Putting Smart Grid Systems to the Test

Executive Summary

Interoperability of Smart Grid systems and devices is a high priority goal cited across many organizations, driving the efforts to enhance our energy infrastructure. System and device testing is a critical foundational issue for Smart Grid deployment. Vast amounts of capital expenditures are underway and the old adage of "measure twice, cut once" has never been so important. The stakes are high to assure that deployed technology has been rigorously tested to assure that requirements are met and systems interoperate as advertised.

This white paper is aimed at helping Smart Grid stakeholders in:

- Understanding the critical role of testing in the decision making process for new technologies and services
- Understanding the cost and time saving benefits of testing, and more importantly, the role of testing in helping to assure consumer expectations are satisfied
- Understanding the different types of test programs used in industry, with the pros and cons of each program type relative to product selection
- Establishing practices for product selection that enhance the technical information available for decision making and raise the bar to provide demonstrated conformance to standards and interoperability BEFORE purchase and deployment
- Providing guidance on testing and certification related questions that stakeholders should consider in verifying that thorough testing has been done

FINAL DRAFT

The Critical Role of Testing

A primary goal for utilities is to make well informed technology selections, while carefully controlling the costs and risks associated with new technology introduction and integration. A reduction in utility internal customized testing and its associated costs can be achieved by advocating the expanded use of industry testing activities that address key conformance and interoperability issues using broadly agreed upon test cases. Well designed and managed industry test programs help to identify potential problems and concerns so that they may be corrected well in advance of integration testing. Robust programs providing this early issue identification can provide a significant benefit in mitigation against the severe cost and schedule impacts caused by insufficiently tested systems and devices.

Market analyst reports on Smart Grid deployment estimate that capital spending for new technologies will annually reach into the tens of billions of dollars within the next few years. The increasing

complexity and speed of new deployments are also driving a shift from single vendor, proprietary systems to products based on open standards that can be supplied by multiple, competing vendors. The risks and benefits associated with this level of spending will require increased scrutiny of technology options and the proven performance of these technologies to meet end user expectations. In some cases, competing technologies will need to be evaluated and decisions made. Within those chosen technology options there will be multiple competing vendors vying to win big with their product offerings. Technology selection decisions will also be heavily influenced by financial aspects such as regulator and consumer expectations for cost effectiveness, along with the expectations that this new and improved grid, with all its new features will operate as advertised.

"Tested Once…..Accepted Everywhere" -- It's a short phrase used with some minor variants by international testing and certification organizations. Simply put, a product vendor should be able to test a product and demonstrate that it meets expectations using one set of methods and metrics that has broad consensus across stakeholders.

The reasons are simple – greatly reduced costs for the purchasers and the vendors, vastly accelerated availability of new technologies, and significantly lowered barriers to global collaboration and trade. The costs to the end customer can be reduced as a result. It's a goal that is not easy to argue against and an approach that is widely used in many global industries.

There is a significant opportunity for Smart Grid stakeholders to actively pursue implementation of these broadly accepted practices to achieve efficiencies in cost and technology acceptance. Detailed requirements, test methods and metrics, as well as widespread adoption of effective industry test programs will provide the basis for enhanced effectiveness in the technology evaluation and selection process. Smart Grid deployment projects provide a green field opportunity to put these practices in place that can eventually be migrated across other technology selection and deployment initiatives as well.

The Costs of Testing – Pay Me Now or Pay Me Later

Thorough upfront testing, well in advance of purchasing decisions and deployment, can save significant money and time. Some will say, and rightly so, that testing already occurs and things work fine. But is it enough? Is the current level of testing sufficiently rigorous across all technology areas, particularly new technologies? Should we be satisfied with products that meet ***most or some*** expectations and accept that some customization and rework will need to be done at deployment?

Major telecommunications companies recognized the value of extensive upfront testing in their network transformations of the last decade – the functional migration to IP based communications protocols and the physical migration to high speed fiber optic infrastructure. The massive investment in achieving that transformation was carefully managed through detailed requirements documentation and performance metrics applied for nearly every conceivable system and device considered for deployment. Rigorous laboratory and test management also was a major part of the process to assure high quality data and

FINAL DRAFT

analysis to support decision making, along with aggressive vendor management to assure performance and cost expectations were being achieved.

When spending tens of millions of dollars, shouldn't it be expected that the product delivered does exactly what's needed and the benefits the customer will receive are what was promised? There is little excuse to allow any shortcuts in doing the homework in product evaluation when dealing with a transformation of the magnitude posed by Smart Grid technologies.

Opposition Views – Some Truth, But Shortsighted

The first argument that naysayers will give on rigorous pre-deployment verification testing is that it will add time and cost to product development. That's typically a true statement, but ignores the long term consequences and total cost of ownership over time. The cost of field customization, rework and repairs may be far more costly than that incurred by being thorough up front. Even worse is the prospect that the product does not perform or last as projected leading to massive costs of replacement.

A product vendor (or even a utility) may argue that all the upfront testing that's being asked for is going to increase the price of the products. There may be some truth to that statement as well, but of course you will be purchasing a more thoroughly analyzed product that has been validated as doing what it is needed to do. There's also the competitive aspect between vendors to consider – an aggressive and efficient vendor, particularly those without the benefit of incumbent status may win the business by doing their upfront validation while controlling price points to beat their competition. A focused pursuit of comprehensively tested products and **demonstrated** interoperability will generate the market forces necessary to get high quality products to market and place stronger cost competitive pressures on incumbents. The scale of the sales opportunity should drive any vendor to meet utility expectations.

Another important consideration in cost effective testing programs is to enable a "tested once, accepted everywhere" approach. Every utility should not need to test every product independently for conformance to a standard or interoperability with other conforming products. For every technology area, a baseline set of requirements, metrics and test processes should be in place to determine if a product conforms to basic expectations. Certainly there will always be organization or business specific needs and applications that require additional customized testing in-house. There is tremendous opportunity for benefit in segmenting the testing and product evaluation process to minimize custom testing wherever possible. Testing for the common expectations of conformance to standards and interoperability can be done via third party programs that are widely accepted with results available to all interested customers. Alternatively, utilities can collaborate to develop an equitable information sharing approach leveraging in-house test results and minimizing duplication of efforts

Third party test programs and/or information sharing creates additional cost savings opportunities. For vendors, cost and time can be reduced by minimizing the need to support numerous testing/trialing activities across multiple potential customers. When done once and accepted everywhere, one program can be sufficient to meet some of the common interoperability expectations across many customers.

FINAL DRAFT

Another advantage is the opportunity to enhance the cost efficiency of investment in laboratory infrastructure – test equipment can be expensive and maintaining staff with latest skills and assuring that equipment is up to date can be a significant undertaking. Shared test infrastructure across utilities, and more importantly close cooperation with third party laboratories will result in a highly efficient testing ecosystem providing broader coverage of testing needs while avoiding the high cost of constructing and maintaining multiple facilities all of which do the same thing.

As stated previously, this vision of a robust testing ecosystem will not eliminate the need for some degree of customized product performance testing and integration/interoperability testing within specific systems. However there is the opportunity to drive down the time and cost of integration/interoperability testing over time as increased numbers of products are "pre-tested" prior to deployment, along with reduction in costly field troubleshooting and mitigation.

Many Types of Test Industry Programs – What Do They Mean?

Utility product selection managers will typically be assured by potential vendors that their products have been thoroughly tested and "meet" certain standards and specifications. While most vendors are diligent about development testing and testing their products within selected industry test programs before release, exactly what they've tested and what their products "meet" often requires a more in depth understanding of the types of test programs that have been used. Additionally, the technical sufficiency of the testing program, specifics on test configuration, and detailed documentation of the results need careful study to validate that the product is truly meeting the needs of the utility.

Discussed below is an introduction to different types of test programs and some of the terminology that is often loosely used in asserting that products "meet" standards. How well the standard is written, test methods defined, and pass/fail metrics specified are additional critical factors requiring consideration. It should also be noted that the term product in this context may be either a hardware or software product.

General categories of industry test programs include:

- Conformance Testing
- Interoperability Testing
- End to End Testing
- "PlugFests" or "Test Events"
- Certification
- Integration Testing

FINAL DRAFT

Conformance testing programs are typically tests of an individual product against an individual standard. Basically an assessment of whether a product conforms to specifically identified requirements within a standard or specification. The basis of the test program may be included in a standard (not typical as standards infrequently specify this level of detail) or a specification managed by an individual organization or industry group (e.g. consortia, alliances etc).

Interoperability testing programs are typically multi-product tests using one or more standards to assess the ability of the products under test to communicate and work together. Products that have been successfully tested for conformance to a standard provide a good baseline going into interoperability testing – *but conforming products may still have issues interoperating with other products*. Reasons for this may include product behavior not specified in a standard or differing interpretation of a standard. This drives the need to move to this next level of performance testing. Such programs are common where industry organizations have formed to test and certify products.

End to end testing is a broader version of interoperability testing, usually looking at specific business functions, use cases and the chain of devices and communications exchanges that must interoperate to enable those functions. End-to-end testing may mean testing of inter-standard communication which individual certifications may not cover. As before, prior success in conformance and interoperability testing provides a baseline, however end to end testing analyzes whether the products can successfully support specific business applications when integrated. This is an area of Smart Grid interoperability that is nascent. Those interested in improving overall Smart Grid industry efficiency, quality and cost reduction should advocate for and support efforts to develop standardized end-end test programs.

Plugfests (sometimes also referred to as test events, plugtests and other names) are usually vendor driven activities where multiple vendors come together to demonstrate specific interoperability functions. These events are highly useful in product development and new standards implementation, but are often limited in their value as a definitive demonstration of product readiness for deployment. Plugfests can be thought of as early interoperability testing programs and may also play an important role in the development of formalized industry test programs.

Integration testing is typically performed during deployment, or in a lab in preparation for a specific deployment scenario on behalf of a specific client. This testing is essential and some level of integration testing will always be necessary. However, significant integration cost and time savings can be achieved when there is a robust set of industry conformance, interoperability and end to end test programs available to provide much of the advanced work that helps identify potential integration issues before reaching this stage. Lack of advance issue identification can lead to substantial cost increases, surprises and delays in service roll out.

Certification testing is a variant of conformance, interoperability and end to end testing. Although sometimes used as more of a marketing or customer assurance vehicle by some organizations, a well-designed certification program can provide added value above and beyond a successful test result. Best of breed certification programs add an element of ongoing conformance via periodic review and surveillance activities that monitor the effects of product model changes and user experience as a

FINAL DRAFT

condition of a product continuing to carry the "certified" moniker over time. Utility product selection personnel need to be cognizant of the meaning of a "certified product" relative to individual programs. Some programs loosely used the term to "certify" that they have tested the product and found it to pass their criteria (and go no further in their relationship with the product/vendor).

The terms conformance testing and compliance testing are loosely used across industry generally with the same intent and meaning. In both cases, the terms refer to testing a system or device against a defined set of criteria, and evaluating the test results against the metrics defined within the criteria. Conformance or compliance to the criteria implies a passing or successful result. The term conformance is more widely used and generally associated with testing programs that are of a voluntary or market driven nature. The term compliance is more closely associated with mandatory or regulatory oriented programs. It should be noted that these generalizations are not absolute, but a trend, and in most cases the terms are used interchangeably.

Key Elements

An additional dimension for each type of testing is the approach in which testing takes place. There are three primary approaches: 1) self-testing by the vendor, 2) end user testing, and 3) independent 3rd party testing (including 3rd party validation of vendor self-testing).

While each approach has its benefits and drawbacks, decision making by product selection staff essentially comes down to three basic alternatives:

- Take the word of the technology provider that its good
- Test or verify it yourself
- Require 3rd party verification of compliance

Accepting the word of the technology provider is sometimes called a "vendor declaration of compliance". Basically it's the honor system. There are many situations where this approach is perfectly acceptable and the most cost effective approach. Products and applications that are relatively mature or low risk, presenting minimal consequences of non-conformance, are reasonable candidates for this approach. When this route is taken, the vendor may take on the responsibility for replacements or repairs as applicable, with large end users often contractually mandating that responsibility along with the associated costs. This approach becomes a very high risk proposition when considering mission critical or widely deployed systems and devices.

Testing or verification performed directly by the end user is not uncommon, and many large companies have established laboratories and test beds to perform their own assessments of selected technologies and product types. There are strong advantages to this approach with the direct control it provides in the testing and the ability to customize evaluations. Significant disadvantages however include potentially high costs of maintaining dedicated test facilities and equipment (and keeping them up to

FINAL DRAFT

date as technology evolves), as well as the difficulty in maintaining staff expertise that can cover the wide breadth of potential technologies requiring evaluation. Some large end users have also had occasion to express concerns that offering this approach allows technology vendors to submit unready products and benefit from the end user bearing the costs of troubleshooting the products. (Some industries performing in-house testing have shifted approach to pass some testing costs back to the technology provider under certain circumstances). Of course technology providers also have some risk exposure by submitting unready product for test, as it can create a negative perception of that provider and the product to the client they are trying to win over – so more often the vendor will have extensively performed their own evaluations in advance of submitting for end user evaluation. A further downside to end-customer test programs, especially for conformance to a standard and interoperability, is that the industry may end up with multiple versions of the technology "standard" and vendors must conform to multiple versions of the same standard, dependent on the varying interpretations of different end-customers.

Third party testing often referred to as independent testing has been in practice for many years, but has become increasingly prevalent across many industries. It has become the preferred approach for high risk systems and devices, whether mandated by regulatory authorities or market practices. This approach can be beneficial where potential customer service impact due to non-conformance is an issue. The potential for high costs of rework and repair also present an opportunity to leverage the use of third party testing. One of the most common applications of this test approach is to address issues that may present potential hazards such as safety. These cases are often mandated by regulatory authorities to be independently tested. The use of third-party testing and certification for functional performance assessments has grown as a means for organizations to manage their technical as well as financial risks associated with new technology deployments.

There is some degree of integration testing that will always be needed by end users to achieve final validation that newly deployed systems and devices will work as expected. Business specific requirements, custom deployment scenarios and other factors will necessitate supplemental evaluations.

FINAL DRAFT

Technology Selection Essentials

The Smart Grid encompasses so many different product types, and with the variety of testing approaches discussed above, it is reasonable to ask: how can utilities incorporate test result expectations with a consistent and thorough approach? Two essential elements are:

- Well defined RFPs, and
- Detailed RFP response requirements

Decision makers on new technologies need to begin with clear and measurable requirements as a part of their request for proposal (RFP) processes. These well-defined criteria need to first consider

expectations for the features, functions and performance of systems and devices. Clearly, whether a product has the capability to provide the intended services and its functionality aligns with the expectations of the purchaser is a first gating factor for selection.

Commercial end user Requests for Proposal (RFPs) should include selected certifications and/or proof of standards conformance as a standard business practice, particularly as those programs become more widely available. Where certification is not yet offered, commercial end users can require test reports and other documentation to verify that standards conformance has been achieved, rather than relying on simple declarations made by the vendors. Such reports, upon review, can highlight the thoroughness and consistency of approach of the technical analyses behind conformance statements (or lack thereof) and help assure competitive vendor claims are comparable. This approach is commonly used in the telecommunications industry and has helped pave the way for rigorous and well-documented test programs that support systems interoperability.

Beyond the assessment of expected functionality however, the selection process needs to dig deeper to consider critical issues such as quality and reliability. Whether purchasing tens or thousands of a particular device, will they all perform consistently? While manufacturing quality processes are an essential step towards achieving consistency, reliability must also be considered. A product manufactured with excellent quality processes might consistently yield products that all have the same defect or failure mechanism. Reliability criteria can help in assuring consistency and correctness.

Longer term assessment of what to expect post-deployment must also be considered in evaluating the true cost of ownership. Ongoing maintenance considerations and serviceability requirements are important. Comparable systems and devices from a functionality viewpoint with similar upfront cost, may have widely different lifecycle costs when considering ongoing operational needs. Robustness of systems and devices is also essential to minimize in the field disruptions that may lead to repair or replacement issues that also drive up long term operating costs.

Detailed RFPs with well-constructed criteria are a key first step. How to assess responses to those RFPs is the next critical function. Where detailed expectations are provided on how the responder should be replying, including expectations on specific supporting information, the better the odds of doing an effective comparative analysis. This is of course compounded by the likelihood that there are so many technical issues and answers to address, that it will typically take a team of reviewers to span the areas of expertise necessary in doing an assessment.

Within the detailed response expectations, it needs to be clearly determined and communicated by the decision makers on those areas requiring independent verification versus a direct declaration of conformance to the criteria. That is -- when is the technology provider's word that it meets the criteria good enough and when is independently validated or tested information required supporting those claims.

Some high level questions and considerations for product selection are provided below. For additional reading on technology selection, the GridWise Architecture Council (GWAC) has published a white paper, "Introduction to Interoperability and Decision-Maker's Interoperability Checklist" released in

FINAL DRAFT

August 2010. It provides a very detailed list of suggested question to be posed in the technology evaluation and selection process.

Questions to Consider

- Has the system/device been tested? If No – Why Not?; If Yes:
    - Was it tested using a documented test plan?
        - Is this an industry accepted test plan (or an internal, custom test plan)?
    - Has a detailed test report been written documenting the results?
        - Are the test methods described in the test report?
        - Are the pass/fail metrics specified in the test report?
        - Are results provided relative to each test requirement?
        - ***It is recommended that the test report be included as backing documentation as part of the decision making process***
    - Was it tested in/by an ISO 17025 accredited laboratory organization?
        - Is the testing organization a 3rd party independent test lab?
        - Was the testing done by internal facilities?
            - What are the internal organization qualifications?
    - Is the product "certified" by an industry organization?
        - Is the certifier an ISO 65 accredited organization?

SGIP and 3rd Party Certification

The Smart Grid Interoperability Panel (SGIP) has been focusing on standards for the Smart Grid and additionally, has placed an emphasis on testing and certification programs supporting conformance and interoperability testing associated with those standards. An SGIP committee of testing experts has been developing recommended practices and processes needed to help enable interoperability, and to provide end user confidence that systems and devices will integrate and operate as advertised.

This committee has released a framework document referred to as the Interoperability Process Reference Manual (IPRM)[1]. The IPRM addresses key elements of industry programs that, when implemented, have helped accelerate technology adoption and provided a high benchmark for the quality and consistency of testing services and their results.

The testing and certification framework focused on the use of 3rd party certification programs that may involve 1st or 3rd party testing, with a strong focus on test construction details, as well as process excellence and quality practices recommended for testing and certification authorities. Test construction best practices were largely developed based on industry analysis and the testing experiences of committee experts, as well as through discussion with other industry stakeholders. Practices for testing and certification authorities were reviewed with a consensus reached to advocate the use of internationally recognized standards for these issues. Specifically, the framework cites ISO Guide 65, *General Requirements for Bodies Operating Product Certification Systems* and ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*.

The SGIP has recommended that certification bodies and test labs work to adopt the applicable criteria specified in those ISO document, and progress towards attaining independent and professional third party accreditation to these standards.

FINAL DRAFT

Conclusions

High stakes purchasing and deployment decisions require thorough technology evaluation. Testing is a critical element in technology evaluation. The wide array of testing approaches and industry programs requires thoughtful consideration as to the necessary depth and objectivity required to provide the desired level of assurance in product performance. Industry programs that can support early indication of performance expectations, and more importantly problem identification, may significantly benefit customer satisfaction with the benefits of the Smart Grid, and help provide energy service providers with confidence in the performance and cost effectiveness of their technology selections.

[1] https://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/SmartGridTestingAndCertificationCommittee/IPRM_final_-_011612.pdf

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FINAL DRAFT