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# ELECTROMAGNETIC POLLUTION INSIDE HIGH VOLTAGE SUBSTATION

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**Key words: Electromagnetic compatibility, Electromagnetic environment, High voltage substation, Low frequency.**

**Possible harmful effects of the low frequency electromagnetic field on human health are studied. This paper presents an experimental investigation of the professional electromagnetic environment inside interconnection high-voltage substation (220/90/60/30 kV), operating in Algeria, in order to compare the results with the international establishing limits for human exposure to low frequency electromagnetic pollution. The measurements were recorded in different passages of workers near the worst pollution sources (bus bars, power lines and power transformers). The technique of electric and magnetic field measurement used in this work is based on an original point of view, because we targeted passages of workers in the 220 kV substation and the passage of 220/60 kV transformers. The maximum electric field values are obtained in 220 kV substation, some of these values exceed the limit set by the standards that can affect the health of workers. Regarding the magnetic field values recorded, they are sufficiently lower compared to the safety guidelines.**

## 1. INTRODUCTION

All power lines are interconnected by high voltage interconnection substations in order to ensure the continuity between the different voltage levels. The interconnection enables: energy exchanges between regions; in case of default on a power line or in a power station, the alimentation by another line; the exchange to neighboring countries (energy exports).

The high voltages and currents circulated in the different components of these substations produce high electric and magnetic field.

The interference of these low frequency (50 Hz) fields with human organisms (working personnel and general public) may cause a threat. This hypothesis has been the subject of several researches over the last few decades. The results of some studies affirmed the possibility of attributing negative effects from human exposure to low frequency electromagnetic fields [1–4]. Other researches indicate that there is no risk [5, 6]. In addition, the influence of low-frequency magnetic fields on medical implants, particularly pacemakers has been studied.

The results have shown that these devices are extremely sensitive to such perturbation, which endanger the patients' life [7, 8]. In 1989, the World Health Organization has proposed a limit of induced current in the human body (10 mA/m$^2$) [9]. Inspired by this proposal and similar recommendation of ICNIRP [10], the European Commission adopted (June 1999) a Council Recommendation concerning the limitation of public exposure to low frequency electromagnetic fields (Table 1).

*Table 1*
Limitation of public exposure
to low frequency electromagnetic field

| | **Electric field** | **Magnetic field** |
|---|---|---|
| Residential Exposure (24h/24h) | 5 kV/m | 100 μT |
| Occupational exposure (8h/j) | 10 kV/m | 500 μT |

In [11], a good review concerning the safety and health legislative requirements regarding workers exposure to risks generated by electromagnetic fields can be found.

In the literature, Safigianni and Tsompanidou have measured the electric and the magnetic field generated in indoor 20/0.4 kV power distribution substation [12], and in outdoor an electric power substation of 150/20 kV [13] in Xanthi, Greece.

In this paper, a measurement protocol has been proposed to study the electric and magnetic fields in the passages of workers near the bus bars, power transformers and power lines indoor 220/90/60/30 kV high voltage interconnection substation (El-Hadjar-Annaba-Algeria).

## 2. DESCRIPTION OF THE STUDIED SUBSTATION

This substation is constituted by three open air substations on different voltage levels (substation 220 kV, substation 90 kV and substation 60 kV), which are connected by three 220/60 kV power transformers and two 90/60 kV power transformers. Figure 1 gives a simple view for this substation.

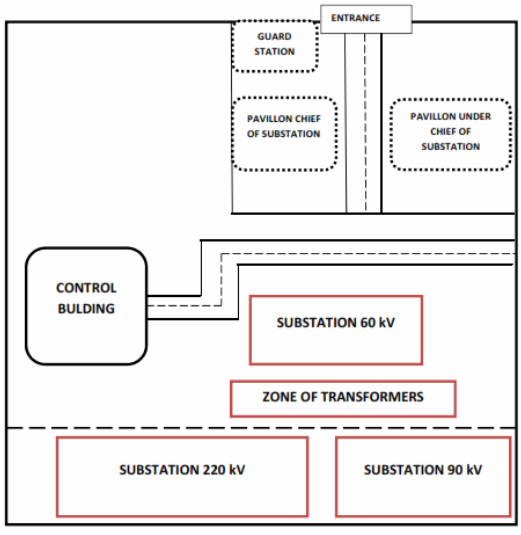


Fig. 1 – Simplified architecture of the studied substation.

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## 3. MATERIAL AND METHOD

The instrument used in this study is an electromagnetic field strength meter NARDA EHP-50C. It measures the electric and magnetic field from a frequency range between 5 Hz to 100 kHz. This device is equipped with a cubic probe posed on a metal rod of 1 m. Two internal sensors measure the *x*, *y*, and *z* vector components of the electric and magnetic field. The measurements can be stored in the instrument's memory and transferred to a personal computer through an optical fiber cable with a USB signal converter port for storage, display, and further analysis. The length of the optical fiber is 10 m, which allows the person who measures the field to stay away from the probe and avoid the modification of the field by his presence.

The technique of electric and magnetic field measurement used in this study based on an original point of view, because we have targeted the passages of workers in the 220 kV substations and the passage of the 220/60 kV transformers.

In these areas, it is estimated that the fields' values are very important. Therefore, workers exposure to the electromagnetic pollution is much more dangerous than others shielded regions (Control rooms...).

All measurements have been performed at 1 m above ground.

### 3.1. MEASUREMENT IN THE SUBSTATION 220 kV

This substation is composed of two 220 kV three-phase bus-bars, five 220 kV lines spans (15 conductors) and nine conductors of the three 220/60 kV power transformers (TR1, TR2, TR3). In this substation there are nine passages allow workers to move, eight passages (P1 to P8) parallel to the direction of the power lines and transformers spans and perpendicular to the direction of the bus bars, and one passage (P9) parallel to the direction of bus bars and perpendicular to the direction of the power lines and the transformers spans (Fig. 2). All measurements in these passages are taken at 1 m above the ground with an increments $\Delta x = 5$ m.

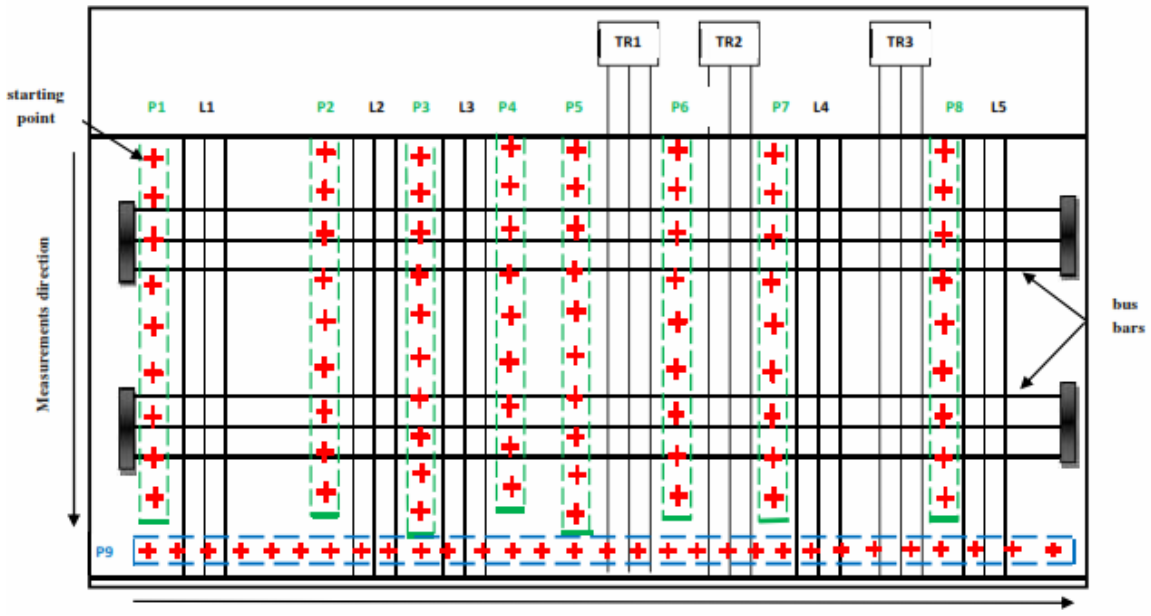


Fig. 2 – 220 kV substation area with the measurement positions.

### 3.2. MEASUREMENT IN THE PASSAGE OF TRANSFORMERS

We have also measured the electric and magnetic fields near of the three 220/60 kV parallel power transformers (Figure 3).

The distance between two neighboring transformers is 15 m. The measurement process has been conducted in the passage opposite to the primary winding of transformers (side 220 kV). Starting with the beginning of the transformer (TR1) to the end of the transformer (TR3) on the longitudinal distance of 57 m at increments of $\Delta x = 3$ m.


Fig. 3 – Passage of power transformers.

## 4. RESULTS AND DISCUSSION

The obtained results have been grouped according to the passages orientation.

## 4.1. BEHAVIOR OF THE ELECTRIC FIELD

### 4.1.1. IN THE 220 kV SUBSTATION

In the first eight passages (P1 to P8) and for a better visualization, the results have been represented in two figures (Figure 4 and Figure 5 ), each figure includes four curves show the electric field profiles in these passages.

The results show that the profiles of the electric fields in the different passages of the 220 kV substation are very important, the maximum value of the electric field 11.450 kV/m has been recorded in point 5 of the passage 03 (between the line span two (L2) and the line span three (L3),we have also found high value of 10.217 kV/m in the measurement point 5 of the passage 04 (left side of the line span three (L3)), these values exceed the established limits by the standards for professional exposure to electric field (10 kV/m). Other high values that exceed the established limits for public exposure (9.820 kV/m, 9.2549 kV/m, 5.4465 kV/m, 7.9838 kV/m, 5.1351 kV/m, 6.1954 kV/m, 9.0219 kV/m, 5.1629 kV/m) are found respectively in the eight passages.

For the passage P9, the profile of the electric field is quite variable. This variation is due to the measurement point location relative to conductors. The highest values (7.8114 kV/m, 5.6873 kV/m, 5.1013 kV/m and 5.8561 kV/m) have been recorded in the areas located under the conductors of lines and transformers spans (Figure 6).

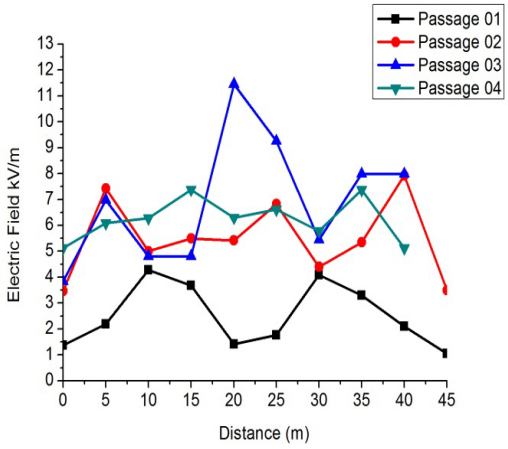


Fig. 4 – Electric field profile in the 220 kV substation (P1 to P4).

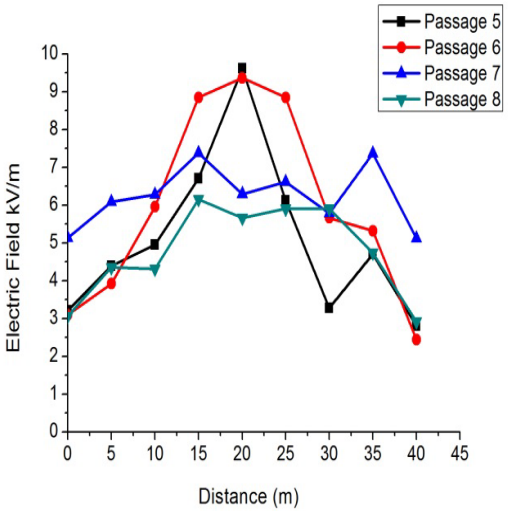


Fig. 5 – Electric field profile in the 220 kV substation (P5 to P8).

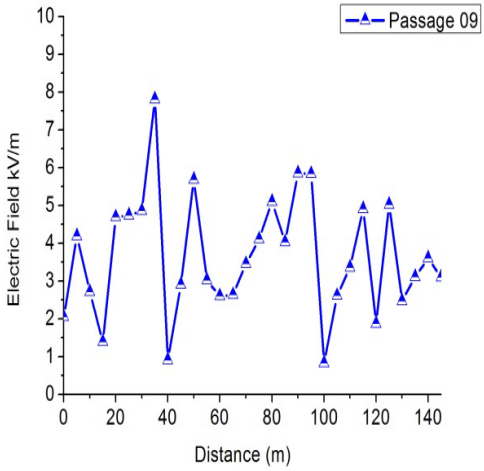


Fig. 6 – Electric field profile of in 220 kV substation (P9).

### 4.1.2 IN THE PASSAGE OF POWER TRANSFORMERS

Figure 7 illustrates the electric field profile through the passage near the transformers (TR1, TR2 and TR3).

According to this curve, the electric field profile is rather variable and it is concentrated near of the transformers, the maximum recorded value is 1.5633 kV/m. In this passage, the measured electric field intensities are lower than the established limits.

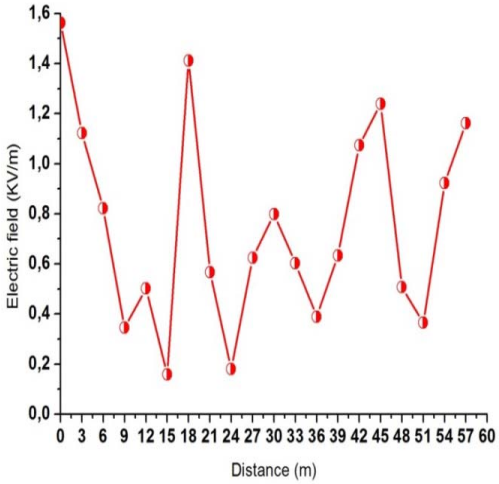


Fig. 7 – Electric field profile in the vicinity of the transformers 220/60 kV.

## 4.2 BEHAVIOR OF THE MAGNETIC FIELD

The magnetic field values depend on the currents circulating in the different conductors. These currents are found to dependent on the load demand. In this work, the magnetic field measurements have been performed under normal load conditions, approximately when the substation operates at 40 % of its nominal power ratings. The average currents flowing in the different lines of the substation, during the measure-ments process, are between 87.4 A to 460 A.

The same strategy has been used to represent the magnetic field profiles.

### 4.2.1 IN THE 220 kV SUBSTATION

The measurements values show that the magnetic field is variable in almost passages, except in the passages P4 and P5, it is found that the magnetic field values vary slightly between (2 µT and 3 µT) and between (6 µT et 8 µT)

respectively. The maximum value has been recorded in the passage P2 (20 µT). In a general way these values are very far to the limit established by the standards (500 µT).

For the passage P9, the maximum value of the recorded magnetic field is 9.5 µT and the minimum value is 1 µT. This considerable variation is due to the variation of current in the lines and the location of the measuring equipment to the lines and bus bars. Figures 8, 9 and 10 show the behavior of the magnetic field in all these passages.

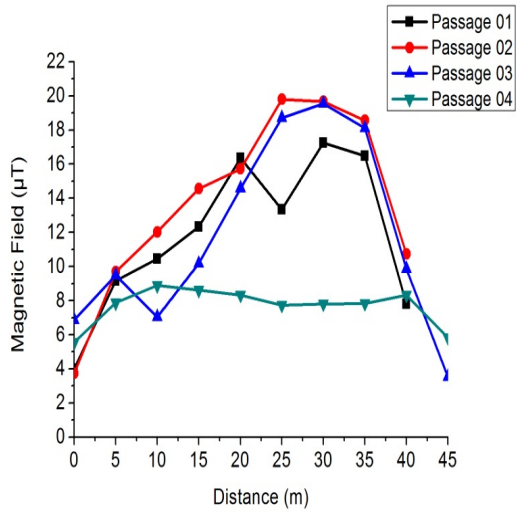


Fig. 8 – Magnetic field profile in the 220 kV substation (P1 to P4).

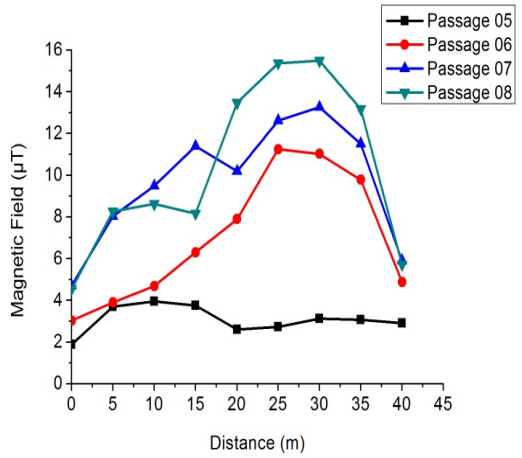


Fig. 9 – Magnetic field profile in the 220 kV substation (P5 to P8).

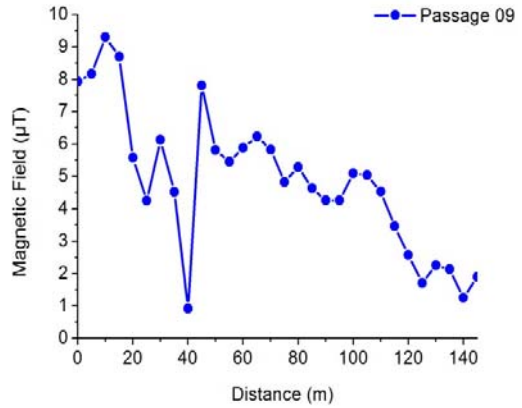


Fig. 10 – Magnetic field profile in the 220 kV substation (P9).

4.2.2 IN THE PASSAGE OF POWER TRANSFORMERS

Concerning the magnetic field in this passage (Figure11), the obtained results in the proximity of the transformers are close.

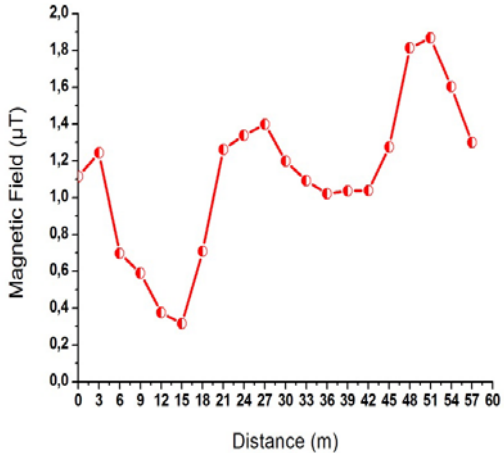


Fig. 11 – Magnetic field profile in the vicinity of the transformers 220/60 kV.

The maximum value is 1.8671 µT has been registered under the transformers lines (TR3) and the minimum value is 0.3150 µT has been found in the area between TR1 and TR2. These values are negligible compared with the established limits (500 µT).

## 5. CONCLUSION

This paper reports the results of electric and magnetic field measurements obtained in different locations inside an open air type high voltage interconnection substation. We have focused on the evaluation of the electromagnetic pollution for the worst cases. Selective representative plots of the electric and magnetic fields are presented and compared with the guidelines applicable in many countries around the world for professional exposure to this kind of fields (10 kV/m for the electric field and 500 µT for the magnetic field). In the different passages of the substation 220 kV, we have found that the electric field values are very important. In some cases, the electric field density has heavily exceeded the limits set by the standards which may constitute a danger to workers circulating close to these areas. Near the transformers (220/60 kV), the measured electric field was found to be very low compared to the guidelines. In all studied cases the magnetic flux density stay very low to the 500 µT.

Based on the obtained results which have shown that the electric field intensity near the high voltage sources is more sever compared to the magnetic flux density and the fact that many studies have proven that it's easy to shield the low frequency electric fields, we suggest to make special clothes to protect the workers' bodies from the electric field pollution.

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