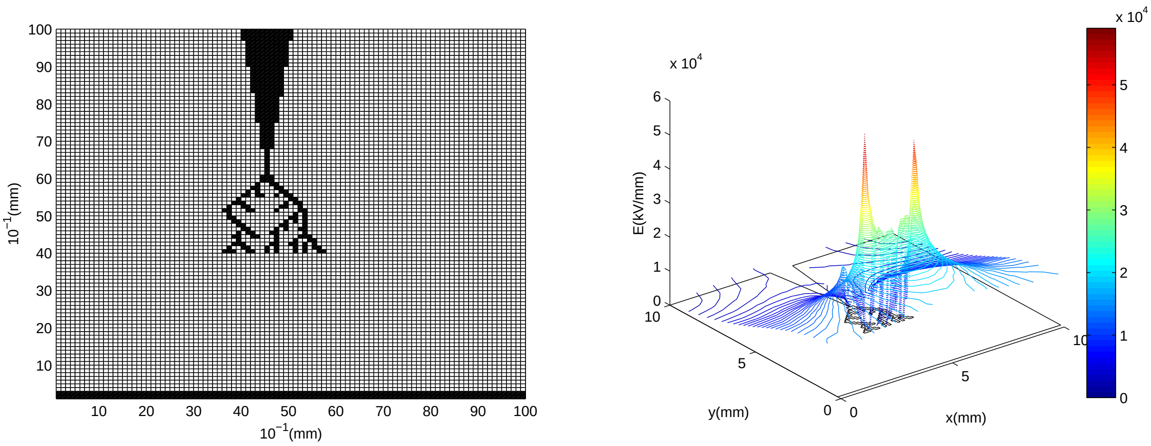
(a) Electrical tree formation in XLPE with CA. (b) Electric field curves distribution.

Fig. 6: Simulation results at $t = 20$ steps and the range of g varied between 0.95–1.04.



(a) Electrical tree formation in XLPE with CA. (b) Electric field curves distribution.

Fig. 7: Simulation results at $t = 20$ steps and the range of g varied between 0.95–1.



(a) Electrical tree formation in XLPE with CA. (b) Electric field curves distribution.

Fig. 8: Simulation results at $t = 20$ steps and the range of g vary between 0.97–1.

than the dielectric strength of the XLPE ($E_{\max} > E_c$). Then, dendrites start advancing toward the plane electrode by activities of discharges within the gas-filled channels following the paths where the homogeneity of XLPE is the weakest. The tree channels consist as conducting material, (i.e. they played the same role of the point electrode), so the potential value at every tree cell is considered to be equal to the value of the potential applied at the end of the needle tip.

In the first case (see Fig. 6), the electrical tree is more extensive. Also, it contains a significant number of branches, due to weak chemical bonds i.e. electric field is strong in numerous cells which means that the dielectric is less crosslinking since its smaller degree of homogeneity.

In contrast, the tree in the case of (Fig. 8) is narrow due to the strong chemical bonds since the range of the variation of the dielectric inhomogeneity factor is too small. Therefore, many structures of tree are formed, Cascade-tree is formed in both cases of (see Fig. 6) and (see Fig. 7) [8], but the tree's shape (see Fig. 8) is branch-tree [3].

Finally, it is clear that the range of the DIF, i.e. the homogeneity of the dielectric material is crucial factor for electrical tree behavior. The results of this simulation are similar to results published in literature [33].

5. Conclusion

The presented contribution consists of a confirmation that the range variation of the Dielectric Inhomogeneity Factor has a pronounced effect on the process of the electrical tree growth in XLPE dielectric. Furthermore, the current study demonstrated that:

- When the range variation of the DIF is very tight, the electrical tree becomes narrow and consists of a minimum number dendrites and vice-versa.
- For the reliable solid dielectric, a tree is produced with only one dendrite that advances perpendicularly toward the plane electrode.
- The range variation of DIF is almost constant for ideal solid dielectric.

References

[1] POLANSKY, R. Thermal Analyses of Cross-Linked Polyethylene. *Advances in Electrical and Electronic Engineering.* 2007, vol. 6, no. 3, pp. 121–126. ISSN 1336-1376.

[2] BAO, M., X. YIN and J. HE. Analysis of electrical tree propagation in XLPE power cable insulation. *Physica B: Condensed Matter.* 2011, vol. 406, no. 8, pp. 1556–1560. ISSN 0921-4526. DOI: 10.1016/j.physb.2011.01.069.

[3] CHEN, X., Y. XU, X. CAO and S. M. GUBANSKI. Electrical treeing behavior at high temperature in XLPE cable insulation samples. *IEEE Transactions on Dielectrics and Electrical Insulation.* 2015, vol. 22, iss. 5, pp. 2841–2851. ISSN 1070-9878. DOI: 10.1109/TDEI.2015.004784.

[4] NOBREGA, A. M., M. MARTINEZ and A. A. DE QUEIROZ. Investigation and analysis of electrical aging of XLPE insulation for medium voltage covered conductors manufactured in Brazil. *IEEE Transactions on Dielectrics and Electrical Insulation.* 2013, vol. 20, iss. 2, pp. 628–640. ISSN 1070-9878. DOI: 10.1109/TDEI.2013.6508767.

[5] DISSADO, L. A. Understanding electrical trees in solids: from experiment to theory. IEEE *Transactions on Dielectrics and Electrical Insulation.* 2002, vol. 9, iss. 4, pp. 483–497. ISSN 1070-9878. DOI: 10.1109/TDEI.2002.1024425.

[6] EL-ZEIN, A., M. TALAAT and M. M. EL BAHY. A numerical model of electrical tree growth in solid insulation. *IEEE Transactions on Dielectrics and Electrical Insulation.* 2009, vol. 16, iss. 6, pp. 1724–1734. ISSN 1070-9878. DOI: 10.1109/TDEI.2009.5361596.

[7] IDDRISSU, I. and S. M. ROWLAND. The impact of DC bias on electrical tree growth characteristics in epoxy resin samples. In: *IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP).* Ann Arbor: IEEE, 2015, pp. 876–879. ISBN 978-1-4673-7496-5. DOI: 10.1109/CEIDP.2015.7352082.

[8] DISSADO, L. A., S. J. DODD, J. V. CHAMPION, P. I. WILLIAMS and J. M. ALISION. Propagation of electrical tree structures in solid polymeric insulation. *IEEE Transactions on Dielectrics and Electrical Insulation.* 1997, vol. 4, iss. 3, pp. 259–279. ISSN 1070-9878. DOI: 10.1109/94.689435.

[9] SARATHI, R. and P. G. RAJU. Diagnostic study of electrical treeing in underground XLPE cables using acoustic emission technique. *Polymer testing.* 2004, vol. 23, iss. 8, pp. 863–869. ISSN 0142-9418. DOI: 10.1016/j.polymertesting.2004.05.007.

[10] SARATHI, R. and P. G. RAJU. Study of electrical treeing phenomena in XLPE cable samples using acoustic techniques. *Electric power systems research.* 2005, vol. 73, iss. 2, pp. 159–168. ISSN 0378-7796. DOI: 10.1016/j.epsr.2004.07.003.

[11] CHO, Y.-S., M.-J. SHIM and S.-W. KIM. Electrical tree initiation mechanism of artificial defects filled XLPE. *Materials chemistry and physics.* 1998, vol. 56, iss. 1, pp. 87–90. ISSN 0254-0584. DOI: 10.1016/S0254-0584(98)00160-6.

[12] SARATHI, R., A. NANDINI and M. DANIKAS. Understanding Electrical Treeing Phenomena in XLPE Cable Insulation Adopting UHF Technique. *Journal of Electrical Engineering.* 2011, vol. 62, iss. 2, pp. 73–79. ISSN 1335-3632. DOI: 10.2478/v10187-011-0012-4.

[13] SHIMIZU, N. and C. LAURENT. Electrical tree initiation. *IEEE Transactions on Dielectrics and Electrical Insulation.* 1998, vol. 5, iss. 5, pp. 651–659. ISSN 1070-9878. DOI: 10.1109/94.729688.

[14] DANIKAS, M. G., I. KARAFYLLIDIS, A. THANAILAKIS and A. M. BRUNING. Simulation of electrical tree growth in solid dielectrics containing voids of arbitrary shape. *Modelling and Simulation in Materials Science and Engineering.* 1996, vol. 4, iss. 6, pp. 535–552. ISSN 0965-0393. DOI: 10.1088/0965-0393/4/6/001.

[15] SCHURCH, R., S. M. ROWLAND, R. S. BRADLEY and P. J. WITHERS. Imaging and analysis techniques for electrical trees using X-ray computed tomography. *IEEE Transactions on Dielectrics and Electrical Insulation.* 2014, vol. 21, iss. 1, pp. 53–63. ISSN 1070-9878. DOI: 10.1109/TDEI.2013.003911.

[16] NOSKOV, M. D., A. S. MALINOVSKI, M. SACK and J. SCHWAB. Self-consistent modeling of electrical tree propagation and PD activity. *IEEE Transactions on Dielectrics and Electrical Insulation.* 2000, vol. 7, iss. 6, pp. 725–733. ISSN 1070-9878. DOI: 10.1109/94.891982.

[17] NIEMEYER, L., L. PIETRONERO and H. J. WIESMANN. Fractal dimension of dielectric breakdown. *Physical Review Letters.* 1984, vol. 52, no. 12, pp. 1033–1036. ISSN 1079–7114. DOI: 10.1103/PhysRevLett.52.1033.

[18] DISSADO, L. A., J. C. FOTHERGILL, N. WISE and J. COOPER. A deterministic model for branched structures in the electrical breakdown of solid polymeric dielectrics. *Journal of Physics D: Applied Physics.* 2000, vol. 33, no. 19, pp. L109–L112. ISSN 0022-3727. DOI: 10.1088/0022-3727/33/19/103.

[19] VARDAKIS, G. and M. DANIKAS. Simulation of tree propagation in polyethylene including air void by using cellular automata: The effect of space charges. *Electrical Engineering.* 2002, vol. 84, no. 4, pp. 211–216. ISSN 1432-0487. DOI: 10.1007/s00202-002-0123-9.

[20] VARDAKIS, G. E. and M. G. DANIKAS. Simulation of electrical tree propagation using cellular automata: the case of conducting particle included in a dielectric in point-plane electrode arrangement. *Journal of electrostatics.* 2005, vol. 63, no. 2, pp. 129–142. ISSN 0304-3886. DOI: 10.1016/j.elstat.2004.06.008.

[21] VARDAKIS, G. E. and M. G. DANIKAS. Simulation of electrical tree propagation in a solid insulating material containing spherical insulating particle of a different permittivity with the aid of cellular automata. *Facta universitatis-series: Electronics and Energetics.* 2004, vol. 17, no. 3, pp. 377–389. ISSN 0353-3670. DOI: 10.2298/FUEE0403377V.

[22] VARDAKIS, G. E., M. G. DANIKAS and I. KARAFYLLIDIS. Simulation of space-charge effects in electrical tree propagation using cellular automata. *Materials Letters.* 2002, vol. 56, no. 4, pp. 404–409. ISSN 0167-577X. DOI: 10.1016/S0167-577X(02)00512-8.

[23] VICHNIAC, G. Y. Simulating physics with cellular automata. *Physica D: Nonlinear Phenomena.* 1984, vol. 10, no. 1, pp. 96–116. ISSN 0167-2789. DOI: 10.1016/0167-2789(84)90253-7.

[24] CHOPARD, B. and M. DROZ. *Cellular automata modeling of physical systems.* 1st ed. Cambridge: Cambridge University Press, 2012. ISBN 978-0-521-67345-7.

[25] VON NEUMANN, J. and A. W. BURKS. *Theory of self-reproducing automata.* 1st ed. Illinois: Illinois University Press, 1966.

[26] KARI, J. Theory of cellular automata: A survey. *Theoretical computer science.* 2005, vol. 334, iss. 1–3, pp. 3–33. ISSN 0304-3975. DOI: 10.1016/j.tcs.2004.11.021.

[27] WOLFRAM, S. *Cellular automata and complexity: collected papers.* 1st ed. Reading: Addison-Wesley, 1994. ISBN 0-201-62664-0.

[28] ATHANASSOPOULOS, S., C. KAKLAMANIS, G. KALFOUTZOS and E. PAPAIOANNOU. Cellular Automata: Simulations Using Matlab. In: *The Sixth International Conference on Digital Society.* Valencia: ICDS, 2012, pp. 63–68. ISBN 978-1-61208-176-2.

[29] MASON, J. H. Breakdown of solid dielectrics in divergent fields. *Proceedings of the IEE-Part C: Monographs.* 1955, vol. 102, no. 2, pp. 254–263. ISSN 0369-8904. DOI: 10.1049/pi-c.1955.0030.

[30] MASON, J. H. The deterioration and breakdown of dielectrics resulting from internal discharges.

Proceedings of the IEE-Part I: General. 1951, vol. 98, no. 109, pp. 44–59. ISSN 2054-0620. DOI: 10.1049/pi-1.1951.0019.

[31] ATTEN, P. and A. SAKER. Streamer propagation over a liquid/solid interface. *IEEE Transactions on Electrical Insulation.* 1993, vol. 28, no. 2, pp. 230–242. ISSN 0018-9367. DOI: 10.1109/14.212248.

[32] KREUGER, F. H. *Industrial high DC voltage: 1. fields, 2. breakdowns, 3. tests.* 1st ed. Delft: Delft University Press, 1995. ISBN 90-407-1110-0.

[33] DISSADO, L. A. and P. J. J. SWEENEY. Physical model for breakdown structures in solid dielectrics. *Physical Review B.* 1993, vol. 48, no. 22, pp. 16261–16268. ISSN 0163-1829. DOI: 10.1103/PhysRevB.48.16261.

About Authors

Hemza MEDOUKALI was born on 24.06.1988 in Algeria. He received his M.Sc. from the Universite de Constantine1 Algeria, in 2011. Since then, He prepares a Ph.D. thesis at the Dielectric materials Laboratory LeDMaScD in the Department of Electrical Engineering at the University Amar Telidji of Laghouat-Algeria. His research interests include: numerical modeling and simulation, high voltage, ageing of dielectric materials.

Mossadek GUIBADJ received his Engineer degree from Czech Technical University in Prague. In 2001, he received, the M.Sc. degree from Universite Ammar Telidji Laghouat- Algeria. He received his Ph.D. degree from Ecole Nationale Polytechnique (ENP) Algeria in 2009. Currently, he is professor and is head of research team in the Dielectric materials Laboratory LeDMaScD in the Department of Electrical Engineering at the University Amar Telidji of Laghouat, in Algeria. His research interests include numerical modeling and simulation, high voltage, partial discharges, dielectric materials.

Boubakeur ZEGNINI was born on 25.01.1968. He received the applied electrical engineering degree from the Ecole Normale d'Enseignement Technique ENSET Laghouat Algeria, in1991, the M.Sc. degree from the institute of Electrical Engineering, Center University of Laghouat in 2001. He received his Ph.D. degree in the field of Dielectric Materials from Universite des sciences et de la technologie USTO Oran Algeria in 2007, from 1991 to 2001 he was professor of technical secondary school. Since 2001 he is working as associate professor with the Department of Electrical Engineering at Amar Telidji University of Laghouat, Algeria. He joined the Laboratory of Electrical Engineering at Paul Sabatier University of Toulouse, France, "solid dielectrics and reliability" research team from 2005 to 2007. Currently, he is head of research team in the Dielectric materials Laboratory LeDMaScD in the Department of Electrical Engineering at the University Amar Telidji of Laghouat, in Algeria. Following this, he became a Full Professor at University Amar Telidji of Laghouat-Algeria, in 2012. His main research interests include high voltage, dielectric materials, outdoor insulation, numerical modeling and simulation. He is author and co-authors of many scientific publications.