Method for Monitoring the Electromagnetic Impacts due to High Voltage Overheads Lines in Aosta Valley

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Abstract—**The aim of this paper is to show the methodology used by the Environment Protection Agency (ARPA*)* of the Aosta Valley for evaluating the electromagnetic impact due to high voltage overhead lines which cross the region, with regards to public exposure. Simulation and inspections have been used to identify the buildings which can be characterized by electromagnetic pollution, due to their proximity to the lines. After the measurements it is definitely possible verify if limits are exceeded, evaluate the exposure level of population living near the lines and identify actions to reduce it. So far, two important branches were examined with the purpose to extend the controls to all lines in Aosta Valley.**

Keywords-power line; electromagnetic impact; public exposure; simulation; measurement.

I. INTRODUCTION

Aosta Valley is an Italian alpine region crossed by many high overhead voltage lines (220 kV or 380 kV) which transport electric power from France and Switzerland to Italy. Moreover, due to orography and water supplies of the region, many local hydroelectric power plants produce and introduce energy into the national transmission network.

The constant increase of the request for electricity and the introduction of economic incentives for renewable energies is incrementing both energy importation and local production. Therefore, the capacity of power lines crossing the Aosta Valley will be enhanced: this will cause an increase of human and environmental exposure to electric and magnetic fields (EMF) generated by high voltage AC lines (ELF).

To check this constant evolution of the exposure, the regional Environmental Protection Agency (ARPA) has been carrying out for some years a systematic monitoring campaign of EMF generated in the environment along the main overhead high voltage lines.

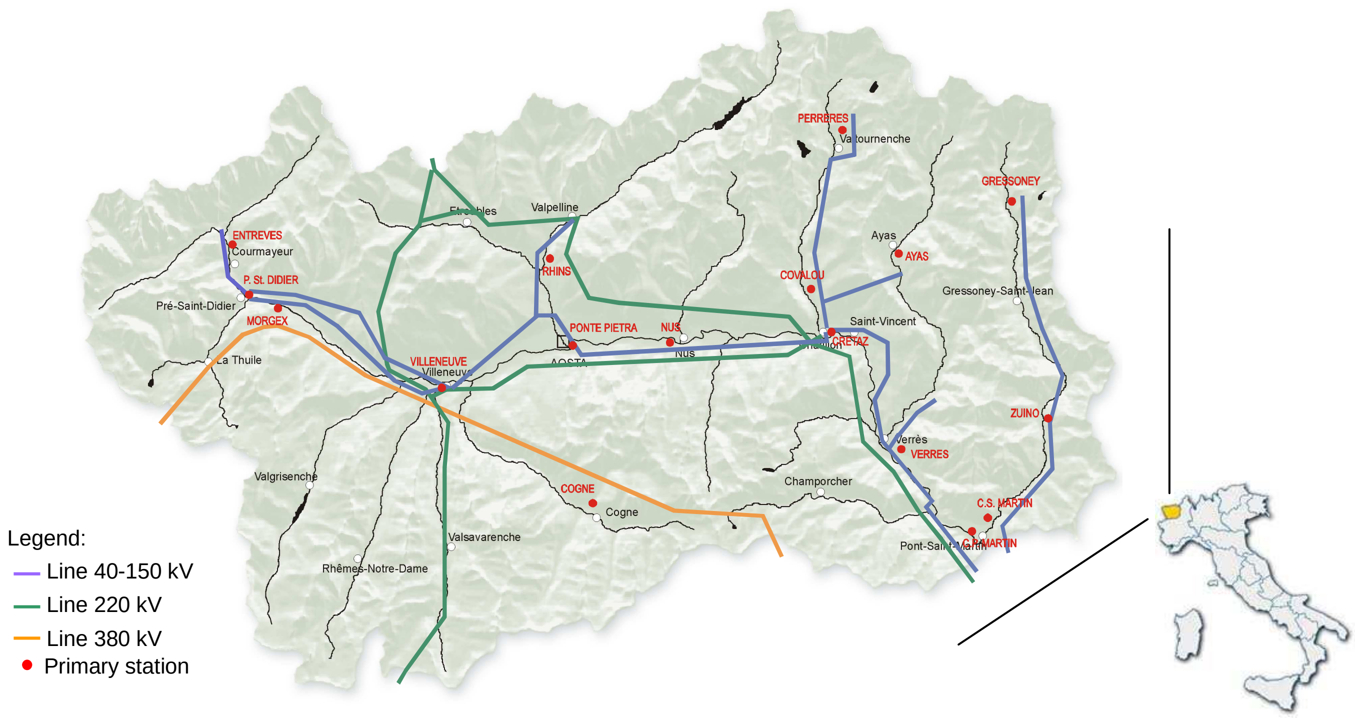

Figure 1. High voltage overhead lines crossing the Aosta Valley region.

II. METHODOLOGY

A. Inspections and Measurements

Two different strategic branches of 220 kV lines in the Aosta Valley have been controlled. The first one is an important line in the national network: in this work we examined the section connecting Villeneuve to Chatillon, named T209. Due to his relevance this line, now operated at 220 kV, will be enhanced to work at 380 kV. The second one, instead, represents the preferential way of transport for the energy both incoming from Switzerland and produced in local hydroelectric power plants. This branch is composed by two lines which run parallel: the first one, the principal, is named T210 Valpelline-Leinì and the second one consists in three lines in series, T207 Valpelline-Chatillon, T211 Chatillon-Montjovet and T215 Montjovet-Leinì that connected three major power stations (Fig. 2).

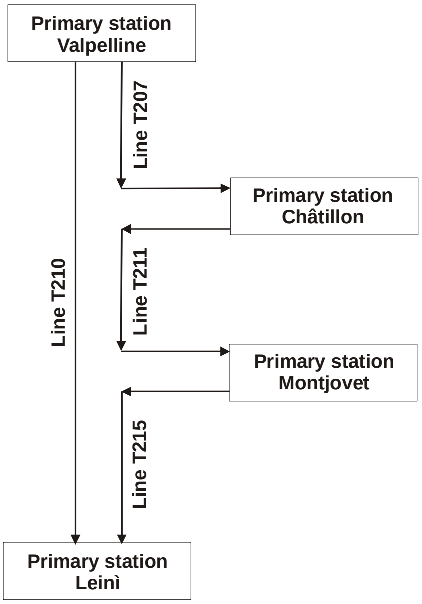

Figure 2. Line layout

The first step to evaluate people exposure to EMF is to make a preliminary simulation of the magnetic field produced along the selected high voltage lines, with the aim to identify restricted areas where carry out inspections and control measurements. The data provided by the power line operator are: shape and coordinates of the pylons, geometry of conductors and current rating in normal service of the conductors (pcsn, as defined by Italian technical standards [1]). The pcsn and the shape of the wider pylons are the data input for the simulation. The simulation is carried out in a spreadsheet.

The result is a volume in the space around the conductors that encloses a predetermined value of magnetic field. The magnetic field value used in the simulation for this study is 10 μT, which represents an important reference level, the attention value, introduced by Italian laws for human electromagnetic fields protection [6]. The maximum extension of this volume was projected to the ground and transferred in a geo-referenced map. So a buffer on both sides of the line was drawn: the buildings standing in this area were taken into account in the following considerations (red lines in Fig 3 and Fig 4).

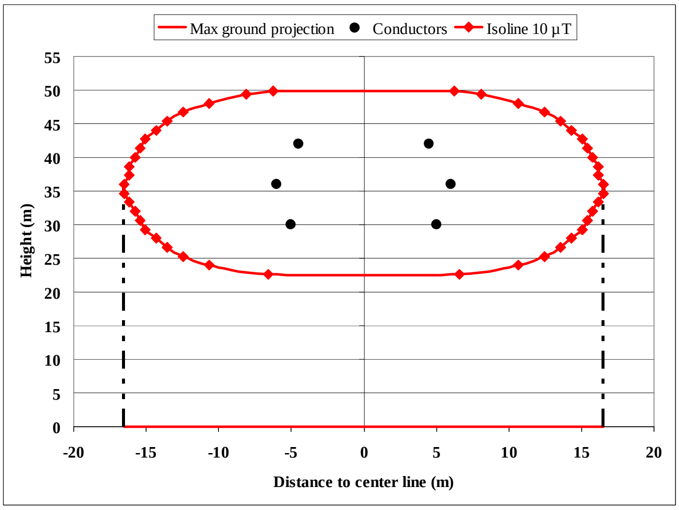

Figure 3. Simulation of volume that encloses the value of magnetic field equal to 10 μT.

After this first theoretical step, inspections were accomplished to identify the buildings that actually require detailed measurements, with the evaluation of both their 3D distance from the conductors and some preventive measures near the buildings. As shown in the Fig. 4, just two buildings, on the total of those falling within the buffer zone, required deeper measurements.

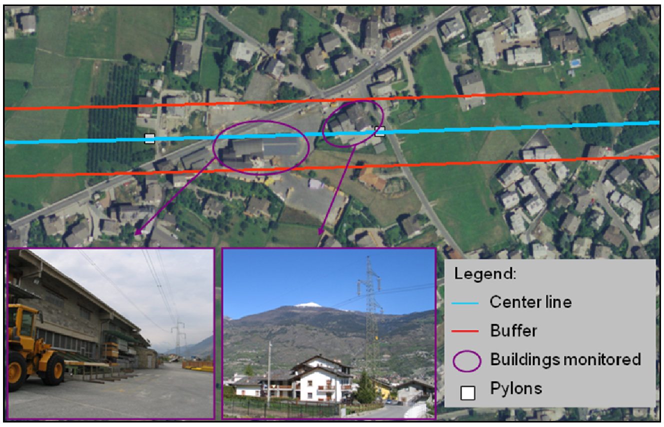

Figure 4. Buffer around center line that represents the projection of the volume of 10 μT. Photos of the two buildings, between all the buildings located in the buffer for their characteristics, where measurements were carried out.

The interventions in the selected buildings consist in both instantaneous measurements of electric and magnetic fields and long-term magnetic measures. The instruments used are the EMDEX II for instantaneous and the EMDEX LITE for long-term surveys. In latter case the instrument acquires data every 30 seconds for periods of about one week.

The EMDEX II has a frequency response range of 40 to 800 Hz and a measuring range of the magnetic induction of 0.01 µT to 300 µT, and, combined with an electric field probe, a measuring range of electric field of 1 V/m to 200 kV/m. The EMDEX LITE has a frequency response range of 40 to 800 Hz and a measuring range of the magnetic induction of 0.01 µT to 70 µT.

As electric field for overhead lines depends on the conductors voltage, which is almost constant, instantaneous measurements are representative of the electric field generated. Electric field values are detected outside the buildings along a section perpendicular to the conductor where they are closer to the ground.

On the contrary, since the magnetic induction depends on the intensity current flowing in the lines, it follows the temporal trend of the current and it is highly variable in time. So the instantaneous magnetic fields measurements are only representative of the specific time investigated. In order to gather information about the average or maximum exposition of the population it is necessary to make some theoretical considerations about the patterns of load of the lines.

B. *Indirect assessment*

The power line operator give to ARPA the trend of the current in the same days when the magnetic long-term measurements were performed. It is so possible to identify the correlation between magnetic field and current, in case of a single line. In the figure below (Fig. 5) the correlation between the two set of data is 0.996. If the correlation is greater then 0.9 it is possible to get an index (the average of the ratio between measure and current in the same time). This index will be used to indirectly derive the value of the magnetic field, whenever the current value is available.

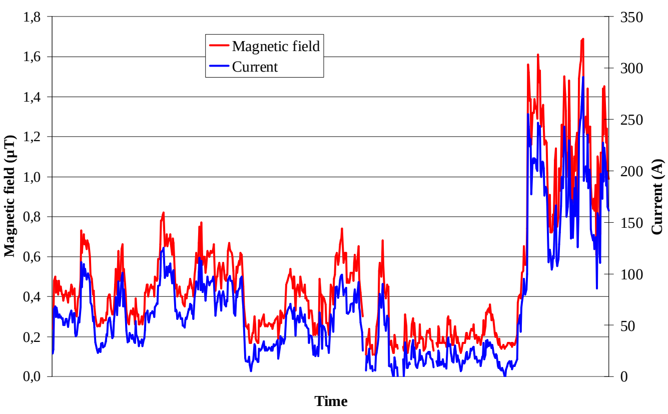

Figure 5. comparison between trend of current flowing in the power lines and the magnetic field measured in the same time with long-term measurements.

When the magnetic induction is generated by more lines and the phases are known, different numerical simulation are carried out with two different softwares: WinELF and MOE.

WinELF is a module of the software WinEDT (by Vector), for calculate magnetic field generated by power lines working at 50 Hz. It can store lots of information, related to operators, geometrical and electrical characteristics of the power lines and spatial data (Fig. 6).

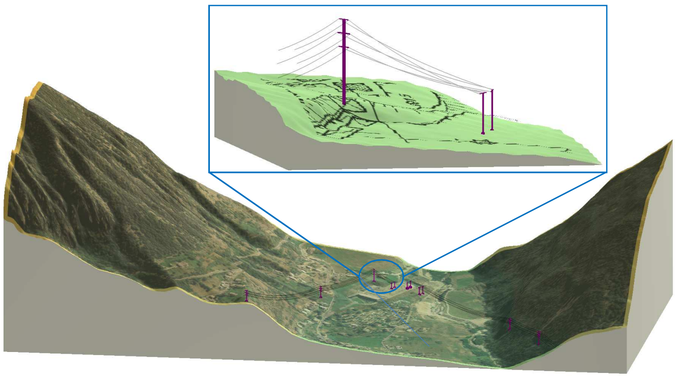

Figure 6. Example of 3D WinELF image.

With the tools in the “Elf analysis” section, the magnetic field can be simulated both in an area near the power lines and in a single point. The principal data needed are the current, the geometry of the line and the position of the point where magnetic field is going to be calculated.

The exact representation of the measurements point was found in WinELF model with subsequent comparison between the value measured and simulated, at the same time with the real current flowing in the lines. This is possible if the correlation between magnetic field and current is greater than 0.9. This step is necessary, since it is not possible to know the correct position of long-term measurement point with Global Positioning System (GPS) because of both the interference with EMF and the intrinsic resolution error.

Once the correctly spatial position of the long-term measurement point is found, this is used, together with the geometry of the transmission lines, in the program MoE.

MoE is a specific application program powered by Italian Experimental Electrotechnical Centre (CESI). It allows to monitor the magnetic field generated by transmission line in a specific point, starting from the current data only. Such a system has the advantage, with respect to an instrument system, of not having to create, manage and maintain a monitoring network. The comparison between the magnetic field measured and simulated is shown in Figure 7. As we can see the trend is very similar.

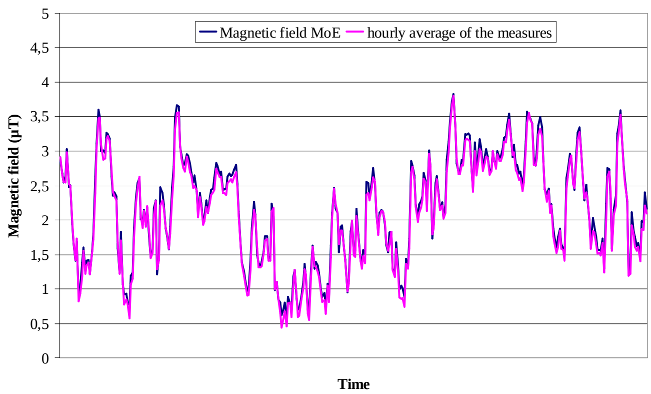

Figure 7. Comparison between measures done in field and simulation of magnetic field with MoE.

After the first year when some measures were done, ARPA implemented, in the same points, the simulation, with the current data throughout time for which operators provided current data. So it was possible to calculate and verify the magnetic field in the average or maximum load conditions and identify any overrun.

If field is generated by two lines and the lines phases are not know it isn't possible to apply any simulation program. In this case it is necessary to repeat the measurements over time.

III. RESULTS

Eight buildings were monitored along the path of the first power line and twenty along the second one.

A. Inspections and Measurements

The electric field values measured outdoor are shown in the Figure 8 while Figure 9 shows the magnetic field values measured both instantaneously, outdoor and indoor, and long-term, in the buildings identified with the methodology stated above.

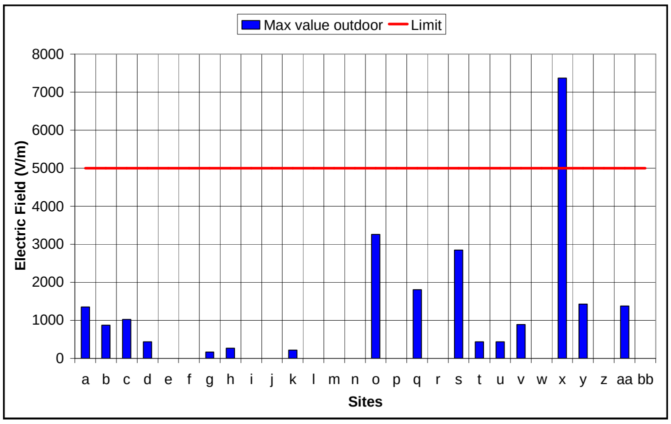

Figure 8. Outdoor electric field values.

As shown in Figure 8, only in one point measurements exceeds the exposure limit provided by the Italian law for the electric field. Instead any point with magnetic field values over the threshold limit is identified (Fig. 9).

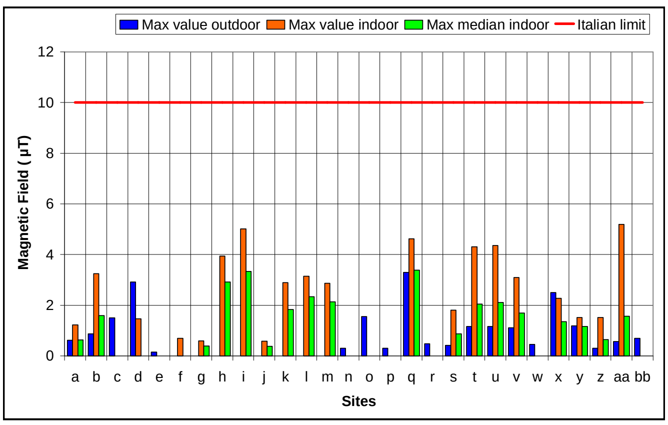

Figure 9. Outdoor, indoor and long-term magnetic field values.

Afterwards some classes of exposure to electric and magnetic fields have been identified, based on the data collected, to assess the statistic distribution of the sample. The results are shown in Figure 10 and Figure 11

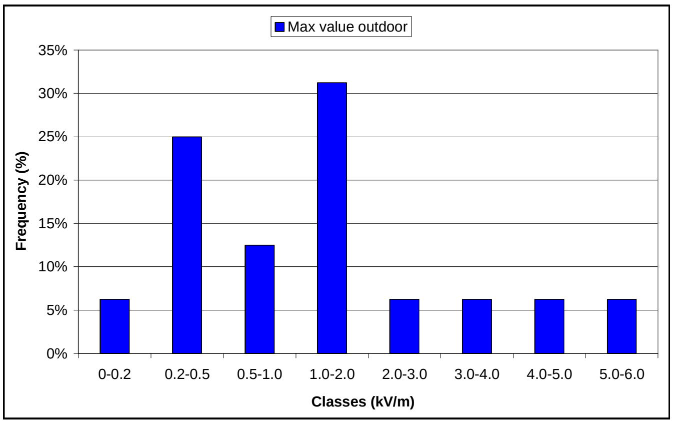

Figure 10. Statistic distribution of electric field values, outdoor measurements.

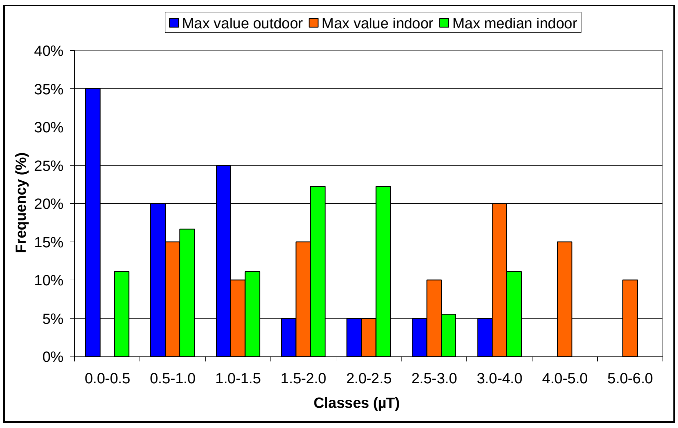

Figure 11. Statistic distribution of magnetic field values, outdoor, indoor and long-term measurements.

B. Indirect assessment

ARPA has collected the current data for all power lines since 2005. So, for those cases that respect boundary conditions described above, it has been possible to perform theoretical elaborations since 2005.

Along the single line path, eight buildings were monitored. In six cases the correlation coefficient between magnetic field and current, flowing during measurements, is more than 0.9. Thus the index could be calculated as described in the previous section. Finally, both the maximum median (Fig. 12) and the annual average values of magnetic field (Fig. 13) throughout all years could be calculated. For the other two buildings no elaborations could be done.

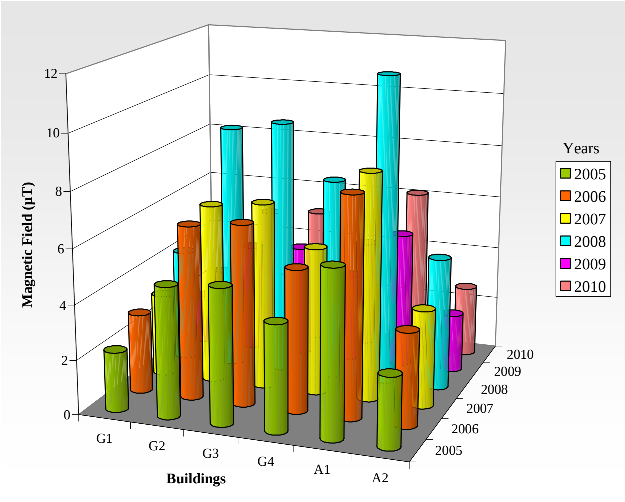

Figure 12. Maximum daily median of magnetic field in the six buildings monitored throughout all years.

As shown in Figure 12, in building A1in 2008 the Italian limit was exceeded. However, this overrun never occurred again in the following years. In addition, further studies have shown that the overrun occurred in one single day.

The magnetic field annual average represents an important indicator of the average exposure (Fig. 13). The values of the annual average are all less than the Italian limits.

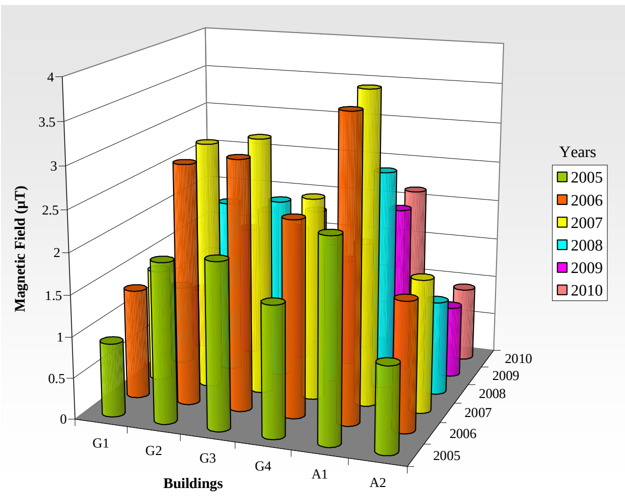

Figure 13. Annual average in the six buildings monitored throughout all years.

The second case studied is characterized by two lines which run parallel sharing the same pylons. Twenty buildings were individuated in the buffer of interest. Just for seven buildings, it was possible to carry out the simulations both with WinEDT and MoE. For the other cases, in fact, the current phases between the two lines weren't known.

In this case too, both the maximum median (Fig. 14) and the annual average of magnetic field (Fig. 15) throughout all years were calculated.

The elaborations have not provided values exceeding the limit.

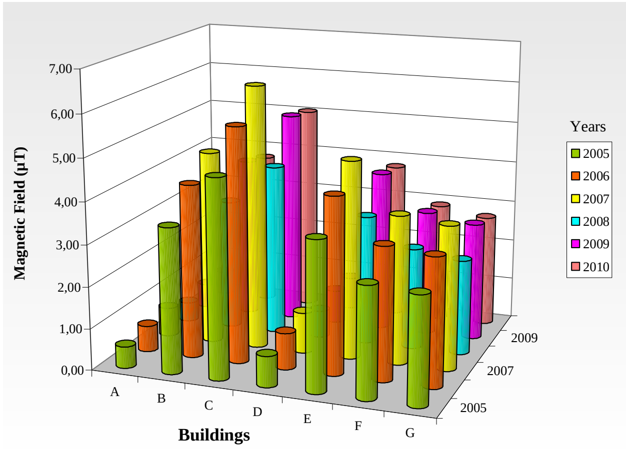

Figure 14. Maximum daily magnetic field median in the seven buildings monitored throughout all years.

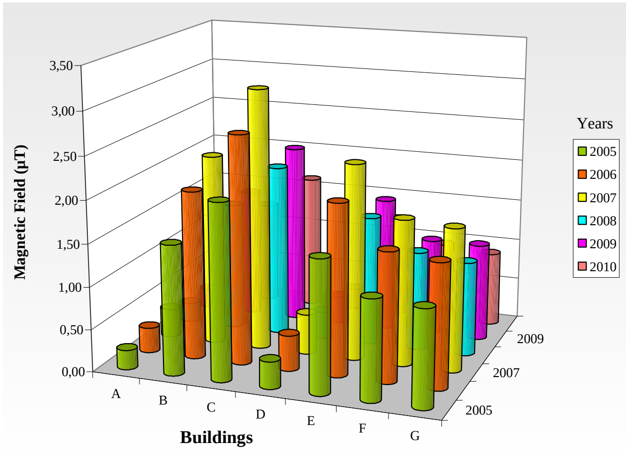

Figure 15. Annual magnetic field average in the seven buildings monitored throughout all years.

IV. CONCLUSIONS

In this paper an investigation method to assess, with subsequent steps, the exposure to electric and magnetic field generated by power lines was described, based both on measurements and simulations.

1) Knowing pylons position and shape and line electrical characteristics, a 2D buffer can be drawn on the map to distinguish buildings to be investigated, due to possible high field exposure.

2) By intervention on the spot, a second screening, considering the height of the buildings with respect to line height, further reduces the number of cases in which measurements are needed.

3) Electric and magnetic field measurements are carried out: the first don’t vary in time so the exposure can be immediately evaluated, the latter, depending on current flow, is not comprehensive and some more analysis has to be accomplished.

4) If values of current flowing in the lines during the field measurements and line phases are known, and correlation between current and field data is higher than 0.9, mathematical methods can be used, both for single or double lines, to evaluate magnetic field values from current data series on any time lapse.

5) If steps from 1 to 4 are verified, the method can be used to investigate exposure limit overrun and evaluate mean exposure on a long period or field values on a specified time, provided that the current data are available.

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