Occupational Exposure Assessment of Power Frequency Magnetic Field in 154/31.5 kV Electric Power Substation in Turkey

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Abstract— The survey of magnetic field measurements from the 154/31.5 kV substation in the city of Antalya have been proposed for an occupational exposure assessment. The magnetic field measurements are carried out from a substation equipment; including all transformers, circuit breakers, feeders and buses, under the in-coming and out-going power lines and operator tables surrounding the substation. The magnetic field is measured as 0.46 μT at the minimum loaded season and 1.34 μT at maximum loaded season over the operator desk. Workers are exposed to 0.3 μT and even more magnetic field for eight hours period per day. In switchgear regions, the maximum magnetic field measurement is 20 μT at the minimum loaded season and may reach up to 65 μT. Outdoor magnetic field values at the circuit breaker region may approach to 45 μT depending on operator heights.

1. INTRODUCTION

The effects of exposure to power frequency electromagnetic fields take the attention of the public as an important topic. These 50-Hz field exposures raise the question of what kind of effects these may have on human health. Some epidemiological studies have found weak associations between the exposure to power-frequency EMFs and some forms of cancer, such as leukemia; while other studies have failed to find such associations. Accordingly, the risk of the adverse health effects is getting higher [1, 2]. The scientific evidence suggesting that ELF-EMF exposures pose any health risk is not sufficient. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is not adequate, the epidemiological studies demonstrate for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. Scientists [3–6] observed an increased leukemia risk for children in one or more exposure group, and the risks of adult cancer based on residential exposure to ELF-EMF have been evaluated in a number of studies. Of great concern are the findings of an Auckland university study detailing very high magnetic fields beneath lines in Auckland with significant effects on occupants [6]. This paper presents the results of measurements of the power frequency magnetic fields on a 154/31.5 kV substation in Turkey. A real time measurements were carried out in substations, since the actual magnetic field exposure to occupants is important.

2. DESCRIPTION OF THE SUBSTATION AND MEASUREMENTS

The substation is situated in a residential area about 10 km west side of city of Antalya. Figure 1 depicts part of the substation and Figure 2 shows the simple layout of the substation. There are two 154 kV incoming lines and two outgoing lines, and twelve 31.5 kV outgoing lines. Tables 1 and 2 depict the power and current load details of feeders loading at the time of measurement recorded.

Magnetic fields in the substation was measured by using a commercially available magnetic field meter, ELT-400 Exposure Level Tester, Narda Safety Test Solutions, and Wandel & Golterman, Germany. Figure 3 depicts the magnetic field variations throughout the control room of the substation. The location of the peak magnetic fields obtained in the control room is the location where AC-DC power unit is present, and magnetic field value reaches up to 4 μT for the substation. For three-control room, operator desks read between 0.33 μT and 1.1 μT. Figure 4(a) represents the magnetic field measurements taken in front of the cells and from the back of the cells. In the switchgear region of substation, measured magnetic field value goes up to 20 μT at both front and

Table 1: 154/31.6 kV Substation loads during the measurements of 31.6 kV lines.

Feeder No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Amp.	**94**	**265**	**35**	**70**	**1.9**	**7.8**	**14**	**25.5**	**220**	**177**	**117**	**176.8**

Table 2: The measured magnetic field different locations in the open areas of the substation.

Measurement Locations	Magnetic field (μT)
31.5 kV side of TR-A	4.7
31.5 kV side of TR-B (2 m from TR-B)	7.4
In front of the circuit breaker (SF6)	8.8
Under the 154 kV busbar for TR-B input	3.95
Under the 154 kV busbar for TR-A input	6.5

Figure 1: Open areas of the substation.

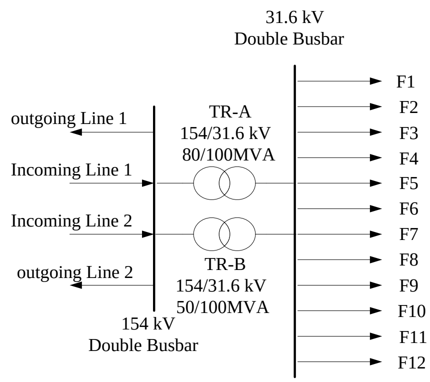

Figure 2: Simple plan layout of the substation.

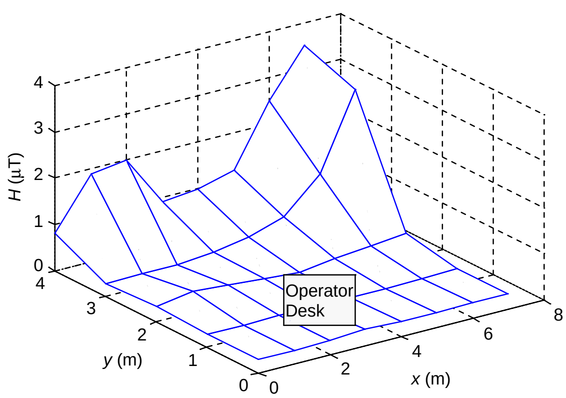

Figure 3: Magnetic field variation for the operator office and daily working room.

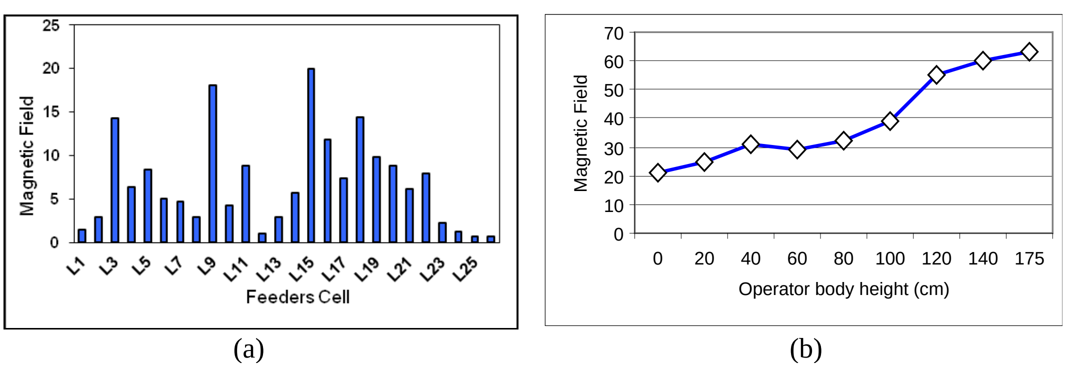

Figure 4: (a) Magnetic field (μT) values at operators working locations. (b) Represents the magnetic field variations over the operator body height while standing in front of 31.5 kV command panel of TR-B.

backside of the related cell. These values are valid at one of the measurement dates. Figure 4(b) shows magnetic field variation over the operator body height while standing in front of 31.5 kV command panel for TR-B. As demonstrated at Figure 4(b), the longitudinal magnetic field varies between 20 μT and 62 μT at the substation.

3. INDUCED ELECTRIC FIELD AND CURRENT DENSITY

The interaction of time varying electric fields with the human body results in the flow of electric charge (current), the polarization of bound charge (for motion of electric dipoles), and reorientation of electric dipoles already present in tissue. The relative magnitudes of these different effects depend on the electrical properties of the body — that is, electrical conductivity and permittivity. Electric conductivity and permittivity vary with the type of body tissue and depend on the frequency of the applied field. Electric fields to the body induce a surface charge on the body; this results in induced currents in the body, the distribution of which depends on exposure conditions, size and shape of the body, and the position of the body in the field [7, 8]. To determine the current density that is induced inside human body standing different locations at substation. The human body is simulated as prolate spheroid [9]. According to Faraday's law, a changing external magnetic field produces an internal electric field inside the body. Thus, the internal induced electric field components can be expressed by the following equations:

$$\vec{E}_x = j\omega\left(\frac{zB_y}{2} - \frac{b^2 yB_z}{a^2+b^2}\right) \tag{1}$$

$$\vec{E}_y = j\omega\left(\frac{a^2}{a^2+b^2}\right)(xB_z - zB_x) \tag{2}$$

$$\vec{E}_z = j\omega\left(\frac{b^2 yB_x}{a^2+b^2} - \frac{xB_y}{2}\right) \tag{3}$$

where B_x, B_y, and B_z are the three components of the external magnetic field and ω is the angular frequency the external magnetic field. Total electric field $\vec{E}$ induced inside the body can be expressed by $E = (E_x^2 + E_x^2 + E_x^2)^{1/2}$, and the current density $\vec{J}$ induced inside the body by the internal field can be determined as $\vec{J} = \sigma\vec{E}$. Where σ is the electric conductivity of the body tissue (S/m). Since we are dealing with the biological body and considering the ELF magnetic field, we have $\sigma \gg \omega\varepsilon$ (ε; permittivity of the body), and hence the displacement current component can be neglected [10–12]. The second-order magnetic field due to the current induced inside the model is also neglected. For this reason, the magnetic field inside the body can be regarded as a uniform. Here, the frequency of external magnetic field is 50 Hz and the conductivity of the body is 0.2 S/m [13]. Table 3 summarizes the maximum induced electric fields and current densities at different operation locations in the substation corresponding to the average magnetic field values resulted from the measurements in the substations.

Table 3: Maximum induced electric fields and current densities for different locations in the substation.

Measurement Locations	**Magnetic field (μT)**	**J(μA/m^2)**
Operator desktop	0.35	1.517
In front of 31.5 kV Command panel for main bar	40	173.416
31.5 kV side of TR-A	4.7	20.376
31.5 kV side of TR-B (2m from TR-B)	7.4	32.082
In front of the circuit breaker (SF6)	8.8	38.15
Under the 154 kV bus bar for TR-B input	3.95	17.124
Under the 154 kV bus bar for TR-A	6.5	28.18

A location that the occupants are working under the maximum average magnetic field was chosen for the data collection. Occupants' desks are reading an induced current density of 1.517 μA/m^2.

4. CONCLUSION

There are four occupants staying 8 hours of shift. Operator desks at substation read a lowest magnetic field of 0.35 μT at minimum loaded season and reached up to 1.1 μT at maximum loaded season that means operators exposed to a magnetic field of 0.35 μT and more by eight hours a day during a year. In switchgear regions, the maximum magnetic field reading is 20 μT at minimum loaded season and reached up to 65 μT. Outdoor magnetic field measurement at circuit breaker region goes up to 40 μT with respect to operator heights. Instead these values are in the limit of International Radiation Protection Association, results given by open literature say that those values are unfortunately in the risk region [1–9]. That's why, employer should force scientists to find a way of decreasing magnetic flux density for such working or living places. For the chosen substations, under the normal load conditions, a maximum magnetic field of 40 μT is measured at 31.5 kV main bus and in the substation. For this magnetic field strength, the maximum internal induced current density is about 173.4 $\mu A/m^2$. For this type of work places, epidemiological and biological studies should be taken into account for a low level magnetic field strength.

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