Smart Inverter Testing for Autonomous Grid

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What is a Smart Inverter?

A Smart Inverter is an inverter system with additional features beyond current utility interconnection requirements.

The CPUC and CEC have jointly formed the Smart Inverter Working Group (SIWG) to identify technical changes to Rule 21 for Smart Inverters. SIWG has defined the smart inverter features recommended for adoption by the CPUC:

Phase 1 – Autonomous Operation (Adopted):
1. Low and High Voltage Ride-Through;
2. Low and High Frequency Ride-Through;
3. Dynamic Volt-VAR Operation;
4. Ramp Rates;
5. Fixed Power Factor;
6. Soft Start Reconnection;
7. Anti-Islanding Protection to reflect proposed new voltage ride-through settings;

Phase 2 – Communications Standards (Road Mapped)

Phase 3 – Advanced Functionalities some of which use Phase 2 Communications Standards (Road Mapped)
1. Watt-Frequency
2. Watt-Volt
3. Limit Real Power

UL (UL 1741 SA Draft) and IEEE (1547) are working on updating standards for Smart Inverters.
Smart Inverter Laboratory Testing:

**Laboratory Testing Effort Driven by two projects:**

*Smart Grid Volt/VAR Project (primary) – Examine interrelation between VVO and SI*

*EPIC 2.3 Smart Inverter Project – Examine both autonomous functionalities and communications methods.*

**Single-unit Testing:**
“Lab testing performed at the ATS facility will evaluate basic SI functionalities on a component (individual inverter) level under normal and abnormal conditions.”

**Group Testing:**
“Beyond those basic SI functions testing, a group use of autonomous functions of SI in close electric proximity to each other will be evaluated more qualitatively.”
**Volt/VAR with Smart Inverters:** It’s all happening on the secondary...

**Secondary is isolated by service transformer**

Transformer between primary and secondary by far the largest impedance

Two things determine how much voltage regulation is possible from a smart inverter: size of the inverter and system impedance

The Secondary is very noisy...
Smart Inverter Test Setup

The smart inverter test setup will simulate a full power secondary residential system.

Design Requirements:
- Secondary cabling impedance included
- 120/240V Single Phase Simulator
- Bi-direction power (both real and reactive)
- Frequency and voltage control
- Simulated variable system source impedance via RTDS interface

Five Major Subsystems:
1. Grid Simulator
2. Load Module
3. SI System
4. Test Setup Monitoring and Control System
5. Communication Infrastructure
Smart Inverter Test Setup – Grid Simulator

Simulation of the distribution transformer and the system impedance is achieved using a bi-directional power amplifier in combination with a high-speed real-time digital computer. This “Grid Simulator” is capable of varying voltage and frequency and capable of simulating various system source impedances.

RTDS receives frequency and RMS values from LabVIEW.
Smart Inverter Test Setup – Load Module

Load Module need to be able to simulate a load of typical residential home:

Design Requirements:
- A “residence” is two 19” racks
- cRIO provides localized monitoring and control.
- Programmable Loads permits fast dynamic load response
- 3 sets of inductors for reactive loads (1kVAR each)
Smart Inverter Test Setup – Smart Inverter System

String Smart Inverters can be installed in any of the 20 racks, micro inverter are fixed in 4 racks:

- String Inverters
- Power Supplies

Variability of Solar Irradiance is simulated by changed current limit on DC power supplies

Smart Inverter System

Micro Inverters

Power Supplies

Smart Grid Pilot Projects
Smart Inverter Test Setup – Test Setup Monitoring and Control System

All monitoring/control of the test setup is done using NI system.

Design Requirements:
• Networked distributed system: master PXI with 12 cRIO
• LabVIEW GUI interface
• Scripts can be loaded to automate testing
• Automated data storage
Smart Inverter Test Setup – Communication Infrastructure

Design Requirements:

- Network to be separate from both UDN and ODN to permit evaluation of non-standard communications systems (TICNET).
- RTAC DNP3 to Modus translator
- SSN capable to try Smart Meter interconnections.
- Wifi and Zigbee also possible
Preliminary Test Results:

**Throttling Example:** String inverter with step change in power level

![Graph showing power output over time with annotations for 75% and 65% power levels and time stamps for throttle changes.](#)
Preliminary Test Results: PF Example: Micro-inverter given step change in PF level

- Power Factor
- Power (Watts)
- Reactive Power (VARs)
- Apparent Power (VA)
Questions?