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Original Article

Measurement and Modeling of Personal Exposure to the Electric and Magnetic Fields in the Vicinity of High Voltage Power Lines

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ABSTRACT

Background: This work presents an experimental and modeling study of the electromagnetic environment in the vicinity of a high voltage substation located in eastern Algeria (Annaba city) specified with a very high population density. The effects of electromagnetic fields emanating from the coupled multi-lines high voltage power systems (MLHV) on the health of the workers and people living in proximity of substations has been analyzed.
Methods: Experimental Measurements for the Multi-lines power system proposed have been conducted in the free space under the high voltage lines. Field's intensities were measured using a referenced and calibrated electromagnetic field meter PMM8053B for the levels 0 m, 1 m, 1.5 m and 1.8 m witch present the sensitive's parts as organs and major functions (head, heart, pelvis and feet) of the human body.
Results: The measurement results were validated by numerical simulation using the finite element method and these results are compared with the limit values of the international standards.
Conclusion: We project to set own national standards for exposure to electromagnetic fields, in order to achieve a regional database that will be at the disposal of partners concerned to ensure safety of people and mainly workers inside high voltage electrical substations.

1. Introduction

Electric power substations, transmission, and distribution lines, are some of the commonly known sources of electromagnetic pollution. The development and expansion of the power systems worldwide, has increased the electromagnetic field level as well as the bioorganism and human body exposure to electromagnetic radiation [1].

Electrical energy is transported from the power station to the substations through overhead electric lines and from there to the final users by electromagnetic fields that are propagated throughout the lines. The fields' magnitudes are highest under the lines and decrease rapidly with the distance from the pylon axes [2]. The evaluation of the electric and magnetic charges quantities in the vicinity of high voltage power lines have been analyzed in several publications [3–5]. The high-intensity of electromagnetic fields can induce important voltages and currents in conducting elements located in their proximity and many publications throughout the world have studied the effects of electromagnetic fields emanating from power lines and stations of mobile communication, and for the analysis of modes of energetic transfers [6–7]. A great deal has been written on the subject and doctors agree with these studies. The 2007 Eurobarometer survey [8] showed a strong concern and preoccupation of the European population to electromagnetic fields. As several studies have focused on the mechanism by which the

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Table 1
Limitation of public exposure to low frequency electromagnetic field

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

electromagnetic fields might influence the health of people, it seems clear that different perceptions of risks can lead to different actions. Some people conclude that the current evidence for health risks from Extremely low frequency (ELF) fields is so tenuous, and the possible risks so small, that no action is necessary. Others find even the slightest possibility of a risk sufficiently disturbing and agree more on the precautionary principle. The idea of prudent avoidance involving limiting exposures has been suggested as a means to control exposures to ELF fields if there is any doubt that they are harmless. Due to this, various occupational health organizations have established limits of exposure to electromagnetic fields in work and public places. Among these organizations are cited the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and standard Institute of Electrical and Electronics Engineers (IEEE) [9–11] guidelines which set a basic restriction on the density of electric current induced in the body by ELF fields mainly to avoid electrical shock hazards, minimize burn hazards, and reduce interference with medicals implants. In 1989, the World Health Organization proposed a limit of induced current in the human body (10 mA/m^2). Inspired by this proposal and a similar recommendation of ICNIRP, in June 1999 the European Commission adopted a Council Recommendation concerning the limitation of public exposure to low frequency electromagnetic fields (Table 1).

Other experimental studies [12–15] have been carried out by our own team, LGEG Laboratory, in collaboration with the electricity producing company SONELGAZ, Annaba, Algeria. These studies focused on the characterization of a high voltage line and operate thereafter as a source of disturbance applied to the study of the electromagnetic compatibility of medical implants (pacemakers, hearing, etc.) [16–18].

As a shortcoming with regard to standards on exposure to low frequency electromagnetic fields in Algeria and in order to achieve a regional database on these fields, evaluations will be at the disposal of responsible institutions to ensure safety of people and workers.

This work is intended to present an experimental and numerical modeling of the electric field (EF) and magnetic field (MF) generated by a circuit of two 220 kV multi-line power systems implanted inside El-Hadjar substations located in eastern Algeria within an urban area. The intensities of fields simulated approach the limit values imposed by the international standards in areas close to large transmission lines, often frequented by electric posts workers. Away from the power lines field levels are much lower than proposed limits. As we can see, none of the regulations are founded on the leakage fields from transmission lines. Therefore, low levels of electrical and magnetic fields from power lines may have no influence on a human body.

2. Materials and methods

2.1. Model description

In this section of work an experimental characterization of electromagnetic field generated by two 220-kV overhead power lines with flat configuration is achieved. Both lines are located next to each other inside the El-Hadjar substation which provides interconnection between Algeria and Tunisia. The line (B) is located 28 m from Line A, they represent respectively Arcelor-Mittal and Kharaza cities. The distance between phase lines, the clearance of conductors, cables guard, the lengths of lines, and the currents in conductors when measuring the fields' intensities are listed in Table 2.

2.2. Measurement protocol

Experimental measurements for the multi-lines power system proposed have been conducted in the free space under the high voltage lines in accordance with the IEEE standards [19]. Fields' intensities were measured using a referenced and calibrated electromagnetic field meter PMM8053B [20] for the levels 0 m, 1 m, 1.5 m, and 1.8 m which present the sensitive parts as organs and

Table 2
Geometrical and electrical data of pylons

Directions	Pylon A 220 Kv KHERAZA	Pylon B 220 Kv ARCELOR-METTAL
Height of the phase 1 (m)	21	21.5
Height of the phase 2 (m)	21	21.5
Height of the phase 3 (m)	21	21.5
Height of the cable guard (m)	25	27
Phase Spacing (m)	7.5	8
Length (Km)	76.98	42
Nub of conductors by phase	01	01
Value of current by phase (A)	270	274.2

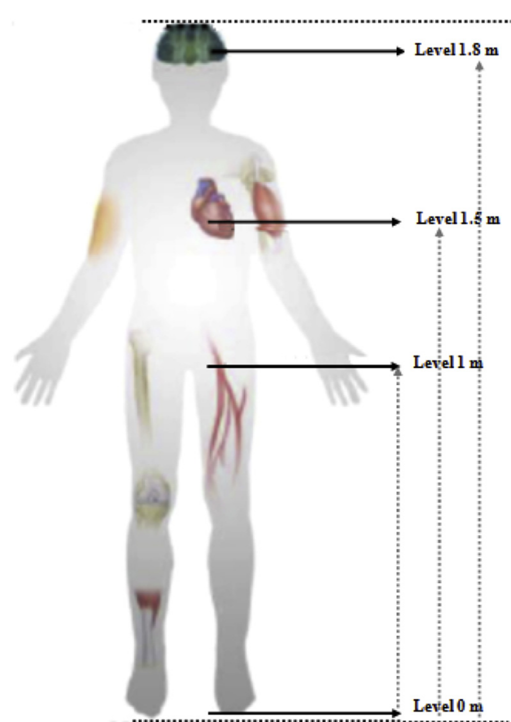

Fig. 1. Sensitive levels of human body exposure.