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# Test Protocols for Advanced Inverter Interoperability Functions

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# Background

- Smart Inverter Communications Project
  - EPRI-led, first launched in 2009 with support from SEPA & Sandia
  - Phase 1 completed in 2010; Phase 2 underway
- Relationship to standardization activities
  - IEC 61850-7-90 Technical Report ("Definitions Document") [1]
  - IEC 61850-7-420: Communications Systems for Distributed Energy Resources (DER) - Logical nodes
  - NIST PAP-7: Electric Storage Interconnection Guidelines)
  - IEEE 1547.X
- Follow-up activities
  - Communications Protocols Implementation
  - Laboratory Testing
  - Field Demonstrations

# Advanced Inverter 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 |
| DS 91 | 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 |

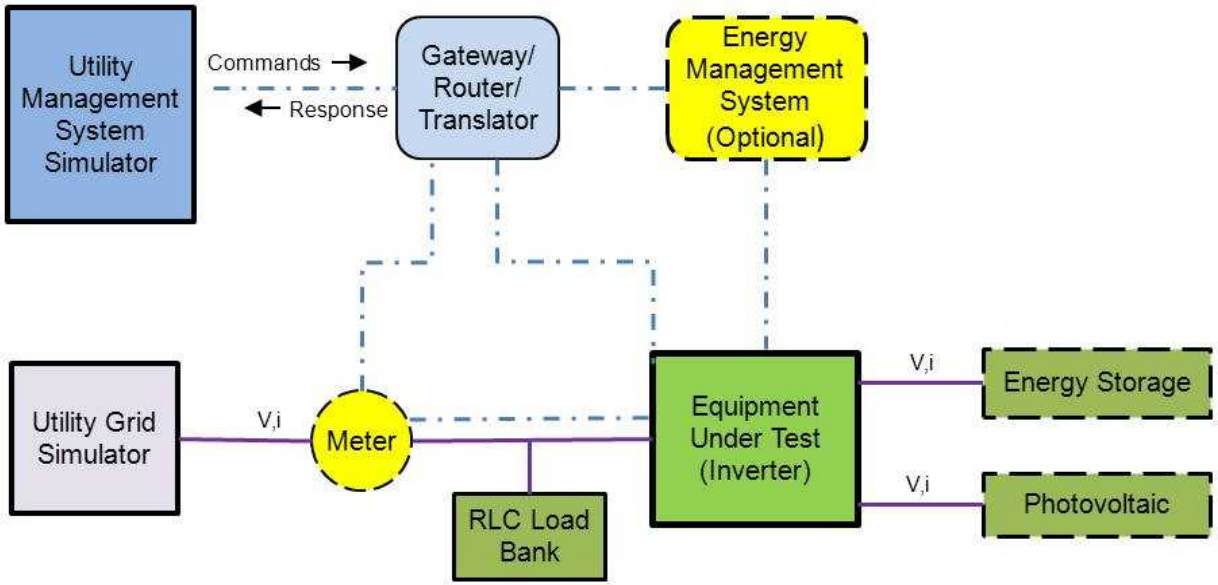
# Test Protocols Document

- The Test Protocols are DO NOT convey any of the following:
  - Equipment performance requirements for interconnection
  - Standard equipment certification procedures
  - Requirements for implementation of the Advanced Functions described in the Definitions Document

- The Test Protocols are intended to be..
  - General guidelines for harmonized equipment testing across different laboratories
  - Precursors to future equipment certification procedures

# Scope of Test Procedures

- Verification of communications interoperability
  - From the point of view of a Utility Management System Simulator
  - Communications interface could be through gateway, EMS or SM
- Characterization of electrical behavior



# Example: INV1 (Connect/Disconnect)

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***A1.1 Parameters***

- *Connect/Disconnect* is a required parameter
- *Time window* is an optional parameter in which the command is executed after a delay (random number between 0 and *Time window*)
  - If the time window is zero, the command should execute immediately.
  - If not included, then the default time window for this function will be used. The default time window is chosen by the EUT manufacturer.
- *Timeout period* is an optional parameter that defines the time after which the EUT reverts to its default status (reconnect or stay connected)
  - If not included, then the default time window for this function will be used.
  - It is only valid for the *Disconnect* command, since inverter default is to be connected
- *Requested ramp time* is an optional parameter defining the time the EUT must move become fully powered after being connected.
  - If not included, then the default ramp time for this function will be used.
  - For *Disconnect*, there will be no ramp rate parameter in the command.

# Example: INV1 (Connect/Disconnect)

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***A1.2 Test Precursors***

- The default value of the EUT is to connect when powered up.
- To test *disconnect,* the EUT is connected to the Utility or Utility Simulator with operation within normal voltage range for a minimum of 5 minutes.
- To test *connect,* the EUT is first given the *disconnect* command and executes it. The EUT remains physically but not electrically connected to the Utility or Utility Simulator for a minimum of 3 minutes (but not longer than the *Timeout period*).
- The EUT is connected to PV or PV simulator, with sufficient power available to operate the EUT above 50% of rated power.
- Communication is established between the Utility Management System Simulator (MS) and the EUT.
- Default parameters have been set in the EUT.

# Example: INV1 (Connect/Disconnect)

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### *A1.3 INV1 Test Protocol Sequence*

| | Step | Task | Function | Notes |
|---|---|---|---|---|
| Communication | 1 | Request Status to EUT. | DS93 – Status Reporting | Log time sent. |
| | 2 | Utility receives response to the command. | | Log time received. |
| | 3 | Utility issues a Disconnect /Connect Command to EUT. [note, Disconnect command must be issued first in order to test Connect command] | INV1 – Connect/ Disconnect | Log time sent.<br>Command may include the following parameters:<br>• time window (optional)<br>• timeout period (optional)<br>• ramp rate (optional) |
| | 4 | EUT receives response to the command. | – | Expected response message:<br>• Successful (includes resulting switch position)<br>• Rejected (includes reason) |

# Example: INV1 (Connect/Disconnect)

| | Stp. | Task | Notes |
|---|---|---|---|
| Electrical Behavior | 5 | If Success response received, verify command was successfully executed. | Monitor EUT output to determine if EUT connects/ disconnects and at what time.<br>• Measure voltage, current power<br>• Record time |
| | 6 | Repeat test with varying parameters (see Table A1-2). Each test should be repeated at least once as needed.<br><br>Validate that the EUT will not change state when disconnected and sent a disconnect command, and when connected sending a connect command.<br><br>Validate that the EUT will not respond to commands that are not addressed to the EUT specifically but repeating the steps with an address different from the EUTs.<br><br>Validate that the EUT will respond to the Broadcast Address (responses to the commands should not be received). | Time window settings:<br>• 0<br>• not included<br>• lower range (e.g., 1 minute)<br>• higher range (e.g., 5 minutes)<br><br>Timeout period settings for a disconnect command:<br>• not included<br>• 5 minutes<br>• 15 minutes<br><br>**Note1:** Longer time window & timeout periods are possible; however, test duration may become unreasonable<br><br>**Note2:** The Definitions Document does not address whether the PV can be used to charge storage when disconnected from the grid. However, for EUT with storage, the entire EUT (including storage) must be disconnected from the grid. |

# Example: INV1 (Connect/Disconnect)

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***Table A1- 2. Test Matrix for INV1***

| INV1 Command | Ramp Rate (watts/sec) as (% nameplate / sec) | Time Delay (secs) | Command Timeout (secs) |
|---|---|---|---|
| **Disconnect** | 0 | 0 (immediate action) | 60, 300, 900 |
| **Connect (from disconnect state)** | Default, 0.5 Default | 60, 300 | N/A |

### *A1.4 Expected Results*

- General: Determine whether the EUT properly received and interpreted the command, and how the command was executed
  - *Disconnect* Command – after the specified or default time window, measured EUT output current is zero.
  - *Reconnect* Command – after the specified or default timeout period, the EUT will reconnect (there may be a delay as EUT determines PV input is above minimum).
  - Determine if the EUT complies with all options, with immediate disconnect, reconnect delay, or if it ever reconnects after timeout period. It is assumed that the default timeout period is on the order of 5 minutes.
  - Determine if the EUT accepts/acts on optional parameters (ramp rate and time delay).

# Discussion Items

- Usefulness of test protocols
- Appropriateness as a SIRFN activity

- What specifically can SIRFN do in this area?
  - Refine / improve document?
  - Validate (e.g., round robin)?
  - Extend to other functions?
  - Offer input to standards/certification bodies

- Looking ahead to Dec 3rd workshop