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ELECTRIC AND MAGNETIC FIELD MEASUREMENTS FOR HIGH VOLTAGE TRANSMISSION LINES: THE CASE OF TURKEY

MERITVE ELEKTRIČNEGA IN MAGNETNEGA POLJA NA VISOKONAPETOSTNIH PRENOSNIH VODIH: NA PRIMERU TURČIJE

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Abstract

A power system is a facility that creates low-frequency electromagnetic fields (EMF) with its high-voltage level and high electric current capacity. In this respect, these electromagnetic fields need to be significantly evaluated from the aspects of both those who are exposed to the fields due to the structure of the facility during their daily lives and those who are exposed to the fields due to their occupation. In this study, the transmission lines and substations in the power system of Turkey are evaluated on account of electric and magnetic field measurements. Firstly, the people living in general public zones near the transmission line or substation were examined. In another part of the study, measurements were made in the occupational exposure of the staff in the energy zone. The results obtained from measurements are compared with the limit values provided by the International Commission on

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Non-Ionizing Radiation Protection (ICNIRP). The measurements were performed by NARDA EFA-300 electromagnetic field measurement. The closest point to the ground was determined as the reference point for the measurements performed on transmission lines. The results for different distances were obtained by performing measurements following those reference points with fixed distances.

Povzetek

Elektroenergetski sistem s svojo visokonapetostno stopnjo in visoko električno zmogljivostjo v okolju ustvarja nizkofrekvenčna elektromagnetna polja (EMF), ki jih je potrebno natančno ovrednotiti tako z vidika tistih, ki so izpostavljeni zaradi same strukture elektroenergetskega sistema v svojem vsakdanjem življenju, kot tistih, ki so poklicno izpostavljeni. V tej raziskavi so z vidika električnega in elektromagnetnega polja na podlagi meritev ovrednoteni daljnovodi in podpostaje v elektroenergetskem sistemu Turčije. V prvem delu raziskave so bile pregledane osebe, ki živijo v splošnih javnih conah v bližini daljnovoda ali podpostaj. V drugem delu so bile izvedene meritve pri poklicni izpostavljenosti osebja v energetskem območju, sami rezultati pa so primerjani z mejnimi vrednostmi, ki jih je zagotovila Mednarodna komisija za zaščito pred neionizirnimi sevanji (ICNIRP). Same meritve so bile izvedene z uporabo merilnika NARDA EFA-300, pri katerih je bila najbližja točka tal določena kot referenčna točka za meritve na daljnovodih. Rezultati za različne razdalje so dobljeni z izvajanjem meritev po referenčnih točkah s fiksno razdaljo.

1 INTRODUCTION

Power lines and electric appliances have separate electric and magnetic fields around them when current flows through them; specifically, these are not coupled electric and magnetic fields. The measurement of the electromagnetic fields that occur around the surroundings of transmission lines is performed via quantitative and analytical methods; the use of these methods began in the 1960s. The electricity current on the high-voltage transmission lines created low-frequency electromagnetic-fields on the environment. Much research has been carried out to investigate health hazards in connection with exposure to electric and magnetic fields from high voltage power lines. Reviews of the available data on the biological effects of exposure to these fields do not allow any definite conclusion concerning the health risk for the general population or for occupationally exposed workers. Concern that magnetic fields (MF) from power lines, commonly referred to as either “electromagnetic fields (EMF)" or "extremely low frequency (ELF) fields" may cause childhood leukaemia has continued to be expressed by some for many years, *[1-4]*.

Studies from the 1970s showed an increase that was statistically significant in childhood leukaemia for children living near power lines. Of the many additional studies since then, about half show small correlations with proximity to power lines and/or weak magnetic fields, and about half do not, *[5]*.

However, the possibility that there may be a cause and effect for long-term exposure to low levels of low-frequency electromagnetic fields has led to the classification by the International Agency for Research on Cancer (IARC), an agency of the World Health Organization (WHO), as a possible cause of cancer. However, this classification has not been included in the International Committee on Electromagnetic Safety or ICNIRP reference levels because of conflicting results and a lack of physical mechanisms by which weak magnetic fields could be expected to modify biological systems. The IARC has published an extensive review of the research epidemiological and laboratory research used in its determination concerning cancer; the WHO previously published a similar monograph concerning low-frequency field effects and various diseases, including cancer, *[2, 5]*. The WHO/International Agency for Research on Cancer (IARC) has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), *[6]*. It is known that the electromagnetic field decreases as the distance from the source that generates the electric and magnetic fields increases.

The continuous increase in the demand for electrical energy, which has an essential place in daily life, reveals the necessity of a more reliable and quality energy concept. Technological criteria in the transmission of electrical energy must be taken into account. In order to operate safely and uninterruptedly, which is the measure of the quality of an electrical transmission system, in addition to the use of some technological developments, it is necessary to consider the electric and magnetic field parameters in the design and operation of the system. Considering the great number of high voltage equipment in the energy transmission systems and the effects of the field parameters generated by this equipment, it is necessary to investigate how are affected the field parameters in which the staff in the energy zone work and the people close to the energy zone live. The exposed electric and field electromagnetic values are given in Table 1 in the power transmission/distribution line for different voltages, *[7]*.

Table 1: *The samples values of electric and magnetic fields in overhead transmission lines at 50 Hz for different voltage levels*

The voltage level of the lines	Electric Field(V/m)			Magnetic Field (μT)		
	under the line	30 m away from axial	100 m away from axial	under the line	30 m away from axial	100 m away from axial
400 kV	5000	2000	200	30	12	1.2
225 kV	3000	400	40	20	3	0.3
90 kV	1000	100	10	10	1	0.1
20 kV	250	10	Negligible	6	0.2	Negligible
230 V	9	0,3	Negligible	0,4	Negligible	Negligible

Because taking into account electrical and magnetic field problems will be increased, high voltage systems should be examined according to the predefined and standardized field parameter sizes at the establishment and design stage.

In this context, the effective values of the magnetic and electric fields were measured in substation and power transmission lines. With these measurements, it was determined to what extent the staff in the energy area were exposed to these areas. Electromagnetic field exposure values were compared with similar studies and standards. In Turkey, as a result of these measurements are made to assessment about transmission system and substation and some suggestions.

2 CASE STUDY

2.1 Material and Methods

In Tables 2 and 3, the reference levels of occupational exposure and the general public for electric and magnetic fields are given. The reference levels assume that the human body is exposed to a homogeneous field and associated with the spatial extension, *[4]*.

Table 2: *Reference levels for occupational exposure to time-varying electric and magnetic fields (unperturbed rms values).*

Frequency range	Electric field strength E (kV/m)	Magnetic field strength H (A/m)	Magnetic flux density B (T)
1 Hz-8 Hz	20	$1,63\times10^5/^2$	$0,2/f^2$
8 Hz-25 Hz	20	$2\times10^4/f$	$2,5\times10^{-2}/f$
25 Hz-300 Hz	$5\times10^2/f$	8×10^2	1×10^{-3}
300 Hz-3kHz	$5\times10^2/f$	$2,4\times10^5/f^2$	0,3/f
3kHz-10 MHz	$1,7x10^{-1}$	80	1×10^{-4}

Table 3: *Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed rms values).*

Frequency range	Electric field strength E (kV/m)	Magnetic field strength H (A/m)	Magnetic flux density B (T)
1 Hz-8 Hz	5	$3,2\times10^4/f^2$	$4\times10^{-2}m\ /f^2$
8 Hz-25 Hz	5	$4\times10^3/f$	$5\times10^{-3}/f$
25 Hz-50 Hz	5	$1,6\times10^2$	2×10^{-4}
50 Hz−400 Hz	$2,5\times10^2/f$	$1,6\times10^2$	2×10^{-4}
400 Hz−3 kHz	$2,5\times10^2/f$	$6,4\times10^4/f$	$8\times10^{-2}/f$
3 kHz−10 MHz	$8,3\times10^{-2}$	21	$2,7\times10^{-5}$

The International Commission on Non-ionizing Radiation Protection (ICNIRP) has established guidelines for the protection of people exposed to electric and magnetic fields in the low-frequency range of electromagnetic fields. The low-frequency range of ICNIRP guides ranges from 1 Hz to 100 kHz.

ICNIRP guidelines above 100 kHz are within the protection range of 100 kHz to about 10 MHz. However, depending on the conditions of exposure to low-frequency effects on the nervous system, high-frequency effects should also be considered. Therefore, ICNIRP guidelines have been extended from 1Hz to 10 MHz to cover the effects of the nervous system.

The main purpose of ICNIRP is to provide guidelines for protection against all adverse health effects of electromagnetic fields and to limit exposure to electric and magnetic fields (EMF). Studies on both the direct and indirect effects of electric and magnetic fields are given by ICNIRP. Electromagnetic effects are caused by direct interaction of fields with the body; indirect effects include interactions with a conductive object when the electrical potential of the object is different from that of the body. The results of laboratory and epidemiological studies and reference levels for the assessment of hazard criteria for exposure to electric and magnetic fields are discussed. Furthermore, the values stated in the ICNIRP apply to both those working under energy and those exposed to the public, *[8]*.

The measurements were made in a substation and transmission line for magnetic and electric field measurements. The devices for electrical and magnetic field measurements are placed in the working area at the height of 2 m from the ground. The maximum approach distances were determined in the measurements in the energy zone. Narda EFA-300 magnetic field and electric field measurement device shown in Fig.1 was used.

Figure 1: *The instrument used in the measurement*

Cross-sections of conductors and the approach distance information on the pole in electromagnetic investigations carried out on the energy transmission line measured as:

- The phase conductor heights from the ground at the measuring point: 16.89 m–17.04 m–16.47 m
- The protection conductor height from the ground: 26.13 m
- Conductor cross-section: 2×954 MCM

In this study, the limit values for extra-low frequency (ELF) electric field strength and magnetic induction by ICNIRP are considered.

2.2 Results and Discussion

The magnetic field on the power transmission line and the situated zero meter point specified in the electric field measurements are the maximum deflection point of the transmission line. “+60 m” and “-60 m” values are taken as the base 60 meters in front of and back of the maximum deflection point of the magnetic field and measured according to these distances. These magnetic and electric field measurements are shown on the graph in Fig. 2 and Fig. 3.

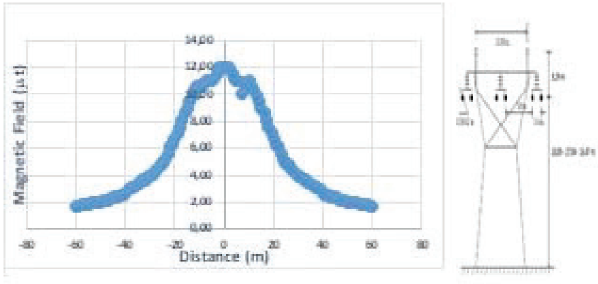

Figure 2: *The measured magnetic field for a transmission line with 400 kV for different distances*

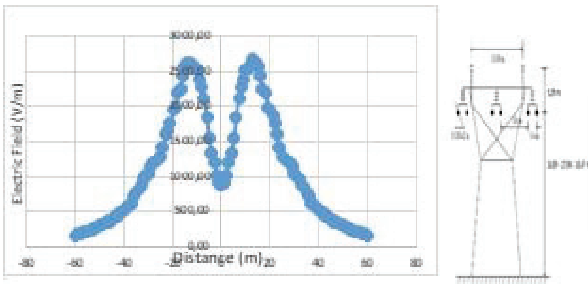

Figure 3: *The measured electric field for a transmission line with 400 kV for different distances*

After examining the transmission lines, the electromagnetic field measurements of the secondary side of 400 kV/154 kV transformer performed at Feeder 1 and Feeder 2 in the substation shown in Fig.4 measured as:

At Feeder 1:

- Current during measurement (A): A phase 334 A / B phase 338 A / C phase 330 A
- Voltage during measurement (kV): A-B phase 157.2 kV / B-C phase 156.2 kV / C-A phase 156 kV
- Conductor Distances: A phase 9.81 m / B phase 9.81 m / C phase 9.81 m
- Conductor cross-section: 954 MCM

At Feeder 2 :

- Current during measurement (A): A phase 334 A / B phase 326 A / C phase 328 A
- Voltage during measurement (kV): A-B phase 158 kV / B-C phase 156.6 kV / C-A phase 156.3 kV
- Conductor Distances: A phase 9.81 m / B phase 9.81 m / C phase 9.81 m

Figure 4: *The 400/154 kV substation in field measurements*

The situated zero meter point indicated in the magnetic and electric field measurements at the substation is the midpoint of Feeder 1 and Feeder 2. "+41 m" and "-41 m" values are taken as the basis of 41 meters right and left from the midpoint of Feeder 1 and Feeder 2. These magnetic and electric field measurements are shown on the graph in Fig. 5 and Fig. 6.

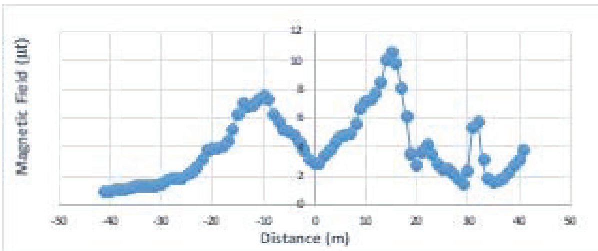

Figure 5: *The measured magnetic field for a substation with 154 kV for different distances*

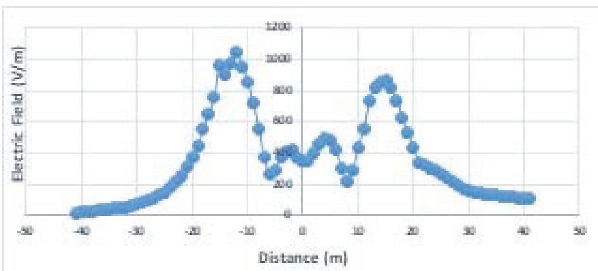

Figure 6: *The measured electric field for a substation with 154 kV for different distances*

3 CONCLUSION

Methods that reduce the effects of electric and magnetic fields are important for the health of both employees and people in public areas.

In this study, firstly, the people living in general public zones near the transmission line or substation are examined. In another part of the study, measurements were made in occupational exposure of the staff in the energy zone. Expanding these measurements will provide important data for both transmission lines and substation design.

In addition, the methods of reducing the electromagnetic effects in terms of the general public zone will raise the awareness of the people living nearby and will contribute to the spread of health measures.

The data obtained as a result of electromagnetic measurements will provide the necessary information about occupational diseases for the staff. Therefore, the investigation of electromagnetic effects on occupational safety and human health will contribute positively to reducing occupational diseases.

ELF in high voltage lines is important for people who are exposed to both occupational and public areas. Employees and the public should be informed about this issue.

The transmission system should be designed in line with the distances obtained during the measurements. The results of this study are below the measured values when compared with the relevant ICNIRP reference values.

As a result of the measurements, it is seen that both the people working under the voltage and the people living in the general public zones are exposed to the effects of the electric and magnetic fields.

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Nomenclature

(Symbols)	(Symbol meaning)
A	Ampere
B	Magnetic flux density
E	Electric field strength
f	Frequency
H	Magnetic field strength
Hz	Hertz
m	Meter
MCM	Micro Circular Mil
T	Tesla
V	Volt