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

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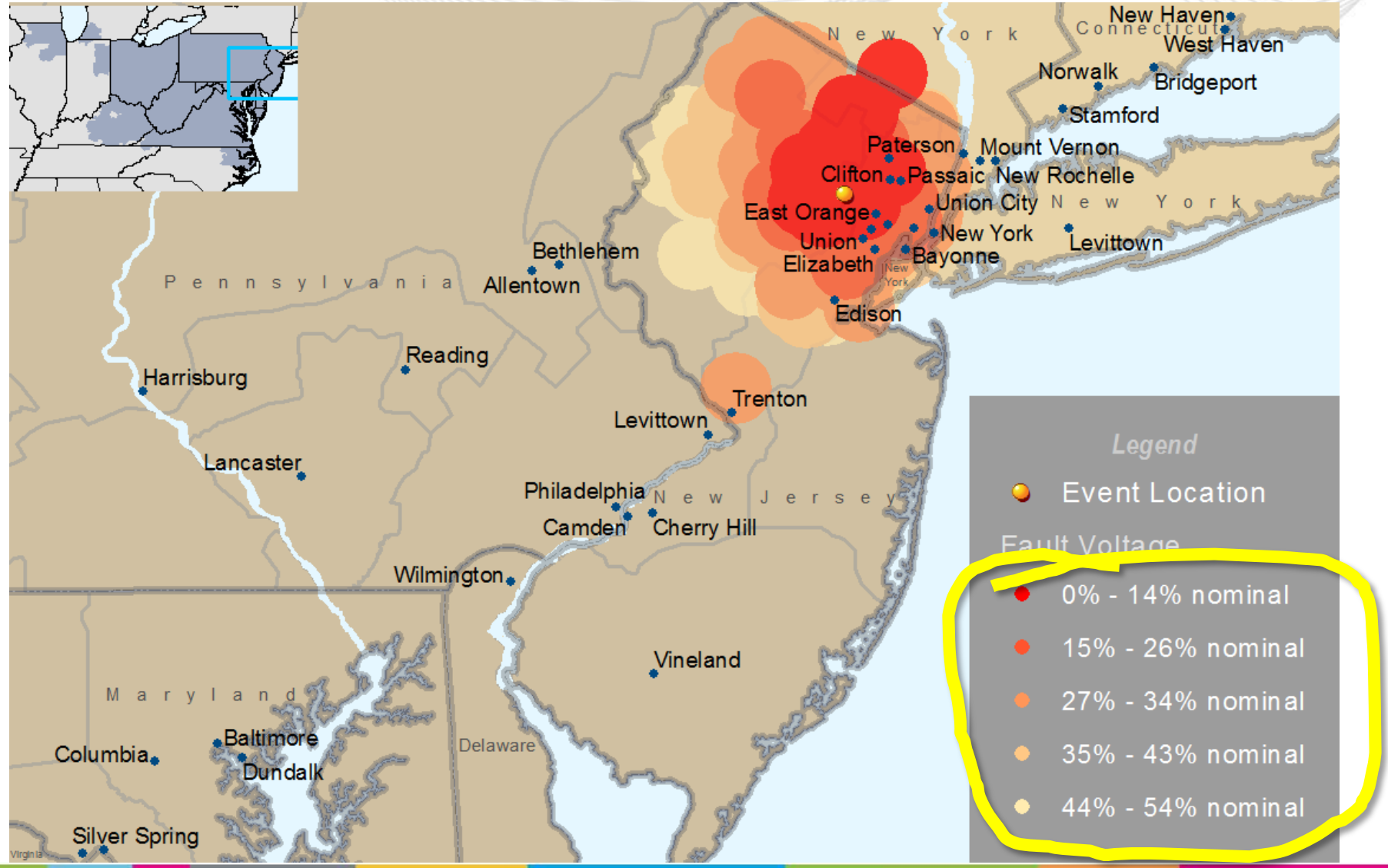
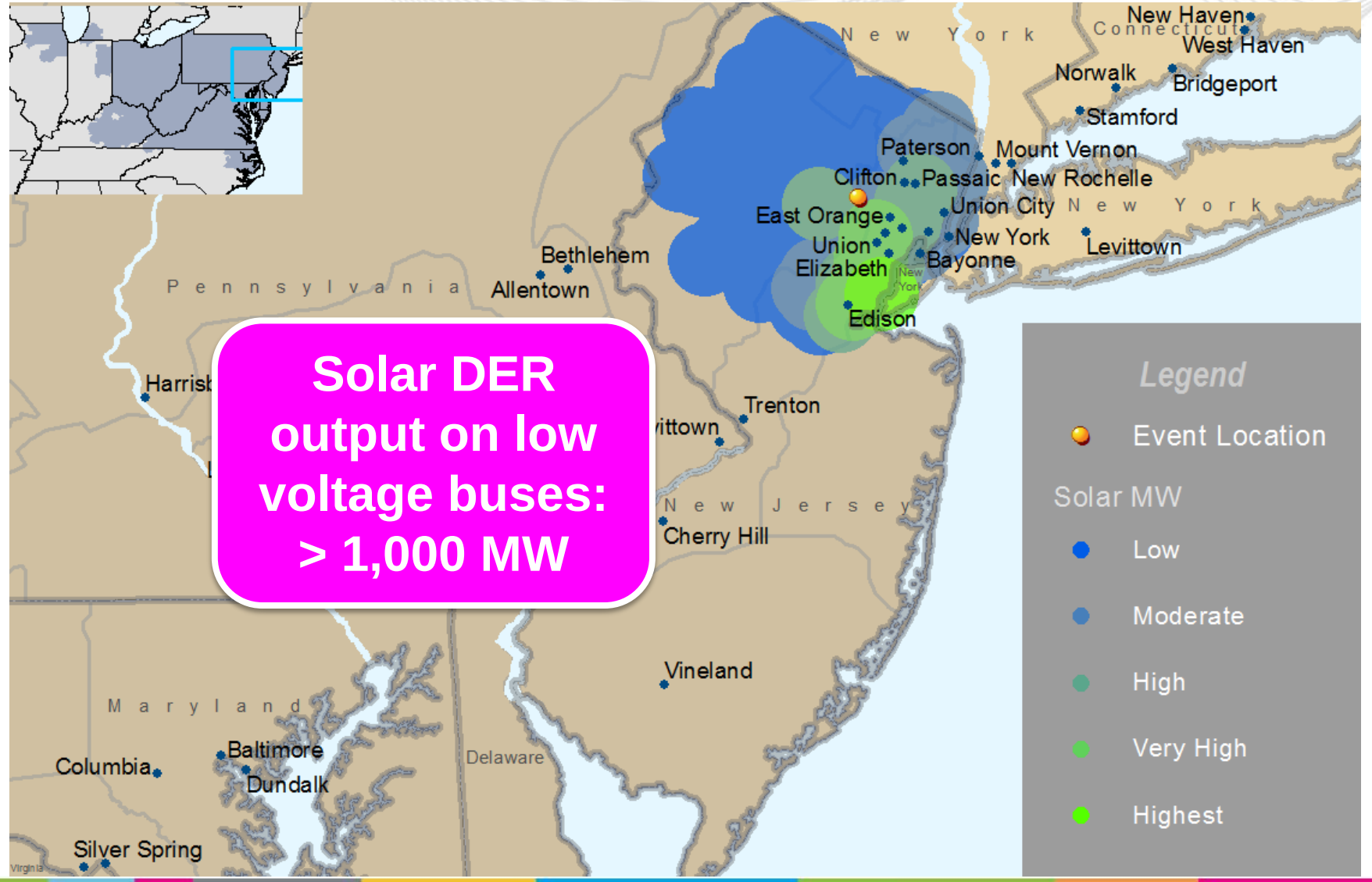
PJM DER Ride Through Task Force

AGGREGATE IMPACTS OF DER ON BULK SYSTEM PERFORMANCE

Transmission Voltage on 3-phase 230kV trip in summer 2021 at 2PM



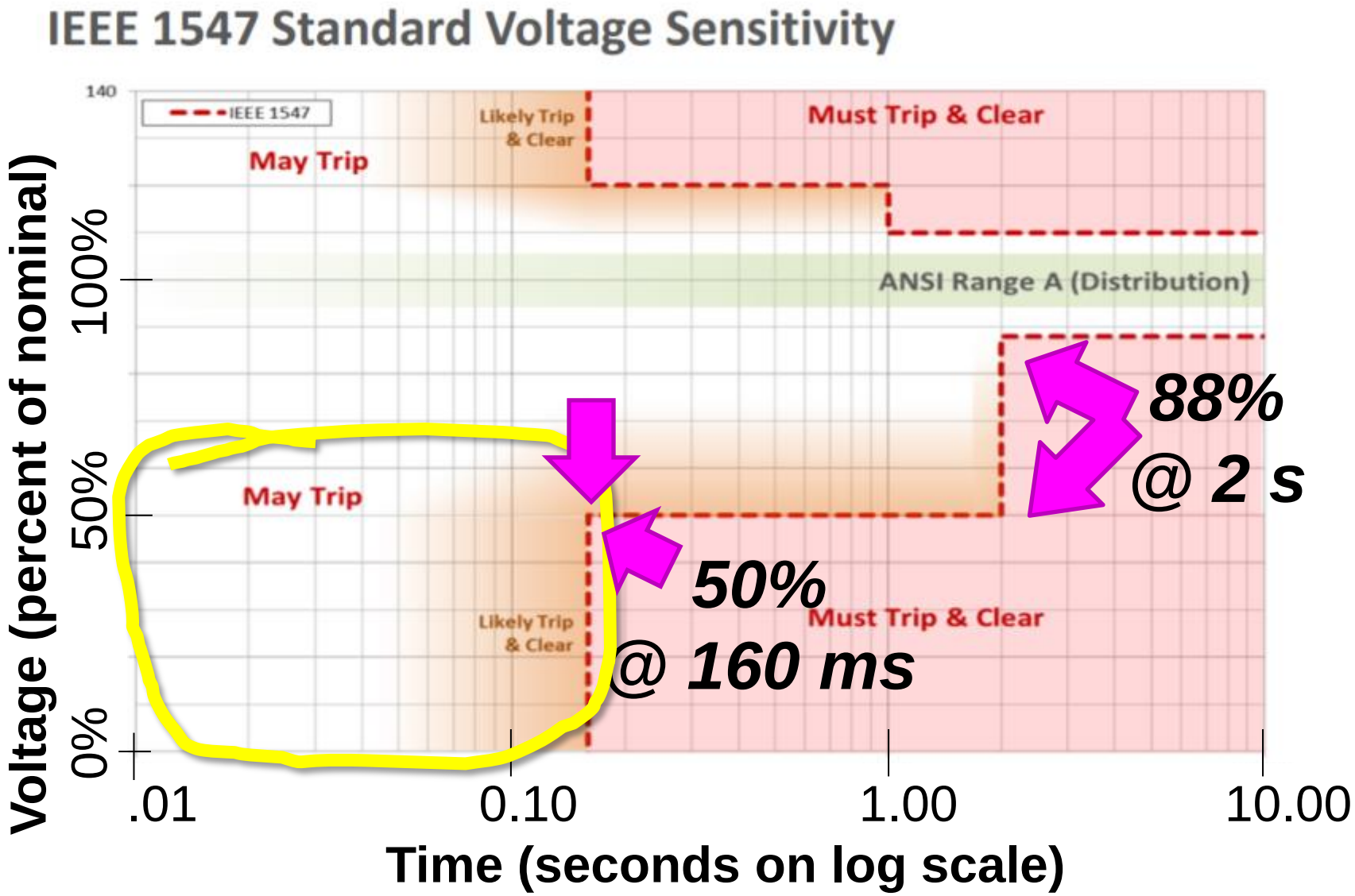
Approx. solar output on low voltage buses in summer 2021 at 2PM



Status Quo—IEEE 1547-2003—DER and "Shall Trip"

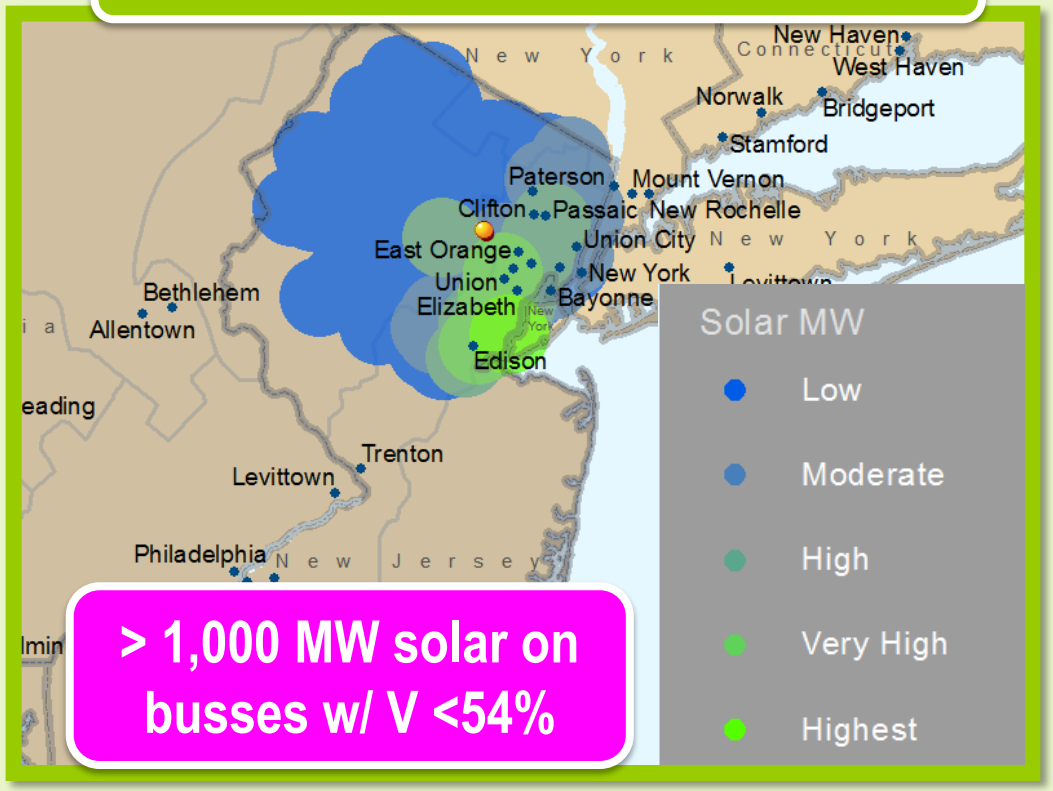
No ride through requirement

Shall trip in 160 ms V <50%



Could Wide Area Undervoltage in PJM Persist to 160 ms or 2s trip point?

Multiphase transmission faults→wide area undervoltage



> 1,000 MW solar on busses w/ V <54%

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

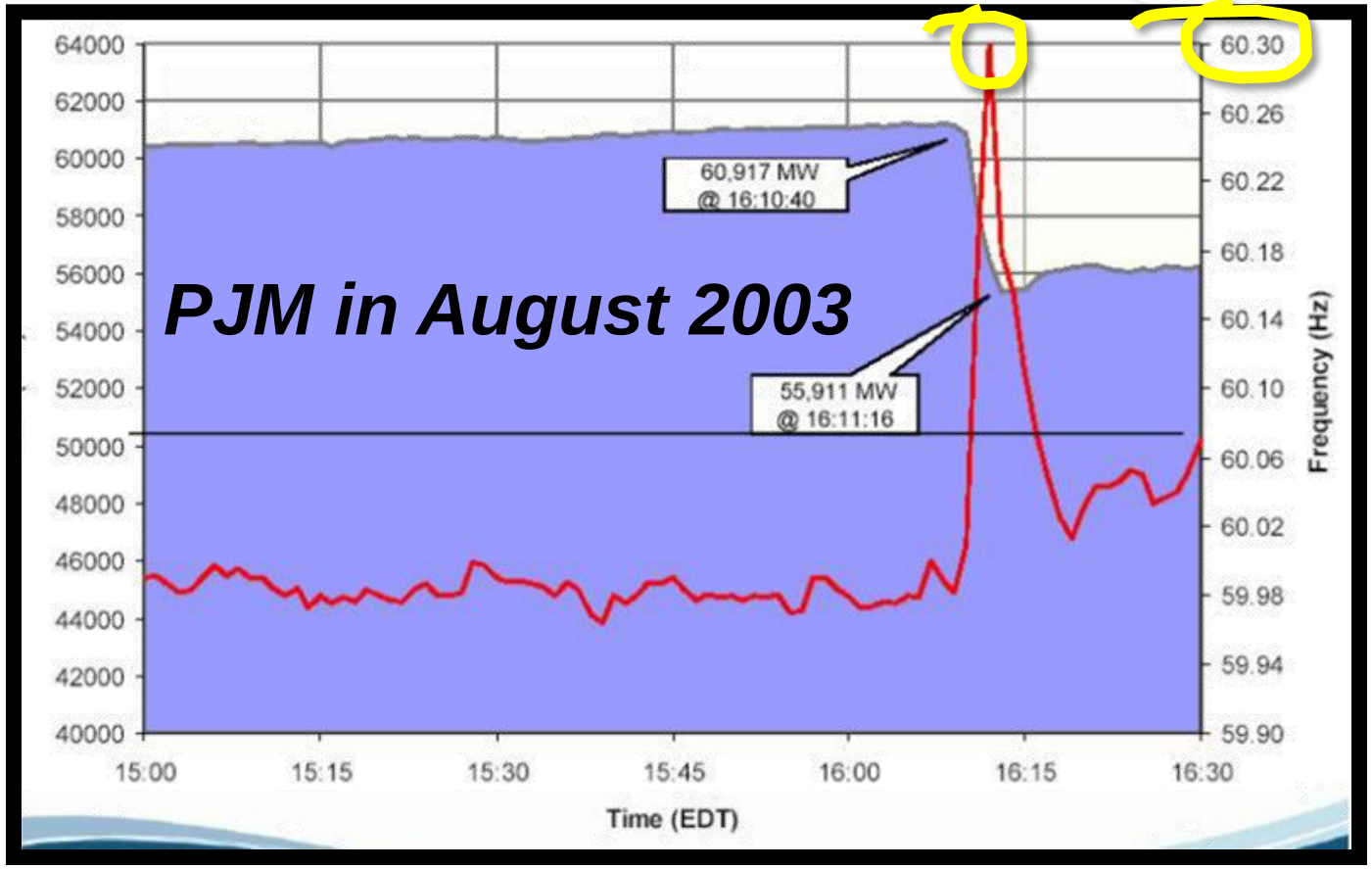
**** EPRI/NERC FORUM ON VOLTAGE STABILITY** at 2/15-24 (Breckenridge, Colo., Sept. 1992) (EPRI TR-102222).*

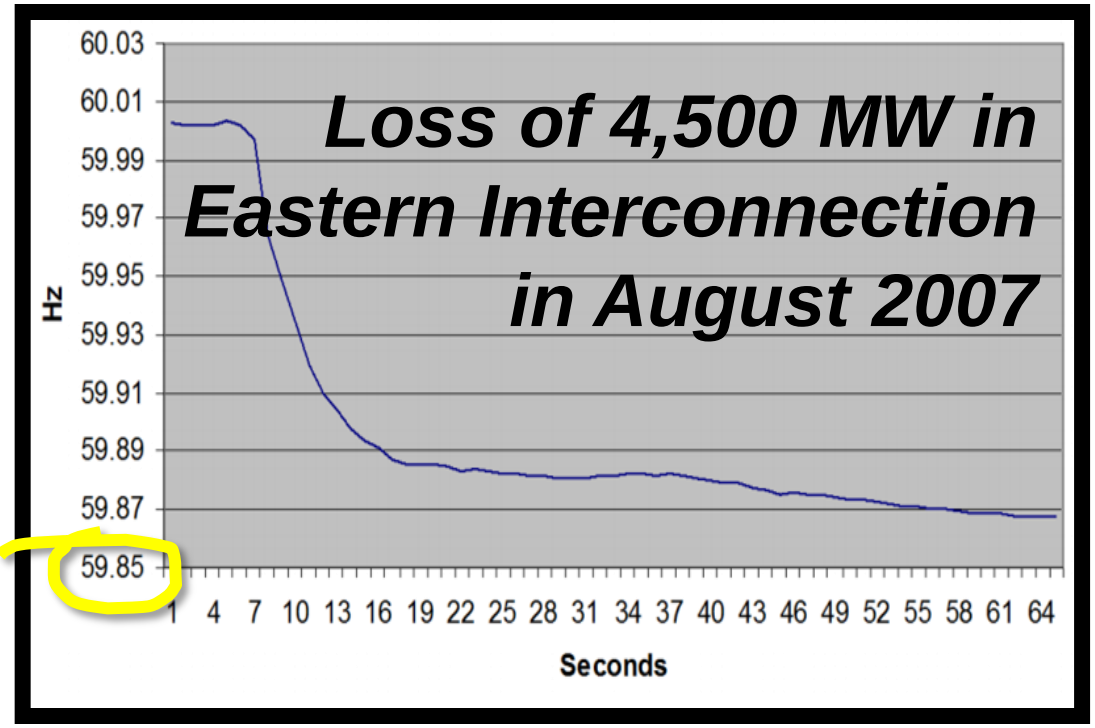
Could 60.5 or 59.8 Hz frequency trip of DER impact PJM?

Catastrophic islanding of interconnection

Black start

Unusually Big Gen Loss





Summary of PJM Interest in DER Ride Through

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.

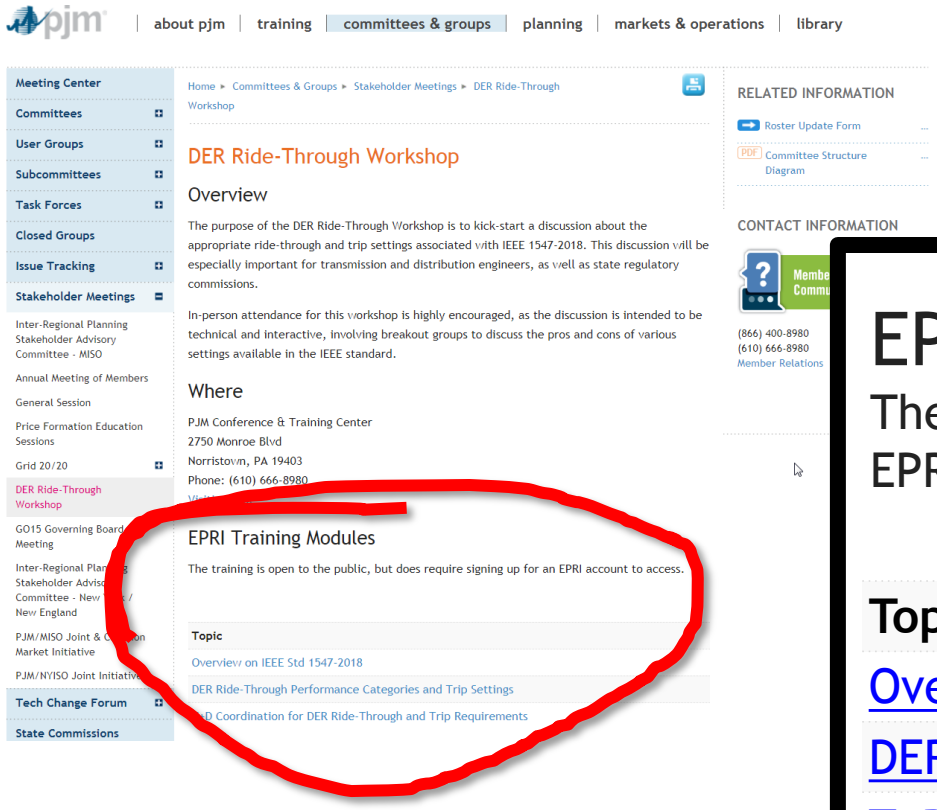
IEEE 1547-2018 EDUCATION

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.
- DERRTTF participants might consider purchasing a licensed copy of the IEEE 1547-2018 standard ($145+): https://standards.ieee.org/standard/1547-2018.html

Valuable EPRI Training Modules on IEEE 1547-2018

https://www.pjm.com/committees-and-groups/stakeholder-meetings/der-ride-through-workshop.aspx



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.

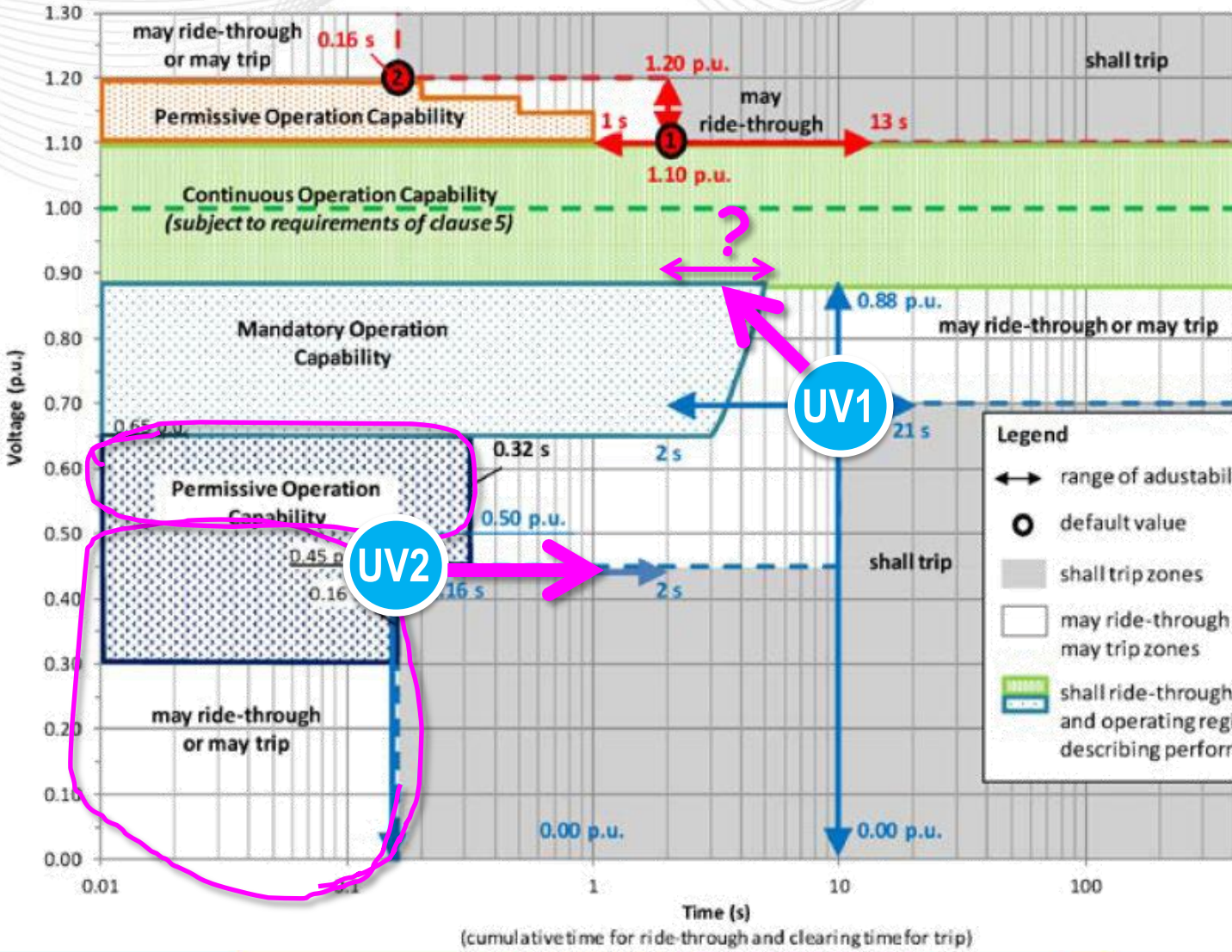
Workshop “Strawman” for PJM DER Voltage Ride Through

IEEE 1547-2018 “Category II” with adjusted trip settings and additions as follows:

a) UV2 increased→1.1 seconds for delayed transmission fault clearing.

b) UV1 time decreased→2 – 5 seconds and volts increased→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 lineworker safety
- Integration with existing distribution protection
- Risk of reclosing into an unintended island given uncertainy 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

IEEE Std 1547-2018 Settings (refer to figures for ranges of allowable settings)	Issues, their limiting factors, and desired values				
	Arc-flash	**Reclosing**	**Distribution Protection**	**Ground-fault overvoltage**	**Bulk System Reliability**
UV1 clearing time and voltage threshold (high impedance faults) ▪ 0.88pu@5.16s	▪ Clearing time < personal protective equipment (PPE) rating (*)	▪ Clearing time < reclose time (may use islanding detection as alternative) (***) ▪ High only if used as back-up to islanding detection	▪ May be relevant for high impedance faults ▪ *How is this different from feeders without DER?* ▪ *How impactful are inverter-based DER versus synchronous DER?*		▪ Clearing time ≥ 3.16 s of NERC PRC-024 ▪ If distribution FIDVR exists, then longer clearing time and/or lower voltage threshold
UV2 clearing time and voltage threshold (most feeder faults) ▪ 0.45pu@1.1s	▪ No impact when combined with Momentary Cessation ▪ If not combined with MC, time incremental impact (**)	▪ No impact when combined with Momentary Cessation ▪ If no MC applied, then clearing time < reclose time (may use islanding detection as alternative)	▪ No impact when combined with Momentary Cessation ▪ If no MC applied, then coordinate with sequential tripping	▪ No impact when combined with Momentary Cessation ▪ If no MC applied, then more complicated.	▪ Clearing time ≥ 0.32 s of NERC PRC-024 ▪ Trip clearing times shall be close to ride-through to reduce uncertainty of actual behavior for transmission modeling
Momentary Cessation (MC) voltage threshold • **0.5 pu**	▪ High enough to account for typical retained voltages during SLG faults	▪ High enough to account for typical retained voltages during islanded conditions	▪ High enough to account for typical retained voltages during feeder faults ▪ Not so relevant for adjacent feeder faults		▪ For modest DER penetrations, as low MC threshold as distribution protection practices allow for
OV1 clearing time and voltage threshold • **1.1pu@2s**		▪ Using OV as AI backup for PDER > Pload.	▪ Already some exposure to GF-OV even with DER. ▪ 110% seems OK for OV1.		▪ Anything greater than 1 sec is good enough.
OV2 clearing time and voltage threshold • **1.2pu@0.16s**		▪ Does not seem to impact.	▪ Default values appear acceptable		▪ Default values appear acceptable.

(*) 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.

Resources (cont.)

EPRI ELECTRIC POWER RESEARCH INSTITUTE

IEEE 1547 Balloting Update

KEY POINTS

- IEEE P1547 requirements can be considered robust, safe, and reliable for most cases. Additional risk assessment may be needed in limited cases. Ongoing and future EPRI research is investigating these cases.
- EPRI members should carefully review the sponsor-ballot Draft 6.7.2 and submit comments for the ballot resolution. EPRI staff will ensure that all comments will be considered, independent of whether they are associated with "approve" or "disapprove" votes.
- Utilities may have to adapt the new requirements to their particular grid conditions to fully exploit the new standard's capabilities. EPRI is offering two supplemental projects, one for utility-specific Application of IEEE 1547 and another one for Evolving DER Connection Processes.
- Distributed generation and energy storage systems certified for compliance with the revised IEEE 1547 may become available as early as the 2019-2020 timeframe.

WHAT IS IEEE 1547?

Over the past several years, the primary interconnection standard for distributed energy resources (DER) in North America,[1] IEEE Std 1547 (abbreviated "1547" throughout this article), has been under revision. Originally, developed in 2003 assuming a low penetration of DER, the voluntary standard has been broadly referenced in the U.S to specify DER capabilities and guide the interconnection process. Technology and economic advances, particularly within the distributed photovoltaics (PV) segment, have, however, led to rising cases of high grid penetration levels and the need for updating the 1547 standard.

Figure 1 illustrates that manner in which the standard has been referenced in individual utility generator connection agreements, state utility laws, national mandates, and certification tests. The standard's primary objective is to *harmonize* interconnection requirements for DER.

As a first step, an amendment to IEEE 1547-2003 (known as IEEE Std 1547a-2014) was adopted in May 2014 that removed restrictions against DER from actively participating in grid voltage regulation. It allows broader inverter support ("smart inverter") and rotating machine support ("field and governor control") functions, such as steady-state voltage control and disturbance ride-through. But it *does not require, nor specify*, grid support along the lines of "grid codes" or "shall" requirements.

Building on the broad flexibility the IEEE 1547a amendment provides to system operators for utilizing DER's grid supportive functions ("may" requirements), revisions to IEEE 1547 now aim to specify further details to manufacturers, utilities, and testing labora-

[1] In 1547-jargon, DERs represent any sources of electric power that are not directly connected to a bulk power system, including distributed generators and energy storage technologies.

DRAFT

Fact Sheet
available on epri.com

NRECA *Revision of IEEE Standard 1547™* Articles	Availability
1. *The Background for Change*, Nov. 2016	Public
2. *New Reactive Power and Voltage Regulation Capability Requirements*, Dec. 2016	Public
3. *New Disturbance Response Requirements*, Feb. 2017	Public
4. *New Power Quality and Islanding Issues*, Apr. 2017	Public
EPRI White Papers	**Availability**
5. *Minimum Requirements for DERs Ride-Through*, May 2015	Public
6. *Communications Interface and Interoperability*, Jul. 2017	Public
7. *Power Quality Considerations for DERs*, Dec. 2017	Public
8. *Impacts of DER Ride-through on Anti-Islanding and Distribution Protection*	Draft