Magnetic Fields of Power Lines Related to Maximal Sag Position

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Abstract: - The possible health risk makes the assessment of extremely low frequency electromagnetic fields of great interest. This paper deals with the lateral magnetic field profiles of overhead power lines. The profiles are related to the maximal sag position having the maximal magnetic field value, since the conductor heights are minimal there. Subsequently, the maximal field value could be compared to values arising from the (inter)national guidelines. A reasonably accurate agreement between computational results and the experimental data is obtained.

Key-Words: - overhead power lines, magnetic field assessment, maximal sag position

1 Introduction

An assessment of extremely low frequency (ELF) electromagnetic fields to which human beings are exposed has been of great interest for many years. Reason for this is the public concern regarding the possible health risk due to human exposure to such field sources. Moreover, there is a possibility of electromagnetic interference (EMI) threat concerning possible malfunction of sensitive electronic equipment. Namely, malfunction of some medical devices could seriously affect the human health. Consequently, an accurate assessment of the maximal ELF field quantities for comparison purposes with the (inter)national guidelines should be considered as a rather important task.

Therefore, a particular attention should be focused to significant ELF field sources such as transmission/distribution power lines. If the computed/measured field values do not comply with the established guidelines, the corresponding protective measures should be applied for decreasing them to an acceptable level (i.e. active and passive shieldings, spatial rearrangements of ELF source equipment, surrounding fences, etc.).

This paper deals with the magnetic fields generated by the overhead power lines. It is to be noticed that the research has been focused only toward the technical aspects of field assessment, not considering the health effects. ELF magnetic fields from overhead transmission or distribution lines have been assessed via calculations or measurement procedures in many papers. Some of them are highlighted in this work [1]-[12].

The aim of this paper is to provide information whether satisfactory accurate computational field results at the maximal sag position arise from a simple modelling of a conductor by one straight segment, only. The comparison with the measurement results obtained at the maximal sag position is performed.

2 Power Line Modelling

The calculation technique based on a discrete approximation of the Biot-Savart law has been presented in [2], where each energised conductor has been divided into a corresponding number of straight segments approximating the conductor catenary curve. The maximum length of each segment has been fixed to 3 m. The approach provides the earth return currents to be included too, by taking into account the image currents placed below the earth's surface in accordance to the skin depth of the soil [1]. However, the influence of the image currents has been neglected in [2] for focusing the analysis on ELF range (50 or 60 Hz).

An additional simplification is undertaken in this paper. Namely, the real catenary curve of a conductor is substituted for a straight segment located at the height h_{min}, which is related to the maximal conductor sag, Fig. 1. Therefore, the required number of segments equals the total number of power line conductors only, thus providing reduction of the computational cost.

If linear mediums are concerned, the ELF magnetic field value in each spatial point can be assessed superposing the contributions of all conductors divided in a certain number of straight segments. A k-th straight segment with the current i_k placed in Cartesian three-dimensional co-ordinate system is shown in Fig.2. Using the Biot-Savart law the magnetic field value in the point *C*, generated by the current i_k, can be written by:

$$B_k(t) = \frac{\mu i_k(t)}{4\pi CD}\left(\frac{AD}{AC} + \frac{DB}{BC}\right), \qquad (1)$$

where the included distances are presented in Fig.2, while μ_0 is the magnetic permeability of the free space.

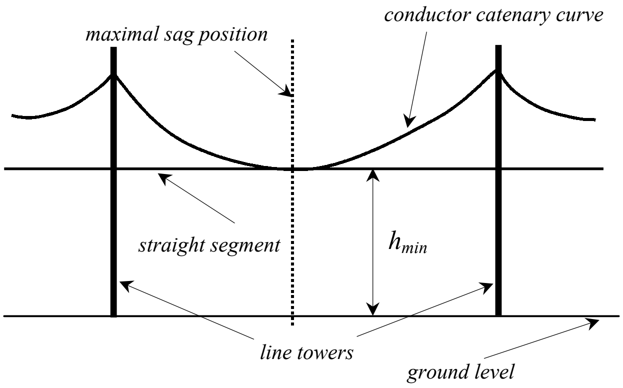

Fig. 1: Catenary curve and the related straight segment.

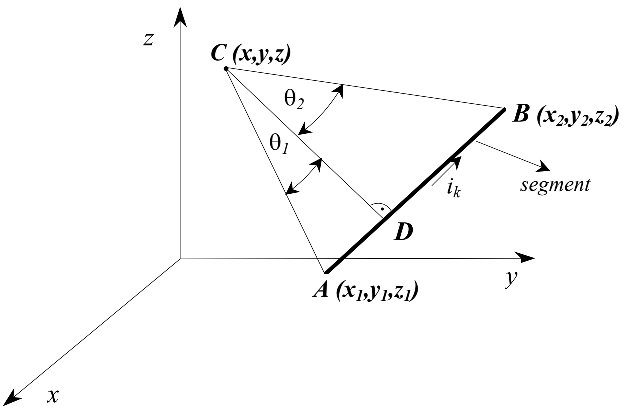

Fig. 2: Straight segment in Cartesian system.

The corresponding magnetic field components produced by the current of the *k*-th straight segment are given by:

$$B_{x,k}(t) = \cos\alpha_B \cdot B_k(t), \qquad (2a)$$

$$B_{y,k}(t) = \cos\beta_B \cdot B_k(t), \qquad (2b)$$

$$B_{z,k}(t) = \cos\gamma_B \cdot B_k(t), \qquad (2c)$$

where α, β and γ are the angles defined by the magnetic field vector $\vec{B}_k$ and co-ordinate axis *x*, *y* and *z*, respectively. The coresponding co-sine functions are given as follows:

$$cos\alpha_B = \frac{\Delta_y\delta_z - \Delta_z\delta_y}{\left((\Delta_y\delta_z - \Delta_z\delta_y)^2 + (\Delta_z\delta_x - \Delta_x\delta_z)^2 + (\Delta_x\delta_y - \Delta_y\delta_x)^2\right)^{\frac{1}{2}}}, (3a)$$

$$cos\beta_B = \frac{\Delta_z\delta_x - \Delta_x\delta_z}{\left((\Delta_y\delta_z - \Delta_z\delta_y)^2 + (\Delta_z\delta_x - \Delta_x\delta_z)^2 + (\Delta_x\delta_y - \Delta_y\delta_x)^2\right)^{\frac{1}{2}}}, (3b)$$

$$cos\gamma_B = \frac{\Delta_x\delta_y - \Delta_y\delta_x}{\left((\Delta_y\delta_z - \Delta_z\delta_y)^2 + (\Delta_z\delta_x - \Delta_x\delta_z)^2 + (\Delta_x\delta_y - \Delta_y\delta_x)^2\right)^{\frac{1}{2}}}, (3c)$$

where:

$$\Delta_x = x_2 - x_1, \qquad (4a)$$

$$\Delta_y = y_2 - y_1, \qquad (4b)$$

$$\Delta_z = z_2 - z_1, \qquad (4c)$$

$$\delta_x = x - x_2, \qquad (5a)$$

$$\delta_y = y - y_2, \qquad (5b)$$

$$\delta_z = z - z_2. \qquad (5c)$$

The total field components produced by the currents of *n* segments are assembled by adding the contributions of each segment. Hence, the total field value in a chosen spatial point written in Cartesian three-dimensional co-ordinate system is:

$$B(t) = \sqrt{\left(\sum_{i=1}^{n} B_{x,i}(t)\right)^2 + \left(\sum_{i=1}^{n} B_{y,i}(t)\right)^2 + \left(\sum_{i=1}^{n} B_{z,i}(t)\right)^2}. (6)$$

3 Computational Results

The technique is validated comparing the computational results with the experimental ones provided in [12]. A three-phase transmission power line *110 kV, 95 A* is considered, Fig.3. The heights shown in Fig.3 are related to the maximal sag position of the line phases. Thus, the total number of *3* conductors equals the required number of straight segments.

The lateral profiles of the magnetic field distribution at heights of $z = 1$ *m* and $z = 2$ *m* above the ground at the maximal sag position are presented in Figs. 3 and 4, respectively. As can be seen, a satisfactory agreement between the computational results and measurement data reported in [12] is obtained.

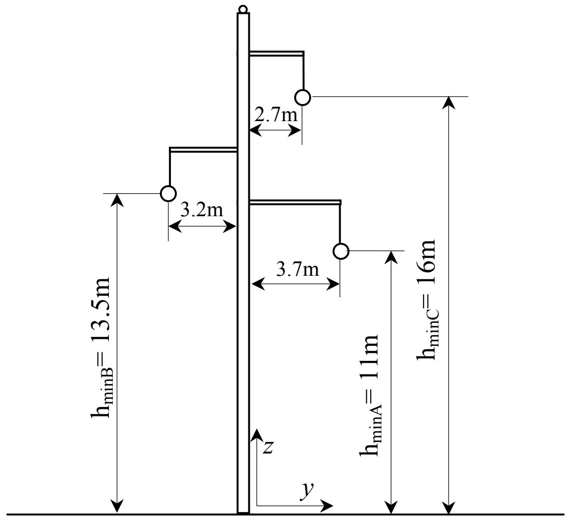

Fig.3: Transmission line configuration.

Also, the resulting error takes the "safe side" because of the computed values being greater than the measured ones. It could be expected since the straight segments are placed closer to the ground then the conductor catenary curves (except for the maximal sag position where the distances to the ground are equal).

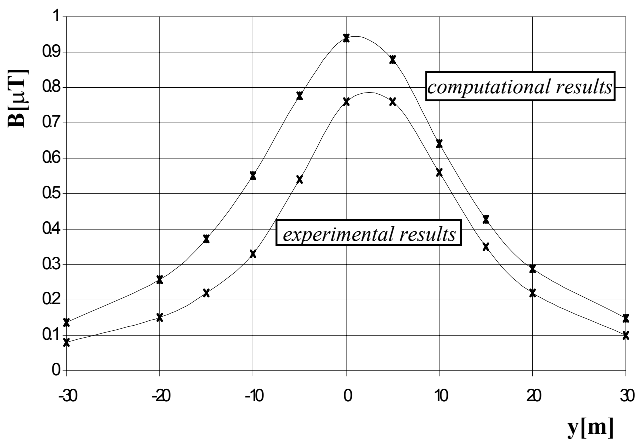

Fig.4: Lateral profile of the magnetic field distribution, *z = 1 m*.

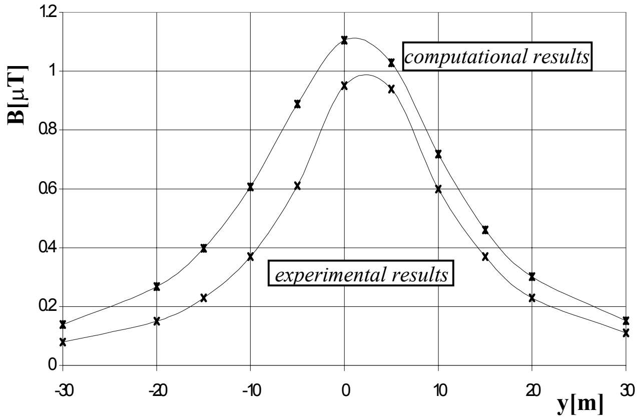

Fig. 5: Lateral profile of the magnetic field distribution, *z = 2 m*.

4 Conclusion

The analysis performed in this paper suggests that catenary curve of power line conductor may be substituted by straight segment for computing the lateral profiles of magnetic field. The profiles are related to the maximal sag position having the maximal magnetic field value, since the conductor heights are minimal there. Subsequently, the maximal field value could be compared to values arising from the (inter)national guidelines.

A reasonably accurate agreement between computational results and the experimental data is obtained.

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