Magnetic field asymmetry at external phases of shielded single-pole three-phase flat high-current busduct

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Abstract. The article shows the total magnetic field distribution in two outer conductors of the flat, three-phase single-pole shielded, high-current busduct is asymmetric. The phase currents in the shielded conductors decide about the magnetic field of such a high-current busduct. The components of this field reflect the magnetic field of the reverse reaction fields of the eddy currents induced in the conductors of the adjacent phases as the results of the proximity effect and the skin effect. The field distribution is shown in the outer area of the outer phases as the function of the parameters reflecting the current frequency, the conductivity, and the transverse dimensions of the tubular conductors.

1 Introduction

In solutions for shielded high-current busducts, a three-phase single-pole flat high-current line is used very often - Figure 1.

Fig. 1. Three-phase flat high-current busduct with isolated phases manufactured by the Holduct company (Myslowice, Poland).

EMFs generated by the alternating magnetic field of currents in phase conductors are induced in the high-current busduct shields. If these shields are shorted inter se or earthed, then so called return currents [1] will occur in them. Values of these currents depend on methods of shield connection inter se, earthing methods and electrical parameters of the shielded high-current busduct, i.e. self-impedances of phase conductors and shields as well as mutual impedances between conductors and shields [2]. These fields of power frequency affect their own elements and the broadly understood environment [3] - other electrical devices and apparatus, steel structures, electronic control [4,5], computers [6,7] and data transmission circuits, the natural environment and the humans [8].

The metal shield for the own phase conductor is the so called open screen and this means that the magnetic field in its external area is the same as in case of lack of shield. The own magnetic field in this area is equal to the field generated by the thread phase conductor with its own phase current. This means that the tubular phase conductors can be replaced with thread conductors [2] with currents $\underline{I}_1$, $\underline{I}_2$ and $\underline{I}_3$ respectively - Figure 2.

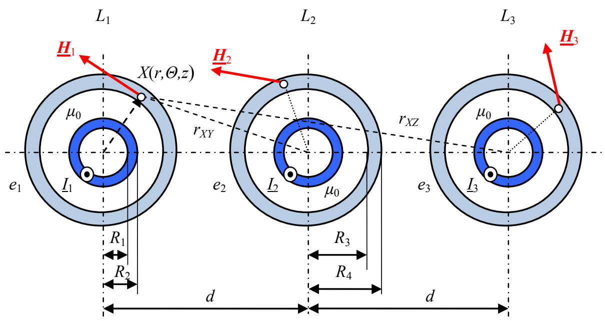

Fig. 2. Three-phase single-pole flat shielded high-current busduct.

It was shown in the work that the magnetic field distribution in two external conductors of the three-phase flat shielded high-current busduct is not equal in spite of symmetry [9] of the system geometry.

2 Magnetic field distribution

In the shielded flat three-phase high current busduct, as shown in Figure 2 we assume a symmetrical threesome of phase currents, i.e. [1,2]

$$\underline{I}_2 = \exp[-\mathrm{j}\frac{2}{3}\pi]\,\underline{I}_1 \quad \text{and} \quad \underline{I}_3 = \exp[\mathrm{j}\frac{2}{3}\pi]\,\underline{I}_1 \qquad (1)$$

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The total magnetic field outside of the conductors of the outer phases can be express with the following formulas [1,2]

$$\underline{\boldsymbol{H}}_1^{ext}(r,\Theta) = \underline{\boldsymbol{H}}_{11}^{ext}(r) + \underline{\boldsymbol{H}}_{12}^{ext}(r,\Theta) + \underline{\boldsymbol{H}}_{13}^{ext}(r,\Theta) = \\ = \underline{\boldsymbol{H}}_{11}^{ext}(r) + \underline{\boldsymbol{H}}_{123}^{ext}(r,\Theta) \quad (2)$$

and

$$\underline{\boldsymbol{H}}_3^{ext}(r,\Theta) = \underline{\boldsymbol{H}}_{33}^{ext}(r) + \underline{\boldsymbol{H}}_{31}^{ext}(r,\Theta) + \underline{\boldsymbol{H}}_{32}^{ext}(r,\Theta) = \\ = \underline{\boldsymbol{H}}_{33}^{ext}(r) + \underline{\boldsymbol{H}}_{321}^{ext}(r,\Theta) \quad (3)$$

The $\underline{\boldsymbol{H}}_{11}^{ext}(r)$ and $\underline{\boldsymbol{H}}_{33}^{ext}(r)$ fields have tangent components only [2]. Therefore, the above vector summing up can be limited to the summing up of the relevant tangent components. That summing up is an operation in the complex number domain, hence the complex sums of tangent components [1,2]

$$\underline{H}_{1\Theta}^{ext}(r,\Theta) = \underline{H}_{11\Theta}^{ext}(r) + \underline{H}_{12\Theta}^{ext}(r,\Theta) + \underline{H}_{13\Theta}^{ext}(r,\Theta) = \\ = \underline{H}_{11\Theta}^{ext}(r) + \underline{H}_{123\Theta}^{ext}(r,\Theta) \quad (4)$$

and

$$\underline{H}_{3\Theta}^{ext}(r,\Theta) = \underline{H}_{33\Theta}^{ext}(r) + \underline{H}_{31\Theta}^{ext}(r,\Theta) + \underline{H}_{32\Theta}^{ext}(r,\Theta) = \\ = \underline{H}_{33\Theta}^{ext}(r) + \underline{H}_{321\Theta}^{ext}(r,\Theta) \quad (5)$$

are determined not only by the modulus values of the sum components, but also their amplitudes, and more precisely the difference of the amplitudes. The distribution of these differences for the outer phases is shown in Figure 3.

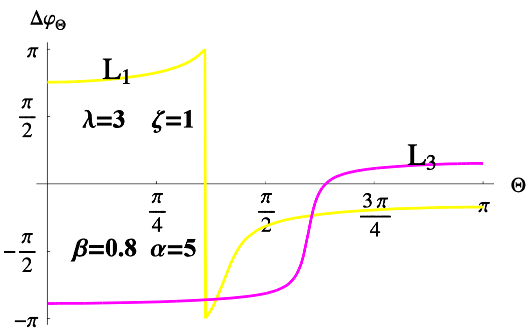

Fig. 3. The distribution of the differences of the amplitudes of the field tangent component of the own phase and the tangent component of the field outside (without the magnetic field of the own phase) of the outer phases of a three-phase single-pole flat high-current busduct with symmetrical currents $\underline{I}_1$, $\underline{I}_2$ and $\underline{I}_3$ ($\lambda = d/R_4$ ($\lambda \geq 1$), $\xi = r/R_4$, $\beta = R_3/R_4$ ($0 \leq \beta < 1$), $\alpha = R_4/\delta = R_4\sqrt{(\omega\mu\gamma)/2}$).

As it can be seen in Figure 3, despite the fact the modulus values of the own fields of individual phases and the modulus values outside of the outer phases are the same the relevant sums of the tangents components in the complex number domain will not have the same modulus values. Therefore, the total magnetic field with the consideration of the magnetic field of the own phase outside of the outer phases is not accordingly symmetrical - Figure 4.

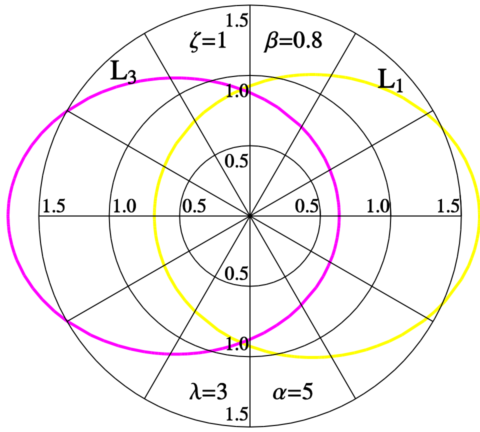

Fig. 4. The distribution of the modulus values of the total magnetic field outside of the conductors of the outer phases of a three-phase single-pole flat high-current busduct with symmetrical currents $\underline{I}_1$, $\underline{I}_2$ and $\underline{I}_3$.

3 Conclusions

The magnetic field distribution in the outside of the phase shield L_3 is not symmetrical to the corresponding distribution in the phase shield L_1 (Figure 4). This results from different vectors of the resultant magnetic field coming from the conductors neighbouring to the shield L_1 and the shield L_3.

This asymmetry increases with the increase of the current frequency, the electrical conductivity, and the outer radius of the conductors.

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