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

Al Hefner

National Institute of Standards and Technology

Presented at NARUC Winter Committee Meeting; February 15, 2015

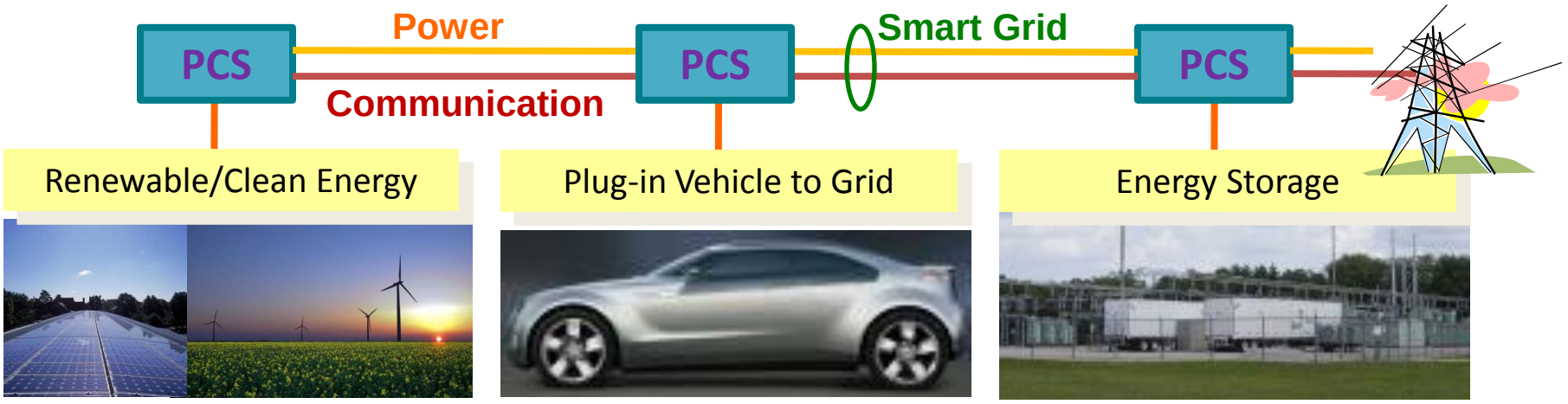
The NIST Role

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

Info exchanges

MIC

PAPs

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;

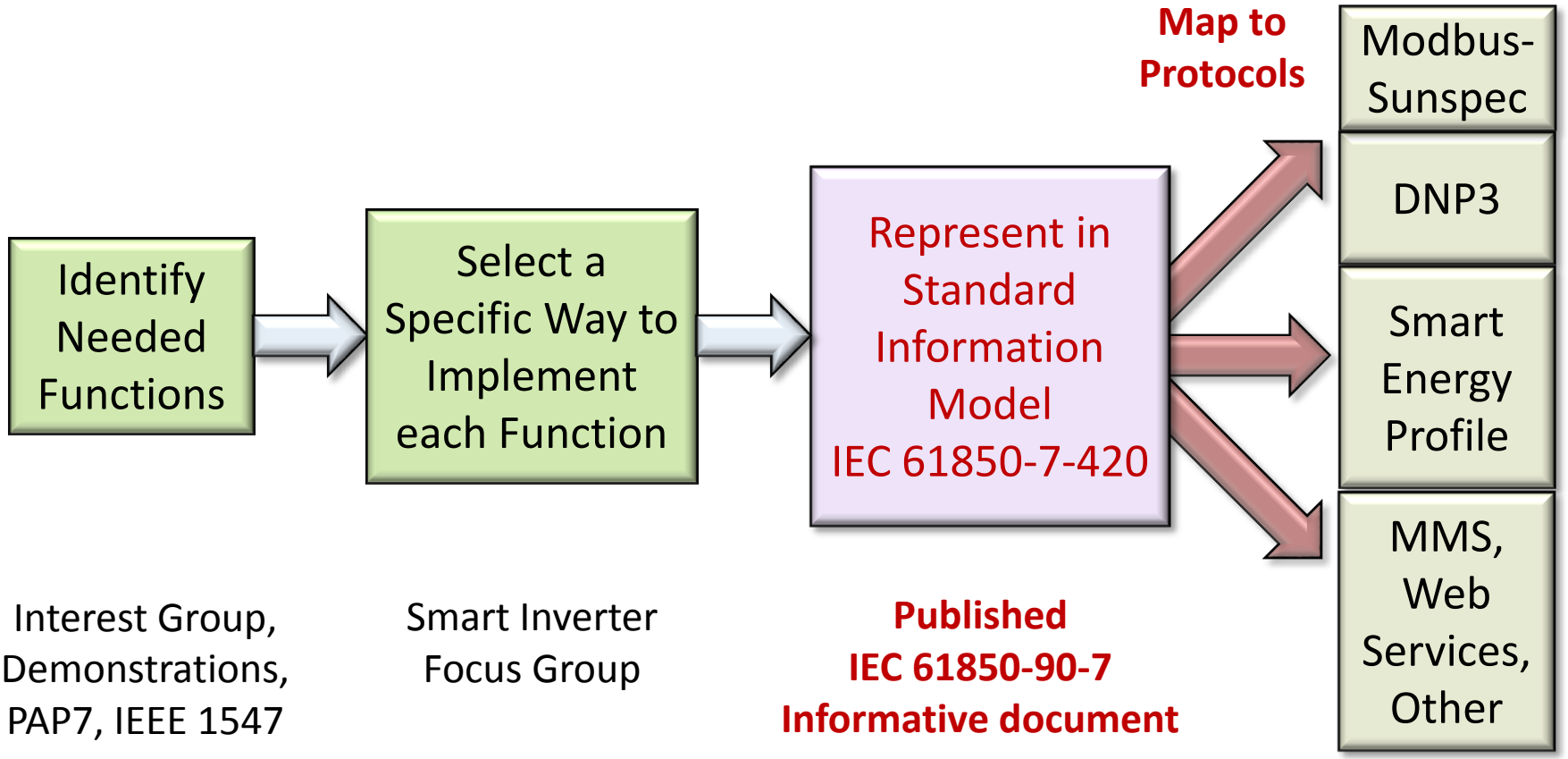
Article 705: interconnection systems (shall be suitable per intended use per UL1741)

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



Interest Group, Demonstrations, PAP7, IEEE 1547

Smart Inverter Focus Group

Published IEC 61850-90-7 Informative document

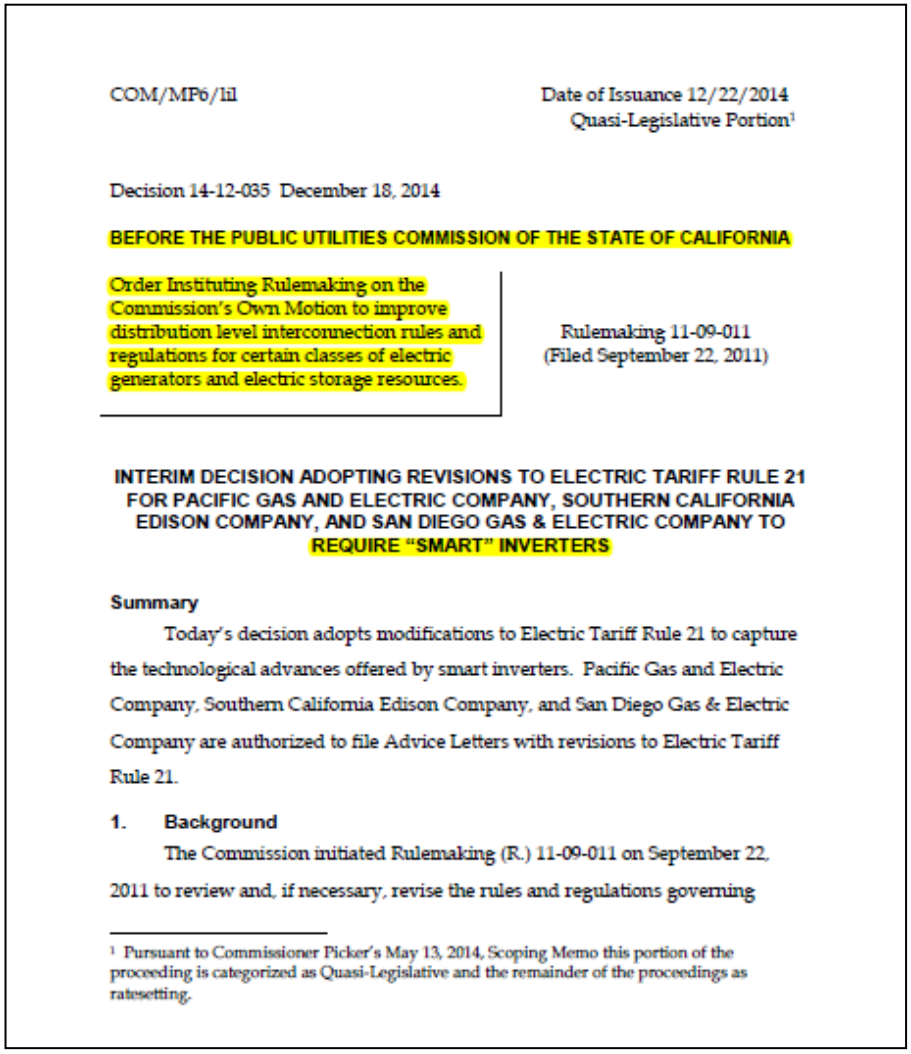
Standards Groups, Funded Efforts

EPRI ELECTRIC POWER RESEARCH INSTITUTE SEPA solar electric power association

Sandia National Laboratories

courtesy: Brian Seal (EPRI)

CPUC Rule 21: Rules and Regulations for Interconnecting DER to Distribution Systems



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Date of Issuance 12/22/2014
Quasi-Legislative Portion[1]

Decision 14-12-035 December 18, 2014

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking on the Commission's Own Motion to improve distribution level interconnection rules and regulations for certain classes of electric generators and electric storage resources.

Rulemaking 11-09-011
(Filed September 22, 2011)

INTERIM DECISION ADOPTING REVISIONS TO ELECTRIC TARIFF RULE 21 FOR PACIFIC GAS AND ELECTRIC COMPANY, SOUTHERN CALIFORNIA EDISON COMPANY, AND SAN DIEGO GAS & ELECTRIC COMPANY TO REQUIRE "SMART" INVERTERS

Summary

Today's decision adopts modifications to Electric Tariff Rule 21 to capture the technological advances offered by smart inverters. Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company are authorized to file Advice Letters with revisions to Electric Tariff Rule 21.

1. Background

The Commission initiated Rulemaking (R.) 11-09-011 on September 22, 2011 to review and, if necessary, revise the rules and regulations governing

[1] Pursuant to Commissioner Picker's May 13, 2014, Scoping Memo this portion of the proceeding is categorized as Quasi-Legislative and the remainder of the proceedings as ratesetting.

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:

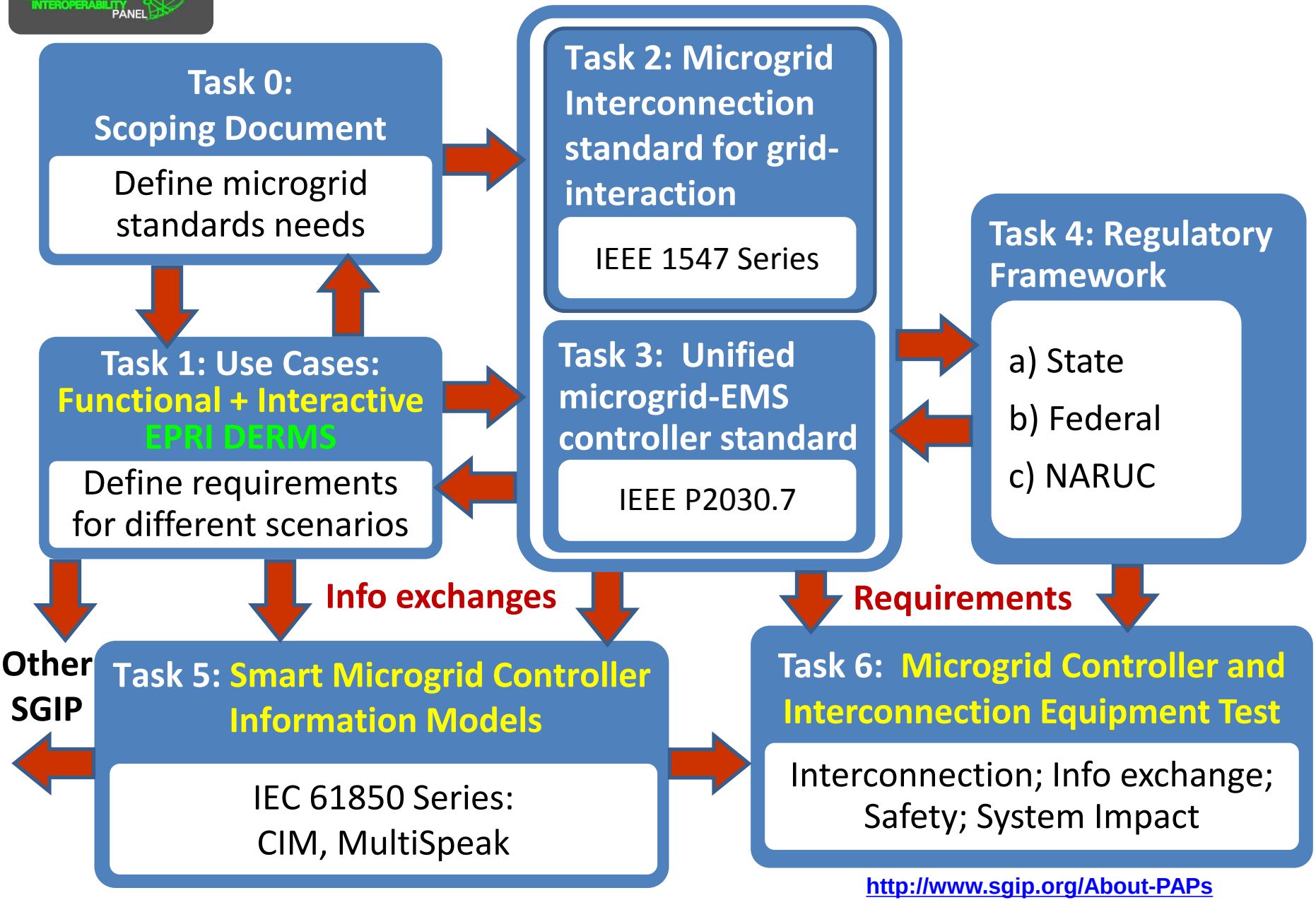
a. Revised Anti-Islanding Protection - consistent with support functions
b. Low/High Voltage Ride Through
c. Low /High Frequency Ride Through
d. Dynamic Volt-Var Operation
e. Ramp Rate requirements
f. Fixed Power Factor function
g. Soft Start Reconnection

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

http://www.cpuc.ca.gov/PUC/energy/rule21.htm/

http://www.energy.ca.gov/electricity_analysis/rule21/

PAP 24: Microgrid Operational Interfaces



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

On June 11, 2014 the IEEE SA Board approved the PAR (IEEE P2030.7), *Standard for the Specification of Microgrid Controllers*.

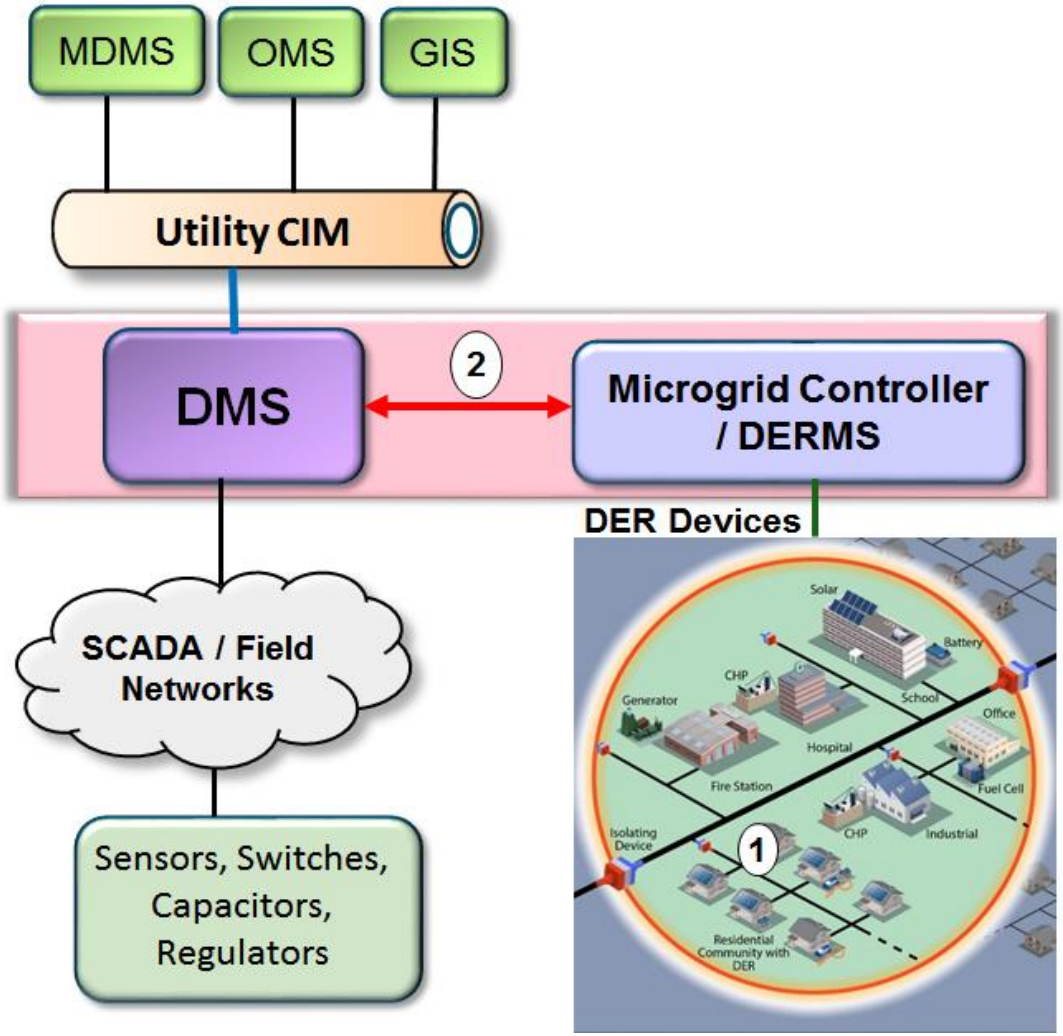
Dr. Geza Joos, McGill, Chair

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.

Relationship Between Microgrid Controller and DER Management System (DERMS)



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.

courtesy: EPRI

CPUC Rulemaking for Public Utility Code Section 769 – Distribution Resource Planning

February 6, 2015

MP6/ek4 2/6/2015

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BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking Regarding Policies, Procedures and Rules for Development of Distribution Resources Plans Pursuant to Public Utilities Code Section 769.

Rulemaking 14-08-013
(Filed August 14, 2014)

ASSIGNED COMMISSIONER'S RULING ON GUIDANCE FOR PUBLIC UTILITIES CODE SECTION 769 – DISTRIBUTION RESOURCE PLANNING

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/

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.

DRAFT White Paper: Regulatory Challenges to Deploying Distributed Energy Resources

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.

courtesy: Amanda Stallings (PUC Ohio)

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)

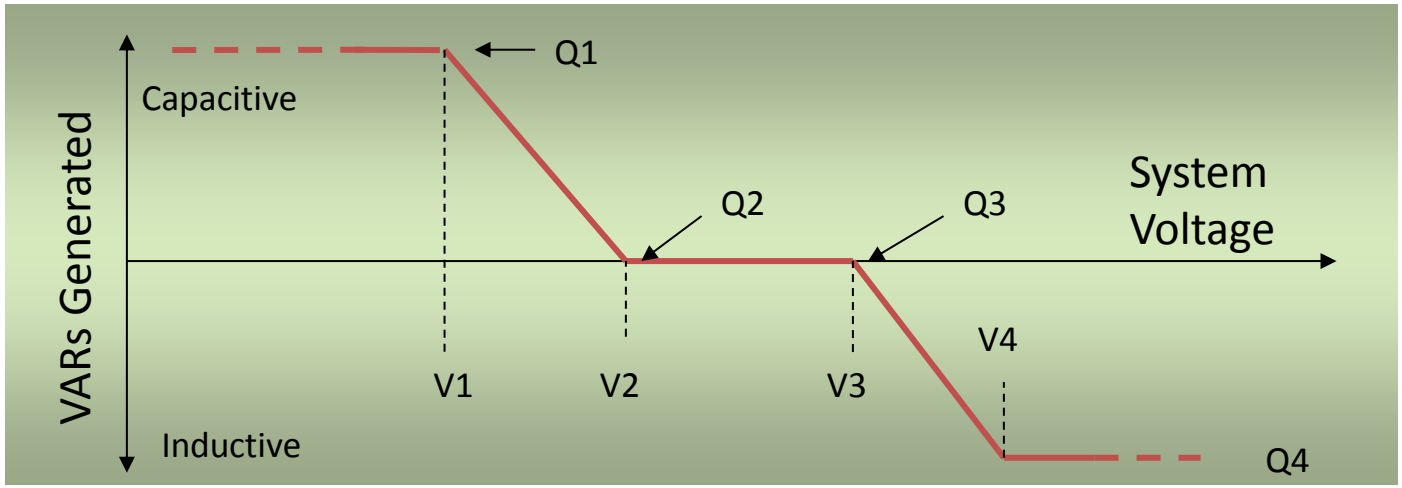
Generic model: Volt-Var Control Function

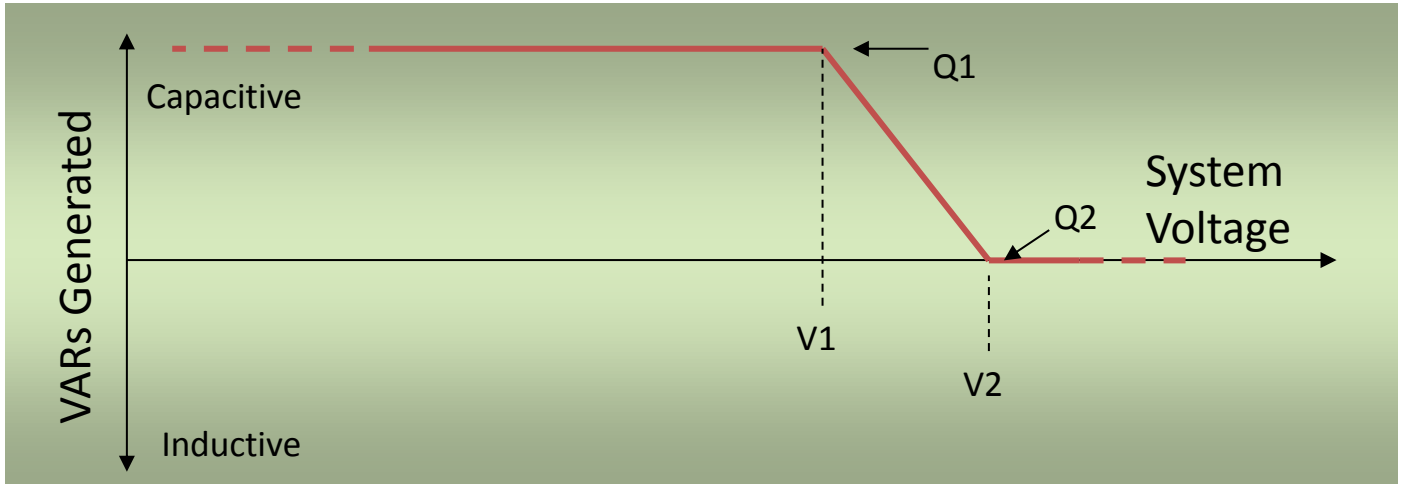
Volt/Var Mode 1 – Normal Regulation

Simple Broadcast

Volt/Var Mode 2 – Transmission VAR Support

Utility-Defined Curve Shapes

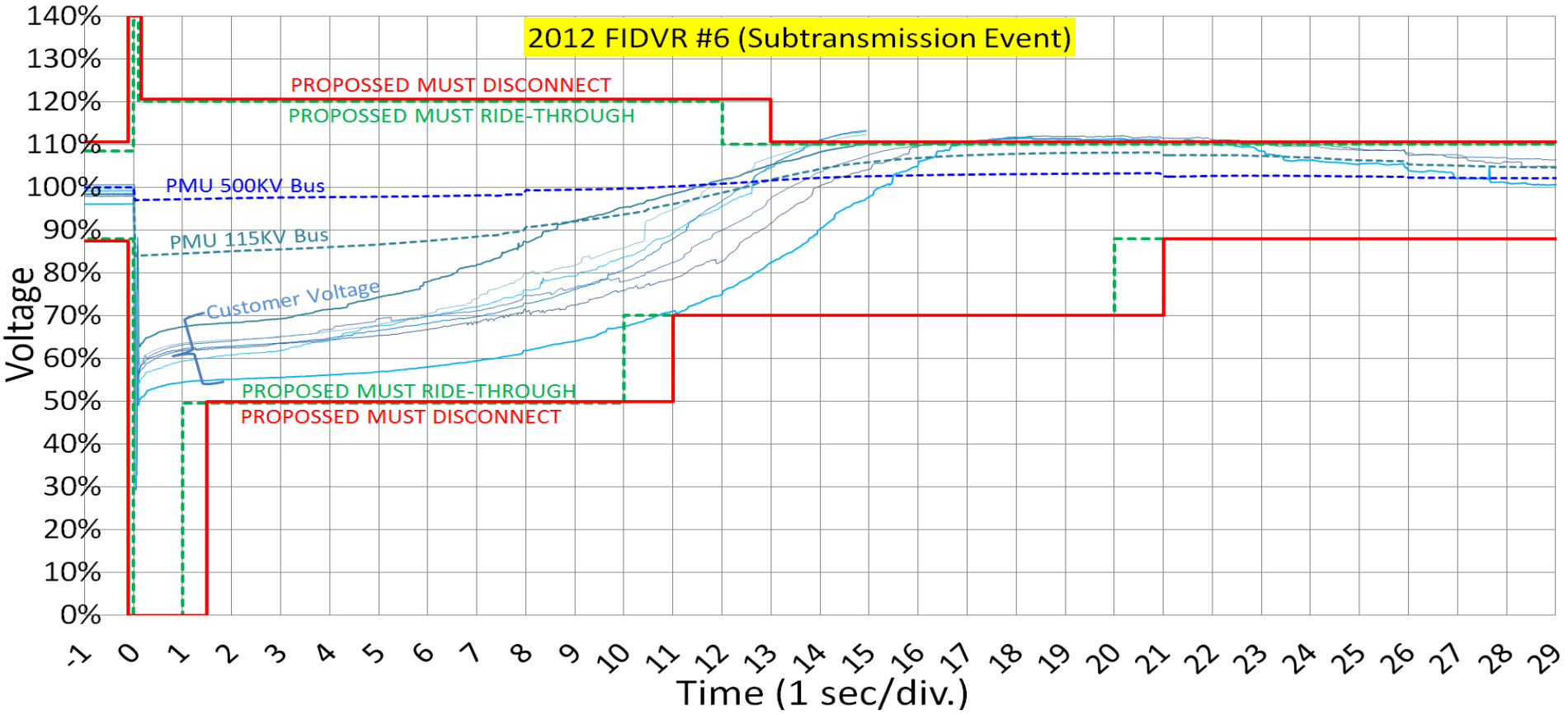




courtesy: Brian Seal (EPRI)

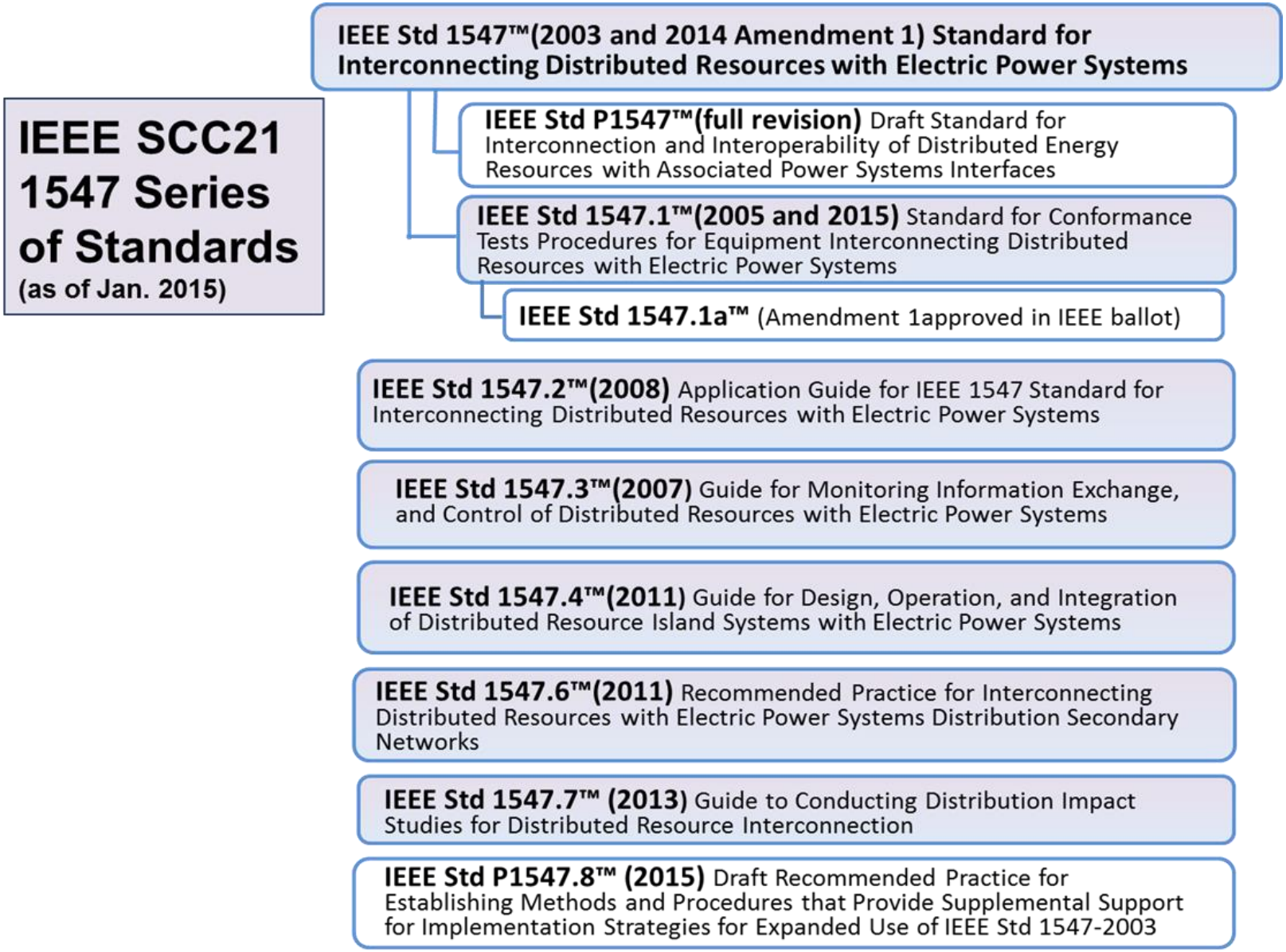
CPUC Rule 21: Voltage Ride Through (VRT)

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



courtesy: Richard Bravo (SCE)

IEEE 1547 Standards Series



courtesy: Tom Basso (NREL)

Smart Inverter Test Protocols

- **Being included in UL1741 (DER Interconnection Equipment Test) Supplement - Grid Supportive Utility Interactive Inverters & Converters**


SANDIA REPORT
SAND2013-9880
Unlimited Release
Printed November 2013

Test Protocols for Advanced Inverter Interoperability Functions – Main Document

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

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

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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).

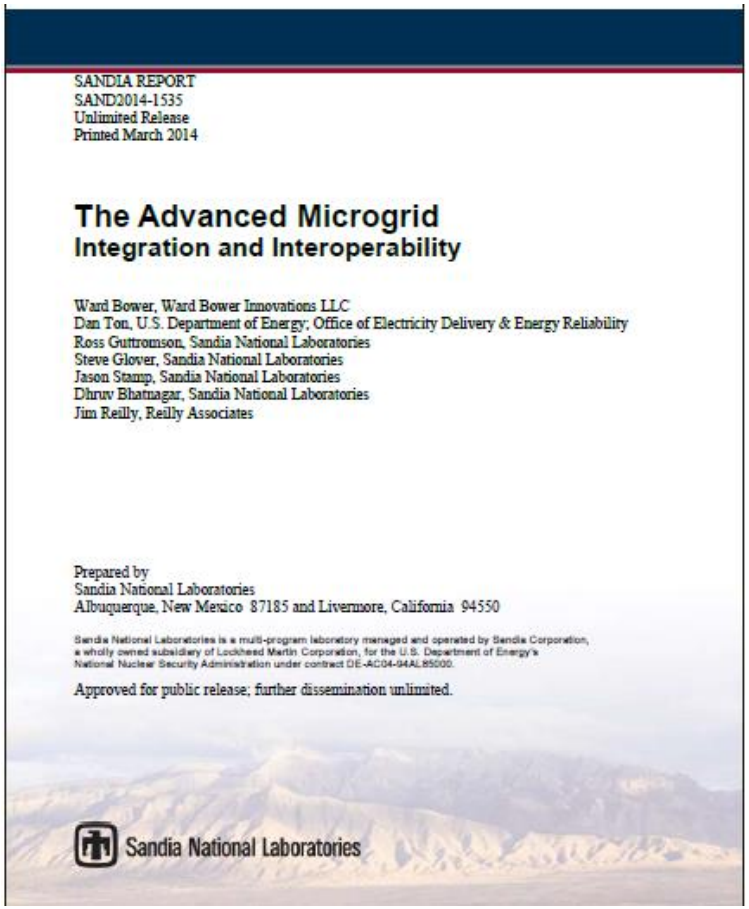
✓ **Energy Storage System (proposed Article 706):** Applies to all permanently installed energy storage systems (ESS) either stand-alone or interactive.

- **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.

The Advanced Microgrid: DOE Supported Report SAND 2014-1525

- Objectives
- Operational modes
- System architecture
- Technical challenges
- Development impact areas
- Ownership of microgrids
- Considerations for systems
- Microgrid applications
- Standards and codes
- Microcontrollers
- Smart grid interoperability panel (SGIP)
- References


SANDIA REPORT
SAND2014-1535
Unlimited Release
Printed March 2014

The Advanced Microgrid
Integration and Interoperability

Ward Bower, Ward Bower Innovations LLC
Dan Ton, U.S. Department of Energy; Office of Electricity Delivery & Energy Reliability
Ross Guttromson, Sandia National Laboratories
Steve Glover, Sandia National Laboratories
Jason Stamp, Sandia National Laboratories
Dhruv Bhatnagar, Sandia National Laboratories
Jim Reilly, Reilly Associates

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"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."

Testing of Microgrid System Design with Controller for DOE Program Activities on Microgrids (DOE OE)

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

DOE Program Activities on Microgrids and Grid Resiliency, Dan Ton, Smart Grid R&D Program Manager, DOE/OE. March 2014.

Microgrid Regulatory Issues

Microgrids: A Regulatory Perspective

California Public Utilities Commission
Policy & Planning Division

Christopher Villarreal
Principal Author
POLICY AND PLANNING DIVISION

David Erickson
Principal Author
ENERGY DIVISION

Marzia Zafar
Director
POLICY AND PLANNING DIVISION

April 14, 2014

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http://www.cpuc.ca.gov/nr/rdonlyres/01eca296-5e7f-4c23-8570-1eff2dc0f278/0/ppdmicrogridpaper414.pdf

CPUC Rulemaking for Public Utility Code Section 769 – Distribution Resource Planning

February 6, 2015

MP6/ek4 2/6/2015

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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.