PJM Interest in DER Ride Through, IEEE 1547-2018, and Review of Prior Workshops

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AGGREGATE IMPACTS OF DER ON BULK SYSTEM PERFORMANCE
Transmission Voltage on 3-phase 230kV trip in summer 2021 at 2PM
Approx. solar output on low voltage buses in summer 2021 at 2PM

Solar DER output on low voltage buses: > 1,000 MW
Status Quo—IEEE 1547-2003—DER and “Shall Trip”

IEEE 1547 Standard Voltage Sensitivity

No ride through requirement

Shall trip in 160 ms V <50%

88% @ 2 s

50% @ 160 ms

0% 50% 100% Voltage (percent of nominal)

0.01 0.10 1.00 10.00 Time (seconds on log scale)

0% 50% 100% Voltage (percent of nominal)

0.01 0.10 1.00 10.00 Time (seconds on log scale)
Could Wide Area Undervoltage in PJM Persist to 160 ms or 2s trip point?

Fault-Induced Delayed Voltage Recovery > 2 s

Voltages on some transmission substation busses decayed to 50% or less of pre-fault conditions. Normal voltage restoration required an extended period of time, estimated to be between 5 and 15 seconds.

15s FIDVR 1992 PECO line-line-ground fault*

Delayed transmission fault clearing

Reclosing and trip timing accumulation

Could 60.5 or 59.8 Hz frequency trip of DER impact PJM?

Catastrophic islanding of interconnection

Black start

Unusually Big Gen Loss

Loss of 4,500 MW in Eastern Interconnection in August 2007

PJM in August 2003
Lack of ride through and faster trip times could lead to:

1. A transmission fault triggering widespread DER tripping and subsequent reliability issues.

2. Deteriorated frequency control during loss of large gen, PJM black start, and similar conditions.
IEEE 1547-2018 EDUCATION
Role and Scope of IEEE 1547-2018

- PJM states, PJM, utilities, and U.S. law cite IEEE Standard 1547 as applicable to DER interconnections.
- IEEE Standard 1547 includes many provisions, including trip times (for 2003 and 2018 revisions) and ride through requirements (only for 2018 revision).
- IEEE Standard 1547-2018 includes 3 options for ride through, each with different default and adjustable trip time options.
- IEEE Standard 1547-2018 specifies precisely what the dynamic expectations are for trip behavior and for various forms of ride through behavior.
- The PJM DERRTTF will specify a technical profile for ride through and trip times based on the IEEE 1547-2018 standard.
Valuable EPRI Training Modules on IEEE 1547-2018


EPRI Training Modules
The training is open to the public, but does require signing up for an EPRI account to access.

**Topic**

- **Overview on IEEE Std 1547-2018**
- **DER Ride-Through Performance Categories and Trip Settings**
- **T+D Coordination for DER Ride-Through and Trip Requirements**
IEEE 1547-2018 Mode Definitions

• **Mandatory Operation** – must not trip; must continue producing pre-disturbance real and reactive current.

• **Momentary Cessation** – must stop producing real current, with rapid return to pre-disturbance output when conditions return to normal.

• **Permissive Operation** – must not trip; may continue producing real current or not.
  – Could accommodate either Mandatory Operation or Momentary Cessation

• **May Ride Through or May Trip** – Allowed to trip, but not required to trip.

• **Trip** – cessation of output **without** immediate return to service (wait ~100s of seconds);
  – **Return to service** – re-entry of DER to service following a trip; equivalent to start-up of DER.
IEEE 1547-2018 “Category II” with adjusted trip settings and additions as follows:

a) UV2 increased $\rightarrow$ 1.1 seconds for delayed transmission fault clearing.

b) UV1 time decreased $\rightarrow$ 2 – 5 seconds and volts increased $\rightarrow$ 88% for arc-flash and recloser concerns.

c) “Permissive Operation” range and severe low voltage “may trip” range is specified to “Mandatory Operation” for $V > 0.50$ and “Momentary Cessation” for $V < 0.50$. 
SUMMARY OF WORKSHOPS
2018 PJM Technical Workshops on Ride Through

• Feb 2018 – Trial workshop among PJM and 4 utilities.
• Oct 2018 – Technical workshop open to all PJM utilities and stakeholders
  – Promote participation by distribution utility engineers ahead of stakeholder task force--> 85% of PJM utilities participated.
  – In-depth technical education
  – Discussions of technical interests and positions
  – Identification of follow-up due diligence, surveys, and analysis
Interest Identification

Distribution:
- Hot lifeworker safety
- Integration with existing distribution protection
- Risk of reclosing into an unintended island given uncertainty in anti-islanding algorithms
- Flexibility to deal with diverse system conditions

Developer and manufacturer:
- Standardization
- Interconnection costs (i.e., transfer trip or upgrade to dead-permissive reclose)
- Reduce nuisance trips

PJM and Transmission:
- Transmission contingencies do not trigger widespread DER trips.
- DER contribute to system stability during black start or similar conditions.
- Both of these are met if meet or exceed NERC PRC-024.
Possible Follow Up Research and Surveys

Future topics for model studies

• BES stability under 2031 high-DER scenario with 1547-2003 behavior as well as 1547-2018 Cat II 600-ms-long momentary cessation at a 50% undervoltage threshold following bad 3-phase 230kV or 500 kV line fault
• Possible Arc flash safety research--impacts of ride through and mitigation from momentary cessation and trip

Possible literature review topics for education

• Anti-islanding
• Island sustainability
• Quantify impact of reclosing into an out of phase DER island
• Quantify cost of hot blocking/dead permissive reclose
• Distribution protection masking
• Presentation on NERC studies justifying the PRC-024 ride through values (esp. 3 seconds at 88%)

Possible survey questions for distribution utilities

• Substation first-try reclose times
• Hot work practices
• Substation relay settings: what are typical pickup values, time-inverse, time-current, etc.?  
• Adjustable reclosers
• Distribution Automation and FLISR and relevant timing
• Regular use of hot blocking (dead permissive) for substation reclosers with presence of DER
• Any available data on retained voltage during arc faults, esp. worst case scenarios
• Which modeling software is used on distribution for:
  – Steady state power flow (e.g. Distribution Engineering workstation)
  – Arc flash safety (e.g. Arcpro)
    • Study assumptions: phase-to-ground vs phase-to-phase, arc impedance
  – Short circuit (e.g. ASPEN)
  – Voltage balance and voltage profile
<table>
<thead>
<tr>
<th><strong>IEEE Std 1547-2018 Settings</strong> (refer to figures for ranges of allowable settings)</th>
<th><strong>Arc-flash</strong></th>
<th><strong>Reclosing</strong></th>
<th><strong>Distribution Protection</strong></th>
<th><strong>Ground fault overvoltage</strong></th>
<th><strong>Bulk System Reliability</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>UV1 clearing time and voltage threshold (high impedance faults)</td>
<td>Clearing time &lt; personal protective equipment (PPE) rating (*)</td>
<td>Clearing time &lt; reclose time (may use islanding detection as alternative)</td>
<td>May be relevant for high impedance faults</td>
<td>Clearing time ≥ 3.16 s of NERC PRC-024</td>
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</tr>
<tr>
<td>• <a href="mailto:0.88pu@5.16s">0.88pu@5.16s</a></td>
<td></td>
<td>High only if used as back-up to islanding detection</td>
<td>How is this different from feeders without DER?</td>
<td>If distribution FIDVR exists, then longer clearing time and/or lower voltage threshold</td>
<td></td>
</tr>
<tr>
<td>UV2 clearing time and voltage threshold (most feeder faults)</td>
<td>No impact when combined with Momentary Cessation</td>
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<td>No impact when combined with Momentary Cessation</td>
<td>Clearing time ≥ 0.32 s of NERC PRC-024</td>
</tr>
<tr>
<td>• <a href="mailto:0.45pu@1.1s">0.45pu@1.1s</a></td>
<td>If not combined with MC, time incremental impact (**)</td>
<td>If no MC applied, then clearing time &lt; reclose time (may use islanding detection as alternative)</td>
<td>No impact when combined with Momentary Cessation</td>
<td>Trip clearing times shall be close to ride-through to reduce uncertainty of actual behavior for transmission modeling</td>
<td>For modest DER penetrations, as low MC threshold as distribution protection practices allow for</td>
</tr>
<tr>
<td>Momentary Cessation (MC) voltage threshold</td>
<td>High enough to account for typical retained voltages during SLG faults</td>
<td>High enough to account for typical retained voltages during islanded conditions</td>
<td>High enough to account for typical retained voltages during feeder faults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 0.5 pu</td>
<td></td>
<td></td>
<td>Not so relevant for adjacent feeder faults</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OV1 clearing time and voltage threshold</td>
<td>Using OV as AI backup for PDER &gt; Pload.</td>
<td>Already some exposure to GF-OV even with DER. 110% seems OK for OV1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 1.1pu@2s</td>
<td></td>
<td></td>
<td>Anything greater than 1 sec is good enough.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OV2 clearing time and voltage threshold</td>
<td>Does not seem to impact.</td>
<td>Default values appear acceptable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• <a href="mailto:1.2pu@0.16s">1.2pu@0.16s</a></td>
<td></td>
<td></td>
<td>Default values appear acceptable.</td>
<td></td>
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</table>

(*) Arc flash involves faults driving voltage into Momentary Cessation and/or UV2, so UV1 settings are actually less relevant. (**) System grounding practices are the critical factor. (***) Voltage may collapse immediately when recloser opens and UV1 may not be needed to coordinate with reclosing.
NRECA Revision of IEEE Standard 1547™

Articles

1. **The Background for Change**, Nov. 2016


EPRI White Papers


6. **Communications Interface and Interoperability**, Jul. 2017

7. **Power Quality Considerations for DERs**, Dec. 2017

8. **Impacts of DER Ride-through on Anti-Islanding and Distribution Protection**

Fact Sheet available on [epri.com](http://epri.com)