A SURVEY OF MAGNETIC FIELD EMISSIONS FOR TYPICAL HV AND MV EQUIPMENTS OF A DISTRIBUTION NETWORK

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ABSTRACT

The IEC 62110 Standard defines measurement procedures for EMF fields regarding average human exposures to comply to ICNIRP guidelines. Applying this Standard, a survey was performed on a representative sample of power equipments located near residential buildings. Overhead lines, underground cables, a HV/MV Substation, a typical LV distribution box and a few HV/LV transformer stations were monitored according to IEC 62110 procedures.
All these equipments were modelled by a suitable software tool with its parameters tuned to fit the observed results, and next the models were applied to simulate the ELF fields in the nearby residences, also as IEC 62110 defines it. The results of the survey are presented.

INTRODUCTION

After a first epidemiological survey performed in a region of the USA in 1979, some concerns on a possible link between low-frequency magnetic fields and an increase in childhood acute lymphoblastic leukemia promoted a lot of international research on possible health effects of these fields [1]. So far a convincing proof of a causal relationship has not be found [1,2], and even the epidemiological evidence has been challenged on the grounds of a strong sensitivity of those epidemiological surveys to bias [3], considering that the mentioned disease is very rare and living near strong sources of magnetic fields is also uncommon, leading to very small statistical samples.
Notwithstanding, in 2000 the European Union mandated CENELEC and IEC to produce a set of standards aiming at assessing EMF emissions [4]. Following this mandate, the IEC 62110 Standard was issued in 2009 [5], defining measurement procedures with regard to public exposure levels from electric and magnetic fields (EMF) generated by AC power systems. In addition, also in 2009 the CIGRÉ WG C4.203 updated a Technical guide for measuring low frequency electric and magnetic fields near overhead power lines [6], which is complementary to the IEC 62110 Standard. Together, these documents provide a technically sound guide to perform the measurement of EMF emissions with regard to public exposure.
These standards provide guides to assess the EMF emission of particular devices in definite locations, but a general knowledge of which type of equipments and location conditions can be at stake requires a broader assessment. This was the goal of a project undertaken by *EDP Distribuição* for the Portuguese Distribution Network, with the cooperation of *Instituto Superior Técnico* (University of Lisbon) and led by the first author.
The project started by defining a comprehensive set of equipments covering from overhead lines with different voltage levels, types and locations, to urban underground cables, Substation and Transformer stations of different types. For these equipments measurements were performed according to the new mentioned standards by a EDP company, LABELEC.
As a second step, these equipments in their locations were modeled by a certified software tool [7], and the models were calibrated until the computed fields fitted the measures. At last, from these models human exposures in nearby buildings were computed for average load levels, in order to estimate their exposure levels for long-term conditions. Despite the network of EDP Distribuição meet the benchmarks established by Portuguese legislation, which maps the European Recommendation 519/1999/EC, these estimates aim at providing a basis to assess the impact of any new constraining laws on EMF emission levels on existing practices, and also to estimate the cost and the benefit of mitigating solutions for the all network.
This paper reports this survey and its findings. Some similar work has been previously performed elsewhere [8], but to these authors knowledge not as broader as this one, neither applying the new spatial and time averaging procedures defined by the new IEC 62110 Standard [5].

THE IEC 62110 AVERAGE EXPOSURE LEVEL

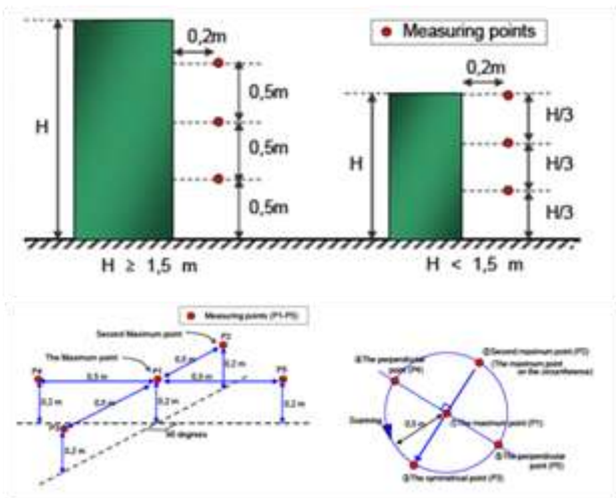

Figure 1: The IEC 62110 3-points (above) and the 5-points (below) measurement methods for averaging exposure levels to non-uniform fields

The IEC 62110 Standard intends to define measurement procedures complying to ICNIRP guidelines for limiting human exposure to EMF [9]. For this it defines spatial averages based either on three-points or on five-points as illustrated in Fig. 1.

Applying these Standard procedures, a survey on the most typical power equipments of *EDP Distribuição* was decided. The range of equipments included 10, 30 and 60kV overhead lines (both simple and double), 10 and 60 kV underground cables, a urban HV/MV Substation, a typical LV street distribution box and a number of HV/LV transformer stations located near residential areas.

ILLUSTRATIONS OF HOW THE SURVEY WAS DONE

As a first illustration of how the survey was performed, Fig. 2 shows the urban insertion of a 60kV double overhead line carrying an average load of 80 MVA. Fig. 3 shows the location of the points where each set of the three measurements specified by the IEC 62110 was made, and Fig. 4 reports the value of those measurements for one of the chosen profiles.

Figure 2: Insertion of a double 60kV overhead line included in the survey

Figure 3: locations of the measurement points (in rose) of the 60kV line in Fig. 2, defined according to [6], where the 3-points were considered as in IEC 62110 [5].

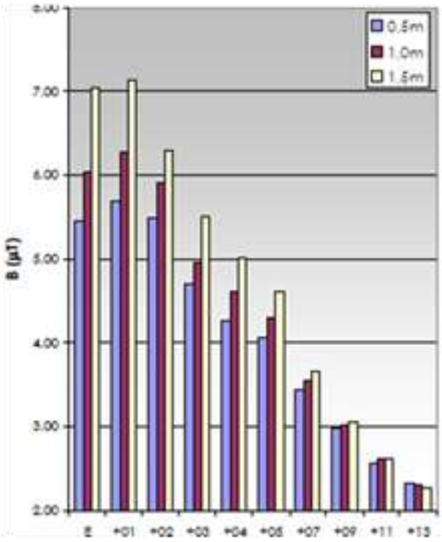

Figure 4: 3-points magnetic field measurements for one of the profiles illustrated in Fig. 3 (perpendicular to the axis of the overhead line)

Both the locations of the measurements and the model parameters had small inaccuracies requiring a calibration to achieve a optimum fit between the registered and the simulated data. In addition, although the current carried by the line and its time was registered according to [6], there were small time-variations which further required a best fit of the model. Fig. 5 compares the observed and the simulated data for this line after achieving a best fit.

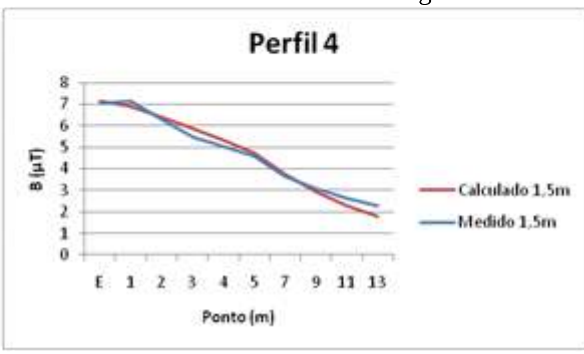

Figure 5: Measured (blue) and computed (red) magnetic fields at a height of 1.5m for the scenario illustrated before.

Next, the model was applied to compute the fields in interesting points and for different load profiles, providing results such as those illustrated in Figs. 6 and 7.

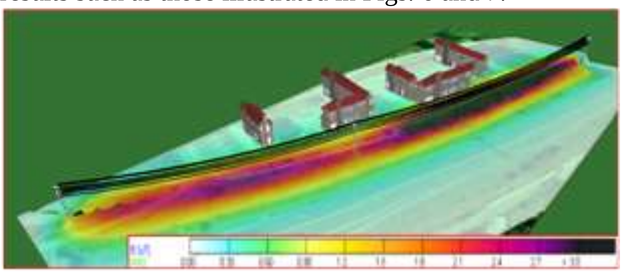

Figure 6: 3D view of the computed magnetic field in the neighboring of the line, after the model was calibrated to yield the results of Fig. 5.

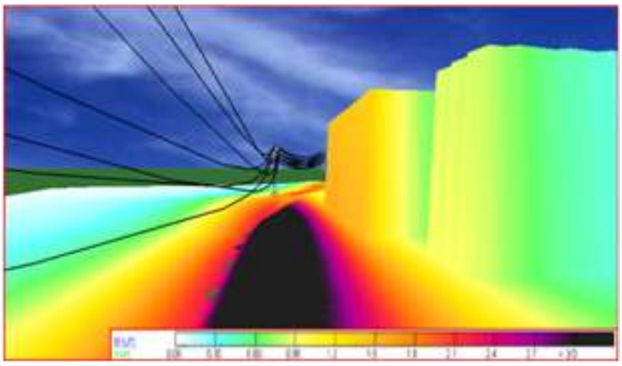

Figure 7: 3D view of the computed magnetic field at the faces of the nearby buildings and at the floor, after calibration of the model.

For underground cables a similar approach was followed. Fig. 8 shows an open ditch enabling the precise location and characterization of 10kV urban cables, with also some LV cables running nearby.

Figure 8: An open ditch showing a 10kV underground cable and some LV cables under a sidewalk.

Fig. 9 illustrates the observed and the computed values for the magnetic field on a plane perpendicular to the cable, at the 3-heights defined by the IEC 62110. The measurements were quite sensitive to the precise measurement positions, and the existence of another nearby 60kV underground cable can be acknowledged on the left of the graphics.

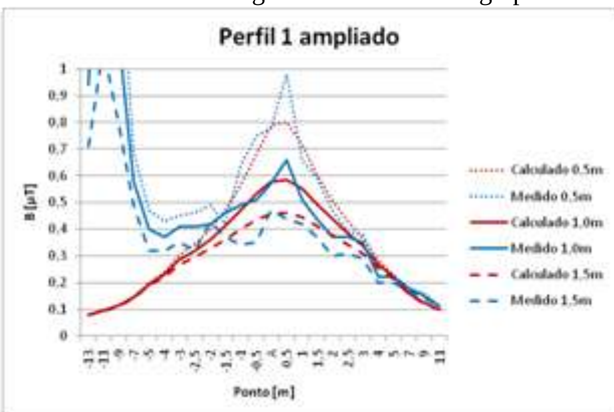

Figure 9: Measured (blue) and computed (red) magnetic fields at a height of 1.5, 1.0 and 0.5m from the ground. On the left the influence of a 60kV cable.

For HV/MV Substations a detailed survey was also performed, acquiring measurements in many points inside and outside the plant, after what a model was developed and fitted to the data, as illustrated in Fig. 10.

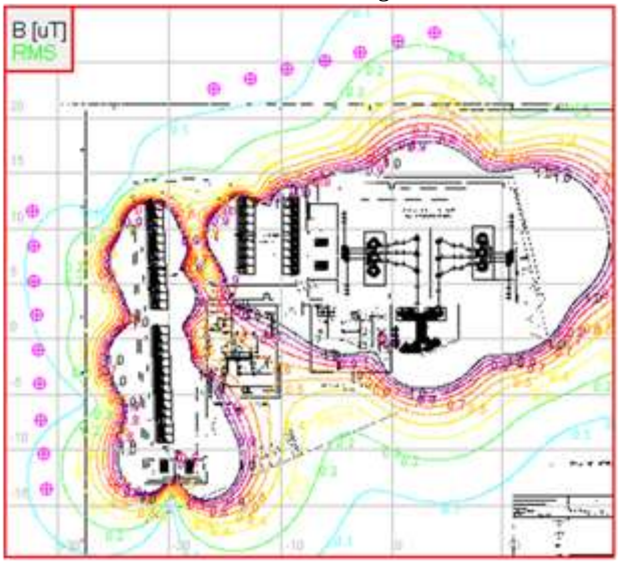

Figure.10: Isolines for the magnetic field around the power equipment of a urban HV/MV Substation. Incoming and outgoing HV and MV cables not included.

Figure.11: The typical street LV cables distribution box

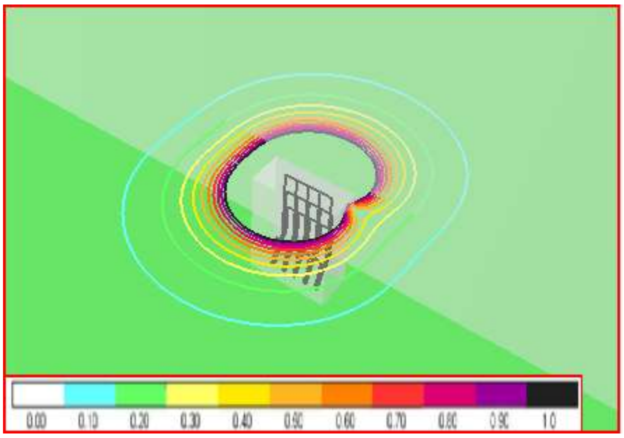

Figure.12: 3D view of the modelled magnetic fields generated by the LV distribution box.

A typical street LV distribution box (Fig. 11) was also monitored and modelled (Fig. 12), but a major part of the work was directed to MV/LV transformer stations. Fig. 13 shows a 3D view of one of these stations, built into residential and office buildings, and Fig. 14 shows the corresponding Isolines for the magnetic field around the equipment, as viewed from above.

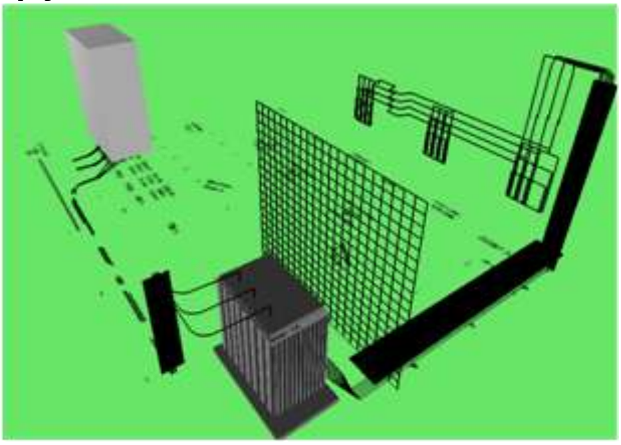

Figure.13: 3D view of the model of a MV/LV transformer station located in the ground floor of a building

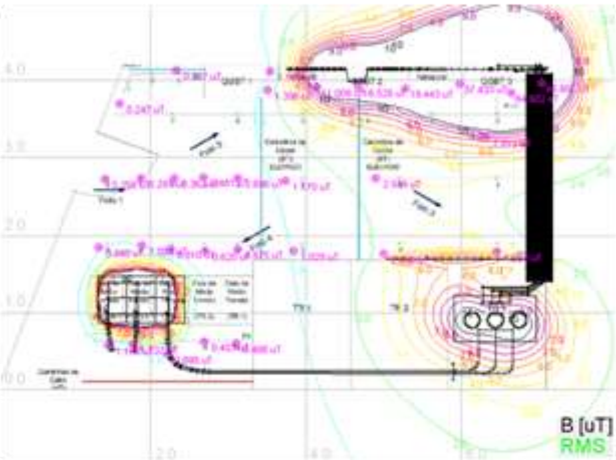

Figure.14: Isolines for the magnetic field around the power equipment of the MV/LV Substation in Fig. 13.

RESULTS AND DISCUSSION

The available space can not afford a detailed presentation and discussion of all the data and information reached by this survey, but a summary will be presented highlighting the most important learned facts:

- For overhead lines, only for 60kV the average exposure level to the generated magnetic fields can reach 1 μT for single lines and only in part of the nearest rooms. For double lines, that level can be reached also by some 30kV lines, but an inexpensive and effective reduction can be achieved by optimum phasing.

- For underground cables, an average exposure level of 1 μT can be reached in the nearest rooms only if the cables are buried too close to the buildings under the sidewalks. That is also valid for the LV Distribution boxes and for the cables going in and out the HV/MV Substations.

- MV/LV Transformer Stations into residential buildings were identified as the most strong source of magnetic fields regarding average exposure levels, but contrary to some previous surveys [10] the highest exposures levels were not found in the apartments above. Instead, those exposures (tens of μT) were found in the same floor, in the rooms beyond the walls where LV switchgear is mounted and as shown in the top of Fig. 14. Mitigation methods are being investigated to reduce the exposure to the magnetic fields generated by the LV cables of these stations.

CONCLUSIONS

EMF average exposure levels resulting from Distribution HV and MV equipments are usually below 1 μT. However, the LV cables of some distribution transformers located into buildings can generate tens of μT in the nearest rooms, justifying further research to mitigate such exposures.

REFERENCES

[1] WHO 2007, *Environmental Health Criteria 238 – Extremely Low Frequency Fields*, WHO, 2007.

[2]National Research Council, *Possible Health Effects of Exposure to Residential Electric and Magnetic Fields*, Academic Press, 1992.

[3] Greenland S. et Kheifets L., "*Leukemia Attributable to Residential Magnetic Fields: Results from Analyses Allowing for Study Biases*", Risk Analysis, Vol. 26, nº2, November 2006.

[4] European Commission, 2000, *Standardization mandate addressed to CEN, CENELEC and ETSI in the field of electrotechnology, information Technology and telecommunications*, Mandate M/305 EN, Brussels, Belgium, 2000.

[5] IEC, 2009, *62110: Measurement Procedures for Electric and Magnetic Field levels Generated by AC Power Systems with Regard to Human Exposure for overhead and underground lines,* ed.1.0, IEC, August 2009.

[6] CIGRÉ, 2009, *Technical Guide for Measurement of Low Frequency Electric and Magnetic Fields near Overhead Power Lines,* Cigre WG C4.203, Electra, April 2009.

[7] NARDA, 2009, *ELF-400LF Simulation Software Data Sheet,* NARDA, Germany, 2005.

[8] Silvia Violanti, *"Cem nelle aree urbane, a Bologna uno studio per valutare i campi a basse frequenze"*, ARPA Rivista Nº1 January-February 2003, pp 30-31, Italy, 2003.

[9] ICNIRP, *Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300GHz*); Health Phys. 74, 494-522, 1998.

[10] Ilonen K, Markkanen A, Mezei G, Juutilainen J, ***"****Indoor transformer stations as predictors of residential elf magnetic field exposure****",*** Bioelectromagnetics. 2008; 29: 213-218.