INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

Grid Engineering Practices & Standards Protection with High Adoption of DER | 5/3/23

An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office

Meeting Notes

Notes synthesizing keys points, insights and questions from the meeting can be found here: Box Link

The first half of this Teams call is being recorded and may be posted on DOE's website or used internally. If you do not wish to have your voice recorded, please do not speak during the call. If you do not wish to have your image recorded, please turn off your camera or participate by phone. If you speak during the call or use a video connection, you are presumed to consent to recording and use of your voice or image.

Recording will stop after the scheduled presentations.

Agenda

- Introduction to i2X Solution e-Xchanges (5 min)
- Overview of Old and New Protection with DER (15 min)
- Technical Presentations (40 min)
  - Mrinmayee Kale (New Leaf Energy)
  - Mike Hanestad (RLC Engineering)
- Interactive Group Discussion (45 min)
  - Why have some utilities moved away from direct transfer trip?
  - How should we evaluate the probability and risk of unintentional islanding?
  - Why have some utilities moved away from de minimus DER limits on secondary networks?
  - What does it take for the engineering community and relay vendors to adopt new protection methods?
- Commenting Process for DER Interconnection Study Guide (5 min)

Interconnection Innovation e-Xchange (i2X)

Mission: To enable a **simpler**, **faster**, and **fairer** interconnection of clean energy resources while enhancing the **reliability**, **resiliency**, and **security** of our **distribution and bulk-power electric grids**

Stakeholder Engagement

Nation-wide engagement platform and collaborative working groups

Data & Analytics

Collect and analyze interconnection data to inform solutions development

Strategic Roadmap

Create roadmap to inform interconnection process improvements

Technical Assistance

Leverage DOE laboratory expertise to support stakeholder roadmap implementation

i2X Solution e-Xchange Topic Areas

- **Queue Management and Cost Allocation**
  - Technology, regulation, administration, and organizational change focus
  - *What* innovative interconnection solutions exist?
- **Grid Engineering Practices and Standards**
  - Engineering and technology focus
  - *How* can proposed solutions be executed?
- **Equity and Energy Justice**
  - Multidisciplinary
  - *Who* is impacted by and benefits from proposed solutions?
- **Data Transparency**
  - Multidisciplinary
  - *What* transparency concerns must be addressed?
- **Interconnection Workforce and Training**
  - Multidisciplinary

Additional subjects, like capacity maps, cross these topics and will be addressed from these different perspectives. Follow the schedule of events on the i2X website.

Key Outcomes from Our e-Xchange Meetings

- Inform and formulate a ***publicly available***, strategic roadmap for interconnection
  - Topical challenges and issues
  - Practical solutions to implement and scale
  - Knowledge and data gaps and new solutions to pilot
  - Success goals and measures of success

- Summary documentation for each meeting regarding ideas discussed and opportunities for targeted stakeholder action
- Provide platform for ongoing engagement before and after meetings
- **Longer term vision** → Solution e-Xchanges to continue building a national forum for all stakeholders as a community of practice, excellence, and innovation

Upcoming Solution e-Xchanges to Consider Joining

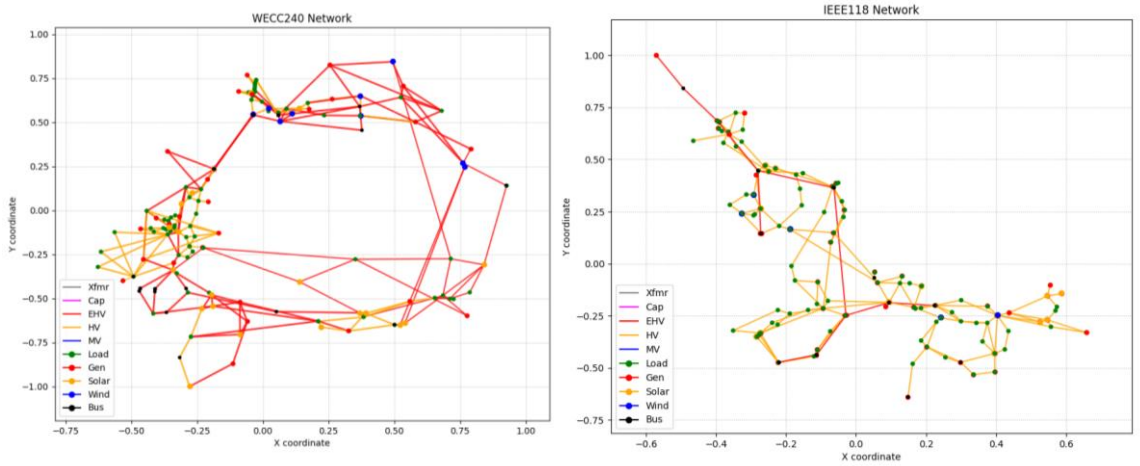
BOLDED ITEMS FOCUSED ON GRID ENGINEERING TOPICS

1. May 11th, 2-4 p.m. Eastern: Managing the Bulk Power System Interconnection Study Process
2. May 24, 2-4 p.m. Eastern: DER Interconnection Process Approaches & Flexible Interconnection
3. May 31, 2-4 p.m. Eastern: Limitations and Barriers to Improving Pre-Application Data Transparency (DER and BES)
4. **August 2nd, 2-4 p.m. Eastern: Synergizing Two Cylinders of Excellence**

Follow the schedule of events on the i2X website.
https://www.energy.gov/eere/i2x/i2x-solution-e-xchanges

i2X has been producing test systems, documents, software tools, visualizations, and proposed new metrics for interconnections.

BES Test Systems for EMT Analysis Boot Camps



Contributions to IEEE P1729, Recommended Practice for Electric Power Distribution Analysis (with Hosting Capacity and Dynamics)

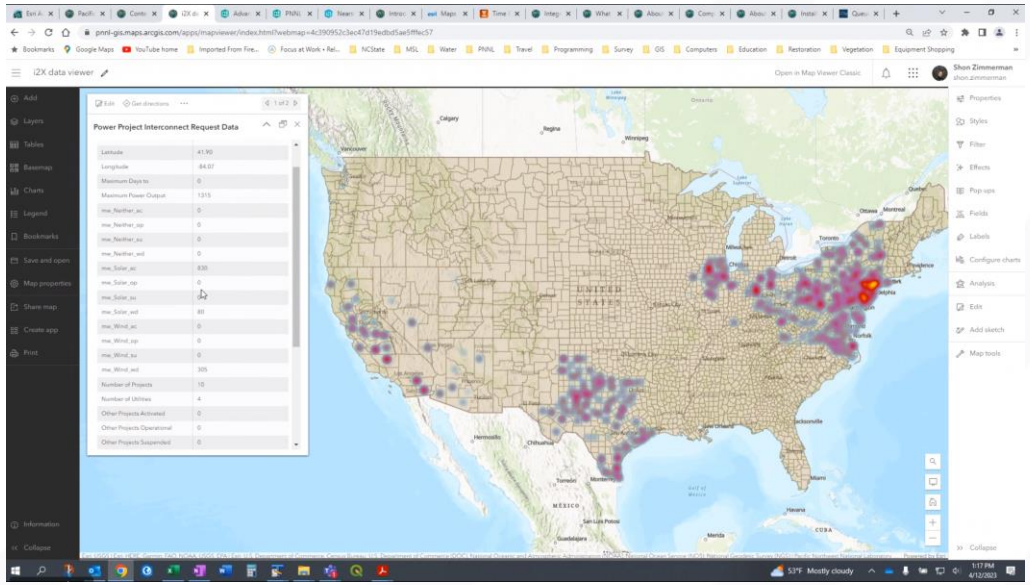
Commonly Applied Boundary Parameters

- Thermal limits (overloading feeder equipment or conductors),
- Voltage limits (steady state),
- Rapid voltage change (dynamic variations),
- Impact on voltage regulators and tap changers operation
- Reverse power flow

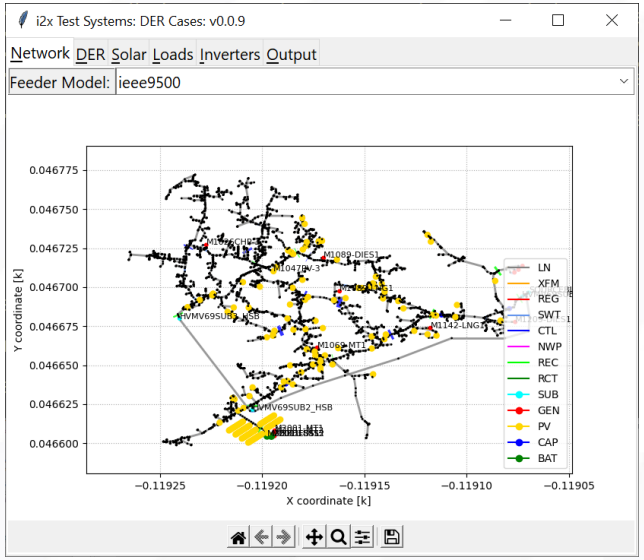
Advanced Boundary Parameters

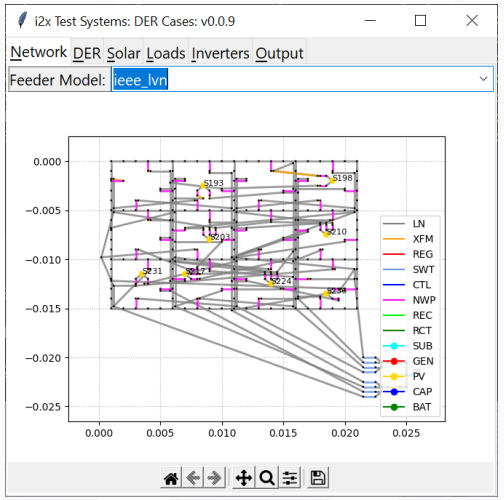
- Protection
  - Reach reduction
  - Sympathetic tripping
- Harmonics
  - Individual harmonics
  - THD / TDD

Source: Quanta / Natural Resources Canada, 2021



GIS Portal for Queued Up, SolarTRACE, and IX Metrics

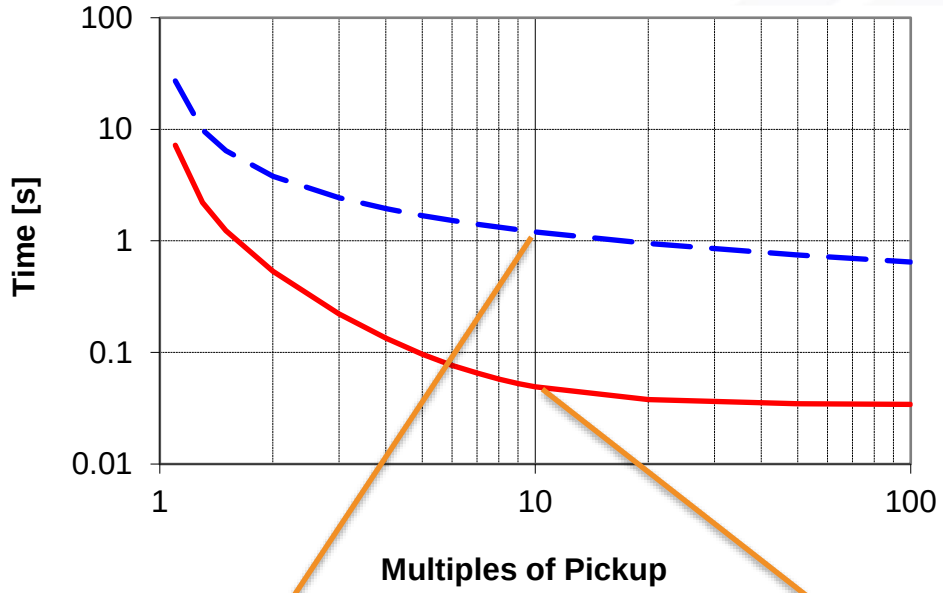




DER Analysis Tool for Boot Camps

Time Overcurrent Protection has worked well on radial feeders without DER.

Recloser



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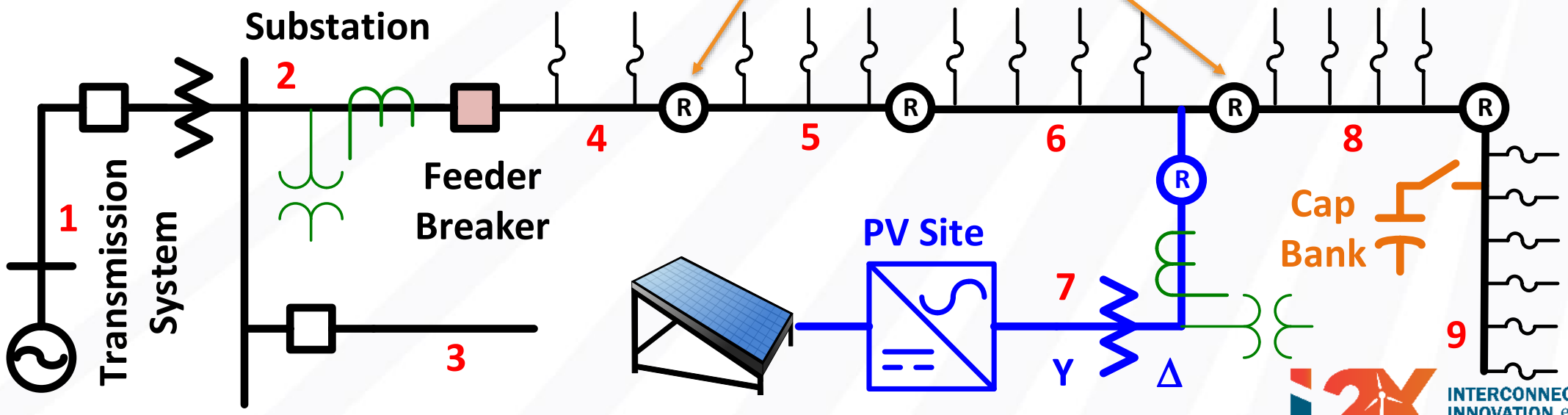

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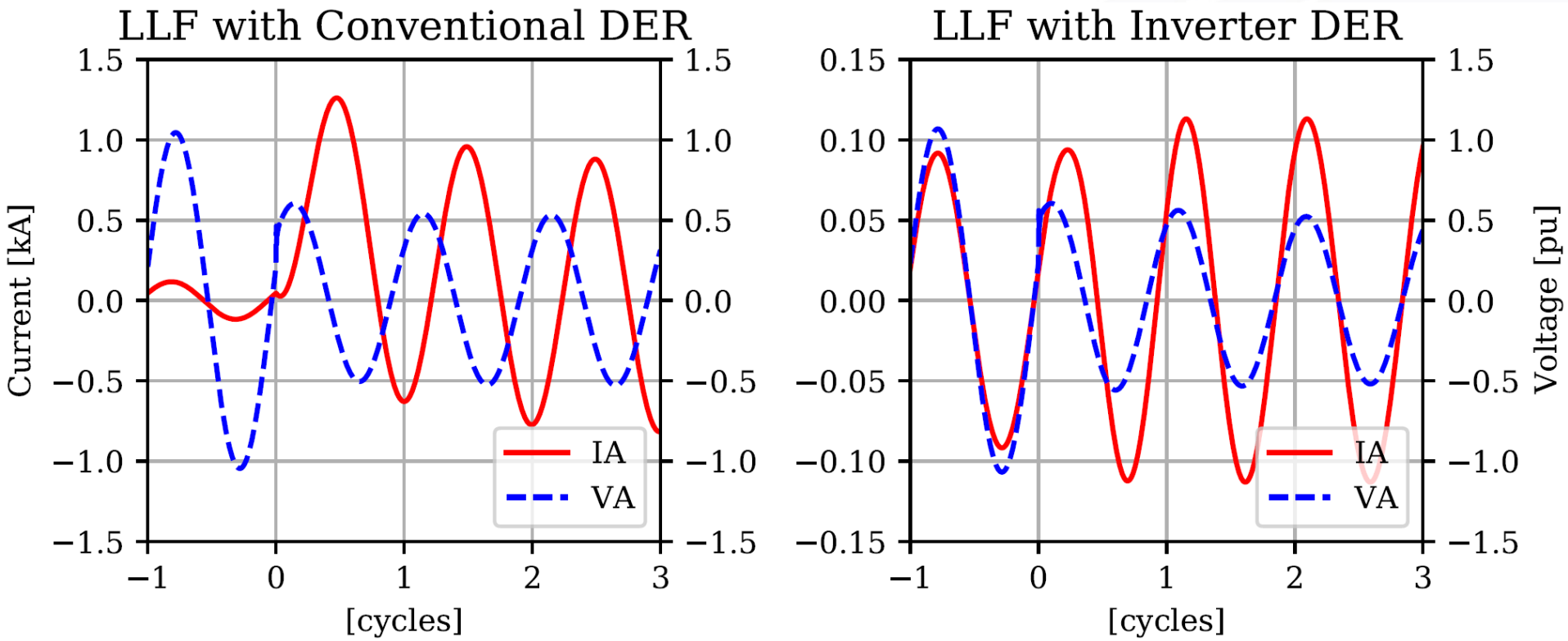
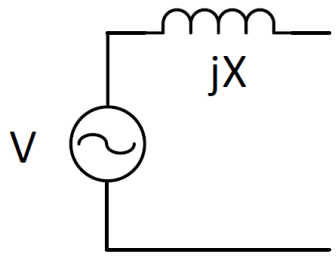
IBR contribute fault currents of lower magnitude and in phase with the voltage, compared to conventional rotating machines.





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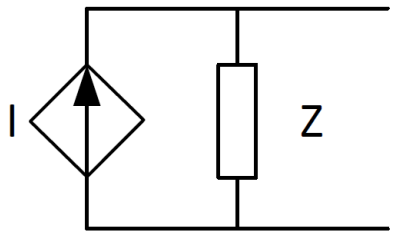
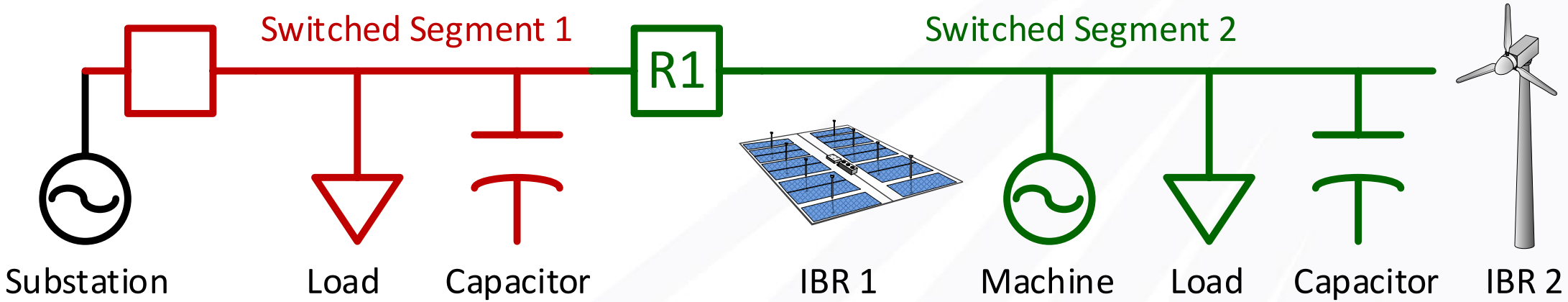


Norton source

Suggested Guidelines for Anti-Islanding Screening (2012)

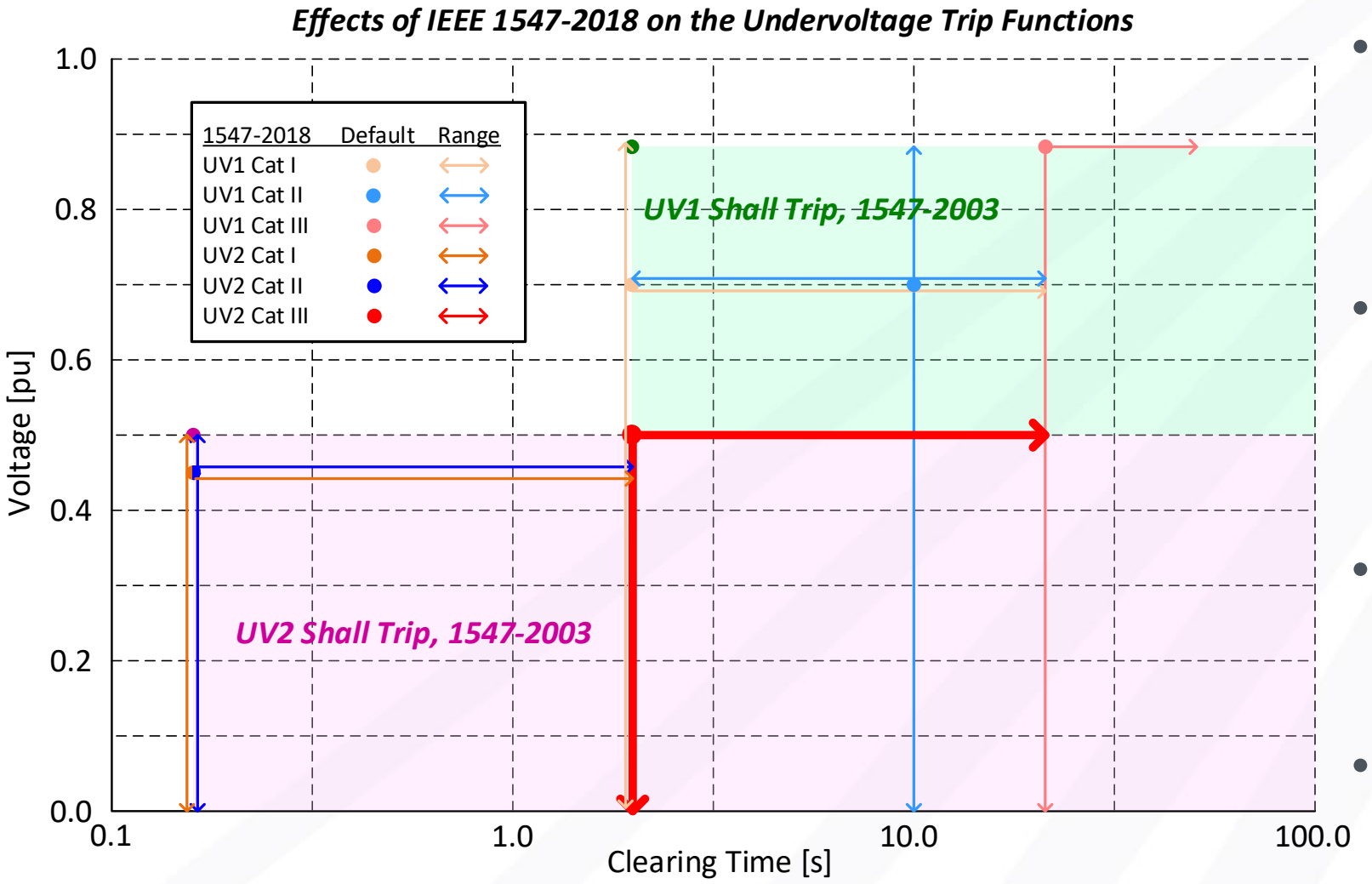


Additional Study Recommended for Direct Transfer Trip if:

- Total DER real power output > 67% of minimum time-coincident segment load. If so:
  - Reactive power balanced in the segment within 1%, or
  - Less than 67% of total IBR capacity comes from the same vendor, or
  - Rotating machine DER is more than 25% of the total DER
- The guidelines rely on undervoltage trip within 2 seconds. With ride-through permitted since 2014, the guideline may no longer apply.

- https://www.osti.gov/servlets/purl/1039001/, then revised to exclude grid impedance screen,
- https://energy.sandia.gov/wp-content/gallery/uploads/SAND2012-1365-v2.pdf

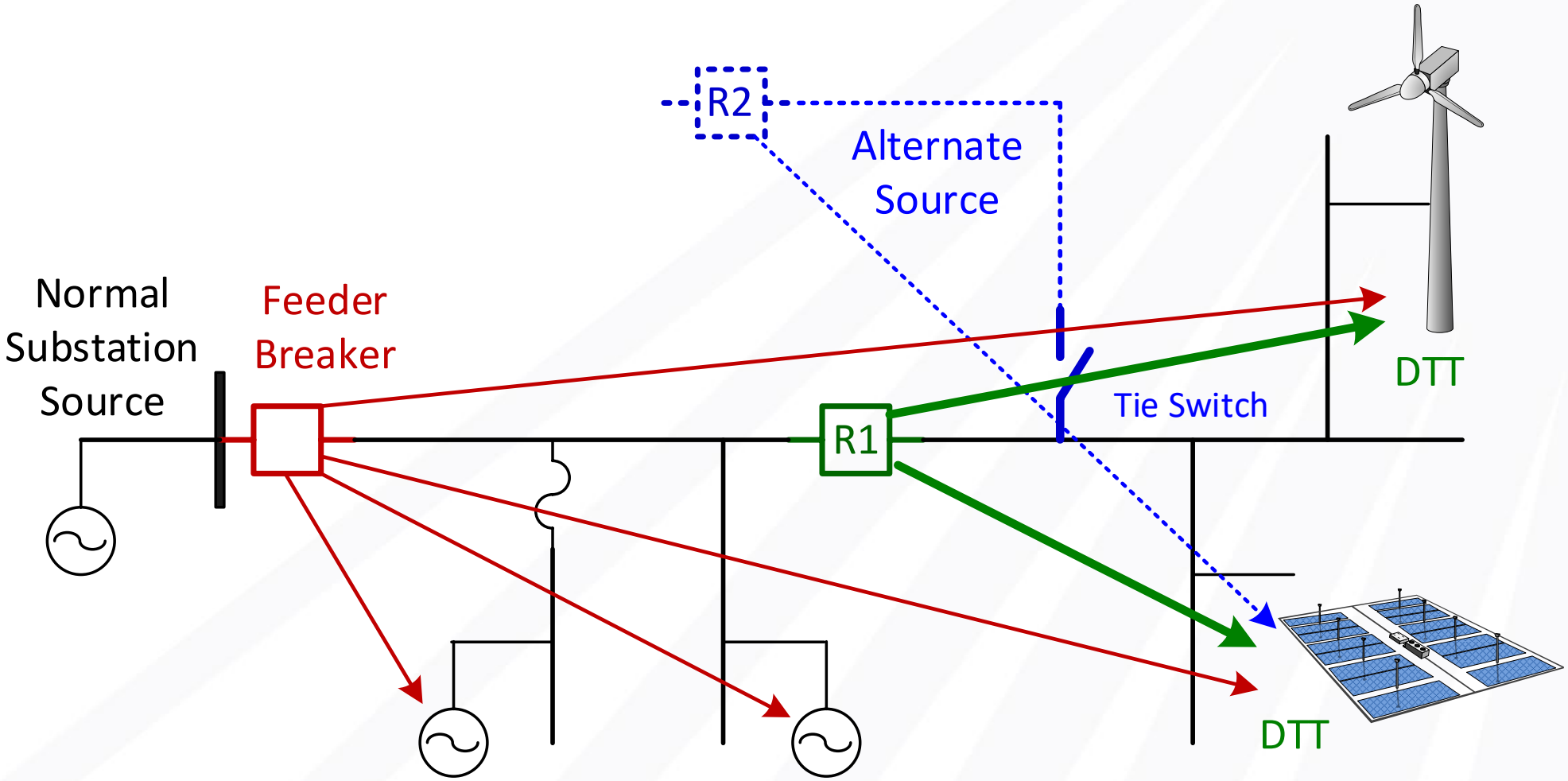
After IEEE 1547-2018 (and the 2014 amendment), we should not count on the undervoltage trip to detect faults or islands.



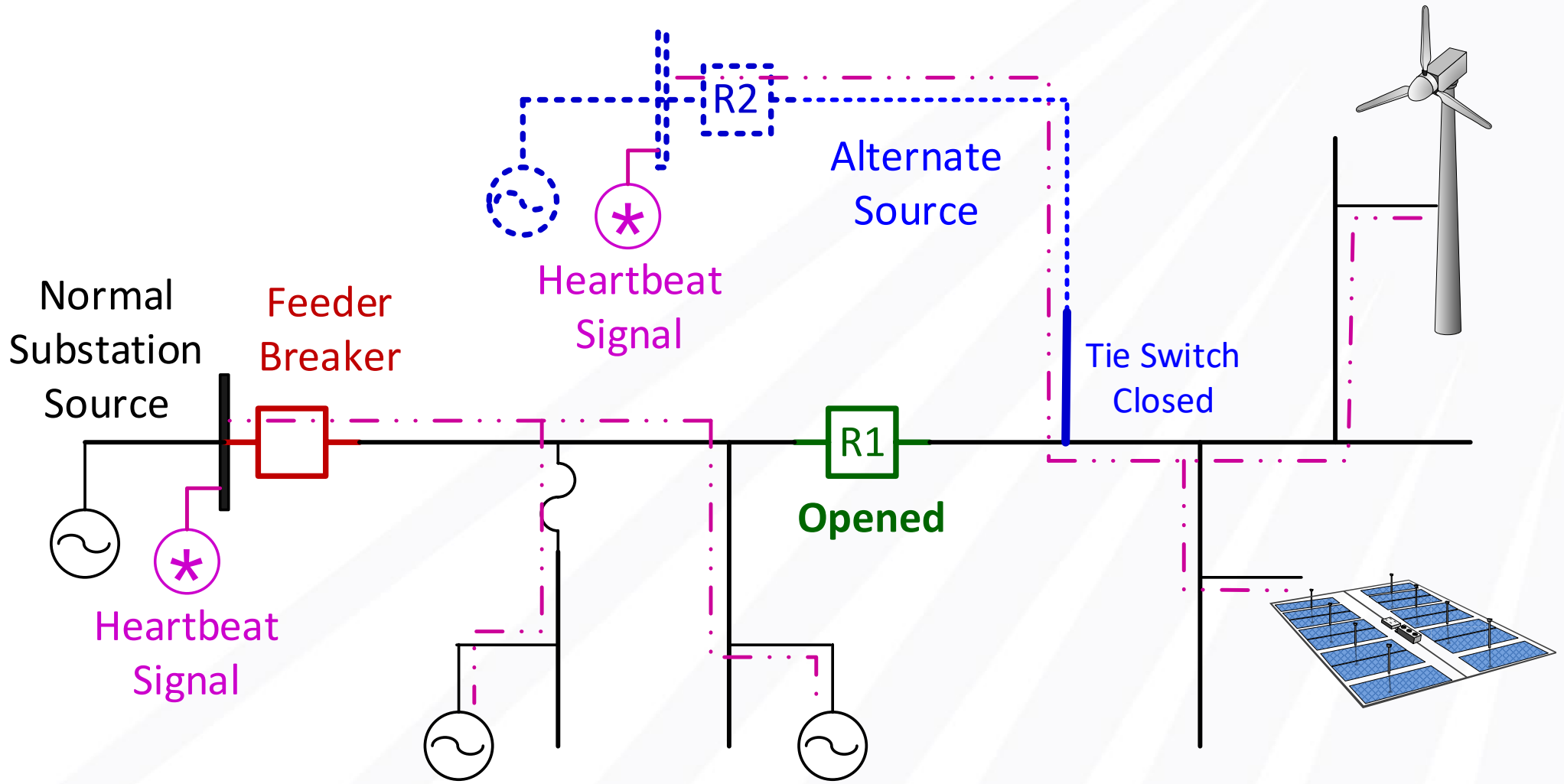
- The 2012 guideline:
  - **UV1 trip at 0.88 pu in 2.0 s**
  - $0.88^2 = 0.77$ pu load
  - **67%** load for safety
- With ride-through, Cat I:
  - **UV1 trip at 0.70 pu in 2.0 s**
  - $0.70^2 = 0.49$ pu load
  - **40%** pu load for safety
- Cat II and III default UV1 trip at 10 s or 21 s, both longer than 2 s allowed for islanding
- UV1 is adjustable up to 21 s, even for Cat I

https://doi.org/10.2172/1834373

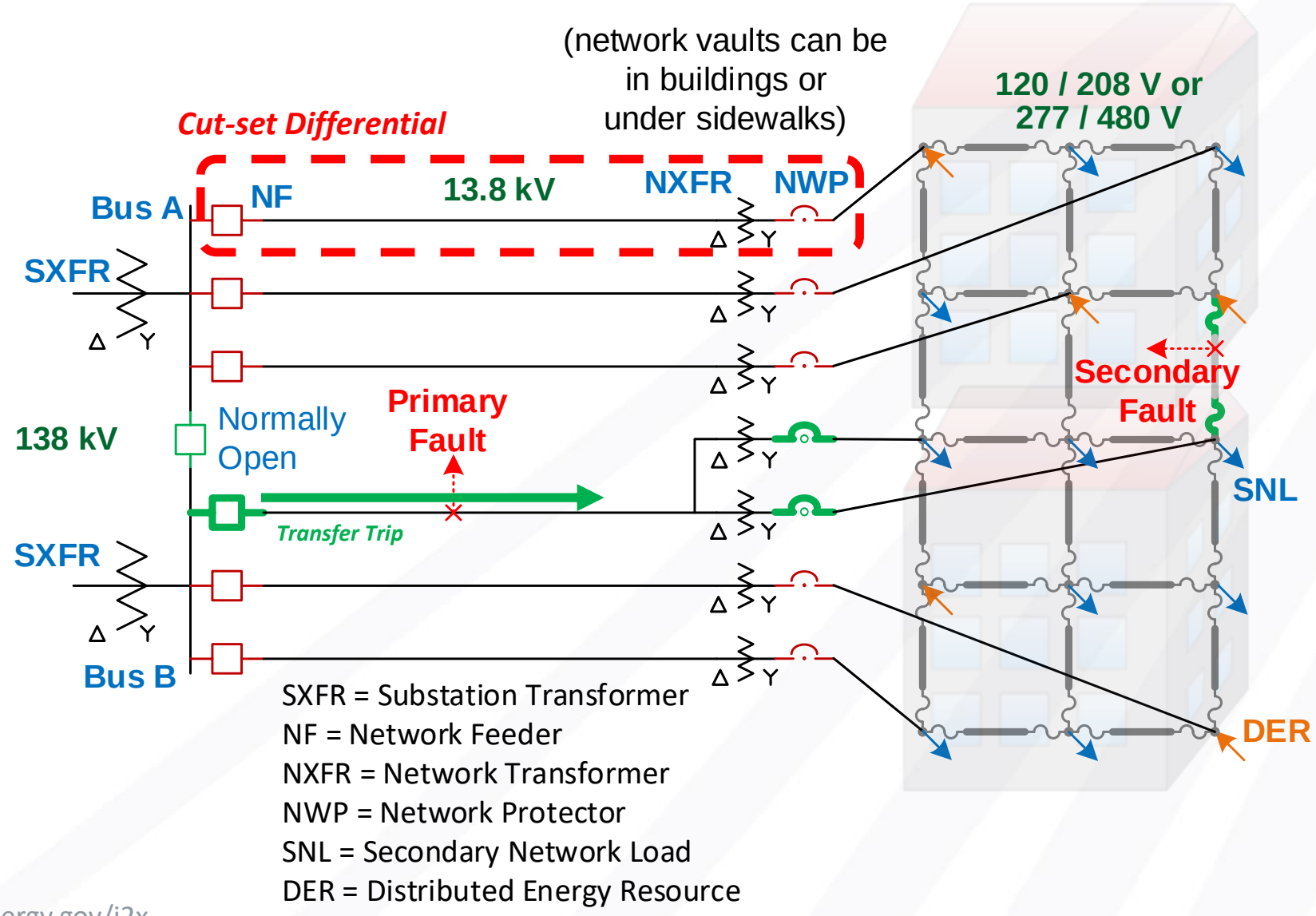
DTT on a distribution circuit with two switched segments, an alternate utility source, and four community, commercial, or utility-scale DER.



Permissive DTT with Wind and Solar DER Connected to Alternate Source



Secondary Networks deliver very reliable service to urban areas, using network protectors that are very sensitive to reverse power flow.



- IEEE 1547.6-2011: "de minimus" means an insignificant effect of the DER, e.g., 7-50% of the facility minimum load
- IEEE P1547.2-2023(?), has advice in clause 9

Virtual Meetings Code of Conduct

1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*

Mutual Respect . Collaboration . Openness

Introduction of Stakeholder Presentations

- Mrinmayee Kale (MK), Lead Grid Integration Engineer, New Leaf Energy, https://www.linkedin.com/in/mrinmayeekale/
- Michael Hanestad, Senior Power System Engineer, RLC Engineering, https://www.linkedin.com/in/michaelhanestad/

Interactive Group Discussion Topics

Word Cloud Icebreaker:

How does your* electric utility manage the risk of undetected fallen conductors?

[Go to **menti.com** and enter event code **9449 5181**]

* You may answer as an employee or customer.

Topic #1: How should we evaluate the probability and risk of unintentional islanding?

- For written commentary, please go to **Menti.com** and enter event code **9449 5181**
  - Meeting chat will be disabled
  - The Menti page will remain open throughout discussion of this topic
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional discussion topics:
  - How much would the risk increase if the islanding detection time increased from 2s to 5s?
  - How can we account for the time-series behavior of loads?
  - What are the advantages and disadvantages of test-based conformance assessment?
  - What are the advantages and disadvantages of model-based conformance assessment?

Discussion Best-Practices

1. *Assume good faith and respect differences*
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3. *Use "Yes and" to build on others' ideas*
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Topic #2: How have some utilities moved away from direct transfer trip?

- For written commentary, please go to **Menti.com** and enter event code **9449 5181**
  - Meeting chat will be disabled
  - The Menti page will remain open throughout discussion of this topic
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional discussion topics:
  - Besides cost, what are the disadvantages of DTT as the adoption of DER increases?
  - What difference does the technology (solar, wind, storage) make?
  - What difference does distance from the substation make?
  - What difference does local topography make?

Discussion Best-Practices

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Topic #3: How have some utilities moved away from de minimus DER limits on secondary networks?

- For written commentary, please go to **Menti.com** and enter event code **9449 5181**
  - Meeting chat will be disabled
  - The Menti page will remain open throughout discussion of this topic
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional discussion topics:
  - What alternatives may exist for urban communities to participate in DER and storage adoption?
  - What about primary voltage connections?
  - What about looped connections of radial feeders?
  - What about commercial electric vehicle chargers in V2G applications?

Discussion Best-Practices

1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*

Topic #4: What does it take for the engineering community and relay vendors to adopt new protection methods?

- For written commentary, please go to **Menti.com** and enter event code **9449 5181**
  - Meeting chat will be disabled
  - The Menti page will remain open throughout discussion of this topic
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional discussion topics:
  - Consider IEEE Power System Relay Committee working groups and task forces, one of the IEEE 1547 guides, utility-sponsored research, vendor research & development, DOE-sponsored research, etc.
  - What are the impediments to adopting newer versions of IEEE 1547-2018?
  - Can there be a comprehensive risk analysis of protection system design options?
  - "Skin in the game" suggestion: Utilities designing their own DER interconnections, e.g., with commercial / industrial partners
  - How do state regulatory agencies evaluate power system protection practices?

Discussion Best-Practices

1. *Assume good faith and respect differences*
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3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*

References on Today's Discussion Topics

- Alternatives to Direct Transfer Trip
  - Manson et. al., "Inverter-Based Radial Distribution System and Associated Protective Relaying", https://selinc.com/api/download/135485/
  - Ma et. al., "Evaluation of Cellular Based DER DTT Technologies", https://doi.org/10.1109/PVSC48317.2022.9938886
  - Yin et. al., "Ground Fault Protection of Microgrid Interconnection Lines Using Distance Relay with Residual Voltage Compensation", May 2021, https://doi.org/10.1109/CPRE48231.2021.9429847
- Secondary Network Protection with DER
  - OE Microgrid Peer Review, July 2022, https://www.nrel.gov/grid/assets/pdfs/05-advanced-protection-for-microgrids-and-der-in-secondary-networks-and-meshed-distribution-systems.pdf
  - Ropp & Reno, IEEE Power & Energy Magazine, April 2021, https://doi.org/10.1109/MPE.2021.3057952
  - Sandia Report (Background), November 2020, https://doi.org/10.2172/1738874
  - Sandia Report (Research Roadmap), January 2022, https://doi.org/10.2172/1839187
  - Sandia Report (Summary of August 2021 Workshop), https://doi.org/10.2172/1844061

Guide to Interconnection Studies of Renewable Distributed Energy Resources – review and comment opportunity will be provided.

1. Introduction and Background
   a) FERC Small Generator Interconnection Process
   b) Sandia Screening Report
   c) IEEE Guide to DER Impact Studies (2013)
2. Utility Organizational Preparation
   a) Tools and Automation
   b) Maintenance of Grid Data
   c) Links to System Planning
   d) Workforce Training
   e) Adoption of Standards
   f) Report Format and Delivery
3. Developer Organization Preparation
   a) DER Models and Validation
   b) Applications to Interconnect
   c) Adoption of Standards
   d) Response to Data Requests
   e) Scoping Meetings
   f) Material Modifications
4. Phases of the Interconnection
   a) Interconnection Application Review
   b) Fast-Track Processes and Screens
   c) Hosting Capacity Analysis
   d) Impact Studies
   e) Commissioning
5. Special Topics
   a) When to use Electromagnetic Transients (EMT)
   b) DER Aggregation
   c) DER Impacts on the BES
   d) Sub-transmission and Transmission Boundaries
6. Interconnection Study Boot Camps
   a. Test systems and tools
   b. Sample problems
7. Roadmap to Future Improvements
8. References

Direct Transfer Trip and other protection concerns

Community Solar's Interconnection Barriers

new leaf energy

Contents

- Introduction
- Survey results from CCSA
- DTT and economic viability
- Why DTT is required by utilities
- Alternative practices by utilities
- Other protection concerns with operations
- Developer/DER owner perspective

new leaf energy

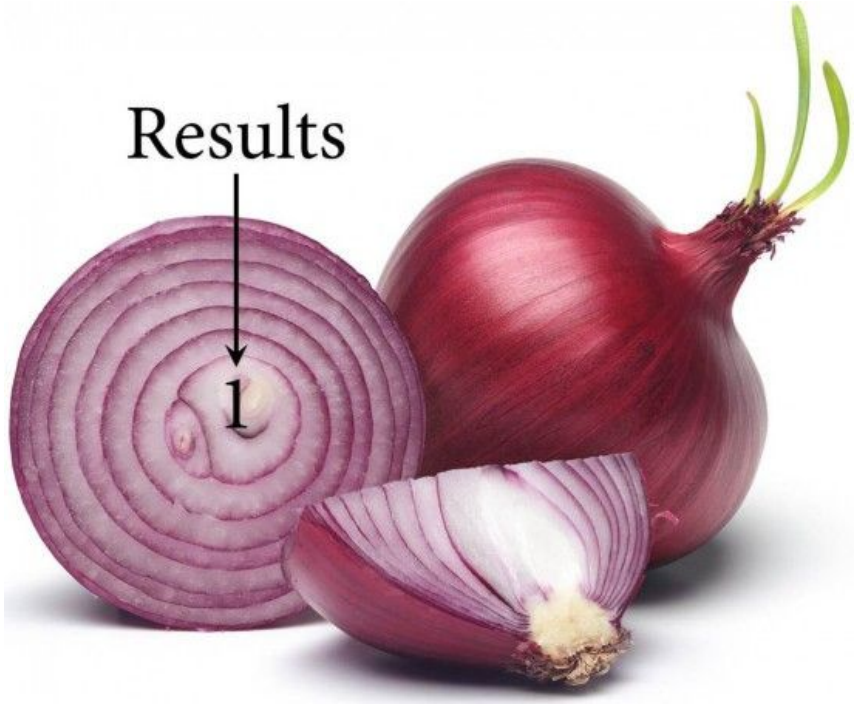
Coalition for community solar access (CCSA)- Survey results

- To gain an initial understanding of how widespread DTT prescription has become, CCSA recently conducted an internal poll of its members. Eleven organizations provided the following information highlighting the prevalence of DTT:
  - DTT has been prescribed by utilities in 14 states, which represents two-thirds of all states that have community solar programs.
  - One-hundred percent of project portfolios in several states – including DE, MD, NY, and VA – were required to install DTT equipment, according to one developer. Others reported that DTT affected anywhere from 8% to 50% of their project portfolios in a given state.
  - Seven out of eleven respondents reported that their companies have had to withdraw projects that were under development, due to high costs and lengthy timelines associated with the requirement to install DTT equipment."

DTT and economic viability

- DTT Scope of work:
  - Addition of Relaying at substation ~$500k
  - **Direct fiber** connection between site and substation - ~$200k/mile
  - Substation control house upgrade - ~$750K-$1M
- No cost sharing applied
- Average acceptable interconnection cost for 3-5MW project size - $900k- 1.5M
- For most projects on the distribution grid, the percentage of intx cost spent on DTT is 60-70%.
- If a control house upgrade is triggered, the project and almost all other projects in queue become economically infeasible.

Why utilities need DTT



Why utilities need DTT

- Risk of Islanding
  - Interactions between mixed DERs (mix of DER technology, mix of manufacturers for inverters, mix of algorithms for island detection)
  - MA utilities considering risk of islanding studies again due to Volt-VAR activation.
  - Non-detection zones with active islanding detection methods
- Ground fault overvoltage on transmission
- Personnel safety in islanding situations
- Alternative to effective grounding in an island
- Relay desensitization
- Reclosing coordination - Inverter trips for adjacent feeder faults, nuisance trips of load shedding schemes
- Increased arc flash energy
- Improved automated switching

Alternative practices from utilities

- Risk of Islanding
  - A combination of **passive and active islanding methods resident in the inverters** themselves are trusted by several utilities. SDG&E, Southern California Edison and PG&E in CA; Unitil and National Grid in MA; Orange and Rockland, NYSEG, CHG&E, ConEd and National Grid in NY; HECO in HI; CMP and Versant in ME, ComEd and Ameren in IL.
  - MA utilities use the **SANDIA 2012 screens**. National Grid in MA further collects information on the inverter manufacturer's anti-islanding method. We believe they are further implementing the findings of the SANDIA 2018 report about mix of inverter islanding detection algorithms.
  - Versant in ME and Eversource in MA will conduct time domain analysis to evaluate projects for risk of islanding if they fail the SANDIA 2012 screens.

Alternative practices from utilities

- Ground fault overvoltage due to transmission faults
  - CMP in ME, National Grid, Orange and Rockland in NY and National Grid in MA **use 3V0 protection scheme** at substations.
  - Average cost ~$500k per substation transformer and one time cost.
  - National Grid NY even piloted this under a pre-emptive upgrade program and later recovered costs through a prorated cost sharing mechanism. This avoids pushing cost of a large upgrade on the project that is first in queue.
  - In both MA and NY, there is a cost sharing mechanism to help spread the cost across multiple projects.

Alternative practices from utilities

- Lack of effective grounding and transient overvoltage concerns
  - Ground fault overvoltage and load rejection overvoltage in an island are serious considerations
  - MA, NY, ME and HI utilities make use of either the inverter's SPOV functionality or set a very fast overvoltage trip, typically set within **~1.3-1.4pu pickup and 1ms** clearing time. HI even has a test procedure that is prescribed for inverter type testing and the newest **IEEE 1547.1 testing procedure standard** will incorporate a similar test for inverters.
  - In cases where the inverter **can't "see"** the GFO voltage, **a grounding transformer or neutral grounding reactor** can be incorporated in the design. MA, NY and ME utilities prescribe a effective grounding standard and perform grounding studies as part of the impact study to determine if DERs are effectively grounded as designed.

    EPRI presented on this topic at the NY ITWG. **They concluded with several recommendations on this issue that do not require installing a DTT.**

Alternative practices from utilities

- Fault contribution - Arc flash and relay desensitization
  - MA and NY utilities have **consider a standard 1.2xFLA** as the fault contribution from an inverter based resource.
  - Utilities use test reports provided by inverter manufacturers. Several show that inverter **fault contribution drops below FLA within a couple of cycles.**
  - Addition of extra line relays/reclosers.

Other protection concerns with operations

- Redundant relaying and automatic reclose delay of 5 mins/300 secs. Most utilities require a redundant relay/recloser at the POCC. The reclose time delay for this is 5mins/300secs in addition to the reclose delay at the inverter relay. This can clearly be reduced to something more reasonable.
- CHG&E in NY requires a negative sequence overcurrent (50Q) and overvoltage setting (59Q) in the POCC reclose for projects with a grounding transformer. They want the DER to trip for single phase loss. The 50Q pickup was set at 2.5% with a time delay of 1 cycle.
- Permissive signals by nature are prone to nuisance tripping. DTT introduces an higher risk for projects to lose production for disturbances to the signal.

Other protection concerns with operations

- Dominion in VA allows for no ride through
  - UL 1741sa and UL 1741sb inverters have this built-in. These are not adjustable according to the inverter manufacturers.
  - Excessive/nuisance tripping of DER for small disturbances on the grid that could further risk stability of the grid.
- Eversource in MA has specified an SPOV trip of 1ms for 1.2pu correction of LROV. This is likely in conflict with the ride through requirement for ISO-NE. It is also of concern to project owners as it could cause nuisance trips that are avoidable.

Function		Set Point	Total Clearing Time (sec)
27	Under-voltage	V < 45% nominal voltage	0.160
		45% ≤ V < 60%	0.160
		60% ≤ V <88%	0.160
59	Over-voltage	110% < V < 120%	0.160
		V ≥ 120% nominal voltage	0.160
81U	Under-frequency	F < 57.0 Hz	0.160
		F < 59.5 Hz	0.160
81O	Over-frequency	F > 60.5 Hz	0.160
		F > 62.0 Hz	0.160
	Overall Anti-Islanding	Disconnect inverter from system (PCC)	0.160
	Steady State Power Factor	UNITY Power Factor	
LVRT	Low Voltage Ride Through	DISABLE	
HVRT	High Voltage Ride Through	DISABLE	
LFRT	Low Frequency Ride Through	DISABLE	
HFRT	High Frequency Ride Through	DISABLE	
ZVRT	Zero Voltage Ride Through	DISABLE	
	Volt/Var Control	DISABLE	
	Volt/Watt Control	DISABLE	
	Frequency/Watt	DISABLE	

Table 2: *DER Inverter Settings*

Developer/DER owner perspective - Comprehensive and long sighted protection philosophy

- Certified inverter based DER with islanding detection capabilities does not materially increase the risk safety risk to personnel or equipment. This topic needs a boost and comprehensive risk analysis that quantifies the risk should be included as part of consideration with DER integration.
- Utilities should adopt the latest suggestions from SANDIA's research about how to incorporate updated screens in managing the risk of islanding.
- **Special time domain studies** can be conducted in cases where there is a mix of synchronous and inverter based DER and **synchronous generators are dominant**. Such studies are **resource and time intensive** and should be considered in **rare circumstances where the risk of islanding is quantifiably high**.
- Utilities should adopt a comprehensive protection philosophy that **allows inverters/DERs to ride through** and provide stability to the system for remote faults and trip for local faults.
- Utilities should **incorporate tested inverter characteristics** when conducting short circuit/arc flash analysis and relay coordination.
- Utilities should **provide customers with acceptable effective grounding design configurations** to avoid overvoltage issues.
- Utilities should **implement a higher threshold of standards for inverter based generation** - For example implement that all inverter based resources implement the SPOV function for voltages higher than 1.2pu. Allow inverters with bi-directional positive feedback frequency and phase shift islanding detection inverters to interconnect without a TD study and require others to go through an extensive study to eliminate the risk of islanding without DTT.

Thank you.

Mrinmayee Kale
Lead Grid Integration Engineer
5/3/2023

new leaf energy