STUDY ON MAGNETIC FIELD REDUCTION NEAR POWER LINE

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Abstract: A possibility of power frequency magnetic field reduction in buildings near power line is studied in this paper. Magnetic flux density in the houses near the 110 kV power line was both measured and calculated. Numerical modeling of the problem shows that the simple shields mounted on the wall, ceiling or roof will not produce considerable magnetic field reduction. Different line configuration seems to be the best option for magnetic field mitigation.

Key Words: power line / passive shielding

1. INTRODUCTION

A possibility of magnetic field reduction in vicinity of the 110 kV power line is studied in this paper. The photograph of the examined line is shown in Fig. 1. Some residential houses are situated 40 m away from the 15 m high power line, as illustrated in Fig. 2.

The measurements were performed using the Narda EFA-300 EM field analyzer [1]. Both electric and magnetic field strengths were measured at a grid of a 2 m step, 1 m above the ground. All measured quantities were found to be below the exposure reference limits [2], [3]. The highest measured value of the magnetic flux density inside the observed house, 1 m above the floor, was 0.24 μT at the time of the measurements (noon, end of July). The corresponding root mean square (rms) power line current was \( I = 180A \). Power frequency magnetic fields are characterized by seasonal and daily variations. The maximum rms current for the season is estimated to be 420A. Hence, the highest magnetic flux density inside the observed house would exceed 0.5 μT.

Inhabitants of urban regions are increasingly exposed to power frequency magnetic fields. There are two typical exposure scenarios: short time high level exposures and long time low level exposures [4]. Basic restrictions proposed by the ICNIRP are established based on acute biological effects with the large safety factors included. The relationship of the low level magnetic field exposure and any long term effect has not yet been established. Therefore, these effects are not included in the basic restrictions [2]. Some findings show that an excess health risk may exist for average exposures exceeding 0.3 – 0.4 μT [2]. Thus, in spite of the fact that the ICNIRP established a continuous magnetic field exposure limit of 200 μT [2] and our national rule book [3] established the limit of 40 μT at 50 Hz, a restrictive value of 0.2 μT was adopted as a safety goal in our work.

In order to reduce the initial magnetic flux density, shielding with simple horizontal and vertical metallic plates is considered. In the calculations, materials with high conductivity, such as copper or aluminum, are modeled as perfect electric conductors (PEC). Materials with high permeability, such as iron, are modeled as perfect magnetic conductors (PMC). Combination of the two materials, denoted by PEC+PMC is also considered.

Since examined shields did not produce enough magnetic field reduction, some other options, such as split phase arrangement [5] are considered too.

2. PROBLEM DESCRIPTION

Mathematical model for the magnetic field calculation is based on many simplifications. The houses are assumed perpendicular to the power line, as shown in Fig. 2. Therefore two dimensional analysis is applicable.
Balanced three phase currents distribution was assumed for the power line.

The geometry of the power line for the calculation of the unperturbed magnetic field is presented in Fig. 3. The houses are assumed to be nonmagnetic and their influence on the magnetic field is neglected. The influence of the earth on the magnetic field in the vicinity of the power line is known to be very small; hence we do not take it into account. The initial magnetic flux density vector is calculated in the space occupied by the buildings prior placing the shields, by summation of the respective vectors,

\[
\vec{B}(x, y) = \sum_{i=1}^{N} \frac{\mu_0 I_i}{2\pi} \left( \frac{x-x_i}{r_i^2} \hat{i} + \frac{y-y_i}{r_i^2} \hat{j} \right)
\]

where \( \mu_0 \) is the free space permeability, \( N \) is the number of the phase conductors, \( I_i \) is the phasor of the current, \( x, y, x_i, y_i \) are the coordinates outlined in Fig.3 and \( r_i \) is the distance from the \( i \)th conductor.

The resultant magnetic flux density \([6]\) is calculated according to

\[
B = \sqrt{B_x^2 + B_y^2},
\]

where \( B_x \) and \( B_y \) are rms values of the magnetic flux density components. The distance between the central conductor and the closest point of the house is 40 m. The power line has only one conductor per phase. The heights of all phase conductors are 15 m. According to the coordinate system depicted in Fig. 3, the power line conductors are horizontally positioned at -5.5 m, 0 m and +5.5 m.

Fig. 3. The geometry of the model.

Calculated magnetic flux for the rms \( I=180A \) versus distance, 1 m above ground, is presented in Fig. 4, together with the measured values. The measured values are higher than the calculated. One possible explanation for this is that the measurements have been affected by the power sources other than the power line, such as ground currents. It is also possible that the power line currents have not been ideally balanced.

Fig. 4. Magnetic flux density 1 m above the ground as a function of the distance from the power line, \( I=180A \).

3. RESULTS

3.1. Results of the shielding

The magnetic field is altered when the shields are present. The effects of the PEC, PMC or a combined PEC+PMC shields are studied using conformal mapping \([7], [8]\). The shields are assumed to be plates of finite width, infinite length and infinitesimal thickness, so that the 2D analysis holds.

Shielding factor (shielding effectiveness) \( S \) is defined as the ratio of the magnetic flux density after the shielding to the magnetic flux density prior the shielding,

\[
S = \frac{B_{with\ shield}}{B_{without\ shield}}.
\]

The lower value of \( S \) means better magnetic field reduction. The value of \( S \) higher than one signifies that the magnetic field is stronger after than before the shielding. The numbers in Figs. 6 to 10 stand for the shielding factor, which, according to (3), relate the new values of the magnetic flux density to the respective old values at the same points, but without the shield.

According to the nature of the buildings, only shields in the form of plates layered on the wall or on the top of the roof and ceiling were acceptable. Several configurations of the wall and roof mounted shields are explored based on the simple geometries. For simplicity, only perfect electric conductor (PEC), perfect magnetic conductor (PMC) and the combination of the two were considered. Some of the results are presented in Figs. 6 and 7. As can be seen from Figs. 6 and 7 the shields only modify the magnetic field distribution, but do not reduce the magnetic field to a large extent. All examined shields that can be mounted on easily accessible places (walls, roofs, or ceilings), PEC, PMC, or the combination of the two, do not substantially reduce the magnetic field.

Fig. 5 shows contour plots of the calculated resultant magnetic flux density around the house, both for the rms value of the current at the time of the measurements, 180 A, and for the maximum estimated current, 420 A.

![Fig. 5. Calculated resultant magnetic flux density in \( \mu T \) around the house for a) \( I=180A \), b) \( I=420A \).](image)
Numerical models show that shielding factor is higher if the shields are inserted into foundation (Figs. 8-10). Procedure like this is almost impossible once the building is erected and inhabited. The placement of the shield into the foundation is only feasible for the new buildings. Both PEC and the combination PEC+PMC shields inserted into foundation may work well. The choice of the particular material can target the field cancellation in certain rooms and provide a better field distribution in rooms where for instance inhabitants spend most of the day (Figs. 8 and 10.)

Magnetic field leakage around the edges of the planar shields, as seen from Fig. 6-10, is significant.

In order to validate our calculations, tests were performed using commercially available software. Simple 2D problems were considered using both conformal mapping and COMSOL [9]. Dimensions of the test examples are much smaller than the dimension of the examined system. In all cases, for high conductivity shields, high permeability shields, as well as for the two layer shields, satisfactory agreement was found between
the results obtained by our calculations and the results obtained by COMSOL.

3.2. The other options of the magnetic field reduction

The other options of the magnetic field reduction were considered too. They include
- adjustment of the height and span of the conductors,
- change of the distance between the phases,
- use of the different line geometry,
- re-arrangement of the line into a split-phase line [5].

Fig. 11. Re-arrangement of the line into a split-phase line.

When the phases of the power line are split into two conductors each, along with the suitable phase sequence, as illustrated in Fig. 11, it is possible to significantly reduce the magnetic field inside the neighboring buildings. The magnetic field reduction in the vicinity of the 110 kV split phase power line is presented in Fig. 12. The numbers in Fig. 12 relate the new values to the respective old values of the magnetic flux density at the same points, but before re-arrangement of the line into a split-phase line. This definition of the magnetic flux density reduction is analogous to the definition of shielding factor (3).

The calculations show that the magnetic field can be noticeably reduced by the re-arrangement of the line into a split-phase line.

Fig. 12. Magnetic field reduction obtained with a split-phase line.

4. CONCLUSIONS

The results of the numerical analysis show that the PEC, PMC and the combination PEC+PMC shields of the simple geometries, placed on easily accessible walls, roof or ceiling do not create desired magnetic field reduction in the buildings close to a 110 kV power line. PEC, PMC or the combination PEC+PMC plates, integrated into the foundation of the buildings during their development offer a possibility of the magnetic field mitigation. Re-arrangement of the power line into the split-phase configuration can produce a significant magnetic field reduction inside the buildings.

5. REFERENCES


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