An Investigation on the Effect of Ground Resistance Value on the Lightning Discharge Current

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Abstract - Due to the height of transmission towers, the probability of lightning striking the towers and conductors is much higher than the probability of hitting the adjacent ground. The lightning strikes the head of the transmission line tower or the protective wires and causes the lightning current to flow from the top of the tower to the bottom, and this huge current increases the voltage due to the characteristic impedance of the tower. As the tower voltage increases, the system may have problems. As a result, the ground impedance is very important in discharging the voltage. In this article, we examine the ground impedance and the discharged voltage and the results are displayed with MATLAB software.

Keywords – Back flashover, Ground impedance, Voltage discharge.

I. INTRODUCTION

The most important parameter of lightning is the current caused by discharging the cloud charge, which by knowing the waveform and its amplitude, the electrical problems of lightning protection can be solved. Usually the amplitude of the current due to the first impact is the highest and the amplitude of the current varies according to the height of the object, the height of the place and the strength of the soil. Lightning strikes the overhead transmission line tower causing a transient voltage across the insulators. If this voltage generated in the insulators is greater than the design voltage for the insulators, then it causes an electrical discharge in the insulators, which is called back flash over [1].

Lightning is a powerful source of electromagnetic energy that can damage equipment and disrupt human life. Statistics show that most line breaks are caused by lightning strikes [2, 3]. Of course, by using appropriate protection methods, the amount of line breaks caused by lightning can be reduced.

Overvoltages caused by lightning are very harmful for equipment with poor and sensitive insulation. Some industries, such as aluminum and steel mills, as well as the petrochemical industry, are often extremely vulnerable to downtime. Also, telecommunication systems are very sensitive to electrical failures and require continuous power supply [3].

Therefore, in modern societies that need stable and quality electricity supply, the development and application of lightning protection measures for transmission lines is of particular importance.In reference [4], a two-circuit transmission system is investigated and the overvoltages caused by lightning strike to the wire guard are studied and used to determine the lightning resistance of the towers. Factors such as tower height, Resistance of the tower ground system, soil strength and polarity of lines are also investigated.

Articles [5, 6] discuss other parameters that affect the performance of transmission lines during lightning strikes. Parameters such as wavehead time, backwave time, insulators length, etc. The return spark performance analysis in a transmission post for insulation coordination is described in [7]. In this paper, it is shown that for better protection of the mentioned post, the foot resistance of the end towers should be reduced as much as possible, and if the reduction rate is not sufficient, other methods such as reducing the wave impedance of the tower should be used.

Under normal conditions, the ground electrode has the potential of distant points (total earth mass) which increases its potential by creating an error current in the electrode. The value of this potential or GPR (increase of ground potential) is obtained by multiplying the fault current in the resistance of the ground electrode, so the lower the resistance of the construction electrode, the lower the surface potential of the ground due to the error will be.

II. IMPLEMENTATION AND MODELING

Figure 1 shows the impact of lightning on the transmission tower. When investigating the effect of lightning on a transmission tower, R-L circuits can be used, as shown in Figure 2, where the tower is considered as a constant inductance, and R_{tf} is the base resistance of the tower, which is considered constant, and L_s is the inductance of shield wires, which is considered constant, and the impedance of the phase conductor is Z_p. I is the current passing through the lightning channel, i_t is the current passing through the tower, i_s is the current passing through the shielding wire and i_p is the current passing through the phase conductor.

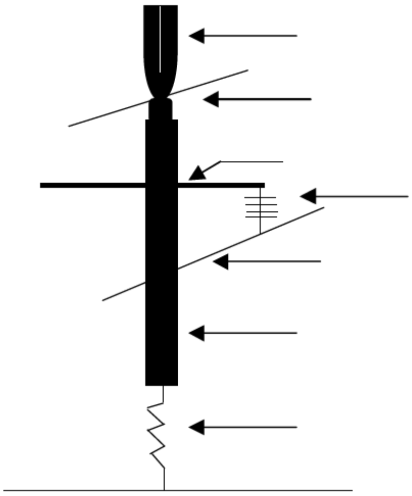

Fig. 1. Circuit equivalent to lightning strike to the transmission

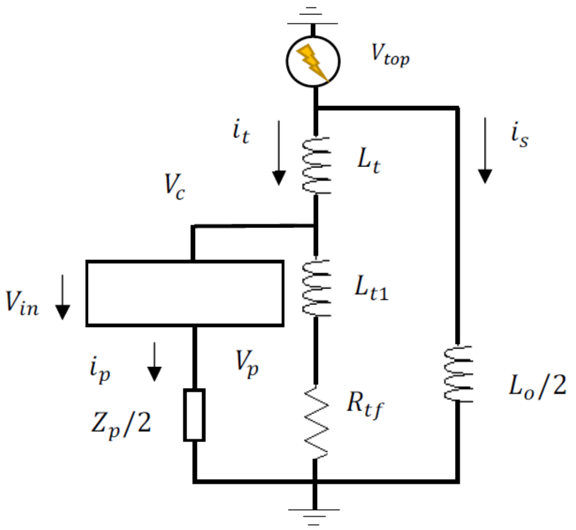

Fig. 2. R-L circuit of a transmission tower

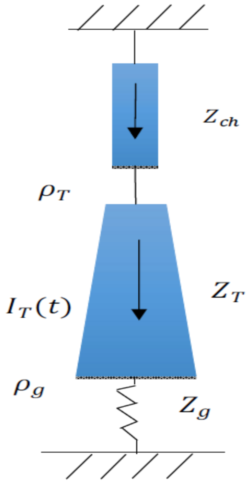

Fig. 3. Lightning strike circuit to the tower

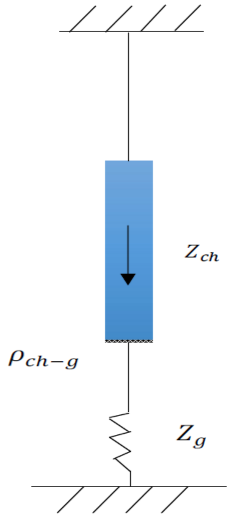

Fig. 4. Lightning current strike circuit to ground

If the lightning current is considered as a ramp function, then the impact on the tower becomes i=αt. The i_t current passes through the tower and the i_s current flows to the adjacent towers. The current flowing through the wire guards is expressed by a factor of β. The current flowing in the tower is in the form of relation 1. To distribute the current, we must express the reflection coefficients for them. For this purpose, z_{ch} ,z_T,z_g are ground impedances, tower and lightning channel, respectively. The reflection coefficient of the current at the base of the tower is as a relation 2 and the reflection coefficient of the current at the top of the tower is as a relation 3 and the reflection coefficient of the current relative to the ground is as a relation 4. Lightning current is also shown in relation 5 [8].

$$i_t = \beta\alpha t \quad (1)$$

$$\rho_g = \frac{Z_T - Z_g}{Z_T + Z_g} \quad (2)$$

$$\rho_T = \frac{Z_T - Z_{ch}}{Z_T + Z_{ch}} \quad (3)$$

$$\rho_{ch-g} = \frac{Z_{ch} - Z_g}{Z_{ch} + Z_g} \quad (4)$$

$$i(t) = 3.4251 \times 10^5 (e^{-0.1259t} - e^{-0.126t}) \ (kA) \quad (5)$$

III. IMPLEMENTATION AND SIMULATION RESULTS

Figure 5 shows the 100 kA current colliding at the top of the tower. In this figure, I_1 is the current of the wave source, I_2 is the current flowing in the tower. In Figure 6, I_1 is the wave source current, I_2 is the current flowing in the ground without the presence of a tower. And the results of Figures 5 and 6 show that if the tower does not exist, the current that reaches the ground will be twice the current of the wave source.

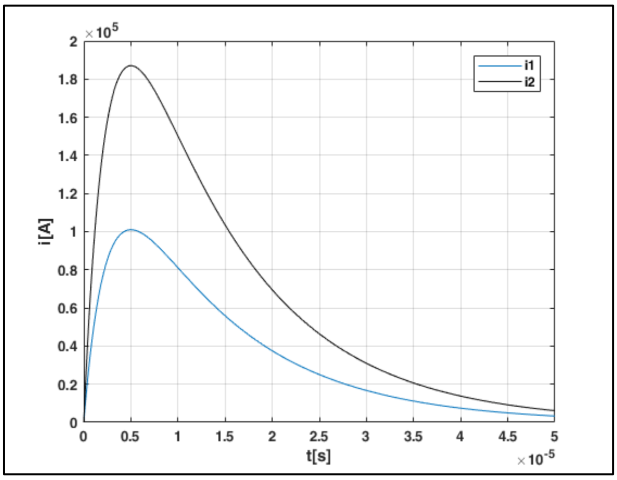

Fig. 5. Lightning current and current flowing in the rig.

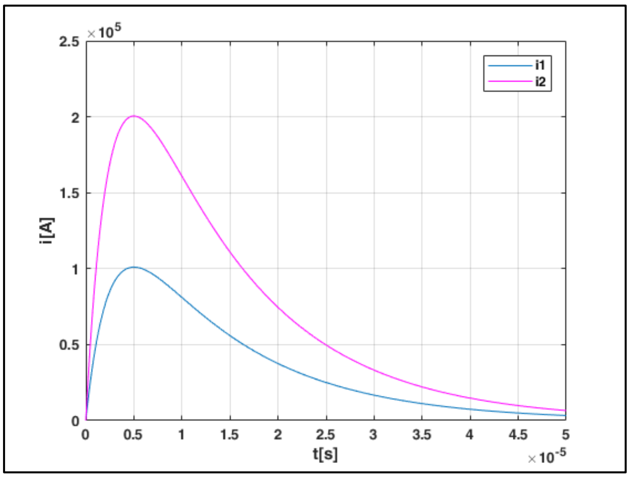

Fig. 6. Lightning current and current flowing in the ground without the presence of the tower

The discharged voltage caused by lightning with the values of the impedance of the tower foot 10, 20, 30, 40 and 50 Ω are shown in Figures 7-11, respectively, and the results show that the higher the impedance of the tower foot, the more dangerous it is and the higher the discharged voltage.

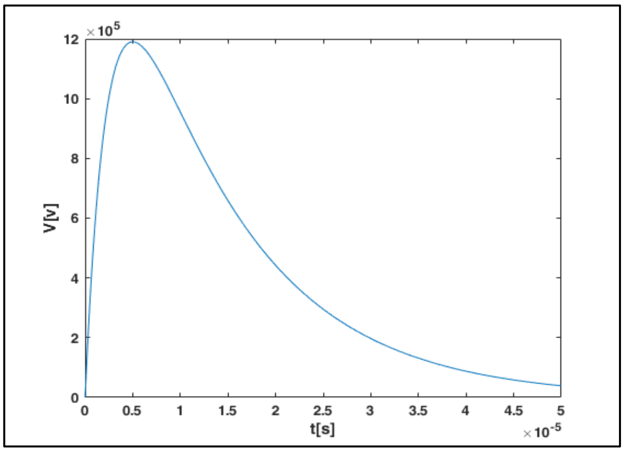

Fig. 7. Voltage discharged with 10 Ω tower foot impedance.

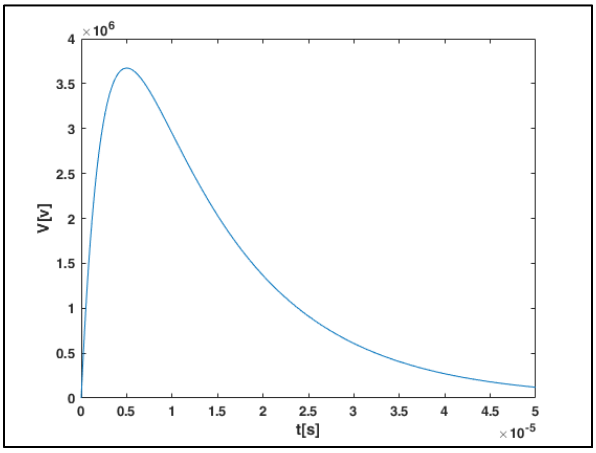

Fig. 8. Voltage discharged with 20 Ω tower foot impedance.

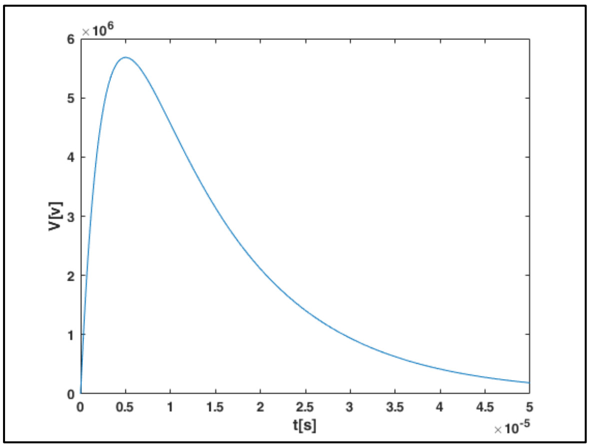

Fig. 9. Voltage discharged with 30 Ω tower foot impedance.

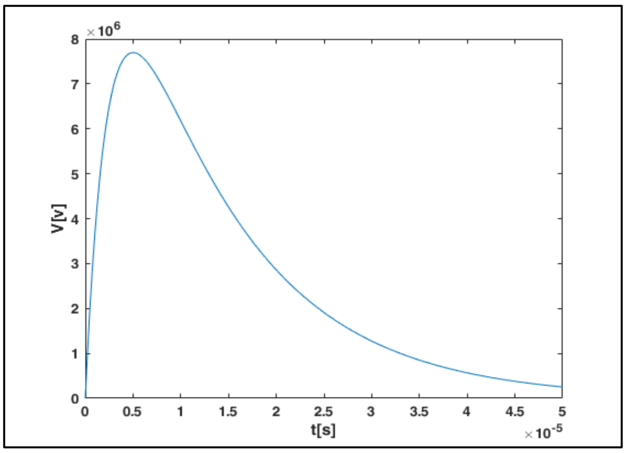

Fig. 10. Voltage discharged with 40 Ω tower foot impedance.

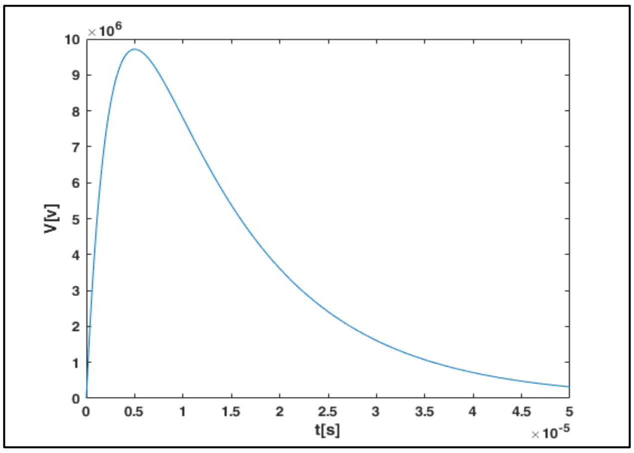

Fig. 11. Voltage discharged with 50 Ω tower foot impedance.

In Figures 12-16, in the absence of the tower, the discharged voltage on the ground with resistances of 10, 20, 30, 40 and 50 Ω is checked, and in comparison with Figures 7-11, it is shown that in the absence of the tower, the discharge voltage caused by Lightning will have more value.

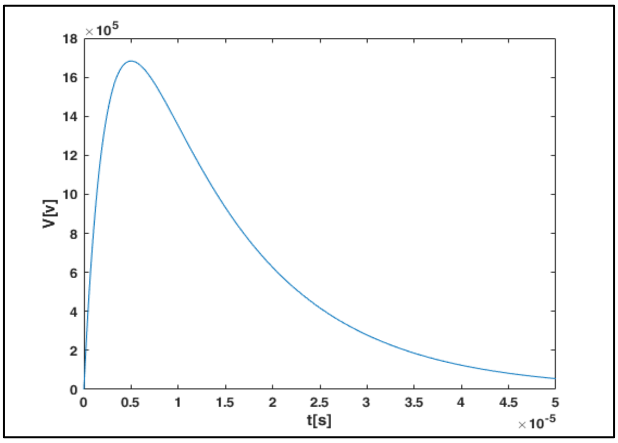

Fig. 12. Voltage discharged with ground impedance 10 Ω.

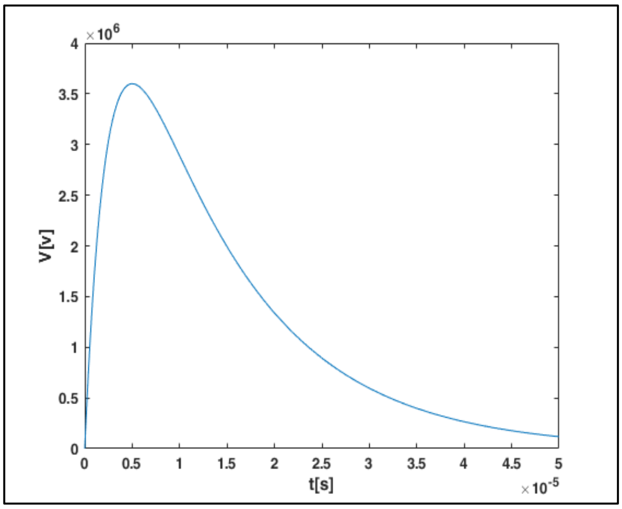

Fig. 13. Voltage discharged with ground impedance 20 Ω.

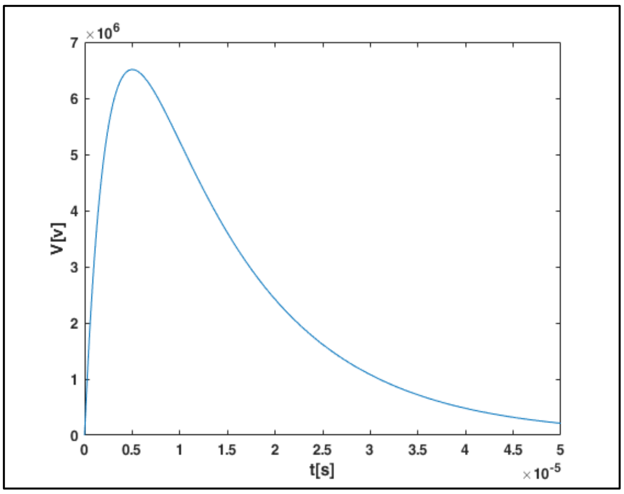

Fig. 14. Voltage discharged with ground impedance 30 Ω.

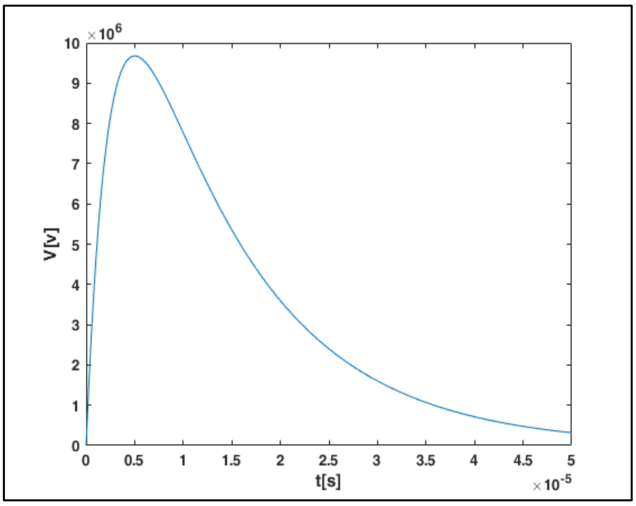

Fig. 15. Voltage discharged with ground impedance 40 Ω.

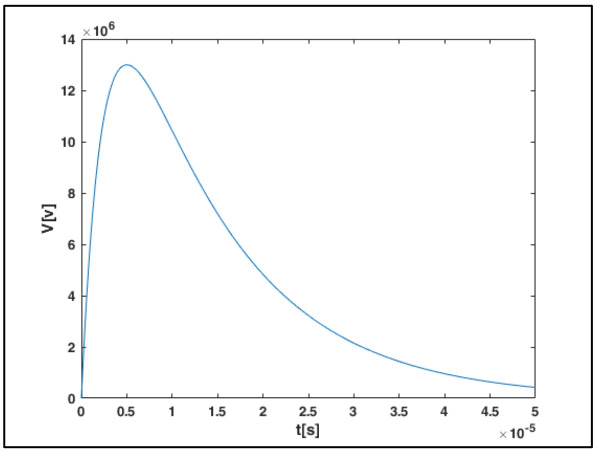

Fig. 16. Voltage discharged with ground impedance 50 Ω.

IV. DISCUSSION AND CONCLUSION

In this paper, the distribution of lightning current near the ground and the current flowing in the tower were investigated and it was shown that in the absence of the tower, the current discharge in the ground system will increase. This high current increases the voltage due to the characteristic impedance of the tower. The discharge voltage was obtained for different impedances and it was shown that with increasing impedance, the discharge voltage increases and there may be ignition between the ground and tower arms as well as between the two tower arms and the system may have problems.

V. REFERENCES

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