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SANDIA DER INTEROPERABILITY TEST PROTOCOLS: RELATIONSHIP TO GRID CODES AND STANDARDS

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Photovoltaic and Distributed Systems Integration

Sandia National Laboratories

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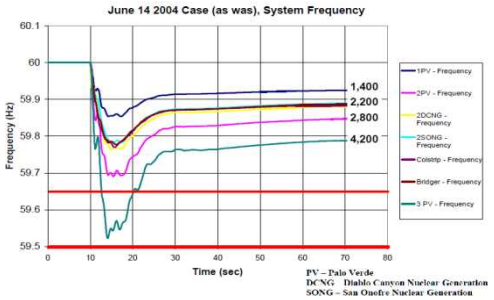
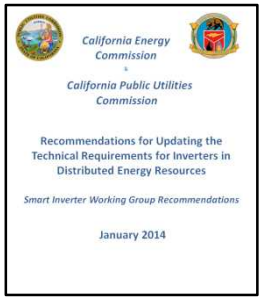
Background



High renewable energy penetrations are leading to grid voltage and frequency stability concerns.

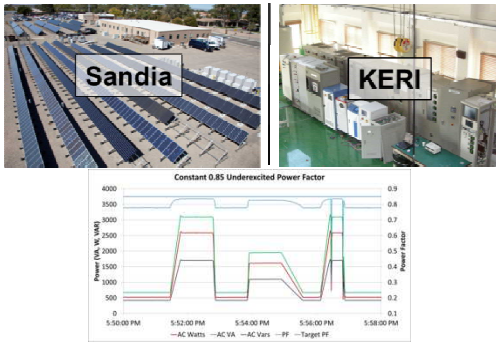
Command	Function
INV1	Connect/Disconnect
INV2	Adjust Max Generation Level
INV3	Adjust Power Factor
INV4	Request Active Power
INV5	PV/Storage Functions
VV11	Volt-Var mode
VV12	Volt-Var mode
VV13	Volt-Var mode
VV14	Volt-Var mode
FW21	Set maximum power output
FW22	Set maximum power output
TV31	Dynamic reactive 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

Based on EPRI and Sandia research, advanced interoperability DER functions are standardized in IEC 61850-90-7.

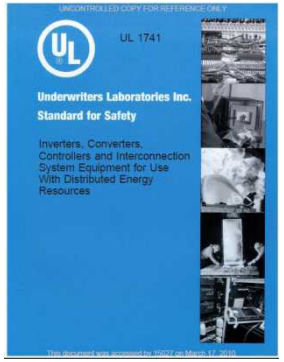


National grid codes are updated to require inverters to have advanced grid functions.

In Nov 2013, Sandia releases the Advance Interoperability Test Protocols matching the IEC functions.



Sandia and other SIRFN laboratories begin exercising the test protocols to refine the procedures, parameter selection, and number of tests.



Based on recommendations from Sandia and other industry experts, IEC and UL create certification standards for advanced DER.

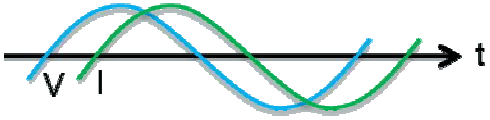
Introduction

- Test Protocols for Advanced Inverter Interoperability Functions Report
  - Creates procedures for testing the interoperability (communications) and electrical behavior of DER devices for different advanced inverter functions
  - Protocols are intended for use by:
    - manufacturers to accelerate development of the advanced functions
    - certification bodies (IEC, UL, etc.) for use as the basis for certification testing procedures.
- The Smart Grid International Research Facility Network (SIRFN) is exercising the test protocols to improve them prior to adoption by certification bodies.
- We identify gaps in the U.S., Spain, Austria, Italy, and the United Kingdom for national grid codes, and definitions and certification procedures for interoperability and advanced functionality.

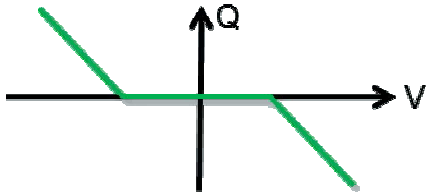
Types of Advanced Inverter Functions

Voltage Support

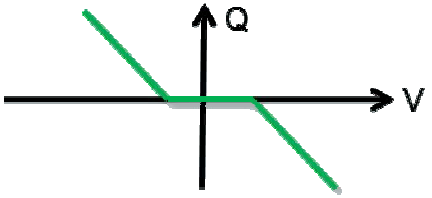
- Adjust Power Factor (INV3)



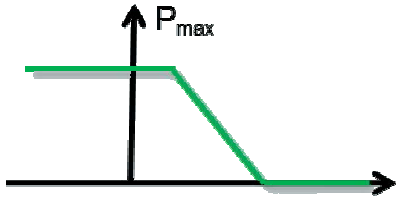
- Volt-Var Mode (VV11, VV12, VV13)



- Dynamic Reactive Power (TV31)



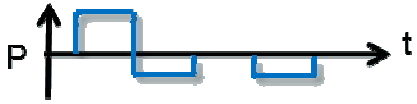
- Volt-Watt Mode (VW51; VW52)



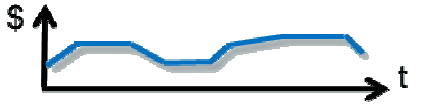
Frequency Support

- Adjust Maximum Active Power (INV2)

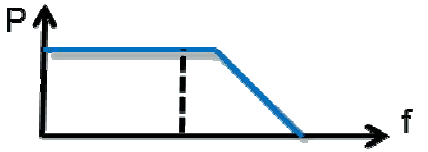
- Request Active Power from Storage (INV4)



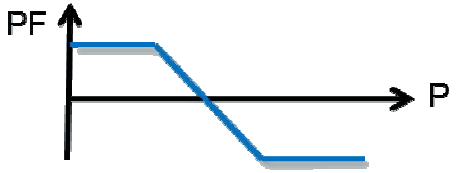
- Signal for Charge/Discharge (INV5)



- Frequency-Watt Mode (FW21, FW22)



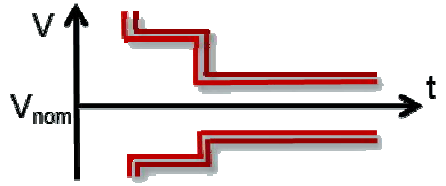
- Watt-Power Factor (WP41, WP42)



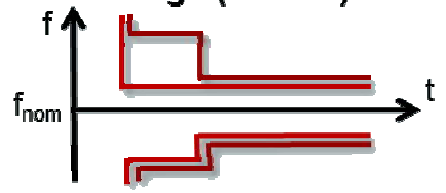
Grid Protection (Response to Disturbances)

- Connect/Disconnect (INV1)

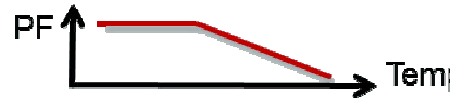
- Low and High Voltage Ride Through (L/HVRT)



- Low and High Frequency Ride Through (L/HFRT)*



- Temperature Mode Behavior (TMP)



*FRT not included in IEC 61850-90-7, but is included in Rule 21 SIWG recommendations and Sandia Test Protocols.

Sandia Test Protocols

- General guidelines for harmonized equipment testing across different laboratories
- Precursor to future equipment certification procedures.
- Two distinct phases for most advanced 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)

	Step	Task	Function	Notes
Communication	1	Utility requests status from EUT.	DS93 – Status Reporting	Log time sent.
	2	Utility receives response to the command.		Log time received.
	3	Utility issues a Volt/Var		Log time sent. Command may include the following parameters: • Requested ramp rate • time window (optional) • (optional)
	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		Monitor and record electrical output of EUT: • Voltage • Active power
	6	Repeat test with varying should be repeated until behavior of the reasonably understood. Test the time out period by returning the test profile in Figure AB-2		
Analysis		Characterize EUT response		Determine if command was

Communication (Tell the inverter what to do. Listen for a response from the inverter.)

Electrical Behavior Characterization (Electrically test the inverter to ensure the new functionality is enabled.)

Analysis (Verify inverter behavior.)

Codes and Standards

Ask experts in U.S., Spain, Austria, Italy, and the United Kingdom to provide references for any of the following codes and standards for each of the advanced functions:

1. *Grid code* - requires grid-interconnected DER to have certain advanced functionality.
2. *Advanced function definitions standard (Adv. Fcn Std.)* - defines the advanced function (parameters and operation).
3. *Advanced function certification standard (Adv. Fcn Cert. Std.)* - defines a test procedure/protocol to verify equipment functionality and certifies the DER for field deployment.
4. *Interoperability definition standard (IOP Std.)* - defines the utility-to-DER or energy management system-to-DER communications.
5. *Interoperability certification standard (IOP Cert. Std.)* - defines a test procedure/protocol to verify the communications to/from DER.

Codes and Standards for the US and Spain

= gaps in standards which the Sandia Test Protocols could fill.

	United States					Spain				
Grid Function	Grid Code	Adv. Fcn Std.	Adv. Fcn Cert. Std.	IOP Std.	IOP Cert. Std.	Grid Code	Adv. Fcn Std.	Adv. Fcn Cert. Std.	IOP Std.	IOP Cert. Std.
Connect/Disconnect (INV1)	CPUC Rule 21 (CA) [4]	IEC TR 61850-90-7 [1]		[1]			UNE 206007-1:2013 IN [15] UNE 206006: 2011 IN [16] EN50438: A9-ES [17] RD 1699:2011 [18], [1]		[15], [16], [17], [18], [1]	
Adjust Maximum Generation Level (INV2)		[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Adjust Power Factor (INV3)	CPUC Rule 21 (CA) [4]	[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Request Active Power from Storage (INV4)		[1]		[1]			[1]		[1]	
Signal for Charge/Discharge Action (INV5)		[1]		[1]			[1]		[1]	
Volt/Var Mode (VV)	CPUC Rule 21 (CA) [4]	[1]		[1]			[1]		[1]	
Frequency/Watt Mode (FW)	CPUC Rule 21 (CA) [4]	[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Dynamic Reactive Current Support (TV)		[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Low/High Voltage Ride Through (VRT)	IEEE 1547a [6]	[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Low/High Frequency Ride Through (FRT)	IEEE 1547a [6]						[15], [16], [17], [18]		[15], [16], [17], [18]	
Watt-Power Factor Settings (WP)		[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Set Output to Smooth Voltage Variations (VW)		[1]		[1]			[15], [16], [17], [18], [1]		[15], [16], [17], [18], [1]	
Temperature Mode Behavior (TMP)		[1]		[1]			[1]		[1]	
Utility Signal Mode (PS)		[1]		[1]			[1]		[1]	
Event History/Logging (DS)		[1]		[1]			[1]		[1]	
Status Reporting (DS)		[1]		[1]			[1]		[1]	

Codes and Standards for Austria, UK, and Italy

= gaps in standards which the Sandia Test Protocols could fill.

	Austria					UK					Italy				
Grid Function	Grid Code	Adv. Fcn Std	Adv. Fcn Cert. Std.	IOP Std.	IOP Cert. Std.	Grid Code	Adv. Fcn Std.	Adv. Fcn Cert. Std.	IOP Std.	IOP Cert. Std.	Grid Code	Adv. Fcn Std.	Adv. Fcn Cert. Std.	IOP Std.	IOP Cert. Std.
Connect/Disconnect (INV1)		[1]		[1]		UK Distribution Code v21 1/ 2014 Small: G83/1-1	Distribution Code DPC6.3, [1]		[1]		HV&MV CEI 0-16 [8] LV CEI 0-21 [9]	[1]		[1]	
Adjust Maximum Generation Level (INV2)	TOR D4 [7]	[1]		[1]			ETR 130 (2006) , [1]		[1]		HV&MV CEI 0-16 [8] LV CEI 0-21 [9]	[1]		[1]	
Adjust Power Factor (INV3)	TOR D4 [7]	[1]		[1]		ER G83-2 v5 Section 5.6	ER G75 Dec 2002 Section 4.8, [1]		[1]		HV&MV CEI 0-16 [8] LV CEI 0-21 [9]	[1]		[1]	
Request Active Power from Storage (INV4)		[1]		[1]			ETR 124 (2004) , [1]		[1]			[1]		[1]	
Signal for Charge/Discharge Action (INV5)		[1]		[1]			[1]		[1]			[1]		[1]	
Volt/Var Mode (VV)	TOR D4 [7] (not mandatory)	[1]		[1]			ETR 126 (2004) , [1]		[1]		HV&MV CEI 0-16 [8] LV CEI 0-21 [9]	[1]		[1]	
Frequency/Watt Mode (FW)	TOR D4 [7]	[1]		[1]		UK Distribution Code DOC 6.5	[1]		[1]		CEI 0-16 [8] (overfrequency, underfrequency in future)	[1]		[1]	
Dynamic Reactive Current Support (TV)	TOR D4 [7] (MV only)	[1]		[1]			[1]		[1]			[1]		[1]	
Low/High Voltage Ride Through (VRT)	TOR D4 [7] (MV only LVRT only)	[1]		[1]		EN 50160:2007 & 2010	BS 7671, [1]		[1]		HV&MV CEI 0-16 [8] LV CEI 0-21 [9]	[1]		[1]	
Low/High Frequency Ride Through (FRT)	TOR D4 [7]					Distribution Code DPC4.2.2.2 Distribution Code DPC7.4.1.3	ER G59/2 9.3.2,				HV&MV CEI 0-16 [8] LV CEI 0-21 [9]				
Watt-Power Factor Settings (WP)	TOR D4 [7]	[1]		[1]			ER G75 Dec 2002, [1]		[1]		HV&MV: CEI 0-16 [8] LV: CEI 0-21 [9]	[1]		[1]	
Set Output to Smooth Voltage Variations (VW)		[1]		[1]		EN 50160:2007 & 2010	BS 7671, [1]		[1]			[1]		[1]	
Temperature Mode Behavior (TMP)		[1]		[1]			[1]		[1]			[1]		[1]	
Utility Signal Mode (PS)	TOR D4 [7] (on DSO request)	[1]		[1]			[1]		[1]		HV&MV CEI 0-16 [8] LV CEI 0-21 [9]	[1]		[1]	
Event History/Logging (DS)		[1]		[1]			Distribution Code DPC7.4.2, [1]		[1]			[1]		[1]	
Status Reporting (DS)		[1]		[1]			[1]		[1]			[1]		[1]	

Conclusions

- Advanced inverter functions can help stabilize grid voltage and frequency.
- Some jurisdictions beginning to require certain 61850-90-7 functions for interconnected PV inverters and other DER.
- Based on this study there is a clear gap in certifications standards for these functions.
- Sandia Test Protocols have the potential to become the basis for the certification tests for the functions defined in IEC TR 61850-90-7.
- If the Sandia Test Protocols are used for all national and international certification test requirements, the testing procedures will be harmonized and manufacturers will not need to preform multiple versions of the certification test.

Contact Information

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