Extended validation and certification of new generation power converters reduce the cost of energy

Words: Ion Etxarri, R&D Quality & Innovation Manager at Ingeteam Wind Energy

As market demand for wind turbines has grown, so too have the demands for quality and performance, in order to reduce the levelized cost of energy (LCoE) and demonstrate that the technology is not just a clean solution for electric power generation, it is also a profitable addition to the energy mix. This is especially the case for critical components such as power converters because the performance of the whole turbine depends on them.

The response is focused on increasing the reliability and durability of these components, making wind turbines more economically viable assets. High quality design and extended validation methods of power converters are key to guaranteeing the reliability and durability of the turbines in wind farms facing the toughest operating conditions.

Ingeteam's new-generation power converters have been validated using the toughest test scenarios and most realistic configurations, to prove in advance that the converter will be properly integrated within the turbine and operate correctly under the most demanding situations.

The market demands continuous performance improvement and regulatory innovations take this factor into account. Ingeteam participates in the committees which issue these requirements and integrates the latest regulatory developments at the design phase of the company's new generation power conversion solutions.

This method is also applied to the company's manufacturing plants to comply with all marking requirements. Indeed, the certification of the converter facilitates the certification process for the whole wind turbine.

Validation process

IEC[1] standards are the reference conformity assessment for all electrical, electronic and related technologies. As a critical wind turbine component, Ingeteam's new-generation

1 International Electrotechnical Commission

Ion Etxarri

power converters must meet the highest quality requirements, since wind turbine performance is dependent upon them.

Ingeteam's new power conversion solutions have been subjected to the tests required by IEC61400 for wind turbines, and IEC62477-1 and IEC61800-3 for power converters, verifying the correct performance and the highest level of safety.

Within this validation process, a large number of tests are focused on the assessment of energy and temperature hazards. For example, the behaviour of the converter in the event of failure of a cooling system or insulation components is assessed by means of functional tests, simulating these failures or in temperature rise tests. In addition, mechanical tests such as IP degree, corrosion, impact, or vibration also form part of the validation. All these tests guarantee the safety and the correct performance of the power conversion solutions.

Based on its experience in the wind turbine market, Ingeteam considers that an 'extended validation' of power converters is appropriate in order to optimize the design and minimize any potential issues that may arise during the integration of the component within the wind turbine.

The objective of this 'extended process of validation' can be summarized as follows:

- To identify design improvements or detect any design failures of the converter at the earliest stage of development, thereby minimizing subsequent design and manufacturing costs due to modifications at a later stage of implementation that would imply the use of more resources.
- To test the converter under the most realistic conditions to validate the design under all possible scenarios and to verify it complies with requirements. The more accurate the test is regarding the behaviour onsite inside the turbine, the greater the reliability of the tests and the results obtained.

Ingeteam carries out four types of test to provide accurate data about the behaviour of its converters when installed onsite:

- Combination tests in full-scale test benches.
- Extreme climatic condition tests.
- Extreme mechanical condition tests.
- Electromagnetic compatibility tests.

Combination tests in full-scale test bench

The correct behaviour of a power converter can be verified without the use of a generator by means of external power supplies and passive components; however, this kind of validation process cannot fully guarantee the correct integration in the field.

Specific characteristics of the generator could affect the behaviour of the converter, and combination tests make it possible to anticipate them. Some processes are not possible to simulate and assess by means of calculations, and empirical methods are the best way to do that.

In addition, combination tests with power-limited generators or mock-ups may not allow the required points to be assessed.

Ingeteam carried out these tests, using the same generator as in the final application, which is critical. The schematic of this kind of tests, together with the final layout of the test bench is shown on the left.

Combination tests with a generator at full scale enable the correct performance assessment of the converter at any desired point. Thus, a full validation process is obtained as the converter operates along the whole operation ranges. This process includes at least the following variable parameters including grid voltage and frequency, generator speed, reactive or active power, or temperature:

Operational range: static (long-time) and dynamic (short-time) load points are used in order to confirm the correct operation of the converter. The limits of the converter are tested and include all the strategies of the control in order to fulfil the requirements of the grid. These tests cover all the operation points of the application and include the following cases:

- Steady and overspeed points within PQVF range
- Static VAR mode
- Efficiency along the P-n curve
- Harmonics
- DVDT
- Dynamic response (torque and Q steps)

As an example, the following figure shows an overspeed working point where GSC & MSC currents, N, P & Q can be seen.

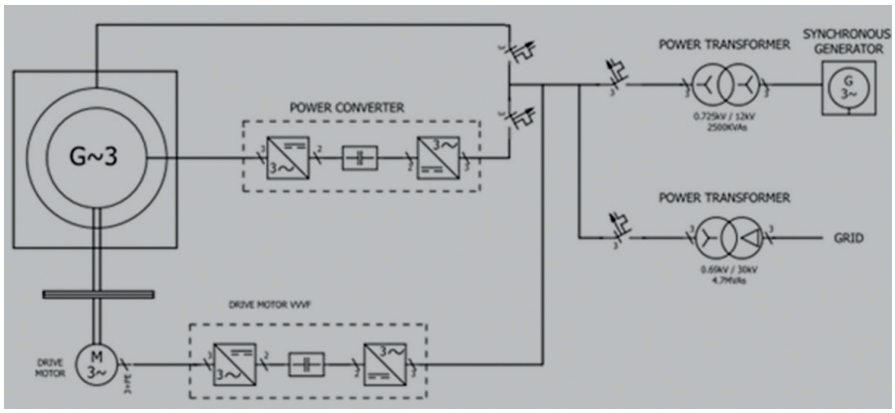

Figure 1: a) Schematic b) Final layout

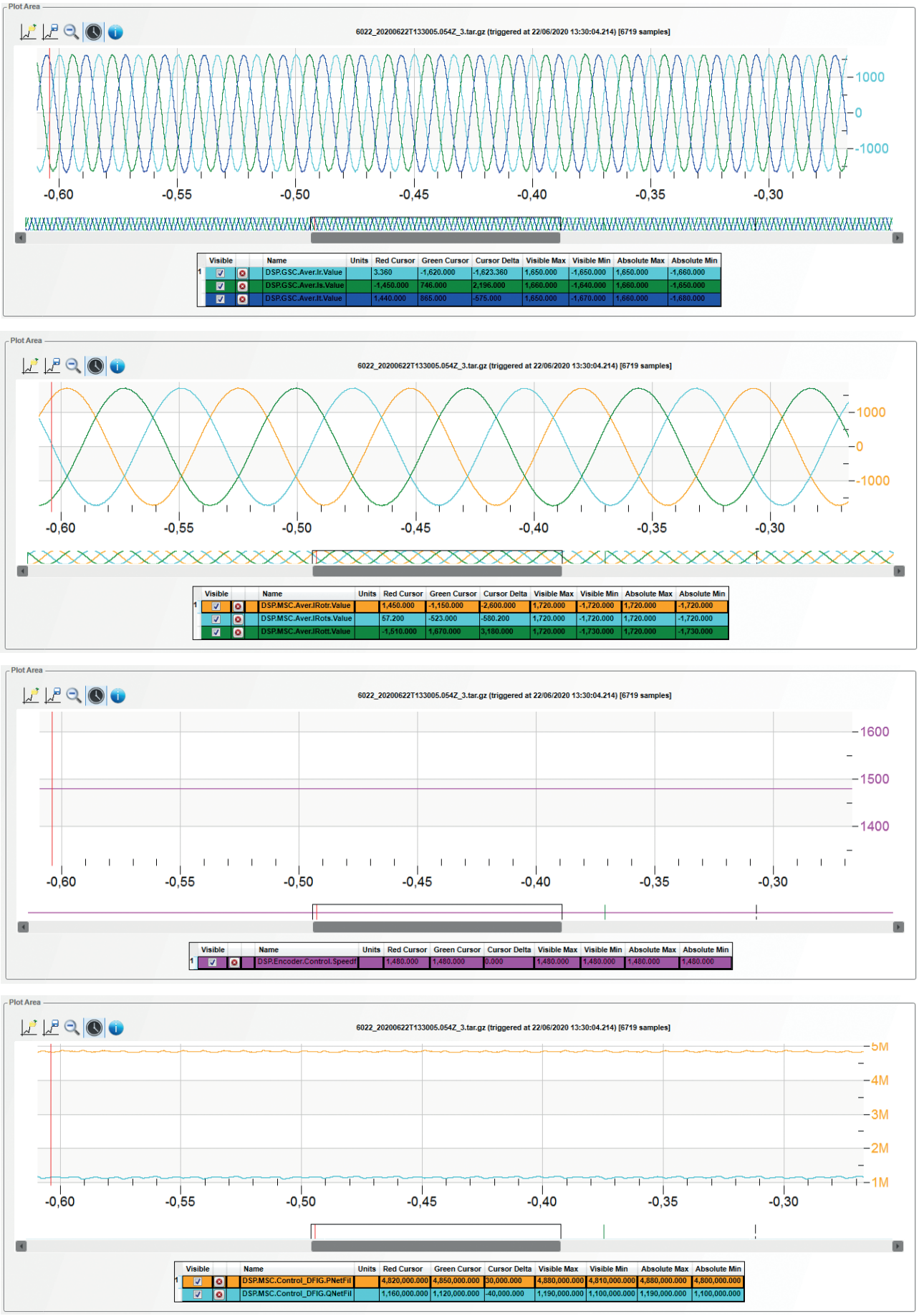

Figure 2: Overspeed working point

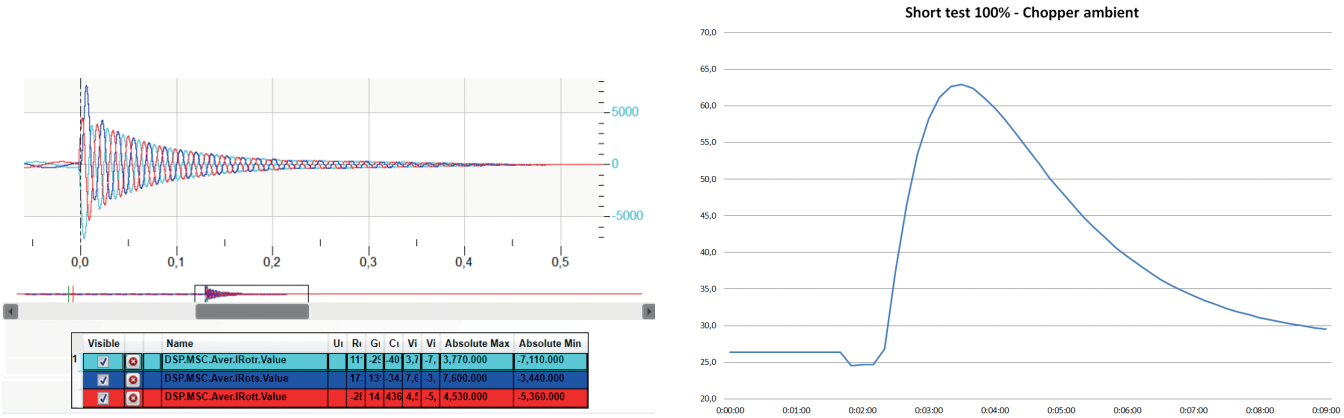

Figure 3: short test at 100%

- Heat run test: the thermal behaviour of the converter is assessed under several operation points of the generator. These tests are used to confirm that no temperature is outside the expected limits as well as to characterize the thermal model of the components. This information is particularly useful in order to detect potential cost reductions based on different geographic areas of wind farms. The new-generation power converter has been tested this way under the worst operation conditions for GSC, MSC and stator circuit.
- Special tests: the configuration used for combination tests also allows some additional tests that reduce integration and FRT behaviour uncertainty to be carried out. In this case, the power converter has been subjected to motor mode test and short circuit at stator, which is critical in case of DFIG application.

As an example, the figure 3 above shows the behaviour of the converter during a short circuit test. On the left side, MSC currents, peak current up to 9kA, in case of a short circuit at stator of 100% of Voltage drop. On the right, the rapid increase of chopper resistor ambient temperature can be seen.

Extreme climatic condition tests

A critical point of a validation process is the climatic one. To be able to verify empirically the correct behaviour of a converter and its components along the whole climatic range is important in order to detect unexpected behaviours that cannot be predicted by means of calculations. Ingeteam is able to carry out a detailed validation thanks to its test benches which are able to control the temperature and the humidity over a very wide range, and where the converters can operate at rated conditions.

Executing tests at the extreme limits of temperature and humidity allows the observation and understanding of the specific behaviour of components when they operate close to their limit, and to define the best options regarding functionality and

Figure 4: Ingeteam climatic (Temp & RH) chamber

cost. Without this empirical analysis, the selection of components would be based on theoretical calculations and datasheets, making a conservative selection that would imply overrun, more likely. With this validation the optimum design is obtained.

In addition, the performance in case of failure can be assessed in detail. Without this kind of test infrastructure, it would be impossible to know how the converter really reacts when a component such as a fan or a cooler fails. The behaviour at a specific room temperature or humidity value could differ drastically from another value. This uncertainty is overcome by carrying out failure tests at several climatic points to identify the real performance at each point without depending on assumptions and calculations that could provide erroneous conclusions and lead to designs that do not fulfil the requirements or could even be dangerous.

The climatic extreme conditions validation includes the following type of tests:

- Heat run tests: the thermal behaviour of the converter is assessed, setting maximum current values and the worst temperatures. The whole range for both operation temperatures and for external ambient and external cooling system is covered. See Figure 5.
- Cold climate tests: in this test, it is verified that the converter is operative in the desired time under the lowest environmental temperatures and once operating starts the cooling/heating logics are valid. Thus, in addition to temperature, DI/DO are monitored. In addition, the operation under variable cycles of external temperature is assessed. See Figure 6.
- Condensation tests to cover the following processes:
  - Detection of the points where condensation could occur by provoking it by means of extreme variations of temperatures with high RH values.
  - Verification of de-humidification time required by heating system once condensation has occurred under the worst conditions.
  - Confirmation of anti-condensation logics validation, where all the possible scenarios are validated.
- Damp heat tests: tests of several days (>96h) are carried out at maximum temperature and RH values. After that, dielectric properties are verified.

Extreme mechanical condition tests

Another critical part of the validation process of the converter for its final application is the assessment of its behaviour and response to low frequency vibrations. Incorrect behaviour could cause severe damage to the converter and the wind turbine.

Depending on the wind turbine, the location of the converter and the fastening structure, the response could change drastically. Thus, this is a process to be carried out for each wind turbine-converter combination.

Prior to the test, Ingeteam develops detailed Finite Elements Models (FEM) to predict the response of the converter and to assess the different design options.

The main test consists in sinusoidal sweeps using the specific 'Frequency-Acceleration profiles'. These profiles are defined based on accelerated test processes with the aim of simulating the whole accumulated damage along the life of the turbine in only a couple of hours.

During the tests, the resonances are checked

Figure 7: Vibration test

because any change on their frequencies could lead to structural damage.

In addition, shock tests with extreme acceleration values are carried out.

Following these tests, the converter must remain operational. No damage affecting safety can be accepted.

Passing these tests guarantees that the combination of converter and wind turbine is correct and will withstand the lifetime of the turbine. The results are also correlated with the FEM models developed.

Electromagnetic compatibility tests

The immunity of the converter against the emissions of the environment or generated by nearby devices is critical to guarantee the maximum availability of the turbine.

Also, the converter itself can generate emissions that could affect the correct operation of nearby items, within or outside the turbine.

To confirm that the converter is able to operate in an environment within the expected emissions limits, compatibility

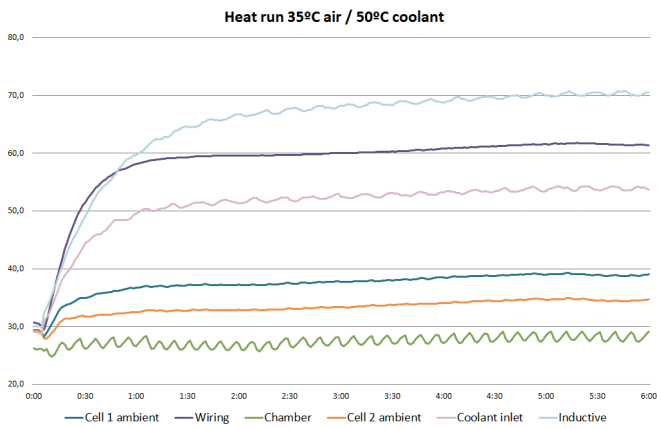

Figure 5: Heat run test

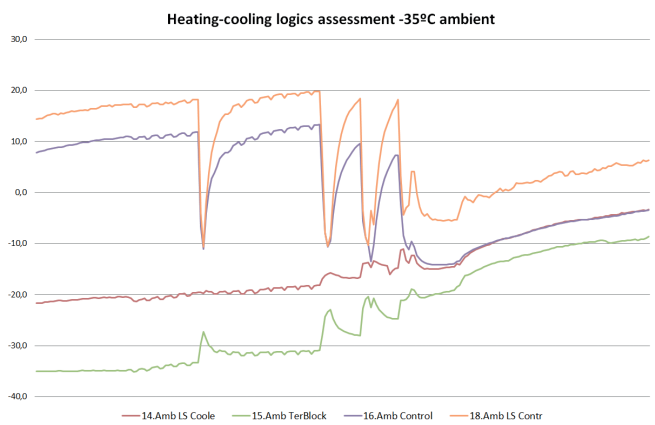

Figure 6: Cold climate test temperatures evolution (peaks due to activation/deactivation logics)

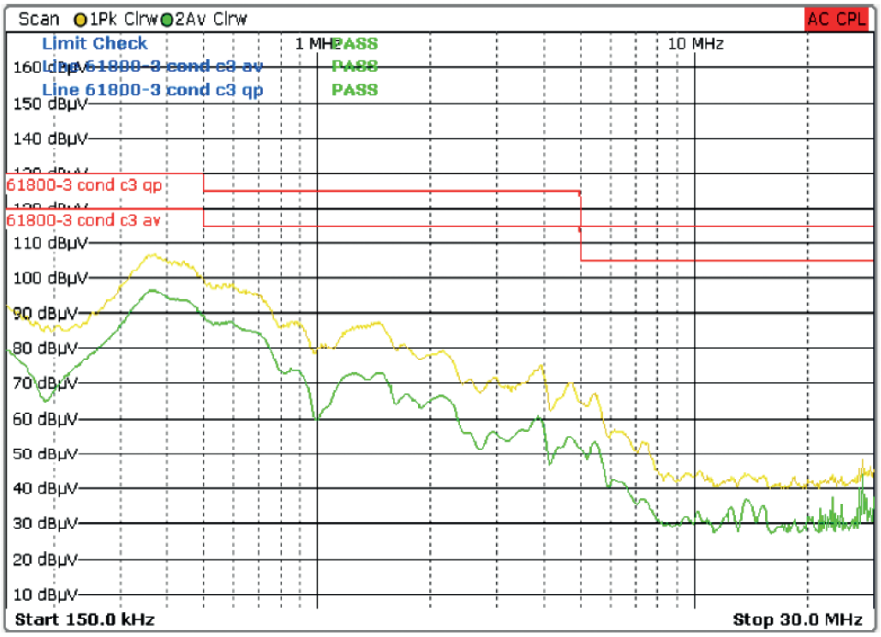

Figure 8: Results for conducted emissions

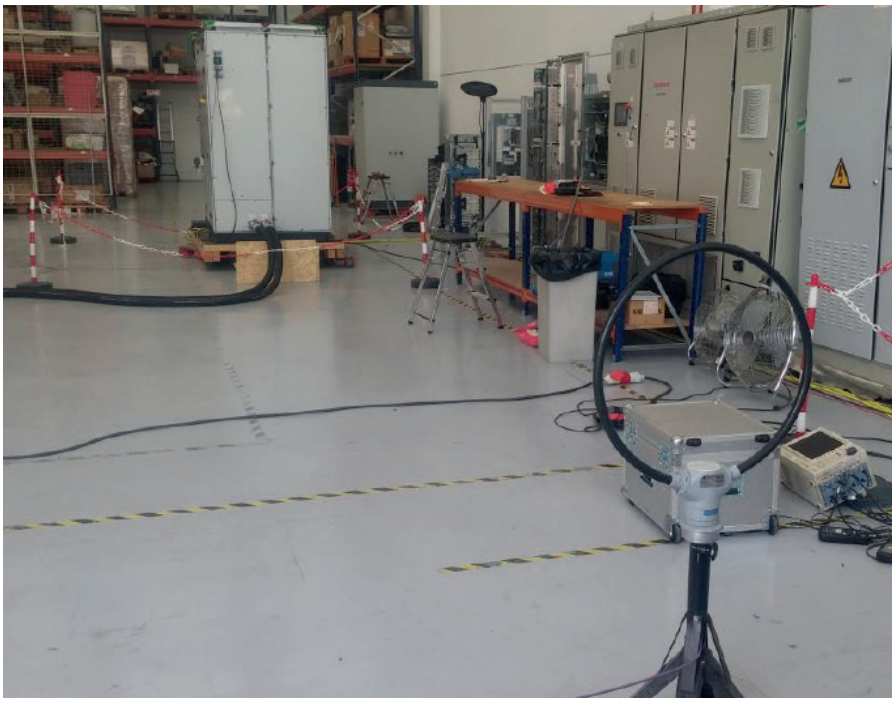

Figure 9: Radiated emissions test

tests according IEC61800-3 standard are included in Ingeteam's validation process.

These tests are carried out in the manufacturing plant, using the most representative configuration, and by certification bodies.

Passing them minimizes drastically the risk and uncertainty regarding EMC.

Certification process

Another cornerstone of Ingeteam's design process is certification. Achieving the combined requirements of maximum durability and reliability with cost-optimization is essential, but Ingeteam understands that different international standards can present a barrier for wind turbine installation.

Therefore, Ingeteam considers the strictest international standards for all its designs.

Ingeteam participates in the committees that issue these requirements and thus it stays up to date of the latest regulatory innovations and implements them from the design phase of the converter. Being proactive regarding regulatory demands leads to the improvement of new converter designs and avoids late modifications that could delay a project. Any new design within the company integrates the strictest standards for all the applicable marks and labels including CE, UL or DNV-GL.

The participation in IEC committees such as TC22 (Electronic Power Conversion) and TC88 (Wind Energy Generation Systems), IECRE (IEC Renewable Energy), as well as in specific working groups within IEC including WG05 (Hazardous Substance) or WG26 (SW testing), or STP UL groups for development of standards like UL508 (Industrial Control Equipment), proves the commitment of Ingeteam to the quality of its products.

Moreover, this approach is not only applied to product design, but also the manufacture of the products in its plants. For that purpose, the plants are certified for the manufacture of any component and marked with the main wind mark labels. These certifications confirm international compliance and avoid project delays due to any marking regulations and barriers. In addition, they facilitate the certification process of the wind turbine.

Ingeteam has already certified its plants for power converter within DNV-GL and UL scopes, and in addition has been trained for APQP4Wind.

Conclusion

Extended validation of Ingeteam's new generation of power converters confirms their operational performance under the most severe conditions. The use of full-scale test benches for integration assessment and climatic behaviour evaluation are key to optimize the design and detect potential improvements at an early stage. The information obtained from the tests assures the optimization of the design and guarantees that the converter is going to operate properly in the field.

The incorporation of the latest and most stringent regulatory requirements at the design phase and also in the certification of the manufacturing for plant, allows Ingeteam to facilitate the wind turbine certification process, wherever the geographical location, thereby reducing the project time-to-market and saving costs throughout the development and validation design processes. Clients can be confident that thanks to extended validation, Ingeteam's new products deliver the best in-field value for money.

www.ingeteam.com