IMPACT ANALYSIS OF THE ELECTROMAGNETIC FIELDS OF TRANSFORMER STATIONS CLOSE TO RESIDENTIAL BUILDINGS

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ABSTRACT

This article focuses on the area of electromagnetic fields that are emitted by transformers and distribution lines placed near the residential areas. This is a high voltage device for transforming AC voltage from 22 kV to 400 V and 230 V. These devices are placed in an brick buildings to avoid the negative effects of electromagnetism on human health. In the paper is analyzed and evaluated the electric field strength E and the magnetic flux density B. In terms of hygiene and health, values were evaluated with legislation in the Slovak Republic, relating to objectification and evaluation of electromagnetic fields. Slovak legislation is based on documents issued by the ICNIRP (International commission on non-ionizing radiation protection). For measurements was used EFA 300 analyzer and probes for electric and magnetic fields, manufactured by Narda.

Keywords: impact, electromagnetic fields, transformer stations

1. INTRODUCTION

ICNIRP notes that the industries causing exposure to electric and magnetic fields are responsible for ensuring compliance with all aspects of the guidelines. Measures for the protection of workers include engineering and administrative controls, personal protection programs, and medical surveillance. Appropriate protective measures must be implemented when exposure in the workplace results in the basic restrictions being exceeded. As a first step, engineering controls should be undertaken wherever possible to reduce device emissions of fields to acceptable levels. Such controls include good safety design and, where necessary, the use of interlocks or similar health protection mechanisms [1].

Basic restrictions that are described in [1], [2] are divided on the basis of various frequency ranges:

- 1 Hz and 10 MHz, basic restrictions are provided on current density to prevent effects on nervous system functions.
- 100 kHz and 10 GHz, basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localized tissue heating.

- 100 kHz–10 MHz, restrictions are provided on both current density and SAR.
- 10 and 300 GHz, basic restrictions are provided on power density to prevent excessive heating in tissue at or near the body surface.

2. OCCUPATIONAL AND GENERAL PUBLIC EXPOSURE LIMITATIONS

The occupationally exposed population consists of adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. By contrast, the general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups or individuals. In many cases, members of the public are unaware of their exposure to EMF. Moreover, individual members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure. It is these considerations that underlie the adoption of more stringent exposure restrictions for the public than for the occupationally exposed population [1].

Tables 1 and 2 summarize the reference levels for occupational exposure and exposure of the general public [1].

Table 1 Reference levels for occupational exposure to time-varying electric and magnetic fields (unperturbed RMS values)

Frequency range	E-field strength ($V\ m^{-1}$)	H-field strength ($A\ m^{-1}$)	B-field (μT)	Equivalent plane wave power density S_{eq} ($W\ m^{-2}$)
up to 1 Hz	—	1.63×10^5	2×10^5	—
1–8 Hz	20,000	$1.63 \times 10^5/f^2$	$2 \times 10^5/f^2$	—
8–25 Hz	20,000	$2 \times 10^4/f$	$2.5 \times 10^4/f$	—
0.025–0.82 kHz	$500/f$	$20/f$	$25/f$	—
0.82–65 kHz	610	24.4	30.7	—
0.065–1 MHz	610	$1.6/f$	$2.0/f$	—
1–10 MHz	$610/f$	$1.6/f$	$2.0/f$	—
10–400 MHz	61	0.16	0.2	10
400–2,000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	$f/40$
2–300 GHz	137	0.36	0.45	50

Table 2 Reference levels for general public exposure to time-varying electric and magnetic fields (unperturbed RMS values)

Frequency range	E-field strength ($V\ m^{-1}$)	H-field strength ($A\ m^{-1}$)	B-field (μT)	Equivalent plane wave power density S_{eq} ($W\ m^{-2}$)
up to 1 Hz	—	3.2×10^4	4×10^4	—
1–8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8–25 Hz	10,000	$4{,}000/f$	$5{,}000/f$	—
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	—
0.15–1 MHz	87	$0.73/f$	$0.92/f$	—
1–10 MHz	$87/f^{1/2}$	$0.73/f$	$0.92/f$	—
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2–300 GHz	61	0.16	0.20	10

Slovak Republic has implemented in their legislation, these reference levels for occupational exposure and general public exposure.

3. DESCRIPTION OF MEASUREMENT

Practices of authors [3], [4], [5] who are engaged of measuring and assessing of the impact of electromagnetic fields are often different. It is associated with a different measuring device as well as different methods of setting values for the assessment. It is necessary for these measurements and assessments to be as possible to comply with ISO and EN standards and ICNIRP standards.

For the measurement of electromagnetic fields, was used measuring chain which consisted of:

- Field analyzer for LF fields, selective and broadband, Narda EFA 300, frequency range from 5 Hz to 32 kHz.
- Isotropic electric (E) field probe, measurement range from 10 V/m to 100 kV/m.
- Isotropic magnetic (B) field probe, measurement range from 100 nT to 32 mT.

For this measurement chain is with our internal directive determined the expanded uncertainty 29,1 %.

For the determination of expanded uncertainty are used methods described in article [7].

Objects of interest of these measurements were brick transformer station for transforming AC voltage from 22 kV to 400 V and 230 V at an network frequency of 50 Hz. Was measured and evaluated 10 of transformer stations, all of which are placed in residential locations. Measurements were carried out in the frequency range from 30 Hz to 2 kHz. Measuring mode has been set for the effective RMS value. The floor inside the buildings is poured concrete, walls are burnt bricks covered with plaster. All doors in the building are metal. All measurements inside the building were carried out at a distance of 1 m from the high voltage transformer at 1,5 m height. Measuring points in the external environment have been placed at a distance of 1 m from the metal door of transformer station towards the apartment block and at height 1,5 m above ground level. For all measurements, has identified with the analyzer EFA 300 the network frequency of 50 Hz.

4. THE MEASUREMENT RESULTS

The results of the measurement of the electric field strength (E) and the magnetic flux density (B) inside the objects of 10 transformer stations are shown in Tab. 3 and graphically in Fig. 1. The measured values are corrected by the expanded uncertainty and compared with the reference levels for occupational exposure.

Table 3 Results of the measurement inside the objects with reference levels for occupational exposure

Marking of transformer station	Measured values of electric field strength	E-values corrected by the expanded uncertainty	Measured values of magnetic flux density	B-values corrected by the expanded uncertainty	Reference level for electric field strength	Reference level for magnetic flux density
	E [V.m^{-1}]	E_C [V.m^{-1}]	B [μT]	B_C [μT]	E_R [V.m^{-1}]	B_R [μT]
TS 403	33,62	43,40	13,17	17,00	10000	500
TS 409	35,41	45,71	15,10	19,49		
TS 411	34,35	44,34	8,05	10,39		
TS 415	37,15	47,96	9,98	12,88		
TS 419	31,36	40,48	11,49	14,83		
TS 421	39,80	51,38	6,21	8,01		
TS 422	39,83	51,42	16,70	21,56		
TS 423	37,73	48,70	10,11	13,05		
TS 424	33,32	43,01	10,01	12,92		
TS 430	34,46	43,40	12,04	17,00		

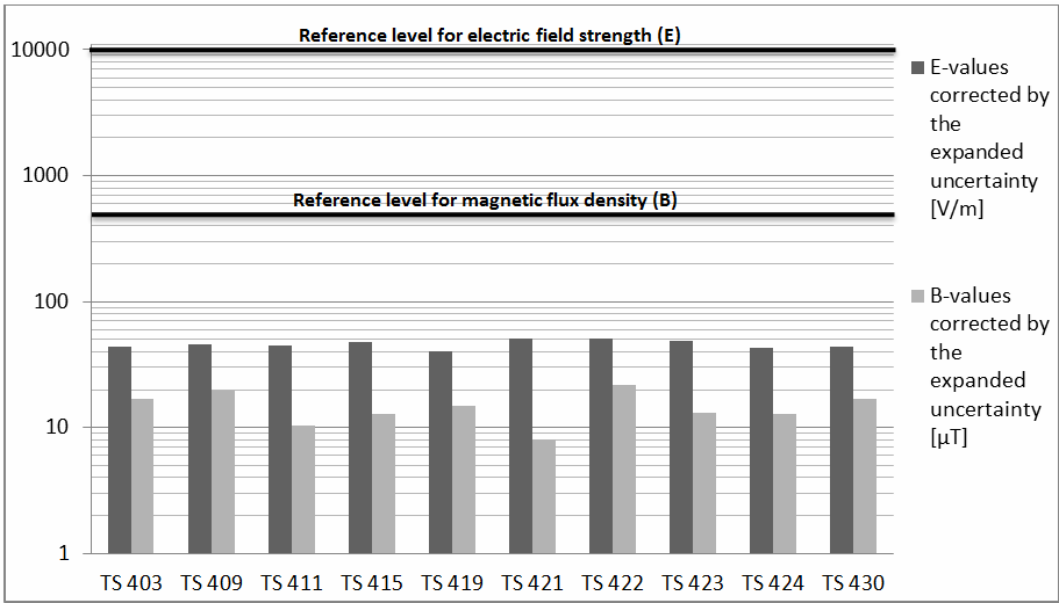

Figure 1 Graphical representation of the results

The results of the measurement of the electric field strength (E) and the magnetic flux density (B) in the external environment near the 10 of transformer stations are shown in Tab. 4 and graphically in Fig. 2. Values of electric field strength were lower than 10 V/m, but this is the minimum value of the measuring range of the E-field probe. Further measurements with the E-field probe was not performed. The measured values are corrected by the expanded uncertainty and compared with the reference levels for general public exposure.

Table 4 Results of the measurement in the external environment with reference levels for general public exposure

Marking of transformer station	Measured values of electric field strength	E-values corrected by the expanded uncertainty	Measured values of magnetic flux density	B-values corrected by the expanded uncertainty	Reference level for electric field strength	Reference level for magnetic flux density
	E [V.m^{-1}]	E_C [V.m^{-1}]	B [μT]	B_C [μT]	E_R [V.m^{-1}]	B_R [μT]
TS 403	< 10	-	0,695	0,897	5000	100
TS 409	< 10	-	0,682	0,880		
TS 411	< 10	-	0,601	0,776		
TS 415	< 10	-	0,732	0,945		
TS 419	< 10	-	0,609	0,786		
TS 421	< 10	-	0,653	0,843		
TS 422	< 10	-	0,600	0,775		
TS 423	< 10	-	0,700	0,904		
TS 424	< 10	-	0,681	0,879		
TS 430	< 10	-	0,698	0,897		

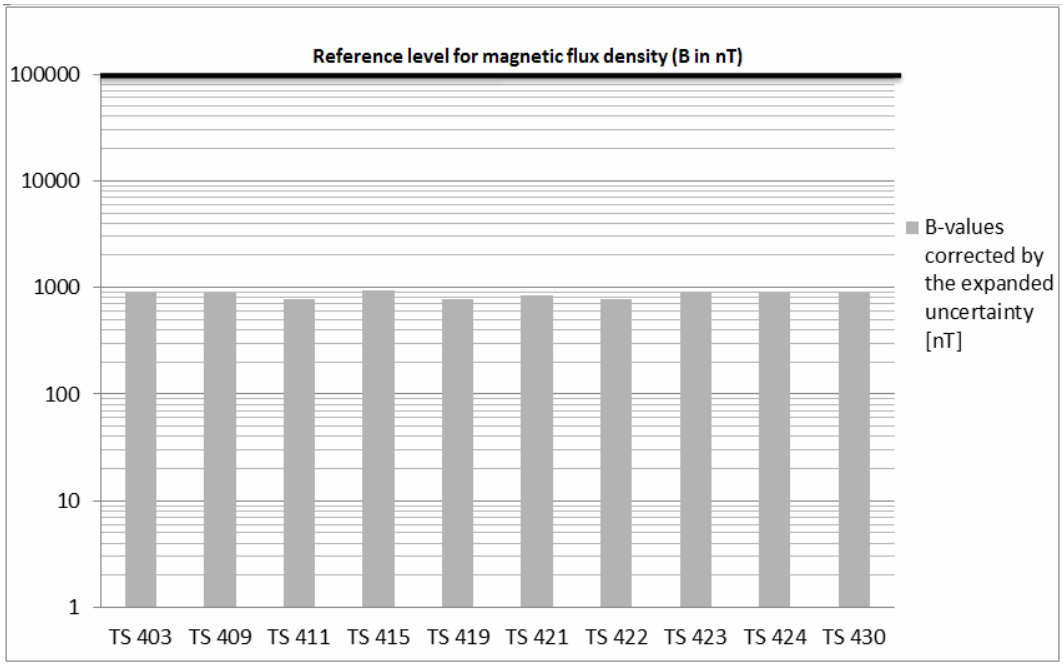

Figure 2 Graphical representation of the results

5. CONCLUSION

In the document [8] is states that reference levels are provided for comparison with measured values of physical quantities compliance with all reference levels given in these guidelines will ensure compliance with basic restrictions. If measured values are higher than reference levels, it does not necessarily follow that the basic restrictions have been exceeded, but a more detailed analysis is necessary to assess compliance with the basic restrictions.

In our measurements, have not exceeded of the reference level in transformer stations and near transformer stations. It can be stated that the effect of electromagnetic fields from transformer stations located near residential buildings is very small. The values of electric field strength with uncertainty were very low and with our device unnoticeable. The values of magnetic flux density did not exceed 1 % of the reference level for general public exposure. Regarding inside the building, the measured values do not exceed the reference levels but the impact of electromagnetic fields on workers could be an individual. Values with expanded uncertainty ranged from 40,48 to 51,42 V/m and from 8,1 to 21,56 μT. Reference levels are in this case determined for electric field strength to 10000 V/m and for magnetic flux density to 500 μT.

Use of the results of these measurements could be applied in mathematical modeling of electromagnetic immissions in the environment using GIS applications. As described in the monograph [6], this could serve as a tool to better informing the general public about it, in which areas are greater incidence of electromagnetic fields and vice versa.

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