SMART GRID INTEROPERABILITY PANEL

Application Note on IEEE 1613-2009 and IEEE 1613.1-2013

A white paper developed by the Smart Grid Interoperability Panel – October 2015

Acknowledgements

The *SGIP-EM Interoperability Issues Working Group* (SGIP EMII WG) acknowledges the *IEEE Power and Energy Society*, *Substations Committee and Transmission and Distribution Committee* for producing IEEE Std. 1613.1™ – 2013. We also recognize the IEC Technical Committees TC 77 (*EMC*) and TC 57 (*Power Systems Management and associated Information Exchange*) for producing IEC 61000-6-5 and IEC 61850-3, respectively.

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About the Smart Grid Interoperability Panel

The Smart Grid Interoperability Panel (SGIP) is a consortium that securely accelerates and advances Grid Modernization through interoperability and the leadership talents of its members. SGIP is committed to improving individual quality of life by integrating energy resources securely, intelligently and efficiently. To learn more about SGIP, visit http://www.sgip.org/.

1. Executive Summary

This Application Note introduces the EMC test requirements in IEEE Std. 1613.1™-2013 and IEEE Std. 1613™-2009 together with its amendment IEEE Std. 1613a-2011 to the target audience comprised of manufacturers, EMC test laboratories, and electric utilities. These IEEE standards are now more closely aligned with International Electrotechnical Commission (IEC) test methods required in the European Union and most other parts of the global economy. The Application Note identifies specific benefits of this alignment to the individual stakeholders and provides recommendations on the application of these standards.

2. Introduction

IEEE Std. 1613.1™-2013 [1] is an extension of IEEE Std. 1613™-2009 [2] together with its amendment IEEE Std. 1613a-2011 [3]. This pair of IEEE standards set environmental and testing requirements for communications networking devices used in electric power transmission and distribution facilities, including substations. The environmental conditions addressed include electrical and electromagnetic (EM) disturbances that may exist in these facilities. Device type-testing and performance requirements are defined for communications networking devices using any media, including radio frequency (RF), carrier current communications, or broadband over power line (BPL) technologies.

IEEE Std. 1613™-2009 is often specified (primarily in North America) to qualify communications equipment to three significant EM disturbances; voltage transients (oscillatory and fast transient), radio frequency interference, and electrostatic discharge. After a thorough review of electromagnetic compatibility (EMC) standards applicable to Smart Grid, the *SGIP-EM Interoperability Issues Working Group* issued a white paper which suggested that five additional EM immunity tests be added to IEEE Std. 1613. The *IEEE Power and Energy Society, Substations Committee* agreed with that suggestion and, in cooperation with the *Transmission and Distribution Committee*, published IEEE Std. 1613.1™-2013. This extension to IEEE Std. 1613™-2009 includes the five immunity tests suggested on page 60 of the EMC and SG Interoperability Issues document [4] (surge, conducted RF, power-frequency magnetic field, damped oscillatory magnetic fields, and conducted common-mode disturbances). IEEE Std. 1613.1™-2013 also includes specific immunity levels required for Zone A and Zone B installations (inside the substation fence and outside the fence in distribution, respectively). The test conditions and acceptance criteria in Annex A require that transmit and receive functions of a communicating device be subjected to the interference stimulus (test level) at some point during the tests identified in Annex A, clauses 4 through 12.

This IEEE Std. 1613 pair (IEEE Std.1613™-2009 and IEEE Std.1613.1™-2013) are now similar to the IEC pair of standards (IEC-61850-3:2013 [5] and IEC 61000-6-5:2015 [6]) using the same or similar test methods and identical acceptance criteria. The acceptance criteria for determining successful completion of an immunity test were copied from the IEEE-1613-2009 document and adopted in total into IEC-61850-3(2013). (See Section 5 below)

This IEEE Std. 1613 pair is not to be used for the evaluation of other sources of EM noise, such as motors, contactors or switchgear that may produce EM emissions as a byproduct of their operation. While these EM noise emissions may cause interference, this equipment is not within the scope of the IEEE Std. 1613 pair. However, their controllers and related communications networks are required to be evaluated according to the IEEE Std. 1613 pair.

The SGIP also published Recommendations for C12.1 (2008) in 2012; a study suggesting specific corrections for the EMC immunity testing of revenue meters in ANSI C12.1-2008 [7]. EMC Immunity testing of revenue meters is covered in ANSI-C12.1, but the communications cards were not installed during the tests. As such, there were no established EMC immunity tests for communications cards installed within meters. This omission has been addressed in IEEE-1613.1™-2013 by requiring that the immunity of the communications modules installed in revenue meters pass the tests described in the IEEE Std. 1613 pair.

The following sections focus on the rationale for using and the possible benefits for utilities and manufacturers who adopt the IEEE pair, the benefits test laboratories could realize from creating a suitable test bed for the IEEE pair, and guidelines to educate manufacturers on the pair's testing process.

3. Benefits for Utilities

Power providers (i.e., utilities) generally rely on manufacturers to adopt and implement EMC immunity standards for the products they buy. The EMC and SG Interoperability Issues authors queried a sampling of power providers that confirmed this tendency. While it is in the best interest of the manufacturer to design, test, and market robust products that perform well, a lack of consistent directives on EMC immunity can result in products that are untested and potentially vulnerable. This model is not the best way to assure that products are consistently designed and manufactured with adequate EM immunity.

A better model can be seen with telephone companies that required their vendors to meet EMC testing standards that are defined by the companies themselves in the document identified as Bellcore (Telcordia) GR-1089 [8]. In exchange, however, the telephone companies are required to contribute yearly dues for the generation and maintenance of these standards. In this case, the IEEE Std. 1613 pair can be used by utilities to guide their acquisitions without the need to form and fund a utility industry standards-generating consortium since these standards are available now and ready for use.

In addition to the cost savings mentioned above, electric power utilities can simplify their acquisitions by specifying compliance with IEEE Std.1613.1™-2013 to define the EMC immunity requirements for communications devices used in substations as well as within the power distribution network. Using this standard eliminates the need to use a collection of various standards proposed by their vendors that may or may not meet their expectations of performance or reliability, which is what EMC immunity testing is meant to address.

The expanded list of immunity tests contained in this IEEE Std. 1613 pair mean that more robust communications products can be offered for utility equipment needs. A product with more testing and better immunity to external sources of interference is, by design, more reliable for use in the field. It is also expected that competition will increase as more vendors from more countries will be offering products tested to nearly identical requirements. This competition could potentially bring about lower prices and introduce greater quality/reliability designed into the utility communications networking equipment used in substation and distribution operations.

4. Benefits for Manufacturers

Manufacturers of communications networking devices can use the IEEE Std. 1613 pair for testing the immunity capabilities of communications devices they sell into transmission and distribution applications. The requirements in the IEEE Std. 1613 pair are very similar to IEC 61850-3:2013 [5] and IEC 61000-6-5:2015 [6], with identical or nearly identical test methods.

While most test levels are identical there are some variations. For example, the IEEE Std. 1613 pair specifies test levels for electrostatic discharge (ESD) to 15 kV to account for very low relative humidity in parts of North America (vs. 8 kV for the IEC standard) and radiated radio frequency immunity to 20 V/m (vs. 10 V/m) with select frequency ranges to 6 GHz. However, the test methods, facilities, and most equipment requirements for these tests are identical to the IEC specifications. Testing labs can perform testing to both the IEEE and IEC standards with the noted variations, allowing manufacturers to access both IEEE and IEC markets more easily. A summary of the specified tests is given in Table 1.

A second benefit that may be realized by adopting the IEEE Std. 1613 pair is the increased reliability associated with designing and testing for immunity to these EM disturbances. Many within the utility community will agree that reliability is the ultimate indicator of quality, and is expected by utility customers regardless of the situation. Since many manufacturers are already advertising their compliance with the IEEE Std. 1613 pair, it makes strategic sense for utility equipment manufacturers to remain competitive by following suit. Their world-class products can then be sold almost anywhere, with nearly uniform immunity testing requirements. If the product is more immune to external sources of interference it is more reliable.

Table 1. Basic EMC test standards specified in IEC 61850-3 and IEEE 1613, 1613.1 standards

Test	**IEC 61850-3:2013** *Differentiated by port and location, as in IEC 61000-6-5*	**IEEE Std. 1613 pair** *Differentiated by location*
ESD	IEC 61000-4-2	C37.90.3
Radiated RF	IEC 61000-4-3	C37.90.2 (IEC 61000-4-3)
Power Freq. Magnetic Field	IEC 61000-4-8	IEC 61000-4-8
Oscillatory surge withstand	IEC 61000-4-18	C37.90.1
Fast Transient burst	IEC 61000-4-4	C37.90.1
Surge	IEC 61000-4-5	IEC 61000-4-5
Conducted induced by RF	IEC 61000-4-6	IEC 61000-4-6
Damped Oscillatory Magnetic Field		IEC 61000-4-10
Voltage Dips/Interruptions	IEC 61000-4-11 IEC 61000-4-29	
Ripple on DC supplies	IEC 61000-4-17	
Mains Frequency voltage Common Mode	IEC 61000-4-16	IEC 61000-4-16
Emissions and other immunity requirements	CISPR 22	

5. Benefits for Laboratories

If a manufacturer does not have in-house capability, external third party test laboratories may be used to determine the immunity of communications networking devices to be installed in substations or used in distribution. Conveniently, the type tests specified to be performed in the IEEE 1613.1 pair are basic EMC tests. These test procedures, referenced in many different product standards, are routinely performed by most EMC test labs to determine the immunity of a wide variety of products that are not necessarily associated with power systems. The labs have test engineers that are already skilled in performing these basic tests and have the test facilities and instrumentation needed to determine the level of product immunity. As we describe in the next section, tests are performed for each of the standards noted in IEEE Std. 1613.1™-2013 and the results of the tests are then documented in test reports.

6. Testing for Immunity

This section provides information to help manufacturers test their products using an accredited testing laboratory. The approach here is to indicate the usual steps in planning the tests, setting up the tests, performing and witnessing the tests, and documenting the test results.

If the communications device meets the acceptance criteria in the IEEE Std. 1613 pair, immunity is demonstrated to the specified disturbance level. If the performance is degraded below the required acceptance criteria, immunity is not achieved and some method of mitigation must be considered and implemented. This can range from a simple mitigation (shield, filter, etc.) to a more complex re-design of the device.

Two tests (or testing at specific levels called out in each pair of standards) may be required to meet both the IEEE and IEC standards. However, there was a concerted effort to “harmonize” applicable test standards between the IEC and IEEE standard pairs to reach the goal of one test with perhaps different applied levels of interference stimulus. A single test setup can be accommodated provided the test configurations are the same leaving only the specified immunity test level to be adjusted according to the standard invoked.

The nearly universal recognized standard for assessing the technical competence and quality control processes for test and calibration laboratories is ISO//IEC 17025:2005 [9]. This standard, along with specific test standards, is used by most laboratory accreditation bodies (A2LA [10], NAVLAP [11], etc.) as part of their laboratory evaluation and accreditation process. The accreditation provides what is considered the best process to provide assurance that the laboratory is competent to perform specific tests within a specific uncertainty. This “third-party” assessment is a vital component to demonstrate an effective quality control process and all stakeholders (manufacturers, vendors, and customers) should insist the laboratory and the testing performed meet this minimum standard. Part of that accreditation process is to identify the specific tests that are within the capabilities of the laboratory, referred to as the scope of accreditation. Clearly, to do the tests shown in the IEEE Std. 1613 pair or the IEC standards the tests must be identified in the scope of the accredited lab. If not, the lab has to add to its scope the missing test(s). Depending on the test, if there is a comparable test in the lab’s present scope, it is usually much easier to have the new test added. But that process is defined by the laboratory’s accrediting body.

Assuming that the tests called out in IEEE 1613-2009 and 1613.1-2013 are within the scope of accreditation, the start of the process is to document a test plan for each test to be performed. This is a formal process where the test lab and the customer requesting testing agree on what is to be tested, which test is performed, which standard is used and the critical acceptance criteria (when the test results are considered a “pass”). The test lab must prepare a test plan in consultation with its customers. The plan serves as a “contract” for services performed and is the guiding document for all tests performed by the accredited lab.

A device must be selected for testing. Since IEEE Std.1613.1™-2013 applies to communications networking devices installed in substations or in the distribution network, the device may consist of a series of interconnected equipment(s) to be tested as a unit. However, in general, each device must be tested separately unless the designs are clearly similar from an EMC perspective as judged by the test laboratory in consultation with the customer. This decision can be made when the test engineer reviews the design and any associated equipment that will have to interact with the device. In any case, all components that the Equipment under Test (EUT) normally communicates with or attaches to must be present, or effectively simulated, to do the testing.

The test engineers who perform the tests identified in Table 1 will set up the EUT following the manufacturer’s instructions and the standards that cover the specific immunity phenomena. They will also attach instrumentation to the EUT to monitor its performance during and after the tests for judging the EUT’s response to the test signal. The “customer” (i.e., the product manufacturer or designee) is invited to witness the test and be ready to answer questions if there are EUT responses that need further clarification.

As noted above a critical part of the test plan is to identify the acceptance criteria used to evaluate the performance of the device during and after immunity testing. The goal is for the EUT to survive in the intended environment and remain interoperable with other parts of the system where it is to be installed. The results of this judgment are recorded in the test report.

The specific acceptance criteria in performing tests to IEEE Std.1613.1™-2013 are found in Annex A., clause A.4 and are repeated below. The test engineer will monitor these criteria for the critical functions identified by the customer or manufacturer and document in the test report:

a) No hardware damage.

b) No loss or corruption of stored memory or data, including active or stored settings.

c) Device reset does not occur, and manual resetting is not required.

d) No changes in the states of the electrical, mechanical, or communication status outputs. This includes alarms, status outputs, or targets.

e) No erroneous, permanent change of state of the visual, audio, or message outputs results. Momentary changes of these outputs during the tests are permitted.

f) During the tests, SCADA[1] analog values shall not change by more than 2% of full-scale values. After the test, accuracy must revert to the manufacturer-claimed accuracy.

The testing laboratory will document the results of all the tests performed. In general, for every test standard used, a report on the EUT's performance during the test will issued. The results apply only to the sample EUT and not necessarily to the production models due to the potential of subsequent changes or variability in manufacturing that might impact the immunity of the product. Generally, on-going immunity checks are performed periodically by taking a sample of current products from the production line to determine continued immunity as exemplified in the original tests***. Note that any prototype or production device subjected to any one of the many EMC type tests in IEEE Std. 1613.1 is no longer suitable for installation, and is in need of repair, refurbishment, or disposal.***

If there was a need to modify or apply mitigation to the product when the test showed that the EUT did not meet the acceptance criteria at the applied immunity test level, the manufacturer is consulted. At that point, the test lab engineer may suggest techniques to improve the immunity of the product. The customer must review the mitigations suggested to determine if:

1) they will not adversely affect product operation;

2) are cost effective; and

3) can, in fact, can be implemented in the manufacturing process.

To verify the effectiveness of the mitigations, testing is performed on the re-designed EUT. If the product passes the re-test, the mitigation is fully described in the test report. The manufacturer is then asked to attest that the mitigation will be fully implemented on each product produced as the test results only apply to the specific EUT tested.

[1] SCADA, *Supervisory Control and Data Acquisition*. An industrial system designed to control and pass data to and from remote equipment.

7. Summary

Smart Grid device interoperability, reliability, and survivability are enhanced when utility communications devices meet EMC requirements as indicated in this document. In addition, acquisition and life cycle costs are likely to be lowered by enabling a larger selection of immune communications devices. Hence devices passing EMC tests at levels replicating the EM environment and phenomena where the devices will be installed should be an integral requirement for Smart Grid.

8. Document References

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[2] IEEE Std. 1613™-2009, *IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations*. Institute of Electrical and Electronic Engineers, New York, NY.

[3] IEEE Std. 1613a™-2011, IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations – Amendment 1: Adding of one Definition, dc power supply requirements (5.1), and Annex E - History. Institute of Electrical and Electronic Engineers, New York, NY.

[4] "Electromagnetic Compatibility and Smart Grid Interoperability Issues," SGIP Document Number 2012-005, Version 1.0. http://members.sgip.org/apps/group_public/download.php/1732/EMII_WG_EMC_White_Paper_SGIP_2012_005.pdf

[5] IEC 61850-2:2013, *Communications networks and systems in substations – Part 3: General requirements.* International Electrotechnical Commission, Geneva, Switzerland.

[6] IEC 61000-6-5:2015, Electromagnetic Compatibility (EMC)-Part 6-5: Generic standards – Immunity for equipment used in power station and substation environments. International Electrotechnical Commission, Geneva, Switzerland.

[7] ANSI C12.1-2008, American National Standard for Electric Meters – Code for Electricity Metering.

[8] Telcordia GR-1089, Electromagnetic Compatibility and Electrical Safety – Generic Criteria for Network Telecommunications Equipment. Telecordia®, Piscataway, NJ. http://telecom-info.telcordia.com/site-cgi/ido/docs.cgi?ID=SEARCH&DOCUMENT=GR-1089#ORD

[9] ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories.

[10] https://www.a2la.org/ , Website accessed 22 June 2015.

[11] http://www.nist.gov/nvlap/ , Website accessed 22 June 2015.

