Screen Conductor Impact on Residential Exposure to Low Frequency Electric and Magnetic Fields

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Abstract
In southern Equator, lower-voltage distribution electric lines are generally built in neighborhoods, being potential sources of exposure to magnetic and electric fields for humans, which could produce adverse effects. Residential and industrial exposure to low frequency electric and magnetic fields generated for utilities and their elements has been associated with possible health effects. In this context, it is important study alternatives in order to mitigate these levels of magnetic and electric field produced by their infrastructure.

The aim of this work is to analyze the influence of screen conductors on values of magnetic and electric field, to which utility’s worker are exposed. The exposure-mitigation method is estimated thought the placement of screen conductors on distribution feeders, which are simulated by using student version Quickfield software. Depending on the exposure-mitigation response, screen conductors in vertical and horizontal topology were modelled, considering four study cases. Two topologies with and without screen conductor, respectively. Results are discussed, analyzed and compared with regulatory norms.

Keywords: Electric and magnetic field, screen conductor, mitigation

INTRODUCTION
On Distribution Feeders (DFs), electromagnetic emission is constant at a frequency ranging from 50 or 60 Hz known as extremely low frequency fields (ELF) [1]. For many years, there has been concern the possibility that electromagnetic fields (EMFs) may influence on the health of persons [2-11]. Hence, elevated EMFs values could increase the risk on a person.

DFs located in electrical substations are imperative sources of EMFs. The most critical factor in contributing to these values is related to the distance to the source and its electrical properties of voltage and current, respectively. In this context, initial results on the determination of the EMF level based on simulations and measurement have been presented in [12-13]. However, it is necessary to analyze possible solutions that help to mitigate those EMFs. Mitigation of those levels is usually done by changing the distribution feeders’ topology. However, it involves a high economic cost. The goal of this paper is to analyze the effects of place screen conductors on DFs in order to determine the exposure-response to humans. Quickfield software is used to simulate the DFs and the screen conductor. Thus, EMF levels are simulated considering different topologies, vertical and horizontal with and without screen conductor, respectively. Results are discussed, analyzed and compared with regulatory norms.

MATERIALS AND METHODS
EMFs values are analyzed by using a three phase real distribution feeder with poles of height 9m of 69kV/22kV located in southern Equator [12]. The topology is shown in Fig. 1 and Fig. 2, respectively. By using the procedure IEEE 644 and the regulation expressed by the Department of Environment of Equator [14-15], EMFs were simulated to 1m from ground level.

![Figure 1. Features of distribution feeder topologies](image1)

![Figure 2. Distribution feeder topology](image2)

Regarding to the simulation software, student version Quickfield software [16] based on Finite Elements (FE) is used. The FE analysis involves basically four steps:
discretizing the solution region into a finite number of sub regions or elements, deriving governing equations for a typical element, assembling all the elements in the solution region, and finally, solving the system of equations obtained. In [12], the procedure to make low frequency EMFs simulation employing Quickfield was presented.

Based on the previous said, in this research the simulated model consists of three parts, first: space or air, second: aluminum conductor, and third: ground (See Fig. 1). It is necessary to specify the geometrical shape of each element and its characteristic values. Fig. 3 shows the voltage, current and permittivity simulation parameters used in this work, considering horizontal and vertical topology with and without screen conductor.

A cross section corresponding to each phase conductor of the DF, the airspace around them, bounded and vertex values were simulated (see Fig. 4.a). On the other hand, in order to make electrostatic and magnetostatic analysis, air permittivity and permeability, zero ground potential, were defined, respectively.

Finally, the low frequency EMFs exposure for different topologies, horizontal and vertical with and without screen conductors, are simulated at 1m from the ground level.

RESULTS AND ANALYSIS

A. EMFs exposure without screen conductor in horizontal topology

The first case analyzed corresponds to a horizontal topology without screen conductor. In order to get a better idea of this topology, it can be seen in Fig. 4.a, which shows the arrangement of DF from a front view. The magnetic field simulation considers that DF is placed at a height of 9 meters and aims to analyze the impact of this at 1 meter height from the ground considering that this would be the point of greatest influence on people (Based on IEEE 644). In Fig. 4.b, it is possible to see that the largest magnetic field amount expands horizontally. However, a wide spectrum analysis reaches a point raised meaning that there will be an impact on people.
The curve corresponding to magnetic flux change at 1 m from the ground, from the feeders to a horizontal distance of 20 m on each side of themselves, is presented in Fig. 4.c. The magnetic flux density reaches a peak value of 1.52 uT to 12 meters. However, when placed just below the feeders, the field density is decreased.

Regarding to the electric field simulation, it allows a broader perspective of the radiation and in which area is the strongest. Fig. 5.a shows the electric field spectrum. In this case, EF simulation is orthogonal to the magnetic field orientation. However, it shows that the EF magnitude becomes zero before reaching the benchmark; do not overlook to raise the respective mitigation. In Fig. 5.b, the EF curve is presented. It is clear that a peak of 319 V/m is localized below the DF.

B. EMFs exposure without screen conductor in vertical topology

As regards to the vertical topology, in Fig. 6.a, their topology is shown. Regarding to the magnetic flux density, it is shown in Fig. 6.b. It is possible to see that there is a notable difference between the magnetic flux density spectrum generated in horizontal and vertical topology, respectively.

In the vertical topology, MF values change its direction and reaches the reference point raised. When framing mitigation, the vertical topology becomes priority because there is a greater risk of people display fields.

Fig. 6.c shows the graph of the magnetic flux density where a remarkable peak is observed in the middle area where the DF is arranged vertically. Similar to the horizontal topology, in order to known magnetic flux density more precisely, in Fig. 6.c, the curve corresponding to magnetic flux change at 1 m from the ground from the feeders to a horizontal distance of 20 m on each side of themselves, is presented. The magnetic flux density reaches a peak value of 3.6 uT.

Regarding to the electric field, their value is more concentrated (See Fig. 7.a). Besides that, their orientation directly affects, and with a greater magnitude raised the point of analysis, becoming a priority because of the effects that it might cause. On the other hand, in Fig. 7.b the electric field simulation curve is presented, obtaining a peak value of 378 V/m below the DF.

Figure 5. Simulation of electric field without screen conductor in horizontal topology: a) spectrum, b) field level at 1 meter height from the ground.

Figure 6. Simulation of magnetic field without screen conductor in vertical topology: a) topologie, b) spectrum, c) field level at 1 meter height from the ground.
C. EMFs exposure with screen conductor in horizontal topology

After EMFs exposure in horizontal topology without screen conductor, are known. In this section, EMFs exposure is determined considering a screen conductor localized below the DF. In Fig. 8.a, their topology is shown.

**Figure 7.** Simulation of electric field without screen conductor in vertical topology: a) spectrum, b) field level at 1 meter height from the ground.

**Figure 8.** Simulation of magnetic field with screen conductor in horizontal topology: a) topology, b) spectrum, c) field level at 1 meter height from the ground.

**Figure 9.** Simulation of electric field with screen conductor in horizontal topology: a) spectrum, b) field level at 1 meter height from the ground.
Fig. 8.b shows that by placing the screen conductor, the generated magnetic field is concentrated closer to the DF, avoiding reaching influence the point of analysis. In addition, the peak magnetic flux is 1.98 μT. However, in Fig. 8.c, it is clear that a damper is produced, reducing those chaotic peaks.

Regarding to the EF, by placing the screen conductor, it is possible to see that the maximum peak (without screen conductor) is now reduced totally free of radiation leaving the point of analysis. See Fig. 9.a. Thus, as is shown in Fig. 9.b, the peak electric field intensity continuously presents and reaches a value of 98 V/m. However, it is limited to one third of the peak that was presented without screen conductor.

D. MFs exposure with screen conductor in vertical topology

Similar to the horizontal topology, a screen conductor is placed in the vertical topology below the DF. In Fig. 10.a, their topology, is shown.

In Fig. 10.b, it is possible to see that magnetic field exposure is significantly lower that the topology without screen conductor. In addition, in Fig. 10.c, it can be observed that, contrary to minimize the effect, the peak is increased to be 4 μT coming.

An interesting phenomenon that appears in the electric field spectrum is that their value is limited in the central part. However, there are two points of incidence on the sides of the center point, which although lower than those recorded without screen conductor, continue focusing on people and other options to try to mitigate them most effectively must be analyzed. See Fig. 11.a.

**Figure 10.** Simulation of magnetic field with screen conductor in vertical topology: a) topology, b) spectrum, c) field level at 1 meter height from the ground.
By observing Fig. 11.b, it notes that the electric field magnitude decreases to 175 V/m. It is necessary to note that the peak previously detected has been transformed into two peaks, although they have less intensity, these should be considered.

The lower magnetic flux density value occurs in the horizontal topology without screen conductor, while the lower electric field value occurs in the horizontal topology with screen conductor.

**CONCLUSIONS**

The electric and magnetic field exposure values generated by the DFs in the horizontal topology are much lower than the exposure fields generated by the DFs in the vertical topology. By placing the screen conductor as mitigation method, horizontal topology is more effective than the vertical topology.

Based on the results, placing the screen conductors can be an alternative to the electric and magnetic field mitigation when a horizontal topology is used. It can be observed that the magnetic field, electrical, magnetic flux density and electric field strength decrease their value. However, by using vertical topology, similar results were not achieved. Therefore, according to these results, the place screen conductors can decrease the electric and magnetic field exposure-response to population, which are far below international reference levels proposed by ICNIRP (International Commission on Non-Ionizing Radiation Protection) and others.

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**REFERENCES**


