CHARACTERISTICS OF MAGNETIC FIELD DISTRIBUTION UNDER TWO DOUBLE-CIRCUIT POWER LINES

T. Matsumoto[1*], H. Hirata[1], H. Tarao[2], N. Hayashi[3] and K. Isaka[4]
[1]Anan National College of Technology, Tokushima 774-0042, Japan
[2]Kagawa National College of Technology, Kagawa, 761-8058, Japan
[3]University of Miyazaki, Miyazaki 889-2192, Japan
[4]The University of Tokushima, Tokushima 770-8506, Japan
*Email: <matumoto@anan-nct.ac.jp>

Abstract: The transmission power lines are the typical facility which generates ELF magnetic fields. These are usually analyzed as double circuits of vertical line configuration or single circuit of horizontal line configuration. However, the overhead two vertical-type double-circuit power line is commonly used in Japan because of the limited space and reducing the construction cost. There are few analyses which considered the phase order configuration of two double-circuit line conductors to decrease magnetic fields in the vicinity of the ground. In this paper, a special emphasis is placed on the effect of the phase order on the total magnetic field distribution. It is found that although the electrical current of the two double-circuit lines carry twice as much as the single one, the maximum of the total magnetic field from the two double-circuit lines is decreased by arranging the phase order.

1 INTRODUCTION

With several epidemiological studies linking extremely low frequency (ELF) magnetic fields with higher rates of cancer, there is a concern in the public mind regarding the potential health effects of these fields [1]-[6]. Although pooled analysis of magnetic fields and childhood leukemia, pooled analysis of magnetic fields and childhood brain tumors have been done, it did not prove relevant evidence [7]-[9]. Epidemiological studies and in vivo and in vitro experimental studies have been carried out recently [10]-[12]. As a trend of Guidelines, WHO published Environmental Health Criteria 238 from the collective views of an international group of experts in 2007. In response to this, ICNIRP published new Guidelines in 2010. The previous Guidelines in 1998 were replaced with this [13]-[15]. Meanwhile, IEEE published Standard for Safety Levels for Low Frequency (0Hz-3kHz) in 2002 and the one for high frequency (3kHz-300GHz) in 2005 [16], [17].

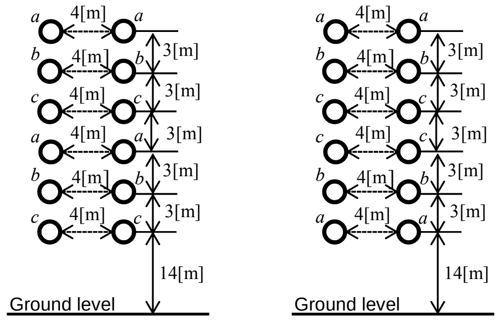
Transmission power lines are a typical facility which generates ELF magnetic fields and are usually analyzed as double circuits of vertical line configuration or single circuit of horizontal line configuration[8]-[21]. There are few analyses which considered the phase order configuration of two double-circuit line conductors to decrease magnetic fields in the vicinity of the ground. The vertical-type two double-circuit power lines used typically in Japan are shown in Figure 1. In this paper, it is found that the phase order configurations affect the total magnetic field in the vicinity of the ground under the power lines by computer calculation.

Figure 1: Vertical-type two double-circuit power lines

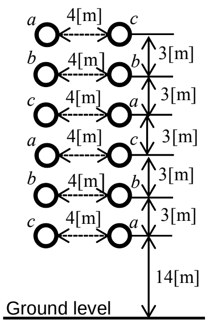
2 CALCULATION METHOD

2.1 Calculation Model

The transmission line model is an overhead vertical-type double-circuit power line, which is commonly used in Japan because of limited space and reduced construction cost. It is assumed in this calculation of magnetic fields generated by high voltage transmission lines that the line conductors are placed in parallel with flat ground, and that the line conductors carry a three-phase balanced current of 100 A. The magnetic shielding effects of the steel tower and the ground wire are ignored. Fig. 2 shows the power line configuration used in the calculation model.



(a) Same phase order (b) Reverse phase order



(c) Different phase order

Figure 2: Power lines configurations

2.2 Calculation Conditions

The magnetic fields are calculated at a height of 1 m above the ground and are the vector sum of 3-dimensional magnetic field components with the phase difference among the line currents. Total magnetic field at a point is the maximum value obtained by composing the magnetic field components.

2.3 Total magnetic field at a point

Since the double-circuit power lines consists of 12 lines each of which has a different phase angle, the summation of the magnetic fields of each line current must be calculated at any point. The magnetic field component on each axis should be added vectorially, for the components are complex vector quantities. According to the phase differences of the magnetic field components, the vector of the total magnetic field at a point rotates on the locus of an ellipsoid in a plane shown in Figure 3. Here, we present the equations on how to compound the total magnetic field by vector operations. If the magnetic field is decomposed as the components of $\vec{H}_x, \vec{H}_y$ and $\vec{H}_z$, they are expressed by the equations (1)-(3), respectively. Where, ω is phase velocity. The angle θ_x, θ_y, and θ_z are the phase angles of the line current respectively.

$$\vec{H}_x = H_x \cos(\omega t + \theta_x)\hat{x} \quad (1)$$

$$\vec{H}_y = H_y \cos(\omega t + \theta_y)\hat{y} \quad (2)$$

$$\vec{H}_z = H_z \cos(\omega t + \theta_z)\hat{z} \quad (3)$$

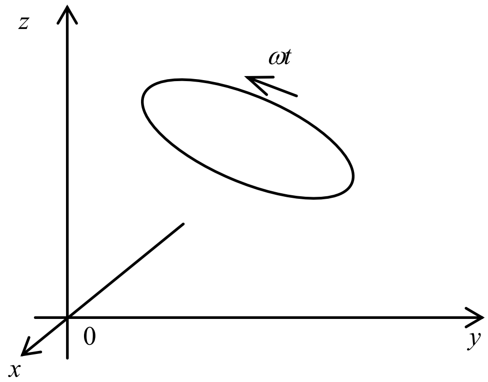


Figure 3: Lucas of the total magnetic field

The total magnetic field is expressed by equation (4) in vector operations. In other words, the equation (4) indicates the locus of an ellipsoid in Figure 3.

$$\left|\vec{H}\right| = \sqrt{H_x^2 \cos^2(\omega t + \theta_x) + H_y^2 \cos^2(\omega t + \theta_y) \; H_z^2 \cos^2(\omega t + \theta_z)} \quad (4)$$

As is evident from Figure 3, the angle ωt_0 at which $\vec{H}$ becomes maximum or minimum satisfies the following condition:

$$\left.\frac{d\left|\vec{H}\right|^2}{dt}\right|_{t=t_0} = -2\omega\{H_x{}^2 \sin(\omega t_0 + \theta_x)\cdot\cos(\omega t_0 + \theta_x) + H_y{}^2 \sin(\omega t_0 + \theta_y)\cdot\cos(\omega t_0 + \theta_y) + H_z{}^2 \sin(\omega t_0 + \theta_z)\cdot\cos(\omega t_0 + \theta_z) \equiv 0 \quad (5)$$

Here, t_0 is the time at which the maximum H appears. From equation (4) and (5), the maximum magnetic field can be determined and the total magnetic field is determined. Magnetic flux density is obtained from equation(6). In this paper, the word " magnetic flux density " is simply referred to as " magnetic field ".

$$B=\mu H \tag{6}$$

The peak of the total magnetic field as an effective value, in other words the length of the major semi-axis of the total magnetic field, is adopted in this calculation. These calculations are repeated at each point, and the distribution of the magnetic field is obtained.

3 CALCULATION RESULTS

We compare the three vertical-type double-circuit lines having different phase order. The maximum of the total magnetic field is 1.1 μT in the case that the phase order is (abc-abc)(abc-abc) shown in Figure 4. If the phase order of lower double-circuit is changed partially, the maximum magnetic is also changed. In the case of the phase order (abc-abc)(cba-cba), the maximum of the total magnetic field is 0.48 μT.

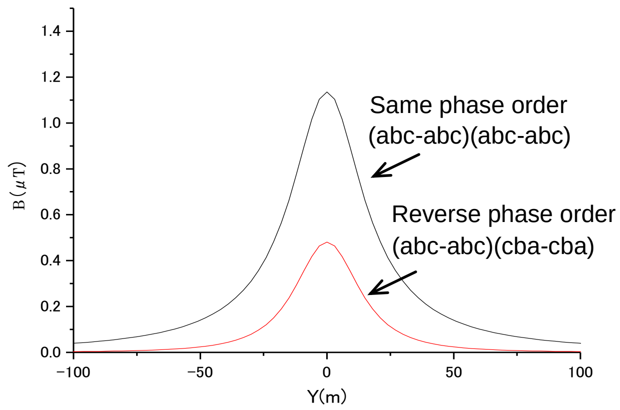


Figure 4: Magnetic field distributions under power line of two double circuits with (abc-abc)(abc-abc) and (abc-abc)(cba-cba)

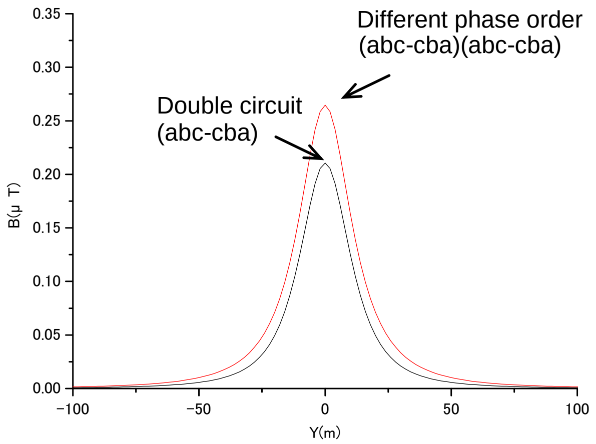


Figure 5: Magnetic field distributions under power line of double circuit with (abc-cba) and two double circuits with (abc-cba)(abc-cba)

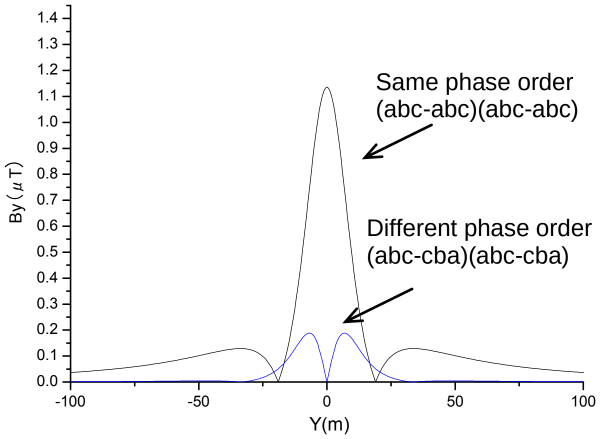


Figure 6: Distributions of horizontal magnetic field components under power line of two double circuits with (abc-abc)(abc-abc) and (abc-cba)(abc-cba)

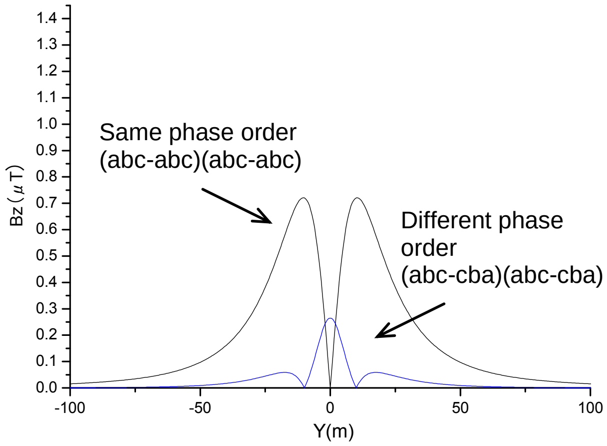


Figure 7: Distributions of vertical magnetic field components under power line of two double circuits with (abc-abc)(abc-abc) and (abc-cba)(abc-cba)

It is decreased by 56 %. Furthermore, the maximum of the total magnetic field is 0.80 μT in the case of a power line(abc-abc). It is found that although the electrical current of the two double-circuit lines carry twice as much as the single one, the maximum of the total magnetic field from the two double-circuit lines is decreased by 40 %.

Usually, the phase order of two double-circuit is symmetry for high voltage power lines. If the phase order is (abc-cba)(abc-cba) showed in Figure 2(c), the maximum value of total magnetic field is reduced more showed in Figure 5.

Distributions of horizontal and vertical magnetic field components under power line of two double circuits with (abc-abc)(abc-abc) and (abc-cba)(abc-cba) are shown in Figure 6 and 7. The maximum of the total magnetic field is dominated by the horizontal component in the case that the phase order is (abc-abc)(abc-abc). Meanwhile, the maximum is dominated by the vertical component in the case of (abc-cba)(abc-cba).

4 CONCLUSION

We compare the three vertical-type double-circuit lines having different phase order. The maximum of the total magnetic field is 1.1 μT in the case that the phase order is (abc-abc)(abc-abc). If the phase order of lower double-circuit is changed partially, the maximum magnetic is also changed. In the case of the phase order (abc-abc)(cba-cba), the maximum of the total magnetic field is 0.48 μT. It is decreased by 56 %. Furthermore, the maximum of the total magnetic field is 0.80 μT in the case of a power line(abc-abc). It is found that although the electrical current of the two double-circuit lines carry twice as much as the single one, the maximum of the total magnetic field from the two double-circuit lines is decreased by 40 %. And the magnetic field component which effects on the maximum of total magnetic field depends on the phase order.

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