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Technical Update on SIRFN and SNL Inverter Interoperability Testing

Grenoble, France – 21 June, 2013

Jay Johnson

Photovoltaic and Distributed Systems Integration

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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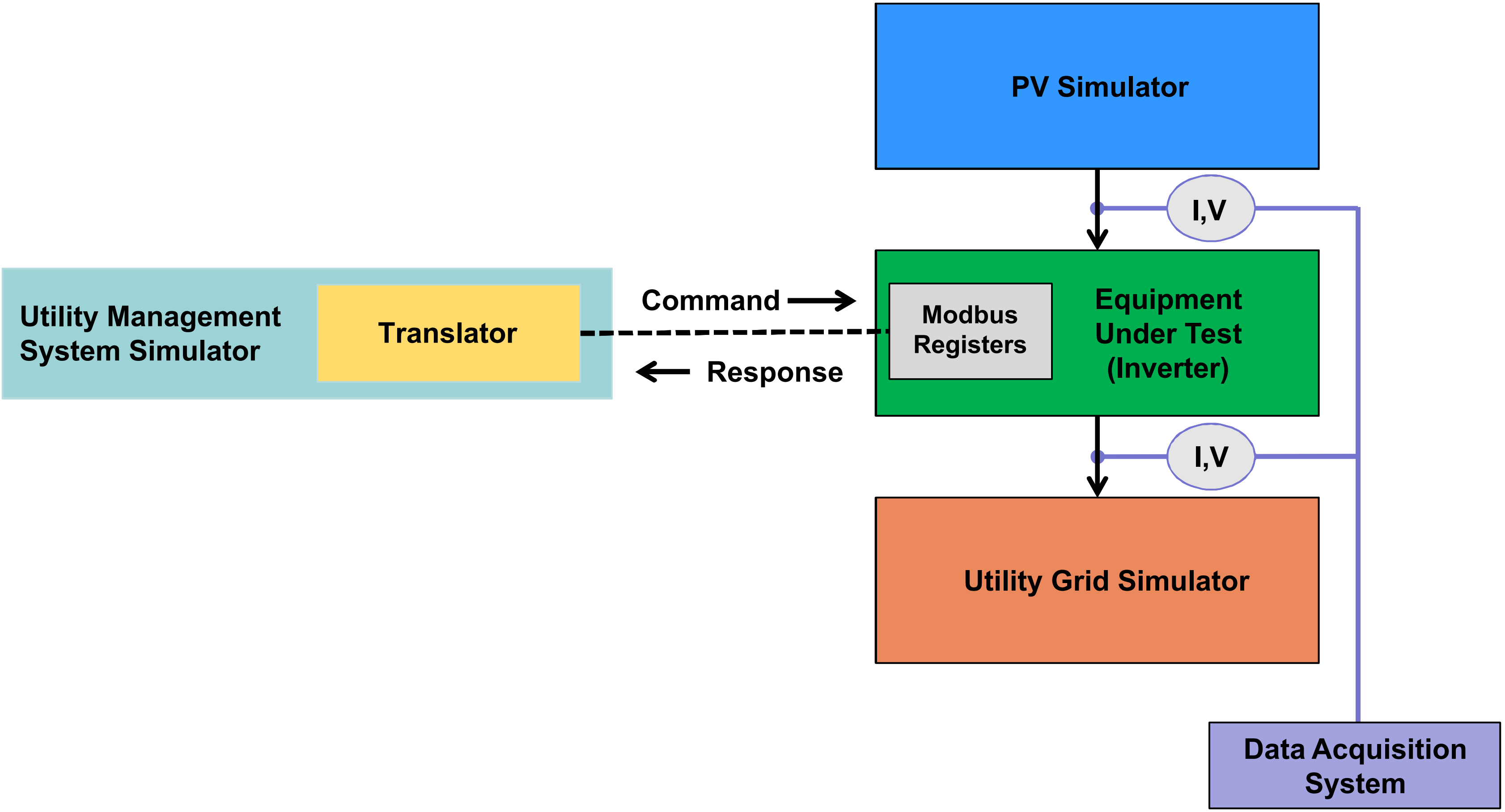
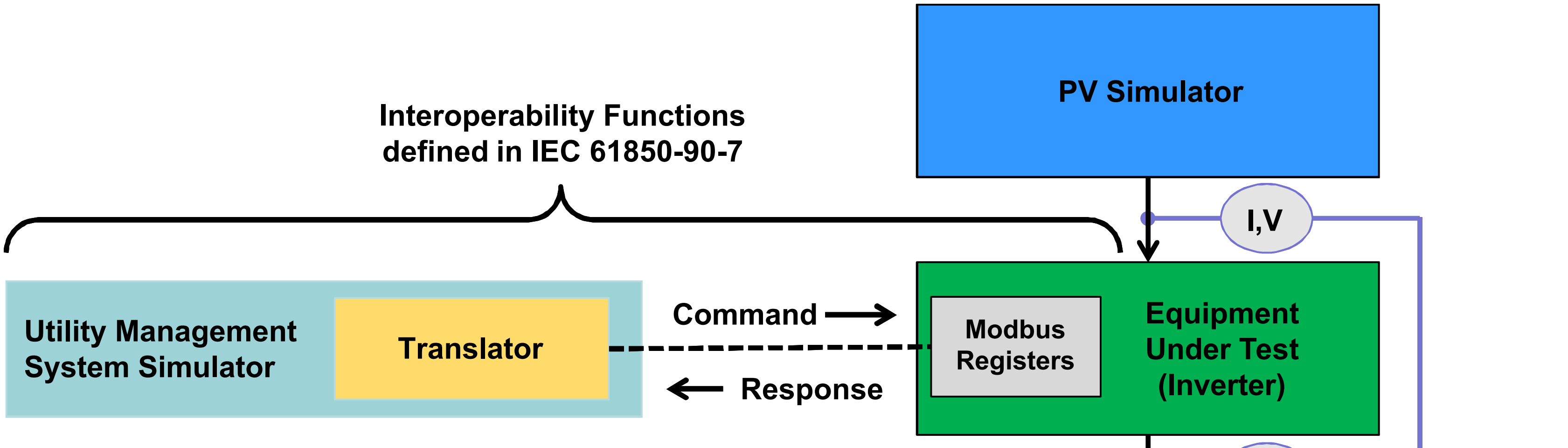
Outline

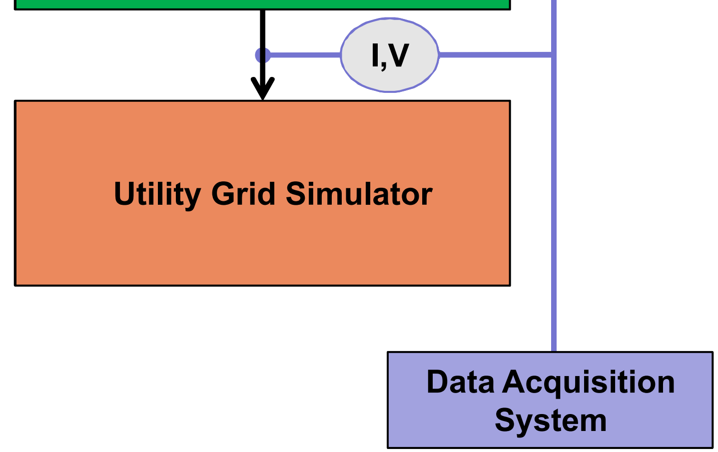
- Overview of interoperability tests
  - Where do the definitions and test documents apply?
- Update on Sandia Test Protocol
- Update on PV inverter interoperability testing at Sandia
  - Interoperability functions for SIRFN first round of testing (examples of Sandia Test Protocol)
- Collaborations within SIRFN and to external partners
- Future work
  - Milestones for CY2013

DER Interoperability Testing



DER Interoperability Testing





Command	Function
INV1	Connect/Disconnect
INV2	Adjust Max Generation Level
INV3	Adjust Power Factor
INV4	Request Active Power
INV5	PV/Storage Functions
VV11	Volt-Var mode
VV12	Volt-Var mode
VV13	Volt-Var mode
VV14	Volt-Var mode
FW21	Set maximum power output
FW22	Set maximum power output
TV31	Dynamic reactive power support
L/H VRT	Connect/disconnect settings
WP41	Power factor settings
WP42	Power factor settings
VW51	Set output to smooth voltage
VW52	Set output to smooth voltage
TMP	Temperature mode behavior
PS	Signal mode behavior
DS91	Modify DER Inverter Settings
DS92	Event/History Logging
DS93	Status Reporting
DS94	Time Synchronization

DER Interoperability Testing

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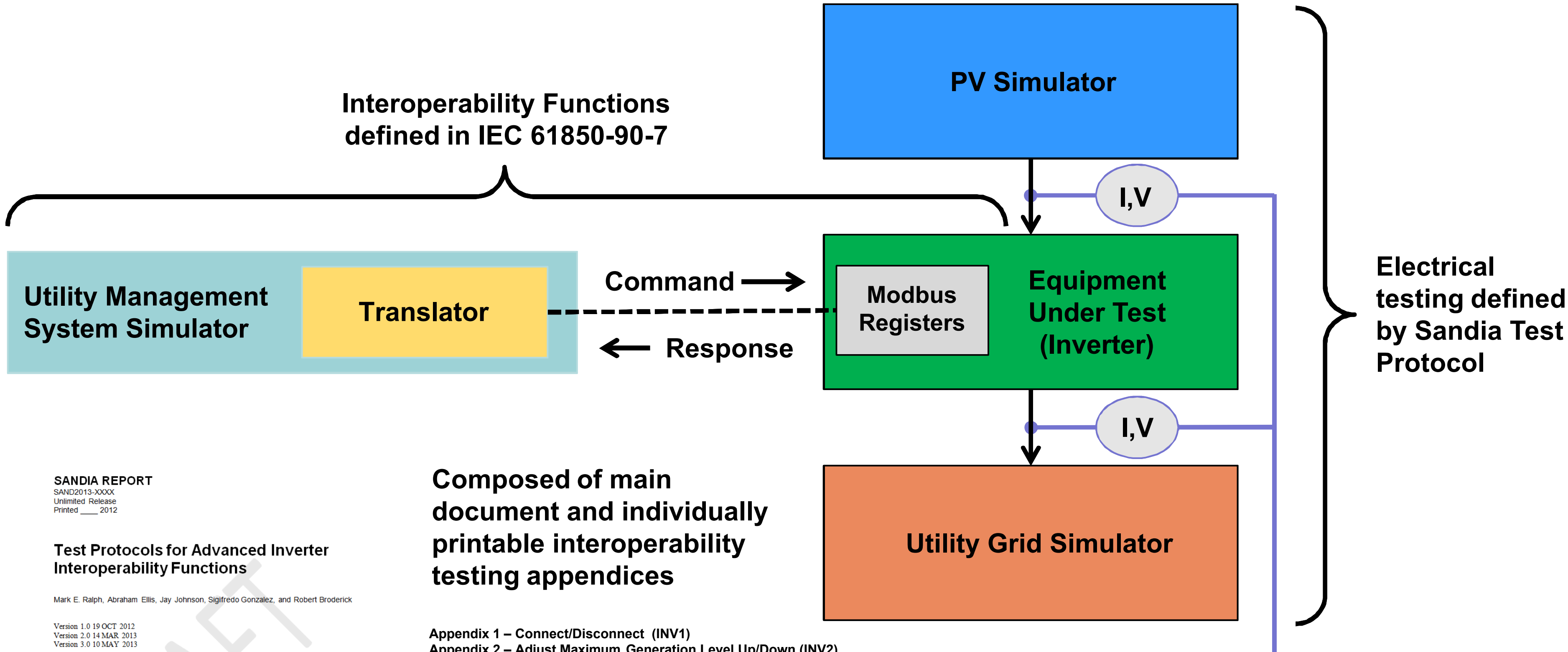

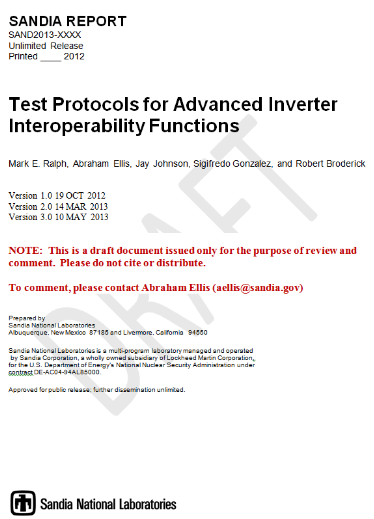

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Test Protocols for Advanced Inverter Interoperability Functions

Mark E. Ralph, Abraham Ellis, Jay Johnson, Sigifredo Gonzalez, and Robert Broderick

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Version 2.0 14 MAR 2013
Version 3.0 10 MAY 2013

NOTE: This is a draft document issued only for the purpose of review and comment. Please do not cite or distribute.

To comment, please contact Abraham Ellis (aellis@sandia.gov)

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DRAFT

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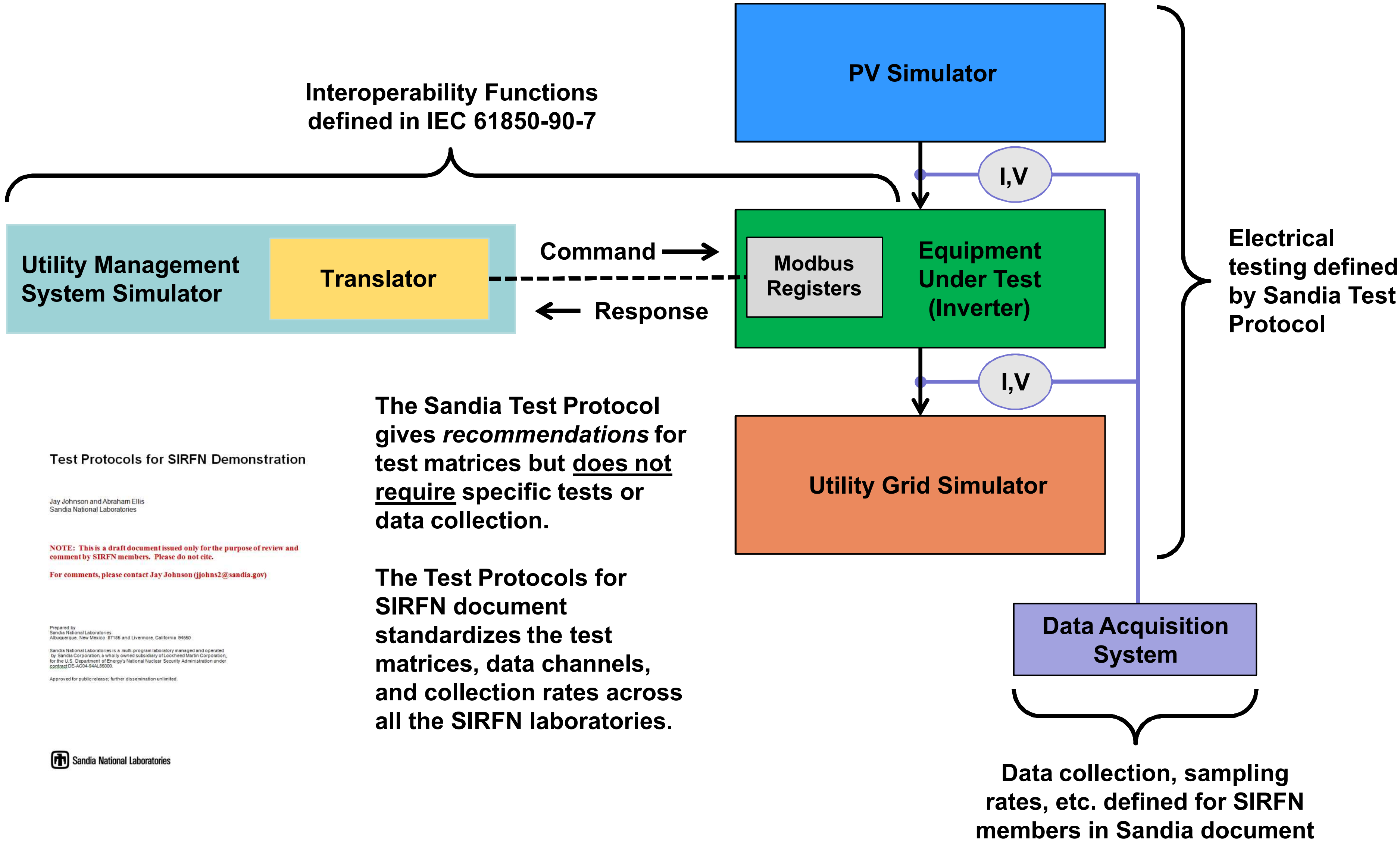
Composed of main document and individually printable interoperability testing appendices

- Appendix 1 – Connect/Disconnect (INV1)
- Appendix 2 – Adjust Maximum Generation Level Up/Down (INV2)
- Appendix 3 – Adjust Power Factor (INV3)
- Appendix 4 –Request Active Power from Storage (INV4)
- Appendix 5 –Signal for Charge/Discharge Action (INV5)
- Appendix 6 – Volt/Var Mode (VV11; VV12; VV13; VV14)
- Appendix 7 – Frequency/Watt Mode (FW21; FW22)
- Appendix 8 – TV Dynamic Reactive Power support (TV31)
- Appendix 9 – Low and High Voltage Ride Through (L/HVRT)
- Appendix 10 – WP Power Factor Settings (WP41; WP42)
- Appendix 11 – VW Set Output to Smooth Voltage Variations (VW51; VW52)
- Appendix 12 –Temperature mode Behavior (TMP)
- Appendix 13 – Utility Signal Mode (PS)
- Appendix 14 – Event History/Logging (DS92)
- Appendix 15 – Status Reporting (DS93)
- Appendix 16 –Time Synchronization (DS94)
- Appendix 17 – Time Window & Random Time Delay
- Appendix 18 – Ramp Rate
- Appendix 19 – Command Timeout

Working with SRA International to finish writing the first draft of all the functions. Many iterations of the test procedures, parametric test matrices, etc. is expected.

DER Interoperability Testing



Test Protocols for SIRFN Demonstration

Jay Johnson and Abraham Ellis
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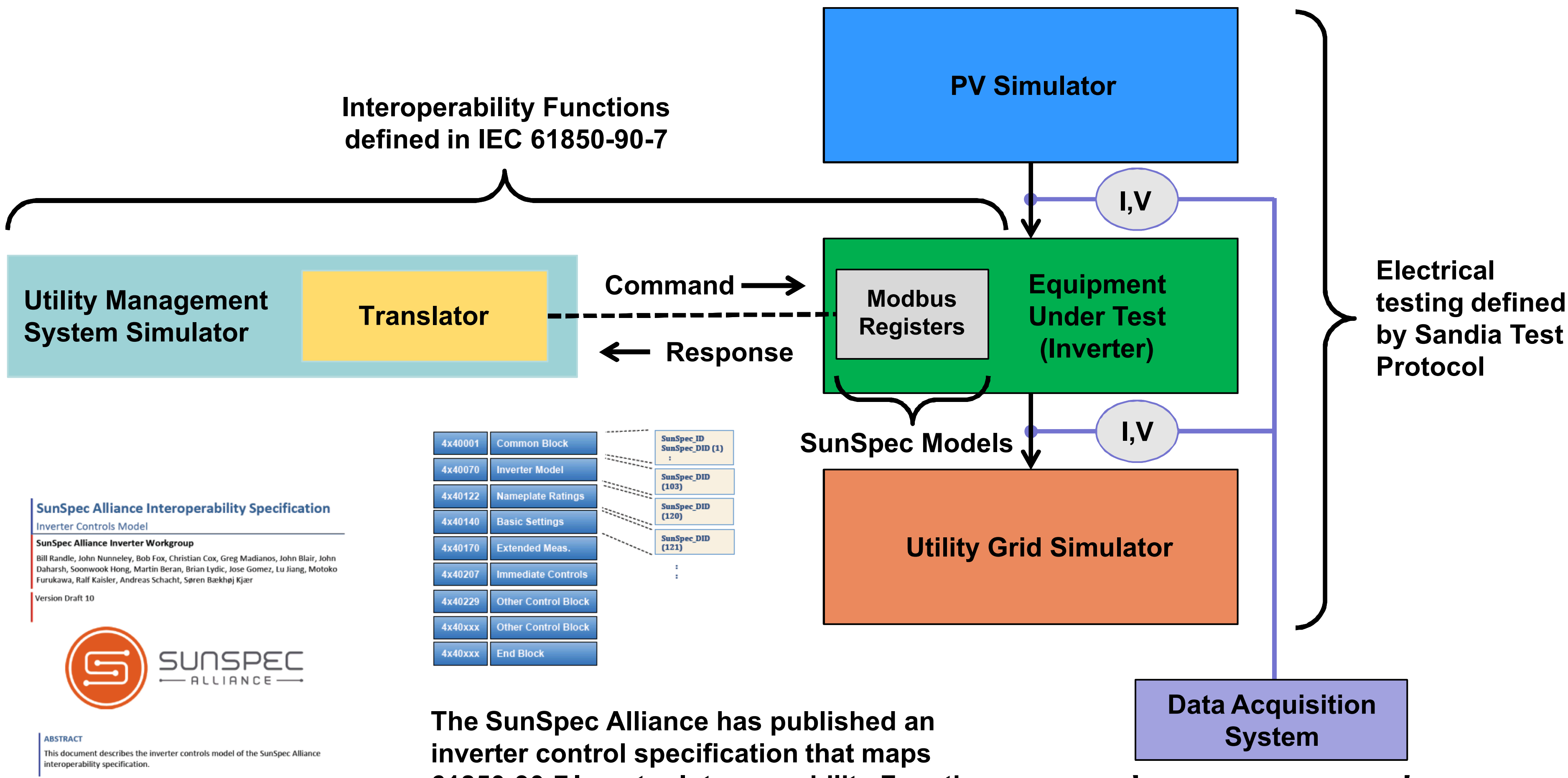
The Sandia Test Protocol gives *recommendations* for test matrices but <u>does not require</u> specific tests or data collection.

The Test Protocols for SIRFN document standardizes the test matrices, data channels, and collection rates across all the SIRFN laboratories.

DER Interoperability Testing



The SunSpec Alliance has published an inverter control specification that maps 61850-90-7 Inverter Interoperability Functions to Modbus and SEP2.0. Manufacturers are incouraged to adopt this standard so utilities do not need multiple translators to communicate to the inverters on their grids.

Data Acquisition System

Data collection, sampling rates, etc. defined for SIRFN members in Sandia document

DER Interoperability Testing

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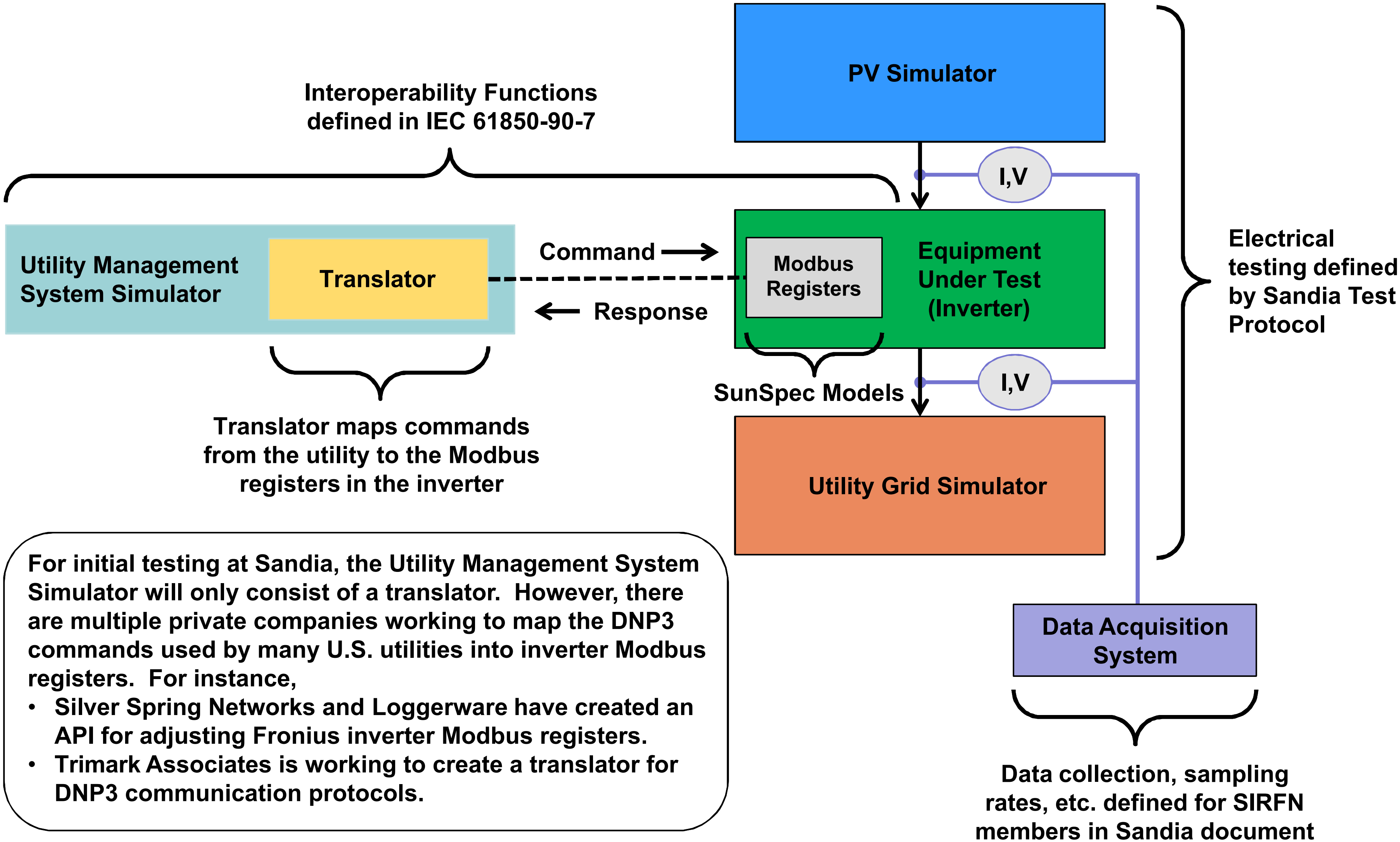

For initial testing at Sandia, the Utility Management System Simulator will only consist of a translator. However, there are multiple private companies working to map the DNP3 commands used by many U.S. utilities into inverter Modbus registers. For instance,

- Silver Spring Networks and Loggerware have created an API for adjusting Fronius inverter Modbus registers.
- Trimark Associates is working to create a translator for DNP3 communication protocols.

IEC 61850-90-7 Inverter Interoperability Functions

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Command	Function	Description	Type
INV1	Connect/Disconnect	Physically connect or disconnect from grid	Command
INV2	Adjust Max Generation Level	Set maximum generation level at Electrical Coupling Point	Command
INV3	Adjust Power Factor	Issues a power factor angle value	Command
INV4	Request Active Power	Request charging or discharging of the storage system	Request
INV5	PV/Storage Functions	Change the signal parameters for the storage system	Request
VV11	Volt-Var mode	Provide vars with no effect on watts	Set Parameter
VV12	Volt-Var mode	Provide maximum vars constrained by WMax	Set Parameter
VV13	Volt-Var mode	Establish fixed var settings	Set Parameter
VV14	Volt-Var mode	No var support	Set Parameter
FW21	Set maximum power output	Active power reduction due to high frequency	Set Parameter
FW22	Set maximum power output	Modify frequency-watts-delivered or watts-received curve	Set Parameter
TV31	Dynamic reactive power support	Provide var support at times of abnormally high or low voltage	Set Parameter
L/H VRT	Connect/disconnect settings	Set voltage ride-through or disconnect requirements	Set Parameter
WP41	Power factor settings	Set power factor in response to feed-in power	Set Parameter
WP42	Power factor settings	Modify power factor-watts curve	Set Parameter
VW51	Set output to smooth voltage	Voltage-watt curve of generator output	Set Parameter
VW52	Set output to smooth voltage	Voltage-watt curve of storage charge/discharge output	Set Parameter
TMP	Temperature mode behavior	Temperature-based curves	Set Parameter
PS	Signal mode behavior	Mode curves based on utility signal	Set Parameter
DS91	Modify DER Inverter Settings	Set default ramp rate, min./max. storage charge/disch. rate	Command
DS92	Event/History Logging	Request event logs	Command
DS93	Status Reporting	Request inverter status	Command
DS94	Time Synchronization	Set inverter time	Command

Implementation Successful (green: INV3, VV11) | **Implementation Partly Successful** (yellow: FW21) | **Implementation Unsuccessful** (red: L/H VRT)

Inverter Interoperability Testing at Sandia

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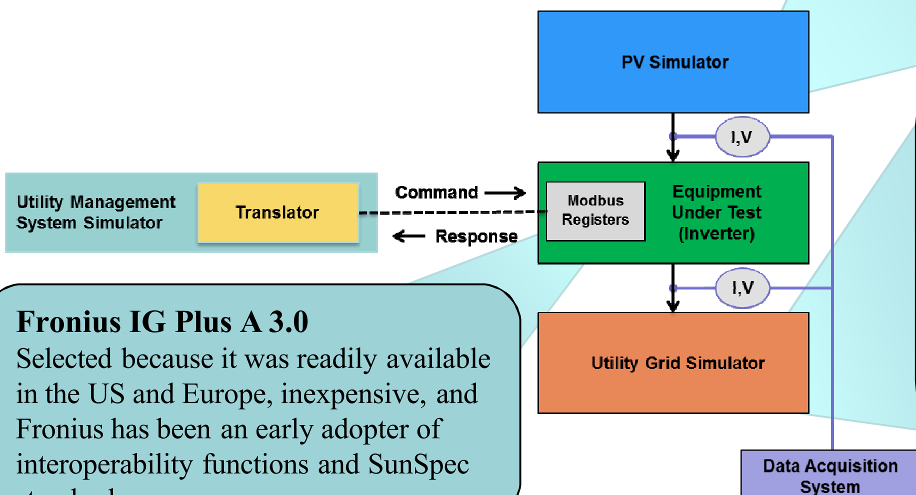
Distributed Energy Technologies Laboratory (DETL) Facilities

DETL is a reconfigurable testbed that can simulate a wide variety of real-world RE and DER integration scenarios.

PV Simulator Specifications:
Power: 200 kW (20 outputs, 10kW each)
Voltage: 0-1000 Vdc/output
Current: 10 A/output

Characteristics:
2 x TerraSAS racks. Individual I-V curve characteristics per output. Outputs can be combined to mimic poor performing string.



Grid Simulator Specifications:
Power: 180 kVA
Voltage: 480 V 3ϕ, up to 300 V_{L-N} (520 Vac)
Current: 700 A/Phase

Characteristics:
2 x AMATEK RS90.

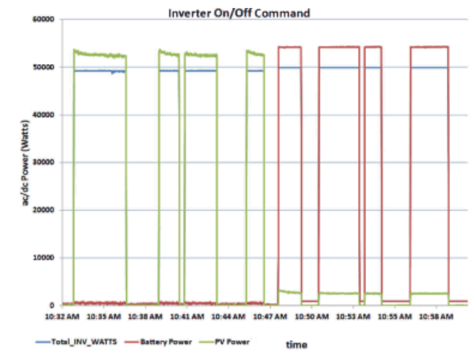
Fronius IG Plus A 3.0
Selected because it was readily available in the US and Europe, inexpensive, and Fronius has been an early adopter of interoperability functions and SunSpec standards.

Previous Interoperability Testing

- Testing performed on a limited number of functions so far
  - Inverter firmware with these functions is in its infancy
  - Communications to the inverters is new and untested
    - Utility-to-Modbus translators are now being developed
- Some early testing by Sandia was presented at 2012 IEEE PVSC conference.
  - See Gonzalez, et al. "Implementation of Advanced Inverter Interoperability and Functionality"
  - Tested INV1, INV2, INV3.
  - The inverter manufacturer provided a GUI to adjust the inverter parameters.
  - No standardized test protocol at that time – part of the impetus for creating the Sandia Test Protocol document.

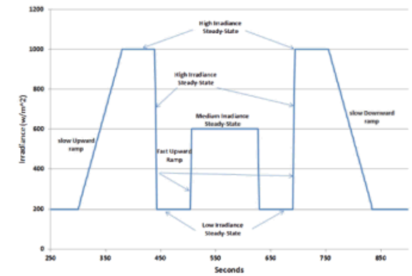
INV1 – On/Off Command

Function	Control Function	Command/ Request	Expected response	Time to response
Function INV1 (PV)	Connect Disconnect	Command ON *request 50kW*	OFF previous Pout= 2kW	4.5 sec
Function INV1 (PV)	Connect Disconnect	Command OFF *request 0kW*	ON previous Pout=49kW	4.3 sec
Function INV1 (Battery)	Connect Disconnect	Command ON *request 50kW*	OFF previous 50kW	4.2 sec
Function INV1 (Battery)	Connect Disconnect	Command ON *request 0kW*	ON previous .2kW	3.9 sec



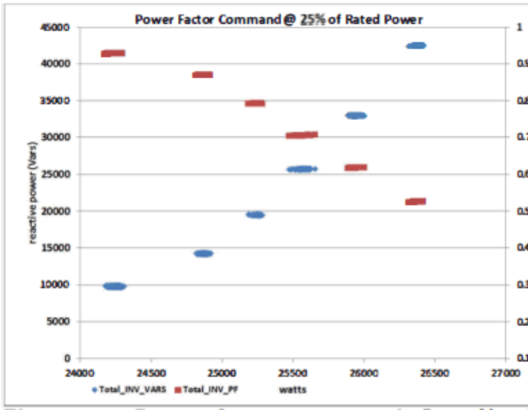
INV2 – Set Max Watts

Function	Control Function	Command/ Level	Measured Level	Time to response
Function INV2 curve (a)	Set Power Level	Commanded 20kW from 0	19.6kW	~ 6 sec
Function INV2 curve (b)	Set Power Level	Commanded to 10kW from 20kW	9.8kW	~6 sec
Function INV2 curve (c)	Set Power Level	Commanded to 25kW (P curve)	24.6kW @ 1000w/^2	N/A
Function INV2 curve (d)	Set Power Level	Commanded to 75kW (P curve)	73.7kW @ 1000w/^2	N/A
Function INV2 curve (e)	Set Power Level	Commanded to 100kW (P curve)	96.7kW @ 1000w/^2	N/A
Function INV2 curve (f)	Set Power Level	Commanded to 50kW and 25kW	50.2kW and 24.kW	~6 sec ~4 sec



INV3 – Set Power Factor

Function	Control Function	Command/ Level	PF Measured	Power Level
Function INV3 PF 1.0 lead	Set Power factor	Commanded 25kW	.93	24.1kW
Function INV3 PF .9 lead	Set Power factor	Commanded 25kW	.87	24.8kW
Function INV3 PF .8 lead	Set Power factor	Commanded 25kW	.79	25.2kW
Function INV3 PF .7 lead	Set Power factor	Commanded 25kW	.7	25.7kW
Function INV3 PF .6 lead	Set Power factor	Commanded 25kW	.62	25.9kW
Function INV3 PF .5 lead	Set Power factor	Commanded 25kW	.52	26.3kW



Sandia Test Protocol

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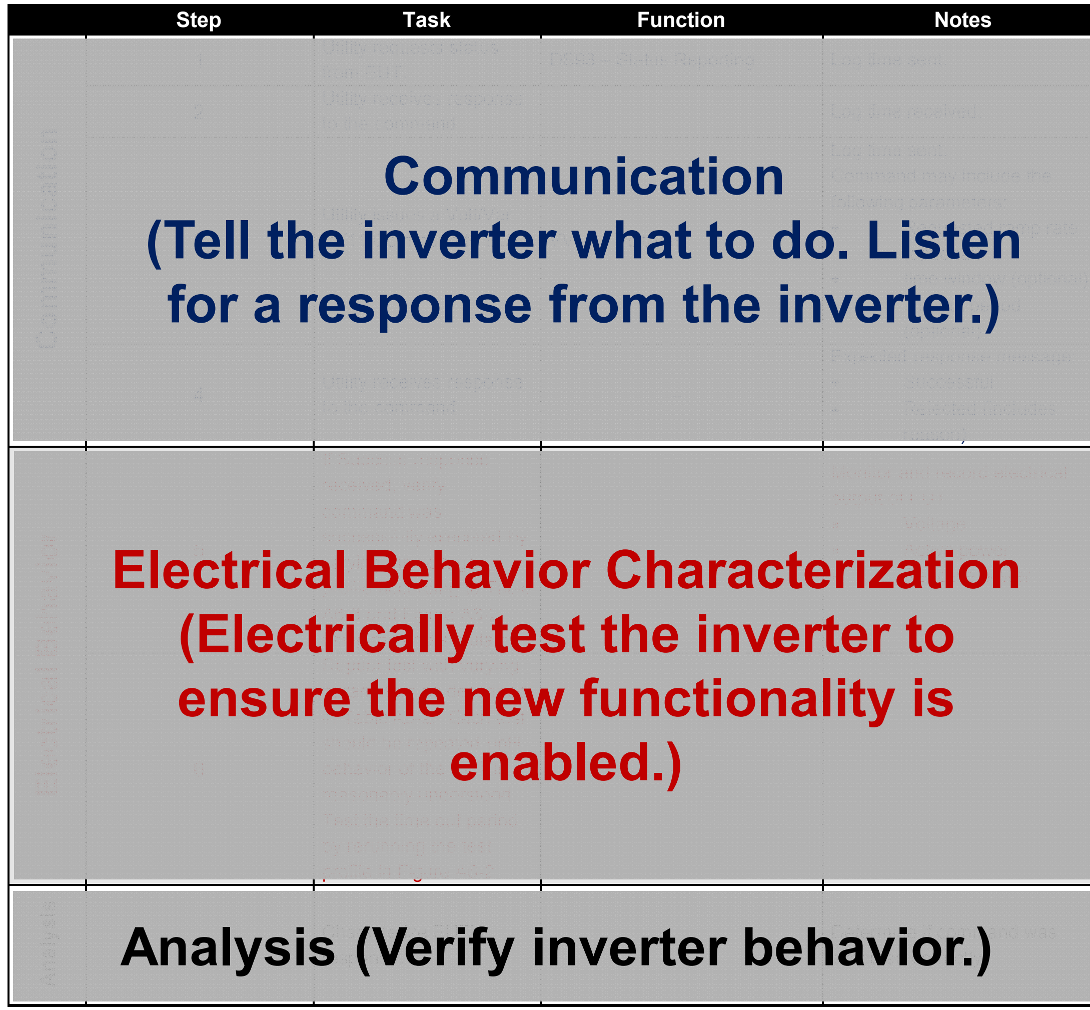
- General guidelines for harmonized equipment testing across different laboratories
- Precursor to future equipment certification procedures.
- Two distinct phases for most functions
  - Communication
    - Send the signal from the Utility Management System Simulator
    - Verify the communications reached the EUT
  - Electrical behavior characterization
    - Measurement of the DC and AC characteristics to verify the inverter updated its operation
- Communication phase of the test protocol sequence may be skipped for some inverters if there is no translator.

Example Test Protocol Sequence (Volt/Var VV11)



Example Function: Volt/Var (VV11)

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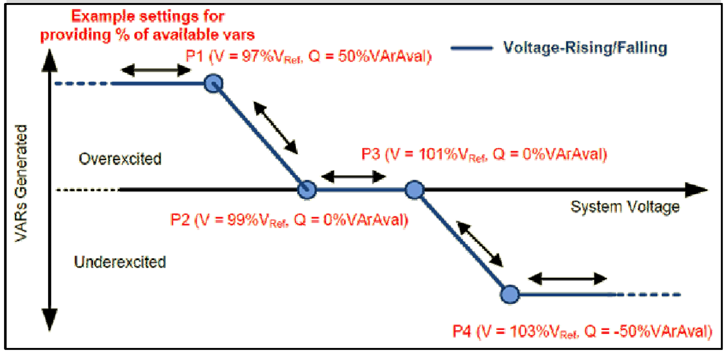
Volt/Var Curve



Test Parameters

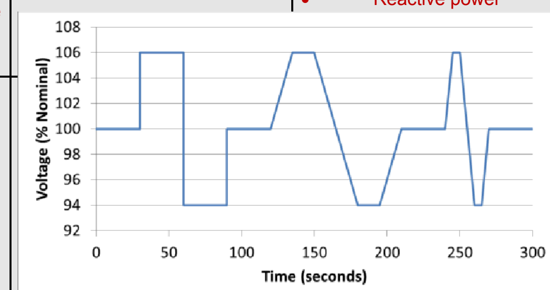
Volt/Var Initiation	Volt/Var [V,Q] Array				Requested Ramp Time (% VArAval/s)	Time Window for Randomization (seconds)	Timeout Period to Reach 95% of Target (seconds)
Binary, 1	V1	97	Q1	50	-	-	-
	V2	99	Q2	0			
	V3	101	Q3	0			
	V4	103	Q4	-50			
Binary, 1	V1	97	Q1	50	25	-	-
	V2	99	Q2	0			
	V3	101	Q3	0			
	V4	103	Q4	-50			
Binary, 1	V1	97	Q1	50	50	-	-
	V2	99	Q2	0			
	V3	101	Q3	0			
	V4	103	Q4	-50			
Binary, 1	V1	97	Q1	50	-	60	-
	V2	99	Q2	0			
	V3	101	Q3	0			
	V4	103	Q4	-50			

Data Collection

Command/Action	Command Send Time (seconds)	EUT Response (seconds)	Time Stamped Data from Volt/Var Test Profile and EUT Response
DS93 Request			
VV11 Parameter Set 1			
DS93 Request			
VV11 Parameter Set 2			
DS93 Request			
VV11 Parameter Set 3			
DS93 Request			
VV11 Parameter Set 4			
. . .			

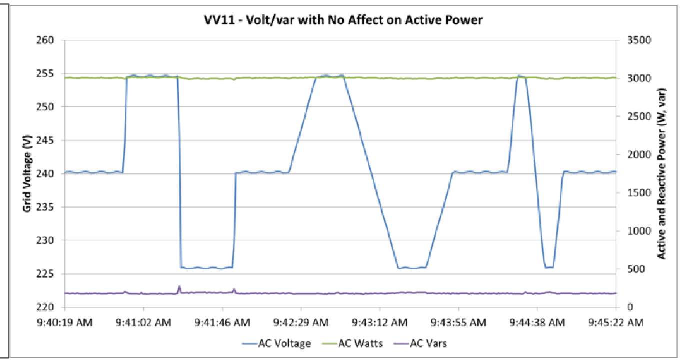
Test Procedure

	Step	Task	Function	Notes
Communication	1	Utility requests status from EUT.	DS93 – Status Reporting	Log time sent.
Communication	2	Utility receives response to the command.		Log time received.
Communication	3	Utility issues a Volt/Var VV11 Command to EUT.	VV11 – Volt/Var	Log time sent. Command may include the following parameters: • Requested ramp rate (optional) • time window (optional) • timeout period (optional)
Communication	4	Utility receives response to the command.	–	Expected response message: • Successful • Rejected (includes reason)
Electrical Behavior	5	If Success response received, verify command was successfully executed by varying the voltage profile according to Table A6-3 and Figure A6-2, using the grid simulator.		Monitor and record electrical output of EUT. • Voltage • Active power • Reactive power
Electrical Behavior	6	Repeat test with varying parameters as described in Table A6-2. Each test should be repeated until behavior of the EUT is reasonably understood. Test the time out period by rerunning the test profile in Figure A6-2.		
Analysis	7	Characterize EUT's response.		Determine if command was executed correctly.



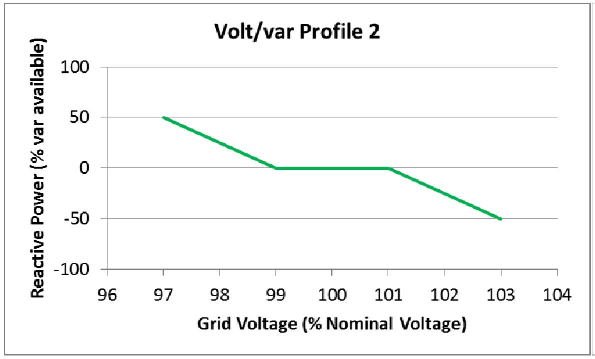
VV11 – Electrical Characterization Results

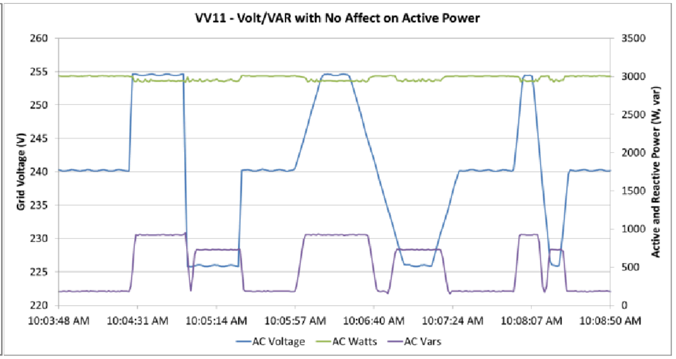
Constant PF = 1.00



Baseline Test Case

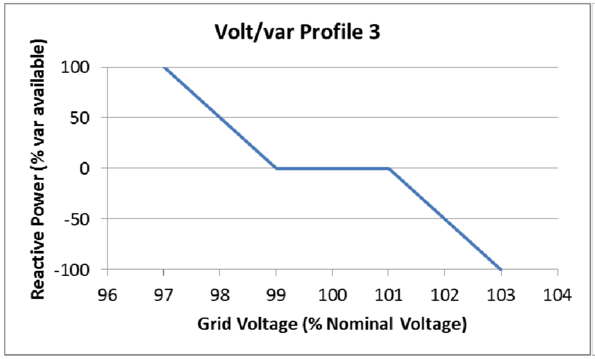
- No change in vars to compensate for grid voltage changes.

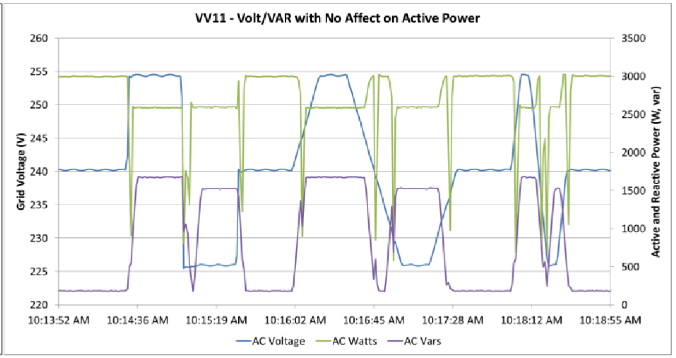




±50% VarAval

- Smooth transitions between cap/ind regions in the volt/var curve.

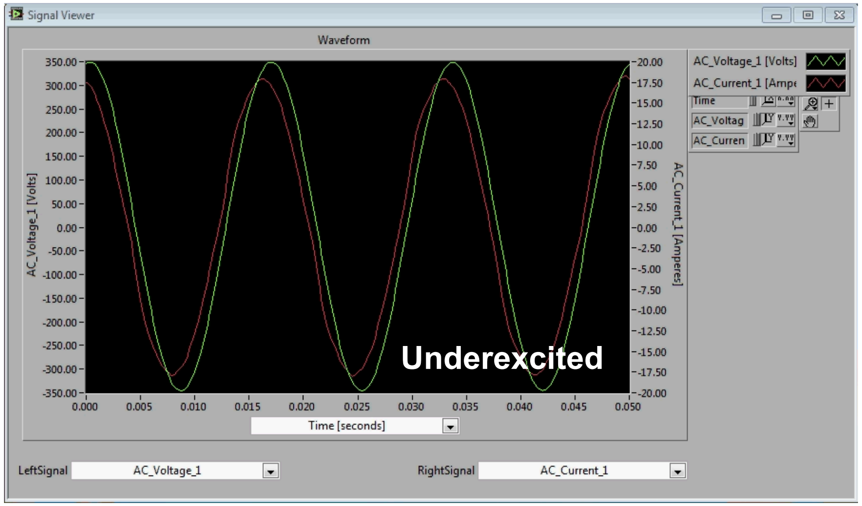


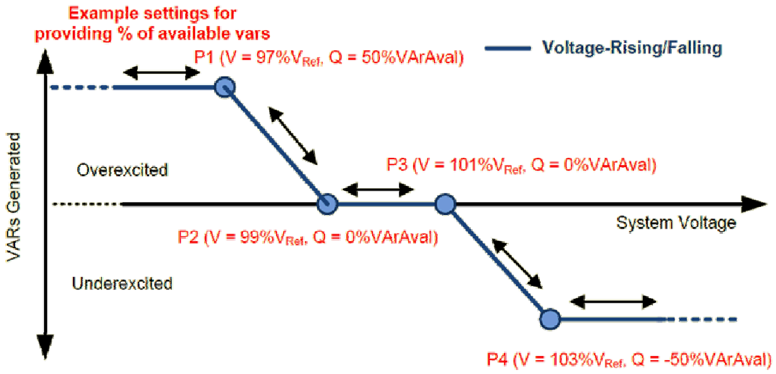


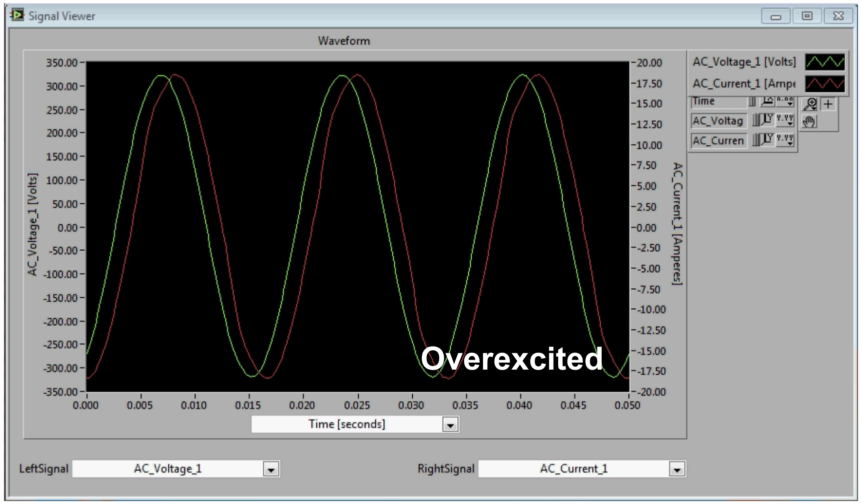
±100% VarAval

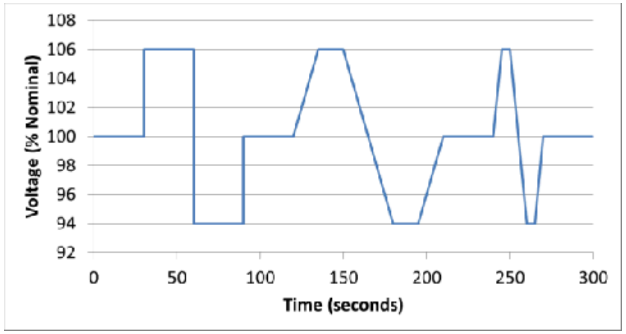
- Larger reactive power production
- Inverter turns off (reduces output current to 0) frequently.
- Recommend tests at inverter limits to find these issues.

Volt/Var Waveforms









INV3 – Adjust PF to Constant

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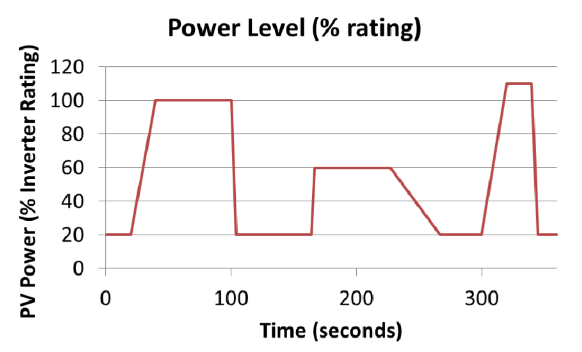
Irradiance Curve from PV Simulator



Test Matrix

Power Factor (INV3)	Ramp Rate (%/sec)	Timeout Period (sec)	Time Delay (sec)
1.00 (default)	Default	Default	0 sec
MaxPFAval (e.g. 0.80)	Default	600	60
MinPFAvail (e.g. -0.80)	Default	Default	300
0.5+MaxPFAval/2 (e.g. 0.90)	10	Default	Default
0.5-MinPFAvail/2 (e.g. -0.90)	Default	1800	Default

Note: PF range for this inverter is 0.85 to -0.85, so the test would look like the following:

Power Factor (INV3)	Ramp Rate (%/sec)	Timeout Period (sec)	Time Delay (sec)
1.00	Default	Default	0 sec
0.85	Default	600	60
-0.85	Default	Default	300
0.93	10	Default	Default
-0.93	Default	1800	Default

Test Procedure

	Step	Task	Function	Notes
Communication	1	UMS requests status.	DS93 (Status Reporting) & DM (direct Measurement) of EUT output	Log time sent.
	2	UMS receives response to DS93 command		Log time received
	3	Inverter EUT output is measured and logged		
	4	Issue Adjust Power Factor Command.	INV3 – Adjust Power Factor	Log time sent. Commands to include at least three power factors: • unity • 0.9 underexcited • 0.9 overexcited Command includes the following parameters: • requested ramp rate (optional) • time window (optional) • timeout period (optional)
	5	EUT responds to command.	DS92 – change in status noted	Log time received. Expected response from EUT: • Successful (DS92 status change logged and DM monitored output) • Rejected (includes reason)
Electrical Behavior	6	Verify command was successfully executed. (DS92 and DM). Conduct the test while varying input PV power according to Table A3-3, Figure A3-1.		Monitor output power factor level to determine if output is adjusted correctly. • Measure power and power factor • Determine ramp rate of response • Record time For three-phase EUTs observe all three phases.
	7	Repeat test with optional parameters (Table A3-4). Each test should be repeated until behavior of the inverter is reasonably understood.		Requested ramp time settings: • not included • lower range setting • higher range setting Time window settings: • 0 • not included • lower range (e.g., 1 minute) • higher range up to 5 minutes Timeout period settings: • not included • 5 minutes • 15 minutes [Note: Longer time window and timeout periods are possible; however, test duration may become unreasonable]
Analysis	8	Characterize EUT's response.	DS92; DM	Determine how command was executed. Verify compliance with time window, ramp rate, time delay, as appropriate

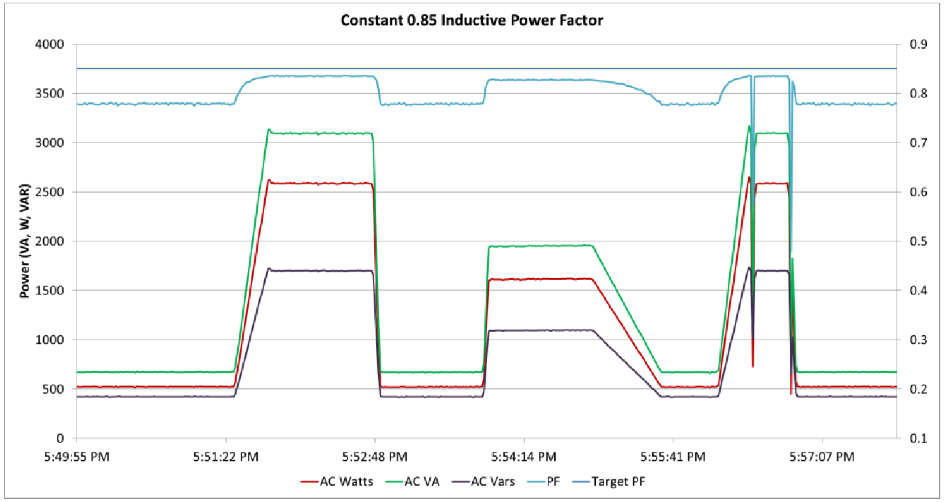
INV3 – Electrical Characterization Results

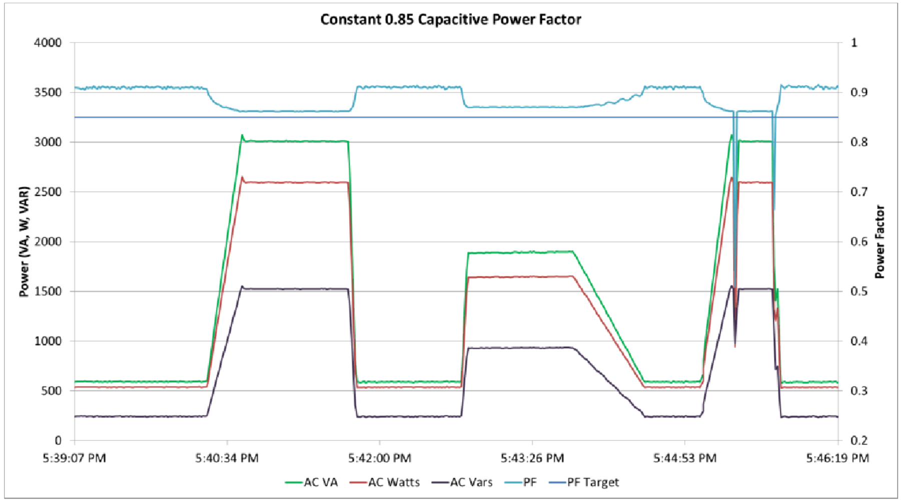
0.85 (Inductive) Power Factor

- Undershoots the target power factor.
- Inverter loses the MPPT when the PV simulator provides more power than the inverter rating: 3300 Wp at the 1100 W/m² level.

0.85 (Capacitive) Power Factor

- Overshoots the target power factor.
- Same trouble with MPPT at 3300 Wdc.





Inductive Power Factor - Powers and Efficiencies

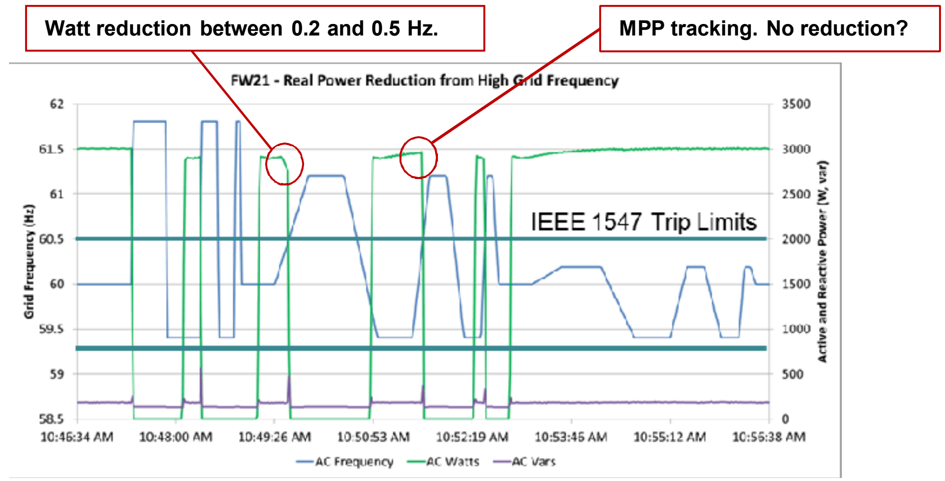
	PF = 1.00		PF = 0.97		PF = 0.94		PF = 0.91		PF = 0.88		PF = 0.85	
	Targ.	Act.	Targ.	Act.	Targ.	Act.	Targ.	Act.	Targ.	Act.	Targ.	Act.
Complex Power (VA)	3000	3000	3000	3080	3000	3085	3000	3090	3000	3090	3000	3095
Real Power (W)	3000	3000	2910	2960	2820	2864	2730	2770	2640	2680	2550	2583
Reactive Power (var)	0	215	729	860	1024	1145	1244	1365	1425	1545	1580	1705
Power Factor	1.000	0.997	0.970	0.961	0.940	0.930	0.910	0.900	0.880	0.860	0.850	0.830
Efficiency (%)		94.7%		94.2%		93.9%		93.7%		93.5%		93.6%

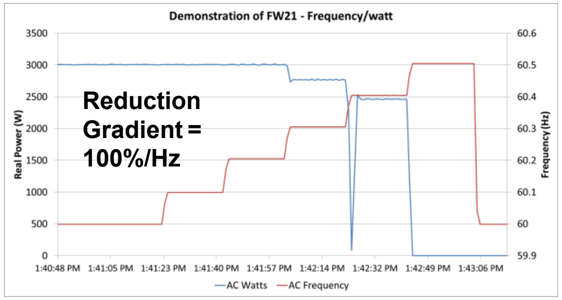
Capacitive Power Factor - Powers and Efficiencies

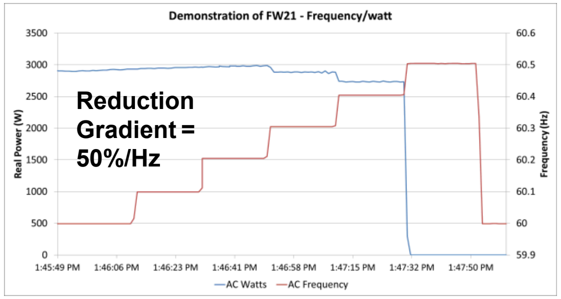
	PF = 0.97		PF = 0.94		PF = 0.91		PF = 0.88		PF = 0.85	
	Targ.	Act.	Targ.	Act.	Targ.	Act.	Targ.	Act.	Targ.	Act.
Complex Power (VA)	3000	3026	3000	3025	3000	3015	3000	3010	3000	3015
Real Power (W)	2910	2955	2820	2875	2730	2780	2640	2685	2550	2595
Reactive Power (var)	729	655	1023.5	945	1244	1155	1425	1360	1580	1525
Power Factor	0.970	0.976	0.940	0.950	0.910	0.923	0.880	0.892	0.850	0.862
Efficiency (%)		94.9%		95.1%		95.1%		95.5%		95.5%

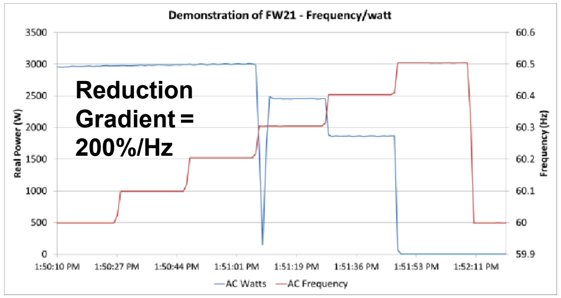
FW21 – Frequency/watt

- Cannot test FW21 with the Sandia Test Protocol because the inverter turns off at the IEEE 1547 frequency trip limits.
  - Can adjust these limits to different values (e.g., IEEE 1547a), but one of the points is not programmable [9 cycles at 60.48 Hz]
  - Error in the firmware?
  - As shown in the tests to the right, the inverter shuts off per IEEE 1547 limits.
- Other issue is that this is based on limited curve with a single variable (Reduction Gradient in %/Hz).

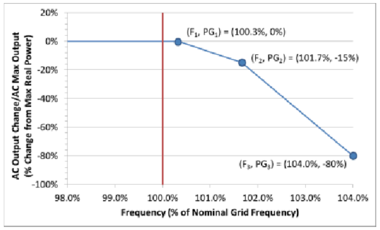






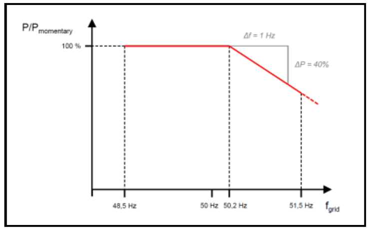


Stepping up the grid frequency by 0.1 Hz increments for 20 seconds shows the power reductions for different frequencies.



IEC 61850-90-7 FW21 Curve

≠

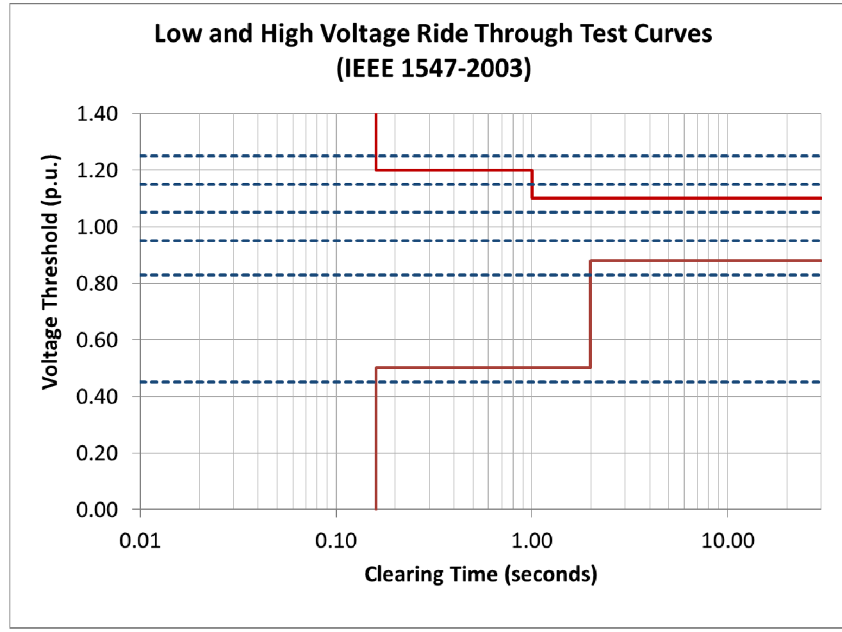


Inverter FW21 Curve

Low and High Voltage Ride-Through

Sandia National Laboratories

- Sandia changed the L/H VRT values within the inverter without any change in the trip behavior.
- The inverter is still functioning with the IEEE 1547 trip levels.

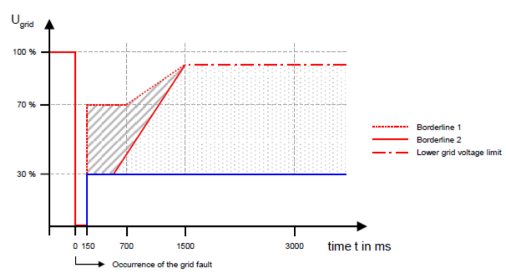


Can do this test. →

Can't do these tests. →

Update L/HVRT Command	Must Trip Upper Limit				May Trip Upper Limit				Must Trip Lower Limit				May Trip Lower Limit			
Binary, 1 (IEEE 1547)	t_1	0.16	V_1	2.00					t_1	0.16	V_1	0.00				
	t_2	0.16	V_2	1.20					t_2	0.16	V_2	0.50				
	t_3	1.00	V_3	1.20					t_3	2.00	V_3	0.50				
	t_4	1.00	V_4	1.10					t_4	2.00	V_4	0.88				
	t_5	30.00	V_5	1.10					t_5	30.00	V_5	0.88				
Binary, 1 (Proposed IEEE 1547)	t_1	0.16	V_1	2.00	t_1	0.10	V_1	2.00	t_1	0.16	V_1	0.00	t_1	0.10	V_1	0.00
	t_2	0.16	V_2	1.20	t_2	0.10	V_2	1.17	t_2	0.16	V_2	0.45	t_2	0.10	V_2	0.50
	t_3	1.00	V_3	1.20	t_3	12.00	V_3	1.17	t_3	11.00	V_3	0.45	t_3	10.00	V_3	0.50
	t_4	1.00	V_4	1.10	t_4	12.00	V_4	1.07	t_4	11.00	V_4	0.60	t_4	10.00	V_4	0.70
	t_5	30.00	V_5	1.10	t_5	30.00	V_5	1.07	t_5	21.00	V_5	0.60	t_5	20.00	V_5	0.70
									t_6	21.00	V_6	0.88	t_6	20.00	V_6	0.92
									t_7	30.00	V_7	0.88	t_7	30.00	V_7	0.92
Binary, 1 (Standard PRC-024-1)	t_1	0.00	V_1	1.20					t_1	0.15	V_1	0.00				
	t_2	0.20	V_2	1.20					t_2	0.15	V_2	0.45				
	t_3	0.20	V_3	1.18					t_3	0.30	V_3	0.45				
	t_4	0.50	V_4	1.18					t_4	0.30	V_4	0.65				
	t_5	0.50	V_5	1.15					t_5	2.00	V_5	0.65				
	t_6	1.00	V_6	1.15					t_6	2.00	V_6	0.75				
	t_7	1.00	V_7	1.10					t_7	3.00	V_7	0.75				
	t_8	4.00	V_8	1.10					t_8	3.00	V_8	0.90				
	t_9	30.00	V_9	1.10					t_9	30.00	V_9	0.90				

LVRT Function in the inverter is based on the German trip curve.



Voltage Range (% of base voltage)	Maximum Clearing time(s)
V < 50	0.16
50 ≤ V < 88	2
110 < V < 120	1
V ≥ 120	0.16

Advanced Inverter Collaboration

- Within the SIRFN group
  - Initial testing presented here, should be recreated (with the addition of the communication testing piece) at AIT, RSE, and other SIRFN laboratories to compare results. Sandia proposes that the same 3.0 kW inverter used at Sandia is used for the tests at the other laboratories because it is inexpensive, easier to test (using smaller PV and grid simulators), from an international inverter manufacturer, SunSpec compliant, and contains many of the IEC functions. Other inverters can be tested as they become available.
  - Sig Gonzalez (Sandia) visited NREL in May 2013 to begin advanced inverter function testing with a domestic company's 500 kW inverter.
- SIRFN Collaborations with other groups
  - SIRFN is updating SGIP (Smart Grid Interoperability Panel) on implementation of test protocols for advanced inverter functions—ensuring there is good coverage of smart grid interoperability standardization. Note, SGIP PAP7 (Priority Action Plan 7) "Energy Storage Interconnection Guidelines" helped to draft IEC 61850-90-7.
  - Collaborating with the California Public Utilities Commission (CPUC) to determine which functions will be listed as Mandated, Recommended, and Optional DER functions for California's new Rule 21.
  - SIRFN is coordinating with IEC TC57 (Frances Cleveland) to provide testing feedback and suggesting new functions to be added to IEC 61850-90-7.

Thank you DERlab.

European Distributed Energy Resources Laboratories: Activity Report 2012/2013 highlighted the importance of SIRFN.

DERlab becomes key partner in the Smart Grid International Research Facility Network (SIRFN)

Impressions from the conference IRED 2012

A key to advancing the deployment of a smarter electric grid is the development of technologies and systems that function effectively in a variety of grid environments and locations. In order to accelerate this development, the IEA Smart Grids Action Network (ISGAN) has endorsed the Smart Grid International Research Facility Network (SIRFN), which right from its kick-off in early 2012 has been acting as a coordinated network of smart grid research and test facilities in countries participating in the ISGAN Implementing Agreement.

The need for multilateral collaboration on smart grid RD&D has been widely recognized as one of the main drives for the establishment of the European Network DERlab. Extending its activities beyond Europe, DERlab has been recognized as an establishment of strong collaborative test and evaluation capabilities that can be leveraged by the international community as a central enabler of the design and implementation of smart grids.

DERlab has been strongly supporting the development of the SIRFN network structure as well as defining its objectives from the very beginning. In this frame, DERlab team and board members have been actively participating in SIRFN events, such as the APEC-ISGAN Smart Grid Test Bed Networks Workshop held in Washington DC in January 2012, where the SIRFN work program has been defined, and a meeting with SIRFN representatives. In December 2012, DERlab and EPRI hosted a dedicated SIRFN workshop organized in the frame of the 5th International Conference on the Integration of Renewable and Distributed Energy Resources, Berlin. The objectives of the workshop were to offer an overview and an update on the SIRFN activities and how it relates to the larger ISGAN effort. Extensive discussions were also focused on the joint effort between Sandia and DERlab on inverter testing protocols, which was then used as an example of how further SIRFN activities might be organized.

In addition to DERlab's involvement in SIRFN, a number of member institutes are also actively participating in SIRFN and contributing to its activities and projects.

For further details and information on how to participate in SIRFN see the ISGAN-SIRFN website (www.iea-isgan.org) or contact the DERlab Team at office@derlab.net.

Joint SIRFN workshop organized by DERlab and EPRI in the frame of the 5th International Conference on the Integration of DER, Berlin, December 2012

Info

SIRFN

The Smart Grid International Research Facility Network (SIRFN) gives participating institutions the ablity to evaluate technologies and systems approaches in a wide range of smart grid implementation use cases using common procedures.

In the frame of joint projects, smart grid research test facilities will conduct specialized, controlled laboratory evaluations of integrated smart grid technologies focusing on topics such as renewable energy integration, EV integration, energy management, automated metering infrastructure, protection, network sensing, cyber security and similar applications.

In this way, research within each individual member country will derive the value of the unique capabilities and environments of the other partner nations. Joint projects conducted within SIRFN will accelerate the development of smart grid system technologies and enabling policies.

Areas of work identified at joint SIRFN-APEC workshop in Washington DC in 2012

The 5th International Conference on Integration of Renewable Energy and Distributed Energy Resources (IRED 2012) in Berlin, Germany, was attended by over 200 participants from 29 countries and covered the latest technical, market and policy aspects related to integration of renewable and distributed energy resources and smart grids. The conference supports the interdisciplinary discussion among different stakeholders and promotes lasting collaboration among key players from all over the world. DERlab and its members have participated in the conference organization since the first conference in 2004. The next IRED will take place in Japan in 2014.

5th International Conference on Integration of Renewable and Distributed Energy Resources
December 4-6 2012 | Berlin, Germany

- http://www.der-lab.net/downloads/derlab_activity_report_2012_2013.pdf

SIRFN Advanced Inverter Milestones

Sandia National Laboratories

Target Date	Activity	Lab
April 2013	Construct DER interoperability testbeds	All
May 2013	Identify inverter manufacturers interested in advanced inverter functionality and willing to participate in SIRFN testing.	SNL
May 2013	Design DER interoperability testbeds and share with partner labs - Hardware (e.g., PV simulator, grid simulator, communication links) - Instrumentation (sensors and data acquisition systems)	All
May 2013	Establish utility-to-DER communication protocols and connections in conjunction with the inverter manufacturer. The utility commands will change depending on the country, so different translators may need to be constructed. The inverter connection and protocol will be the same in each lab.	All
May 2013	Test PV inverters with 2 to 4 functions. These first tests will be of the following functions: INV1, VV11, FW21, and L/H VRT.	All
June 2013	Compare results from all the laboratories for the first 2-4 functions.	All
June 2013	Present preliminary results/comparisons at the SIRFN meeting in Grenoble	All
June 2013	Draft standardized test procedure and data acquisition protocol for all the functions	SNL
June 2013	Draft standardized analysis and test reporting for all the functions	SNL
July 2013	Agreement on next inverter functions to exercise	All
August 2013	Reconfigure test beds and schedules as needed	All
September 2013	Open testing to second round of participants (if necessary)	All
October 2013	Status report and deliverables (updated test procedures and data acquisition)	All
Dec 2013	Conduct 3-10 new inverter functions on one or more inverters	All
March 2014	Revise interoperability protocol based on results	SNL
March 2014	Design, construct, exercise testbed for ESS incorporation	All
March 2014	Open testing to new round of participants (if necessary)	All
June 2014	Compare results from the new functions	All
Dec 2014	Perform PV and ESS tests. Complete tests of all inverter functions.	All
June 2015	Final report on program and results.	All
Sept 2015	Use experimental results to propose a test protocol standard (IEC)	All

Discussion Items

- What specifically can SIRFN do?
  - Refine/improve Sandia Test Protocol document.
  - Validate testing procedures by testing the same inverter and comparing results.
  - Offer input to standards/certification bodies.
    - Suggest new functions to be added to the IEC technical report.

- Looking ahead to next meeting.
  - Goal 1: Establish communications with the inverter through a 3rd party platform.
  - Goal 2: Begin collaborative testing and compare results for the same inverter to demonstrate/exercise the Sandia Test Protocol.
  - Goal 3: Standardize testing for SIRFN members (data collection, etc.) and standardize reporting for interoperability results.

SunSpec Registers for Inverters

Start	End	size	R/W	Name	Type	Units	Scale Factor	Contents	Description
1	1	1	R	C SunSpec DID	uint16	N/A	N/A	101, 102, or 103	Uniquely identifies this as a SunSpec Inverter Modbus Map; 101: single phase, 102: split phase 103: three phase
2	2	1	R	C_SunSpec_Length	uint16	Registers	N/A	50	Length of model block
3	3	1	R	I_AC_Current	uint16	Amps	_SF	Measured	AC Total Current value
4	4	1	R	I_AC_CurrentA	uint16	Amps	_SF	Measured	AC Phase-A Current value
5	5	1	R	I_AC_CurrentB	uint16	Amps	_SF	Measured	AC Phase-B Current value
6	6	1	R	I_AC_CurrentC	uint16	Amps	_SF	Measured	AC Phase-C Current value
7	7	1	R	I_AC_Current_SF	int16	SF	N/A		AC Current Scale factor
8	8	1	R	I_AC_VoltageAB	uint16	Volts	_SF	Measured	AC Voltage Phase-AB value
9	9	1	R	I_AC_VoltageBC	uint16	Volts	_SF	Measured	AC Voltage Phase BC value
10	10	1	R	I_AC_VoltageCA	uint16	Volts	_SF	Measured	AC Voltage Phase CA value
11	11	1	R	I_AC_VoltageAN	uint16	Volts	_SF	Measured	AC Voltage Phase-A-to-neutral value
12	12	1	R	I_AC_VoltageBN	uint16	Volts	_SF	Measured	AC Voltage Phase B-to-neutral value
13	13	1	R	I_AC_VoltageCN	uint16	Volts	_SF	Measured	AC Voltage Phase C-to-neutral value
14	14	1	R	I_AC_Voltage_SF	int16	SF	N/A		AC Voltage Scale factor
15	15	1	R	I_AC_Power	int16	Watts	_SF	Measured	AC Power value
16	16	1	R	I_AC_Power_SF	int16	SF	N/A		AC Power Scale factor
17	17	1	R	I_AC_Frequency	uint16	Hertz	_SF	Measured	AC Frequency value