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Mitigation of Low Frequency Magnetic Field Emitted by 10/0.4 kV Substation in the School

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ABSTRACT

The article is related to mitigation of magnetic field emitted by a 10/0.4 kV substation located in a primary school in Belgrade, Serbia. During the first testing in the classroom located directly above the substation, the measured values of magnetic flux density significantly exceeded the reference level of 40 μT prescribed by Serbian legislation, and it was concluded that the field levels at the transformer rated load could exceed the reference level of 100 μT prescribed by European Council Recommendation 1999/519/EC. For that reason, the 0.4 kV busbars located near the ceiling of the substation were removed and replaced with cables that were placed on the floor of the substation. The testing was repeated and the measured values as well as the values at the rated load were lower than 40 μT. However, above the locations where the cables were connected to the transformer and to the 0.4 kV switchboard, the field levels were still higher than in the rest of the classroom. The focus of this article is to analyze different solutions based on passive shielding for the reduction of magnetic field in these two areas. Seven solutions based on conductive shields with different geometries are analyzed. The substation and the shields are modeled by using appropriate software tools to determine which shield is the most effective. In the case of Solution 7, the lowest field values were obtained. The highest value of magnetic flux density in this case was 6.95 μT at the transformer rated load.

1 | Introduction

The topic of the article is related to mitigation of low frequency magnetic field emitted by a 10/0.4 kV substation located in the basement of a primary school in Belgrade, Serbia. During the first measurement in the classroom for preschool children located directly above the substation, the measured values of magnetic flux density significantly exceeded the reference level prescribed by Serbian legislation [1–3] at several measurement points. The Rulebook [2] established the reference level of 40 μT for magnetic flux density. This reference level refers to the power frequency field (50 Hz) inside the increased sensitivity areas that include "residential areas where people can stay 24 hours a day, schools, homes, preschools, maternity wards, hospitals, tourist facilities, children playgrounds, and areas of undeveloped parcels intended for specified purposes, according to the urban development plan." Based on the obtained measurement results, it was concluded that the field levels could also exceed the reference level of 100 μT prescribed by European Council Recommendation 1999/519/EC [4] in the large part of the classroom during the period of the transformer rated load. For the abovementioned reasons, the measures for reducing the magnetic field levels were urgently implemented and the measurements were repeated [5]. The measured values as well as the values of magnetic flux density that would occur at the rated load of the transformer were lower than 40 μT. However, in two areas of the classroom, above the location where the cables were connected to the transformer and to the 0.4 kV switchboard, the field levels were still higher than in the rest of the classroom. For

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that reason, it is necessary to analyze different solutions for the additional reduction of magnetic field in these two areas, which is the main topic of this paper. In this article, we consider passive shields [6–16], more specifically, the analyzed solutions are based on conductive shields made of aluminum with different geometries, with the aim to determine the most effective solution.

2 | Methods

2.1 | Measurements

The magnetic flux density measurements in the school were carried out in accordance with the requirements of the relevant standards [17–20]. During the testing, the RMS values of magnetic flux density were measured isotropically, using a magnetic field analyzer connected to the isotropic probe for magnetic field measurements [18, 19]. Electric field testing was not performed because it is theoretically known that in these cases electric field levels are negligible [20].

The measurement points were placed along horizontal measurement profiles at the height of 1 m from the classroom floor, as well as along vertical profiles, at the heights of 0, 0.5, 1, 1.5, and 2 m, with the specified order. When the field source is located below the floor and there is a reasonable possibility that a person is likely to lie down above it, five-point measurements at the height of 0.2 m above the floor should be performed as well, in accordance with the requirements of the standard [20]. In the analyzed case, a group of preschool children spends a lot of their time in the classroom, playing and lying on the classroom floor directly above the substation. For that reason, five-point measurements were performed at a height of 0.2 m from the classroom floor [20].

Since the magnetic field is proportional to the currents, the transformer load currents were measured in all three phases during the entire period of magnetic flux density measurements.

When estimating the highest possible levels of magnetic flux density, it is necessary to take into account the highest possible load of the magnetic field source, that is, the transformer rated current.

2.2 | Formulation

The evaluation of a shielding performance is a multiscale problem because, in a relatively large volume (e.g., a substation), we have to consider the presence of cables, which can be considered filamentary sources, and passive shields, which are usually made of thin metal plates. In these cases, it is convenient to avoid volume formulations (e.g., finite-element method) because it is hard to find a good trade-off for meshing elements with such different aspect ratios. For these types of problems, integral methods should be preferred. They do not require the air to be meshed, allowing different aspect ratios to be conveniently considered, and therefore, the result is more stable and accurate compared to volume methods [13–15, 21].

In this article, the magnetic field sources are power cables. They can be considered filamentary sources divided into straight segments. It is easy to apply the Biot-Savart law to calculate the magnetic flux density due to each segment [22].

The literature shows that the shielding effectiveness of a ferromagnetic material is very high close to the shield but decreases rapidly away from the shield. Ferromagnetic materials are often the preferred solution for closed shielding [9, 23]. Conversely, a conductive material provides a lower shielding efficiency close to the shield, but the decrease in performance with distance is less. For this reason, the conductive material is often preferred for open shielding [8]. Moreover, aluminum plates are usually lighter and less expensive compared to other conductive materials (e.g., copper). Keeping all this in mind, in this article, all shielding solutions are made of aluminum material. The numerical model used in this article to treat thin conductive plates is the low-frequency PEEC formulation [24–26], which is based on the circuit interpretation of the terms of the low-frequency electric field integral equation (EFIE):

$$\frac{\vec{J}(\vec{r})}{\sigma} + \frac{\partial \vec{A}(\vec{r})}{\partial t} + \nabla \varphi(\vec{r}) = 0 \tag{1}$$

where $\vec{J}(\vec{r})$ is the current density, σ is the electrical conductivity, and $\vec{A}(\vec{r})$ and $\vec{\varphi}(\vec{r})$ are the magnetic vector and electric scalar potential, respectively. The problem is solved by discretizing (1) on two systems of surface cells linked by duality relations [27]. Variables are associated to elements defined on both meshes: scalar potentials are assigned to primal nodes, voltage drops to primal edges, and currents to dual faces. The basic idea is to consider the thickness of the shield small enough to neglect the variation of quantities along its depth (δ), thus considering the shield as a two-dimensional surface. The problem is discretized by expanding current densities by linear shape functions. The same functions are also used as test functions in a Galerkin weighted residual scheme. The result is the interpretation of Equation (1) as a branch constitutive equation, having as electric parameters:

- Partial self and mutual inductances, representing the magnetic field couplings:

$$L_{k\alpha,h\beta} = \frac{\mu_0}{4\pi} \int_{\Omega_k} \vec{w}_{k\alpha} \cdot \int_{\Omega_h} \frac{\vec{w}_{h\beta}}{r_{kh}} d\Omega_h d\Omega_k \tag{2}$$

where μ_0 is the magnetic permeability of air and r_{kh} is the relative distance between k and h cells.

- Resistive terms between nodes, representing the Joule losses in the conductive material (only local coupling):

$$R_{k\alpha,h\beta} = \frac{1}{\delta_k \sigma_k} \int_{\Omega_h} \vec{w}_{k\alpha} \vec{w}_{h\beta} d\Omega_h d\Omega_k \tag{3}$$

In the previous formulas, indices h and k are associated with cells, while α and β are generic edges of cell k. $\vec{w}_{k\alpha}$ is the vector basis function associated with αth edge of cell k which is used to expand the current density inside each cell [27].

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Figure 1 shows an elementary discretization and the corresponding circuit branch. An electrical node is placed corresponding to the barycenter of each element. A circuit branch connects two neighboring nodes. The electrical parameters of the lth branch are the resistance R_{ll} and the self-inductance L_{ll}. Magnetic mutual coupling is taken into account by the current controlled voltage source $e_l(t)$. For a low frequency problem, the typical capacitive term of the PEEC formulation is missing. In this way, a field problem with generic geometry can be solved using standard circuit Spice-like simulators. The formulation is quite general, as both unstructured and structured networks can be easily included [27]. The model is verified by comparing the obtained results with the measurement results. For each analyzed solution, the shielding factor (SF) is also calculated, as the ratio between magnetic flux density values before and after mitigation at the specified point. Furthermore, by means of the lumped parameters defined in (3), it is straightforward to compute Joule losses in the shield.

3 | Results and Discussion

3.1 | Magnetic Field Source

The source of magnetic field is the 10/0.4 kV substation located in the basement of a primary school, which consists of a 1000 kVA transformer, an MV switchboard (10 kV) and an LV switchboard (0.4 kV). The value of transformer rated current, derived from its rated power of 1000 kVA, amounts to 1443.4 A at the 0.4 kV voltage level.

3.2 | First Magnetic Field Testing

During the first testing the measurements were performed in the rooms located on the first floor of the school. These rooms were chosen because the levels of magnetic field are the highest in the rooms that are the closest to the substation. The highest values of magnetic flux density were measured in the classroom located directly above the substation. Measured values of magnetic flux density significantly exceeded the prescribed reference level of 40 μT at several measurement points. The highest value of magnetic flux density, which amounted to 84.10 μT, was measured at the height of 0.2 m from the classroom floor. During the testing the transformer load was between 24% and 38% of the rated load. Detailed results of this measurement are shown in [5].

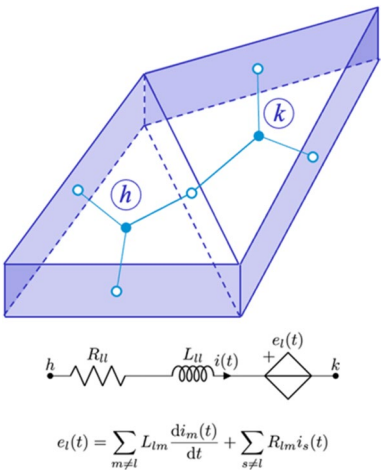


FIGURE 1 | Elementary discretization and the corresponding circuit branch (PEEC).

Having in mind that high levels of magnetic flux density were measured at the transformer load of 24%–38% of its rated power, the results were extrapolated, and it is estimated that the levels of magnetic flux density could have exceeded the value of 100 μT in the large part of the classroom during the period of the transformer rated load.

3.3 | Magnetic Field Mitigation

The 0.4 kV busbars located near the ceiling of the substation, that is, directly under the classroom floor, were identified as the main source of magnetic field. For that reason, the busbars were removed (Figure 2) and instead of them cables connecting the transformer to the LV switchboard were placed on the floor of the substation.

The situation after the reconstruction of the substation is shown in Figures 3 and 4. The applied technique was based on the increase in distance between the magnetic field source and the protected area.

3.4 | Second Magnetic Field Testing

After the implementation of measures, the magnetic field testing was repeated.



FIGURE 2 | Removal of 0.4 kV busbars.



FIGURE 3 | The 0.4 kV switchboard.

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FIGURE 4 | The 10/0.4 kV transformer.

Magnetic flux density measurements within the classroom were made at 155 points. The measurement points were distributed along 8 horizontal measurement profiles (P1–P8) set at 1 m height, 9 vertical profiles (V1–V9), while five-point measurements were carried out at 5 locations at 0.2 m height. The locations of measurement points are shown in Figure 5.

The results of magnetic flux density measurements are shown in Figures 6 and 7. It can be concluded that measured values did not exceed the prescribed reference level of 40 μT at any of the measurement points.

The highest value of magnetic flux density of 7.03 μT was measured at point No. 123, which is located at a height of 0.2 m measured from the room floor. The reason why the magnetic flux density levels at point No. 123 and surrounding points (124–128) are higher compared to the levels in the rest of the classroom is because the cables are connected to the transformer below that location, and consequently, their distance to the classroom floor is smaller. Another area with increased magnetic field levels is above the location where the cables are connected to the 0.4 kV switchboard.

During the measurements, the transformer load was between 18% and 36% of the rated load.

It is concluded that the magnetic flux density levels would not exceed the prescribed reference level of 40 μT at the maximum designed load of the substation. However, the unfavorable particular situation of exposure should also be taken into account because the children of the age of 6 spend a great deal of time playing and lying on the floor of the classroom, which leads to direct exposure of the central nervous system, which is the most sensitive to low frequency non-ionizing radiation. For these reasons, the possible solutions for the additional reduction of magnetic flux density should also be considered.

3.5 | Model for Magnetic Flux Density Calculations

The 3D model of the magnetic field source used for calculations is shown in Figure 8.

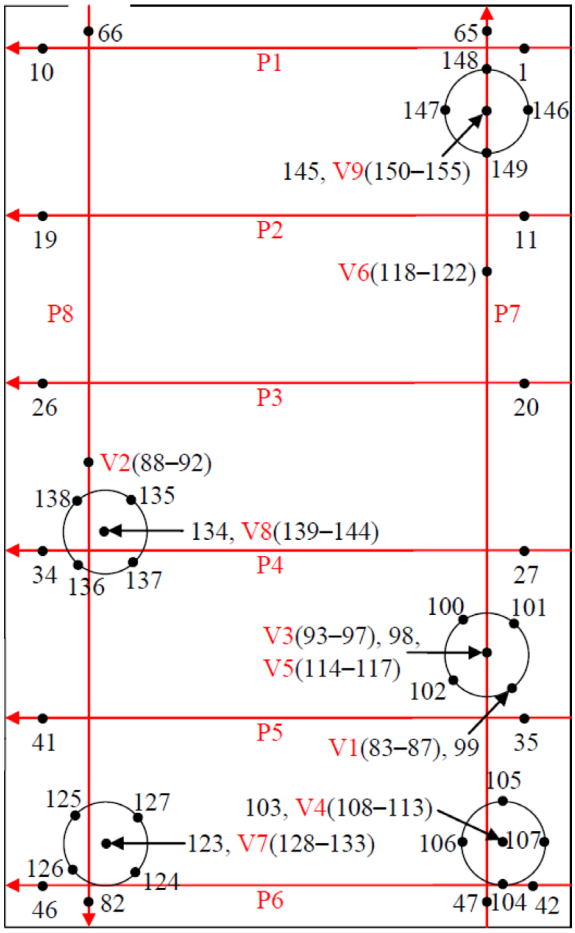


FIGURE 5 | Locations of measurement points in the classroom during second testing.

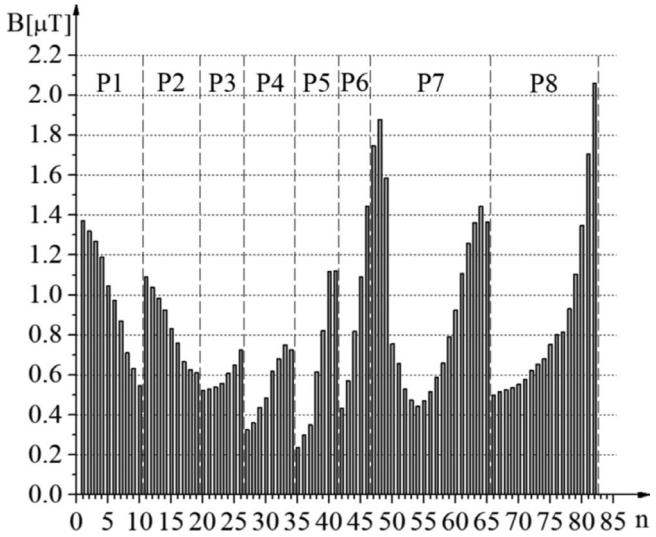


FIGURE 6 | Results of magnetic flux density measurements along horizontal measurement profiles obtained during second testing.

Calculations of magnetic flux density in the classroom are based on 3D simulations of the most relevant magnetic field source, that is, the 0.4 kV conductors connecting the transformer to the 0.4 kV switchboard. The 0.4 kV conductors are modeled by a set of straight-line segments.

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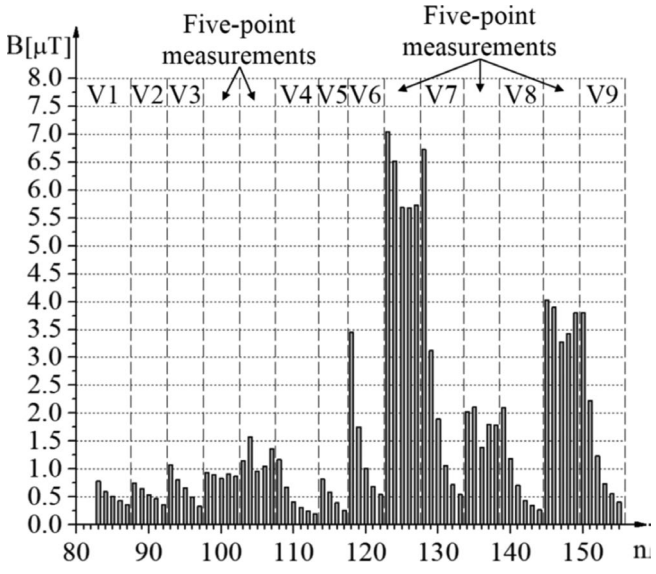


FIGURE 7 | Results of five-point measurements and measurements at different heights during second testing.

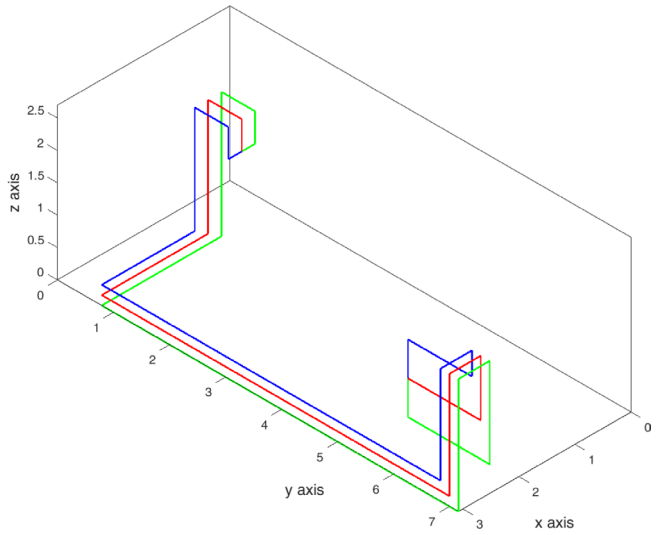


FIGURE 8 | 3D model for magnetic field calculations.

3.6 | Comparison Between the Results Obtained by Measurements and Calculations

The comparison between measurement and calculation results was performed to verify the model of magnetic field source. Figure 9 shows the calculation results obtained for the case when the system is balanced and all three currents amount to 1000 A. The highest value of magnetic flux density in this case amounts to 18.75 μT.

The comparison was carried out for two selected measurement points where the highest values of magnetic flux density were measured. The first one is located above the transformer, and the second one is above the 0.4 kV switchboard. The highest value of magnetic flux density in the classroom was measured at measurement point No. 123, and it was 7.03 μT. The transformer load currents at the moment of this measurement were 395.2, 344, and 346 A at the 0.4 kV voltage level. The calculations were carried out assuming that the system is balanced and that all three currents amount to 361.7 A which is the mean value of the three phase currents. The highest value of magnetic flux density obtained by calculations carried out under these conditions was 6.78 μT.

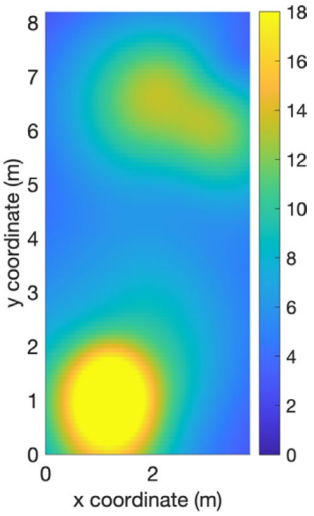


FIGURE 9 | Results of magnetic flux density calculations (μT) for the load currents of 1000 A.

The highest value of magnetic flux density above the 0.4 kV switchboard was measured at measurement point No. 145, and it was 4.02 μT. The transformer load currents at the moment of this measurement were 433.30, 373.30, and 397.60 A at the 0.4 kV voltage level. The calculations were carried out assuming that the system is balanced and that all three currents amount to 401.4 A which is the mean value of the three phase currents. The highest value of magnetic flux density obtained by calculations carried out under these conditions in the area above the 0.4 kV switchboard was 3.72 μT.

3.7 | Calculations for the Transformer-Rated Load

Since the previous analysis showed that there is an agreement between the results obtained by measurements and calculations, it can be concluded that the 3D model used for calculations is verified. The next step is to calculate magnetic flux density in the classroom for the case of the transformer rated load, that is, under the assumption that the system is balanced and that all three phase currents amount to 1443.4 A. The assessment of people to electromagnetic field has to take into account the worst case scenario [17], which in this case refers to the situation when the transformer load currents are equal to the rated currents. The highest value of magnetic flux density obtained in this case is 27.06 μT. Therefore, it can be concluded that the values of magnetic flux density cannot exceed the reference level of 40 μT prescribed for increased sensitivity areas in Serbia. However, taking into account that a group of preschool children spends a lot of their time in the classroom, possibilities for additional reduction of magnetic field levels should be considered. For that reason, several solutions for magnetic field mitigation are analyzed.

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3.8 | Solutions for Magnetic Field Mitigation in the Classroom

All the solutions analyzed in this article are based on conductive shields made of aluminum with different dimensions and geometries. The thickness of the shield is 3 mm, and its conductivity is 35 MS/m.

3.8.1 | Solution 1

Solution 1 is shown in Figure 10. The shield is made of flat plate located above the transformer. The dimensions of the plate are 2.5 × 2.9 m, and it is positioned directly below the ceiling of the substation, that is, at the height of 2.9 m.

The values of magnetic flux density calculations obtained after the application of this solution are shown in Figure 11, and the values of the SF are shown in Figure 12.

The highest value of magnetic flux density after the mitigation amounts to 15.10 μT, and it appears in the area above the transformer. This value is caused by the edge effect of the shield.

The highest value of magnetic flux density is reduced from 27.06 to 15.10 μT, while the magnetic flux density levels above the 0.4 kV switchboard are basically not changed. The highest value of the SF is 3.94, and it appears in the area above the transformer. Finally, the total losses inside the shield are 142 mW.

3.8.2 | Solution 2

Solution 2 is similar to Solution 1 with the only difference in the height of the shield which is located at the height of 2.7 m in this case, that is, it is closer to the transformer.

The highest value of magnetic flux density in the area above the transformer amounts to 12.92 μT, that is, it is lower than in the previous case. The highest value of magnetic flux density in the classroom now appears above the 0.4 kV switchboard and it amounts to 13.42 μT. The highest value of the SF in this case is 3.73. Finally, the total losses inside the shield are 462 mW.

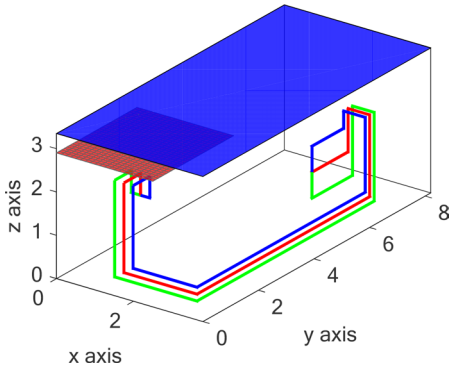


FIGURE 10 | Solution 1. The shield is colored red and located above the transformer. The effect of the shield is verified on the inspection plane represented in blue.

3.8.3 | Solution 3

Solution 3 is shown in Figure 13. The shield is the same as in the previous case with the addition of four side plates which are 0.5 m high. All plates are mutually connected.

The highest value of magnetic flux density in the area above the transformer amounts to 9.39 μT, that is, it is lower than in the previous two cases.

The highest value of magnetic flux density in the classroom amounts to 13.41 μT, and it appears in the area above the 0.4 kV switchboard. The highest value of the SF in this case is 4.41. Finally, the total losses inside the shield are 528 mW.

3.8.4 | Solution 4

Solution 4 is shown in Figure 14. The shield located above the transformer is the same as in the previous case and another shield located above the 0.4 kV switchboard is added. The dimensions of the horizontal plate of the second shield are 2 × 5 m

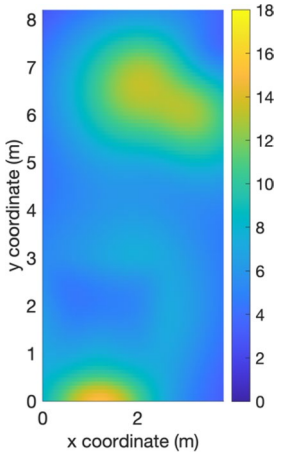


FIGURE 11 | Results of magnetic flux density calculations (μT) for the transformer rated load after the application of Solution 1.

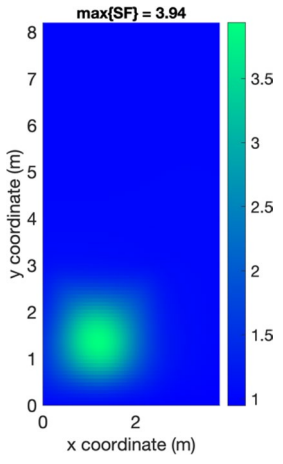


FIGURE 12 | Results of the shielding factor obtained by calculations for the case of Solution 1.

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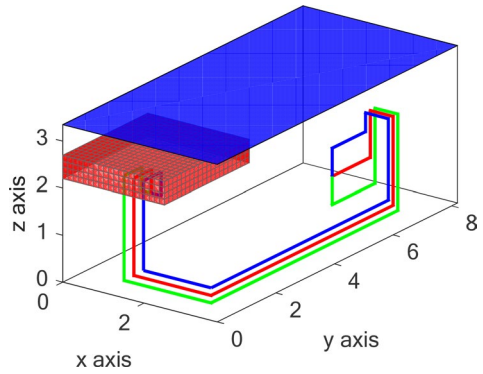


FIGURE 13 | Solution 3. The shield is colored red and located above the transformer. The effect of the shield is verified on the inspection plane represented in blue.

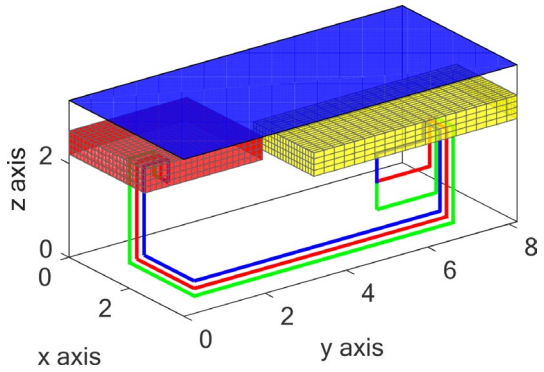


FIGURE 14 | Solution 4. Shield 1 (red) is above the transformer and Shield 2 (yellow) is above the LV switchboard. The effect of the shields is verified on the inspection plane represented in blue.

and the four side plates are 0.5 m high. The second shield is positioned at the same height as the first one.

The values of magnetic flux density calculations obtained after the application of this solution are shown in Figure 15, and the values of the SF are shown in Figure 16.

The highest value of magnetic flux density after the mitigation amounts to 9.92 μT, and it appears in the area close to 0.4 kV switchboard. The highest value of the SF amounts to 4.53, and the total losses inside the shield are 683 mW.

3.8.5 | Solution 5

Solution 5, presented in Figure 17, is the improved version of Solution 4 with four vertical plates added. The dimensions of the vertical plates added to the first shield are 2.9×2.2 m and 2.5×2.2 m. The dimensions of the vertical plates added to the second shield are 2×2.2 m and 5×2.2 m.

The calculation results are shown in Figures 18 and 19.

The highest value of magnetic flux density amounts to 7.62 μT, that is, it is lower than in the previous case. The highest value of the SF amounts to 9.99, and the total losses inside the shield are 2502 mW.

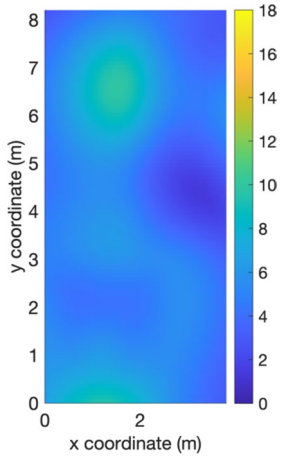


FIGURE 15 | Results of magnetic flux density calculations (μT) for the transformer rated load after the application of Solution 4.

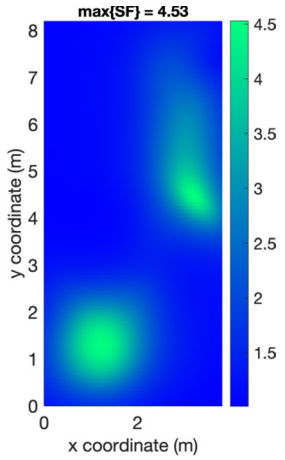


FIGURE 16 | Results of the shielding factor obtained by calculations for the case of Solution 4.

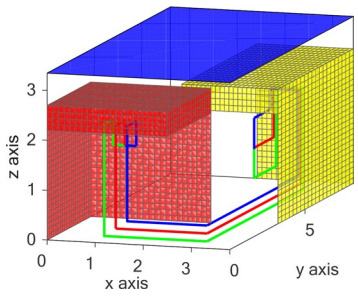


FIGURE 17 | Solution 5. Shield 1 (red) is above the transformer and Shield 2 (yellow) is above the LV switchboard. The effect of the shields is verified on the inspection plane represented in blue.

3.8.6 | Solution 6

Solution 6 is shown in Figure 20, and it represents the improved version of Solution 5.

The dimensions of the horizontal plate of the first shield are increased and amount to 3.8×2.9 m. The dimensions of the horizontal plate of the second shield are also increased and amount

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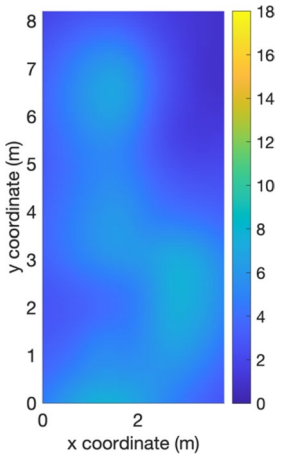


FIGURE 18 | Results of magnetic flux density calculations (μT) for the transformer rated load after the application of Solution 5.

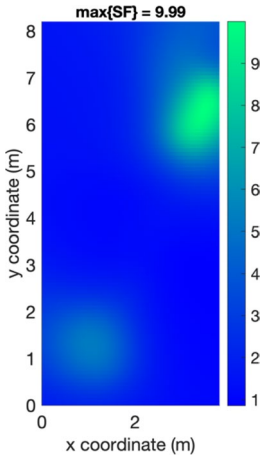


FIGURE 19 | Results of the shielding factor obtained by calculations for the case of Solution 5.

to 3.8×5 m. The dimensions of one vertical plate corresponding to the second shield are also increased from 2×2.2 m to 3.8×2.2 m.

The calculation results are shown in Figures 21 and 22.

The highest value of magnetic flux density after the mitigation in this case amounts to 7.17 μT, and it appears in the area above the transformer and it is caused by the edge effect of the shield. The highest value of the SF amounts to 16.64. Finally, the total losses inside the shield are 2318 mW.

3.8.7 | Solution 7

Solution 7 is shown in Figure 23, and it represents the improved version of the Solution 6 with two more vertical plates added. The dimensions of the vertical plate added to the first shield are 2.9×2.2 m. The dimensions of the vertical plate added to the second shield are 5×2.2 m. The calculation results are shown in Figures 24 and 25.

The highest value of magnetic flux density after the mitigation in this case amounts to 6.95 μT and it appears in the area above

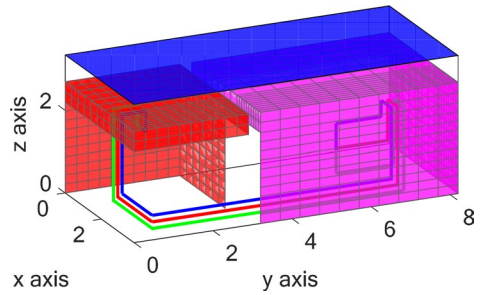


FIGURE 20 | Solution 6. Shield 1 (red) is above the transformer and Shield 2 (magenta) is above the LV switchboard. The effect of the shields is verified on the inspection plane represented in blue.

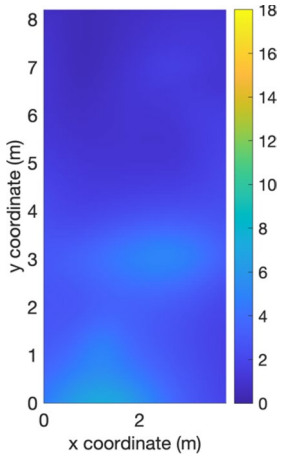


FIGURE 21 | Results of magnetic flux density calculations (μT) for the transformer rated load after the application of Solution 6.

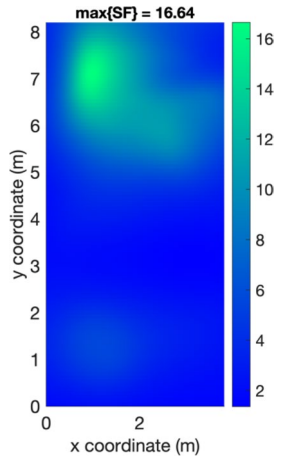


FIGURE 22 | Results of the shielding factor obtained by calculations for the case of Solution 6.

the transformer and it is caused by the edge effect of the shield. The highest value of the SF amounts to 11.23. Finally, the total losses inside the shield are 2725 mW.

3.8.8 | Comparison of Results

The comparative review of the results is given in Table 1. For each analyzed solution, the highest value of magnetic flux

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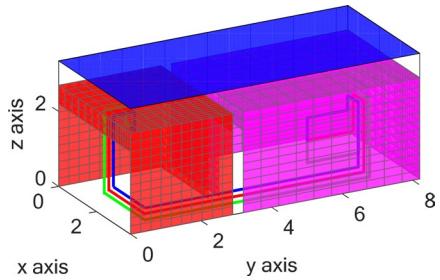


FIGURE 23 | Solution 7. Shield 1 (red) is above the transformer and Shield 2 (magenta) is above the LV switchboard. The effect of the shields is verified on the inspection plane represented in blue.

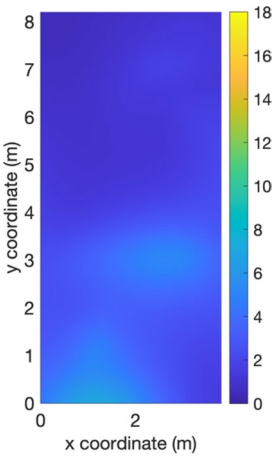


FIGURE 24 | Results of magnetic flux density calculations (μT) for the transformer-rated load after the application of Solution 7.

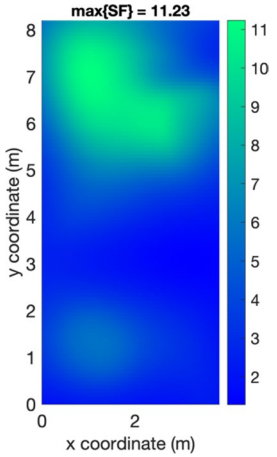


FIGURE 25 | Results of the shielding factor obtained by calculations for the case of Solution 7.

density in the classroom (B_{max}) is presented as well as the location where this value appears. The values of the Joule losses and the maximum value of the SF for each solution are also given in Table 1.

On the basis of the presented results, it can be concluded that Solution 7 ensures the lowest levels of magnetic flux density in the entire classroom. In this way, the values of magnetic flux density are decreased both in the area above the transformer and in the area above the LV switchboard. The highest value of magnetic flux density in this case amounts to 6.95 μT. This value appears in the area above the transformer next to the wall, and it is caused by the edge effect of the shield. In the rest of the classroom, the values of magnetic flux density do not exceed 6 μT.

TABLE 1 | Comparison of the results.

Solution	B_{max} (μT)	SF_{max}	Losses (mW)	Location of B_{max}
1	15.10	3.94	142	Above the transformer
2	13.42	3.73	462	Above the 0.4 kV switchboard
3	13.41	4.41	528	Above the 0.4 kV switchboard
4	9.92	4.53	683	Near 0.4 kV switchboard
5	7.62	9.99	2502	Between the transformer and 0.4 kV switchboard
6	7.17	16.64	2318	Above the transformer
7	6.95	11.23	2725	Above the transformer

Solution 6 proved to be very efficient as well. In this case, the highest value of magnetic flux density amounts to 7.17 μT, and it also appears next to the wall due to the edge effect of the shield. In the rest of the classroom, the levels of magnetic field are similar to the results obtained with Solution 7. Regarding the thermal problem, the Joule losses in all configurations are very low (below 3 W). Therefore, differently from other shielding techniques [28], there is no need to further investigate the possible overheating of the shielding system.

4 | Conclusion

The results presented in the article show that 10/0.4 kV substations located inside buildings can be a significant source of magnetic field in the rooms located next to the substation. The levels of the magnetic field inside these rooms significantly depend on the transformer rated power and the disposition of the equipment in the substation. For that reason, special attention should be paid to the arrangement of the equipment when designing new substations located in the buildings. It is very important to emphasize that the 10/0.4 kV substations with the 0.4 kV busbars located immediately next to the ceiling or outer wall of a substation are the most unfavorable configuration from the aspect of exposure to the magnetic field if there is an increased sensitivity area on the other side of the ceiling or the wall. Therefore, these configurations should be avoided when building new substations

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within houses, schools, and other buildings which can be categorized as increased sensitivity areas. In this article, the case of the 10/0.4 kV substation located inside the school was analyzed. The measurements performed in the classroom located directly above the substation showed that there are areas with increased levels of magnetic field. Although the magnetic field levels were within the prescribed limits, the possibilities for the additional reduction of magnetic field levels were analyzed bearing in mind that a group of preschool children spends a lot of their time in the classroom. Therefore, seven solutions based on passive shielding were analyzed. The results showed that the application of conductive shields can lead to a significant reduction of the magnetic field in the classroom and that solutions based on conductive shields can be used for mitigating the environmental impact of 10/0.4 kV substations located inside buildings.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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