Integration, Management, and Control of Supply-Side DER

Patrick Dalton, ICF

Integrated Distribution System Planning Training for Western States February 26, 2021
DER integration considerations vary by technology type and use case

Grid planners and modelers review a standard set of physical and control impacts

Operational, planning, and market integration needs are evolving

DER controls can be autonomous (e.g., inverter), centralized (e.g., Advanced Distribution Management System or Distributed Energy Resource Management System), or a combination

- Use cases drive the type of control needed

Interoperability is key for remote control and management
Brief Overview of DER Technologies
DER Integration Considerations Vary by Technology

Rotating Machine
- Mechanically coupled response
- Higher fault current levels
- Well-characterized fault current response
- Able to sustain islands (voltage source)
- Limited reactive power capabilities

Inverter-Based
- Software defined response
- Lower fault current levels
- Wide range of fault current responses
- Not able to sustain islands (current source)
- Full range of reactive power capabilities

Source: rotating machine image from https://electricallive.com/2015/03/salient-pole-synchronous-motor.html
Inverters Are a Growing, Flexible Interface

- Converts direct current to alternating current
- Act as a “current source” that follows system voltage
- Software-defined advanced functions (i.e., Smart Inverters)

Battery Energy Storage Adds Another Control Layer

- Inverter based with battery management system (BMS)
- IEEE P1547.9 – Draft Guide on Energy Storage DER is underway

---

DER Integration Considerations
A Progression for Integrating DER

- **Lower Complexity**
  - Voltage limits
  - Thermal constraints
  - Control compatibility
  - Protection

- **Higher Complexity**
  - Situational awareness
  - “Hidden Load”
  - Remote control
  - Bulk system reliability (e.g., ride-through)

- **DER as an Integrated Distribution and Bulk System Resource**
  - Non-wires alternatives
  - Market services

**DER Interconnection**

**DER Planning and Operational Needs**
DER Reverse Power Impacts Feeder Voltage

Reverse Power Flow from Generator Can Lead to High Voltage
DER Controls can Mitigate High Voltage

Two ways DER can reduce voltage:

1. Consume Reactive Power (vars)
2. Reduce Active Power Injection (Watts)
Situational Awareness Needs

- Monitoring and estimation of DER output and system conditions
  - Data also informs planning models

- Balance of direct monitoring and estimation
  - Tools for estimating load hidden by behind the meter increasingly important

Example of feeder switching

Reverse power flow
Potential for thermal and/or voltage issues
DER Management and Control
IEEE 1547-2018 Standard Control Capabilities

Voltage and Reactive Power Control

- Constant Power Factor
- Constant Reactive Power
- Voltage – Reactive Power (Volt-Var)
- Active Power – Reactive (Watt-Var)*

Voltage and Active Power Control

- Voltage – Real Power (Volt-Watt)*

* Required for Category A only (i.e., rotating machines)

- Default mode is unity power factor (Constant Power Factor)
- Reactive power modes are mutually exclusive (i.e. one-at-a-time)
- Volt-Watt can be stacked on reactive power functions
Volt-Var Mode Senses and Reacts to Grid Voltage

Voltage-Reactive Power Mode (Volt-Var)
► Reactive power absorption or injection is changed based on voltage
  - Absorbing Vars $\rightarrow$ Lowers voltage
  - Injecting Vars $\rightarrow$ Raises voltage

Diagram:
- $(V_1, Q_1)$
- $(V_2, Q_2)$
- $(V_3, Q_3)$
- $(V_4, Q_4)$
- $V_L$: Voltage Lower Limit for DER Continuous operation
- $V_H$: Voltage Upper Limit for DER Continuous operation
- $V_{Ref}$
- Dead Band
Volt-Watt Acts as a Soft Shutdown for High Voltages

Voltage-Active Power Mode (Volt-Watt)

- Power output reduced when voltage limit is reached
- Reduced power results in lower voltage
Application of Volt-Watt

Per unit volages

DER 1 MW Nameplate
- V = 1.07 pu
- P = 250 kW

Substation Bravo
- Automated Reclosers

Active Power (Generation)
- P_{\text{rated}}
- (P_1, V_1)
- (P_2, V_2)
- 1.05
- V_1
- V_2
- 1.08
- V_H

V = 1.05 pu, P = 1 MW
V = 1.07 pu, P = 250 kW
Stacking Smart Inverter Functions to Address Operational Needs

- Reactive power control functions for normal (long term operating) voltage conditions and Real power control for contingency (unplanned emergency or temporarily maintenance) voltage conditions
Bulk Power System Perspective on DER

Distribution System Needs

- Short trip times
- Ride-through with momentary cessation
- Voltage rise concerns
- Islanding concerns
- Protection coordination
- Line worker safety

Bulk Power System Needs

- Long trip times
- Ride-through with constrained momentary cessation
- Reactive power demands
- Dynamic voltage support
- Frequency support

The need for transmission and distribution coordination is increasing.

Continuous Operation:
Normal production with all standard requirements applicable

Mandatory Operation:
required to maintain exchange of active and reactive power

Momentary Cessation:
remains connected and synchronized, but stops producing power
ISO/RTO Guidelines Modify Undervoltage Performance

- ISO/RTO guidelines modified default undervoltage trip settings

- Developers and utilities will be responsible for implementing settings

Source: ICF
NARUC passed a resolution in January 2020 recommending that State commissions, consistent with the practices and procedures of that State, convene proceedings that engage stakeholders as soon as possible; utilize existing research and experience and make evidence-based decisions to adopt the current IEEE 1547; and align implementation of the Standard with the availability of certified equipment.
## State-Level Developments

<table>
<thead>
<tr>
<th>State</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>Awaiting utility Advice Letters following the completion of Smart Inverter Working Group meetings; potential harmonization with Rule 21.</td>
</tr>
<tr>
<td>DC</td>
<td>Planned roll-out January 1, 2022, for 1547-2018 capabilities.</td>
</tr>
<tr>
<td>MD</td>
<td>Register (statewide interconnection rule) is now published. Rule requires 1547-2018 compliance by January 1, 2022; utility interconnection rules to follow.</td>
</tr>
<tr>
<td>HI</td>
<td>HECO Source Requirement Document 2.0 published July 1, 2020, containing non-1547-2018 requirements; January 1, 2022, final deadline for UL 1741 SB certification.</td>
</tr>
<tr>
<td>ID</td>
<td>Idaho Power proposed a default setting of Category B for reactive power, and Category III for voltage ride-through. Staff comments in January 2021 supported the utility’s proposals for export and non-export systems.</td>
</tr>
<tr>
<td>NM</td>
<td>Action 11 of the Public Regulation Commission 2-Year plan highlights implementation of advanced inverter functions with 1547-2018 capabilities.</td>
</tr>
<tr>
<td>KY</td>
<td>LG&amp;E/KU interconnection requirements reference current 1547-2018 being enforced today.</td>
</tr>
<tr>
<td>NY</td>
<td>Conversations are underway in the Interconnection Technical Working Group. In August 2020, the ITWG reviewed a proposal to develop a regional reliability guideline for DER ride-through capability and trip settings through adoption of IEEE 1547-2018.</td>
</tr>
</tbody>
</table>
DER Interoperability Unlocking Monitoring, Control, and Management
Interoperability Scope of IEEE 1547-2018

- Monitoring, Control, and Information Exchange
- Information Models
- Protocols

Key
- In Scope
- Out of Scope
# DER Monitoring and Control through a Standard Communications Interface

<table>
<thead>
<tr>
<th>Nameplate (Read-Only)</th>
<th>Configuration (Read/Write)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Each rating in the Nameplate Information Table is configurable</td>
</tr>
<tr>
<td>Equipment Ratings</td>
<td>Not intended for continuous dynamic adjustment</td>
</tr>
<tr>
<td>Performance Category</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>Abnormal</td>
<td></td>
</tr>
<tr>
<td>Supported Control Modes</td>
<td></td>
</tr>
<tr>
<td>Make, Model, Version</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitoring (Read-Only)</th>
<th>Management (Read/Write)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Power</td>
<td>Control mode settings</td>
</tr>
<tr>
<td>Reactive Power</td>
<td>Voltage/frequency tripping</td>
</tr>
<tr>
<td>Voltage</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
</tr>
<tr>
<td>Operational Status</td>
<td></td>
</tr>
<tr>
<td>Connection Status</td>
<td></td>
</tr>
<tr>
<td>Alarm Status</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limit maximum active power</td>
</tr>
</tbody>
</table>
Use Cases for Interoperability

- Monitoring of near real-time status for Operations
- Remote settings changes for contingency or emergency situations
- Coordination with Advanced Distribution Management System (ADMS) applications and DERMS
- Supporting flexible interconnections
Accounting for DER in ADMS

► Situational awareness – “hidden load”
  ■ Balance of Estimated vs Measured

► Fault calculation impacts – FLISR
  ■ Reduced system fault current

► Voltage regulation – IVVO
  ■ Coordination with local voltage controls (e.g., inverter volt-var)
Relationship of ADMS, DERMS, and Aggregators

- **Cyber security** is a growing consideration as DER is networked and relied upon for critical grid operations.

- **Market and Distribution Non-Wires** likely to interact with aggregation platforms.

Source: Power Grid International

https://www.power-grid.com/2019/02/05/a-look-towards-the-future-integrating-derms-and-adms/#gref
Key Takeaways

- DER integration considerations vary by technology type and use case
- Grid planners and modelers review a standard set of physical and control impacts
- Operational, planning, and market integration needs are evolving
- DER controls can be autonomous (e.g., inverter), centralized (e.g., ADMS or DERMS), or a combination
  - Use cases drive the type of control needed
- Interoperability is key for remote control and management
Key Questions States Can Ask About DER Integration

► What DER-related grid constraints are most commonly leading to mitigations or system upgrades?
► How and when will smart inverters be used as a mitigation?
► What state-level or utility IEEE 1547-2018 implementation processes are needed to unlock the value of smart inverters?
► How do planned or proposed grid modernization investments contribute to DER integration?
► What steps can be taken today to plan for true interoperability between DER owners, utilities, and third-party aggregators?
Resources for More Information

https://www.nrel.gov/docs/fy19osti/72102.pdf

► NARUC, Adoption of IEEE 1547-2018 and Interconnection Procedures, 2020,
https://pubs.naruc.org/pub/7A52CAA7-155D-0A36-31F0-7455E3DBB548

► NREL, High-Penetration PV Integration Handbook for Distribution Engineers, 2016
https://www.nrel.gov/docs/fy16osti/63114.pdf

► NREL, Sequential Mitigation Solutions to Enable Distributed PV Grid Integration
https://www.nrel.gov/docs/fy19osti/70411.pdf

► NREL, New Approaches to Distributed PV Interconnection: Implementing Considerations for Addressing Emerging Issues
https://www.nrel.gov/docs/fy19osti/72038.pdf

► DOE, Revised IEEE 1547-2018 Standard Will Aid Solar Integration, 2019

► NERC, Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018, 2020
Thank you!

Patrick Dalton

patrick.dalton@icf.com