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International Development of a Distributed Energy Resource Test Platform for Electrical and Interoperability Certification

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***Abstract* — Several international research laboratories are collaborating under a Smart Grid International Research Facility Network (SIRFN) project to develop certification procedures for advanced distributed energy resources (DER). To effectively evaluate interoperability and grid-support functionality in DER equipment, test permutations across the full range of modes and parameters are required. It is impractical to complete these experiments manually so the project team is working to develop a software tool, associated abstraction layers, and hardware drivers to execute the experiments autonomously using the same open-source test logic. This software can then be programmed to complete interoperable DER certification experiments at DER vendor facilities, certification laboratories, or research institutions. By sharing the codebase with all institutions, barriers to adoption steadily decrease. Test results for volt-var, fixed power factor, and frequency-watt functions from multiple laboratories are presented and compared.**

***Index Terms* — interoperability, grid-support functions, certification protocols, DER testing, smart grid**

I. Introduction

In the last decade, grid codes around the world have been changing to require photovoltaic systems and other distributed energy resources (DER) to provide grid services through autonomous and commanded control functions [1]-[3]. These functions provide grid operators with methods to provide voltage regulation [4], bulk system services [5], power system visibility [6], and other grid services [7]—thereby, increasing the renewable energy hosting capacity of the power system. As these new requirements go into place, there is growing need to evaluate the functionality of these devices to the electrical requirements and verify the communications capabilities provide the desired behavior [8].

The Smart Grid International Research Facility Network (SIRFN) operates as an International Energy Association (IEA) International Smart Grid Action Network (ISGAN) research program with multiple research areas. One of the research programs is focused on the development and evaluations of interoperable DER certification protocols. The ultimate goal of the effort is to enable greater penetrations of renewables by accelerating the adoption of smart grid converter technologies. Technical challenges that prevent greater deployment of renewable technologies can be mitigated with advanced DER technologies, but DER vendors will not interconnect products with these capabilities unless grid code requirements exist. In many cases, the equipment being installed already has the hardware and software components required to provide this functionality—because it is required in other jurisdictions—but it is disabled because these functions are disallowed or not required. Therefore, in cases where SIRFN laboratories are operating in regions without DER grid-support requirements or certification protocols (such as in Mexico or India), executing interoperability DER experiments can help (a) advise DER interconnection and communication requirements by demonstrating DER grid-support capabilities and (b) accelerate the development of certification procedures by rapidly iterating and exercising draft test sequences.

Previously, the team developed test protocols for the IEC 61850-90-7 functions [9]-[10] and test protocols for energy storage systems [11]. Experimental results from these protocols as well as national requirements—i.e., the US DER certification protocol, UL 1741 [12]—have been presented for residential and commercial scale devices [8], [13] and a 34.5

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kW smart grid converter deployed in a controller hardware-in-the-loop environment [10], [14]. To execute these experiments, each research laboratory developed their own DER testbeds with unique data acquisition systems and test equipment (PV simulators, grid simulators, etc.). Differences in the results between laboratories highlighted the need to have a common set of test logic that would be executed the same way at all the labs. This would minimize the human element in the experiments; although some variance will inherently exist in the results due to differences in test equipment, data acquisition systems, and the devices under test.

In 2014, the SunSpec Alliance and Sandia began a joint project to automate the test protocols by creating a software tool, called the SunSpec System Validation Platform, which orchestrated test sequences by communicating to data acquisition systems, power equipment, and devices under test [15]. Ultimately, the ability to full automate steady-state test sequences was developed [16] and the capability to work with other lab equipment over a range of protocols and media was created using abstraction layers and device drivers [17]. This tool remains in development but as the open-source repository of test code and device drivers grows (see [18]), new laboratories come up to speed much quicker. Gradually, more SIRFN laboratories have become interested in participating in the project and contributing to the SVP development.

This manuscript describes the SIRFN collaboration, SVP development, and presents test results generated from multiple laboratories using the same test scripts. The results show the benefits with working within an open community, the speed and consistency of the SVP, and the reactive and active power grid-support function capabilities of PV inverters.

II. System Validation Platform

The SVP is designed to communicate to laboratory equipment and the device under test, as shown in Fig. 1. Python scripts are developed with user-defined parameters. The parameters define the test sequence by:

- selecting which portion of the test sequence should be executed,
- setting the power, voltage, current, etc. levels for the test based on the EUT ratings, and
- configuring battery simulators, data acquisition systems (DAS), equipment under test (EUT), grid simulators, PV or DC simulators, hardware-in-the-loop systems, and resistive, capacitive or inductive load banks.

Abstraction layers are employed to select equipment drivers for a given laboratory testbed—basically, the same script command (e.g., 'set PV power to 100% of nominal') will issue different device commands over a user-selected protocol and communication media, depending on the selected driver parameters. A representation of the abstraction layers pointing to specific devices is shown in Fig. 2.

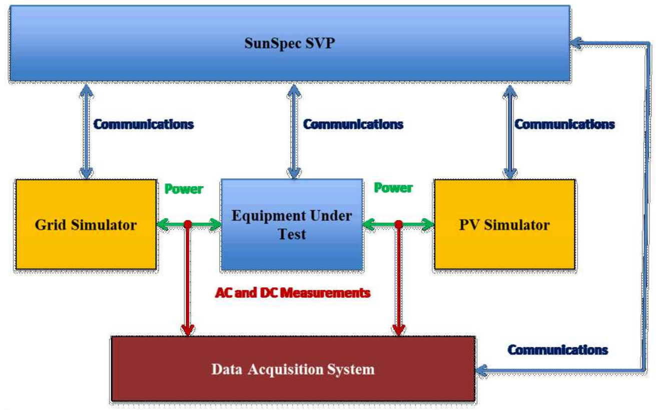

Fig. 1. SVP interaction with laboratory equipment.

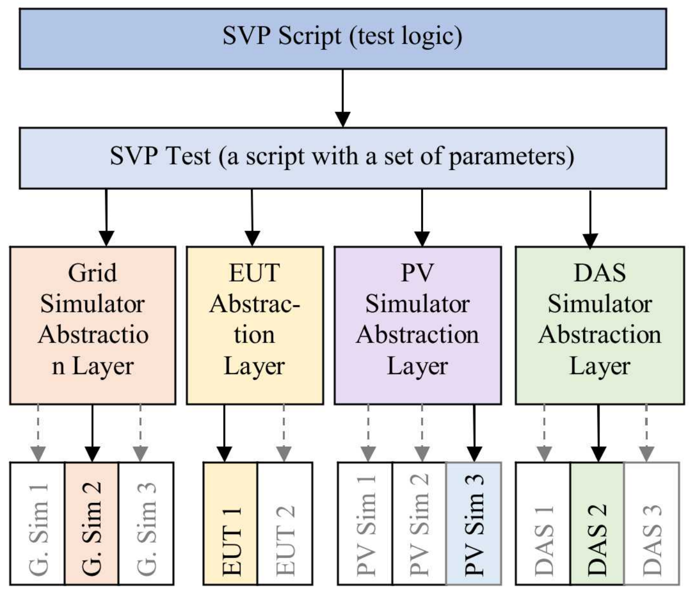

Fig. 2. SVP interaction with laboratory equipment.

III. Experimental Results

The final paper will present results from the SIRFN labs conducting experiments with the SVP to evaluate DER interoperable grid-support functions (e.g., volt-var, fixed power factor, and frequency-watt functions) using the UL 1741 Supplement A certification protocol. Detailed comparisons of the results and any issues with the SVP scripts and drivers will be documented. For reference, prior examples of SIRFN results and comparisons are presented in [2] and [3].

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