New ways to approach EMC in lift industry. Case of ITER[1] project

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Abstract. Over the years, designs have been developed considering the requirements of Electromagnetic Compatibility (EMC) for lifts, following the EN 12015 & EN 12016 standards, to achieve and increase quality and reliability. To achieve this, EMC requirements are considered from the first steps of the design, other requirements are established when testing in a laboratory and, then, collaborations have been carried out with partners to achieve the EMC compliance of the complete electrical installation.

A new challenge in EMC currently being worked on is designing lifts for a singular installation: the ITER project. This facility requires special actions to meet such unique requirements as the project is, especially in terms of magnetic fields. The project involves not only a challenge for designing, but also for the companies who cooperate in tests and simulations as they must manufacture ad hoc instrumentation, thus innovating in the process to perform the tests.

1 INTRODUCTION

1.1 EMC requirements

All electric devices or installations influence each other when they are interconnected or close to each other. The purpose of electromagnetic compatibility (EMC) is to keep all those side effects under reasonable control.

Electrical and electronics equipment shall be designed and manufactured to meet the essential requirements of 2014/30/EU Electromagnetic Compatibility (EMC) directive:

"(a) The electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;

(b) It has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use."

The Electromagnetic Compatibility (EMC) Directive 2014/30/EU requires that electrical and electronic equipment does not generate, or is not affected by, electromagnetic disturbance. Following harmonized standards, we can get the presumption of conformity with those essential requirements.

1.2 EMC lifts requirements

The Directive 2014/33/EU on lifts indirectly includes EMC requirements: EN 12016 and EN 81-20 standards provide presumption of conformity with the Directive. EN 12016 and EN 12015 are also included in EN 81-20 standard, where the procedure that must be followed by the installer of a lift or by the manufacturer of a safety component, before it is placed on the market, in order to ensure that his lift or safety component complies the Directive. The Lifts Directive details the essential

[1] ITER: International Thermonuclear Experimental Reactor

requirements the product must meet to allow the lift installer or the manufacturer of the safety components for lifts can affix the CE marking. The electrical installation of the lift shall comply with the electromagnetic compatibility requirements according to clause 5.10.1.1.3 of the EN 81-20:2014, where it is stated that the electromagnetic compatibility shall comply with the requirements of EN 12015 and EN 12016 standards (harmonized standard with the EMC directive). Safety circuit equipment shall comply with special immunity requirements of the EN 12016 standard.

2 EMC REQUIREMENTS FOR LIFTS, EN 12015 & EN 12016

2.1 Emissions requirements, EN 12015

There are two kinds of emission requirements as per EN 12015 standard, conducted and radiated, in three range of frequencies, harmonics limits for lower range (from 2^{nd} to 40^{th} current harmonic, thus up to 2 kHz), conducted limits above 150 kHz up to 30 MHz and radiated from 30 MHz to 1 GHz. Those radiated measurements should be done in a semi-anechoic chamber. Note there are no requirements from 2 kHz to 150 kHz.

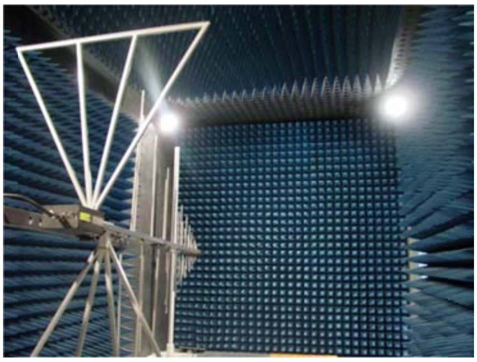

Figure 1: Semi-anechoic chamber in the EMC laboratory. Courtesy of MP Lifts

2.2 Immunity requirements, EN 12016

This European Standard specifies the immunity performance criteria and test levels for apparatus used in lifts, escalators and moving walks which are intended to be permanently installed in buildings including the basic safety requirements in regard to their electromagnetic environment.

The standard refers to EM conditions as those existing in residential, office and industrial buildings. This standard addresses commonly known EMC related hazards and hazardous situations relevant to lifts when they are used as intended and under the conditions foreseen by the lift installer or manufacturer.

However, performance criteria and test levels for lifts do not cover situations with an extremely low probability of occurrence. It does not include magnetic field immunity tests that are applied to other products, such as information technology equipment, according to EN 55024 standard.

2.3 Collaborations

The compliance of EMC requirements is not only a matter of affixing a CE marking to the product and signing the EU declaration of Conformity. It has also to do with achieving and increasing the quality and reliability. To do so, the EMC requirements are considered from the first steps of the design, other requirements are established when testing in a laboratory and, then, collaborations are carried out with partners and providers to reach the EMC compliance of the complete electrical installation. We usually collaborate with Universities, technological centres and independent experts during the design process.

It is necessary to define internal protocols to go further than those indicated in the standards, thus ensuring the robustness of the product design. Immunity tests applied with safety factors between 2 and 8, and acceptance criteria more stringent than those specified in the standard, may reduce fails and damage in lift electronics.

3 CASE OF ITER PROJECT. SPECIAL EMC REQUIREMENTS

The International Thermonuclear Experimental Reactor (ITER) is a project to prove that fusion power can be produced on a commercial scale and it is sustainable. The Tokamak is an experimental machine designed to harness the energy of fusion. ITER will be the world's largest Tokamak machine, with a plasma radius (R) of 6.2 m and a plasma volume of 840 m^3. Fusion is the process that powers the sun and the stars: when light atomic nuclei fuse together to form heavier ones, a large amount of energy is released. Fusion research is aimed at developing a clean, safe, abundant, economic and environmentally responsible energy source.

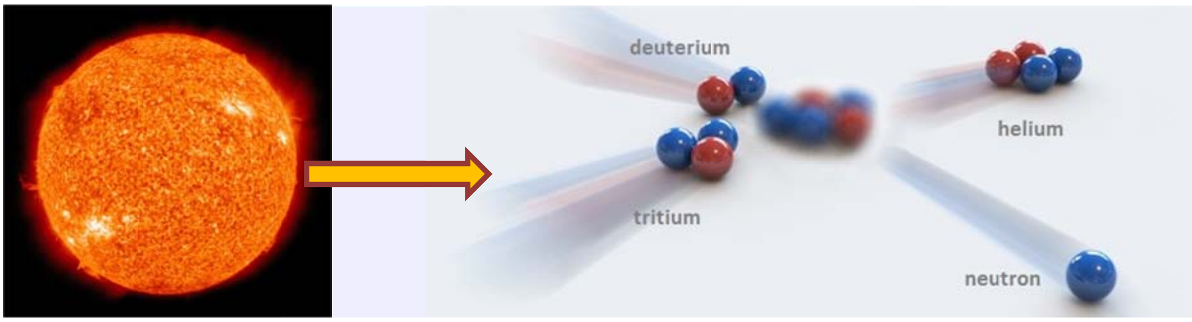

Figure 2: Fusion process in the sun

The ITER facility is being built in southern France by a scientific partnership of 35 countries.

Six ring-shaped poloidal field magnets will surround the toroidal field magnet system to shape the plasma and contribute to its stability by "pinching" it away from the walls. The largest coil has a diameter of 24 meters; the heaviest is 400 metric tons.

This means that all the equipment inside the reactor buildings will be subjected to high DC magnetic fields included the lifts. Also, electromagnetic interference could affect the stability of the plasma.

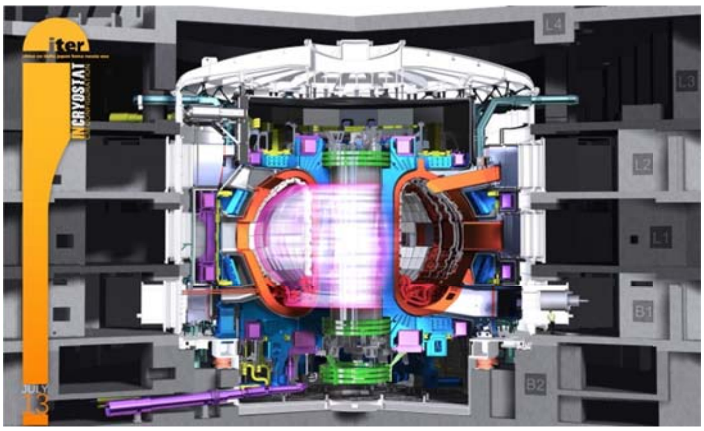

Figure 3: Tokamak machine diagram

When the author arrived at this project, as the responsible technician for electromagnetic & radiation design of the lifts, it was definitely the biggest technological challenge in his professional career. He was in charge of carrying out all the studies and tests related to electromagnetic field and radiation to ensure the viability of the lifts in the environment of the ITER project.

4 TECHNOLOGICAL CHALLENGES

In the ITER project, a series of extremely tight requirements must be considered where the EMC ones are especially important. As a matter of fact, the electromagnetic disturbances of the building equipment could affect the stability of the reactor plasma. If that happens, it would have catastrophic consequences.

For the lifts, we considered the here below EMC requirements in the qualification process:

- Emission limits according to EN 12015 standard
- Specific conducted emission limits, tested according to MIL-STD-461F (CE 101/2)
- Immunity according to EN 12016 standard
- Immunity to fluctuating magnetic fields (50Hz). It was tested according to EN 61000-4-8, with specific levels.
- Immunity to DC magnetic field requirements with specific field level up to 20mT. It was tested according to EN 61000-4-8 and a specific methodology (defined in clause 5.4).

There are two key aspects of the requirements to be met that represent a technological and new challenge for lifts to achieve the goals:

- Specific conducted emission limits, tested according to MIL-STD-461F (CE 101/2), from 50 Hz up to 30 MHz, covering a new range of frequencies for lifts: from 2 kHz to 150 kHz, and stricter limits for frequencies upper than 150 kHz. Thankfully, the goal was reached and we only had to apply traditional EMC resources, like a few decoupling capacitors.

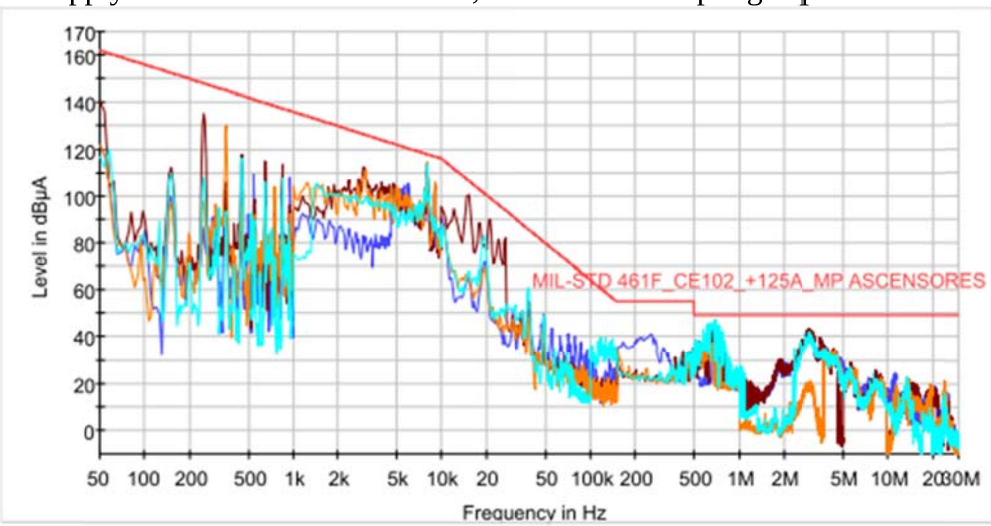

Figure 4: Conducted emissions results according to MIL-STD-461F for goods lifts.

- However, the bigger challenge was the immunity to magnetic field due to the following reasons:
  - The company never had any experience in this kind of test, only with communications devices in the car (emergency phone), with much lower levels.

- Non-existent instrumentation for specific requirements, because the level of magnetic field had never been never tested before. It was a challenge for us and for the laboratory. EN 61000-4-8 standard levels are in the range of μT, and DC magnetic field level are 20 mT (thousands times greater).
- These issues generated high uncertainties.
- Both electric and mechanical components had to be considered due to the effects that could be produced by magnetic field: movement, heating, etc.

Hereafter, we will only deal with the magnetic field requirement that it is the greater innovation brought and tested.

5 MAGNETIC FIELD ACTIONS: ANALYSIS, SIMULATIONS & TESTS

To achieve the compliance with the requirements of magnetic field, a path of actions had been set, considering three steps: analysis, simulations and tests.

5.1 Analysis

An analysis phase was developed, where the following actions were carried out:

- A documentary and detailed review of the requirements; as we will see in next chapter.
- A design review of the electric installation to locate critical components based on its operating principle (for example: magnetic positioning) that could be affected by the field.
- Meetings with the responsible technicians for electromagnetic compatibility laboratories where magnetic field immunity tests are usually carried out.
- Meetings with the manager of the nuclear fusion laboratory in Madrid, to know the effects and mitigation measures applied to solve the problems in their instrumentation.
- Support of external consultants: University of Seville and Technological Institute of Aragon.

And, of course, we always had to apply a large amount of common sense.

The result was that we were lead to some inevitable design changes and new resources for the protection of critical equipment were required. But we also got the base of experience that was not available at the beginning and the conviction that nobody had been faced to a similar problem before.

5.2 Requirement analysis

As already mentioned, it was performed a comprehensive analysis of the necessary requirements, to know exactly which lift components had to be tested, which resources have to be dedicated to, which were the protection options, which kind of resources can be used to apply solutions and measurements during the tests.

The analysis conclusion was that the test would be passed if the lift operation remained correct in presence of the magnetic field, considering these additional points:

- Functional point of view:
  - log of car and landing calls,
  - car motion to all the floors from where a call is made,
  - information on the car display,
  - emergency mode and communications,
- The magnetic forces do not generate any missile effect (capability of the static magnetic field to attract ferromagnetic objects, drawing it quickly by considerable force).
- No fire breaks out due to overheating or currents produced by the magnetic field.

If the magnetic field has a residual effect on ferromagnetic parts of the lift, it can generate heavy soiling with effects in the mechanical functions. This point has to be considered for the maintenance works. We also need to evaluate that the entire electronics works properly (not only functionally).

5.3 Simulations

Simulations of the magnetic field to critical facilities for the ITER in reactor buildings were performed in order to evaluate possible solutions to the magnetic field issues.

These studies were developed in collaboration with ITAINNOVA ("*Instituto Tecnológico de Aragón*"), which is a technological centre, and whose specialists were our advisors.

The first step consisted of looking for protection options through the simulations: full protection of the lift shaft vs individualized protection only for critical parts.

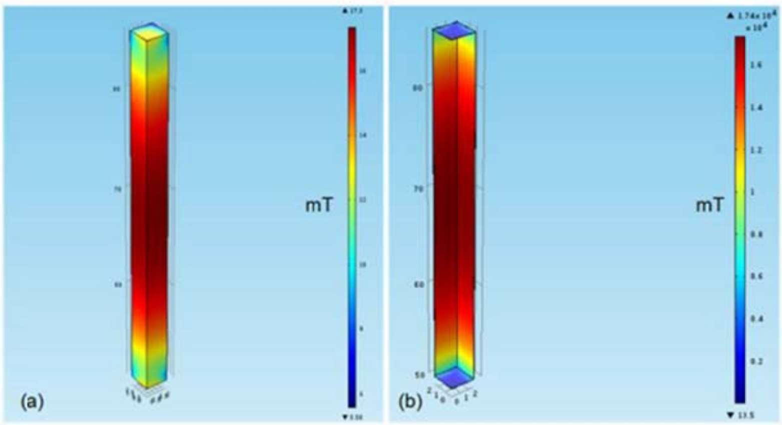

Figure 5 Shaft simulation. Magnetic field inside the shaft with complete shielding.

The first result ruled out the complete protection. So we started to simulate individualized shielding for critical parts of the lifts: control box, landing operating panels, car operating panels and harmonic filter protections.

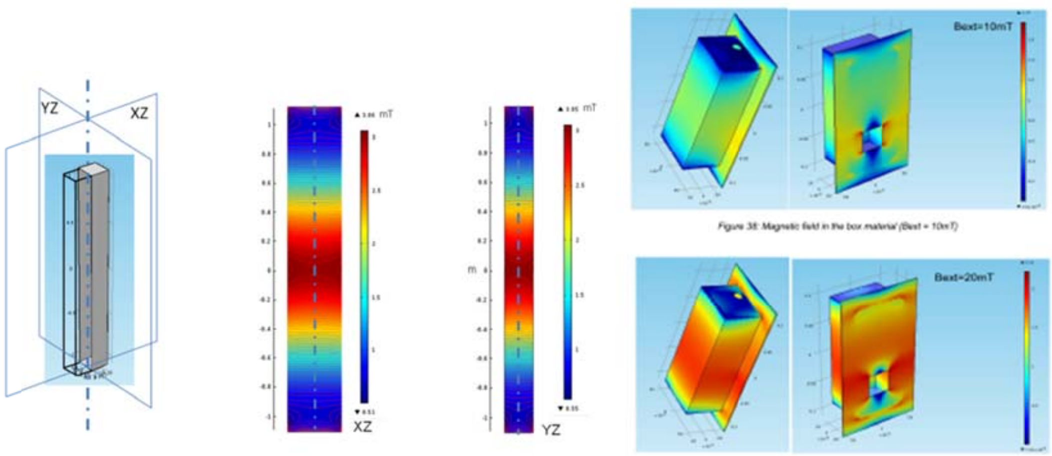

Figure 6: Simulation of the magnetic field inside the protected control box and landing operating panels.

This step result was that we found out how to get prepared for the testing phase, and we selected all the protection alternatives, materials, thickness, shape and designs.

5.4 Tests methodology

The laboratory selected to verify magnetic field requirements was the Official Central Electrical Engineering Laboratory (LCOE). This technical body is accredited by ENAC, according to ISO/IEC 17025. It is also Notified Body for EMC Directive (2014/30/EU). In that laboratory, we tested the following requirements:

a) Immunity to fluctuating magnetic field (50 Hz): EN 61000-4-8 standard.

b) Immunity to static magnetic field (DC): with levels up to 20 mT

As there was not any international standard related to this subject (DC field), we designed the test methodology to certify the lift operation for the existing magnetic field in the buildings.

For this test, an antenna, provided with a special coil and able to support the current to achieve the required DC magnetic field, had been purpose-built. Other laboratories were also contacted, but they did not have power supply enough to apply this level of magnetic field. This fact gave to us an idea about how difficult it is to test and to accomplish the requirement.

The DC magnetic field range in the buildings is between 1 mT to 10 mT at the levels and rooms where the lifts are. And, according ITER requirements (2X safety factor), the level of 20 mT is selected for testing personnel lifts and 10mT for goods lifts.

The assembly of apparatus had to pass the functional performance criteria in such a way it had to continue to operate as intended. No degradation of performance or loss of function is allowed below a performance level, when the assembly of apparatus is used as intended.

As per the specific requirements, it has to be ensured there is no generation of any missile effect, nor fire (caused by overheating) due to the magnetic forces and currents produced by the Tokamak magnetic field.

From the analysis of the requirements, the first conclusion was that several measurements had to be applied. A new test methodology (see Table 1) was developed, whereby a series of additional measurements during the magnetic field application tests were done to detect other non-visual effects:

- The performance of functions of the lift was observed by visual inspection of the correct operations and means of the own resources (informative tools of the control electronics) of the electrical installation: informative LEDs, console and car display. This is the traditional method for general requirements: visual monitoring of the sample.

- Input current measurements were made in the power supply of the installation, and this measure can give us a qualitative idea how EMC filters and electronics works, to evaluate it. If the current measurements are modified, there are indications that the electrical installation is working with different conditions (For example, if the harmonics filter fails, then current measurement increase its value when the nominal speed is attained).

- Thermographic measurements were made at the start and end of each test. This one can clarify if any current is produced by the magnetic field in some mechanical parts.

- Residual magnetism measurements were made on the components under test by a gaussmeter.

Type	Requirement	Effect	Measure
General	Functional performance criteria	Failed operations due to magnetic field	Visual monitoring
Specific (ITER)	Not missile effect	Moving parts	Visual monitoring
	Not fire	Overheating due to the magnetic forces and currents in metallic parts	Thermographic measures
Specific (MP)	Residual magnetism	Heavy soiling in mechanical parts	Gaussmeter measures
	Filters and electronics	Operation of electronics and filters	Current measures

Table 1: Methodology summary

5.5 Tests results

The tests in the LCOE laboratory started in October 2017 and ended in April 2018. Tests were carried out on samples of the passenger lift, and the goods lift.

During the tests, some effects were found on the residual current circuit breaker, the contactors and the door operator. All those effects were resolved by using the shielding designed during the simulation phase, changing some metallic parts to stainless steel and changing magnetic sensors by mechanical contacts.

To check if magnetic field had a residual effect on the components (magnetic remanence), magnetic field measurements were performed with a gaussmeter on critical components after the tests. With this measure, we identified the critical components to be verified during the maintenance works.

With a thermographic camera and multimeters, the author had been able to state that there are no thermal and current effects and, also, the electronics and filter operations are right.

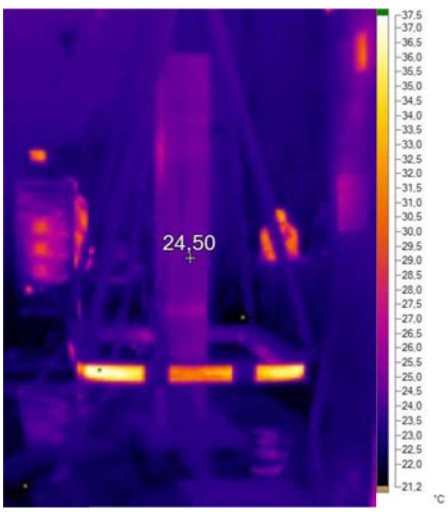

Figure 7: Thermographic picture. MRL control panel.

Figure 8: MRL Control panel

6 CONCLUSIONS

Thanks to the detailed analysis of the environmental requirements at ITER buildings, the simulation phase, the application of additional measures during the monitoring of the tests and the construction of new instrumentation resources to generate the required field, the qualification of the samples has been obtained successfully.

To meet this result, a global view (mechanical, electrical and electronic) of the samples under test has been applied.

Finally, our lifts move upward the raw material to get the clean energy of the future and the people involved in the project. And, in the other hand, these people go on moving further and higher. We will be there to come along with them.

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BIOGRAPHICAL DETAILS

José Carlos Feria Moreno is B.Sc. degree in electrical engineering (University of Seville) and works in the R&D department at MACPUAR SA since 1998. He started working in the laboratory of EMC: testing and providing EMC solutions to MACPUAR SA products. Since 2009, he is currently responsible for Electronics and Electrical R&D laboratories where functional, thermal, electronic characterization, electromagnetic compatibility and other tests are being run. He has an extensive experience in EMC, testing resources and he had been collaborating in some research projects with the University of Seville.

About ITER Project: As the responsible for Electromagnetic & radiation design, he was in charge of carrying out all the studies and tests related to electromagnetic field and radiation to ensure the viability of the lifts in the environment of ITER project.