Exposure to 50 Hz magnetic fields in residential apartment building close to Transformer Substation – worst case scenario

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Short abstract. Transformer substations located close to the living areas have been identified as a source of high long-term exposures to extremely low frequency magnetic fields. In the study we analyzed a worst case exposure to 50 Hz magnetic fields in residential apartment building close to transformer substation in Slovenia. In addition we have used numerical dosimetry models of the adult male, pregnant female and 6 years old child to asses in situ electric field strength according to ICNIRP guidelines from 2010.

Keywords: exposure assessment, transformer substation, numerical dosimetry, EMF

1. Introduction

Based on the results of two studies [1, 2], which showed that elevated 24 hours averaged values of ELF magnetic field (<0.3-0.4 μT) do increase the risk of childhood leukemia, International Agency for Research on Cancer included extremely low frequency (ELF) magnetic field among the possibly carcinogenic factors for humans [3]. However the biological mechanisms of this risk remain unknown [3, 4, 5, 6].

Transformer substations (TS) located close to the residential apartments are without doubts important sources of ELF magnetic fields inside them. In a study carried out in Finland [7] they found that in more than 70 % of the apartments above TS the daily average value of the magnetic flux density exceeds 0.4 μT, whereas in higher stories this was true only for 6.7 % apartments.

Based on results of measurements and numerical modelling we investigated the levels of magnetic field presented in the apartment located above the TS. The results obtained by measurements and calculations were used as an input to numerical dosimetry model to investigate the induced electric field in the adult male, pregnant female and 6 years old child living in the apartment above the TS.

2. Materials and methods

Situation

Typical TS with nominal power 630 kVA, nominal voltage 10/0.4 kV is located in the basement of the residential apartment building in Slovenia.

We were contacted by the owner of the apartment above the TS to estimate the field levels inside the apartment. First measurements shoved magnetic flux density up to values of 15 μT inside the apartment above the TS.

Measurements

Magnetic field is linearly correlated to the actual current load, but this can vary during the day depending on the present use. To obtain the detailed snapshot of the magnetic field in the apartment above the TS it is therefore not enough to make only spot measurements, but also 24-hour measurements to evaluate the time variability of the magnetic field and determine worst case condition.

For spot measurements we have used Wandel & Goltermann EM field analyzer EFA-3 with the B field probe. For 24-hour measurements we used the automatic measurement station PMM 8055 which

measures the magnetic flux density continuously. It consists of a measurement probe for ELF magnetic flux density HP-051, control unit with a GSM modem to send the measurements from the measurement station to the server connected to the internet, and a housing with solar cells and accumulator.
According to the Slovenian legislation the magnetic flux density is measured at the height of 1 or 1.5 m above the ground. But in the apartment, it is not uncommon that the children have their beds on the floor or for them to play on the floor, therefore, the exposure would be greatly underestimate by measurements 1 m above the ground. Therefore all the measurements – spot and continuous 24-hour measurements – were taken at the height of 0.2 m above the ground.

Numerical calculations
We used program package Narda EFC-400EP for numerical modelling of the magnetic flux density in the vicinity of the TS. It is based on segmentation method where each conductor is presented with finite segments. Corresponding material and electromagnetic characteristics are assigned to all the segments and the resulting magnetic field is the sum of the contributions of all the segments.

Dosimetric computations
By the survey study with portable exposimeters we obtained the values of the external electric and magnetic field. Measured results were later used to numerically compute the *in-situ* electric field strengths and SAR values for different exposure scenarios using the SEMCAD X software package (SPEAG, Zurich, Switzerland).
We used 6 y.o. female with a height of 107 cm and weight of 17 kg (Thelonious) and 34 y.o. male with a height of 174 cm and weight of 70 kg model from the Virtual Family set [8] and pregnant woman model based on [9]. Basic restrictions from ICNIRP guidelines [10] were used to evaluate the exposure.
For 50 Hz (LF) exposure basic restrictions for internal electric field strength in central nervous system of the head are 20 mV/m and 0.4 V/m for the whole body. Reference levels for 50 Hz are 5 kV/m for electric field strength and 200 μT for magnetic flux density.

3. Results

Measurements
Spot measurements taken on 17 locations in the apartment above the TS showed that the value of the magnetic flux varied between 0.26 and 11.4 μT. Based on the data from electric distribution company the value of the current in the LV busbar during measurements was ≈100 A.
During continuous 24-hour measurements which lasted for 3 months the highest measured magnetic flux density in the living room was 15.6 μT with the highest 24-hour average of 9.4 μT. During spot measurements in the whole living room the magnetic flux denisty was higher than 1 μT.
A nominal load with the current 909 A represents the worst case condition where such conditions in real situations are very unlikely. Based on the results of continuous measurements we estimated that in realistic worst case conditions, the current in the LV busbar is ≈200 A.

Numerical calculations
To further analyze magnetic field in the apartment above TS we numerically calculated magnetic flux density in the vicinity of the TS. Results are shown in Figure 1.

Dosimetric calculations
In-situ electric field strength was calculated for three different models and different exposure situations. Table 1 shows the *in situ* electric fields in mV/m for calculated exposure situations. Basic restriction at 50 Hz is 400 mV/m for the whole body and 20 mV/m for the central nervous system. The results of the numerical calculation for the measured worst case situation show that the highest *in situ* electric field for the sitting man was 58 mV/m and in the central nervous system it was 0.08 mV/m. For the 6 years old child laying 1 cm above the floor the highest *in situ* electric field was 33.2 mV/m and 0.7 mV/m in the central nervous system; in the case when he was standing it was much lower (1 mV/m for the whole body and 0.05 mV/m for the central nervous system).

For pregnant female laying 10 cm above the floor the highest *in situ* electric field was 14.4 mV/m and 1 mV/m in the central nervous system and in the fetus, which is 30 % higher compared to the worst case situation for central nervous system of 6 years old child.

4. Discussion and conclusion

Results show that the ratio between the highest whole body current density and the highest current density in the central nervous system is much higher for the adult than for the child. Nevertheless that the current density is in general higher for the adult, as the induction loop is larger in the case of the larger body, the highest values of the current density in the central nervous system are still higher in the child model.

Our results show that although the induced electric fields are below the basic restrictions in the worst case in apartments directly above typical transformer substations, exposure from such a source can reach a substantial fraction of the basic restrictions.

5. References

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Table 1: In situ electric field inside different models. The model of the children was positioned in 4 different orientations, whereas adult male and pregnant female model were positioned in one orientation. Basic restriction at 50 Hz is 400 mV/m for the whole body and 20 mV/m for the central nervous system.

Model	Orientation	Whole body [mV/m]	Central nervous system [mV/m]
6 y-o child	Lying on the back	33.2	0.7
6 y-o child	Lying on the side	18.0	0.824
6 y-o child	Standing upright	1.04	0.05
6 y-o child	Standing upright	0.28	0.0608
Adult male	Sitting	58.0	0.0798
Pregnant female	Lying on the back	14.4	1.076

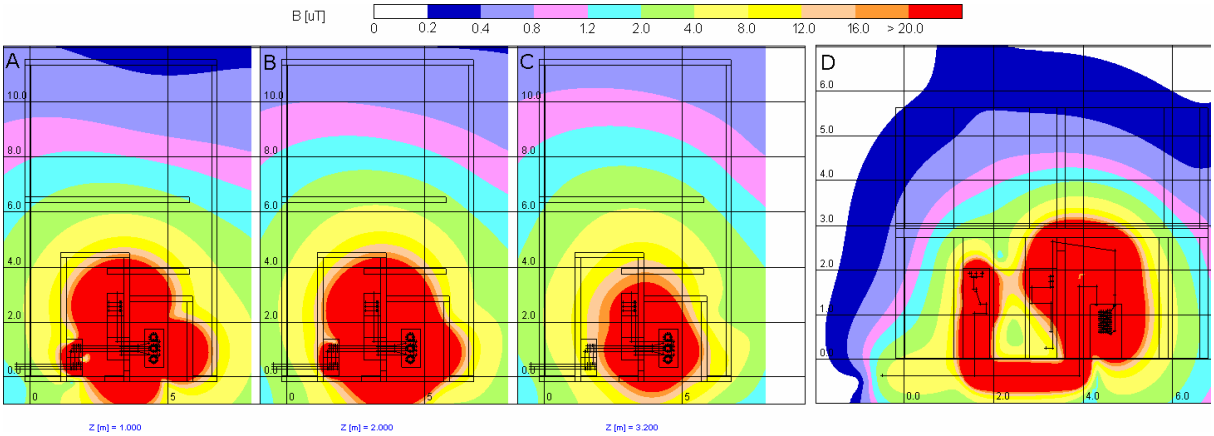

Figure 1: Magnetic flux density in the TS and apartment above the TS in a horizontal cross-sections at various heights (A, B, C) and in vertical cross-section (D) for the current in the LV busbar of 200 A.