

Original Article: Evaluation of Scattered and Random Magnetic Fields by Considering the Radius Caused by Charging

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ABSTRACT

When the conductor voltage at the transmission line rises from a specific threshold called the corona threshold voltage, the conductor moves to the corona and increases the leakage and charging current around the conductor. In this paper, different ways of corona effect on the transmitted pulses on the transmission line and the equations of the transmission line with the presence of corona are evaluated. Further, by evaluating the emission of lightning pulses along the transmission line in the form of numerical analysis on the radius caused by charging, an attempt has been made to provide an accurate calculation. Therefore, one of the key points raised in this paper is the effect of transmission line equations and the effects of the desired magnetic field.

Introduction

When the voltage in the conductor in a high voltage transmission line passes through a special threshold called the shock wave voltage threshold, one can divide the shock wave voltage threshold by the electrical characteristic impedance, a shock

threshold current threshold, the minimum current required in the conductor for defined the creation of the impact crown [1-3]. From the transmission line, the desired high voltage goes to the impact crown and causes current and load leakage from the conductor to the surrounding environment. Evaluating how the electromagnetic transient current signature or voltage changes during propagation along an

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overhead transmission line in the presence of an impact corona is an old problem in power transmission and distribution [4-6]. The traditional method of solving this problem is to assume that the impact corona eventually increases to a dynamic increase in the capacity of the high voltage transmission line [7-9]. In this paper, by examining the equations of the high voltage transmission line in the presence of an impact corona, we will analyze various methods in which the effects of an impact corona on the pulse emission have been very evident. We will show that the effects of the impact crown on pulse propagation can be described in a number of ways through mathematical numerical analysis, all of which lead to an important result. The results of this study are then applied to the study of reversal stroke, the conduit as a high voltage transmission line, with special attention to the return speed and the various concepts used in the construction of ideal engineering models of thunder return [10-13].

In this paper, the effects of an impact corona on voltage pulses or currents emitted along a high voltage transmission line can also be evaluated by providing a time-varying capacity and a conductivity to the transmission line. If the capacitor of the time variable is assumed to be proportional to the ratio between the load of the impact crown and the applied voltage, one needs to do this

and guide the time variable to show the effects of the impact crown more accurately. Reverse stroke analysis as one of the most important current pulses along a high voltage transmission line under the impact corona, suggests that corona effects may be due to the fact that the measured return stroke velocity is significantly lower than the speed of light. Also, based on the results of impact crown effects, the physical justification of the concepts used in the current type of reversible stroke models is properly presented [13-16].

Transmission line equations considering corona effects

Transmission line equations by considering the corona and the effects of the external magnetic field to evaluate the transient current and voltage that usually appear at the input of sensitive electrical equipment. In Figure (1) the air conductor is located along the x-axis and the height h. The conductor radius is ra. In the ground z < 0 area, it is assumed that the conduction is good. Area z > 0 includes air. E (x, y, z, t) is the total electric field and B (x, y, z, t) is the magnetic flux density at the transmission line. Faraday's law is applied to the part designation as a dotted line in figure (2). On the left side of the equation, the line integral is taken from the electric field, and on the right side of the equation, the magnitude of the magnetic flux changes is calculated.

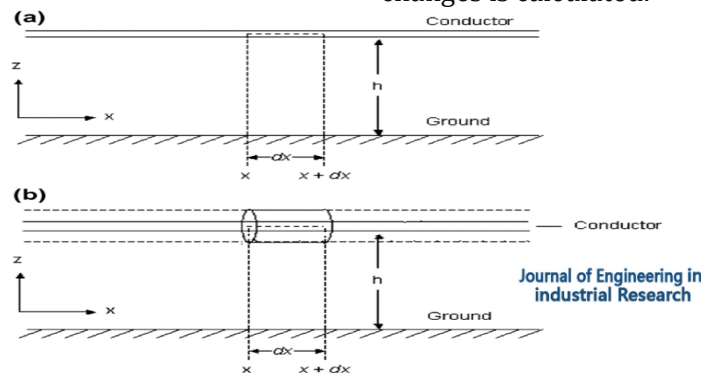


Figure 1. (a) The shape of the transmission line in the absence of a corona (b) derive the equation of the transmission line

$$\oint E \cdot dl = - \frac{\partial}{\partial t} \int_s B \cdot dS$$

$$\int_0^h [E_z(t, x + dx, z) - E_z(t, x, z)].dz$$

$$\int_x^{x+dx} E_x(t, x, h)dx + \frac{\partial}{\partial t} \int_x^{x+dx} dx \int_0^h B_y(t, x, z)dz$$

In this inference $E_x(t, x, 0)$ is considered zero. By dividing the two sides of the equation by dx and taking the limit that dx is zero, we have:

(3)

$$\frac{\partial}{\partial x} \int_0^h E_x(t, x, z) dz - E_x(t, x, h) = -\frac{\partial}{\partial t} \int_0^h B_y(t, x, z) dz$$

The total magnetic field adjacent to the line consists of the sum of the scattered magnetic field and the random magnetic field. S represents a scattered magnetic field and i represents a random magnetic field.

$$(4) \quad E_z = E_z^s + E_z^i$$

$$(5) \quad E_x = E_x^s + E_x^i$$

$$(6) \quad B_y = B_y^s + B_y^i$$

(7)

$$\left[\frac{\partial}{\partial x} \int_0^h E_z^s(t, x, z) dz - \frac{\partial}{\partial t} \int_0^h B_y^s(t, x, z) dz - E_x(t, x, h) \right]$$

$$= \left[-\frac{\partial}{\partial x} \int_0^h E_z^i(t, x, z) dz + \frac{\partial}{\partial t} \int_0^h B_y^i(t, x, z) dz \right]$$

To obtain the distributed voltage with integral from the surface yz , we have:

$$(8) \quad V^s(t, x) = -\int_0^h E_z^s(t, x, z) dz$$

$$(9) \quad \int_0^h B_z^s(t, x, z) dz = L.I(x)$$

By substituting (8) and (9) in (7) we have:

(10)

$$\begin{aligned} \frac{\partial V^s(t, x)}{\partial x} + L \frac{\partial I(t, x)}{\partial t} + E_x(t, x, h) \\ = \frac{\partial}{\partial x} \int_0^h E_z^i(t, x, z) dz - \frac{\partial}{\partial t} \int_0^h B_y^i(t, x, z) dz \end{aligned}$$

In order to simplify (10) Faraday law was applied to the components of the random field and we have:

(11)

$$\frac{\partial}{\partial x} \int_0^h E_z^i(t, x, z) dz - \frac{\partial}{\partial t} \int_0^h B_y^i(t, x, z) dz = E_x^i(t, x, h)$$

With this calculation, the equation of the first transmission line is obtained:

(12)

$$\frac{\partial V^s(t, x)}{\partial x} + L \frac{\partial I(t, x)}{\partial t} + R.I(t, x) = E_x^i(t, x, h)$$

To derive the equation of the second transmission line, Curl Maxwell must first be considered. The values of the vectors H , J , and D are the magnetic field, current density, and electric flux density, respectively.

$$(13) \quad \nabla \times H = J + \frac{\partial D}{\partial t}$$

$$(14) \quad \nabla \cdot (J + \frac{\partial D}{\partial t}) = 0$$

The conductor element is located between x and $x + dx$. The corona increases in this part and it is assumed that during time t , the radius of the corona is $R_c(t, x)$.

$$(15) \quad \int_s J \cdot ds = \frac{\partial}{\partial t} \int_s D \cdot ds$$

The equation on the left is divided into two parts, one for the end of the cylindrical element and the other for the surface. And from the left of equation (15) we can conclude (18):

$$(16) \quad \int_{end} J \cdot ds = I(t, x + dx) - I(t, x)$$

$$(17) \quad \int_{surface} J \cdot ds = 0$$

$$(18) \quad \frac{\partial}{\partial t} \int_s D \cdot ds = \frac{\partial Q(t, x)}{\partial t} dx$$

And the total electric charge on the transmission line is given below. C is the capacitance of the line. And for each value of V_s , $q_a(t, x)$ is defined.

$$(19) \quad q_a(t, x) = C.V^s(t, x)$$

$$(20) \quad Q(t, x) = q_c(t, x) + q_a(t, x)$$

(21)

$$I(t, x + dx) - I(t, x) = -C \frac{\partial V^s(t, x)}{\partial t} dx - \frac{\partial q_c(t, x)}{\partial t} dx$$

In the boundary conditions of the end of the line with impedances Z1 and Z2 with ε1 and ε2 we have:

$$(22)$$

$$V^s(t, \xi_1) = -Z_1 \cdot I(t, \xi_1) + \int_0^h E_z^i(t, \xi_1, z) \cdot dz$$

$$(23)$$

$$V^s(t, \xi_2) = -Z_2 \cdot I(t, \xi_2) + \int_0^h E_z^i(t, \xi_2, z) \cdot dz$$

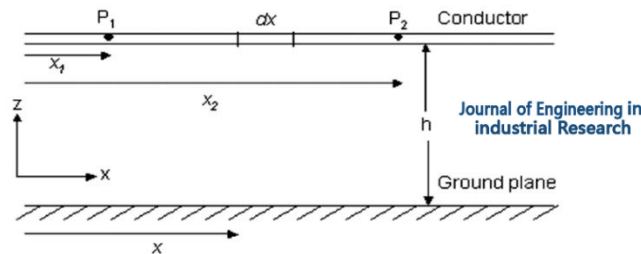


Figure 2. Locations of points P1 and P2 according to the dx element of the high voltage transmission line

The x component represents the electric field of the output with the element $E_x(t, x)$. The interaction of the output electric field happens with the dx element of the transmission line in the form of an increase in the transient infinite current waveform that appears in the opposite direction along the transmission line at a speed of $1/\sqrt{\epsilon c}$. This speed is similar to the speed of light in the open air for the transmission line in the air. By ignoring the resistance of current shocks at points p1 and p2, the results of the interaction of the electric field of the output and the dx element of the line are given in (24) and (25).

$$(24) \quad \left. \begin{aligned} dI_{FP1}(t, x_1) &= \frac{E_x^i(t - \frac{(x-x_1)}{c}, x) \cdot dx}{2z} \\ t &> \frac{(x-x_1)}{c} \end{aligned} \right\}$$

$$(25) \quad \left. \begin{aligned} dI_{FP2}(t, x_2) &= \frac{E_x^i(t - \frac{(x_2-x)}{c}, x) \cdot dx}{2z} \\ t &> \frac{(x_2-x)}{c} \end{aligned} \right\}$$

Electric field interaction

The transmission line equations together with the given boundary conditions are fully explained in the interaction of the transmission line with the external magnetic fields and the corona. Consider the element dx, which is located at a distance x from the origin. The geometry of this condition is shown in Figure (2).

The flow results at points p1 and p2 due to the corona in the dx line element are shown in Equations (26) and (27). $dI_c(t, x)$ is the corona prionite flow.

$$(26)$$

$$dI_{cor p1}(t, x_1) = dI_c \left(t - \frac{(x-x_1)}{c}, x \right) \cdot \frac{dx}{2} \left. \begin{aligned} t &> \frac{(x-x_1)}{c} \end{aligned} \right\}$$

$$(27)$$

$$dI_{cor p2}(t, x_2) = -dI_c \left(t - \frac{(x_2-x)}{c}, x \right) \cdot \frac{dx}{2} \left. \begin{aligned} t &> \frac{(x_2-x)}{c} \end{aligned} \right\}$$

Simulation results

The effect of corona on voltage and current pulses in the transmission line can be evaluated using the extracted equations. The horizontal conductor of the transmission line with a radius of 1cm and a height of 5m above the ground is considered. It is assumed that

the positive current pulses hit one of the two ends of the line. The peak injection pulse current is fixed at 12KA. In this paper, by

giving voltage pulses to the input of the equations, the total current of the line priority is evaluated.

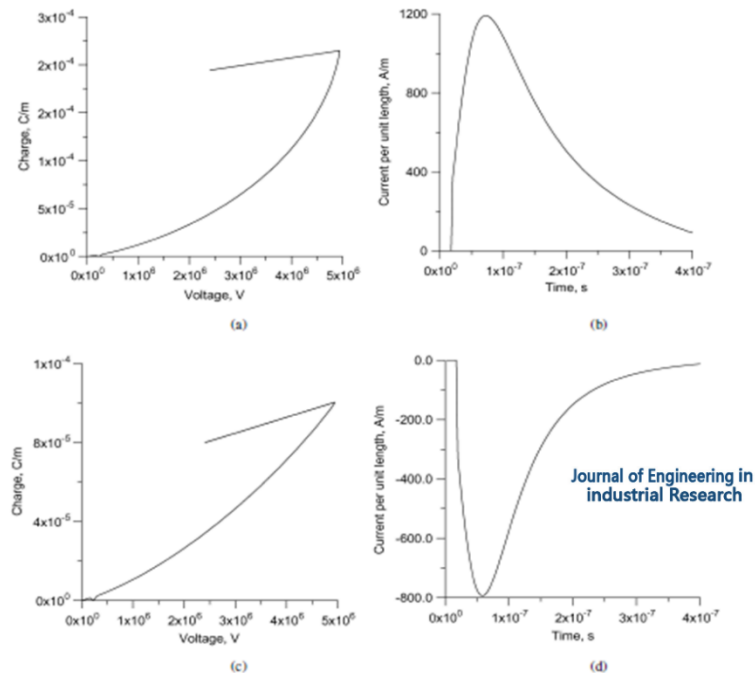


Figure 3. Changes in electrical charge per unit (a) under positive voltage shock (c) under negative voltage shock. Calculated corona current (b) under positive voltage shock (d) under negative voltage shock

Conclusion

Analysis of the high voltage transmission line equations in the presence of the impact corona states that the impact corona generated by a current or pulse propagation voltage along a high voltage transmission line can be used as current sources of the corona distributed along the current source line of the corona corresponds to a given line. When the current in that line element increases, the element turns on. The shock threshold current or when the amplitude of the voltage is greater than the shock threshold voltage threshold. The main current pulses and current pulses generated by the corona move along the transmission line at light speed. The results obtained from pulse propagation in transmission lines despite corona and its implications in lightning strikes showed that corona has two effects on the propagation of pulse current and voltage along the transmission line, the first effect is the reduction of pulse amplitude and the second

effect of pulse efficiency whose amplitude is greater than the corona threshold; it moves at a slower speed than the speed of light, and also in the lightning channel, so the higher the altitude, the slower the propagation speed.

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References

- [1] E.A. Mahdiraji, N. Ramezani, *International Academic Journal of Science and Engineering*, **2019**, 6, 39-50. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [2] T. Kawady, J. Stenzel, *IEEE Transactions on Power Delivery*, **2003**, 18, 1166-1173. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [3] F. Zare Kazemabadi, A. Heydarinasab, A. Akbarzadeh, M. Ardjmand, *Artificial cells, nanomedicine, and biotechnology*, **2019**, 47, 3222-3230. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]

- [4] M.S. Amiri, E.A. Mahdiraji, *Journal of Science and Technology Research*, **2021**, *1*, 11-19. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [5] S.M. Brahma, A.A. Girgis, *IEEE Transactions on Power Delivery*, **2004**, *19*, 1619-1622. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [6] E.A. Mahdiraji, *Journal of Science and Technology Research*, **2021**, *1*, 40-47. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [7] E.A. Mahdiraji, M.S. Amiri, *Journal of Engineering in Industrial Research*, **2021**, *2*, 7-16. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [8] E.A. Mahdiraji, S.M. Shariatmadar, *Advanced Journal of Science and Engineering*, **2020**, *1*, 27-31. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [9] R. Kolbadinezhad, E.A. Mahdiraji, *Journal of Science and Technology Research*, **2021**, *1*, 75-82. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [10] E.A. Mahdiraji, M.S. Amiri, *Journal of Engineering Technology and Applied Sciences*. **2020**, *5*, 133-147. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [11] Y. Liu, S. Meliopoulos, N. Tai, L. Sun, B. Xie, *2017 IEEE Power & Energy Society General Meeting*, **2017**, 1-5. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [12] E.A. Mahdiraji, *Journal of Scientific Perspectives*, **2020**, *4*, 245-254. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [13] T. Wu, C. Chung, I. Kamwa, J. Li, M. Qin, *IET Gener. Transm. Distrib.*, **2016**, *10*, 1815-1824, May. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [14] Y. Lee, T. Lin, C. Liu, *IEEE Transactions on Power Delivery*, **2019**, *34*, 1030-1038. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [15] F. Zare Kazemabadi, A. Heydarinasab, A. Akbarzadehkhayavi, M. Ardjmand, *Chemical Methodologies*, **2021**, *5*, 135-152. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]
- [16] S. M. S. Mirnezami, F. Zare Kazemabadi, A. Heydarinasab, *Progress in Chemical and Biochemical Research*, **2021**, *4*, 191-206. [[crossref](#)], [[Google Scholar](#)], [[Publisher](#)]