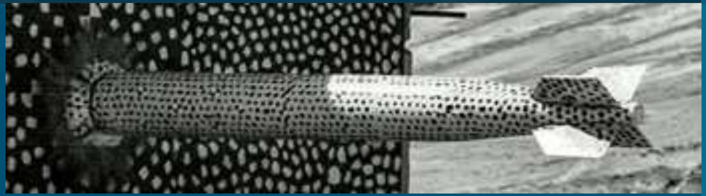
Sandia National Laboratories

# Technical issues arising from distributed energy resource interconnections



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U.S. DEPARTMENT OF ENERGY NNSA

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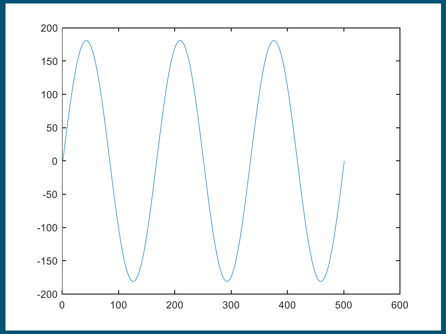
# Potential technical issues at the distribution level

## Important ones for *inverter-based resources (IBRs)* *:

- Abnormal voltages
  - Steady-state: the IBR pushes out too much power and drives the voltage up too high
  - Transient: during certain conditions like system startup/shutdown or certain short-circuit conditions, IBRs *can* cause high or low voltages on the circuit
- Thermal loading—don't want IBR to push out so much power that lines overheat
- Power quality: want this

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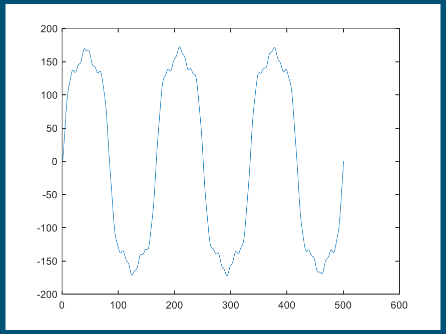
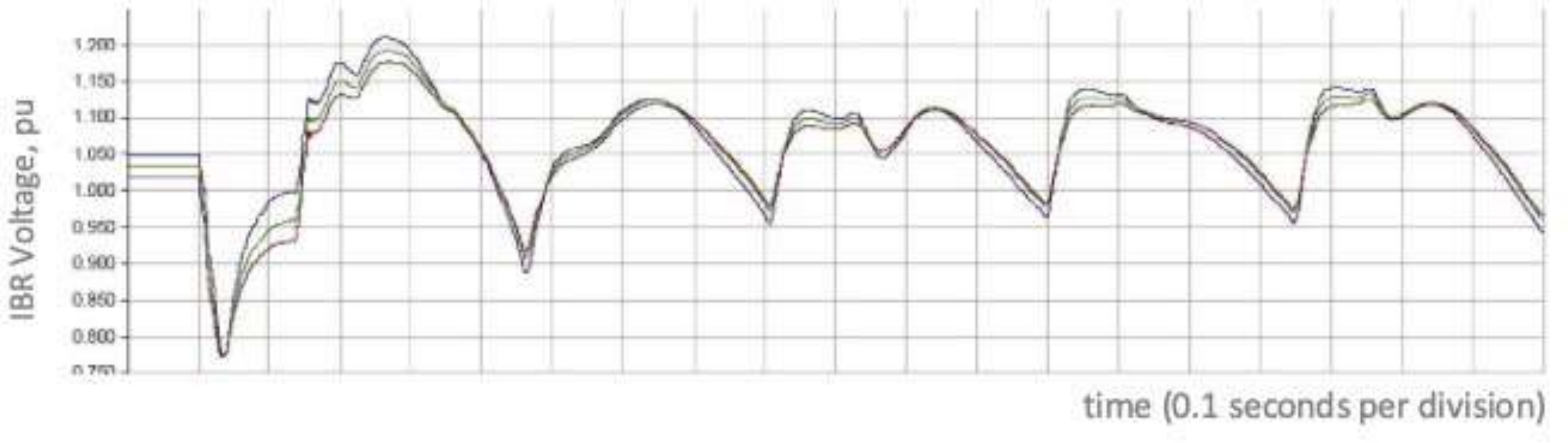



- Protection coordination—IBRs can't mess up system protection
- Unintentional islanding—IBRs need to not energize an unintentional island

*Rotating DERs are handled differently.

# Potential technical issues at the transmission level

- Impacts of large fleets of IBRs on the dynamics of the bulk system
- Impacts on system protection
- Potential for instability
  - IBRs adversely interacting with each other
  - “Weak system” issues or resonances



# Communications and cybersecurity

**Lots of work in this area at the moment (much of it at Sandia).**

**Standards: IEEE P1547.3 is being drafted now**

# Checking for problems: detailed studies

Computer simulation tools are available that allow us to study the circuit/situation and check for these issues.

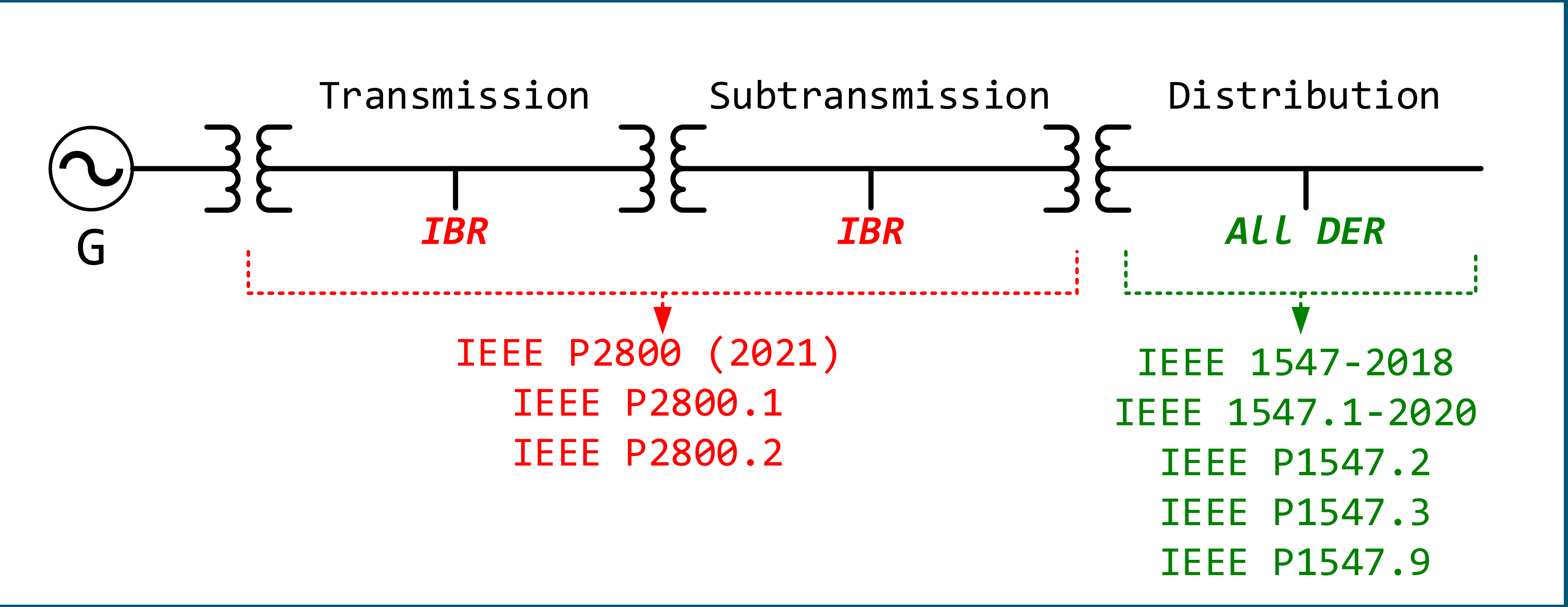
Pros: A detailed simulation model can provide a "digital twin" or "virtual laboratory" that allows experiments to be run safely and accurately, and provides detailed impacts of the DER on the proposed host circuit. ***Provides reliable, quantitative answers.***

Cons: detailed studies can be costly (depending on the DER, system and issue to be studied, anywhere from a few k$ to many tens of k$) and can take 2-4 months to complete.

# Faster, cheaper ways of checking for these problems

- For issues related mostly to inverters themselves (power quality, unintentional islanding, transient overvoltages): rely on inverters certified to comply with standards requirements (i.e., UL 1741 certified inverters), and on specific design requirements (i.e., use a particular type of transformer). **"Type tests".**
- For other more system-level issues (steady-state overvoltages, thermal overloads, protection): try to rely on ***screens***, simple "yes/no" thresholds. Quick, easy, cheap—but ***must be conservative to avoid compromising safety/reliability***.

# IEEE standards for interconnection





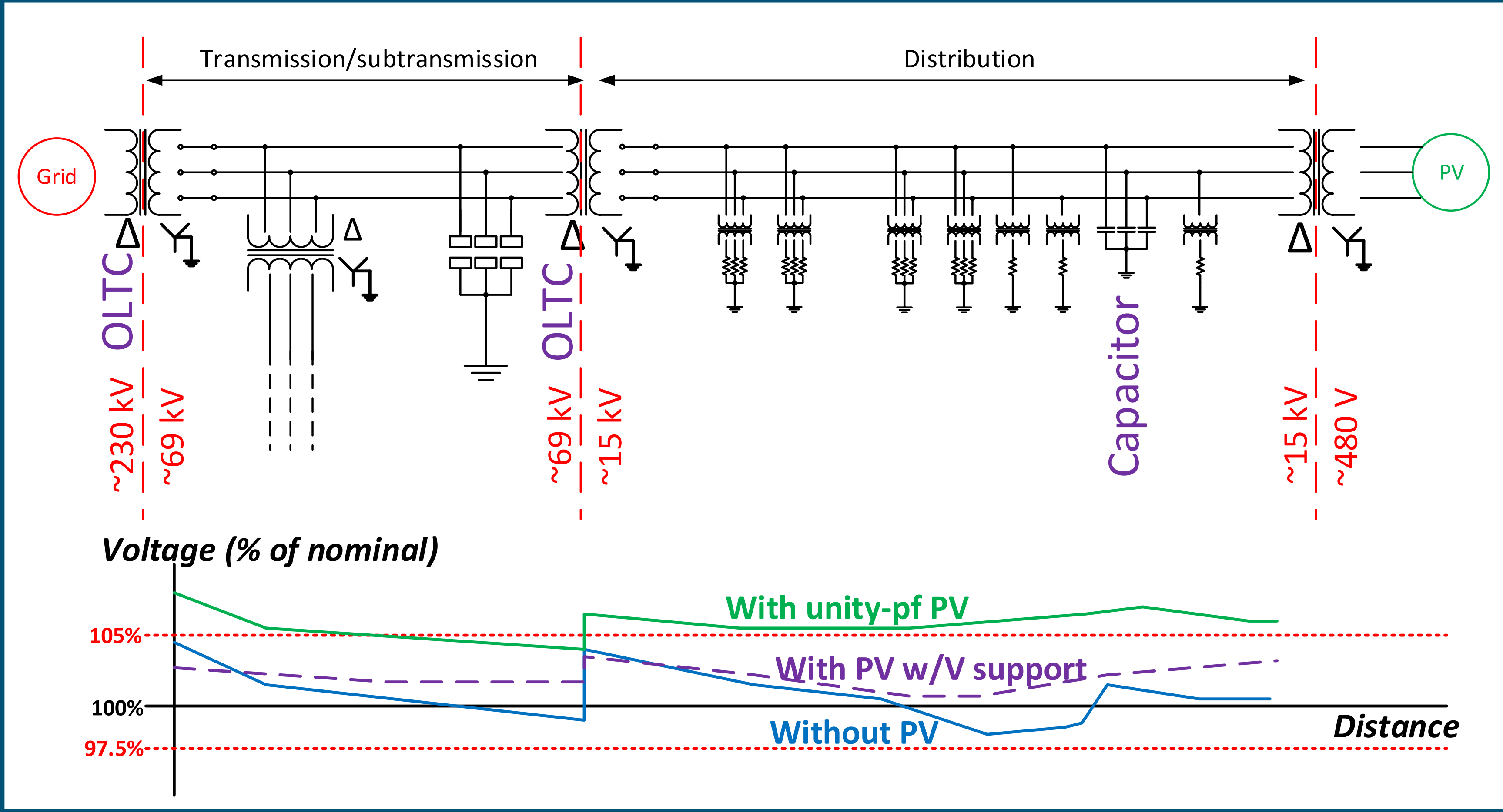
*connects with UL 1741

# Tools to address these challenges at the distribution level

**IEEE Std 1547-2018™ and IEEE Std 1547-2020™ mandate that inverters provide tools to solve many of these challenges. Key examples:**

- Several inverter modes to help keep local voltages within tolerances
- Low voltage and low frequency ride-throughs (helps support the larger system when things go bad)
- Frequency support functions (also about supporting the larger system in bad times)
- Interoperability requirements (make sure devices can talk to each other and the utility—cybersecurity is addressed separately)

# Challenge #1: voltage regulation




Challenge: DER produces a "negative voltage drop". Utility V regulators can't control it.

Solutions: fixed-pf operation; volt-var and volt-watt controls; voltage regulation.

# Challenge #1: voltage regulation

**IEEE Std 1547-2018™ provides new tools for dealing with this.**

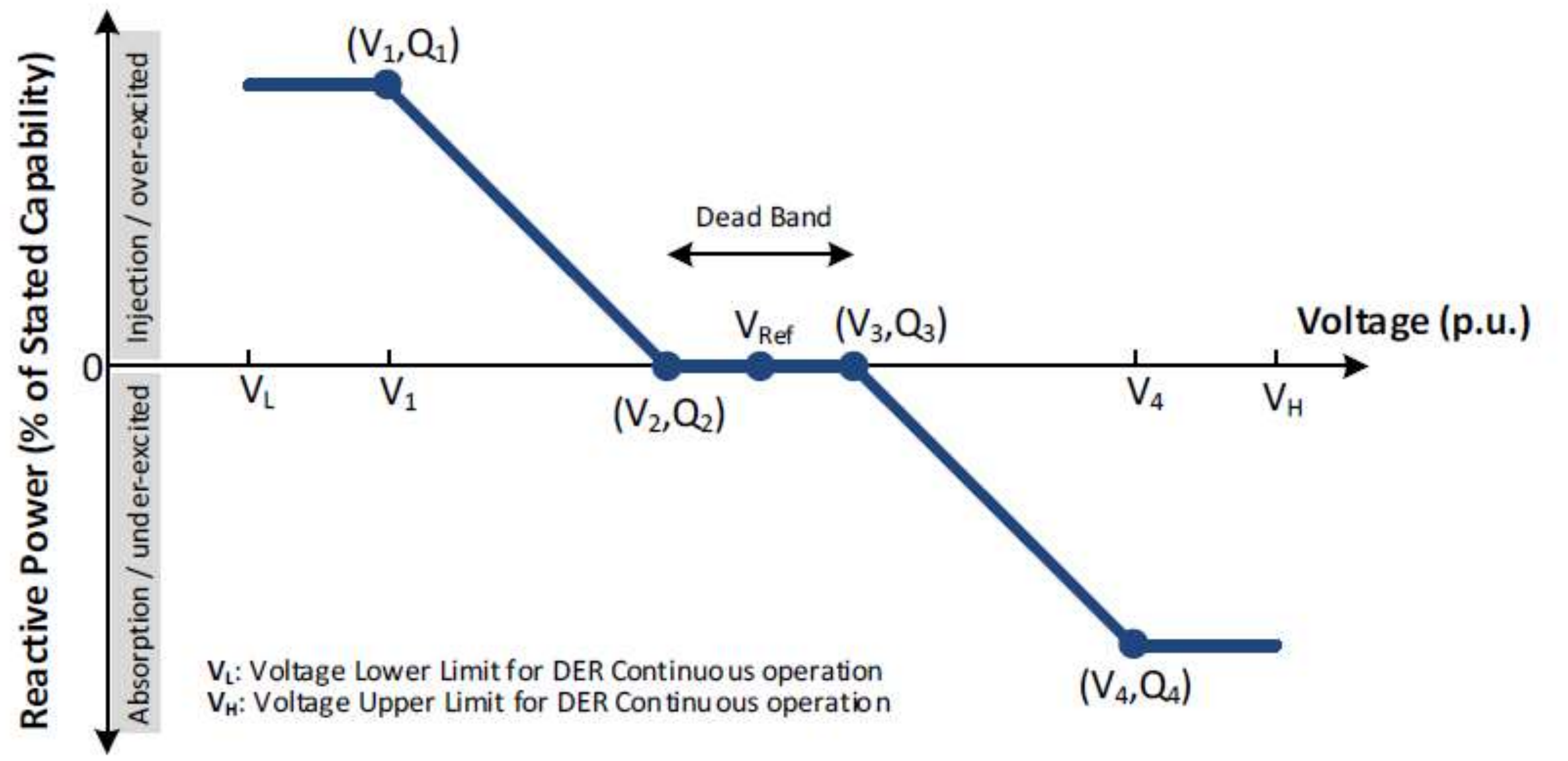



Figure H.4—Example voltage-reactive power characteristic

*Source: IEEE Std 1547-2018™*

# Challenge #1: voltage regulation

## How well do these solutions work?

### Fixed-pf operation (most common solution)

☑Simple; inherently stable (no interactions between inverters)

☒Requires the utility to supply more vars; doesn't change if new PV is added

### Volt-var and volt-watt (usually implemented in plant controller @ PCC)

☑Adaptively adjust output to help maintain healthy voltage

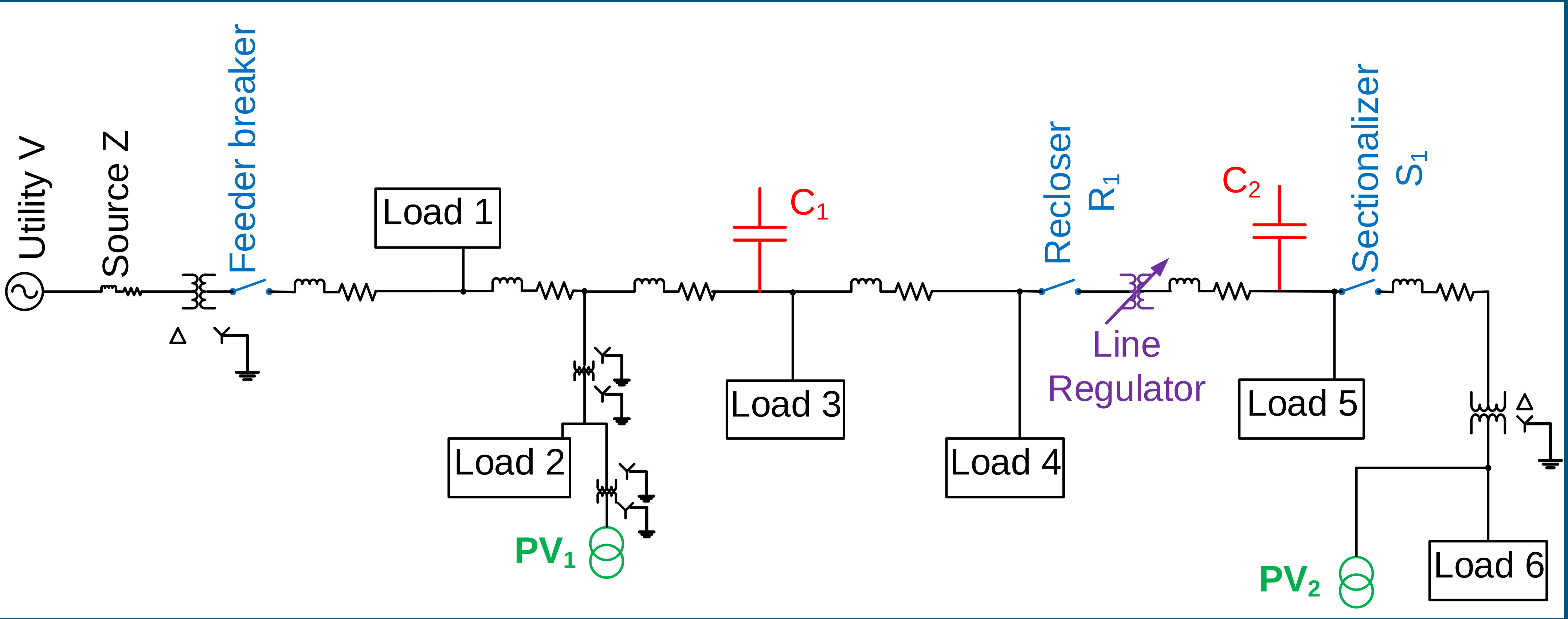
☒Some possibility for inverters "fighting" with each other; usually requires PCC measurement; needs to be coordinated with CVR; can result in lower PV output

### Voltage regulation (implemented in plant controller @ PCC)

☑Best voltage control; adapts to changing conditions; can significantly improve circuit voltage profile

☒Must be set carefully to avoid inverters "fighting" with each other (may require comms); requires PCC measurement; has to be coordinated with CVR

# Challenge #2: unintentional islanding




Challenge: if generation balances load and a switch opens, DERs may not see it and continue to "run on". ***(VERY LOW-PROBABILITY EVENT.)***

Solution: today, inverter-resident active anti-islanding. Tomorrow: wide-area communications-based methods.

# Challenge #2: unintentional islanding

## How well do these solutions work?

### Inverter-resident active anti-islanding

☑Extremely effective if all inverters are doing the same thing; still works well even with grid-support functions active

☒Inverter-inverter interactions possible; can degrade system transient response if there are enough DERs

### Wide-area communications-based methods

☑Potentially an "ultimate" solution: DERs have system-level awareness they can use to detect unintentional islands, as well as provide intelligent grid support

☒High cost is a barrier; also need further field demonstration of effectiveness

# Challenge #3: PV and bulk system dynamics

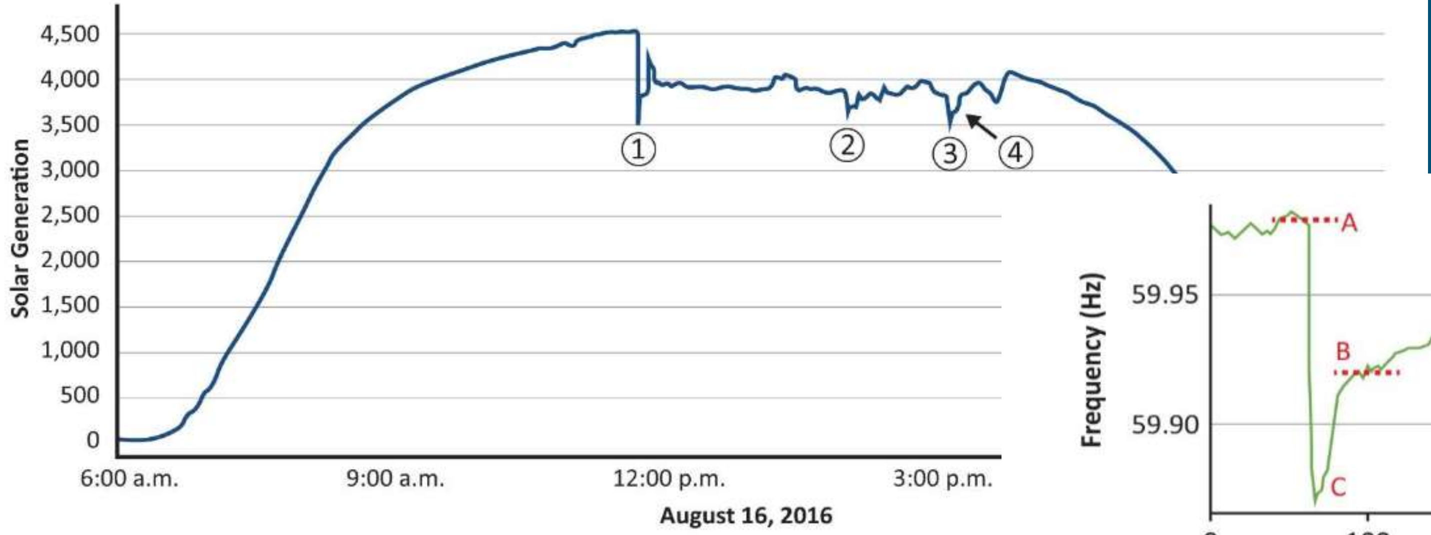



**Figure 1.3: Utility-Scale Solar PV Output in SCE Footprint o**

Over 1000 MW of large PV tripped during a system event when it shouldn't have. There was a measurable, negative bulk-system impact.

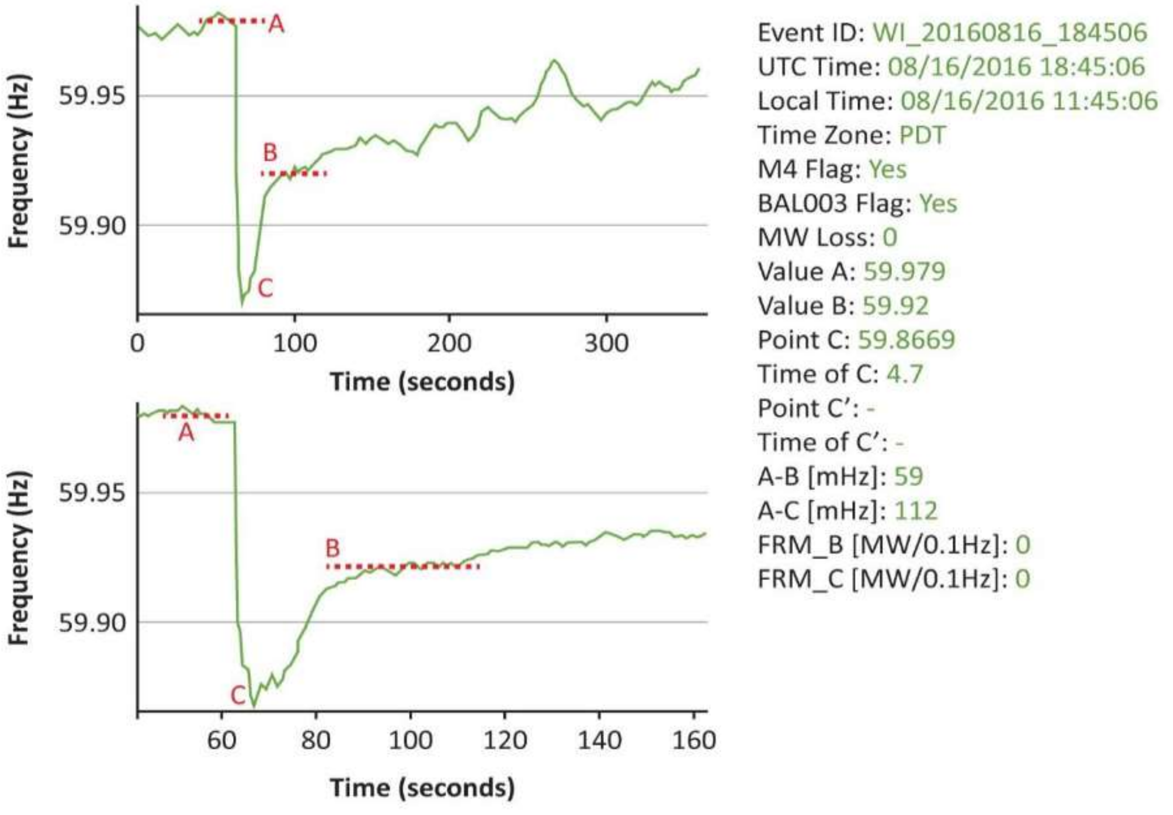



**Figure 1.2: Western Interconnection Frequency during Fault**

*Source: NERC, "1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report", June 2017.*

# Challenge #3: DERs and bulk system impacts

## What is being done to alleviate this?

IEEE Std 1547-2018™ and IEEE Std 1547.1-2020™.

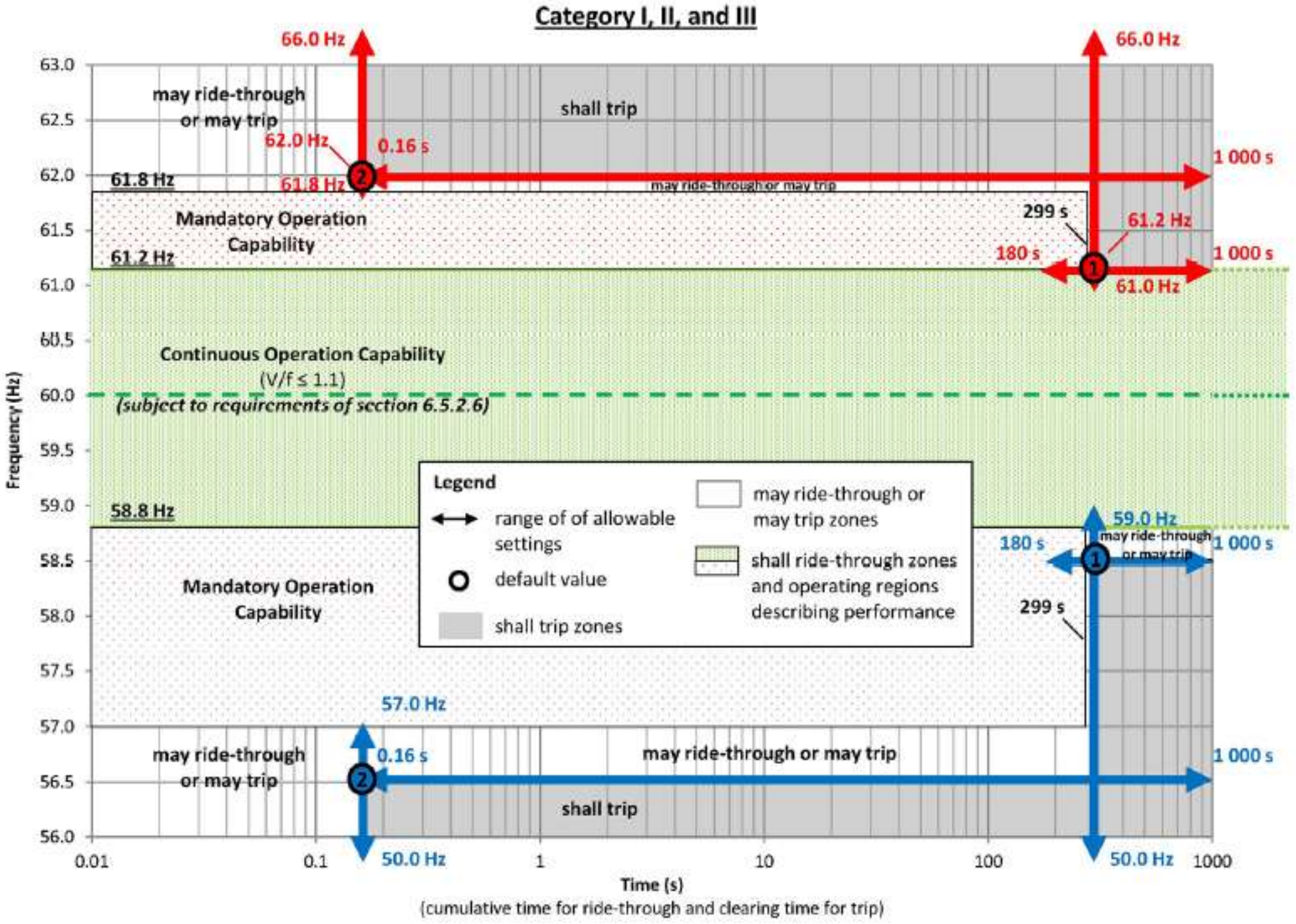
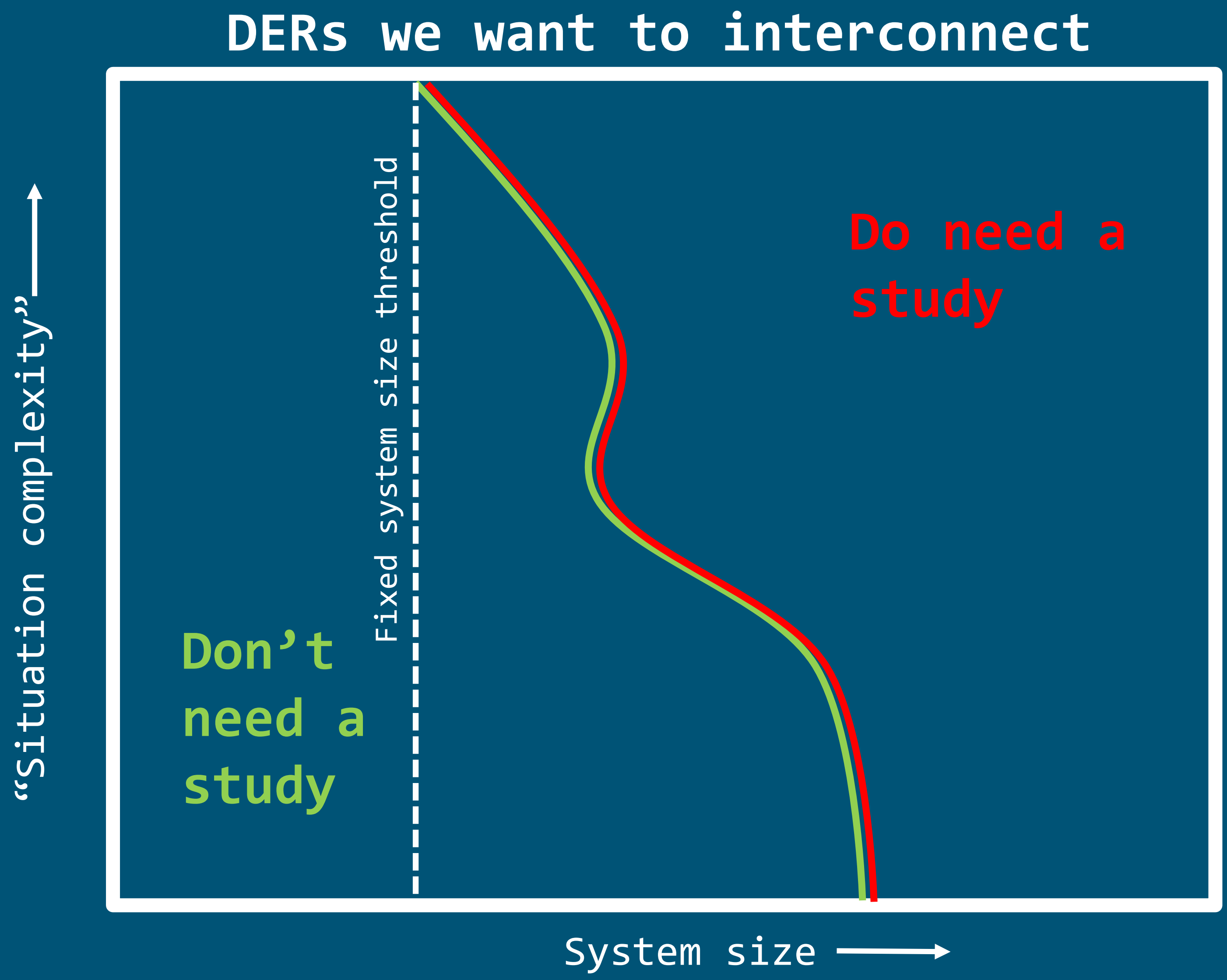



**Figure H.10—DER default response to abnormal frequencies and frequency ride-through requirements for DER of abnormal operating performance Category I, Category II, and Category III**

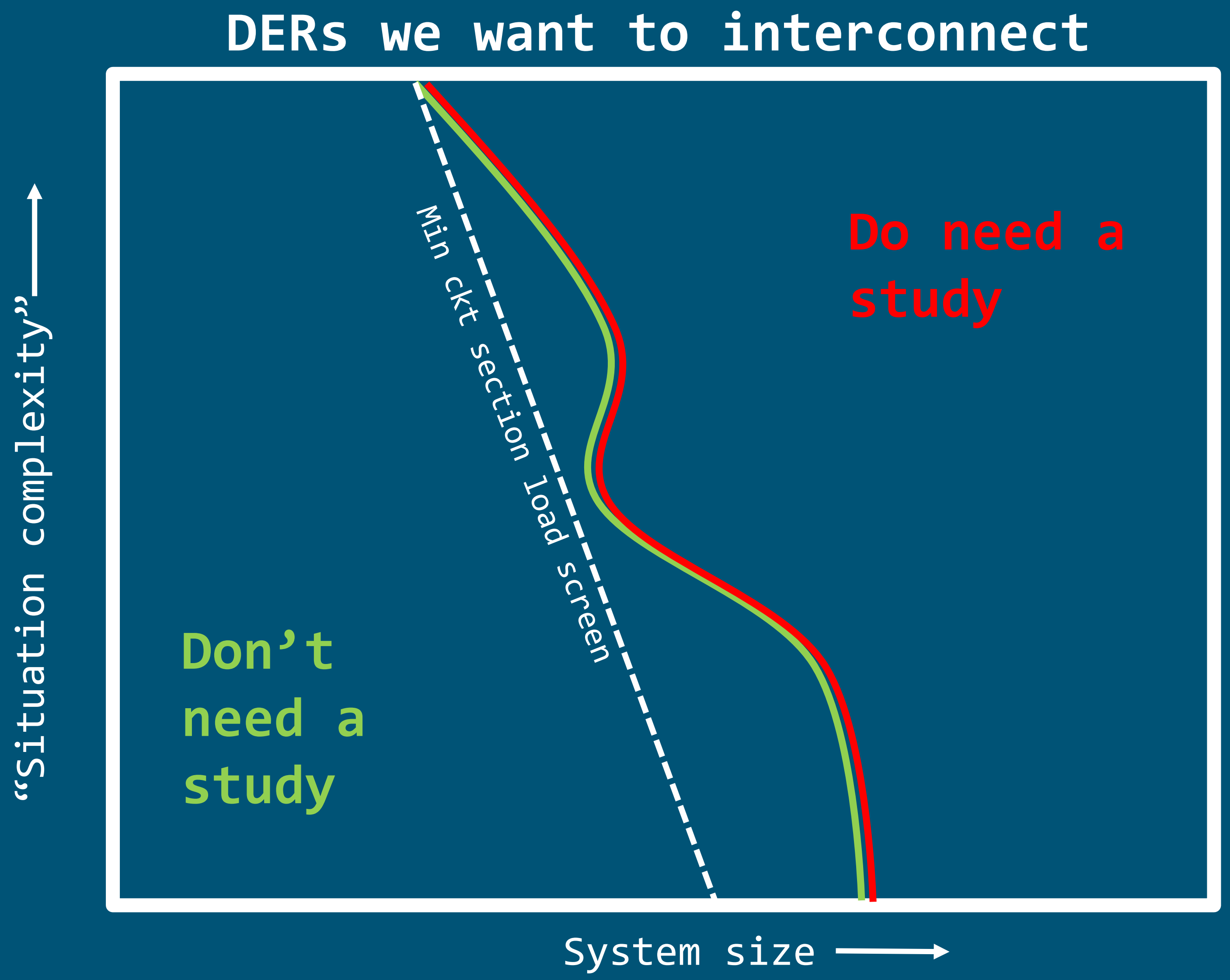
*Source: IEEE Std 1547-2018™*

# Understanding how well screens work



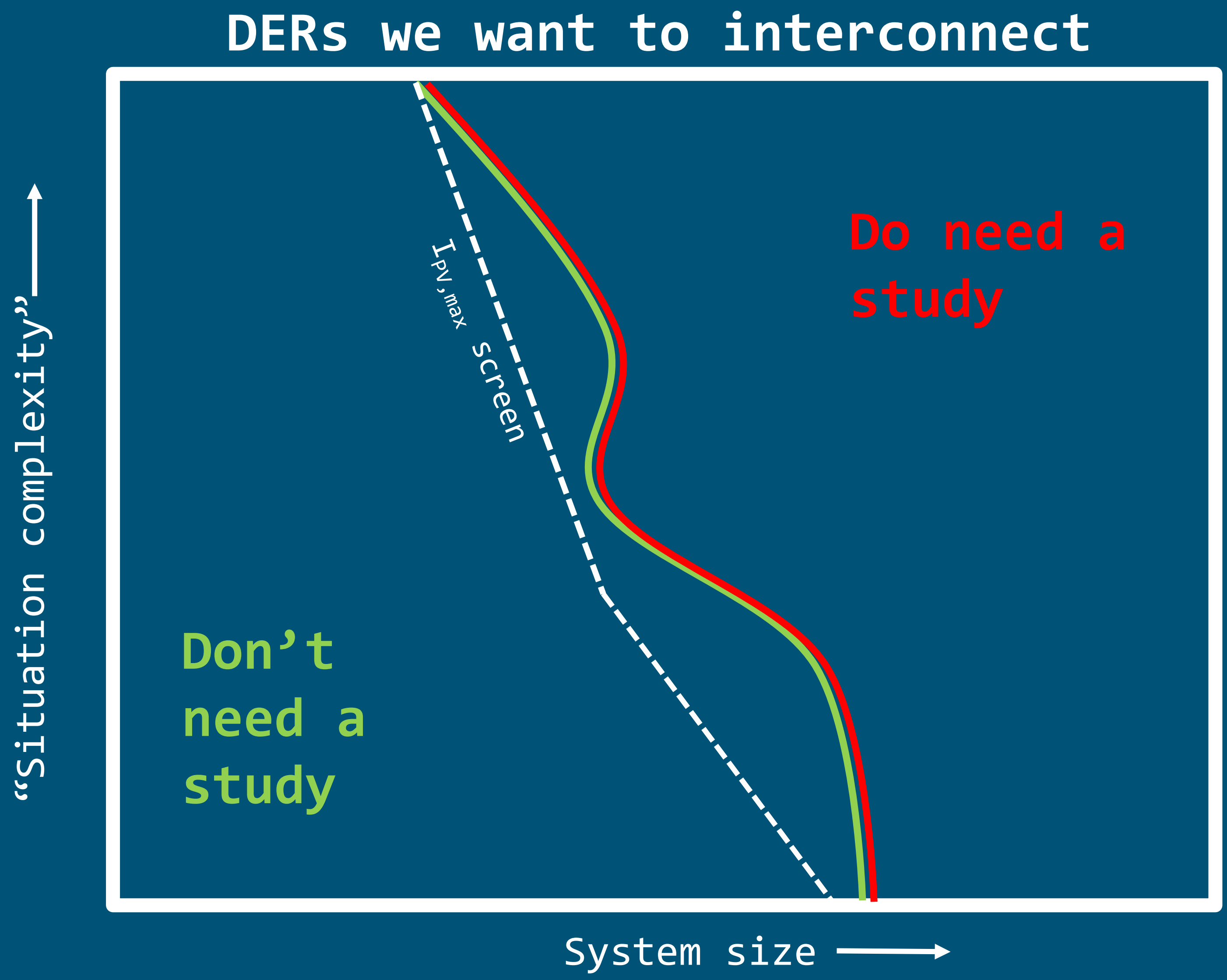

A fixed-system-size threshold is very simple, but also simplistic in the sense that a lot of unnecessary studies will be triggered.

# Understanding how well screens work




Going to a minimum circuit section load screen leads to a variable system size threshold, "trimming" the number of unnecessary studies.

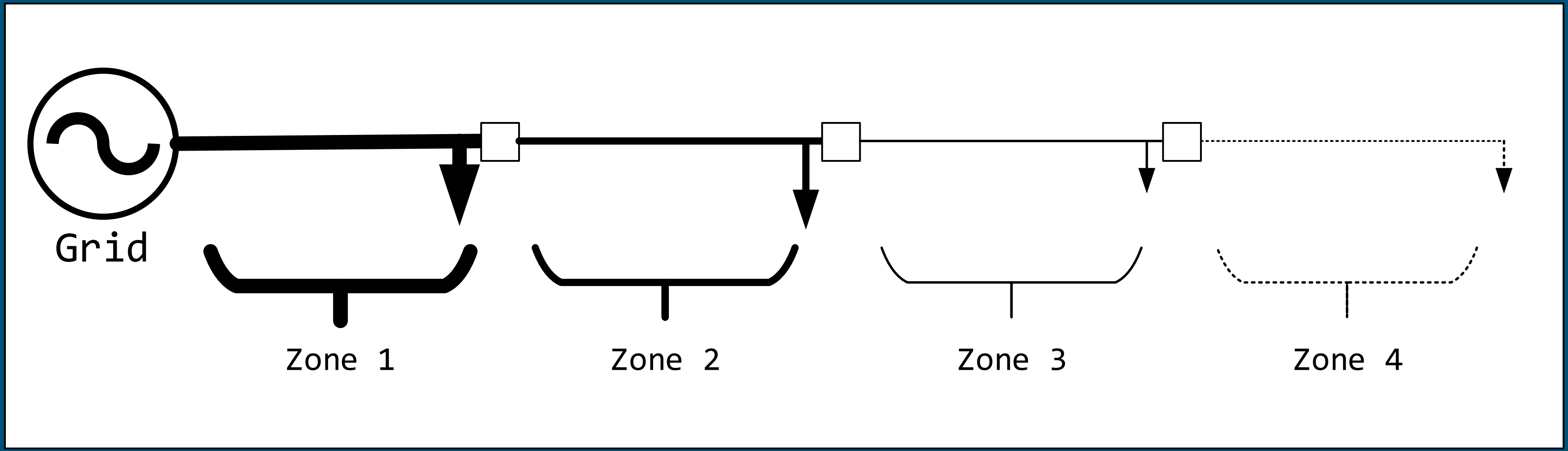
# Understanding how well screens work




A more complex screen with more decision elements can cause the screen to match more closely with the boundary line.

# DER hosting capacity screens—how much IBR is OK?

- Up to 100% of minimum load (minimum *daytime* load for PV), per circuit section/zone. At 100% of minimum zone load, DER is producing only as much current as that zone was already designed to handle. Addresses steady-state overvoltage, and thermal overload.

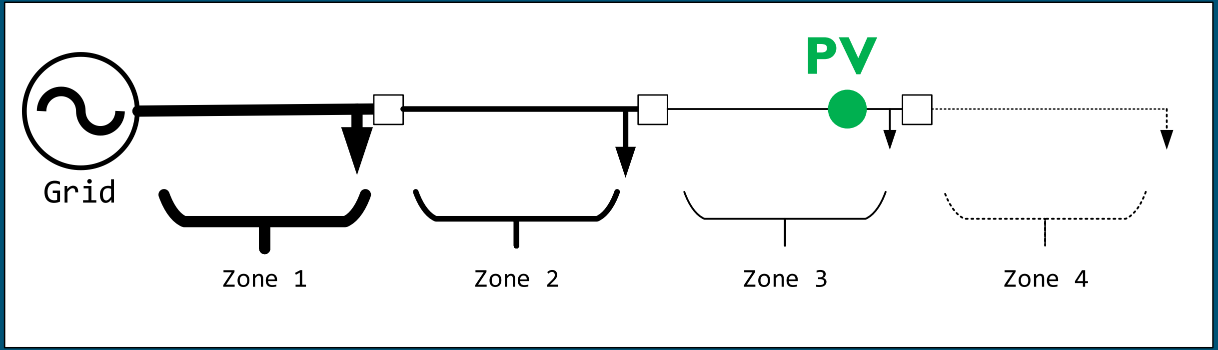


# Toward a better screen

A possible alternative:

$$I_{PV,max} = \frac{V_{rise,max}}{Z_{source.,max}}, \text{subject to}$$

$$\left\| I_{PV,max} \right\| < I_{ampacity,min}$$




So if we're putting PV at the green dot, $Z_{source,max}$ is the maximum source impedance from that point (including contingencies), and $I_{ampacity,min}$ is the minimum cable ampacity in the path to the source (here, the ampacity in Zone 3). $V_{rise,max}$ is typically 5% of the nominal voltage.

***This is very similar to what most utilities do when developing hosting capacity maps.***

# Thank you!

**Please feel free to email me with questions:**

**meropp@sandia.gov**

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