An Approximate Formula for Estimating the Peak Value of Lightning-Induced Overvoltage Considering the Stratified Conducting Ground

Lightning Detection Technologies

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The calculation of the lightning-induced voltages on overhead line is very important for the lightning protection. Assuming the ground to be perfectly conducting, Rusck, Chowdhuri et al., Liew et al., Jankov, Høidalen et al. and Andreotti et al., presented several analytical expressions for estimating the lightning-induced voltages on overhead lines. Taking into account the effect of the finitely conducting soil, Høidalen et al. [14] proposed an approximate formula, however, their formula is complicated and time consuming. Baker et al and Darverniza further proposed an empirical formula based on experimental data and theoretical analysis. Paulino et al also presents an approximate formula considering finitely conducting soil and later they revised it using trapezoidal lightning return stroke current waveform and typical representative discharges parameter values. The approximate formula they proposed is very important and convenient, however, it is only valid under the homogeneously conducting ground. It is generally known that the real soil is better represented by horizontally or vertically stratified models, so it is more practical and meaningful to develop an approximate formula to the case of horizontally stratified ground.

In this paper we have revised and extended the approximate formula proposed by Paulino et al to the case of horizontally stratified ground and test its accuracy by using 2-D FDTD method and the Agrawal coupling model. The revised formula can be written as:

$$V_p = kc \times \left\{ \sqrt{3}(v_r)^{\frac{1}{3}} \times I_0 \times \sqrt{\frac{\rho_1}{y}} \left[1 + 2\sum_{i=1}^{\infty} k^i \exp(-2h_1 \alpha i) \right] + 8.5 I_0 \frac{h}{y^{3/4}} \right\}$$

In the formula, kc =0.9,k is reflection coefficient ,α is the attenuation factor, h_1 is the first layer depth, y is horizontal distance, h is line height, I_0 is the stroke current peak value . The results show that when the upper ground layer has a higher conductivity than the lower layer, the lightning-induced wave peak decreases with the increase of the depth of the upper layer, and the difference between the approximate formula and computer simulation is less than 10% for distances ranging from 50 m to 400 m from the lightning channel. When the upper ground layer has a lower conductivity than the lower layer, the induced wave peak increases with the increase of the depth of the upper layer and the difference between two methods is dominantly less than 10 % for distances ranging from 50 m to 400 m from the lightning channel except for the cases of the d=400 m and h1>5 m.

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