Coordinating Standards Development for Smart Grid Integration of DER – Smart Inverters and Microgrids

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The NIST Role

*Energy Independence and Security Act (2007)*

In cooperation with the DoE, NEMA, IEEE, GWAC, and other stakeholders, **NIST** has “primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…”

- NIST Framework and Roadmap
- Smart Grid Interoperability Panel (SGIP)
- SG Interoperability Testbed
High Penetration of Distributed Energy Resources

- Power Conditioning Systems (PCS) convert to/from 60 Hz AC for interconnection of renewable energy, electric storage, and PEVs

- “Smart Grid Interconnection Standards” required for devices to be utility-controlled operational asset and enable high penetration:
  - Dispatchable real and reactive power
  - Acceptable ramp-rates to mitigate renewable intermittency
  - Accommodate faults without cascading/common-mode events
  - Voltage regulation and utility-coordinated islanding

http://www.nist.gov/pml/high_megawatt/2008_workshop.cfm
PAP 7: Smart Grid ES-DER Standards

Task 0: Scoping Document
Prioritized timeline for ES-DER standards

Task 1: Use Cases, *EPRI Smart Inverter
Define requirements for different scenarios

Task 2: IEEE 1547.4 for island applications and IEEE 1547.6 for secondary networks

Task 3: Unified interconnection method with multifunctional operational interface for range of storage and generation/storage.

- IEEE 1547.8
  - (a) Operational interface
  - (b) Storage without gen
  - (c) PV with storage
  - (d) Wind with storage
  - (e) PEV as storage

Task 4: DER Object Models and Mappings
IEC 61850-7-420, -90-7: Expanded to include
- Multifunctional ES-DER operational interface
- Harmonized with CIM & MultiSpeak
- Map to MMS, DNP3, web services, & SEP 2

Task 5: Test, Safe and Reliable Implementation
UL 1741, NEC-NFPA70, SAE, CSA and IEC

http://www.sgip.org/About-PAPs
IEEE 1547 Standards Use in the USA

**IEEE 1547**
Interconnection System and Test Requirements
- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

**IEEE 1547.1**
Interconnection System Testing
- O/U Voltage and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC Injection
- Harmonics
- Islanding
- Reconnection

**UL 1741**
*Interconnection Equipment*
- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

**NEC**
- Article 690 PV Systems;
- Article 705: interconnection systems (shall be suitable per intended use per UL1741)

**PJM Interconnection, Inc.**
Small Generator Interconnection Standards
FERC approved
(0-to<10MW and 10-to-20 MW; incorporate 1547 and 1547.1)

* UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1

** Articles: 480 Storage Batteries;
692 Fuel Cell Systems;
694 Wind Electric Systems
(NEC info. based on NEC 2011)
Smart Inverter Information Model and Mapping to Protocols

1. Identify Needed Functions
2. Select a Specific Way to Implement each Function
3. Represent in Standard Information Model: IEC 61850-7-420
   - Map to Protocols: Modbus-Sunspec, DNP3, Smart Energy Profile, MMS, Web Services, Other

- Published: IEC 61850-90-7 Informative document
- Interest Group, Demonstrations, PAP7, IEEE 1547
- Smart Inverter Focus Group
- Standards Groups, Funded Efforts

courtesy: Brian Seal (EPRI)
CPUC Rule 21: Rules and Regulations for Interconnecting DER to Distribution Systems

CPUC Rule 21 - Based on IEEE 1547 Std

Phase 1: Rule 21 Amendment (Dec. ’14) Requires Smart Inverter Functions from SIWG after UL 1741 update is complete:

a. Revised Anti-Islanding Protection - consistent with support functions
b. Low/High Voltage Ride Through
c. Low/High Frequency Ride Through
d. Dynamic Volt-Var Operation
e. Ramp Rate requirements
f. Fixed Power Factor function
g. Soft Start Reconnection

Phase 2&3: Communication requirements and communication-based functions.

PAP 24: Microgrid Operational Interfaces

Task 0: Scoping Document
Define microgrid standards needs

Task 1: Use Cases: Functional + Interactive EPRI DERMS
Define requirements for different scenarios

Task 5: Smart Microgrid Controller Information Models
IEC 61850 Series: CIM, MultiSpeak

Task 2: Microgrid Interconnection standard for grid-interaction
IEEE 1547 Series

Task 3: Unified microgrid-EMS controller standard
IEEE P2030.7

Task 4: Regulatory Framework
a) State
b) Federal
c) NARUC

Task 6: Microgrid Controller and Interconnection Equipment Test
Interconnection; Info exchange; Safety; System Impact

http://www.sgip.org/About-PAPs
Use Cases for Advanced Microgrids

Control and operation functions:
1. Frequency control
2. Voltage control (grid-connected & islanding)
3. Grid-connected to islanding transition – intentional
4. Grid-connected to islanding transition – unintentional
5. Islanding to grid-connected transition
6. Energy management (grid-connected & islanding)
7. Protection
8. Ancillary services (Grid-connected)
9. Black start
10. User interface and data management

Information support functions:
1. Coordination of EPS and microgrid load shedding schemes (based on UFLS)
2. Volt/VAR control in connected mode under Normal Operating Conditions
3. Update aggregated at PCC real and reactive load-to-voltage and load-to-frequency dependencies
4. Updates of aggregated capability curves at the microgrid’s PCC
5. Updates of information on microgrid dispatchable load
6. Updates of the information on overlaps of different load management means within microgrids
7. Updates of dependencies of the components of the microgrid operational model on external conditions

courtesy: Jim Reilly (PAP 24 Leader)
IEEE P2030.7: Standard for the Specification of Microgrid Controllers


Dr. Geza Joos, McGill, Chair
Shay Bahramirad, ComEd, Vice-Chair
Alexs Dmitrovskia, ORNL, Secretary

Scope: A key element of microgrid operation is the Microgrid Energy Management System. It includes the control functions that define the microgrid as system that can manage itself, and operate autonomously or grid connected, and seamlessly connect to and disconnect from the main distribution grid for the exchange of power and the supply of ancillary services. The scope of this standard is to address the technical issues and challenges associated with the proper operation of the Microgrid Energy Management System that are common to all microgrids, regardless of topology, configuration or jurisdiction, and to present the control approaches required from the distribution system operator and the microgrid operator. Testing procedures are addressed.
There is a need to develop standardized functions for the microgrid controller and establish the relationship with the utility DMS system at the DSO level leading to technical and business processes that are both effective and replicable in many jurisdictions with increasing adoption of microgrids and DER.
February 6, 2015

Microgrids in guidance for DRPs:

**Year 1 after DRP:** Demonstration project where the Utility would serve as a distribution system operator of a microgrid:
- DERs serve a significant portion of customer load and reliability services
- operations of multiple DERs managed by a dedicated control system
- demonstrate and define necessary operational functionalities
- employ third-party and Utility-owned DER

**Phase 2b (Ongoing, 2018 and Beyond):**
- Procurement policy will be competitively neutral and will accommodate development of non-utility-owned distribution systems such as islandable microgrids and parallel direct current and thermal distribution systems.

On August 14, 2014, the Commission issued Rulemaking (R.) 14-08-013 to establish policies, procedures, and rules to guide California investor-owned electric utilities (IOUs) in developing their Distribution Resources Plan (DRP), required to be filed by July 1, 2015. This Rulemaking also intends to evaluate the IOUs existing and future electric distribution infrastructure and planning procedures with respect to incorporating Distributed Energy Resources (DERs) into the planning and operations of their electric distribution systems.

http://www.cpuc.ca.gov/PUC/energy/drp/
This whitepaper focuses on a variety of potential market and regulatory challenges that could affect the successful roll-out of DER at a large scale including:

- DER implementation in IEEE standards.
- Traditional market components that may hinder DER participation.
- Market and regulatory challenges of net metering.
- Balancing compensation for DER services with potential system impacts.
- Environmental impacts of DER and Renewable Portfolio Standards requirements.
- Regulatory issues of smart inverter technologies.
- Balancing implementation of wide-scale photovoltaic (PV) systems.
- Regulatory issues of microgrids and Plug-In Electric Vehicles.
- Balancing grid reliability and stability with a robust energy portfolio.
Backup Charts for Questions
EPRI/Sandia NL: Smart Inverter Functions

Goals/Accomplishments:
• Coordinated with IEEE P1547.8 and NIST SGIP PAP7 & SGIP DRGS
• Functions represented in IEC 61850-90-7 and eventually in IEC 61850-7-420
• Mapping to DNP3, SEP2, Modbus

Phase 1 Functions:
• Connect/Disconnect – Non Islanding
• Max Generation Level Control
• Smart VAR Management and PF
• Storage Management
• State/Status Monitoring
• Event Logging
• Time Adjustment

Phase 2 Functions:
• Voltage Ride-Through
• Autonomous Watt-Voltage Management (transient and steady-state)
• Autonomous Watt-Frequency Management
• Islanding (multiple configurations)
• Additions to State/Status Monitoring

Recently added:
• Frequency Ride-Through
• Coordinated Storage Management

Related Developments:
• DERMS (DMS functions for managing DER)
• Sunspec data exchange profile for CPUC Smart Inverter Working Group (SWIG)

http://xanthus-consulting.com/Publications/documents/
Advanced_Functions_for_DER_Inverters_Modeled_in_IEC_61850-90-7.pdf
courtesy: Brian Seal (EPRI)
Generic model: Volt-Var Control Function

Utility-Defined Curve Shapes

Volt/Var Mode 1 – Normal Regulation
Simple Broadcast

Volt/Var Mode 2 – Transmission VAR Support

courtesy: Brian Seal (EPRI)
CPUC Rule 21: Voltage Ride Through (VRT)

- VRT adopted parameters are based on actual field event data captured in Southern California with instrumentation provided by LBNL (DOE).
IEEE 1547 Standards Series

IEEE SCC21
1547 Series of Standards (as of Jan. 2015)

IEEE Std 1547™ (2003 and 2014 Amendment 1) Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547™ (full revision) Draft Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Power Systems Interfaces


IEEE Std 1547.1a™ (Amendment 1 approved in IEEE ballot)


IEEE Std 1547.6™ (2011) Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks


courtesy: Tom Basso (NREL)
Test protocols to verify conformance with respect to the functions described in IEC 61850-90-7.

Verification of compliance involves testing two performance aspects:

(1) Communications – determining if the device or equipment under test is receiving and understanding the request or input (communications);

(1) Electrical – determining if the device or equipment responds by initiating the correct commands to the electrical and mechanical equipment, and if the equipment responds properly to those control commands.
NFPA 70 - National Electrical Code
Proposed new Articles for 2017 edition

• Interconnected Power Production Sources (existing Article 705): applies to any system producing electricity and operating in parallel with the utility grid.

• Solar Photovoltaic (PV) Systems (existing Article 690): Applies to PV electrical energy systems, array circuit(s), inverter(s), and charge controller(s) for PV systems, which may be interactive with other electrical power sources (electric utility) or stand-alone with or without energy storage (batteries).

✓ Energy Storage System (proposed Article 706): Applies to all permanently installed energy storage systems (ESS) either stand-alone or interactive.

• Microgrids (proposed Article 710): Applies to microgrids including one or more electric power production sources and the interconnected loads. (Not intended for UPSs). Instead, Code Panel proposed revision of Article 705 to include stand-alone systems and the island interconnection device.

✓ DC Microgrid (proposed Article 712): Applies to power distribution system consisting of one or more interconnected dc power sources, dc-dc converters, dc loads, and ac loads powered by dc-ac inverters.
An advanced microgrid is one that provides functions at the PCC beyond basic islanding (disconnect) and synchronization (reconnection) functions. An Advanced Microgrid interacts with the larger grid (macrogrid) cooperatively managing power flows across the PCC optimizing benefits for both the microgrid and macrogrid.
Preliminary test plan for technical feasibility and economic performance of the system design/controller, due with each application submission
Test plan to cover test methodology and scenarios, and technique for data gathering and analysis (FOA evaluation criterion)

Full and detailed test plan for submission for DOE review, due 9 months after the start of an award

Review by DOE Technical Advisory Group (TAG) to ensure consistency in testing and analyzing performance of microgrid design/controller

Six months of testing and data analysis, per the DOE-approved test plan

Final technical report including test data and analysis of test results, due 90 days after expiration of the award

Will work jointly with NIST in reviewing and implementing final test plans to consistently test all microgrid system designs and controller functions from FOA projects
Microgrid Regulatory Issues

Microgrids: A Regulatory Perspective

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April 14, 2014

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http://www.cpuc.ca.gov/nr/rdonlyres/01eca296-5e7f-4c23-8570-1eff2dc0f278/0/ppdmicrogridpaper414.pdf
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http://www.cpuc.ca.gov/PUC/energy/drp/
Phase 1 (2 years, 2016-2017)
• Evaluate capacity of the distribution system to support DER under the current load forecasting scenarios.

Phase 2a (2 years, 2018-2019)
• Determine impacts on the distribution system at the substation or feeder level.
• Identify both optimal locations and combinations of DERs that can provide services in those locations.

Phase 2b (Ongoing, 2018 and Beyond)
• Stakeholder-driven development of DER procurement policy and mechanisms for the IOUs.
• Procurement policy will be competitively neutral and will accommodate development of non-utility-owned distribution systems such as islandable microgrids and parallel direct current and thermal distribution systems.

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