Measurements of 50-Hz Electromagnetic Fields in Different Environments

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Abstract – **The power companies as well as the public are becoming increasingly interested in the possible link between exposure to power frequency magnetic fields and the human health. Therefore, special attention is given to measurements of the magnetic field level and their comparison to the established or recommended limits according to national standards in different environments**

Keywords – **electromagnetic fields, measurements of the magnetic field, influence to human health**

I. Introduction

The development and the frequent diffusion of the various parts of the electrical energy sector and the consumers' systems are increasing the safety hazards and impose obligations concerning the maximum allowed human exposure to magnetic fields. This has led to standards defining magnetic field reference levels, aimed at providing simpler means of verifying compliance with the basic restrictions and assessing field effects. The CENELEC European Pre-standard ENV 50166-1 defines the magnetic field reference levels for workers and for the general public as follows:

Table 1: Magnetic field reference level - Workers

Frequency f [Hz]	Magnetic field B
0 - 0,1	2 T
0,1 - 0,23	1,4 T
0,23 - 1	320/ f [mT]
1 - 4	320/ f^2 [mT]
4 - 1500	80/ f [mT] (1,6 mT at 50 Hz)
1500 - 10000	0,053 mT

Table 2: Magnetic field reference level - General public

Frequency f [Hz]	Magnetic field B
0 - 0,1	0,04 T
0,1 - 1,15	0,028 T
1,15 - 1500	32/ f [mT] (0,64 mT at 50 Hz)
1500 - 10000	0,021 mT

These values are only for an 8-hour time-weighted average and generally allow higher levels for limbs. Nevertheless, even this pre-standard mentions reports stating that electromagnetic fields of lower intensity than the reference levels specified in the standard may have long-term effects on health, but currently available research however has not established adverse effects and does not provide a basis for further restriction of exposure.

The remaining obligation is therefore to design systems or perform measurement campaigns that can analyse the magnetic field levels in both working and residential environments and determine whether they fit in the defined reference levels. Furthermore, it is important to observe the maximum and mean field values, their relationship and their occurrence especially in systems where calculation is not available.

The purpose of this paper is to examine the magnetic fields in residential environments and fields generated by transmission overhead lines. The long time monitoring of the magnetic fields has been achievable with the development of a new generation of microprocessor-based instrumentation. The investigation of the electromagnetic fields (EMF) under power transmission lines are directed towards improving the analytical models for predicting those fields and to find lines with reduce EMF emissions.

The measurements in residential apartments were carried with a field analyser (Wandel & Golterman, Germany) whose three-dimensional isotropic probes are used to record data allowing non-directional measurement. It measures extremely-low frequency (ELF) magnetic fields in the range of 5 Hz to 30 kHz, with the possibility of spectral recording of field components. The main attention during the measurements was given to power frequency (50 Hz) magnetic fields, but rms values of the field in the widest range (5 Hz - 30 kHz) were also recorded for comparison. The EFM measurements under transmission lines were performed with three axis data logging instrument - Emdex C with triggering wheel, made by EFM Company, U.S.A. The Emdex C instrument incorporates technology developed under the sponsorship of EPRI. The magnetic field waveform measurements were conducted with FLUKE scopemeter with EFM 140 magnetic sensor. Those measurements were single axis.

II. Measurements in Residential Environment

The measurements in this environment were carried in 4 apartments in different multi-dwelling buildings, all of them located in the central distribution area of Skopje. Since significantly different measurement results can be obtained using different protocols and instrumentation, the Protocol for spot measurements of residential power frequency magnetic fields, which is a report of the IEEE Magnetic Fields Task Force [1], was followed, meaning measurements were done with appliances left as found; in five rooms frequently used by the occupants (the protocol requires at least three rooms) and near the centre of each room and away from appliances.

The last comment is especially important having in mind the results of the survey, as reported in [2], on the spatial variations of the power frequency magnetic field levels in

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the same room. The correlation between measurements in the centre of the room and at other points varies from 0.642 (in kitchens) to 0.789 (in living rooms), probably due to the dominant presence of appliances in former. Additionally, during the measurement large variations were detected close to appliances that were noted in the mentioned protocol, as well.

The measurement campaign covered a 16-hour period during which the magnetic levels were recorded in every hour. The recordings contain values of the maximum (B_{max}) and root-mean-square value (B_{rms}) of the power frequency magnetic field, as well as the rms value of the magnetic field in the bandwidth of 5 Hz to 30 kHz (B_{wb}).

Table 3 contains the average values for these quantities, while Table 4 contains the average values of the ratio between rms and maximum value as well as the ratio between the rms value for 50 Hz and the wide-band all this in different rooms in apartments #1 to #4. In both tables, overall averages and standard deviations are also presented.

Table 3 – Average values of the measured magnetic field level [µT]

	Apartment #1			Apartment #3		
	B_{max}	B_{rms}	B_{wb}	B_{max}	B_{rms}	B_{wb}
Living	0.080	0.045	0.131	0.149	0.090	0.138
Entry	0.109	0.063	0.142	0.128	0.080	0.131
Kitchen	0.105	0.063	0.138	0.163	0.104	0.150
Bedro.1	0.116	0.069	0.149	0.184	0.122	0.158
Bedro.2	0.091	0.054	0.145	0.198	0.127	0.164
Average	0.100	0.059	0.141	0.164	0.105	0.148
Stan.dev	0.015	0.009	0.007	0.028	0.020	0.014
	Apartment #3			Apartment #4		
Living	0.174	0.111	0.174	0.111	0.174	0.111
Entry	0.223	0.140	0.223	0.140	0.223	0.140
Kitchen	0.205	0.134	0.205	0.134	0.205	0.134
Bedro.1	0.224	0.153	0.224	0.153	0.224	0.153
Bedro.2	0.172	0.109	0.172	0.109	0.172	0.109
Average	0.200	0.129	0.174	0.960	0.675	0.669
Stan.dev	0.025	0.019	0.013	0.373	0.322	0.306

Table 4 – Average ratios [%]

	Apartment #1		Apartment #2	
	Brms/Bmax	Brms/Bwb	Brms/Bmax	Brms/Bwb
Living	55.92	34.47	59.46	62.12
Entry	56.07	42.68	60.61	58.81
Kitchen	59.93	44.87	61.09	64.26
Bedro.1	60.01	47.49	63.72	72.63
Bedro.2	59.03	37.44	63.81	76.31
Average	58.19	41.39	61.74	66.83
Stan.dev	2.04	5.35	1.94	7.36
	Apartment #3		Apartment #4	
Living	64.30	64.79	74.60	100.86
Entry	64.72	80.38	69.25	99.51
Kitchen	65.03	75.67	75.19	99.58
Bedro.1	67.83	84.44	76.38	110.07
Bedro.2	64.68	72.49	56.05	90.87
Average	65.31	75.55	70.29	100.18
Stan.dev	1.43	7.54	8.42	6.82

It is important to note that apartment #4 steps out of the magnetic field range in which the other ones lay, due to closeness of a 110 kV transmission lines.

III. Measurements under Transmission Lines

This part included electric and magnetic fields measurements under transmission and distribution lines. Also, the appropriate computer programs were developed for the calculation of the electric and the magnetic fields using the quasi-static approach.

Field levels were recorded along the way perpendicular to the overhead line and passing through line lowest point, 1m above the ground. The measurements of the electric field must be made with extreme caution, because the electric field is influenced by close objects.

Additional problem could be the exact height of transmission line conductors, because the designed values of the lines heights could be different from real.

The measured and calculated curves of the electric fields under 220 kV and 110 kV line are given on Fig. 1 and 3. The values of the measured curves are smaller than calculated one, as input data for the height of the conductors were used designed values of the transmission lines. The measured magnetic field under 220 kV and 110kV lines are shown on Fig. 2 and 4. For the 220 V line (Fig. 2) the curve 2 is calculated with measured height and curve 3 is calculated with

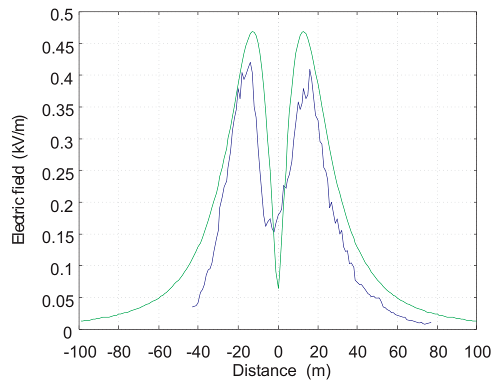

Fig. 1. Measured (1) and calculated (2) curves of electric field under 220 kV line Skopje 1 - Kosovo

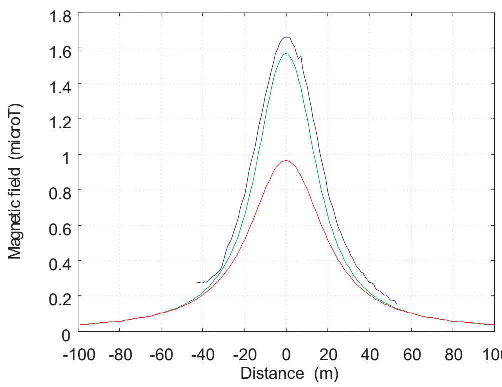

Fig. 2. Measured (1) and calculated (2) and (3) curves of magnetic field under 220 kV line Skopje 1 - Kosovo

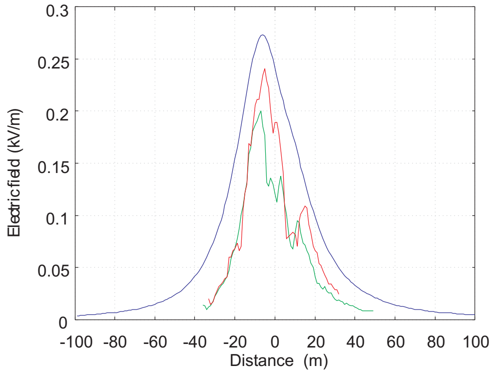

Fig. 3. Measured (1), (2) and calculated (3) curves of electric field under 110kV line Skopje-Tetovo

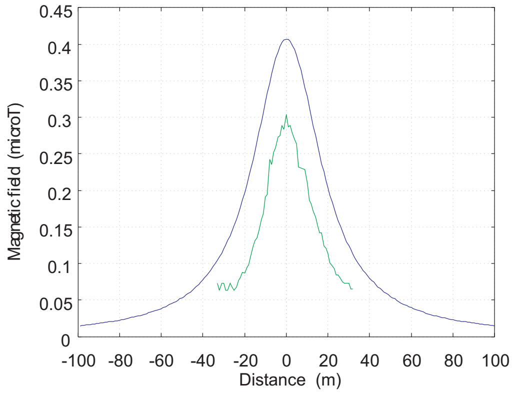

Fig. 4. Measured (1) and calculated (2) curve for magnetic field under 110kV line Skopje - Tetovo

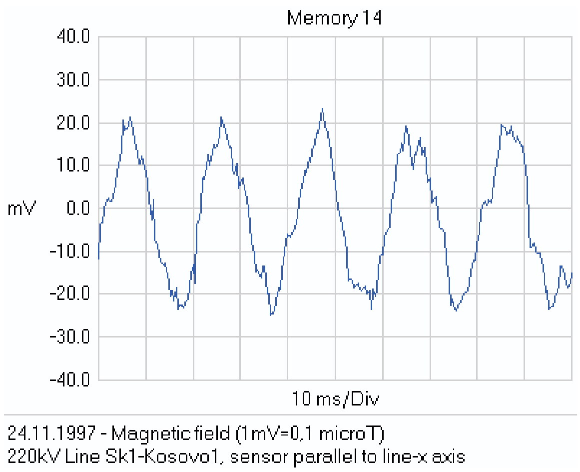

Fig. 5. Magnetic field under 220kV line

designed height of the line conductors.

The measured values of magnetic fields are well below some recommended limits [6], this is due low line load in the moment of measurements. The measured data were used for calculating the normalized values that correspond to the maximum load. The average normalized density peaks mounted to the 16,96 μT for 110 kV line, 18,35 μT (220kV line) and 34,18 μT (400 kV line).

The influence of the soil resistivity on the magnetic fields was also considered and it had no importance for the distances near power lines. Single-axis waveform measurements of the magnetic field were made under 220kV transmission line (Fig. 5) and under 35kV distribution line (Fig. 6). Spectrum analyses were performed for measured waveforms (Fig. 7 and 8). The harmonic content is richer

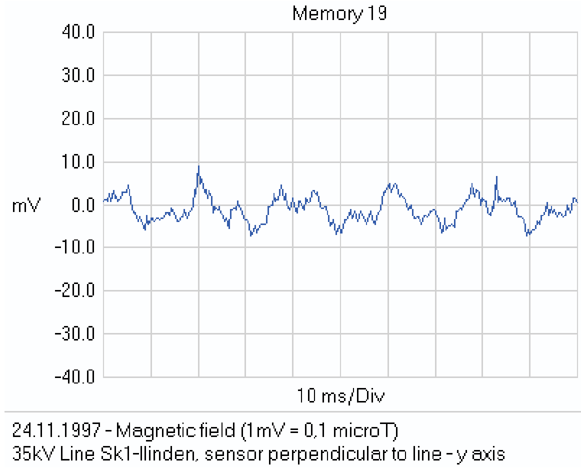

Fig. 6. Magnetic field under 35 kV line

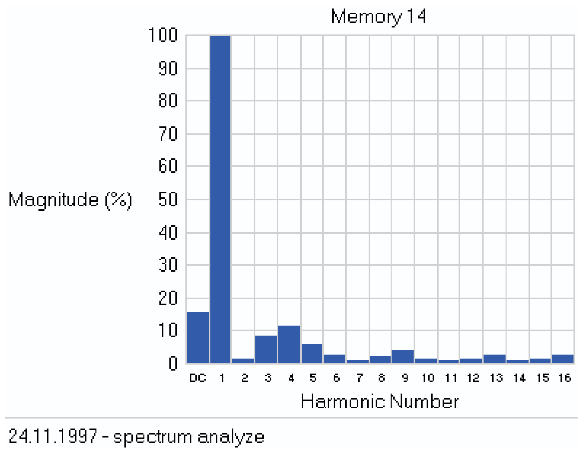

Fig. 7. Spectrum content of magnetic field under 220kV line

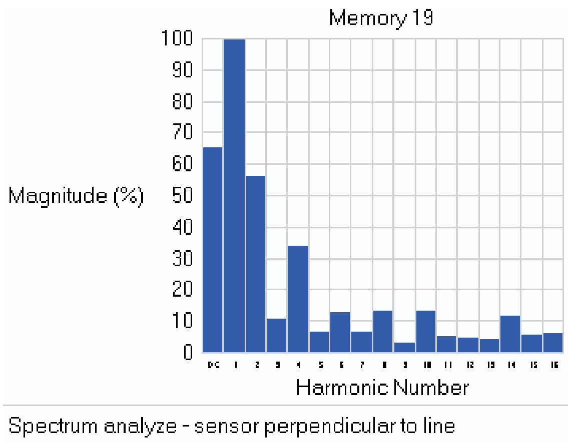

Fig. 8. Spectrum content of magnetic field under 35kV line

for 35kV line, it seems that phase currents in this line is less balanced.

Two cases of private houses in the vicinity of transmission lines were closely observed. In both cases, the limits defined in standards were not exceeded, the normalized peak values reached 30,7 μT (on the estate very close to 400kV line) and 5 μT (under 110kV line), which is hardly recommendable for permanent environment and it is difficult to estimate the long-term effect of the EMF on humans health.

IV. Conclusions

This part of the measurement campaign covered residential environments and transmission lines. Generating stations, distribution substations, large consumers and offices will be included in the second phase.

The residential environments are characterized by a low magnetic field level, way below the standard limits. Even the apartment with the highest level has an average almost 1000 times smaller then the limit prescribed by CENELEC standard (0,675 μT as opposed to 0,64 mT).

The highest values of B_{rms} peaks in all apartments were recorded in kitchens. However, this is not the case with their average values, due to significant sags characteristic of kitchen.

Also, the three axis and the single axis measurements of the EMF under the power transmission and distribution lines have been done. The measurements are compared against computer calculations, a close correspondence between them has been observed. Observation of the spectrum content of the magnetic field under transmission and distribution lines was made.

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