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Studying Transient Lightning Effects on 230 KV Double-Circuit Lines using Tower Modeling

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Abstract- Excess lightning voltage in long transmission lines are of great importance. In this article, we attempt to study the 230 KV double-circuit transmission line. In the carried out study, in order to evaluate phase to earth sparks, and tower side sparking to conductors, three prevalent tower models in transient studies including simplified multistory, and simplified extended line model were evaluated. Results obtained from simulations using ATP/EMTP software will prove helpful in finding the best model in terms of performance against lightning.

Keywords*- Excess Voltage, Transient Behavior, Multistory Model, Simplified Multistory Model, Simplified Extended Line Model, ATP/EMTP Software*

I. INTRODUCTION

Lightning, as the most important external source of excess transient voltage generation in power networks. The added importance of transient voltages caused by lightning can be found in their destructive role in power networks. With the development of power transmission lines and the importance of power supply to different regions, power transmission line cuts due to lightning strike has attracted the attention of man engineering and designers of power transmission line. Lightning can cause destruction of conductors, and this problem mainly results in power line cuts leading to power outages. The problem of modeling transient behavior of a tower at the time of lightning strikes in very important, and was accomplished in 1930. For a well-designed transmission line, direct contact of phase conductors rarely occurs. Nonetheless, lightning strikes account for numerous yearly exits due to sparking phenomena from towers to conductors (back flashover) [2]. Field measurements and tests are effective tools in evaluating and obtaining insight of transient structure of a tower. Insulative design of power systems and studying the behavior of lightning and thunder strikes on power systems is necessary. Therefore, excess voltage from thunder strikes is an important factor in conserving post and power station instruments [3]. Hence, a combination model from transmission lines and tower are employed for analyzing the effect of thunder strikes on power systems, and some studies have been carried out in this regard, which based on the applied model for the tower, it is expected that results will differ to some extent. One of the suitable new proposed models for towers is the multistory model, which is a parallel R-L model with wide usage in Japan for analysis of thunder strikes.

II. SYSTEM MODEL

The 230 KV double-circuit transmission line is used in some regions based on the special conditions of transmission paths. Figure (1) shows the structure and geometrical parameters of the studied tower. The tower foot resistance is 10 ohms, and wave range of the thunder strike is 50 KA. [6].

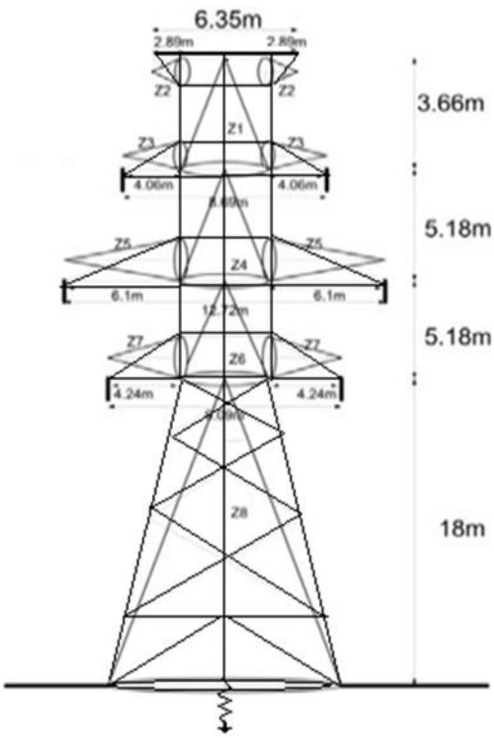


Figure 1. Tower model

III. DIFFERENT TOWER MODELS

In order to model the tower in form of a transmission line, the specific impedance and wave velocity must be determined.

Then, they can be modeled using the steady transmission lines model. Further, we will attempt to examine different models for tower modeling, which have been obtained using theoretical laboratory approximations.

A. Multistory Model

The tower and its multistory model are shown in figure (1). In this model, the transmission line tower is considered as a collection of series circuits along with parallel R-L circuits. The mentioned circuits signal attenuation of fluid wave along the length of the tower. Because only R-L parameters for 500 KV transmission line are accessible, therefore in order to use them for a 230 KV sample, geometrical dimensions must be converted. For this purpose, equations (1) to (4) have been employed. Here γ is coefficient of diffusion equal to 0.8, α is coefficient of damping equal to 1, V_t is wave diffusion velocity equal to 300*m*/μs[8, 9].

$$Ri = \frac{-2Zti\,.\ln\sqrt{\gamma}}{h_1+h_2+h_3} * h_i \quad (\Omega) \qquad (i = 1-3) \tag{1}$$

$$R4 = -2\,Zt4\,.\ln\sqrt{\gamma} \quad (\Omega) \tag{2}$$

$$Li = \alpha\,.Ri\,.\frac{2H}{V_t} \quad (\mu h) \quad (i = 1-4) \tag{3}$$

$$H = h_1 + h_2 + h_3 + h_4 \;\; (m) \tag{4}$$

The tower's multistory model is shown in figure (2), and values matching this model are given in table 1. Impedance for each section of the tower is a constant value given in reference [7] for all towers.

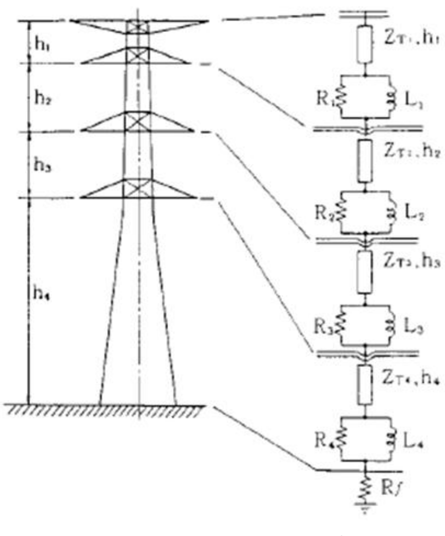


Figure 2. The multistory model of a tower

TABLE I. EQUIVALENT PARAMETERS OF THE MULTISTORY MODEL

R1(Ω)	12/81	L1(*mh*)	0.00273	Zt1(Ω)	220
R2(Ω)	18/13	L2(*mh*)	0.00387	Zt2(Ω)	220
R3(Ω)	18/13	L3(*mh*)	0.00387	Zt3(Ω)	220
R4(Ω)	33/47	L4(*mh*)	0.00714	Zt4(Ω)	150
R (Ω)	10	----	-----	-----	----

Figure (3) shows the simulated circuit in ATP/EMTP for the multistory tower.

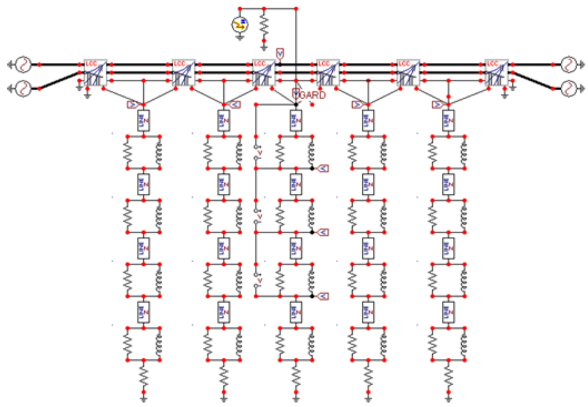


Figure 3. Multistory equivalent circuit

B. Simplified Multistory Model

In this model, the parallel R-L circuits present in the multistory model are eliminated. One of the reasons for sparking in the multistory model is the presence of the parallel R-L circuits. Hence, simulation has been carried out using the simplified Multistory model, in other words without the parallel R-L circuits [8, 9]. The specific impedance and other parameters of the simplified model are the same as those of the multistory tower. Moreover, the equivalent circuit used in ATP/EMTP software is shown in figure (4).

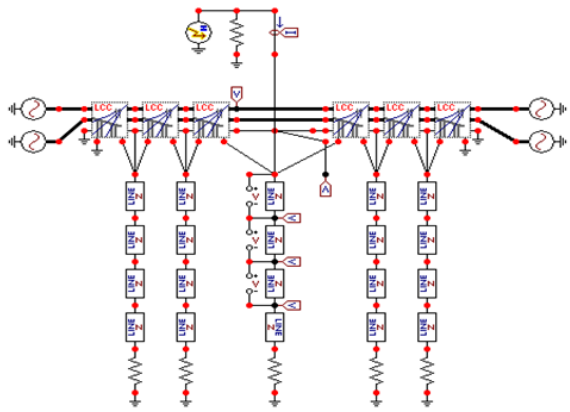


Figure 4. The simplified multistory equivalent circuit

Because the Multistory model is designed for a 500 KV transmission line, and the fact that the height of the 500 KV tower is not the same as the 230 KV tower, therefore evaluating the specific impedance of the tower is necessary. Different relations have been presented regarding the method of calculating the specific impedance of a tower. The relation given in equation (5), while simple and easy, presents an acceptable and adaptable value with the measured specific impedance of the tower. The mentioned equation is obtained from figure (5) and presented as follows [10]:

$$Z = 60 . [\ln\left(\frac{H}{R}\right) - 1] \quad (5)$$

Where $R \leq H$ is the total equivalent radius. R is obtained from equation (6).

$$R = \frac{(r_1 h_2 + r_2 H + r_3 h_1)}{2H} \quad (6)$$

The model of the tower used in ATP/EMTP software is shown in figure (6). In all conducted simulations, eave velocity is equal to light speed and considered 300m/μs.

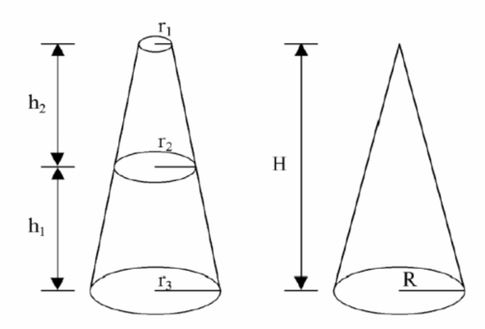
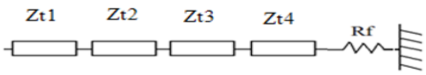


Figure 5. Tower equivalent structure



Zt1= Zt2= Zt3= Zt4= 126.7(Ω)

Figure 6. Impedance equivalent to the simplified extended line

IV. Examining Simulation Results

In this section, results gathered from simulation using ATP/EMTP software are presented. A shockwave has a range of 50 KA, wave front of 1 microsecond, and wave tail of 70 microseconds. The thunder strike current on surge, for example, reaches its peak within the period of 0 to 10 microseconds (wave face), and then reduces to half of this amount within 20 to 100 microseconds (wave tail). The distribution of this current is shown in figure (9). 50% of thunder strikes have a peak current larger than 50 KA. In rare cases, the peak current can surpass 200 KA. In addition, measurement results show that approximately 90% of thunder strikes are negative [11]. Therefore, in this article, the negative peak of thunder strikes was simulated and tested. Figure (7) shows the thunder strike wave simulated in ATP/EMTP software.

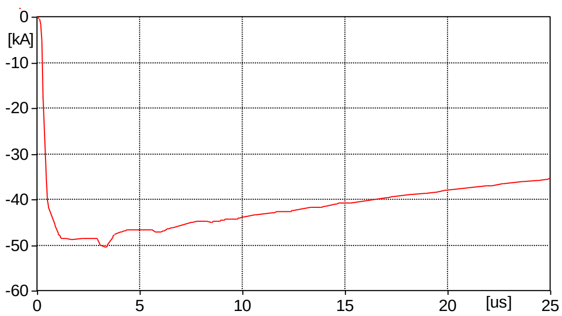


Figure 7. Shockwave with negative peak

Figure (8) to (10) show the range of excess voltages generated on the tower head (place of thunder strikesurge). As seen in the mentioned figures, the highest created excess voltage on the tower head is of the multistory model, and the lowest value relates to the simplified extended line, while the simplified multistory model stands in between.

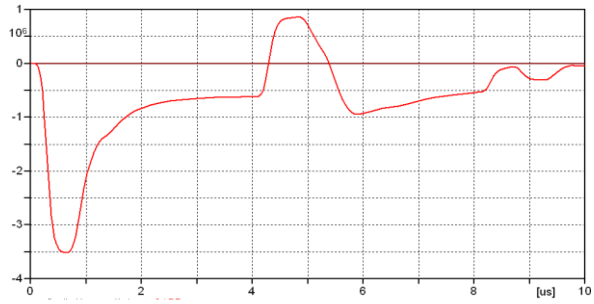


Figure 8. Range of the generated voltage in the place of thunder strike surge in the multistory model

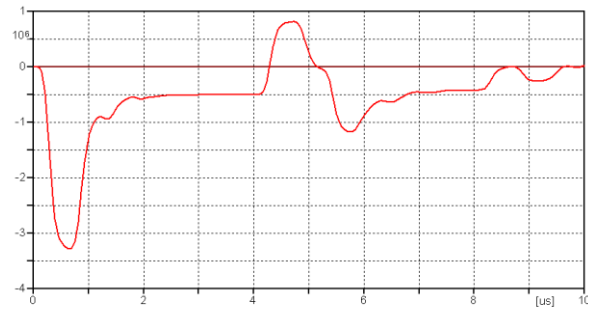


Figure 9. Range of the generated voltage in the place of thunder strike surge in the simplified multistory model

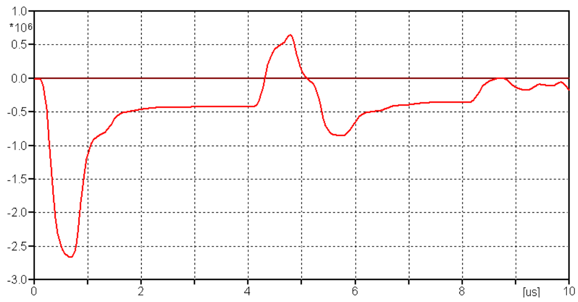


Figure 10. Range of the generated voltage in the place of thunder strike surge in the simplified extended line model

Figure (11) to (13) show the range of excess voltage generation in tower arms relative to the ground. It can be seen that the range differences relative to the ground is low in the extended line model and simplified multistory, and the possibility of sparking on this phase is less. However, in the multistory model, there is a larger difference in tower arm voltages.

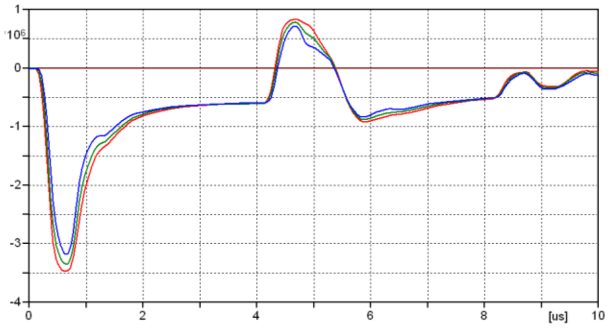


Figure 11. Voltage range created in tower arms relative to the ground in the multistory model

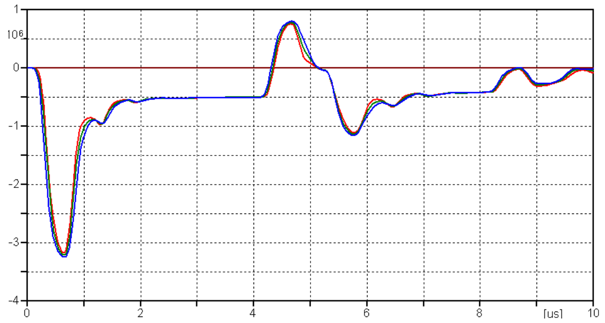


Figure 12. Voltage range created in tower arms relative to the ground in the simplified multistory model

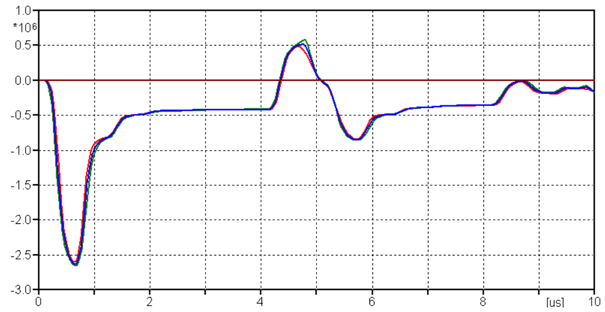


Figure 13. Voltage range created in tower arms relative to the ground in the simplified extended line model

Figure (14) and (16) show the shape of waves generated on both ends of the insulators.

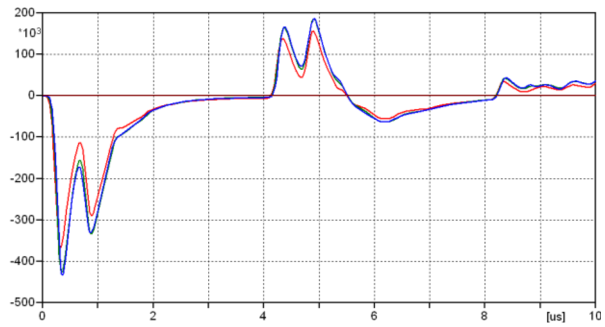


Figure 14. Range of the voltage generated on both ends of insulators in the multistory model

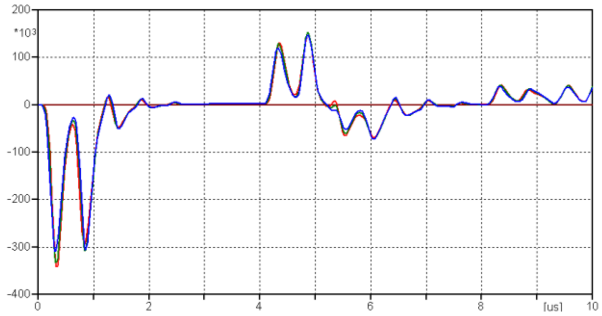


Figure 15. Range of the voltage generated on both ends of insulators in the simplified multistory model

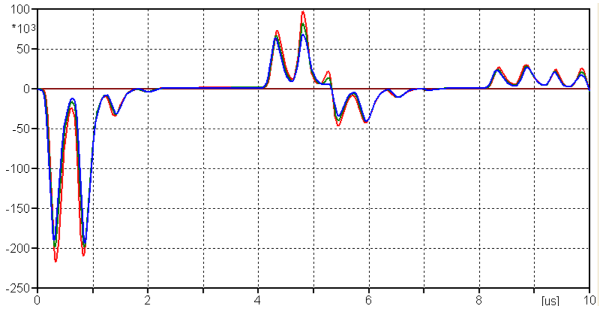


Figure 16. Range of the voltage generated on both ends of insulators in the simplified extended line model

Figures (17) and (18) show the wave forms generated in phases relative to the ground.

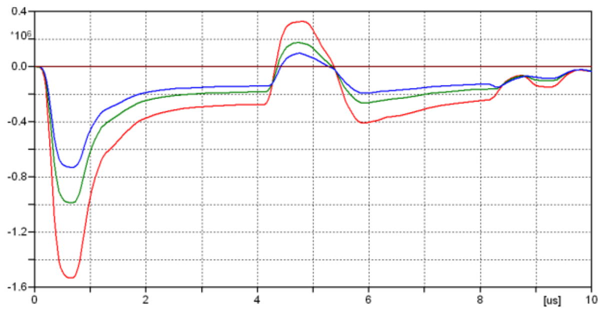


Figure 17. Range of excess voltage generated in phases of the multistory model

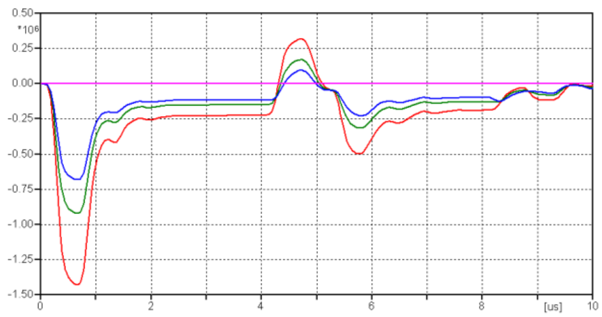


Figure 18. Range of excess voltage generated in phases of the simplified multistory model

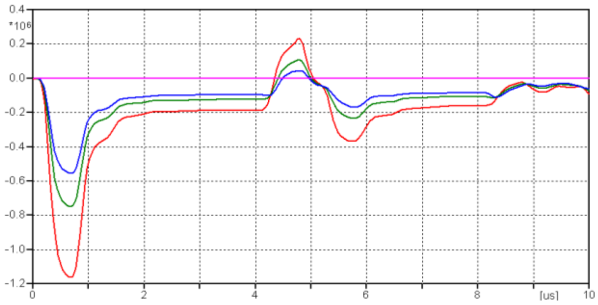


Figure 19. Range of excess voltage generated in phases of the extended line model

V. COCLUSION

According to the results from simulations for different tower types, and by applying negative polarity waves on the tower, the following results were obtained:

1. For negative polarity, the current range due to thunder strike on the surge point for the extended line model has the lowest amount of excess voltage range, and the Multistory model acquires the highest excess voltage range, while the simplified Multistory model stand in between.

2. According to this negative polarity of voltage ranges from the tower arm to the ground, the multistory model gained the highest value, and the simplified extended line had the lowest value. The simplified Multistory model stands in between, and due to the fact that the difference between phase ranges in the extended line model and simplified multistory are not significant, this notions a possibility of equal probability in flashover in all three phases.

3. The voltage range due to thunder strike surge on insulators in the multistory model has the highest value, and the simplified extended line model the lowest, while the simplified multistory model stands in between.

4. Excess voltage range in phases of the multistory model has the highest value, and the simplified extended line model the lowest, while the simplified multistory model stands in between. The obtained results indicate that for the examined line, the simplified extended line model is suitable for this tower.

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