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# A STATE INDICATOR ON REGIONAL SCALE FOR HIGH-VOLTAGE POWER LINES: DEFINING A PRIORITY FOR *IN SITU* INSPECTIONS

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**An integrated system to evaluate the magnetic field generated by power lines exposure has been developed using a specific simulation model (PLEIA-EMF). This is part of a software toolset, subjected to internal suitability verifications and in-field validations. A state indicator related to each span has been determined using the data extracted from digital cartography, the magnetic field calculated by PLEIA and the number of people living in the nearest buildings. In this way, it is possible to determine eventual criticalities in the considered area, focusing attention on those cases with more considerable exposure levels and involving a higher number of people. A campaign of inspections has been planned using PLEIA simulations. The reliability of stored technical data and the real population exposure levels have been evaluated in critical cases, individuated through the following described methodology. The procedures leading to the indicator determination and the modalities of *in situ* inspections are here presented.**

Magnetic induction levels inside buildings close to power lines greatly depend on the receptor distance from the wires and on their geometry. The elements likely to cause modelling errors have been studied in detail(1).

While power lines routes and other technical data are provided by the owners, the pylons elevation can be deduced by digital cartography. Several *in situ* inspections have been carried on to verify both the technical data reliability and the accuracy of regional digital cartography. The agency operators have obtained the real position of pylons bases and their ground levels using a single-frequency GPS detector. This device has been equipped by a palmtop storing the digital cartography of involved areas. Using a laser telemeter, the distances between pylons and closer buildings and the heights of wire connections to pylons have been measured. For each building and as near as possible to the ground, the height of the lowest wire has been determined. This has allowed calculating unambiguously the correct position in space of the catenary describing the span.

Spans to be verified have been chosen through a classification of the most impacting tracts, in the whole regional territory of Tuscany, made by a proper state indicator associated with each of them.

## DETERMINING THE STATE INDICATOR

The state indicator associated with each span has been defined considering the exposure in surrounding buildings and their number of inhabitants. In this way, the critical power lines tracts, because of both high field values and a wide number of exposed people, are highlighted.

The state indicator has been defined through the following relation:

$$I_{\text{state}} = \sum_i B_i N_i \tag{1}$$

where $B_i$ is the magnetic induction evaluated in each building and $N_i$ is the number of people living inside it. The sum has been calculated on buildings close to each considered span.

The procedure to define such indicator has been, at first, developed in the GIS environment, extracting the involved buildings and associating them with the data necessary to the calculation. This has been executed using the PLEIA (Power Line Electromagnetic Impact Assessment) software(2).

Among the buildings in 1:10 000 scale cartography, only residential houses have been examined. The number of inhabitants in each of them has been determined using the 2001 Italian census data.

The reference level for the magnetic field is set to 0.4 μT and it is based on the results of the epidemiological studies described in the chapter 'Human carcinogenicity data' of the IARC Monographs volume 80(3).

The volume including the magnetic field >0.4 μT has been projected to the ground, defining the first level band around each line. The field values have been determined using the historical mean current

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values. Only the buildings inside these bands have been, then, selected.

In this way, using a precautional procedure, all buildings which could present a relevant exposure level are considered. Their number has been so largely reduced, limiting the calculation time.

All data necessary to evaluate the field are now available. Through PLEIA, the magnetic induction mean value, in the desired time interval, has been evaluated in the centroid of each building. The height of the calculation has been that of 2 m from the ground. Specific tests, on a reduced sample of buildings, have previously shown that the elevation value is not important in defining a criticality degree.

The outputs are shown in the Figure 1. The state indicator distribution is shown in the Figure 2.

In detail, the value of the span indicator and the evaluated field in each building are highlighted (see Figure 3).

## *IN SITU* INSPECTIONS

Data stored in the power lines database of Tuscany (CERT, Catasto degli Elettrodotti della Regione Toscana) have been validated on the aspects described in the following.

### Pylon position

The owners' data regarding the base positions of the pylons have been compared with those from 1:10 000 and 1:2 000 scale digital cartography.

Figure 1. Calculation of spans indicator throughout the regional territory.

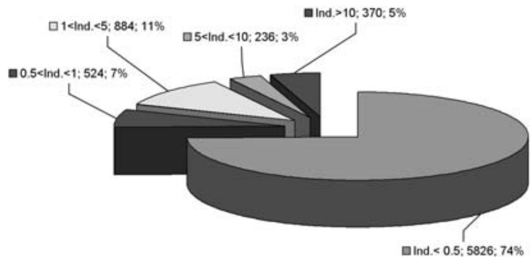


Figure 2. The state indicator distribution.

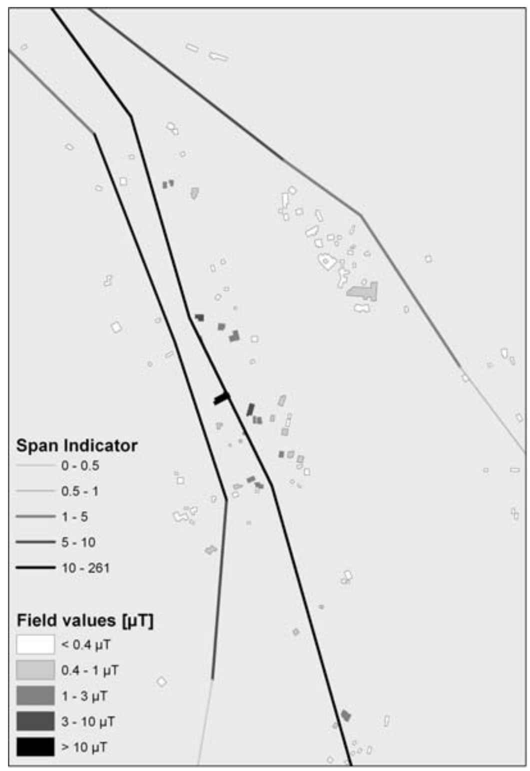


Figure 3. Display of indicator and field values.

Inspections in proximity of pylons have been performed especially in the open plain, or where it has been possible to reach the pylon bases, setting up the equipment correctly. This has allowed giving priority to densely populated regions with notable population exposure, excluding hills and mountains with fewer buildings.

The outcomes are reported in Table 1.

### Pylon geometry

Where possible, the pylon heads have been photographed from the front, to individualise if they

**Table 1. Differences between pylons base positions in the two available cartographies and those coming from the inspections data.**

| | 1:10 000 cartography (m) | 1:2000 cartography (m) |
|---|---|---|
| Minimum | 0.1 | 0.0 |
| Maximum | 10.6 | 3.1 |
| Avg ± std. Dev. | 1.8 ± 1.7 | 0.7 ± 0.5 |

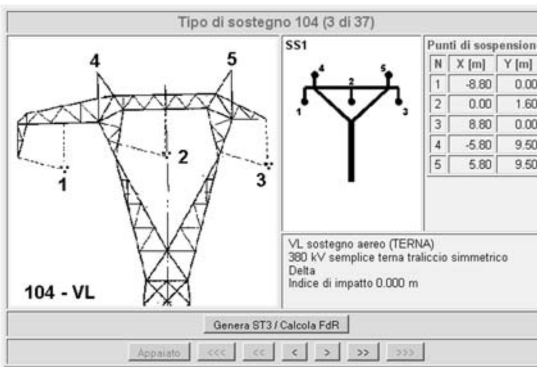


Figure 4. Data related to the position of the wires.

Figure 5. The Vertex VL400.

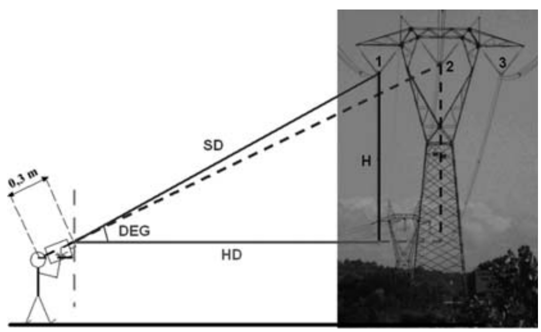


Figure 6. Heights and distances detectable through the Vertex VL400.

match with the types stored in the database (see Figure 4). This method does not allow distinguishing between structures having the central wire on different levels.

Differences between the archive data and all the checked configurations have not been found.

## Lower wire altitude

The Haglöf Vertex VL400 (see Figure 5) laser hypsometer allows determining the distance from the observer to the points of suspension of the wires (see Figure 6).

When the hypsometer is used in the angle modality, the following parameters are returned:

- SD: distance from the observer to the measured point (i.e. wire suspension point);
- HD: horizontal projection of SD;
- DEG: angle referred to horizontal plane;
- $H$: height from ground.

It is then possible to determine the altitude of the wires and, in detail, one of the suspension points.

When possible, the suspension points of wires have been measured frontally.

The angle amplitude (DEG) generally varies between 20° and 70°. This causes the height ($H$) uncertainty to vary from 0.2 to 0.5 m.

The height ($H_{\mathrm{CERT}}$) reported by the owners of the lines falls inside the range defined by the measured height ($H_{\mathrm{MEAS}}$) of the lower wires and its uncertainty ($\Delta H$):

$$H_{\mathrm{MEAS}} - \Delta H \leq H_{\mathrm{CERT}} \leq H_{\mathrm{MEAS}} + \Delta H \qquad (2)$$

## Straddles altitudes

The straddles amplitudes are obtained using the previously shown method, as well.

The Vertex has been set on the vertical plane, orthogonal to the power line axes, and passing through the suspension points of the wires.

Always considering the angle (DEG) variability between 20° and 70°, the straddles uncertainty varies from 0.4 to 1 m. In some cases, the straddle closest to the observer is obtained with a good precision, while instead the furthest one is under- or overestimated. To obtain a more correct and symmetric evaluation of the straddles, the same procedure has been repeated on the opposite side of the pylon, when possible.

This method allows distinguishing among cases in which the pylon head is of the same kind, and the difference of the straddles lengths exceeds at least 0.5 m. As an example, it is possible to distinguish the pylon head named MV (or LV, or NV) from the VV type.

Within the confidence interval of the method, no discrepancies have been pointed out between the data stored in the database and the experimental ones.

### Buildings heights

The altitudes of buildings close to power lines have been determined using the laser telemeter. The *in situ* inspections have pointed out differences from information in the digital format. This happens especially in the absence of 1:2000 scale cartography, and on hills and mountains (where the altitude errors are up to some metres).

Differences between digital cartography and surveys have also been noticed in presence of 1:2000 cartography and on the plain.

## CONCLUSIONS

The ARPAT inspections have shown, for 380-kV power lines, a good agreement with technical data (heads geometry, wires heights and straddles amplitudes) provided by the lines owners. In detail, wires heights from the ground level have been measured with a maximum uncertainty of 0.5 m, and the straddles amplitudes with a maximum uncertainty of 1.0 m. These appear superimposable, in all examined cases, to those declared by power lines owners. Using such uncertainties on straddles lengths, it is possible to calculate the first approximation distance[4] related to each pylon, with a relative error lower than 10%.

Verified differences concern the geographical coordinates of pylons bases. These differ, sometimes in an important way, from the regional digital cartography. In detail, such position discrepancy varies from 0.5 to 0.7 m (average values) in the 1:2000 scale cartography, and from 1.7 to 1.8 m in the 1:10 000 scale one.

Inspections on buildings heights show discrepancies from cartographic data depending on the terrain orography, especially in cases with stronger slope.

The owners' data are particularly deficient for 132 kV lines, because of their old age and their lack of pylons standardisation. Uncertainties related to the first-level bands are consequently expected to be larger in percentage, for them. The importance of a reliable tool to predict the power lines impact is therefore evident for purposes of a correct land planning in terms of its usage destination.

## REFERENCES


1. Comelli, M., Colonna, N., Licciardello, C. and Licitra, G. *3-Dimensional modelling in evaluating ELF fields exposure*. In: Fifth International Workshop on Biological Effects of Electromagnetic Fields, Città del Mare, Terrasini (PA), Italy, 28 September–2 October 2008.
2. Andreuccetti, D. and Zoppetti, N. *Magnetic fields dispersed by high-voltage power lines: an advanced evaluation method based on 3-D models of electrical lines and the territory*. Radiat. Prot. Dosimetry **111**(4), 343–347 (2004).
3. WHO IARC. *Non-ionising radiation, part 1: static and extremely low-frequency (elf) electric and magnetic fields*. IARC Monographs on the Evaluation of Carcinogenic Risk to Humans (Lyon: IARC Press) (2002).
4. *Approvazione della metodologia di calcolo per la determinazione delle fasce di rispetto per gli elettrodotti*. DM 29/05/2008, G.U. 08/07/2008 (in Italian).