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WHITE PAPER

DER End-End Assurance: California's Rule 21 Conundrum

In this paper we look at the current plans for developing a standardized method to communicate with and manage the growing penetration of DER assets at the distribution level and how well they will ensure the desired performance of smart inverters under the direction of a utility DER management system. This paper reflects the opinions of QualityLogic on the conundrum created by the specific decisions in CA Rule as of January 2020.

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Overview

Led by California and the IEEE 1547 Work Group, the electric utility industry is rapidly developing a standardized method to communicate with and manage the growing penetration of DER assets at the distribution level. The California PUC, in conjunction with the IOUs and vendor community, has established a set of procedures for ensuring that the smart inverters meet both performance and communications requirements that the IOUs in California require of the rapidly growing fleet of smart inverters.

This article looks at the current plans and how well they will ensure the desired performance of smart inverters under the direction of a utility DER management system.

While the test and certification procedures being put in place will make a huge difference in how well systems will interoperate and meet performance requirements, a major gap remains unaddressed and additional testing will be required to ensure end-end interoperability and performance.

The CA Rule 21 Test and Certification Plan

CA Rule 21 specifies how distributed energy resources (DERs) such as Solar PV and battery storage interconnect to the grid. To address smart inverters, the updated Rule is organized into three implementation phases that correlate to three distinct parts of the testing and certification of the inverters and communications systems for California.

Two certification phases are currently available and mandated and the 3rd is coming in 2020.

Phase One:

- Phase 1 is already in place and specifies a set of "autonomous" inverter functions that are tested and certified according to the UL 1741SA procedures.

Phase Two:

- The second phase is the communications requirement and any system that will be communicating directly with the utility DERMS[1] must be tested and certified according to the SunSpec CSIP Test Procedures and Program. The CPUC recently extended the deadline for certification to June 22, 2020.[2]

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[1] *This is an acronym for "DER Management System", a rather loose term to describe a system which is intended to understand the state, capabilities and local grid conditions in order to "manage" the behavior of DER assets via communication of specific commands. The industry is still evolving the definition of what a "DERMS" is.*

[2] *We believe this will be the last extension and was allowed only to give some additional time to vendors in the process of certifying their products. That process is in full swing, so additional delays are unlikely.*

QualityLogic was and continues to be a major contributor to the SunSpec CSIP IEEE 2030.5 Test Specification.

Phase Three:

- The 3rd phase includes additional smart inverter functions requiring more intense communications and these will be tested and certified based a combination of the current UL 1741SA and appendices[3], pending IEEE 1547.1-2020 test procedures for both the functions and the communications about these functions, and attestations of vendors until such time as nationally recognized tests are available[4].

The overriding goal of these programs is to reduce the costs and time associated with adding and managing DERs for the benefit of the distribution system and its customers. Key to accomplishing this is the standardization of the functionality of smart inverters and the communications used to manage the DER assets. The goal of the testing and certification process is to ensure the intent of the utility is communicated to and performed correctly by the smart inverters.

Let's dig a bit deeper into the current process to understand the likelihood of achieving these goals.

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[3] *Testing of Phase 3, Functions 2 and 3 were recently specified by a September 2019, Underwriters Labs Certification Requirement Decision (CRD) that added SA17 and SA18 to the UL 1741 (Supplement A) Test Specification.*

[4] *See CPUC Resolution E-5000, July 11, 2019, Appendix D for a summary of certification requirements of all of the Phase 3 functions.*

Tackling the End-End Problem One Step at a Time

While the goal is assurance that the smart inverters will behave as instructed by the IOUs, the goal of end-end testing is the validation of the that behavioral intent, thus reducing the likelihood of issues in the system. Because of the system complexity, CA Rule 21 testing takes a building block approach. This makes sense in that there are so many potential use case scenarios and combinations of equipment, systems, aggregators, etc., that validating even a fraction of actual end-end possible implementation scenarios is an unmanageable task.

The building block approach is the way we test most complex systems today. For instance, we test printers so they can communicate over Wi-Fi and wired networks, but we separately test that computer systems can also communicate using Wi-Fi. And we separately test that the actual printing instructions result in the desired output. The industry has refined the tools, testing and certification so that you can take any Wi-Fi certified printer and it will almost surely "plug and play" with any other Wi-Fi certified PC even if the two have not been tested and certified together.

The Building Blocks to End-End Interoperability and Performance

The CA Rule 21 approach is to test the inverter functionality separate from the communications protocol. Inverter functionality is tested and certified

by Nationally Recognized Test Labs (NRTL) accredited for certifying inverters to the UL 1741SA test specification. This covers the CA Rule 21 Phase 1 functions but only 4 of the 8 Phase 3 smart inverter functions[5]. UL 1741SA does not address any of the required CA Rule 21 communications capabilities. Its purpose is to validate that the tested inverter functions do indeed operate as intended.

Once the updated IEEE 1547.1 test standard for smart inverter functions is approved, smart inverters will be tested by the NRTLs using that test specification . IEEE 1547.1 will be more comprehensive and test additional Phase 3 functions (though not all).

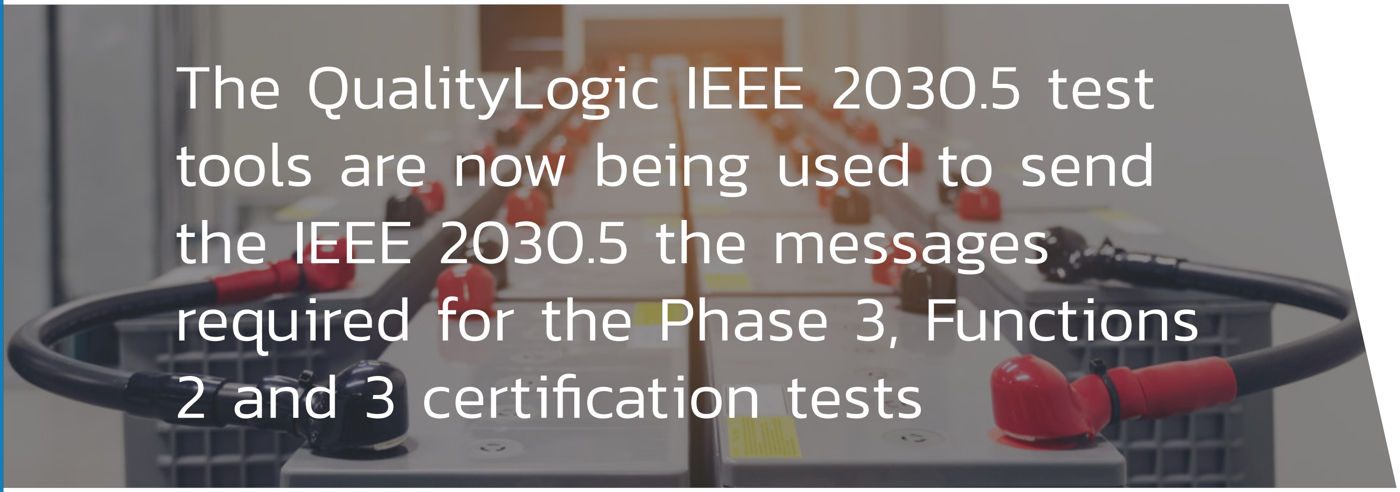
While IEEE 1547.1 is primarily a functionality test comparable to (but more comprehensive than) UL 1741SA[6], it also adds for the first time testing of a required communications capability using one of three designated protocols:

- SunSpec Modbus
- IEEE 1815 (DNP3)
- IEEE 2030.5

This is a huge step forward in that for the first time a hardware certification program will validate that sending instructions or information to a smart

[5] With the addition of SA17 and SA18 to UL 1741SA.

[6] Note that UL plans to update its UL 1741 Test Standard to incorporate the IEEE 1547.1-2020 test procedures.



The QualityLogic IEEE 2030.5 test tools are now being used to send the IEEE 2030.5 the messages required for the Phase 3, Functions 2 and 3 certification tests inverter in an industry standard protocol will indeed achieve the desired behavior of the system.

But the 1547.1 protocol testing is not a complete protocol conformance test like the SunSpec CSIP test for IEEE 2030.5. And there do not exist as of now similar protocol certification programs for either DNP3 or SunSpec Modbus protocols. The CA Rule 21 Phase 2 mandated IEEE 2030.5 communications is independently tested and certified using the SunSpec CSIP IEEE 2030.5 Test Specification and Program. This validates that the communications capabilities of the smart inverter, building EMS, or Aggregator can correctly exchange information and instructions with the utility DERMS systems using IEEE 2030.5.

But the CSIP IEEE 2020.5 certification testing does not validate that the smart inverters actually perform the intended functionality. Indeed, the protocol test does not even require an inverter as part of the test set-up unless the IEEE 2030.5 end-device client is embedded in the inverter communications system.

The significance of this building block approach for managing DER assets cannot be over-emphasized. It is a great starting point for gaining confidence in the interoperability AND performance of an aggregator, building EMS or smart inverter in a portfolio of well-designed and implemented certification programs. But it is not a thorough end-end test that provides assurance that the smart inverters will perform as the utilities require them to.

Does the CA Rule 21 Plan Guarantee End-End Performance?

One downside is that if an inverter is certified interoperable in 1547.1 in one protocol (SunSpec, DNP3 or IEEE 2030.5), that does not mean that using a different protocol would work as well unless it was also certified using that protocol. For example, an inverter certified using SunSpec Modbus must have some form of protocol translator to convert an IEEE 2030.5 message into the SunSpec Modbus messages. Such a protocol adapter will need its own certification program at some point to ensure the conversions between IEEE 2030.5 and SunSpec Modbus produce the intended inverter results.

There is a misconception that the SunSpec CSIP IEEE 2030.5 certification program actually validates inverter performance. In reality, it only validates that the control system (whether local or in the cloud) correctly receives and understands the instructions in the IEEE 2030.5 messages. It validates the correct understanding of the message by the receiving party, but this assumes an accurate translation to the internal programming and behaviors of the physical inverter. While a critical building block to end-end interoperability and performance, this certification needs to be coupled with UL1741SA (and IEEE 1547.1 in the future) to get to some sort of end-end performance assurance.

The theory is that if a utility DERMS is sending a 2030.5 message to a SunSpec CSIP certified inverter, building EMS or an Aggregator client, the message will be correctly interpreted, and the behavior of the controlled

inverters changed to reflect the utility instructions. Thus, it should be possible for a utility to communicate with any UL 1741SA and SunSpec CSIP IEEE 2030.5 certified smart inverter, any SunSpec CSIP certified building EMS and any SunSpec CSIP certified Aggregator and the resulting inverter behavior will be as intended by the utility.

Interoperability challenges solved, right? More accurately, the interoperability challenges are being addressed and some of the necessary procedures put in place. While this greatly reduces the chances of interoperability issues, it does not guarantee that there won't still be significant issues in the integrated system.

CA Rule 21 Testing: What's Missing?

The CA Rule 21 plan is a huge step in the right direction and the SunSpec CSIP certification program will greatly increase the probability that certified systems will work together as intended. The elements in the building block approach are an absolutely necessary step to achieve the end goals. Those building blocks start with the UL 1741SA testing (to be replaced with testing to the IEEE 1547-2018 when available) and then move to the SunSpec CSIP testing for the IEEE 2030.5 communications between utilities and inverters, building EMS or aggregator systems.

But there is not yet a formal testing and certification plan for the links between an inverter, aggregator or building EMS receiving an IEEE 2030.5 CSIP message and the actual inverter behaviors. And the actual test

and certification programs, while extremely valuable, do not guarantee interoperability. Why is that?

The Certification Program's Missing Elements

It is useful to think of test and certification programs as risk management tools. While the long-term goal of a certification program may be 99.99% interoperability and performance, the reality of programs just starting up is that they are focused on the 20% of actual features and functions that make up 80% of the interactions between systems. This is because the amount of testing one could do to reach a 99% confidence level is usually impractical.

With unlimited time and resources, we could conduct comprehensive testing to certify a system, but the reality dictates finding the point of diminishing returns that let us balance costs versus quality.

A good example is the developing IEEE 1547-2018 interoperability testing. The interoperability testing is intended to demonstrate that one of the three named standards in the IEEE 1547-2018 standard (SunSpec, DNP3 or IEEE 2030.5) can be used to receive messages at the inverter and that those messages will result in the intended inverter settings and behaviors. A comprehensive approach would be to send messages that cover every possible function setting and combinations of settings and measure the resulting inverter behaviors. But this is more comprehensive than conducting a complete IEEE 1547.1 test and would take potentially months to complete.

Table 1 summarizes the current and anticipated certifications for smart inverters and servers and aggregators under CA Rule 21.

Table 1: Summary of CA Rule 21 Certifications

Communications Interface/Functions	CSIP IEEE 2030.5 Server	CSIP IEEE 2030.5 Aggregator Client	CSIP IEEE 2030.5 End-Device Client	IEEE 1547-2018 / UL 1741-2020
DER Phase 1 Smart Functions				√ (2020)
DER Phase 3 Smart Functions				√ (2020)
Phase 2 Direct Utility to DER	√ (2020)		√ (2020)	
Phase 2 Utility to GFEMS	√ (2020)		√ (2020)	
Phase 2 Utility to Aggregator	√ (2020)	√ (2020)		
GFEMS to DER	CALSSA Testing Pathway (2020) ------------------------------------			
Aggregator to DER	CALSSA Testing Pathway (2020) ------------------------------------			
DER Interop Communi-cations (SunSpec, DNP3, IEEE 2030.5)				√ (2020/2021)

QualityLogic has trained dozens of development and utility teams in the IEEE 2030.5 protocol.

Instead, recognizing that the vendors themselves conduct comprehensive testing and that testing a sample of potential inverter functions will increase the confidence that all functions are correct, the testing can be thought of as more of a spot check. If there are no problems with testing a sampling of behaviors using the communications protocol, then this should provide increased confidence that the inverter will interoperate successfully with other systems and perform per the instructions given it. If, on the other hand, some issues show up in the spot checks, then it won't be certified, and the vendor will have information that allows it to do a deeper dive to understand specific and systemic issues with their implementation and fix them.

The New CALSSA Testing Pathway

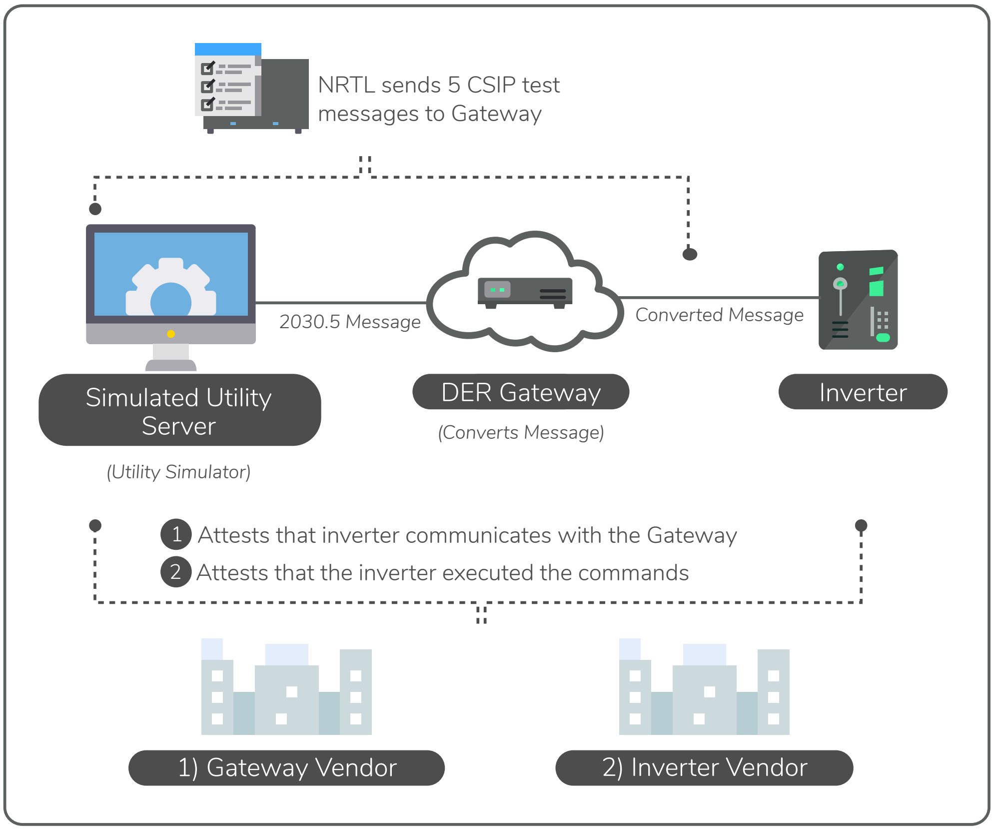
One of the compromises in defining the CSIP requirements was that communication from an aggregator or building EMS to the DER was out-of-scope and therefore undefined. The CPUC is labeling these two entities as "gateways" even though that is not really a correct term. But we will use the "gateway" term in this discussion to mean these entities and any other system component that acts as the interface between the utility DERMS and the end-DER system.

The revised, final E-5000 order included a "testing pathway" for non-CSIP inverters proposed by CALSSA. Essentially, the new testing pathway relies on

"...type testing to allow inverter manufacturers to demonstrate that their

products meet the Phase 2 communications requirements via Nationally Recognized Testing Lab (NRTL) testing only...the NRTL would test each model with each compatible gateway and then produce two types of reports: one test report stating that the gateway meets CSIP requirements and one letter that states which inverter models successfully connected to the gateway during testing."

Figure 1: CALSSA Testing Pathway



The plan does not require the lab to verify that the inverter actually performed the required functions but allows the vendor to "attest" to conformance with the functional requirements. These non-CSIP inverters must tested and listed by the June 22, 2020 date in order to be sold and interconnected in CA after that date.

Since the E-5000 Order was published in July 2019, there have been several clarifications that have allowed the testing and listing of these inverters to proceed.

What are the implications of this new "testing pathway" for end-end assurance? Our initial conclusions are:

1. The tests are only a fraction of the CSIP Tests (5 of 70+) and only touch a small subset of inverter behaviors.
2. There is no validation that the IEEE 2030.5 message from the simulated (or real) DERMS is translated correctly into the protocol used between the gateway and the inverter. If an intended Volt-Var curve is inverted in the translation, there is no mechanism for discovering this. The only attestation is that messages are translated and communications between the gateway and inverter did occur.
3. Since the inverter performance is done by attestation of the inverter vendor, there is not an independent validation of the functional behaviors. While most of the vendors are creditable and their assurances should be relied on, it is not the best practice if a high-degree of assurance is required.

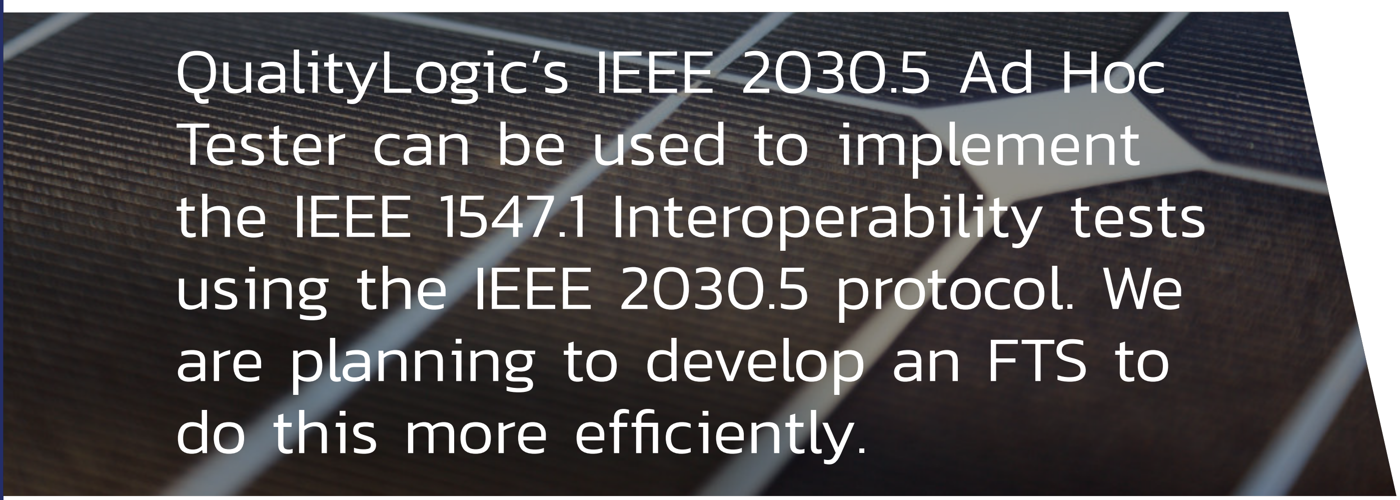
One concern with the program is what happens when there is actually a need to manage a specific end device? If an inverter is on the CEC approved list because it demonstrated it can communicate with a specific gateway platform, it is not required to do so when interconnected. It could be one or two years before the IOUs are ready to communicate with these inverters. By then, not only has the firmware probably changed (and may not have not been re-tested), the chances that the same gateway platform would be the interface to the grid seems remote. We can envision that some sort of IOU communications commissioning process will be required to address this issue.

The adoption of the CALSSA testing pathway is definitely a step forward that provides a mechanism to determine which inverters can be interconnected with the CA IOUs. However, it clearly leaves a number of questions which will need to be addressed in the future

One Step Towards End-End Guarantees

An even better approach would be to use one of the named protocols to conduct all the specified IEEE 1547.1 functional tests. This would provide confidence that both the functions and the communications about those functions using SunSpec, DNP3 or IEEE 2030.5 behave as intended. The only downside is that this doesn't validate that use of either of the other two non-tested protocols results in the same level of performance.

Assume we have a certified IEEE 1547-2018 inverter that includes validation of the IEEE 2030.5 messaging; a SunSpec CSIP IEEE 2030.5



certified inverter client and a SunSpec certified DERMS IEEE 2030.5 server. We plug them together and start sending instructions. If the instructions are only those that have been tested and certified, there is a high probability of successful interoperation.

However, there are cases that are not tested in the certification processes and may cause issues. For instance, if interoperability testing does not include tests for complex programs that include multiple inverter function setting changes in one message, there is a risk that such a message would result in an unexpected behavior.

When building EMS and aggregator systems are added to the mix, even more interoperability risks are created. A SunSpec CSIP certified Aggregator validates that it can correctly exchange information and instructions with a DERMS CSIP server, but it does not test at all that the instructions and information are correctly translated into whatever protocol it uses to communicate to an inverter. Even if the inverters are certified for IEEE 1547-2018, unless a specific test and certification step validating that the aggregator-inverter interface delivers the intent of the DERMS server message, a new risk has been introduced. Every time an IEEE 2030.5 message is translated into any other protocol (whether a standard or proprietary one), new possibilities for errors are created. And as of now, we don't have a process in place or planned to address this issue.

What Can A Utility do to Ensure End-End DER Performance?

It makes little sense for a utility to replicate all the testing that is already being required for CA Rule 21 acceptance. First and foremost, a utility can absolutely mandate that any DER inverters, building EMS systems or aggregators, and their own IEEE 2030.5 server pass the UL 1741SA/ IEEE 1547.1-2020 and/or SunSpec CSIP IEEE 2030.5 certifications before even being considered for demonstrations, pilots or deployments of DER management systems.

Starting with these “building blocks”, the level of effort to reduce risk of interoperability problems becomes manageable. The new IEEE 1547.1-2020 test procedures include commissioning tests. These make sense for larger, one-off installations but are not very practical for any sort of large-scale deployment of smaller inverters. In this case, the most useful next step is to design and execute a use-case specific acceptance test process to be conducted internally or using a 3rd party lab with appropriate equipment and skills.

The primary focus of any utility testing program should be to ensure that its unique planned deployment scenarios are tested for the end-end system. If the deployment is focused on using behind-the-meter storage to manage excess solar PV through an aggregator, then the test design and test lab should be designed to validate that DERMS 2030.5 messages are implemented correctly in the end inverters. This would require:

- A clear specification of the use case including the types and nature of the messages and instructions – e.g., requests to the aggregator for storage and solar PV status updates; new ramp rates for storage; schedules of when to store and when to discharge into the grid; schedules or instructions to the PV inverters to change curves and settings.
- A grid simulator and a PV simulator along with measurement devices to capture both the inverter settings and inverter electrical behaviors.
- A set of tests that implement the use case specification focused on the more complex scenarios such as multiple DER functional curves and setting changes in one message and scheduling of storage and PV inverter behaviors.

With such a test system in place, it would be relatively straight-forward to validate each of the candidate aggregator and DER systems from an end-end perspective.

Over time, this task should shrink as the IEEE 1547.1 certification is put in place and future end-end certifications are designed and implemented by the industry.

An issue that was raised in comments to the CPUC was the number of inverter/gateway combinations that could potentially be tested. The CALSSA

Testing Pathway is a start at addressing this issue[7]. But as noted, it is not a robust 3rd party certification program and does not ensure that inverters will have a particular gateway when IOU communications is ready to begin.

While someone may insist on testing all possible combinations of inverters and gateways, this makes no sense. A utility could establish an acceptance testing program to qualify gateway/inverter combinations as a requirement to interconnection. If vendors paid for some or all of the testing costs, the market would act to constrain the total number of combinations tested and accepted for a particular IOU interconnection.

There may be other approaches to this end-end challenge and we expect that the CPUC and CA IOUs, along with their industry and lab partners will continue working on this issue until a reasonable solution is in place.

[7] *See CPUC Resolution E-5000, July 11, 2019, Appendix C.*

Summary

There is no question that the CA Rule 21 test and certification requirements already being put in place will go a long way to reducing the cost and time to implement an effective DER communications system. This will benefit utilities, vendors and consumers not just in California but globally since the standardization makes leveraging the investments very easy and attractive.

For utilities with particularly unique or complex use cases, the CA Rule 21 procedures will make their specification and implementations tasks much easier. But there still will be cases where additional end-end testing will be required to gain the assurance required in relying on DER's as a critical part of the grid.

For More Information

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