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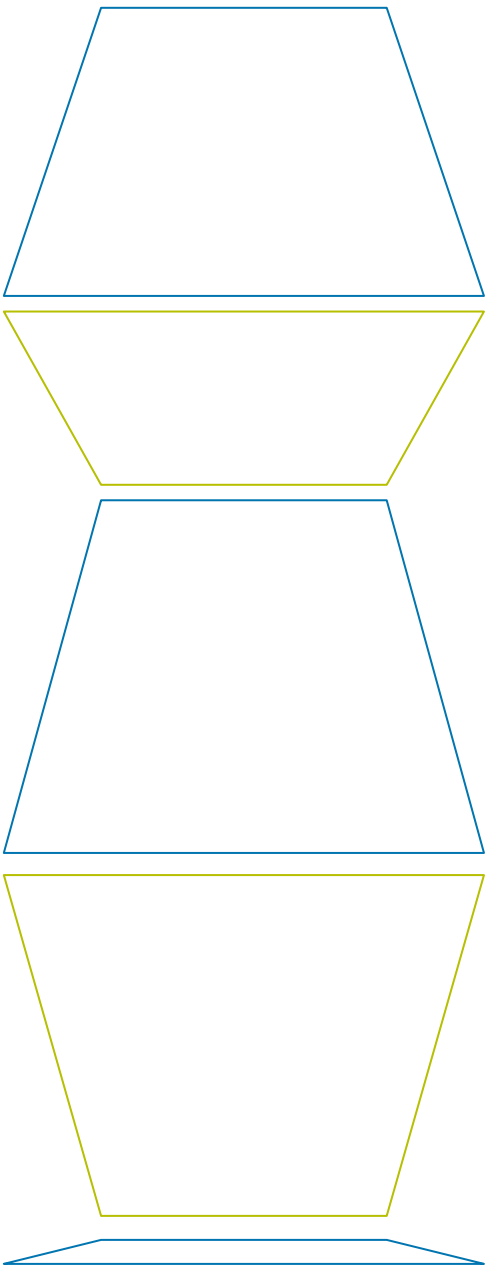

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Virtual Magnetic Field Assessment of HV/LV Prefabricated Substations According to IEC/TR 62271-208

Virtual Testing Lab (VTLab) 2014

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Abstract

For many years the evaluation of the electromagnetic fields (EMF) generated by HV/LV prefabricated substations has been an extremely cumbersome, unreliable and expensive process. Manufacturers and users lacked a broadly accepted assessment procedure specified in an international reference standard. The publication of the Technical Report IEC/TR 62271-208, included in the new 62271-202:2014 as a reference, solves this situation since it describes the methodology that should be followed to evaluate the electromagnetic fields generated by a prefabricated substation, opening the possibility of employing simulation technologies for this purpose.

Once the simulation model has been validated, IEC/TR 62271-208 allows its use for evaluating the EMF generated by the prefabricated substation without the need of empirical testing. This implies not only a reduction of costs and time-to-market, but also a highly efficient method to test "what if" virtual scenarios able to drive to better sustainable products.

This white paper describes the virtual testing of a new HV/LV prefabricated substation for the 50 Hz EMF assessment according to IEC/TR 62271-208.

1 Introduction

In recent years, the electric and magnetic fields emitted by electrical equipment and installations have received a lot of interest from the general public, and as such, no less attention has been paid by regulators, scientists, manufacturers and electrical companies. National and international regulations have set the limits of human exposure to these type of fields based on current scientific evidence and a precautionary principle. However, even when the limits are well specified, the assessment or testing methods remain unclear or troublesome, at least with respect to medium voltage (MV) switchgears and HV/LV transformer substations (TS).

Laboratory testing and assessment have some advantages associated with the controlled conditions but also some drawbacks which increase the costs (transportation to the laboratory, test arrangement and measurements), time-to-market and the TS carbon footprint.

IEC/TR 62271-208 [1] describes a methodology for the evaluation (measurement or simulation) of generated EMF. Therefore, this Technical Report allows the use of validated calculations (simulations) as an alternative to measurements (physical testing).

Taking advantage of these possibilities, ORMAZABAL has carried out research, within the CRISALIDA [1] project [2-5], on the magnetic fields generated by MV switchgear [6] and HV/LV TS, with a twofold objective: first, the MF characterisation of TS by means of magnetic field measurements, and second, the validation of the finite-element method models, using EMF measurements, according to the IEC/TR 62271-208 procedure [7, 8]. After simulation accuracy validation, this IEC Technical Report allows the use of the virtual model for evaluating the magnetic fields generated by similar TS without empirical testing, with the obvious reduction of costs, development time and carbon footprint.

This White Paper describes the assessment of a TS by means of a virtual EMF calculation, according the IEC/TR 62271-208.

2 IEC/TR 62271-208

2.1 Scope and Object

IEC/TR 62271-208:2009 gives practical guidance for the evaluation and documentation of the external electromagnetic fields which are generated by HV switchgear assemblies and HV/LV prefabricated substations. Basic requirements to measure or calculate the electric and magnetic fields are summarised for switchgear assemblies covered by IEC 62271-200 and IEC 62271-201, and for prefabricated substations covered by IEC 62271-202. This technical report applies to equipment rated for voltages up to

[1] Belonging CRISALIDA to the program CENIT (part of the program INGENIO 2010) funded by CDTI - office inside the Spanish Ministry of Science and Innovation.

and including 52 kV and power-frequencies from 15 Hz to 60 Hz.

2.2 Qualification by Calculation

The EMF characteristic may be evaluated by measurement or by calculation. The IEC/TR particularly recommends the validation of simulation models against the laboratory measurements.

Once a virtual model has been validated against one equipment, *"it is generally acceptable to characterise similar equipment by calculation, without the need for measurements*".

ORMAZABAL's **Virtual Testing Lab** has accredited engineers to perform and supervise any EMF simulation.

2.3 Virtual Model Accuracy

Compared with measurements, the calculated field values at the measurement surface should agree to within ±10%. The location of each calculated "hot spot" (point where the EMF is maximum) on the measurement surface should be accepted as accurate if it is within a specific area centred on the measured "hot spot". This area should be of dimensions 10% height x 10% length of the measurement surface on which a measured "hot spot" is located.

3 MAGNETIC FIELD EXPOSURE LIMITS

Even when IEC/TR 62271-208 does not specify any limits for the magnetic fields regarding human exposure, the results of the proposed evaluation can be compared with national and international regulations. Among others, the worldwide reference ICNIRP Guidelines [9] and the Spanish Royal Decree 1066/2001 [10] define a magnetic field emissions limit (50 Hz) of 100μT for the general public and 500μT for workers.

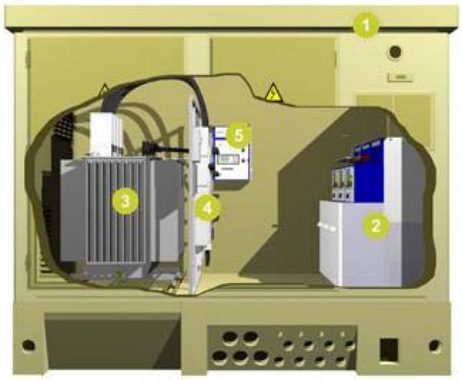
Although the recent EU Directive 2013/35/EU of 26 June 2013 [11] set new limits from 1000μT to 18000μT for workers, ORMAZABAL still consider the more restrictive 500μT limit.

4 MAGNETIC FIELD EVALUATION EXAMPLE

The aim of this assessment is to calculate the magnetic field emission of an ORMAZABAL prefabricated substation including:

- 630kVA transformer, 20KV/400V (3 in Pict. 1).
- Medium voltage (MV) switchgear: RMU 24kV (2 in Pict. 1).
- Low voltage (LV) board (4 in Pict. 1).
- LV connections.

Picture 1. ORMAZABAL prefabricated substation



Note: Electric field evaluation is not necessary because both the electric equipment enclosures and the MV cables sheath are grounded and LV cables contribution (400V) is negligible. Furthermore, the TS concrete enclosures are usually grounded.

4.1 Study

These are the studies that have been carried out:

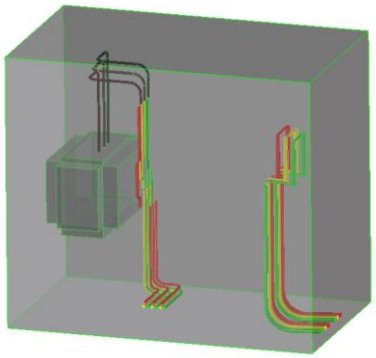
1) Electromagnetic emission over 100 μT (General Public – Council Recommendation 1999/519/EC).

2) Electromagnetic emission over 500 μT (Workers – Directive 2004/40/EC).

4.2 Simulation model

Both the MV ring main (loop) and the LV connections have been represented.

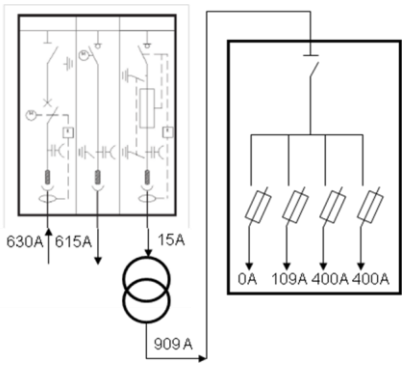
Picture 2. Simulation model



4.3 Excitation

As the transformer has a rated power of 630kVA and the expected secondary voltage is 400V, the LV maximum current is 909A. That means that the current flowing through the MV cables is only 15A, while the maximum current of the MV ring main is 630A (loop cables + feeder switchgear busbars).

Picture 3. Excitation distribution



In the case of the LV board each phase can deliver 4 LV outputs each one limited to 400A by a fuse. In order to simulate the worst case scenario the outputs excitation has been set as follows (from left to right): 0A, 109A, 400A, 400A. The latter being the closest to the concrete enclosure.

4.4 Simulation assumptions

These are the simulation assumptions:

1) MV cables are negligible (only 15A). LV connections and MV ring main contribution is by far more critical to magnetic field emissions.

2) Transformer is not considered because its contribution to the whole substation magnetic field is insignificant due to the high permeability (100) of the steel enclosure avoiding significant magnetic field emission. Therefore, the contribution of the transformer to the magnetic field characteristic is by definition stray flux, not flux in the core.

3) Frequency = 50Hz.

4) Three-phase balanced system.

5) Neither the reinforced concrete enclosure, nor the galvanized steel doors and louvers are taken into account (worst case scenario, there is no substation building).

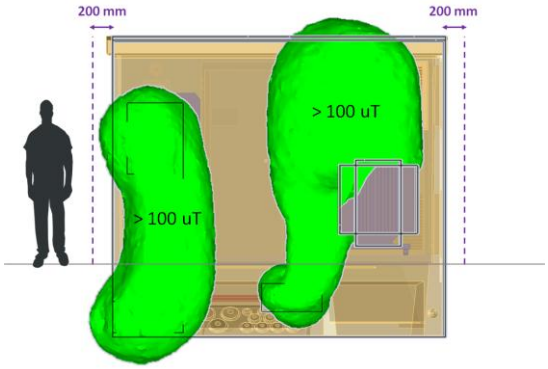
4.5 Results analysis

Taking into account the practical sizes of field probes and the necessary clearance to avoid direct contact of the probe with the accessible surface, 200 mm are considered the minimum measurement distance (IEC/TR 62271-208).

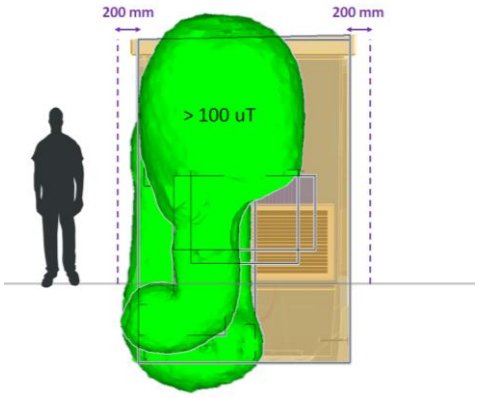
Besides, measurements must be performed at a horizontal distance (of 200 mm) from its surface or boundary or wall (IEC 62110). That means that it is not necessary to measure the building roof (where a person should not be).

The following pictures represent the **electromagnetic emission over 100μT**.

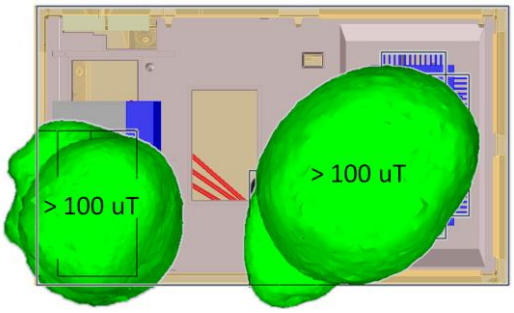
Picture 4. TS front view (Magnetic field over 100μT).



Picture 5. TS right view (Magnetic field over 100μT).

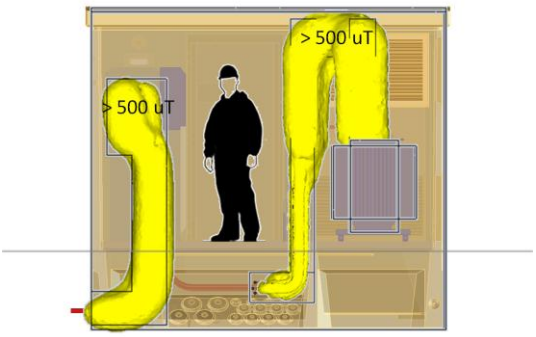


Picture 6. TS top view (Magnetic field over 100μT).

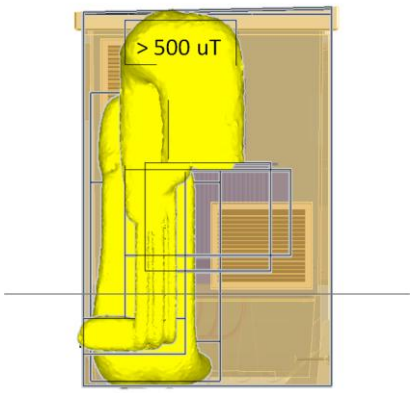


The following pictures represent the **electromagnetic emission over 500μT**.

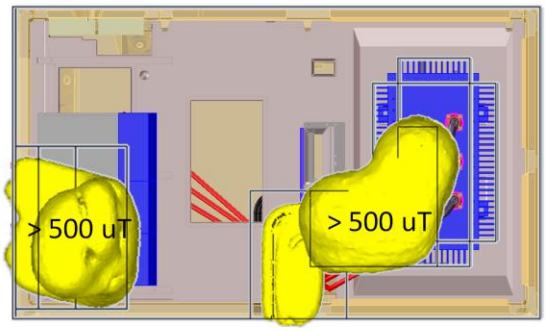
Picture 7. TS front view (Magnetic field over 500μT).



Picture 8. TS right view (Magnetic field over 500μT).



Picture 9. TS top view (Magnetic field over 500μT).



5 CONCLUSIONS

ORMAZABAL prefabricated substations fulfil EMF emission standards even in the worst case scenario since the substation has been modelled at full (rated) power, considering the worst LV board output distribution, and not taking into account neither the switchgear and LV board enclosures, nor the reinforced concrete substation building.

According to the results shown in this White Paper we can conclude that the general public are not affected by the 100 μT magnetic field.

On the other hand we can also conclude that the 500 μT magnetic field, defined by ORMAZABAL for workers, does not affect them when operating the MV switchgear manually.

Besides, the electric field evaluation is not necessary because both the electric equipment enclosures and the MV cables sheath are grounded.

The EMF simulation model used in this White Paper is suitable for the evaluation of magnetic fields generated by TS, according to IEC/TR 62271-208. However, to obtain accurate results it is important to observe the following rules:

1. Users must possess enough technical knowledge both about the physical phenomenon and the application of the finite element method as a means of MF simulation;

2. Reinforced concrete shielding has to be characterized and its linear behaviour proven;

3. The testing probe has to be characterized, knowing how it works, where the measurements are taken (physical/virtual location inside the probe) and the data acquisition accuracy;

4. A precise 3D CAD file is needed, especially for the LV bridge geometry;

5. The final TS installation must follow the strict indications provided by the manufacturer, ensuring LV bridge assembly homogeneity.

Under these conditions the model can be validated with an acceptable accuracy (±10%), and IEC/TR 62271-208 allows the TS modelling and simulation as an alternative to empirical measurements of similar equipment.

References

[1] IEC/TR 62271-208: "High voltage switchgear and controlgear – Part 208: Methods to quantify the steady state, power-frequency electromagnetic fields generated by HV switchgear assemblies and HV/LV prefabricated substations," IEC Technical Report, Oct. 2009.

[2] ITE. Informe E.6.6. Metodología para conseguir la correcta distribución de elementos en el interior del centro, Proyecto Crisálida, 2009.

[3] ITE. Informe E.6.7. Propuestas para los nuevos diseños de elementos particulares (cuadros de baja tensión), Proyecto Crisálida, 2009.

[4] ITE. Informe E.6.8. Configuración de estructuras de apantallamiento, Proyecto Crisálida, 2009.

[5] ITE. Informe E.6.9. Resultados de estudio de viabilidad sobre apantallamiento activo, Proyecto Crisálida, 2009.

[6] "Magnetic field density analysis in switchgears," International Conference on Renewable Energies and Power Quality,ICREPQ'11, Las Palmas de Gran Canarias, Spain, Apr.2011.

[7] "Validation of a simulation tool for evaluation of magnetic fields generated by transformer substations according to IEC/TR 62271-208," 2nd International Conference on EMF-ELF'11, Paris, France, Mar. 2011.

[8] "Application of a new IEC magnetic field assessment methodology to promote

transformer substation sustainable development". IEEE EnergyTech 2011: Technology frontiers in sustainable power and energy. Cleveland, May 25-26, 2011.

[9] International Commission on Non-Ionizing Radiation Protection, "Guidelines for limiting exposure to time varying electric, magnetic, and electromagnetic fields (up to 300 GHz)," Health Physics, Volume 74, Nº 4, Apr. 1998.

[10] Real Decreto 1066/2001, de 28 de septiembre, por el que se aprueba el Reglamento que establece condiciones de protección del dominio público radioeléctrico, restricciones a las emisiones radioeléctricas y medidas de protección sanitaria frente a emisiones radioeléctricas, Boletín Oficial del Estado Nº 234, 29 Sept. 2001.

[11] Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC.

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