7 What: Energy Storage Interconnection Guidelines (6.2.3)

7.1 Abstract:

Energy storage is expected to play an increasingly important role in the evolution of the power grid particularly to accommodate increasing penetration of intermittent renewable energy resources and to improve electrical power system (EPS) performance. Coordinated, consistent, interconnection standards, communication standards, and implementation guidelines are required for energy storage devices (ES), power electronics connected distributed energy resources (DER), hybrid generation-storage systems (ES-DER), and plug-in electric vehicles (PEV).

A broad set of stakeholders and SDOs are needed to address this coordination and evolution in order to update or augment the 1547 standards series as appropriate to accommodate Smart Grid requirements and ES-DER object models in IEC 61850-7-420. Coordination with UL, SAE, NEC-NFPA70, and CSA will be required to ensure safe and reliable implementation. This effort will need to address residential, commercial, and industrial applications at the grid distribution level and utility/RTO applications at the grid transmission level.

7.2 Description:

Electrical interconnection guidelines and standards for energy storage, hybrid generation-storage, and other power electronics-based ES-DER equipment need to be developed along with the ES-DER object models for power system operational requirements.

7.3 Objectives*:*

- Involve a broad set of stakeholders to address ES-DER electric interconnection issues, including utilities from different regions, the international community, groups addressing similar issues (such as wind turbine interconnection), vendors, researchers, and others.
- Develop Scoping Document to identify the ES-DER interconnection and operational interface requirements for the full spectrum of application issues: high penetration of ES-DER, ride-through of power system anomalies, plug-in electric vehicles, and all sizes of ES-DER systems, including those at customer sites, within distribution systems, and at transmission level. These may end up with multiple projects, some of which may be done in parallel, and may lead to a planning guideline.
- Develop Use Cases to identify interconnection and object modeling requirements for ES-DER before electrical connectivity standards are developed. These Use Cases would include coordination with PEV and Wind Use Cases.
- Update or augment the IEEE 1547 distribution level standards series as appropriate to accommodate the wide range of ES-DER system requirements.

- Augment the IEC 61850-7-420 object models for ES-DER through IEC TC57 WG17.
- Initiate development of transmission level standards for ES-DER. These should build on the FERC wind plant interconnect guidelines and European practice (e.g. e-on, ESB). These will be needed to extend to utility scale PV and energy storage systems.
- Harmonize the distribution and transmission level standards, where possible.

7.4 Why:

Energy storage, by itself and in combination with distributed generation (termed ES-DER), is a new and emerging technology that has been identified by FERC as a key functionality of the smart grid, and standards related to storage should be treated as a key priority by the Institute and industry in the interoperability standards development process, subject to certain reservations. Coupled with inverter-based technology, these systems can be used to improve EPS performance. Due to the infancy of the use of storage and inverter technologies as a grid-integrated operational asset there are few standards that exist to capture how it could or should be utilized on the legacy grid and Smart Grid. For example, to date there exist no guidance or standards to address grid-specific aspects of aggregating large or small mobile storage, such as Plug-in Hybrid Electric Vehicles (PHEVs). ES-DER is treated as a distributed energy resource in some standards, but there may be distinctions between electric storage and connected generation. In particular, storage-based systems may function as a load more than 50% of the time.

At the same time, we are moving towards large penetration of renewables into the Grid, which could be destabilizing, but should, in the context of the Smart Grid, allow these renewables to be true utility assets. The potential for instability is twofold; first, due to the intermittent nature of renewables and therefore their unsuitability to be dispatchable resources, and second, due to the interconnection regulations themselves that can lead the electronic interconnection interface (the inverter) to trip off in response to minor variations in grid voltage or frequency. As low frequency is the result of insufficient generation, tripping a high level of inverter based systems would contribute to the problem and cause possible stability issues in response to a relatively minor disturbance. Appropriate interconnection standards, smart grid devices, and storage are all key elements of the solution.

In addition, ES-DER systems based on photovoltaic, wind, and other renewable, intermittent sources of energy are also exploring the use of storage to help smooth their intermittency, augment their ability to respond to distribution power grid management requirements, such as avoiding back-flow on networked power grids, and enhance commercial output by shifting when the energy is delivered. Eventually electric storage will play a larger role in islanded systems by helping to stabilize generation and load variations. Island system applications do provide some early examples of the stabilizing support needed when renewable are added to islanded (weak electrical) systems.

Various types of ES-DER systems are emerging. Each type will have different ranges of abilities to respond to power grid management requests, and will use different system parameters and technology specific constraints for forecasting their availability. Furthermore, the storage needs (power, energy, duty cycle, and functionality) will also depend on the grid domain where the storage is used (e.g., transmission, distribution, consumer, etc.). These considerations should be included in the storage and hybrid generation-storage interconnection and information model standards.

Examples of the different storage requirements for grid services include:

- Ancillary Services – including load following, operational reserve, frequency regulation, and 15 minutes fast response.
- Peak shaving
- Black start, islanding
- Renewables integration: ramp rate control, solar cloud ride thru
- Managing diurnal cycles for wind/solar: large energy capacity, peak shift
- Relieving congestion and constraints: short-duration (power application, stability) and long-duration (energy application, relieve thermal loading).
- As part of a microgrid.

Examples of storage technologies being considered include:

- Pumped Hydro
- Compressed Air Energy Storage (CAES)
- Flywheels
- Batteries, mobile and stationary
- Super-Capacitors (SuperCaps)
- Superconducting Magnetics
- Thermal Storage
- Fuel Cells (reversible)
- Hydrogen Storage

Currently, IEEE 1547 defines the interconnection of distributed energy resources (DER) rated 10 MVA and less with the electric power system.[1] This standard defines DER as a small-scale electric generator located in and connected to the local electric power system (e.g., the customer facility), near the loads being served with an electric grid interconnection. The standard does not specify a distinction between energy storage devices and generators within the DER portfolio. However, there is no standardization for functioning during islanding (P1547.4 is still a draft), there are no ramp rate specifications that would enable hybrid generation-storage to mitigate intermittency of renewables, the trip point specifications do not enable renewables or storage to avoid tripling under moderate grid transients, there are no voltage support specifications, and there are inconsistencies between the anti-islanding requirements of IEEE 1547 and the ride through requirements defined by FERC’s Large Generator Interconnection Procedure (LGIP), depending on interpretation and application. In particular, the

[1] Note – DOE uses the term DER, IEEE 1547 refers to DR, but that is confusing due to the increased use of demand response.

standards that cover the period between event onset and when a resource must stay on or must disconnect from the grid can have conflicting time requirements, and the FERC LGIP ride through requirements extend beyond the 1547 default values for DER ceasing to energize the point of common coupling with the grid.

Regulatory issues also need coordination. FERC Order 719 currently prohibits generation of power within islanding. Distribution systems are beyond the purview of FERC and regulation does not exist for authorizing the application and dispatch of storage. ISOs and regulatory bodies today have a tendency to treat storage as a generation device and struggle with seeing transmission or distribution entities owning storage. Revision or augmentation of IEEE 1547 will need to be closely coordinated with FERC. FERC has requested that the individual specification of IEEE 1547 be itemized (e.g., 1547.8.1) so that they can be adopted individually as FERC requirements.

IEEE 1547 was developed for interconnected systems of limited DER and renewable energy system penetration levels. The proposed new IEEE SCC21 P1547.8.x Standards are needed to enable the grid to accommodate increased renewable penetration levels, systems greater than 10 MVA, and to get value from inverter based systems to improve EPS performance, and further address end-use operational support, applications and regulatory technical needs.

7.5 Where:

The primary requirement is for P1547.8x's to develop appropriate electrical interconnection standards for electric storage and hybrid generation/storage that will enable substantial grid stability and security enhancements and permit a larger penetration of renewable energy resources and PHEVs, and further address end-use operational support, applications and regulatory technical needs.

Additional efforts will include validating and enhancing the IEC 61850-7-420 semantic layer object model standard for storage devices and hybrid generation-storage systems, including covering more storage devices than just batteries. PEV object modeling will be handled by a different PAP.

IEEE 1679, that is standardizing the characterization of grid storage units, can coordinate efforts to assure that object models for storage are consistent with a common basis for characterizing the underlying performance attributes of grid connected storage systems.

7.6 How and When:

The key stakeholder groups are: IEEE SCC21 P1547 WGs, IEEE P2030 and IEEE P1679; UL, SAE, NEC-NFPA70, and CSA for PEV storage issues; IEC TC8; and IEC TC57 WG17 and ZigBee Smart Energy Profile efforts for semantic object models.

7.6.1 Task Descriptions

Task Description	Completion Date

<table>
<tr><th>Task Description</th><th>Completion Date</th></tr>
<tr><td>Task 0: Develop Scoping Document to identify range of applications to be addressed and standards that already address these applications (and gaps).

Create broad set of stakeholders as part of this effort

Utilities
ISO/RTO
Vendors
Research
Regulators
Etc.

Coordinated with Use Case development (may be part of Task 1)

Identifies applications that require more effort for the actual use cases

Gaps that need to be addressed in the short term
Provide input to the subsequent tasks defined
Presentations for industry feedback

ESA Meeting
EESAT

Who – (NIST/EPRI to lead effort – target document by Oct 31)

Energy Sources under TF1 of IEEE P2030 - Alex Takahashi
IEEE Integration of Renewable Energy into the Transmission and Distribution Grids Subcommittee - Ernst Camm
IEEE Distribution Automation WG – Georges Simard
IEEE 1547.2 – Bob Saint
NEMA Energy Storage Council (Aug 11 meeting) – Ben Biroschak, Brad Roberts
EPRI – Smart Grid Demo Initiative – Matt Wakefield, Dan Rastler
Electricity Storage Association – Rahul Walawalker, Ali Nourai, Brad Roberts
ISO/RTO Council – Ken Huber
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Task Description	Completion Date
• Technology Representative: Power Conditioning System (PCS) and inverter vendor community – Leo Casey, Le Tang; Energy storage vendor community – Charlie Vartanian, David Nichols, Kevin Dennis, Matt Lazarewicz • DOE – Dick DeBlasio, Imre Gyuk, Dan Ton (SEGIS/ES), John Boyes (Sandia), NETL • DOE Office of Vehicle Technologies – Sue Rogers • SAE – George Bellino • NERC/FERC – Stan Johnson, Bob Cummings, Mark Lauby • EEI – Raj Patel (Transmission and Substations systems), Greg Obenchain (Distribution Systems), Mike Oldak • NRECA – Bob Saint • UL Safety Standards to assure that smart grid interfaces do not create safety problems– Tim Zgonena (wind, inverters, engine generators), Lauri Florence (batteries, ultra-capacitors, fuel cells), Ken Donahue (electric vehicles) • IBEW – • NEC/NFPA – Kathleen Almand • CSA Standards – Julie Cairns • DTE – Hawk Asgeirsson • UCI – Nokhum Markushevich	
Task 1: Develop (possibly within IEEE SCC21 P2030) Use Case scenarios and business processes to define the different requirements for electrical interconnections, focusing on scenarios involving high penetration of DER, potential microgrid formation, aggregated DER/Storage/PEVs in neighborhoods with no clearly defined Point of Common Coupling (PCC), grid operations with significant market involvement of aggregated DER systems, and adequate responses to frequency and voltage anomalies to avoid power system instabilities. These Use Cases will be recommended to be used as inputs for additions and modifications of the IEEE 1547 series of standard and the IEC object modeling standards. The Use Cases should look at • Systems of different sizes kw-100s MW • Connection at D, T or at the customer (greater than 20 MVA is	December 2009

Task Description	Completion Date
the threshold for more complex LGIP, treat as a separate case) • Some voltages fall under NEC (34.5 kV). No rules for applications above 34.5 kV • Grid connected, islanded and consumer stand alone operation • Inverter and traditional based generation • Aggregation issues • ES-DER as a load • ES-DER for frequency regulation • (Consistent definition of actors and applications) • Opportunity to use stimulus projects and other deployments as a basis for collecting use cases, application descriptions, example specifications, etc. – need a coordination of input from these projects • Requirement for Wind and Photovoltaic firming	
Task 2: Complete the development of IEEE 1547-4 for island applications and 1547-6 for distribution secondary grid networks. – ballot ready drafts.	Spring 2010
Task 3: Develop an IEEE Standards Board Project Authorization Request (PAR) that can be used to define a new SCC21 standard project (e.g., 1547.8 including subtask elements/parts described in tasks 3a through 3e below, i.e., 1547.8.1 through 1547.8.5). The P1547.8 will address the definition of unified methods for interconnection and further address end-use operational support, applications and regulatory technical needs for generic generation systems, storage systems, and hybrid generation-storage systems. This would define dispatchable service types that might be of value for the utility or local Energy Management System (EMS); define generic generation/storage system type specification including power capacity for generation, power and energy capacities for storage, grid services capabilities and types of intermittency; and define methods for specifying generic generation/storage status parameters including probabilistic representation of availability (capacity versus time within percent certainty), and cost of providing each service type including impact of equipment wear-out (e.g., impact of battery cycling). Promote accelerated timeframe development and initiate the project concurrent with IEEE approval.	Spring 2010
Task 3a: Complete the proposal to develop new SCC21 standard project (e.g., 1547.8.1 for example) to represent methods for interconnection of generic generation/storage systems (developed in Task 3) as itemized individual requirements for interconnection of specific system types in specific domains (e.g., VAR support specification of storage system within distribution domain) so that they can be referenced as individual requirements by FERC etc.). Promote accelerated timeframe development and initiate the project concurrent	Spring 2010

Task Description	Completion Date
with IEEE approval.	
Task 3b: Complete the proposal to develop new SCC21 project for itemized requirements for interconnection of STORAGE energy systems (without net generation capability) in specific domains so that they can be referenced as individual requirements by FERC etc. (itemize as 1547.8.2 for example). Promote accelerated timeframe development and initiate the project concurrent with IEEE approval	Spring 2010
Task 3c: Complete the proposal to develop new SCC21 project for itemized requirements for interconnection of PHOTOVOLTAIC energy systems with storage in specific domains so that they can be referenced as individual requirements by FERC etc. (itemize as 1547.8.3 for example). Promote accelerated timeframe development and initiate the project concurrent with IEEE approval	Spring 2010
Task 3d: Complete the proposal to develop itemized requirements for interconnection of WIND energy systems with storage in specific domains so that they can be referenced as individual requirements by FERC etc. (itemize as 1547.8.4 for example). Promote accelerated timeframe development and initiate the project concurrent with IEEE approval	Spring 2010
Task 3e: Complete the proposal to develop new SCC21 project for itemized requirements for interconnection of PEV energy systems with storage in specific domains so that they can be referenced as individual requirements by FERC etc. (itemize as 1547.8.5 for example). Promote accelerated timeframe development and initiate project concurrent with IEEE approval.	Spring 2010
Task 4: Continue development of object model standards for distributed energy resources (e.g., IEC TC57 WG17 to enhance IEC61850-7-420 and IEC TC57 WG14 to develop DER models in IEC 61968 CIM), including object models for managing generic storage/generation systems. In addition, these abstract object models will require mapping to the ZigBee Smart Energy Profile (SEP), to Web Services, and potentially to other standard protocols as appropriate for different configurations, environments, and migration from legacy systems. Object models developed under this task should be coordinated with IEEE Std P1679 - Recommended Practice for the Characterization and Evaluation of Emerging Battery Technologies in Stationary Applications.	Developed with continuous information exchange from Task 3. Each subtask completed within 3 months after the completion of the respective subtasks of Task 3. A TC57 WG17 CDV (Committee draft for vote) may meet this schedule.
Task 5: UL, NEC-NFPA70, SAE, and CSA will develop codes and test	Developed with

Task Description	Completion Date
methods to ensure safe and reliable implementation of Tasks 3 within the residential-consumer, and commercial building-consumer domains.	continuous information exchange from Task 3. Each subtask would be completed within 6 months after the completion of the respective subtasks of Task 3.

7.6.2 Deliverables

Develop along with project team.

7.7 Who:

Project Team			
NIST Lead: Al Hefner			
EPRI Leads: Frances Cleveland, Mark McGranaghan			
SDO Leads:			
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