Original Article: Consideration of the Radius Caused by Charging Electrotherapeutic Signals for the Evaluation of Scattered and Random Magnetic Fields

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ABSTRACT

The conductor goes to the corona and increases the leakage and charging current surrounding the conductor when the conductor voltage at the transmission line rises from a particular threshold known as the corona threshold voltage. This study evaluates various corona effects on transmitted pulses on transmission lines as well as the equations for the transmission line when corona is present. This work attempts to offer an accurate assessment by evaluating the emission of lightning pulses along the transmission line in the form of numerical analysis on the radius induced by charging. The impact of transmission line equations and the impact of the desired magnetic field is thus one of the major issues discussed in this study.

Introduction

One can calculate the minimum current necessary in the conductor to define the creation of the impact crown by dividing the shock wave voltage threshold by the electrical characteristic impedance when the voltage in the conductor in question in a high voltage transmission line crosses through a specific threshold known as the shock wave voltage threshold. The required high voltage from the transmission line travels to the impact crown and causes current and load leakage from the conductor to the environment. A long-standing issue in power transmission and distribution is determining how the electromagnetic transient current signature or voltage varies during propagation through an overhead transmission line in the presence of an impact corona [1]. Assuming that the impact

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corona eventually increases to a dynamic increase in the high voltage transmission line's capacity is the conventional approach to solving this problem [2]. The impacts of an impact corona on the pulse emission will be examined using various ways in this study by examining the equations of the high voltage transmission line in the presence of an impact corona. Through rigorous numerical analysis, we will demonstrate how the impact crown's impacts on pulse propagation can be explained in a variety of ways, all of which lead to a significant conclusion [3]. The study's findings and recommendations are then applied to the study of reverse stroke, the conduit as a high-voltage transmission line, with a focus on the return speed and the many ideas involved in creating the best engineering models of thunder return.

The effects of an impact corona on voltage pulses or currents emitted along a high voltage transmission line can also be assessed in this work by giving the transmission line a time-varying capacity and conductivity [4-6]. One needs to accomplish this and guide the time variable to more correctly depict the impact crown's effects if the capacitor of the time variable is considered to be proportionate to the ratio between the load of the impact crown and the applied voltage [7]. Reverse stroke analysis reveals that corona effects may be caused by the fact that the recorded return stroke velocity is much slower than the speed of light. This current pulse is one of the most significant ones along a high voltage transmission line beneath the impact corona. Additionally, the principles used in the current type of reversible stroke models are correctly justified physically based on the findings of impact crown effects.

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 [8-10]. 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.

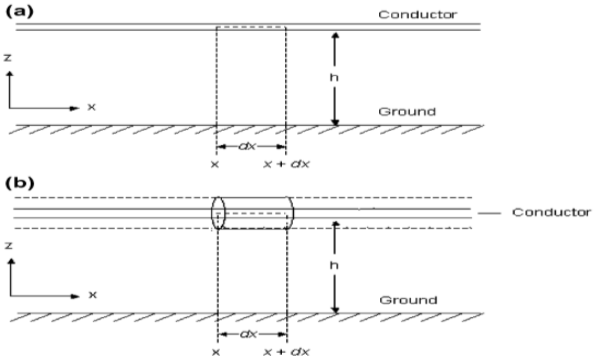

Figure (1). (a) The shape of the transmission line in the absence of a corona (b) derive the equation of the transmission line

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

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

(1)

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

(2)

In this inference Ex (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:

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

(3)

The total magnetic field adjacent to the line consists of the sum of the scattered magnetic field and the random magnetic field [11]. S represents a scattered magnetic field and i represents a random magnetic field.

$$E_z = E_z^s + E_z^i$$

(4)

$$E_x = E_s^s + E_s^i$$

(5)

$$B_y = B_y^s + B_y^i$$

(6)

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

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

(7)

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

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

(8)

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

(9)

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

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

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

(10)

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

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

(11)

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

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

(12)

To derive the equation of the second transmission line, Curl Maxwell must first be considered [12-14]. The values of the vectors *H*, *J*, and *D* are the magnetic field, current density, and electric flux density, respectively.

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

(13)

$$\nabla \bullet (J + \frac{\partial D}{\partial t}) = 0$$

(14)

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 Rc (t, x).

$$\int_s J \bullet ds = \frac{\partial}{\partial t}\int_s D \bullet ds$$

(15)

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):

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

(16)

$$\int_{surface} J.ds = 0$$

(17)

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

(18)

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

$$qa(t,x) = C.V^s(t,x)$$

(19)

$$Q(t,x) = q_c(t,x) + q_a(t,x)$$

(20)

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

(21)

In the boundary conditions of the end of the line with impedances Z_1 and Z_2 with ε_1 and ε_2 we have:

$$V^{s}(t,\xi_{1})=-Z_{1}.I(t,\xi_{1})+\int_{0}^{h}E_{z}^{i}(t,\xi_{1},z).dz$$

(22)

$$V^{s}(t,\xi_{2})=-Z_{2}.I(t,\xi_{2})+\int_{0}^{h}E_{z}^{i}(t,\xi_{2},z).dz$$

(23)

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 [15]. Consider the element dx, which is located at a distance x from the origin [16]. The geometry of this condition is shown in Figure (2).

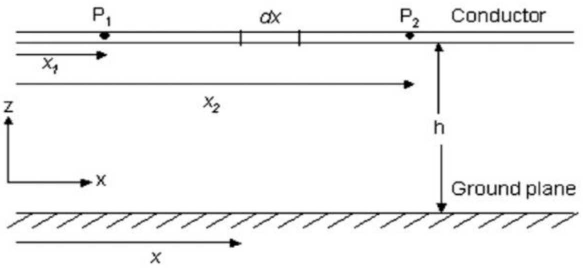

Figure (2). Locations of points P1 and P2 according to the dx element of the high voltage transmission line

The x component represents the electric field of the output with the element Ex (t, x). The interaction of the output electric field 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/√lc. 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).

$$\left.\begin{array}{l} dI_{FP1}(t,x_{1})=\dfrac{E_{x}^{i}(t-\dfrac{(x-x_{1})}{c},x).dx}{2z} \\ t>\dfrac{(x-x_{1})}{c} \end{array}\right\}$$

(24)

$$\left.\begin{array}{l} dI_{FP2}(t,x_{2})=\dfrac{E_{x}^{i}(t-\dfrac{(x_{2}-x)}{c},x).dx}{2z} \\ t>\dfrac{(x_{2}-x)}{c} \end{array}\right\}$$

(25)

The flow results at points p_1 and p_2 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.

$$\left.\begin{array}{l} dI_{cor}\,p_{1}(t,x_{1})=dI_{c}(t-\dfrac{(x-x_{1})}{c},x).\dfrac{dx}{2} \\ t>\dfrac{(x-x_{1})}{c} \end{array}\right\}$$

(26)

$$\left.\begin{array}{l} dI_{cor}\,p_{2}(t,x_{2})=-dI_{c}(t-\dfrac{(x_{2}-x)}{c},x).\dfrac{dx}{2} \\ t>\dfrac{(x_{2}-x)}{c} \end{array}\right\}$$

(27)

Simulation results

The derived equations can be used to assess how corona affects voltage and current pulses in the transmission line [14]. Considered is the transmission line's horizontal conductor, which has a radius of 1 cm and is 5 m above the ground. One of the two ends of the wire is thought to have been struck by the positive current pulses

[12]. The maximum pulse current for injection is fixed at 12 KA. The line priority's total current is calculated in this study by applying voltage pulses to the equations' input.

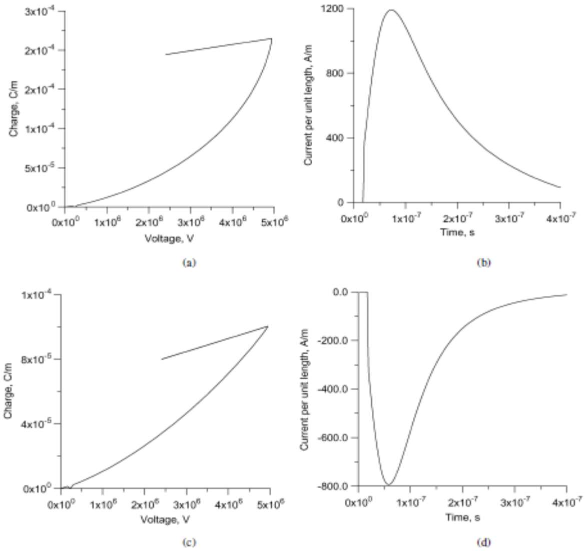

Figure (3). Changes in electrical charge per unit (a) under positive voltage shock (c) under negative voltage shock. Calculated corona current (b) under positive voltage shock (d) under negative voltage shock.

Conclusion

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, according to analysis of the high voltage transmission line equations in the presence of the impact corona. The line element in question turns on when the current through it rises. When the voltage amplitude exceeds the shock threshold voltage threshold or the shock threshold current threshold. Both the primary current pulses and the corona-generated current pulses travel along the transmission line at the speed of light. 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 is the pulse efficiency. These effects are revealed by the results of pulse propagation in transmission lines despite corona and their implications in lightning strikes. Whose amplitude is bigger than the corona threshold travels slower than light, and in the lightning channel, the propagation speed decreases with increasing altitude.

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