Measurements of electric and magnetic fields, in heavy vehicles parking space, in the vicinity of a power station with 150kv to 20kv transformers

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Abstract. The present paper investigates the electric and magnetic fields of extremely low frequencies in substations which step down voltage in Kozani, which is a city of about 65,000 inhabitants. In the substation, apart from the presence of voltage distribution transformers there are also power cables of 150 kV generated in pillars as well as power cables of 20 kV and 380V for the power supply of the city. Pillars with high, medium and low voltage power cables cross the parking space of heavy vehicles.

1. Introduction

The problem of power consumption and energy saving solutions has been one of the most significant global issues in contemporary society. As conditions seem to be worsening in the last decades, owing to high percentages of urbanization and industrialization, the use of energy reduction methods and efficient power management systems is essential. However, apart from the increase in demand for energy, there is also created an energy hub of concentration points, such as the points in electrical nodes. Obviously, the larger the urban area, the greater or more energy nodes should be built.

Needless to say, the energy nodes, which are built, are closely associated with the emitted pollutants (i.e. air, soil, water pollutants, etc.). In this case, as energy nodes are electric power nodes, the resulting pollution will be electric and magnetic field pollution and the potential soil pollution will result from fluid leakage from voltage distribution transformers.

The Electric fields occur either when there is charge concentration under certain conditions (static case), or whenever they exist in a conductor. In the case of a rectilinear current-carrying conductor of infinite length, the electric field, E, is constant, depending on the distance of the measuring point from the conductor, in which there is an electron flow.

\[
E = \frac{1}{4\pi \varepsilon_0} \sum_{i=1}^{N} \frac{q_i}{r_i^2} \hat{r}_i \quad \text{(Newton/Coulomb)} \quad (1)
\]
or \[ E = \frac{V}{r} \text{ (Volt} / \text{m)} \] (2)

The magnetic flux, which is created around the conductor of infinite length, is given by the Biot-Savart law

\[ dB = \kappa_\mu \frac{I \cdot dL \cdot \sin \alpha}{r^2} \] (3)

Where \( I \) is the current intensity in A, \( dL \) is the elementary length of the straight conductor in meters, \( r \) is the distance of point A from the primary conductor, \( \alpha \) is the angle between \( r \) and \( dL \), because if the distance between two supporting pillars are large, then the wires are curved due to the weight (Figure 1.a)

Where \( \kappa_\mu = \frac{\mu_0}{4\pi} = 10^{-7} \frac{N}{A^2} \) (4)

\( \kappa_\mu \) is the magnetic constant, and \( \mu_0 \) is the magnetic permeability of vacuum

![Diagram](image)

(a) (b) (c)

Figure 1: a. Infinite length case, b, c Infinite length, straight conductor case

In the first approach, if we consider a conductor of infinite length, the equation is simplified, and taking into account the cases of Figure 1.b and Figure 1.c [1]

\[ r = \frac{a}{\sin \alpha} \] and \[ dL = \frac{rd\alpha}{\sin \alpha} = \frac{ad\alpha}{\sin^2 \alpha} \] (5)

\[ B = \int_0^{\pi} \kappa_\mu \frac{l}{a} \sin \alpha d\alpha = \kappa_\mu \frac{l}{a} \int_0^{\pi} \sin \alpha d\alpha = -\kappa_\mu \frac{l}{a} \cos \alpha|_0^\pi = -\kappa_\mu \frac{l}{a} (-1 - 1) = \kappa_\mu \frac{2l}{a} \] (6)

\[ B = \kappa_\mu \frac{2I}{a} = \frac{\mu_0}{2\pi} \frac{I}{a} \] with measurement unit for the \( [B] = \left[ \frac{V \cdot s}{m^2} \right] \) Tesla (T) (7)
In this particular case, we were asked to study a place that belongs to the municipality of Kozani. To check if there were elevated intensities of electric and / or magnetic fields due to the direct proximity of such an energy hub that will probably affect the people who will be active there.

According to World Health Organization [2]:

The bodies of humans significantly perturb the spatial distribution of ELF electric field. At low frequencies the human body is a good conductor. The key features of dosimetry for humans to expose to ELF electric fields are as follow.

• The electric field inside the body is normally five to six orders of magnitude smaller than the external electric field.
• When exposure is mostly to the vertical field, the predominant direction of the induced fields is also vertical.
• For a given external electric field, the strongest induced fields are for the human body in perfect contact through the feet with ground (electrically grounded) and the weakest induced fields are for the body insulated from the ground (in “free space”).
• The total current flowing in a body in perfect contact with ground is determined by the body size and shape (including posture), rather than tissue conductivity.
• The distribution of induced currents across the various organs and tissues is determined by the conductivity of those tissues.
• The distribution of an induced electric field is also affected by the conductivities, but less so than the induced current.
• There is also a separate phenomenon in which the current in the body is produced by means of contact with a conductive object located in an electric field.

For magnetic fields the permeability of the tissue is the same as that of the air, so the field in tissue is the same as the external field. The main interaction of magnetic fields is the Faraday induction of electric fields and is associated with current densities in the conductive tissue. The key features of dosimetry for the exposure of humans to ELF electric fields are as follow.

• The induced electric field and current depend on the orientation of the external field. Induced fields in the body as a whole are greater when the field is aligned from the front to the back of the body, but for some individual organs the highest values are for the field aligned from side to side.
• The weakest electric fields are induced by a magnetic field oriented along the vertical body axis.
• For a given magnetic field strength and orientation, higher electric fields are induced in larger bodies.
• The distribution of the induced electric field is affected by the conductivity of the various organs and tissues. These have a limited effect on the distribution of induced current density.

Proximity to high-low voltage transformers, and especially the high-low-voltage cables of ELF waves, for which, we must notice that can penetrate seawater to a depth of hundreds of meters, always creates phobias in the general population since sometimes they are responsible for perturbation in:

Biophysical mechanisms, Neurobehaviour, Neuroendocrine system, Neurodegenerative disorders, Cardiovascular disorders, Immunology and Haematology, Reproduction and Development and Cancer.

The theme cannot be exhausted in any case and for this reason there are continuous research and recommendations for further research as in the example that is indexed in references [2],[3] and [4].

In diverse studies for frequencies above 0 to 100Hz we notice that by far the majority of studies have been conducted on power frequency (50 on 60 Hz) magnetic fields, with a few studies using power frequency electric fields.

Furthermore, fear and mistrust is increased because in terms of dosimetry there is a non-linear dose-effect relationship (cause / effect) according to the hitherto experimental data that are related to biological / health effects particularly in ELF frequencies. In addition, while we can accurately estimate the energy absorbed, either in whole or in part, this is not possible in the microscopic (cellular) level. Because of the above it is possible for an EM field of a much lower frequency than
that of microwaves, not to create a problem due to thermal energy, kT, caused by oscillations, but to create other serious biological effects without the effect of heating [6].

2. Technical details

**Technical data of the area interest and the requested area.**
The object of the study is the measurement of electrical and magnetic fields that belong to the SLF (super low frequency), including EM waves in the frequency between 30 and 300 Hertz in which also belong the frequencies of AC power grids (50Hz and 60 Hz). There is also a conflict designation which includes this frequency range in the extremely low frequency (ELF) in some contexts.

For the particular case, we refer to the electric energy supply of the capital city of West Macedonia, Kozani which is powered by a substation in the immediate vicinity, with the parking space having the following characteristics.

Power station and parking space characteristics:
- 2 great transformers from 150kV to 20 kV of 20 MW each or 25 each under cooling
- More transformers to 380 V.
- Pillars with cables of high voltage of 150kV, 20 kV and 380 which transverse the parking station.

The area of the parking is 41000 m$^2$ and only a wall separates the power station and the parking area as shown in the following maps. Both the power station and the vehicle parking are placed at a distance of 3 km out of the city of Kozani.

![Figure 2. Google map of the station and the parking](image-url)
Figure 3. The Parking dimensions and the pillars with the cables of high and medium voltage.

In the municipality of Kozani a problem has occurred due to the existence of this power station, which is connected with the parking, in which there are daily people working. For this reason, we studied the intensities of EM fields in the respective area and compared with those provided by the World Health Organization, as well as those provided by the Greek legislation through the Greek Atomic Energy Commission and listed in the following tables so as to ascertain the conditions for its operation.

Data related with permissible values of electric and magnetic fields, which led various organizations and states.

Table 1. E.U. proposal for the E.M. Fields/Greek law nr.512 /25/4/2002 about limitations for Electric, Magnetic and EM fields.

| Frequency Range | Electric Field E Intensity (V/m) | Magnetic Field H Intensity (A/m) | Magnetic Inductance B (μT) |
|-----------------|---------------------------------|---------------------------------|---------------------------|
| 0-1 Hz          | ---                             | 3,2x10^4                        | 4x10^4                    |
| 1-8 Hz          | 10000                           | 3,2x10^4/f^2                   | 4x10^4/f^2               |
| 8-25 Hz         | 10000                           | 4000/f                         | 5000/f                    |
| 0.025-0.8 kHz   | 250/f                           | 4/f                            | 5/f                       |
| 0.8-3 kHz       | 250/f                           | 5                               | 6,25                      |
| 3-150 kHz       | 87                              | 5                               | 6,25                      |
Table II. Values in the frame of the Greek Law (the one with the 50Hz).

| General population | Magnetic Field | Professional employees | Magnetic Field |
|---------------------|----------------|-------------------------|----------------|
| Electric Field      | Magnetic Field | Electric Field          | Magnetic Field |
| 5 kV/m (50 Hz)      | 100 μT (50 Hz) | 10 kV/m (50 Hz)         | 500 μT (50 Hz) |
| 4.2 kV/m (60 Hz)    | 84 μT (60 Hz)  | 8.3 kV/m (60 Hz)        | 420 μT (60 Hz) |

Instrumentation and Methodology.

The apparatus that was used for the measurements was the EFA-300 model equipped with an external B-field Probe for the measurement of the magnetic field values, and with an electric field unit in order to measure electric fields (Figure 4) for which more precautions must be taken because in addition to the magnetic field measurements, the measurements of the electric fields are easily influenced by people or objects near the sensor.

EFA-300 Basic Unit   B-Field Probe 100 cm²   EFA-300 E-Field Unit

Figure 4. EFA apparatus with its electric and magnetic components

The measurements were carried out in 768 places in the area of interest. A lot of them, particularly the electrical ones were repeated because the area was already used by several cars, which influence the spatial distribution of the electric field.
Measurements were taken in the morning, because the period was in the mid-July and the temperatures during midday in the open parking space were very high.

The measurements were made at 1 meter from the ground which corresponds approximately to the height of the main vital organs in the average human

- Measurements at 0; 1; 5; 10 and 15 meters distance from the separation wall.
- Measurements at 0; 1; 5; 10 and 15 meters distance from the high and medium voltage pillars circularly, within the space of interest.
- Measurements from 0 to 1; 5; 10 and 15 meters away from the high voltage cables and pillars of media interest in the interior space.

3. Results

Sample measurements and graphs

Measurement results for magnetic fields B in μT and for electric fields E in Volt/m are displayed in the following graphs:

**Magnetic Fields**

![Magnetic Field Graph](image)

**Figure 5. Magnetic field around medium voltage pillar (G point)**
Figure 6. Magnetic Field around the walls (Points A-E)

Figure 7. Magnetic field around a pillar of high voltage. (Point F)
Electric fields

Figure 8. Electric field around the medium voltage pillar (G point)

Figure 9. Electric Field around the walls (Points A-E)
4. Discussion and Conclusions.

Based on the measurements made on the magnetic fields elevated values were observed near the high voltage line and near the low and/or medium voltage cables where their values do not exceed the permissible limits (Table 2). Also we noticed that the point on the transformer from Hellenic Public Power Corporation (HPPC) (the entrance to the site) generated locally elevated magnetic field, but fell in a short distance (<5 meters) without even exceeding the permissible limits (Table 2). However, the low or medium voltage cables starting from the transformers that are on HPPC side substation, created elevated magnetic fields due to the leakage of a high amount of current which is modulated according to the load of the feeding line.

As for the electric field it is mainly due to the high voltage power lines. The field is stronger under the transmission lines whereas the electric field generated only by the transformer and it is outside the field of the power lines, is lower.

This is true for the measurements shown in the figures above and the same applies for measured values. Increased electric field values were recorded outdoors near the high or medium voltage lines. We observed that in the case of the electric fields the highest values obtained are lower than the statutory lower value than the Greek Atomic Energy Commission (GAEC) set. We report that during the measurements there were parked vehicles which hindered measurements.

An attempt was made to compare the measured values measured with those arising from the theory, using where necessary formulas and fields consisting of two lines, but in many cases there were divergences. The reason is due to several intersecting lines. This shows how to explore in the near
future the possibility of the possible creation of a model that responds to the values that were measured.

We have attempted to attribute S.A.R. values (Specific Absorption Rate) since the operation of heavy vehicles parking is constant. The first performance tests have already been conducted using the values measured and based on the following relationship:

\[
SAR = \frac{1}{V_{\text{sample}}} \int \frac{\sigma(r) |E(r)|^2}{\rho(r)} d(r)
\]

and finally

\[
SAR = \frac{\sigma E^2}{\rho}
\]

Where \( \sigma \) – is the sample conductivity, \( E \) - is the RMS generated internal electric field \( \rho \) – is the sample density and \( V \) – is the sample volume.

We considered the height at which measurements were approximately equivalent to the height of the main vital organs of man. Also we considered an average human tissue density and an average conductance value. Since the values of the density and conductivity differ too much, e.g. density of fat is 0.9 g/cm\(^3\) while the bones’ 1.8 g/cm\(^3\) and the conductivity of muscle from \(~1.000\) S/m reaches \(~0.005\) S/m for the fat, we decided to conclude it in a future study.

**References**

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[4]  Health Council of the Netherlands 2006 Proposals for research info health effects of electromagnetic fields (0-300Hz) from the Hague Publications no2006/11E.

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