Assessing Potential Risks to the Bulk Power System from Older Inverter-based Distribution Generation

NECPUC meeting

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NARUC-2023-645-DCH163

March 22, 2024

Classification: **public**

Background and Problem Definition

- **About 4,400 MW** aggregate capacity from **Legacy DER** are **installed in the ISO-NE area**
  - These Legacy DER comprise about 160,000 sites

- Large amount of **Legacy DER** could pose a **reliability risk to the bulk power system**
  - Legacy DER may have limited ride-through capability
  - Legacy inverters are UL 1741 certified based on IEEE 1547-2003 and often configured with sensitive trip settings
  - The ISO-NE's TPCET Pilot study and subsequent improvements to its modeling assumptions identified a risk of ~950 MW of DER potentially tripping simultaneously in a worst case

➢ NARUC contracted EPRI* to **assess the risk and investigate possible mitigation strategies**

*Solicitation NARUC-2023-645-DCH163,
"Assessing Potential Risks to the Distribution System from Older Inverter-based Distribution Generation"

Assessing Risk and Investigating Possible Mitigation Strategies in Four Steps

Step 1

Analyzed data set provided by ISO-NE and other Electric Distribution Companies by aggregation of total capacity (MW) and number of DER sites

- IEEE 1547-2003 ("Legacy DER") vs. IEEE 1547-2018 ("Modern DER")
- Fuel type (e.g., solar, wind, etc.)
- Inverter vs. non-inverter

Step 2

Reviewed ISO-NE system analysis studies assessing the amount of Legacy DER capacity at risk of tripping due to a transmission fault

Step 3

Investigated capability of Legacy DER to be reconfigured remotely such that the risk of tripping due to a transmission fault could be reduced

Step 4

Performed a meta-analysis with a qualitative cost-benefit analysis and ranked potential solutions to reduce risk

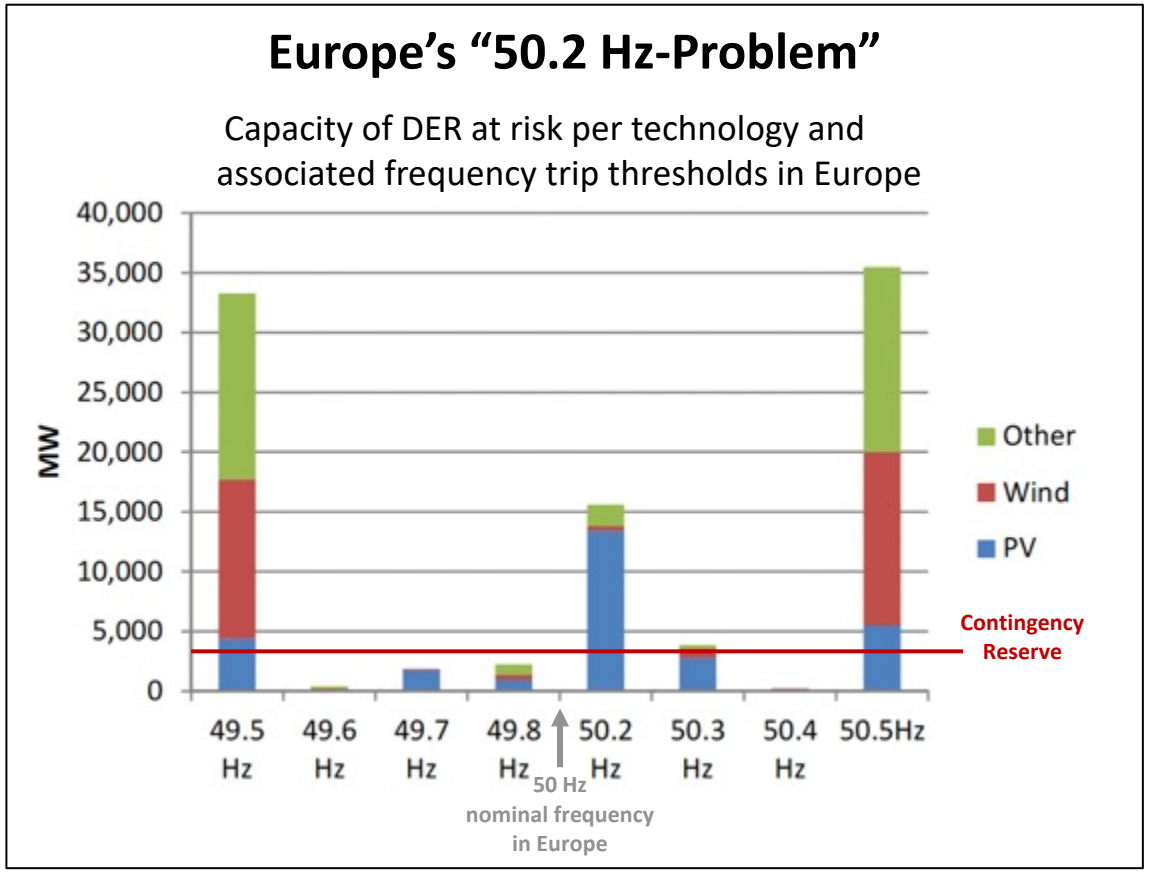
Mistakes Are Part of Every Transformation Process

Problem Definition

- Gigawatts of solar PV, wind, etc. installed in the 2000's
- Configured with trip settings near nominal frequency
- ➢ Potential risk of large-scale blackouts after bulk power system splits (2003 and 2006)

Lessons Learned

- DER deployment was underestimated due to different stakeholder mindsets
- DER interconnection requirements were insufficient due to a lack of stakeholder coordination
- Abnormal transmission frequency and voltage conditions were not considered in DER impact studies



ENTSO-E (2014): Dispersed Generation Impact on CE Region Security. Dynamic Study. 2014 Report Update. [Online]

Accept Responsibility, Manage Risks

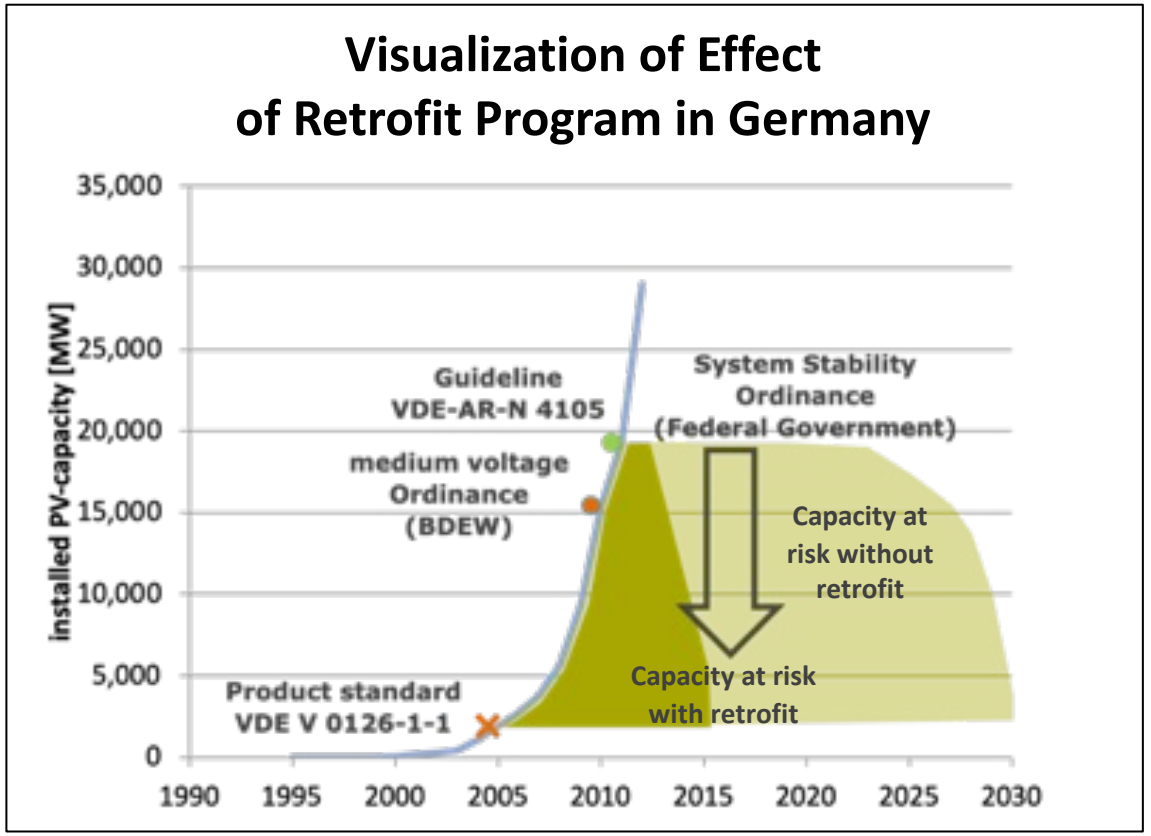
Retrofit Programs Come with Logistical Challenges and Costs

Solutions

- Changed interconnection requirements as soon as possible to remove risk from newly connecting resources
- Conducted a multi-stakeholder analysis and joint study to quantify risk and develop consensus mitigation strategies
- ➢ European and government directives to design and execute major retrofit programs across Europe

Lessons Learned

- Germany alone retrofitted more than 300,000 solar PV systems larger 10 kWp over 3–4 years at €200M
- Delayed response due to lack of DER data collection, modeling, and remote configurability
- Retrofits are costly, complicated, and frustrating



Note: VDE-AR-N 4105, BDEW, etc. are German guidelines that specify frequency trip settings.

K. Burges/Ecofys (2014): Grid code compliance in a changing environment. *In:* 4th Int. Workshop on Integration of Solar Power into Power Systems. Berlin, Germany, Nov. 10-11.

Opportunity to Learn from Other Countries' Experiences

IEEE 1547 Interconnection Standard Has Evolved Gradually

Diverse

- **Unknown** or not harmonized across utilities

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

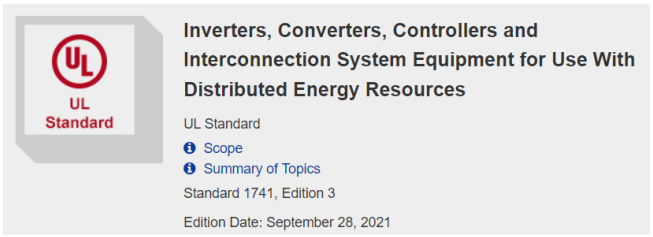
IEEE 1547-2018

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

IEEE 1547a-2020

- **More flexibility** for configuration of the **degree to which** the Category III voltage ride-through **capability may be utilized**

IEEE 1547-2018 Compatible DER Products Are Available



Certified Product Availability ?

2022

2023

2024

80% of inverters families already certified

Sep 28, 2021

1741 Ed. 3/ 1741SB

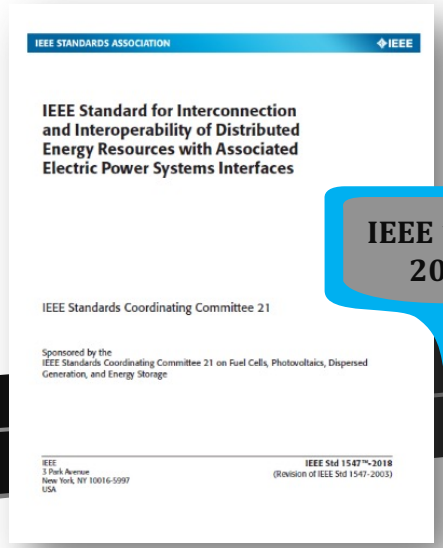
IEEE 1547-2018

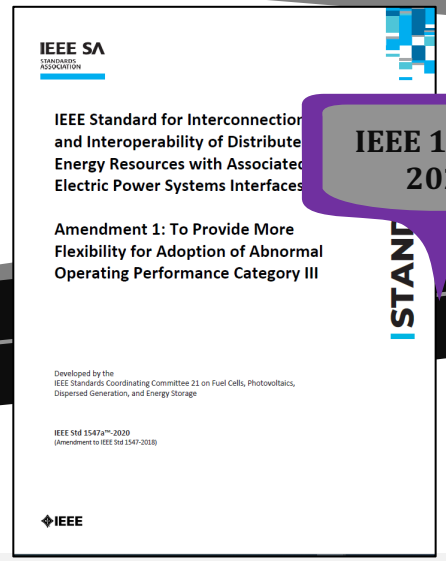
IEEE 1547a-2020

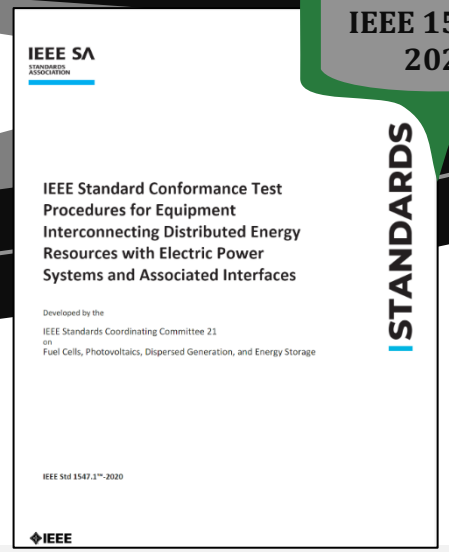
IEEE 1547.1-2020

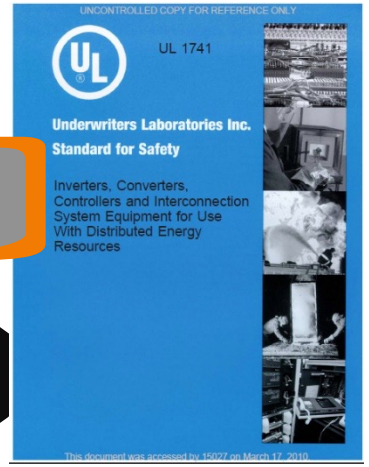
Sep 16, 2020

1741 Ed. 2/ 1741SB



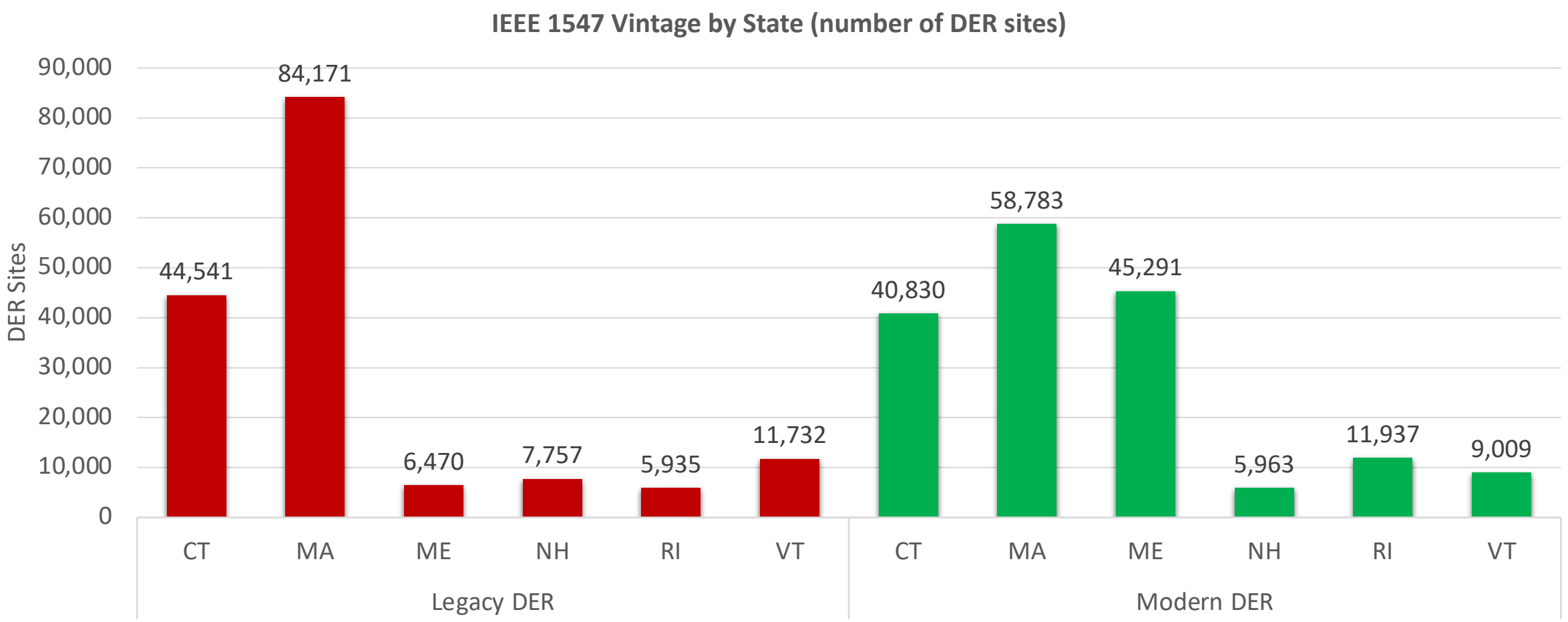






Source: EPRI

About 4,400 MW from Legacy DER Installed in ISO-NE



Applicable IEEE 1547 version: IEEE 1547-2003 (“Legacy DER”) vs. IEEE 1547-2018 (“Modern DER”)

About 160,000 Legacy DER Sites may be in Scope

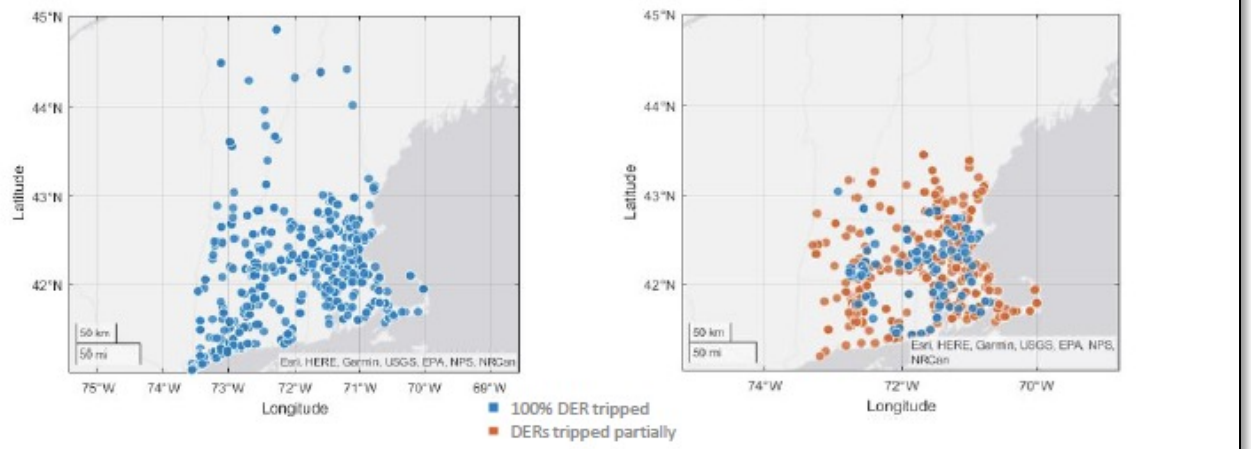
Only a Fraction of the DER Capacity at Risk could Trip

Impact Of Revised IEEE 1547-2003 DER Trip Assumptions

- ISO-NE revisited the fault that caused considerable DER tripping in the TPCET Pilot study – a single-line-to-ground (SLG) fault with breaker failure on the SEMA/RI 345 kV in the Spring Weekend Mid-Day Minimum Load study conditions

Simulation results with old assumptions: 1,855 MW of DERs tripped, out of which 1,495 MW were IEEE 1547-2003 <1 MW DERs

Simulation results with new Assumptions: 950 MW of DERs tripped, out of which 570 MW were IEEE 1547-2003 <1 MW DERs



ISO-NE PUBLIC

21

Source: *Updates to IEEE 1547-2003 DER Modeling Assumptions.* Planning Advisory Committee. ISO-NE. August 24, 2022. Webex

OEM Confidence in Ability to Identify & Reconfigure DERs is Low

OEMs report they may not be able to accurately identify DERs' location, vintage, and remote configurability.

- OEMs often sell equipment to distributers with little visibility of where it gets installed
- Customers may not have to register their inverters with the OEMs to obtain warranty
- With no collection of customer data about inverter makes, models, and firmware versions, neither EDCs nor PUCs have such information

OEMs report many Legacy DERs cannot ride through abnormal voltage or frequency conditions by reconfiguration/firmware update.

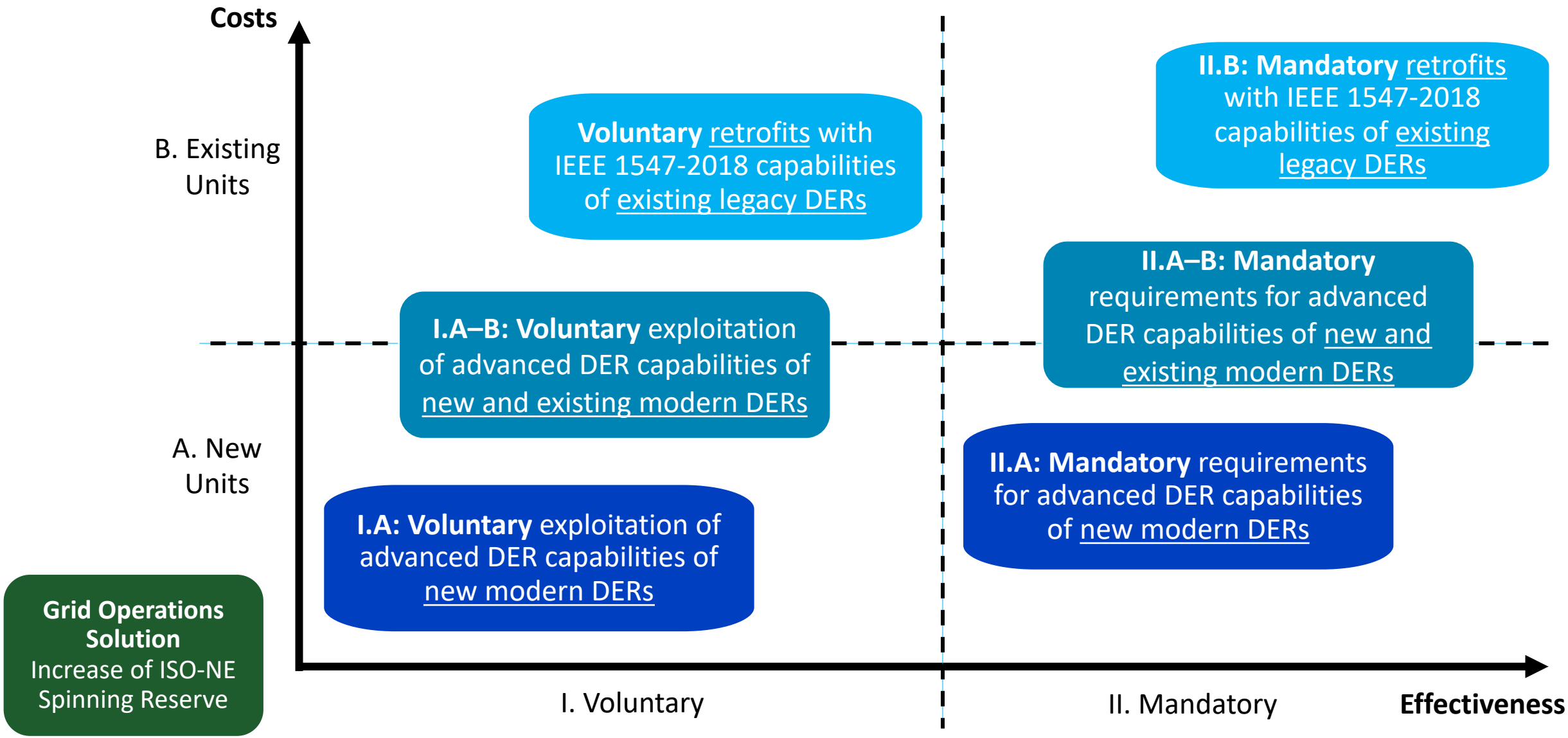
- Inverters in Legacy DERs without sufficient ride-through capability would have to be replaced, i.e., retrofitted at market prices

Side Note: Retrofitting could bring secondary benefits for the distribution system like improved reactive power capability and voltage support functions

OEMs report their physical or remote access to Legacy DERs that can be reconfigured is restricted

- Many interconnection agreements do not include clauses that allow for periodic testing or reconfiguration
- Only those inverters in Legacy DERs that were registered with the OEM by the customer and that have an active internet connection can be remotely accessed through OEM portals
- Physical access to inverters in Legacy DER site may not be granted by customers

Ranking of Potential Solutions to Reduce Risk



Expand Stakeholder Collaboration to Assess and Mitigate Risk

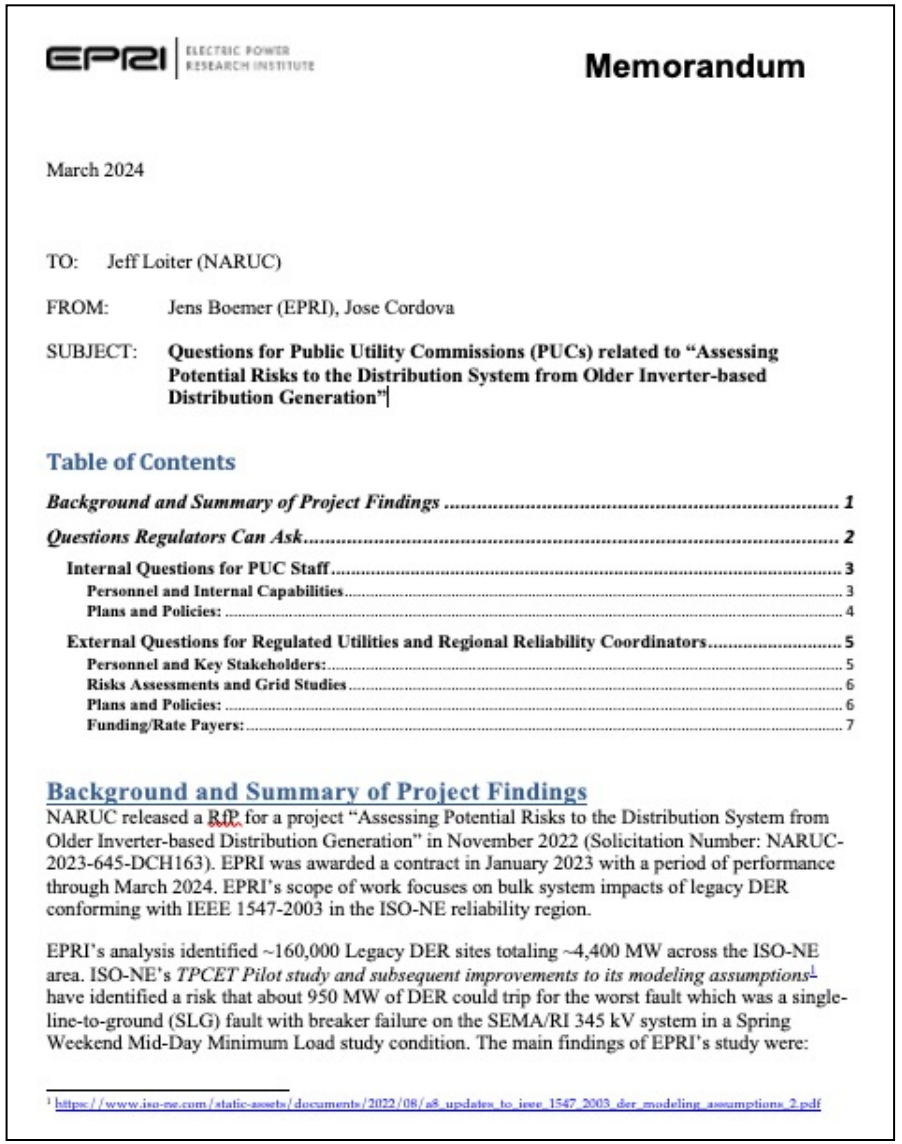
Legacy inverter-based DER can pose a risk to bulk power system reliability.

Modern inverter-based DER can provide advanced grid support, if adequately configured.

The **costs-benefits** of potential solutions to reduce risk were analyzed and ranked qualitatively.

Further Explorations can also Prepare for Future Risks

Guiding PUC Questions to Expand Stakeholder Collaboration



EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Memorandum

March 2024

TO: Jeff Loiter (NARUC)

FROM: Jens Boemer (EPRI), Jose Cordova

SUBJECT: **Questions for Public Utility Commissions (PUCs) related to "Assessing Potential Risks to the Distribution System from Older Inverter-based Distribution Generation"**

Table of Contents

Background and Summary of Project Findings

NARUC released a RfP for a project "Assessing Potential Risks to the Distribution System from Older Inverter-based Distribution Generation" in November 2022 (Solicitation Number: NARUC-2023-645-DCH163). EPRI was awarded a contract in January 2023 with a period of performance through March 2024. EPRI's scope of work focuses on bulk system impacts of legacy DER conforming with IEEE 1547-2003 in the ISO-NE reliability region.

EPRI's analysis identified ~160,000 Legacy DER sites totaling ~4,400 MW across the ISO-NE area. ISO-NE's *TPCET Pilot study and subsequent improvements to its modeling assumptions*[1] have identified a risk that about 950 MW of DER could trip for the worst fault which was a single-line-to-ground (SLG) fault with breaker failure on the SEMA/RI 345 kV system in a Spring Weekend Mid-Day Minimum Load study condition. The main findings of EPRI's study were:

[1] https://www.iso-ne.com/static-assets/documents/2022/08/a8_updates_to_ieee_1547_2003_der_modeling_assumptions_2.pdf

Developed a memorandum with questions that public utility commissions (PUCs) can ask to leverage the findings of this study.

Content

- Background and Summary of Project Findings
- Questions Regulators Can Ask
  - Internal Questions for PUC Staff
    - Personnel and Internal Capabilities
    - Plans and Policies
  - External Questions for Regulated Utilities and Regional Reliability Coordinators
    - Personnel and Key Stakeholders
    - Risks Assessments and Grid Studies
    - Plans and Policies

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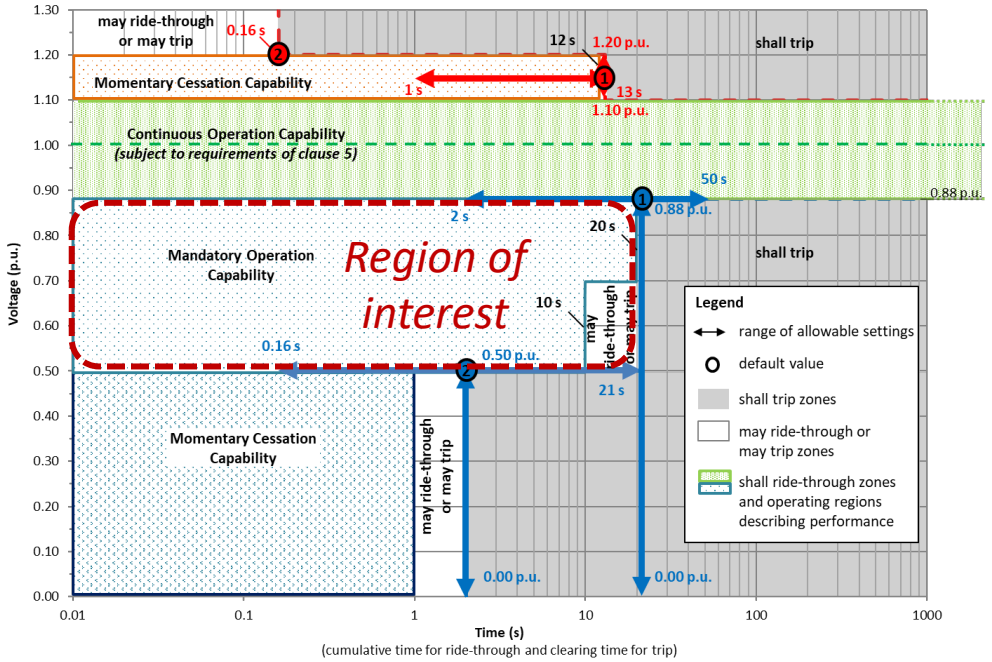
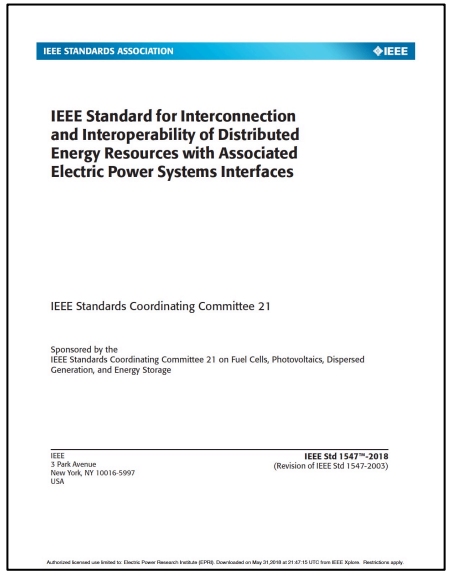
Potential Solutions to Reduce Risk

II.A: Mandatory requirements for advanced DER capabilities of new modern DERs



- Specified requirements apply to modern inverter-based DERs with UL 1741 SB certified inverters.


IEEE STANDARDS ASSOCIATION

IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

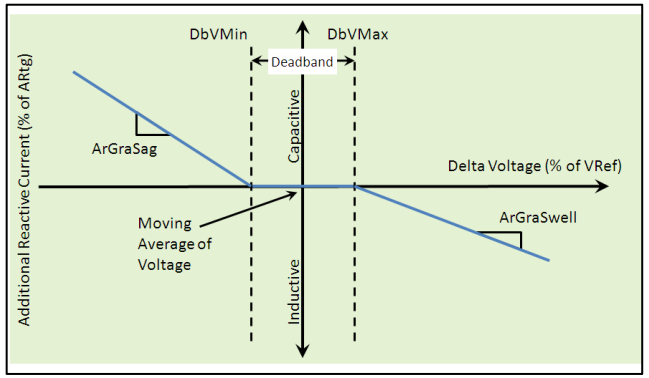
IEEE Standards Coordinating Committee 21

Sponsored by the IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

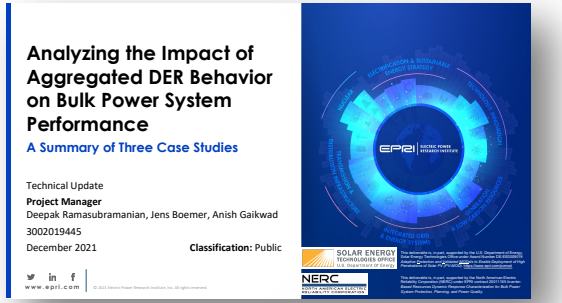
IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)

DER Dynamic Voltage Support (DVS) – optional and not specified in IEEE 1547-2018



- Some inverters **may additionally have**:
  - Ability to configure the voltage threshold below which the inverter switches to Momentary Cessation (MC, also: current blocking).
  - Dynamic Voltage Support (DVS) capability in the Mandatory Operation Capability region (see figure to left).


Analyzing the Impact of Aggregated DER Behavior on Bulk Power System Performance

A Summary of Three Case Studies

Technical Update

Project Manager
Deepak Ramasubramanian, Jens Boemer, Anish Gaikwad

3002019445

December 2021

Classification: Public

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[3002019445]

- Enabling DVS resulted in improved BPS voltage and frequency for the scenarios considered in this case study
- DVS was observed to improve the ride-through of the overall fleet of DER, including Legacy DER

Industry Terms for Safety, Quality, and Efficiency

Compatibility[1]

(unit/equipment)

- Design equipment to support conformity or compliance of a complex system (e.g., DER plant)

Conformity[2]

(plant/system)

- Adherence to certain voluntary industry standards or procedures (e.g., IEEE 1547/.1)

Compliance

(plant/system)

- Meeting mandatory legal and regulatory obligations (e.g., NERC Reliability Standards)

[1] In some cases, e.g., UL 1741 SB, compatibility of equipment is certified based on a Source Requirement Document (SRD).

[2] The term “conformance” is depreciated and should not be used any longer.

References:

- https://www.inboundlogistics.com/articles/conformance-vs-compliance
- https://www.linkedin.com/pulse/conformity-vs-conformance-compliance-carlos-cisneros-cqa/
- https://www.standardsuniversity.org/e-magazine/september-2017/introduction-conformity-assessment-compliance/
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- Inverter Source Requirement Document of ISO New England (ISO-NE). ISO New England, Inc.: 2018 [Online]
- Default New England Bulk System Area Settings Requirement. ISO New England, Inc.: 2021 [Online]
- Assessing Potential Risks to the Distribution System and Bulk System from Older Inverter-based Distribution Generation. Final Report including Deliverables 1.A, 1.B, 2, and 3. NARUC-2023-645-DCH163. EPRI. Palo Alto, CA: 2024 *(may be provided on request to NARUC)*