EFFECT OF CORONA ON THE WAVE PROPAGATION ALONG OVERHEAD TRANSMISSION LINES

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ABSTRACT

By means of a previously used and developed model, which contains non-linear shunt conductance in parallel with non-linear shunt capacitance, the effects of corona on travelling waves along h. v. transmission line are presented. A mathematical formula is used to evaluate its parameters. Simulink method of mat lab software is used to simulate the problem and solve the line differential equations including corona which is a part of it. A summary of pervious literature with different models is discussed. The result of the resent model compared with previous one.

KEYWORDS

Component, corona, conductance, protection, transmission lines.

1. INTRODUCTION

Overvoltage protection and insulation coordination are based to the knowledge of the magnitudes and waveforms of overvoltage. The corona attenuation and distortion of overvoltage wave is an important factor in determination of the overvoltage level in the electrical system due atmospheric lightning discharge.

Two kinds of significant phenomena affect the attenuation and distortion of overvoltage which is propagating along overhead transmission lines:

1) variation of transversal parameters due to corona.
2) frequency dependence of longitudinal parameters caused by skin effect of conductors.
3) frequency dependent of ground parameters.

Simulation of overvoltage wave propagation in electrical network by digital procedure is often used for solving the problem of the effect of corona on the wave propagation process.

The aims of this paper are:

To discuss some methods of corona modeling which already have been presented by some authors concerning either linear or non-linear approach to the problem.
To show and discuss the effect of corona which is represented by non-linear shunt capacitance in parallel with non-linear shunt conductance together with numerical example.

To develop practical model using the image method to calculate the dynamic capacitance of the line in corona [2]. This model has advantage that its parameters can be determined before and according to the condition of the line. Also, a concept of time delay in the formation of space charges, their development and their displacement are taken into account.

The short discussion of some of these methods is given here. The multi layer three-phase corona model presented in a study [1]. This model is developed going out from microscopically physical laws and reflected relations between charge and electrical field intensity or voltage. Space charges, their development and their displacement are taken into account. The parameters of the model are determined so that the simulated (q-v) curves closely fit those available from measurement. Then the corona model is used as an element of the discretized transmission line model. This consists either of longitudinal inductance or of travel delay modules.

The line equations are integrated using the trapezoidal rule, so that Norton equivalents are obtained for the two line ends to interfacing with the external system.

The researcher develops practical model using the image method to calculate the dynamic capacitance of the line in corona [2]. This model has advantage that its parameters can be determined before and according to the condition of the line. Also, a concept of time delay in the formation of space charges is introduced to make the model more logic and accurate both in simulation results and in understanding of many important characteristics of (q-v) curves. This model can be used to calculate corona effect on travelling wave.

In other hand, the researchers present the non-linearity model of corona, the consideration of non-linear characteristic of the corona discharge as a shunt variable conductance GC to represent the discharge resistance and a shunt variable capacitance to represent the capacitive effect [5]. The value of shunt admittance of the non-linear corona model is dependent on the value of the operating voltage at the buses. Mathematically the dynamic variation of the shunt discharge resistance \( R_C \), where
The wave front cause charge to the corona discharge. The phenomena by the modified transmission line equation:

$$i_{\text{corona}} = i_{\text{corona}} + i_g$$

$$i_g = i_G + i_{G0}$$

$$= (G + G_0)u_2$$

According to attenuation of the wave front caused by corona can be explained by an increase in shunt capacitance. Then, the increase in shunt capacitance is proportional to the voltage above critical voltage $V_{\text{CO}}$ [6], i.e.:

$$C_{\text{corona}} = 2K_C \left(1 - \frac{u_o}{u}\right)$$

Where

$$K_C = \sigma_C \sqrt{\frac{r}{2h}} \times 10^{-11}$$

$\sigma_C$ is corona loss constant.

R, h is radius and height above the ground of conductor.

So, this increase in capacitance can be modeled as capacitance branch to ground with capacitive current loss $i_c$ where;

$$i_c = 2K_C \left(1 - \frac{u_o}{u}\right) \frac{\partial u}{\partial t}$$

By adding this part to transmission line differential equations, the capacitive corona will be presented.

According to (v-i) characteristic for non-linear conductance, i.e.

$$i_g = \left[(G + G_0) (u - u_o) + \frac{G}{u} (u - u_o)\right]u_2$$

Where G is constant value we take it as 3e-5.

The initial conditions for current in this model are,

$$i = \begin{cases} 1 & \text{for } u_2 \geq u_0 \\ 0 & \text{for } u_2 \leq u_0 \end{cases}$$

Where $u_o$ is the output voltage and $u_0$ is critical corona voltage.

From equations (2, 3, and 5) we have,

$$i = C \frac{\partial u_2}{\partial t} + 2K_C \left(1 - \frac{u_o}{u}\right) \frac{\partial u_2}{\partial t} + \left[(G + G_0) (u - u_o) + \frac{G}{u} (u - u_o)\right]u_2$$

Where $u_o$ is the output voltage and $u_0$ is critical corona voltage.

From equations (2, 3, and 5) we have,

$$\frac{\partial u_2}{\partial t} = \frac{1}{2K_C \left(1 - \frac{u_o}{u}\right) + C} \left[\frac{G + G_0 (u - u_o)}{u_2} \right]u_2$$

Now the equations (1 & 8) are put in matrix form to prepare it in computer program, then,
\[
\frac{\partial^2 u}{\partial t^2} = \frac{R}{L} \frac{\partial u}{\partial t} + \frac{1}{L} \left( C \left( 1 - \frac{u_0}{u} \right) + C \right) - \frac{G}{L} \left( u - u_0 \right)
\]

(11)

\[
\left[ i \right] = \left[ \begin{array}{c}
\frac{u}{L} \\
\frac{u}{L}
\end{array} \right]
\]

And we have,

\[
u_2 = \left[ \begin{array}{c}
i \\
u_2
\end{array} \right] \left[ \begin{array}{c}0 \\
n\end{array} \right]
\]

(12)

4. METHOD OF SOLUTION AND DATA APPROXIMATION

The Matlab software is used to simulate the problem. First, the double exponential wave is applied on the sending end of the line (eq. 13), and then by solving the transmission line differential equations with corona using mat lab simulation software the output voltage is obtained. The output results represent the effect of corona as voltage-time characteristic.

\[
U(t) = 10.38U_m \left( \exp(-0.48t) - \exp(-0.97t) \right)
\]

(13)

The data are carried out on a single phase two wire system, with 9 km long divided into three sections each one 3Km. The cross section of conductor was 411 mm², with diameter of 26.4 mm [9]. The space between the bundle conductors was 0.457 m and the height above the earth is 12m [10].

The effect of corona phenomenon can be presented by solving the transmission line partial differential equations describing the electromagnetic wave propagation adding extra terms representing the capacitive corona and discharge resistance due corona. The value of parameter \( K_c \) can be evaluated from the equation at \( \sigma=20 \).

\[
K_c = \sigma C \sqrt{\frac{r}{2h}} \times 10^{-1} \text{ F/m}
\]

The values of shunt admittance \( G \) is according to assumption, taking in account three values of \( V_e/V_c \) ratio is 0.8, and weather factor as 0.9, it found approximately \( 3.36 \times 10^{-8} \) 1/Ω.

The values line parameter is determined according the transmission line parameters equations as:

\[
R_{dc} = \frac{\rho l}{A} \text{ Ω/m}
\]

At fixed frequency (60 Hz), the value of ac resistance is a few percentage higher than the dc value, so we assume its value as 0.25Ω[11-14].

For a single phase two wire the conductance can be calculated from the equation[8]:

\[
L = 4 \times 10^7 \ln \frac{D}{r} \text{ H/m}
\]

Where \( r' = 0.7788 \) r.

For the same line the capacitance can be calculated as [11]:

\[
C = \frac{2\pi \varepsilon}{\ln(2h/r)} \text{ F/m}
\]

4.1. Results

Figure 2: Show voltage-time curve and the attenuation of applied wave caused by corona. The corona has a very high effect on the propagation of overvoltage wave: increased attenuation, distortion, and reduction in the crest value of the wave took place. So according to this we can write:

- The effect of corona reduces and retards the crest value of the surge as it travels along the line.
- A simulation method to solve the deferential equations of the transmission line with corona “which is consider a part of it” was done using the Simulink method on the mat lab software, to show the effect of corona on traveling surge.
- The corona was modeled by non-linear shunt capacitance in parallel with non-linear shunt conductance. A mathematical formula used to evaluate the values of these parameters.
- Double exponential wave was applied on sending end of the line; the output was taken in two sections, at the middle and at the end of it.
- Figure 2: Show voltage-time curve and the attenuation of applied wave caused by corona.

It clears from the previous graph, that the overvoltage’s wave which propagate along transmission line, are subjected to attenuation and distortion, the main source of it here, is corona which is a very non-linear phenomenon.

REFERENCES


