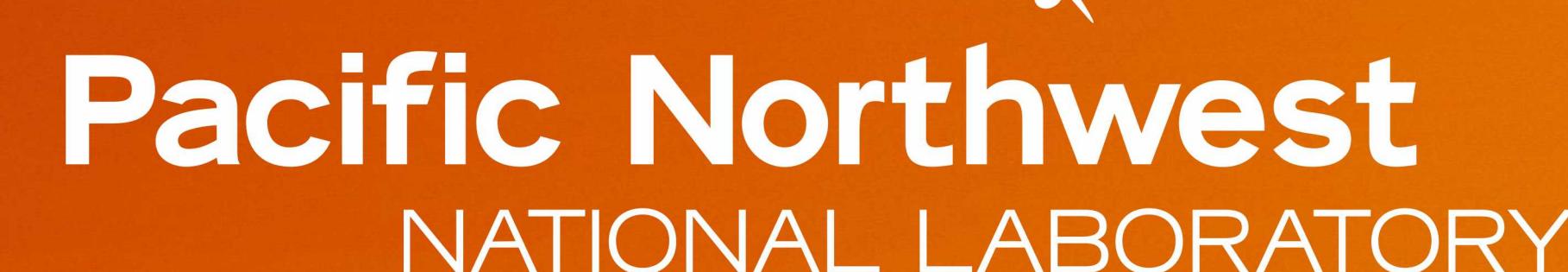


Interconnection Writ Large: Non-technical solutions to connecting renewables and storage to the grid



Sandia National Laboratories



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Introduction Grid interconnection standards and practices are being updated to keep up with the rapid development and use of newer grid technologies, including battery-based energy storage (ES) and distributed renewable resources. However, the authors posit that the power industry can further benefit by ‘Interconnecting’ a broader set of stakeholder communities. Grid interconnection practices provide both a model and an opportunity – i.e. bridging technical and policy stakeholders so they can better coordinate advances in both technical standards, and the related policy & regulations that reference technical standards. Achieving broader stakeholder engagement and coordination across technical and regulatory policy communities will lower the risk of unintended barriers to the continued adoption, deployment, and use of grid connected ES.

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Policy Promoting Consistent Use of Interconnection Technical Standard Removed a Barrier to DER Adoption

Importance of IEEE 1547

- Energy Policy Act (2005) Cites and requires consideration of IEEE 1547 Standards and Best Practices for Interconnection; all states use or cite 1547.
- Energy Independence and Security Act (2007) IEEE cited as a standards development organization partner to NIST as Lead to coordinate framework and roadmap for Smart Grid Interoperability standards and protocols {IEEE 1547 & 2030 series being expanded};
- Federal ARRA (2009) Smart Grid & High Penetration DER projects {use IEEE stds}.

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IEEE

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Policy & Transmission Connected BESS: Technicals integrated via FERC Order 888 SGIP/LGIP*

1996, FERC 888, Transmission Open Access
GVEA-BESS
1 star

2006, FERC 679, Transco's, Advanced Tech
NHC-LEAPS
0 stars

2007, FERC 890, Open and Transparent T-Planning
WGD-BESS
1 star

2011, FERC 1000, Transm. Alt's
ETT-Presidio
1 star

2011 FERC 755, Pay for Perf.
PJM-Queued Storage
2 stars

2013, FERC 784, Storage T&D Acct'g
CA AB2514, PPA's
2 stars

2018, FERC 841, Open Markets to ES
CA AB2514, Utility Owned
3 stars

* SGIP, Small Generator Interconnection Procedure, LGIP, Large Generator Interconnection Procedure

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Evolving Grid Necessitated Updating Interconnection Technical Standards

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Evolution of the Grid

Current Power System

- Large generation systems
- Central control
- Highly regulated

Future Power Systems

- Geothermal Power Plant
- Power Plant
- Solar Arrays
- Rooftop PV
- Wind Farm
- Ultra High Efficiency Building
- Energy Storage

New Challenges

- New energy technologies and services
- Penetration of variable renewables in grid
- New communications and controls (e.g., Smart Grids)
- Electrification of transportation
- Integration of distributed energy storage
- Regulatory advances

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IEEE 1547 Evolution of Grid Support Functions

IEEE 1547-2003

- Shall NOT actively regulate voltage
- Shall trip on abnormal voltage/frequency

IEEE 1547a-2014 (Amendment 1)

- May actively regulate voltage
- May ride through abnormal voltage or frequency
- May provide frequency response

IEEE 1547-2018

- Shall be capable of actively regulating voltage
- Shall ride through abnormal voltage/frequency
- Shall be capable of frequency response

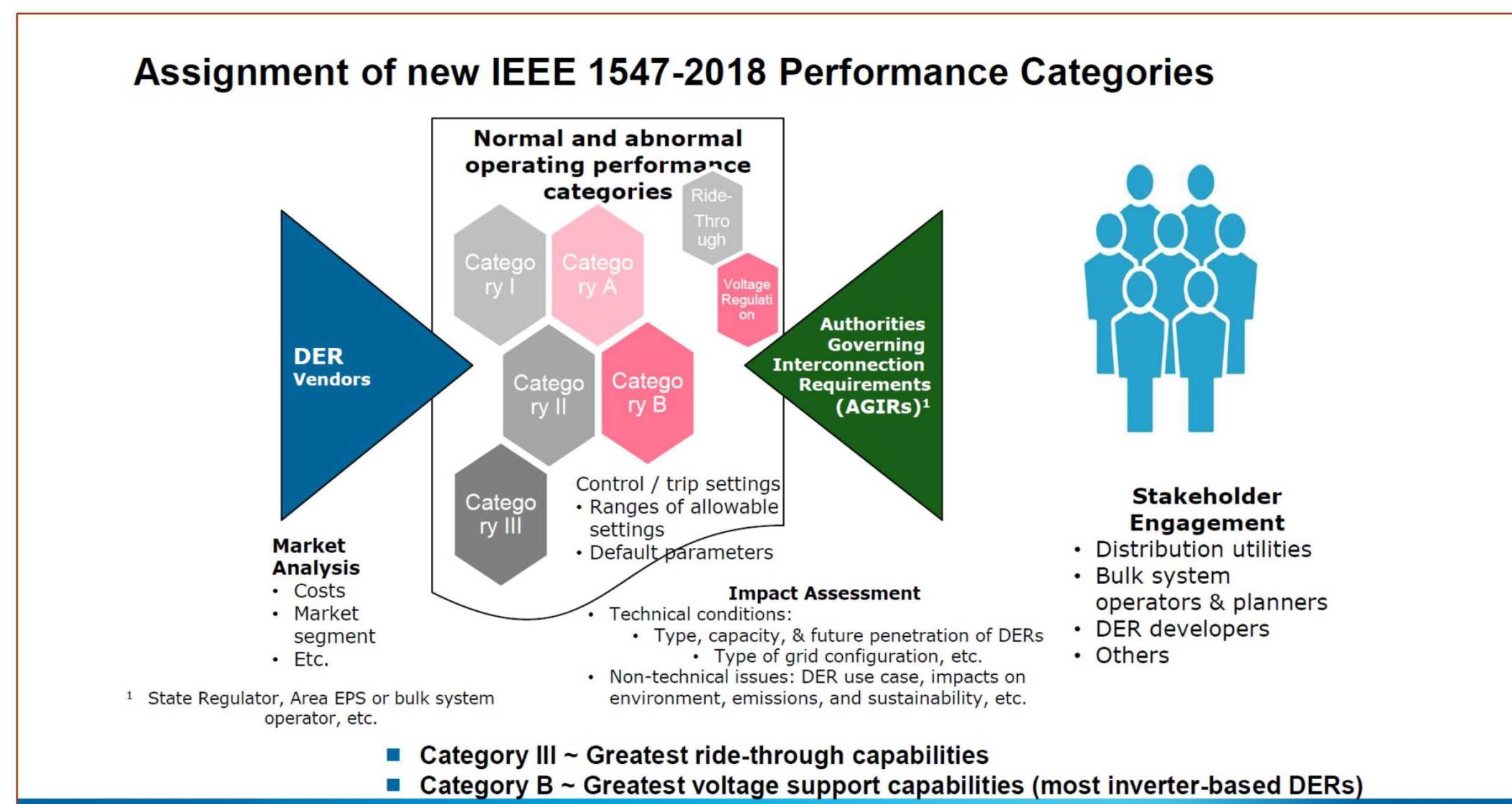
Source, IEEE

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Complex Standards Complicate Adoption, Wide Stakeholder Engagement Will Help Facilitate Adoption by AHJ's*

Assignment of new IEEE 1547-2018 Performance Categories



Normal and abnormal operating performance categories

- Category I
- Category A
- Category II
- Category B
- Category III
- Ride-Through
- Voltage Regulation

DER Vendors

Market Analysis

- Costs
- Market segment
- Etc.

Authorities Governing Interconnection Requirements (AGIRs)¹

Impact Assessment

- Control / trip settings
 - Ranges of allowable settings
 - Default parameters
- Technical conditions:
 - Type, capacity, & future penetration of DERs
 - Type of grid configuration, etc.
- Non-technical issues: DER use case, impacts on environment, emissions, and sustainability, etc.

Stakeholder Engagement

- Distribution utilities
- Bulk system operators & planners
- DER developers
- Others

¹ State Regulator, Area EPS or bulk system operator, etc.

■ Category III ~ Greatest ride-through capabilities
■ Category B ~ Greatest voltage support capabilities (most inverter-based DERs)

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*AHJ, Authority Having Jurisdiction

Source, IEEE

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Without Updated Standards Plus Adoption by AHJ's, Valuable Services from ES Won't Be Deliverable

Category	Storage "End Use"
ISO/Market	<ul style="list-style-type: none"> Frequency regulation Spin/non-spin/replacement reserves Ramp Black start Real time energy balancing Energy price arbitrage Resource adequacy <p>1547-2003 vs. new CA 21 & 1547 Revision</p>
VER Generation	<ul style="list-style-type: none"> Intermittent resource integration: wind (ramp/voltage support) Intermittent resource integration: photovoltaic (time shift, voltage sag, rapid demand support) Supply firming
Transmission/Distribution	<ul style="list-style-type: none"> Peak shaving: off-to-on peak energy shifting (operational) Transmission peak capacity support (upgrade deferral) Transmission operation (short duration performance, inertia, system reliability) Transmission congestion relief Distribution peak capacity support (upgrade deferral) Distribution operation (Voltage Support/VAR Support) Outage mitigation: micro-grid
Customer 7	<ul style="list-style-type: none"> Time-of-use /demand charge bill management (load shift) Power quality Peak shaving (demand response), Back-up power



**A Model of Wide Stakeholder Engagement:
SNL/PNNL ES Safety Collaborative**

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ESS Safety Collaborative

ES SAFETY COLLABORATIVE

- ▶ Identify gaps in safety research.
- ▶ Participate & support C&S development.
- ▶ Repository for collaborative resources.



www.sandia.gov/energystoragesafety

DOE OE Energy Storage Systems Safety Roadmap

GOAL
Foster confidence in the safety and reliability of energy storage systems.

BACKGROUND
Energy Storage Systems (ESS) are an increased demand for electric power systems. The storage adoption in the U.S. of stationary ESS has raised concerns about the degree of risks they pose, and questions about how to best understand and mitigate such risks. Stationary energy storage can bring with it risks to the public, communities, and the environment associated with ensuring public safety. There is no expectation that the rapid evolution of stationary storage associated with energy storage technologies will slow as the costs continue to fall, new applications are developed, and the benefits of ESS continue to pour ESS implementation. There has been and continues to be a pressing need for coordinated, industry-wide actions to improve the safety and reliability of energy storage systems.

INTRODUCTION
This document is the result of past efforts as described above and most notably the Energy Storage Safety Forum held in late February 2017 which had over 100 attendees representing a wide range of stakeholders associated with ESS development and adoption.

The primary focus of this roadmap is to establish a goal and then a path toward achieving that goal. The roadmap provides a specific goal and the specific objectives identified to reach that goal. The objective has specific actions to enable successful realization of the objective. The tasks outlined under each objective fall naturally into the past activities associated with the ESS Working Group and are in line with other DOE programs and activities.

The roadmap objectives fall into the following categories: research/development, codes/standards, and collaborative resources.

Grid Energy Storage, US DOE, December, 2013. http://www.sandia.gov/energystoragesafety/Grid_Energy_Storage.pdf

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Other Active Stakeholder Communities:& References:
IEEE P147.9 Working Group,
https://standards.ieee.org/project/1547_9.html

PNNL Energy Storage Research Program,
<https://energystorage.pnnl.gov/>

Sandia Energy Storage Research Program,
<https://www.sandia.gov/ess-ssl/>

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U.S. DEPARTMENT OF ENERGY