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US Experience with Inverter Interoperability Standardization

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Future Distribution Grids Empowering Prosumers
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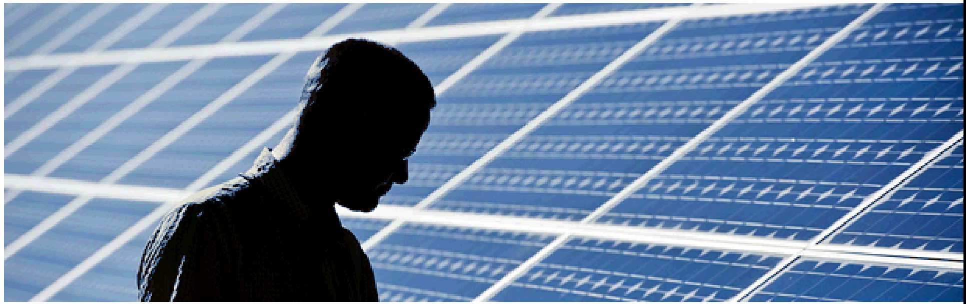
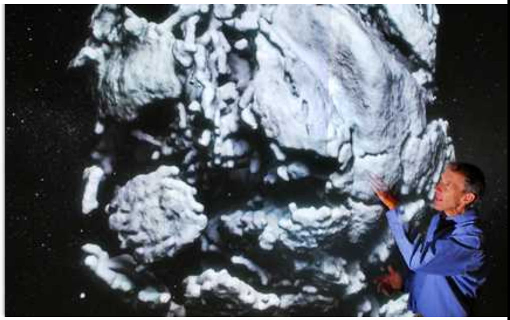
International Conference for ISGAN Knowledge Exchange on Distributed Generation, Microgrids and Smart Metering

Central Power Research Institute
Bangalore, India





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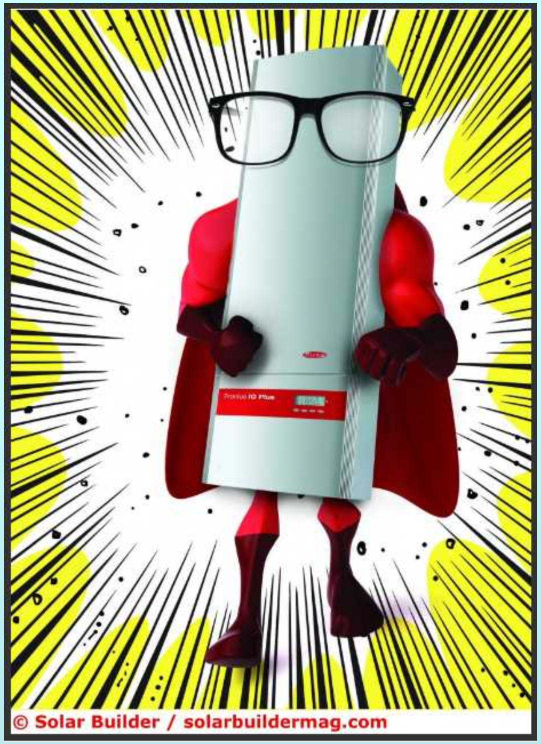
Introduction

- 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



...Faster than a tap changer

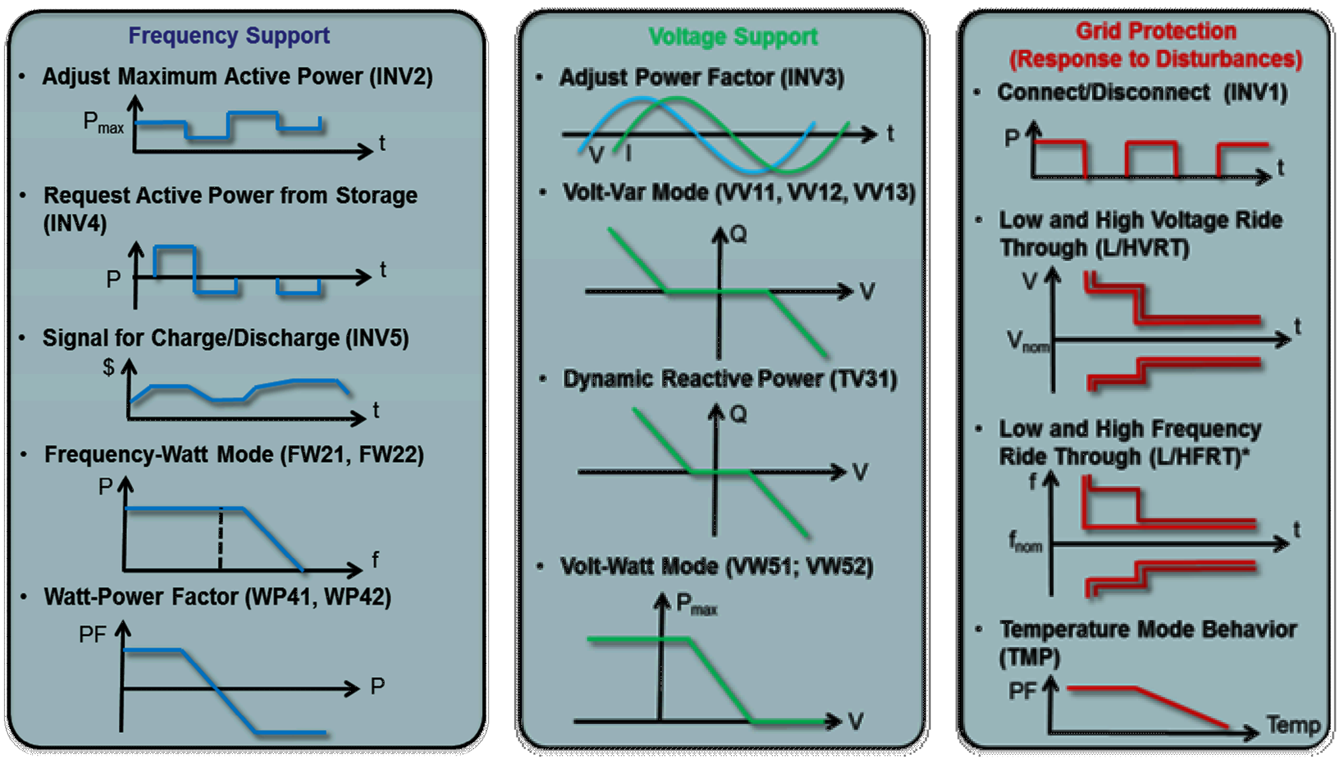
...More powerful than a rotating machine

...Able to leap deep voltage sags in a single bound

Courtessy of Fronius

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



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

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)**

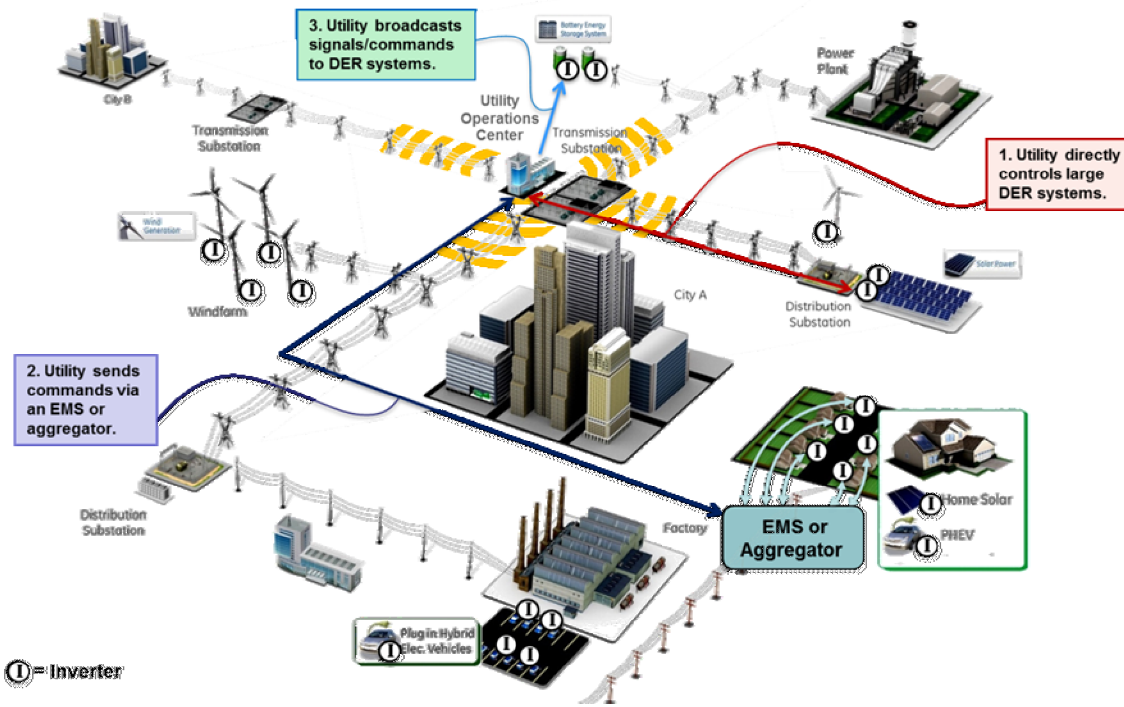
DER Functions Help with Grid Operator Needs

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	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 PCC	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 (Emergency)	Mode: High/low voltage ride-through or trip	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
	Utility Actions											DER or PCC Autonomous Modes																				
	Static		Monitoring				Controlling					Real Power							PF		Freq. Support				Voltage Support					Resilience		
ISO/RTO Balancing Authority & Market																																
Fixed																																
Resource Adequacy (Capacity, Generation, Bl. Start)	x	x					x	x	x	x																						
Resource Adequacy (Flexibility, Ramping, Market)	x	x									x	x	x	x	x	x	x	x				x	x			x	x	x	x	x	x	x
Variable																																
Energy (shifting in time)	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x																
Frequency regulation	x	x	x	x	x	x		x	x		x										x	x		x								
Frequency smoothing	x	x	x	x	x	x		x	x														x									
Spinning reserve	x	x	x	x	x	x		x	x					x	x	x								x								
Non-spinning reserve	x	x	x	x	x	x		x	x					x	x	x															x	x
Transmission Operations																																
Fixed																																
Upgrade deferral due to congestion mitigation	x	x																														x
Variable																																
Transmission voltage support	x	x	x	x	x		x	x	x	x									x	x					x	x	x	x	x			
Transmission congestion relief	x	x	x	x	x		x	x	x	x		x	x	x	x	x																
Efficiency (loss reduction)	x	x	x	x	x		x	x	x	x							x															
Reliability (redundancy, inertia)	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x
Distribution Operations																																
Fixed																																
Upgrade deferral due to load levels & patterns	x	x										x	x	x	x	x	x	x								x	x					x
Variable																																
Provide distribution voltage support	x	x	x	x	x	x	x	x	x	x									x	x					x	x	x	x	x			
Maintain CVR	x	x	x	x	x	x	x	x	x	x																x	x	x				
Reduce number/duration of outages	x	x	x	x	x	x	x	x	x	x														x	x	x	x	x	x			
Improve power quality (spikes, harmonics)	x	x	x	x	x	x	x	x	x	x															x	x	x	x	x			
Improve efficiency	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x							x	x	x	x	x			
Avoid equipment overload, loss of life	x	x	x	x	x	x	x	x	x	x															x	x	x	x	x			
Improve equipment life	x	x	x	x	x	x	x	x	x	x															x	x	x	x	x			
Support safety	x	x	x	x	x	x	x	x	x	x											x				x							
Customer/End User																																
Fixed																																
Procurement risk mitigation																																
Variable																																
Support customer choice		x	x	x	x	x	x	x	x	x			x		x	x	x		x	x		x	x	x		x	x	x		x	x	x
Reduce energy costs		x	x	x	x	x	x					x	x	x	x	x														x		x
Improve power quality (spikes, harmonics)																			x	x			x	x		x	x	x	x			
Avoid equipment damage			x		x	x	x														x				x					x		x
Support safety		x	x		x	x	x														x				x					x		x
Improve reliability (microgrids, backup power)		x	x		x	x	x																							x		x
Price & performance risk mitigation		x	x	x	x	x																										
Societal																																
Variable																																
Reduce CO2 emissions		x																														
Reduce pollutants		x																														
Improve energy security		x																														
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.

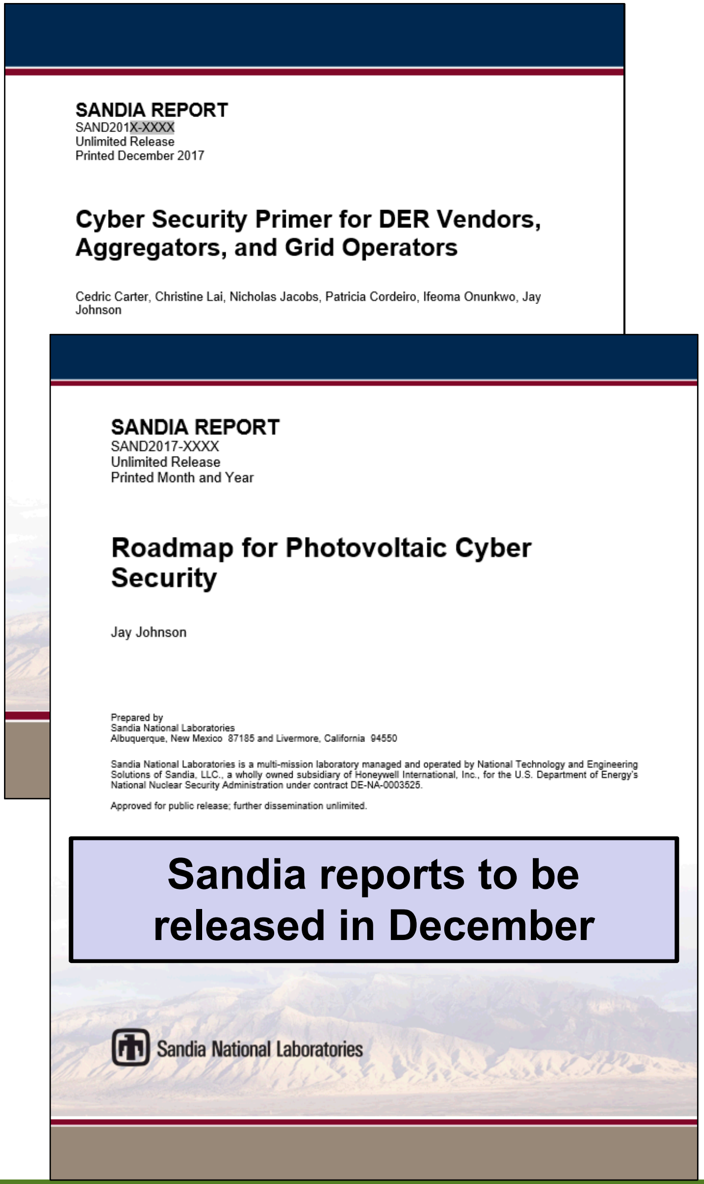
- **Certification Standards Updates.** As interconnection standards are finalized, certification standards must to be created for electrical performance and communications.
  - IEEE 1547.1 is being updated to include the new IEEE 1547 functions and communications.
  - UL 1741 Supplement A was created 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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Cyber Security Primer for DER Vendors, Aggregators, and Grid Operators

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Roadmap for Photovoltaic Cyber Security

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Sandia National Laboratories

Sandia reports to be released in December

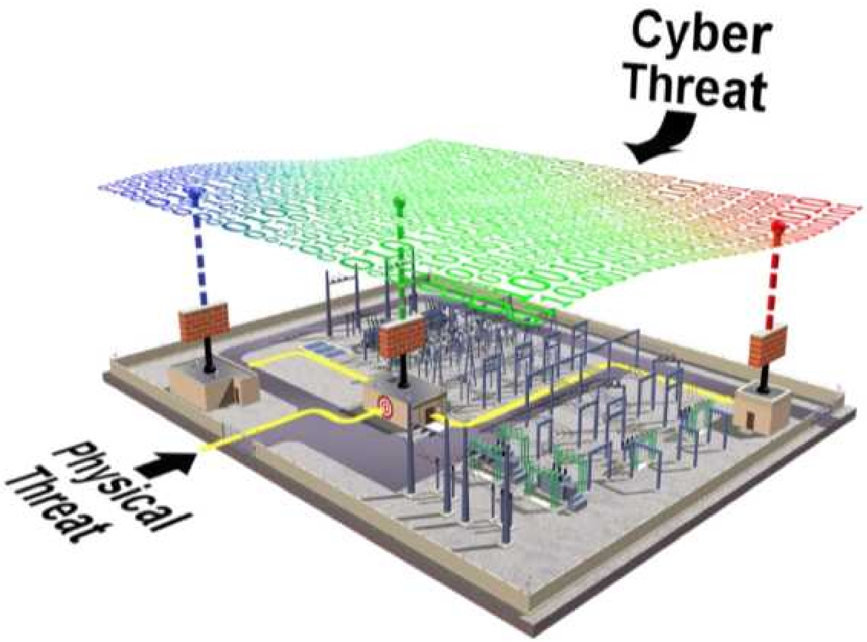
DER Cyber Security Working Group

- **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?

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