$R_C = 1/G_C$ can be represented by;

$$R_C = \frac{2.142\times10^3 m}{n}\left[\log_{10}\frac{D}{r}\right]^2 \exp[-4.772]\frac{V_e}{V_c} \qquad (1)$$

where, V_e / V_c is the ratio between the operating voltage and critical corona voltage respectively, n is the length of the transmission line in km, D is the distance between the conductors, r is the conductor radius, and m is the weather factor equal about 1 to 0.7.

The shunt capacitance can be calculated for the phase conductor from the following equation:

$$C_c = 2\delta_c\left[\frac{r}{2h}\right]^{1/2}\left[1-\frac{V_c}{V_e}\right]10^{-11} \qquad (2)$$

Where C_c the corona capacitance, r and h are radius and height of the conductor respectively, δ_c is the corona loss constant normally in the range of (15 to 30).

Besides that, the researcher presents similar model for non-linear corona, describing the corona phenomena by the modified transmission differential equations [6]. The phenomena can be studied accurately by solving the equations describing the electromagnetic wave propagation, taking into account corona i.e. adding two parts to transmission line differential equations: one of them represent the non-linear corona capacitance and other represent the non-linear corona resistance.

Next, the researcher presents the first case by a switching capacitor C_0, which is included in the circuit only during the corona period [7]. The value of this capacitance may be obtained as constant using a straight-line approximation of the computed q-v curve for the conductor geometry. In most theories describing corona it is assumed that the corona effects are a function of voltage only, in fact this assumption is not correct, and the other researcher discusses this point [8]. So, in order to calculate the part played by corona in causing distortion and attenuation, the corona current must be first defined and then calculated, as his conclusion, the influence of corona on overvoltage occurring on lines can be predicted only by observing the voltage "and its previous history" at some points along the line and by calculating the corona current at these points.

3.CORONA MODELING AND TRANSMISSION LINE EQUATIONS

Corona effect is modeled with two branches in parallel, one of them is non-linear shunt capacitance to present the corona capacitance, and the other is non-linear shunt conductance to present the corona discharge resistance, and they are considered as a part of transmission line differential equations.

From figure (1) The transmission line differential equations can be written as:

$$u_2 = iR + L\frac{\partial}{\partial} + i_1$$
$$\frac{\partial}{\partial} = -\frac{R}{L}i - \frac{1}{L}u_2 + \frac{1}{L}u_1 \qquad (3)$$

$$i = C\frac{\partial u}{\partial} + i_{Corona} \qquad (4)$$

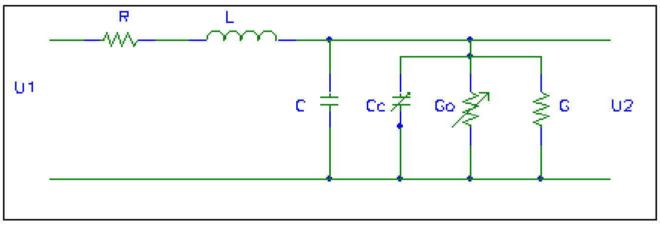

Figure 1: Transmission line model with corona

$$i_{Corona} = i_{C_{corona}} + i_G$$
$$i_g = i_G + i_{Go}$$
$$= (G+G_0)u_2 \qquad (5)$$

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_{CO} [6], i.e.

$$C_{corona} = 2K_C\left(1-\frac{u_O}{u}\right) \qquad (6)$$

Where

$$K_C = \sigma_C\sqrt{\frac{r}{2h}}\times10^{-11} \quad \text{F/m}$$

σ_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;

$$i_{C_{corona}} = 2K_C.\left(1-\frac{u_O}{u}\right)\frac{\partial u}{\partial} \qquad (7)$$

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

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

$$i_g = \left[G+G_o.1(u-u_0).u\ .(u-u_o)\right]u_2 \qquad (8)$$

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

The initial conditions for current in this model are,

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

Where u_2 is the output voltage and u_0 is critical corona voltage.
From equations (2, 3, and 5) we have,

$$i = C\frac{\partial u_2}{\partial} + 2K_C\left(1-\frac{u_O}{u}\right)\frac{\partial u_2}{\partial} + \left[G+G_O.1(u-u_O)\right]u_2 \qquad (9)$$

$$\frac{\partial u_2}{\partial} = \frac{1}{2K_C\left(1-\frac{u_O}{u}\right)+C}.i + \frac{G+G_O(u-u_O)}{2K_C\left(1-\frac{u_O}{u}\right)+C}.u_2 \qquad (10)$$

Now the equations (1&8) are put in matrix form to prepare it in computer program, then,

$$\begin{vmatrix} \frac{\partial i}{\partial t} \\ \frac{\partial u_2}{\partial t}\end{vmatrix} = \begin{vmatrix} -\frac{R}{L} & -\frac{1}{L} \\ \frac{1}{2K_C\left(1-\frac{u_O}{u}\right)+C} & -\frac{G+G_O(u-u_O)}{2K_C\left(1-\frac{u_O}{u}\right)} \end{vmatrix} \cdot \begin{vmatrix} i \\ u_2 \end{vmatrix} + \frac{u}{L}\cdot\begin{vmatrix}1\\0\end{vmatrix} \qquad (11)$$

And we have,

$$u_2 = \begin{vmatrix} i \\ u_2 \end{vmatrix} \cdot \begin{vmatrix} 0 & 1 \end{vmatrix} \qquad (12)$$

4.METHOD OF SOLUTION AND DATA APPROXIMATION

The Matlab software program 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.

$$U(t) = 10.38U_m\left[(\exp - 0.048t) - (\exp - 0.97t)\right] \qquad (13)$$

The data are carried out on a single phase two wire 220 kv line, with 9 km long divided to three sections each one 3Km. The cross-section of conductor was 411 mm, 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 represent the capacitive corona and discharge resistance due corona.

The value of parameter K_C can be evaluated from the equation at σ=20.

$$K_C = \sigma_C \sqrt{\frac{r}{2h}} \times 10^{-11} \quad \text{F/m}$$

The value of shunt admittance Go is according to assumption, taking in account three values of Ve/Vc ratio is 0.8, and weather factor as 0.9, it found approximately 3.36×10^{-8} 1/Ω.

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

$$R_{dc} = \frac{\rho l}{A} \quad \Omega/\text{m}$$

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]:

$$\text{L} = 4 \times 10^{-7} \ln \frac{\text{D}}{\text{r}'} \quad \text{H/m}$$

Where $\text{r}' = 0.7788\ \text{r}$.

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

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

Table 1: gives the values of this parameter according the sections of line length.

Parameters/Length	At 3Km	At 6Km	At 9Km
R Ω	0.3	0.5	0.7
L mH	4.551	9.107	13.66
C μF	0.222	0.444	0.666
K_C μF	0.141	0.282	0.424

4.1. Results

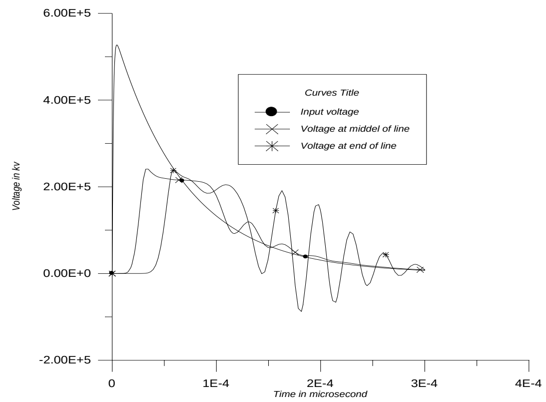

Figure 2: Show voltage-time curve and the attenuation of applied wave caused by corona

5.CONCLUSION AND DISCUSSION

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.

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