SIMULATION OF LIGHTNING PERFORMANCE OF MEDIUM VOLTAGE DISTRIBUTION LINES

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1.0 INTRODUCTION

The Electrical power system of a country and its proper operation is crucial for a country Socially and Economically. Power outages affects day to day human activities as well as Economic performance of a country. This is evident by the close correlation of the GDP of the country and the Electricity Supply.

Availability of power is mostly dependent on the capacity of the system as well as the reliability of the distribution system. The reliability of the Distribution system is mostly dependent on the transmission line performance. Disturbances due to lightning is responsible for a significant part of the distribution faults.

Faults due to lightning can be divided in to two categories, namely temporary and permanent. Temporary faults can be cleared by using a breaker or a recloser. Even though this was acceptable in the past, with the wide use of delicate devises like computers and memory devices temporary power outages will also matter. Permanent faults may be due to fuses blowing and other faults which are in permanent nature.

Measurement of lightning performance of a distribution line is a dominant factor in designing the distribution line. Behaviour of a distribution line due to the lightning is dependent on many factors namely, Basic Insulation Level (BIL), ground flash density or keraunic level of the terrain, shielding factor and magnitude of lightning current.

The scope of this project was to implement a “Lightning Analyzer” software to enable the line design Engineers to calculate the required parameters for designing purposes.

2.0 EVALUATION OF LIGHTNING PERFORMANCE OF MEDIUM VOLTAGE DISTRIBUTION LINES

Lightning Flashes can create over voltages in medium voltage lines in two ways,

i. due to direct strikes to poles or conductors.
ii. due to Electromagnetic Induction.

The Basic Insulation levels (BIL) in medium voltage lines are relatively low. Therefore, it can be assumed that each direct lightning strike, most of the time causes line flashovers. Therefore, in this research we concentrated on induced over voltage pattern due to lightning.

2.1 Over voltage due to Direct Lightning

Number of direct flashes (N) to a typical medium voltage line (figure 2.1)can be calculated in the following manner.

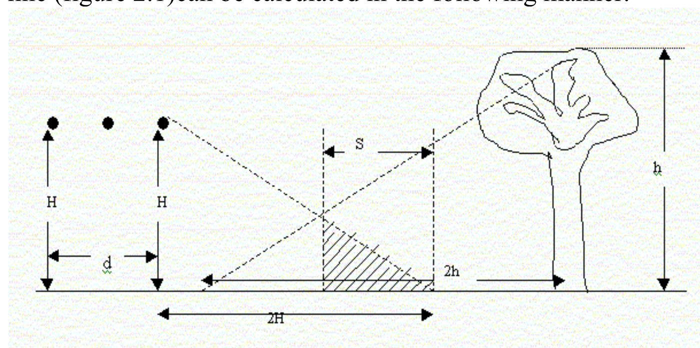


Figure 2.1

$$N = N_g\,(d + 28\,H^{0.6})(1\text{-}S_f)\,10^{-6}$$ Strokes per meter per year

where N_g Ground Flash Density (GFD)
d distance between the outer most 2 conductors
H height above the ground (m)
S_f is the shielding due to near by objects.

2.2 Over Voltage Due to Indirect Lightning surges.

A cloud-to-ground lightning flash generates a transient electromagnetic field, which can induce over voltages of significant magnitude on overhead power lines situated in the vicinity. Voltages are induced in transmission lines due to electromagnetic coupling.

There are several models to calculate the induced voltage due to lightning on a transmission line. They are Rusk Model, Agrawal Model and Chowdhuri Model. But practically, Chowdhuri Model is the most important and this project is based on the Chowdhuri Model.

2.2.1 Modeling of lightning induced over voltages

When deciding lightning induced over voltages, important parameters are ,

i. Peak of return stroke current(I_0)
ii. Return stroke velocity(v)
iii. Front time(t_f)
iv. Perpendicular distance for lightning stroke from line on horizontally on ground plane(y_0)
v. Height of the cloud charge center (h_c) or total length of return stroke channel.

The Chowdhuri Model can be explained as follows.

According to Chowdhuri Model a typical arrangement of a lightning activity near by an electric power line shown in figure 2.2.

The Line is assumed to be located at a perpendicular distance of y_0 meters from the point of strike, having a mean height of h meters above ground and point of consideration for induced voltage calculation is x meters down the line from point ‘O’

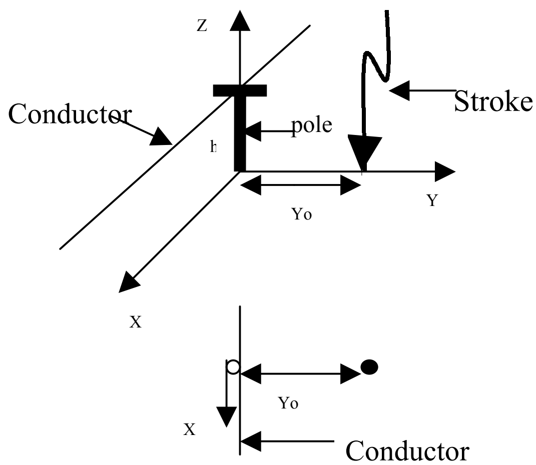


Figure 2.2

According to the Chowdhuri model, the total induced Electric field can be defined as follows.

$$E_i = E_{ei} + E_{mi}$$

where

E_{ei} is the electric field due to charge of the lightning stroke. This is known to be the field due to electric coupling.

E_{mi} is the electric field due to the current of returning stroke. This is known to be the field due to magnetic coupling.

Induced electric field Ei is a function of several parameters as given below.

$$\mathbf{Ei = \frac{30 x I_0}{t_f\, x b x c} f_1 (b,c, t_f, h_c, x, y_0, z,t)}$$

where

- Ei Resultant electric field intensity (V/m)
- c Speed of light
- z Height of the point of consideration above ground
- b Ratio between velocity of return stroke to velocity of light in free space
- h Height of the distribution line above the ground
- x Distance to point of consideration on the line from the closest point to the near by lightning
- t Time

However, for a given lightning stroke b, c, t_f , and h_c are constants. Therefore, Ei will only be a function of x, y , z and t.

By integrating Ei from zero (ground level) to the height **h** of the line, the voltage induced in the line with respect to ground can be calculated.

$$\mathbf{Vi(t) = \int_0^h E(x,y,z,t)\, dz}$$

$$\mathbf{= \int_0^h \frac{30 I_0}{tfbc} f1(b, c, t_f, hc, x, y0, z, t)}$$

$$\mathbf{Vi(t) = \frac{30\, I_0\, h}{Tfbc}\; f2(b,c, t_f, hc, x, y0, t)}$$

The above expression has been presented as a simplified set of expressions, which can be easily solved by numerical methods. This set of equations are used in this project.

As explained above, the major scope was to calculate the number of flashovers due to lighting with the variation of insulation level (BIL). Further, the “Lightning Analyzer” software is capable of analyzing the following variations as well.

1. Induced Voltage of an overhead line with the variation of Time.

This plot is drawn according to data which is calculated by Choudhiri model. A waveform of an induced voltage due to a linearly rising return stroke current on overhead line obtained using “Lighting Analyzer” as shown in fig.

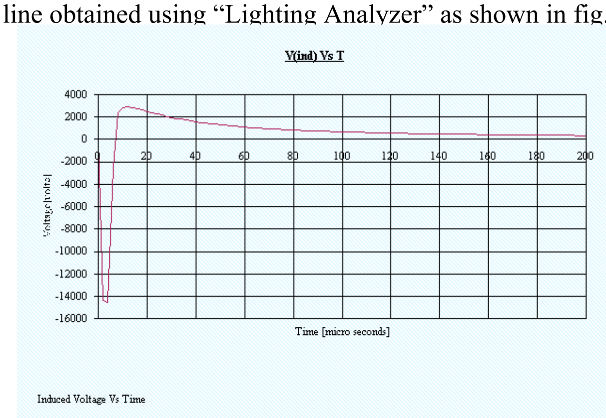


Figure 2.3

The waveform is obtained for lightning currents of 10kA with front time of 5µs and charge cloud center height of 3km. Line parameters are height 10m and minimum distance from the line to lightning is 100m.

2. Induced peak voltage with the variation of front time.

Relationship of peak value of induced voltage with wave front time for a 10kA lightning ,which strikes 100m away from a 10m tall overhead line shown in fig. According to the fig. It is quite evident that peak magnitude of the induced voltage is highly dependant on the front time.

Therefore selection of accurate front time is very important when using this "Lightning Analyzer.

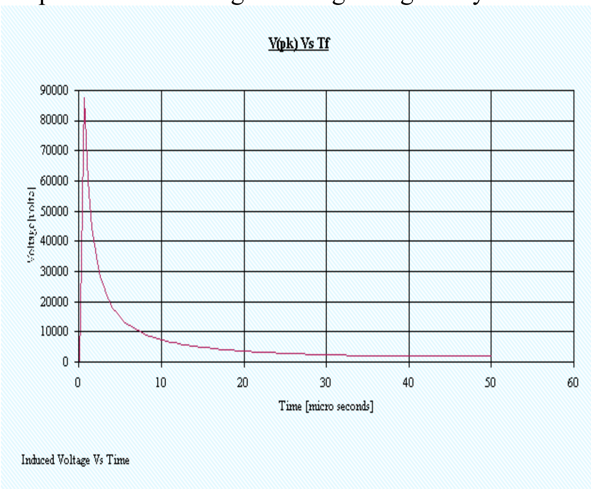


Figure 2.4

3. Minimum lightning stroke current with the variation of distance from the line to point o f strike.

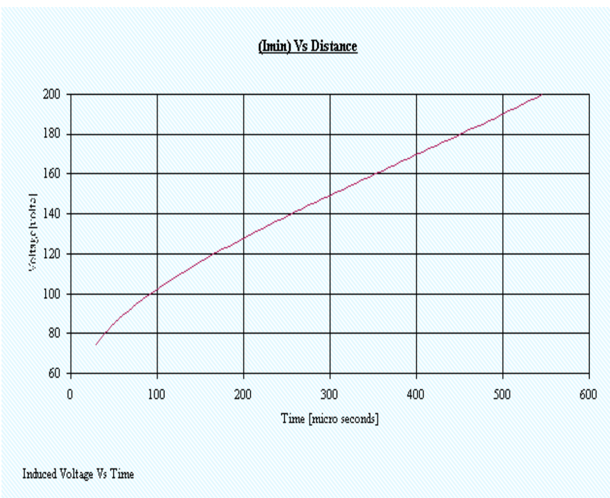


Figure 2.5

This graph is obtained for an insulation level of 200kV and 1km along the line and front time of 5µs. I_{0min} is the minimum lightning current required to cause line flashover. Here we can find what is the effective distance from the line for line flashover.

4. Probability distribution of Minimum lightning stroke current with the variation of distance from the line to point o f strike.

Probability, $P[I_{0min}(y_0)]$, of getting a lightning whose magnitude is greater than $I_{0mi}(y_0)$can be obtained using,

$$\mathbf{P[I_{0min}(y_0)]= e^{-0.02291*I0min(y)}}$$

Then the number of flashes (ΔN_i), which will cause induced voltages with peak magnitudes greater than the line BIL,is calculated as follows.

$$\mathbf{\Delta N_I= 2*Ng*\Delta y* P[I_{0min}(y_0)]}$$

Finally by adding all ΔN_I together, the total number of line flashes can be calculated. Therefore Probability distribution of Minimum lightning stroke current with the variation of distance from the line to point of strike is very important.

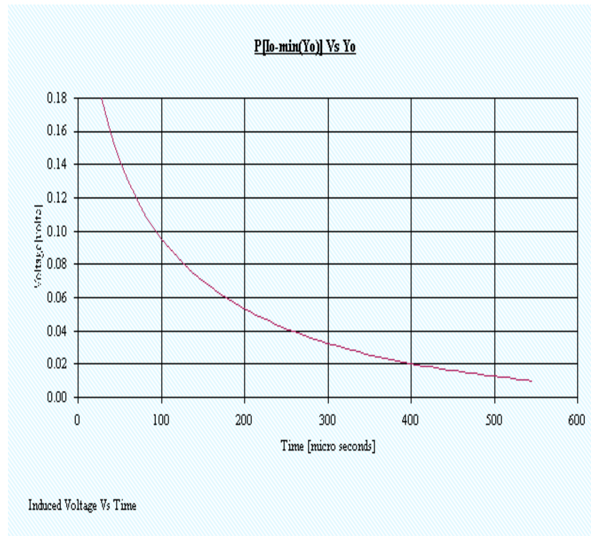


Figure 2.6

5. Variation of lightning induced flashover with line insulation levels(BIL)

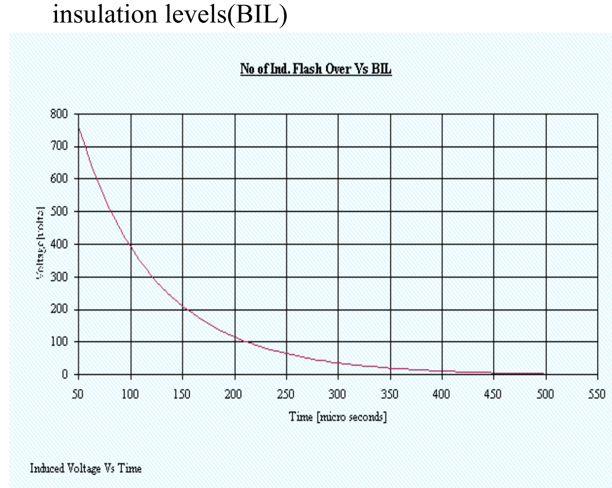


Figure 2.7

The above relationship of line flash over with line BIL for a MV distribution line is obtained for line parameters of h=10m, d=3m, and ground flash density of 10stroke/km^2/year. We can use this for designing MV distribution line as well as analyzing lightning performance at different conditions.

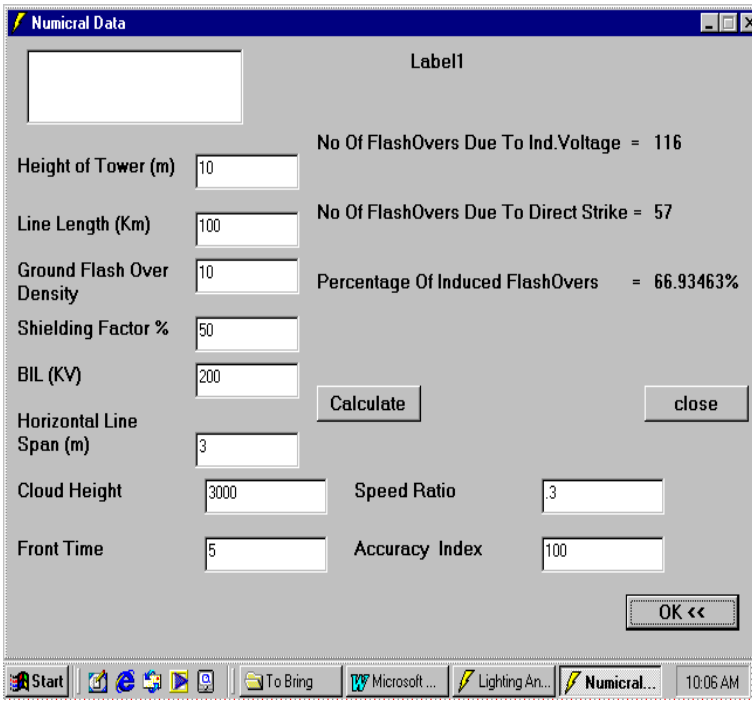
6. Determination of the Total flash over Rate of MV Overhead line due to lightning surges

Total flashover consists of two components. They are

i. Due to direct lightning

ii. Due to induced lightning

"Lightning Analyzer" gives these data in numerical form as follows.



3.0 CONCLUSION

Lighting Analyzer software is based on the Choudhiri model of induced lighting. However if the other available models such as Agrawal and Rusk were used results would be comparable from each model

In our analysis we have kept some factors constant, like Keraunic level and tower height. Therefore improved version of this software should be able to plot the number of flashover variation with variables like Keraunic level and line height etc.

Only Visual Basic software was used for the implementation since Object Linking with Mathlab creates slow response output.

4.0 REFERENCES

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2. P.Chowdhuri, "Analysis of Lightning induced voltages on overhead lines" IEEE Transactions on power delivery,1989.