US Experience with Inverter Interoperability Standardization

Jay Johnson

Sandia National Laboratories, Albuquerque, NM, USA

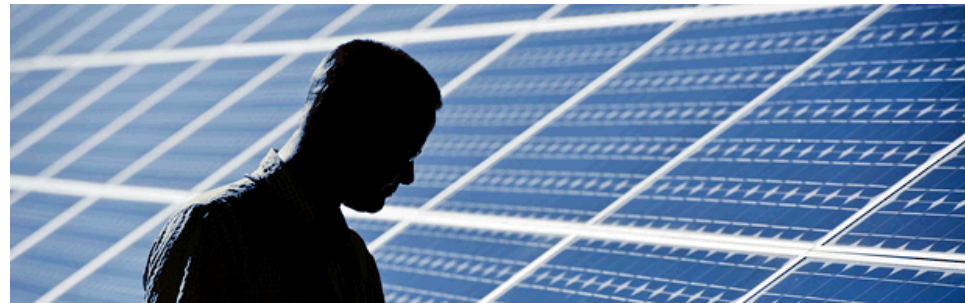**Future Distribution Grids Empowering Prosumers**
14 November 2017

International Conference for ISGAN Knowledge Exchange on Distributed Generation, Microgrids and Smart Metering

Central Power Research Institute
Bangalore, India

Introduction

- Service Models
  - Grid-support functionality
  - Mapping distributed energy resource (DER) functions to grid services

- Interoperability Requirements in the US
  - California Electric Rule 21, Phase 2
  - IEEE 1547

- Standardization Activities
  - Communication protocols
  - Certification standards

- Cyber Security
  - Need new standards for cyber security
  - Cyber security guiding reports and cyber security working group

Why communicate to inverters?

- It is increasingly difficult and expensive to integrate more renewable energy

- A big part of the solution: deployment of advanced inverters
  - Mitigate high-pen impacts and enhance value of PV to owner and grid

- Advanced inverters…
  - Actively support voltage and frequency by modulating the output
  - Have high tolerance to grid disturbances
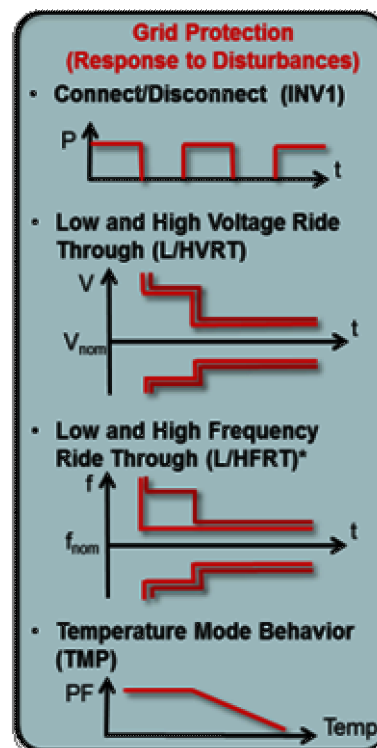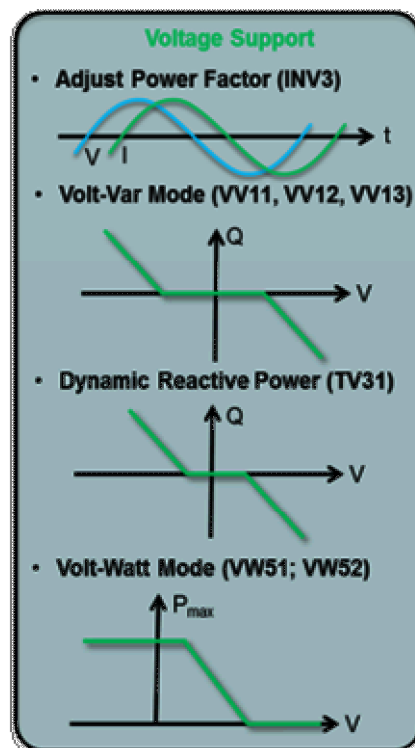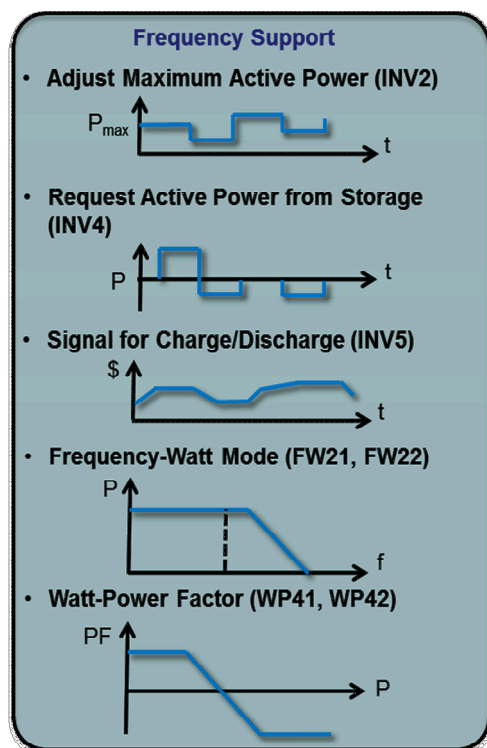 - Interact with the system via communications for optimized operations

© Solar Builder / solarbuildermag.com

…Faster than a tap changer
…More powerful than a rotating machine
…Able to leap deep voltage sags in a single bound

Courtessy of Fronius

3

Grid-Support Functions

- **Smart Inverter Functions**
  - Autonomous: Inverter response to local voltage and frequency conditions
  - Commanded: Remote control (e.g., on/off) & configure autonomous behavior

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)

Voltage Support
- Adjust Power Factor (INV3)
- Volt-Var Mode (VV11, VV12, VV13)
- Dynamic Reactive Power (TV31)
- Volt-Watt Mode (VW51; VW52)

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)

Functions defined in:
- IEC 61850-90-7 and IEC 61850-7-420
- EPRI "Common Functions for Smart Inverters" Report
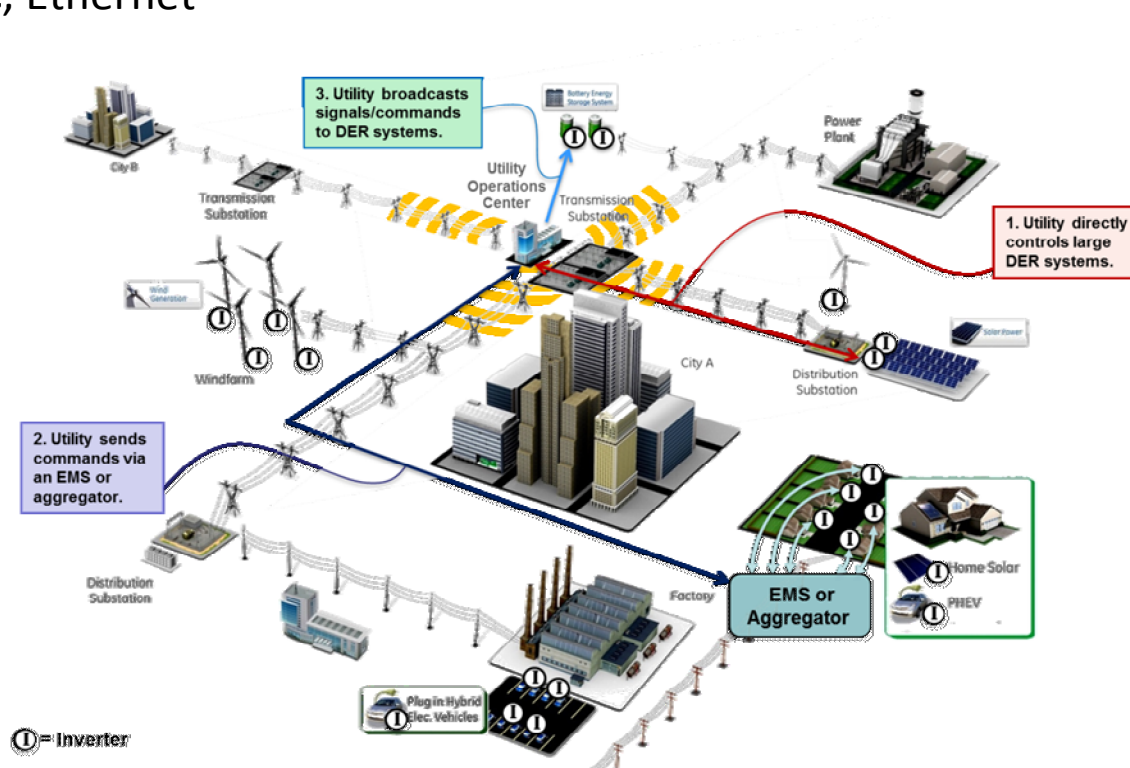- California Rule 21
- IEEE 1547 (2018 Full Revision)

Advanced functions as defined in IEC 61850-90-7.

DER Functions Help with Grid Operator Needs

Sandia National Laboratories

SIWG Economic and Technical Use Cases for Smart DER Functions, Categorized by the DRP's More-Than-Smart *"Mutually Exclusive and Collectively Exhaustive (MECE)"* List

Utility Actions — Static | Monitoring | Controlling

DER or PCC Autonomous Modes — Real Power | PF | Freq. Support | Voltage Support | Resilience

Column headers:
- Access: DER and/or PCC nameplate data
- Access: DER/PCC capabilities and supported modes
- Monitor: DER and/or PCC operational characteristics
- Monitor: Short term forecast of DER/PCC energy
- Monitor: Permitted/available DER/PCC modes
- Monitor: DER and/or PCC status & measurements
- Control: Start/stop DER
- Control: Enable/disable modes of DER/PCC
- Control: Set mode parameters and curves for DER/PCC
- Control: Schedule real power and modes of DER/PCC
- Control: Issue AGC Reg Up and Down
- Mode: Limit maximum DER real power output
- Mode: Limit maximum ESS charging rate
- Mode: Set real power output of DER or at PCC
- Mode: Set real power (dis)charging rate of ESS or at
- Mode: Load / generation following by DER or ESS
- Mode: Smoothing of real power spikes and sags
- Mode: Soft-Start Reconnection
- Mode: Fixed power factor
- Mode: Power factor correction
- Mode: High/low frequency ride-through or trip
- Mode: AGC (utility sends Reg up and down commands)
- Mode: Frequency smoothing (rapid frequency deviations)
- Mode: Frequency-watt
- Mode: High/low voltage ride-through or trip (Emergency)
- Mode: Volt-var control
- Mode: Volt-watt control (autonomous)
- Mode: Fast var support
- Mode: Dynamic reactive current support
- Mode: Backup power
- Mode: Provide black start
- Mode: Convert into microgrid

Row groups:

ISO/RTO Balancing Authority & Market
- Fixed
  - Resource Adequacy (Capacity, Generation, Bl. Start)
  - Resource Adequacy (Flexibility, Ramping, Market)
- Variable
  - Energy (shifting in time)
  - Frequency regulation
  - Frequency smoothing
  - Spinning reserve
  - Non-spinning reserve

Transmission Operations
- Fixed
  - Upgrade deferral due to congestion mitigation
- Variable
  - Transmission voltage support
  - Transmission congestion relief
  - Efficiency (loss reduction)
  - Reliability (redundancy, inertia)

Distribution Operations
- Fixed
  - Upgrade deferral due to load levels & patterns
- Variable
  - Provide distribution voltage support
  - Maintain CVR
  - Reduce number/duration of outages
  - Improve power quality (spikes, harmonics)
  - Improve efficiency
  - Avoid equipment overload, loss of life
  - Improve equipment life
  - Support safety

Customer/End User
- Fixed
  - Procurement risk mitigation
- Variable
  - Support customer choice
  - Reduce energy costs
  - Improve power quality (spikes, harmonics)
  - Avoid equipment damage
  - Support safety
  - Improve reliability (microgrids, backup power)
  - Price & performance risk mitigation

Societal
- Variable
  - Reduce CO_2 emissions
  - Reduce pollutants
  - Improve energy security
  - Improve water usage
  - Improve land usage
  - Improve economy

Control Architecture

- How will grid operators, aggregators, and smart inverters interact?

- Multiple communications solutions
  - Protocols: IEEE 1815, IEEE 2030.5, IEC 61850, SunSpec, OpenADR
  - Medium: Wi-Fi, Radio, PLC, Ethernet
  - Method: direct, broadcast

- Open challenges
  - Interoperability
  - Cyber Security
  - Optimization

➢ Sandia is collaborating with key stakeholders to address interoperability and cyber security gaps.

US Interoperability Requirements

- California Electric Rule 21 (Interconnection Standard)
  - Rollout of advanced DER functionality in three phases.
    - Phase 1 requires DER to have autonomous functions as of Sept 2017.
    - Phase 2 requires DER communications. Submitted on 20 Dec 2016 but not yet ratified by California Public Utilities Commission (CPUC).
    - Phase 3 requires communication-enabled grid-support functions. IOUs submitted advice letters to CPUC August 2017.

- IEEE 1547 (National Interconnection Standard)
  - Multi-year effort to complete 1547 full revision.
  - Ballot passed 18 June 2017 with ~1500 comments.
  - Ballot resolution team resolved comments and recirculated twice.
  - Submitting to IEEE-SA Standards Board (SASB) mid-Nov.
  - Publication expected in Q2/Q3 2018.
  - Must be adopted by public utilities commissions before it is law.
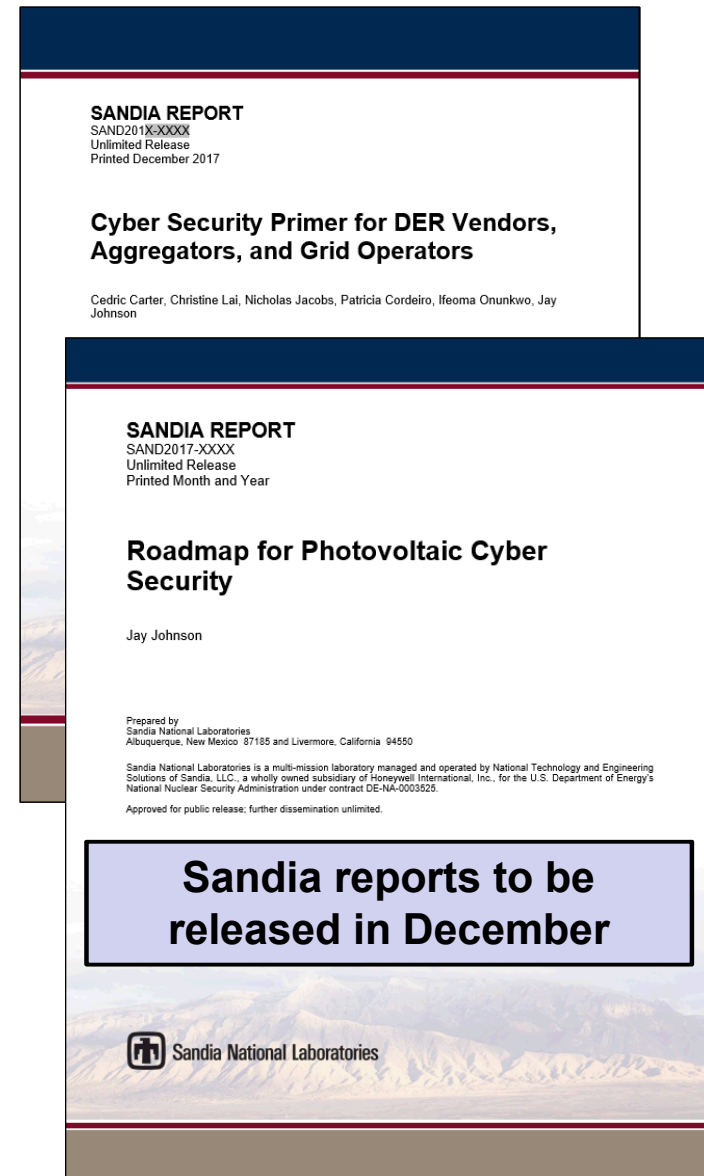
Interoperability Standards Updates

- **Communication Protocol Updates.** IEEE 1547 allows DER to communicate IEEE 2030.5 (SEP 2.0), IEEE 1815 (DNP3), and SunSpec Modbus.
    - Each of these protocols must be updated to include the functions and settings prescribed in IEEE 1547 and Rule 21 Phase 3.

- **Certification Standards Updates.** As interconnection standards are finalized, certification standards must to be created for electrical performance and communications.
    - IEEE 1547.1 is being updated to include the new IEEE 1547 functions and communications.
    - UL 1741 Supplement A was created for the CA Rule 21, Phase 1 functions.
        - It will need to be update again for IEEE 1547 and Phase 3 functions
        - Must include a communication component to the testing
    - Need certification procedures for each of the protocols – there are clear gaps.
        - SunSpec certification only checks the communications, not the electrical performance.
        - SunSpec is developing a certification program for IEEE 2030.5

- **Cyber Security Standards.** DER communications opens new cyber security risks to the power system.
    - Need new cyber security requirements for DER equipment.
    - These standards must address minimum security requirements and certification procedures to verify compliance to these requirements.
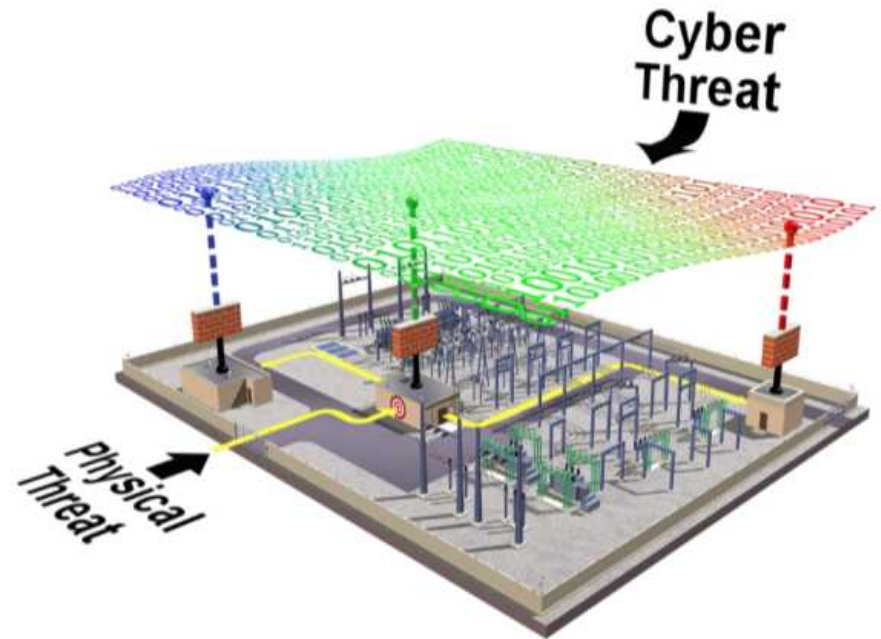
DER Cyber Security Primer and Roadmap

- Sandia producing two guiding documents.

- **Cyber Security Primer**
  - Cyber security principles
    - Confidentiality, integrity, availability, etc.
  - Types of cyber attacks and threats
  - DER communication protocols
  - Cyber security guidelines, standards, and best practices
  - DER cyber recommendations

- **Cyber Security Roadmap**
  - How PV cyber fits within the larger context of cyber security for critical infrastructure
  - Two-pronged approach:
    - Research and development
    - Stakeholder engagement
  - Intent is that this roadmap also acts as blueprint for other DER technologies

There will be opportunities for broad stakeholder input

SANDIA REPORT
SAND201X-XXXX
Unlimited Release
Printed December 2017

Cyber Security Primer for DER Vendors, Aggregators, and Grid Operators

Cedric Carter, Christine Lai, Nicholas Jacobs, Patricia Cordeiro, Ifeoma Onunkwo, Jay Johnson

---

SANDIA REPORT
SAND2017-XXXX
Unlimited Release
Printed Month and Year

Roadmap for Photovoltaic Cyber Security

Jay Johnson

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

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525.

Approved for public release; further dissemination unlimited.

Sandia reports to be released in December

Sandia National Laboratories

DER Cyber Security Working Group

- **The DER Cyber Security Working Group will bring together DER interoperability and cyber security experts to discuss security for DER devices, gateways, and other networking equipment, owned or operated by end users, aggregators, utilities, and grid operators.**

- **Primary Goal: generate a collection of best practices that act as basis for national or international DER cyber security standards.**

- Secondary Goal: facilitate DER cyber security discussions among stakeholders to exchange perspectives and gain broad buy-in from the industry.

- Sign up at http://sunspec.org/sunspec-cybersecurity-workgroup/
- Review the background materials
- Contact membership@sunspec.org for enrollment questions

Questions?

Jay Johnson

Photovoltaic and Distributed Systems Integration

Sandia National Laboratories

P.O. Box 5800 MS1033

Albuquerque, NM 87185-1033

Phone: 505-284-9586

jjohns2@sandia.gov