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CHALLENGES AND PRACTICAL EXPERIENCES IN POWER QUALITY AND ELECTRICAL CONNECTION OF DISTRIBUTED ENERGY RESOURCES FOR CERTIFICATION LABORATORIES

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ABSTRACT
Recently, new standards dealing with power quality or connection requirements of distributed energy resources to the electrical network have been or are being published. For example, the prEN50438 standard about the connection of microgenerators, the P.O. 12.3 stating requirements to be complied by wind farms not to disconnect from the electrical network after a certain voltage dip, or the IEC 61000-3-11 or IEC 61000-3-12 about the limitation of flicker or harmonics emissions, respectively, can be mentioned among others. As a consequence, also new standards about measurement techniques or requirements that must be complied by measurement equipment have appeared or are appearing like the IEC 61000-4-7, that providing guides for harmonic and interharmonic measurements, the IEC 61000-4-34 about measurement techniques for voltage dips, short interruptions and voltage variations immunity test, or the IEC 61000-4-30 concerning Power Quality measurement methods.

In consequence, laboratories have new challenges in order to continue being accredited certification bodies in the electrical sector, more concretely in the case of distributed energy resources connection, power quality and EMC. However, great investment efforts to purchase new measurement equipment and personnel training are needed.

This paper describes concrete experiences and gives technical examples of the efforts being done by one of these accredited certification entities. The paper starts with a new laboratory specification, design and investment, analyzes the first experimental tests and results to show the capabilities of the laboratory against some of the standards mentioned above, and finishes with a description of an accreditation process.

KEY WORDS
Power Quality, electrical connection, Distributed Generation, certification.

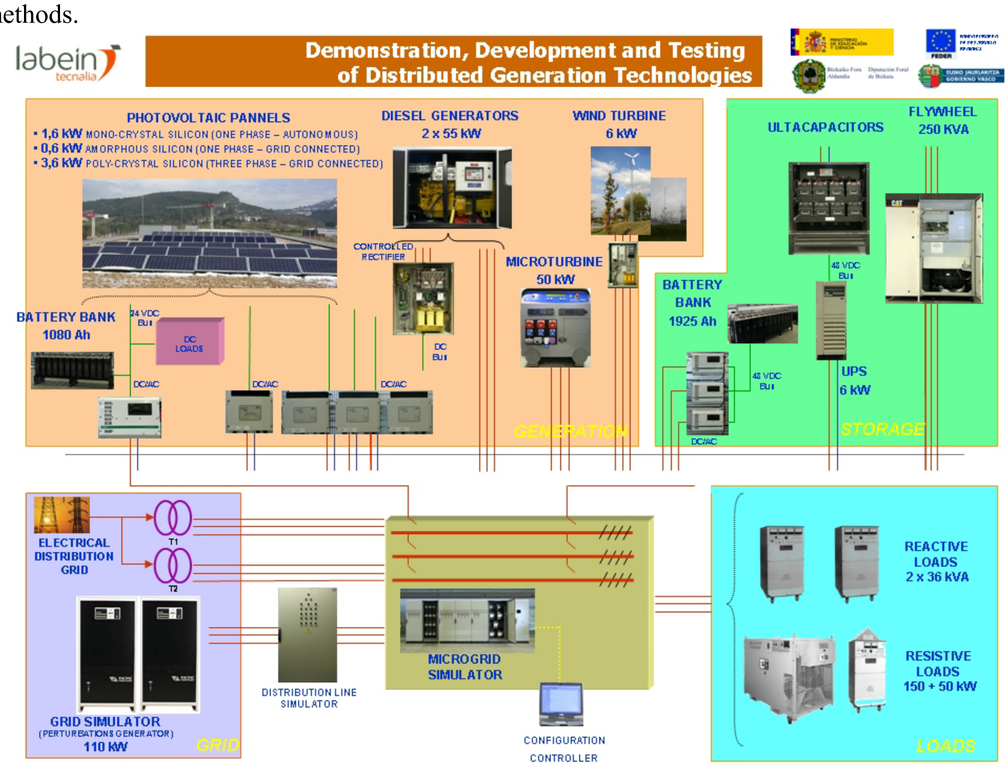

Figure 1. Distributed Generation Technologies Demonstration, Development and Testing facility of LABEIN-Tecnalia

1. Introduction

The present paper intends to describe and let know the actual challenges and incurred risks undertaken, and benefits obtained by certification laboratories in the electrical sector.
First, the different processes for standards publication that must be surveyed, and then, the steps that should be carried out to give a high quality compliance certification service are exposed from a certification laboratory point of view.
This description is accompanied with concrete examples and references to illustrate the overall process.

2. International Research, Development and Innovation projects, Technical Committees of Standardization Organizations and detected needs

One of the macroeconomic indicators of a country's development degree is the ratio of its resources devoted to research, development and innovation activities. Other indicators like the number of patents (mainly, the ones really being exploited), copyrights, PhD, recently created small and medium enterprises also deal with the same issue.
In Europe, lots of the Research, Development and Innovation activities are partially or even fully funded by the European Commission (FrameWork Programs, FEDER…), National Governments and Regional Administrations. These activities in the electrical sector are concretized in projects with specific research, development and innovation objectives, budget, financing and duration, where manufacturers, utilities, regulatory bodies, engineering companies, auditors, technological centres, universities and others interchange know-how. The projects can be traditional ones in order to research and develop new power electronics devices to support the Quality of Supply in high Distributed Generation environment [1], for pushing new concepts as electrical and thermal microgrids [2, 3] or the Distributed Generation from the demand side approach [4], for specification, design and implementation of virtual power plants for dispatch and control of the Distributed Energy Resources by the utility [5]… or for the creation of networks of excellence or training projects for actors of the electrical sector of the new members of the European Union, etc.
Of course, it must be taken into account what is being researched outside Europe, most of the times with a valuable mark.
One example of a Network of Excellence promoted by the European Union is DERlab, which is in charge of analyzing pre-normative requirements for the connection of Distributed Generation to the public electrical distribution network, interchanging personnel or equipment to complete their testing capabilities, unifying the testing criteria to certify the conformity of the equipment with published standards, among other objectives.
Other important Research, Development and Innovation activities are carried out by International Standardization Bodies. IEC, CENELEC, IEEE and CIGRE are the most involved in the standardization activities in the electic sector. Others like CISPR also deal with EMC issues.
Actually reference Technical Committees studying connection issues are IEC TC8 and more concretely the Working Group WG AHG 2 about the "Connection to the electric supply system", and CLC/TC 8x about "System aspects of electrical energy of supply" divided into WG2 "Domestic generation (microgeneration)" and AH WG5 "Connection of generators exceeding 16 A per phase".
There are different type of standard documents: Standards, Technical Specification, Technical Reports, Guides… among others.
Standard is defined like a document established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context [6], with a note adding that standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.
In all these forums technical problems are discussed, pre standardization solutions are proposed and finally, if considered adequate, standards are created. Some of the following problems can be mentioned as relevant (but they are not the only ones):

- Distributed Generation conception as a negative load that must not disturb the Quality of Supply parameters of the public electrical distribution network.
- Disconnection of Distributed Generation sources when an event disturbs some Power Quality parameter in the electrical public distribution network (islanding prevention).
- Disconnection of wind farms when voltage sags occur.
- Sensitive loads in production processes to electric events like voltage sags, over voltages, transients or short duration interruptions, even if the EN 50160 [7] Power Quality standard is complied[1].

[1] Electrical events in the public network can be produced by natural disasters (lightning, shortcircuit caused by fallen trees), and they are statistically controlled (interruptions) [TIEPI, NIEPI, SAIFI, CAIDI], almost immediately recovered by means of protections and network reconfiguration. However, inside the industrial installations other equipment can cause steady state perturbations as flicker, harmonics, unbalances, or periodic cumbersome events (transients by capacitor switching).

3. Regulation Bodies and the manufacturers race

End users like Transmission or Distribution Electrical Network Operators demand equipment compliant with recently approved standards, like for example happens with the IEC 61000-4-30 [8].
Sometimes, other procedures developed by these Operators are presented to their providers as a prescriptive requirements. For example the P.O.12.3 of Red Eléctrica Española (REE), finally imposed as mandatory in the recently approved Royal Decree [9].
Finally, end users can oblige providers to fulfil requirements non existing in any standard, like the connection requirements of photovoltaic installations to Medium Voltage lines. It must be noted that in Spain, the Royal Decree RD1663/2000 [10] covers only the generation of units with produced power lower than 100 kW and connection to Low Voltage lines; or even more strict that those appearing in any standard.
Under this scenario, one of the main objectives of manufacturers of electrical equipment is to develop and commercialize products compliant with the specifications marked by Regulatory Bodies, published Standards required as pertinent by end users, or other specifications. Several times this compliance is adopted as a decisive criterion for the equipment acquisition instead of those of the competitors.
Once the product is developed, manufacturers go to laboratories demanding for the compliance certification, even if there is any laboratory accredited in the specific standard.

4. Verification/Certification of technical requirements

The certification that electrical equipment complies with a new standard is a challenge and also a potential business for a laboratory. The performance of certain services and the assumed risk (depending on the frequency of the demanded tests and the type of service) are difficult to quantify. There is a number of issues that must be considered like personnel training, new measurement equipment acquisition, installations conditioning, testing procedures development, accreditation process and related costs that must be taken into account.
Several funding measures exist. Some funding are public, mainly for non profit organizations, and others private ones. Normally, both are considered in different percentages.
Other possible determinant fact is to be aware of the decisions about the type of standards to be published and the adopted criteria by the end users. Thus, it is important to be member of the Technical Committees of Standardization Committees or at least representative of the National Delegations. It is also recommendable to participate in research, development and innovation projects dealing with the interested issue.

4.1 A concrete experience: Exploitation of an electrical microgrid conceived for Demonstration, Development and Testing of Distributed Generation Technologies

Thanks to the help provided by the European Commission, the Science and Education Ministry of Spain, the Basque Government and the Regional Administration of Bizkaia (Diputación Foral de Bizkaia), the Energy Department of LABEIN Tecnalia specified, designed and developed an electrical microgrid conceived for the Demonstration, Development and Testing of Distributed Generation Technologies
The microgrid, illustrated in fig. 1 is formed by an electrical grid simulator generator, some electric generation systems (photovoltaic panels, small wind generator, diesel generators, microturbine), a set of storage devices (fly-wheel, ultracapacitors, batteries), adjustable resistors and inductances, a distribution line simulator and a microgrid simulator. Some commercial and home made inverters help to connect the different technologies to the network in a flexible manner.
This set of equipment constitutes a configurable microgrid able to work islanded or connected to the main electrical distribution network. Three different set ups can be configured and tested at the same.

4.2 Certification of compliance with respect to the IEC 61000-3-11 and the IEC 61000-3-12

The Electromagnetic Compatibility (EMC) Part 3-11: "Limits Limitation of voltage changes, voltage fluctuations and flicker in public low voltage supply systems Equipment with rated current≤75 A and subject to conditional connection" (or the European version adopted by CENELEC EN 61000-3-11 (2000)) is the standard regarding flicker to be complied by generation sources (for example, photovoltaic panels and inverters) connected to the electrical distribution network.
The Electromagnetic Compatibility (EMC) Part 3-12: Limits Limits for harmonic currents produced by equipment connected to public low voltage systems with input current >16 A and ≤75 A per phase" (or the European version EN 61000-3-12 (2005) adopted by CENELEC) is the standard regarding harmonics and interharmonics to be complied by generation sources connected to the electrical distribution network.
Both standards demand a test set-up formed by an AC electrical grid to which the generation source will inject its output power and a DC bus to feed the DC side of the inverter.
The main AC requirements demanded by these standards to the measurement set up are among others:

- Combination of grid simulator for Low Voltage supply and loads or other type of electric source able to dissipate up to 50 kW of power.
- In the case of the IEC 61000-3-11, an adjustable and controllable output impedance of the electric source (in this case, grid simulator). This impedance is called Zref or

Ztest in the standard depending on the characteristics of the equipment under test and the clause to be complied with. It can equal the following values:

- R_A=0,24 Ω; X_A=0,15 Ω; R_N=0,16 Ω; X_N=0,10 Ω at 50 Hz;
- R_A=0,15 Ω; X_A=0,15 Ω; R_N=0,10 Ω; X_N=0,10 Ω at 50 Hz;
- R_A=0,25 Ω; X_A=0,25 Ω at 50 Hz.

- In the case of the IEC 61000-3-12, adjustable and controllable output impedance of the electric source (in this case grid simulator), in such a way that the short circuit ratio, defined as the short circuit apparent power of the electric source with respect to the apparent power of the equipment under test, equals different concrete values within the range going from 33 to 350.
- Power Quality measuring device compliant with[2]:
  - the EN 60868 flickermeter standard [11], and
  - the IEC 61000-4-7 standard [12].

In addition, the DC side must be able to feed a wide range of DC voltages and powers, depending on the specific inverters manufacturer design.

4.3 Automation of the compliance testing

It is evident that the different requirements imposed not only by the standards but also by the different characteristics of the equipments to be tested are valuable inputs for the specification, design, characterization, adaptation and new investments of the laboratory.
Concretely, for the testing according to the IEC 61000-3-11 and IEC 61000-3-12, the availability of an appropriate grid simulator with a configurable output impedance by hardware[3], the 50 kW absorption capability and the possibility to feed a wide range of DC voltages are essential. With the same purpose, the characterization of the cable impedances and short circuit power capability of the microgrid are also important.

4.4 Analysis of observed results

Distribution Network Operators impose to Distributed Generation sources to generate current:

- with an harmonic content below the values specified in the IEC 61000-3-12,
- and not influencing the voltage in the point of common coupling with fluctuations lower than the limits specified in IEC 61000-3-11.

These two standards are dedicated to generic electrical and electronic products with rated current between 16 A and 75 A per phase (single phase equipment also included). They are not specifically conceived for electric generation sources.

- Concerning the limits specified in the IEC 61000-3-12 standard, normally electric generation sources under test emit currents with a much lower harmonic content that the one specified in the standard. The source of harmonics is often the power electronics module (rectifiers and inverters in this case), and since the tested units are designed to inject currents in the electrical network at nominal frequency, adequate filters are included.

Other industrial loads including power electronics have much higher currents, thus, it seems that limits are specified for such chases.

- In the standard IEC 61000-3-11, it is not specified at what power the tests must be performed. It is supposed that the equipment under test must be tested at its nominal power. In the specific case of Distributed Generation sources testing, and more concretely inverters behaving as an interface between the photovoltaic panels and the electrical network, its output is dependent on climatic conditions (solar radiation). This output power variation, that can lead to voltage fluctuations, are not tested in principle.

4.5 Accreditation of the certification laboratories

In Spain, ENAC (Entidad Nacional de Acreditación) is the accreditation authorized organization. It periodically exams and audits the technical competence in terms of personnel qualification, equipment adequacy, calibration procedures of equipment, testing procedures, uncertainties calculation procedures and previous experiences of the laboratory or compliance evaluation body that wants to be accredited to perform tests against a certain standard.
Most of the standards give limits, detail test conditions and requirements of measurement equipment, but the exact testing procedure and/or uncertainties calculation are not completely specified. These aspects are then solved by the personnel of the entity who will perform the tests. As it has been said before, technical auditors periodically review the applied testing procedures.
Accreditation supposes an exigent technical and administrative process for the laboratory, but, even if it is not always mandatory, it is profitable because it means that a high quality service is being provided in the compliance certification activity of a certain standard test. Most of the times, end users of equipment demand to the manufacturers to test their equipment in accredited laboratories.
The scope of the accreditation does not only cover the standards being published by the International Standardization Bodies, but also standards published by end-users.

[2] Power Quality measurement equipment compliant with the accuracy limits given for Class A equipment respect to the IEC 61000-4-30 standard is also compliant with IEC 868 and IEC 61000-4-7.

[3] The output impedance of the voltage source must be the same in all the frequency spectrum considered in the harmonics measurement.

5. Conclusion

New standards either published by International Standardization Organizations, Regulatory Bodies, Governments or end-users are being published trying to give answers to technical needs related to the connection of Distributed Energy Resources to the electrical distribution network. The publication of these standards are the start of a race for manufacturers trying to be pioneers in the compliant product development and commercialization.
Meanwhile, certification laboratories should decide about the convenience of new measurement equipment acquisition, personnel training, testing procedures development and accreditation obtaining. During this period, fluent communication with customers and comprehension are important. Test procedures and their execution also improve once they are repeated.
The success of the certification laboratories is based on the information obtained in advance with the participation in the different technical discussion forums, strategic decisions adoption and the maintenance of the fundamentals of the certification laboratories: exactness, objectivity, confidentiality and marketing.

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