Elevate Comments on NOGRR 245

ERCOT TAC Meeting

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May 22, 2024

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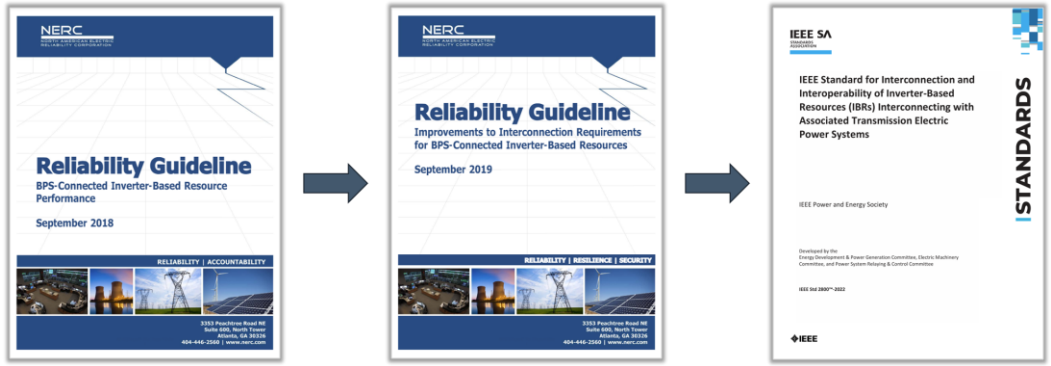
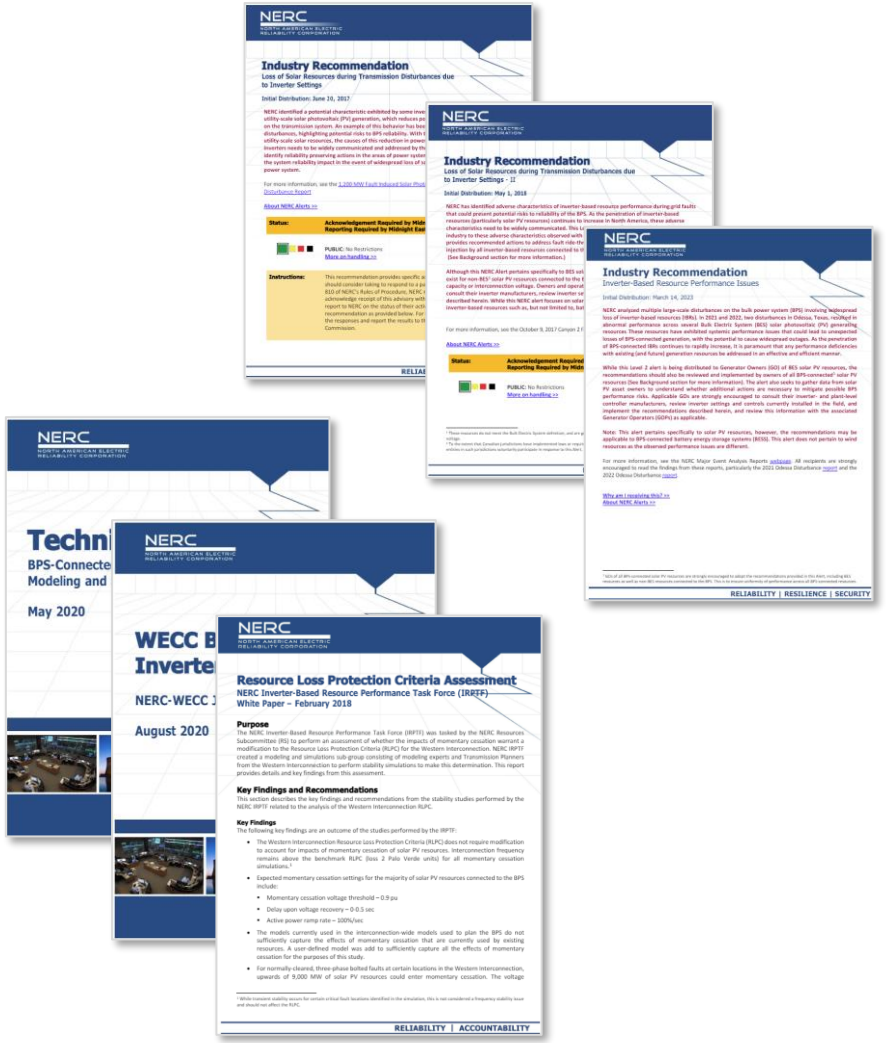
Elevate Experience and Expertise





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Background

Relevant Information for Later Discussion

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Background

- Elevate submitted independent comments on NOGRR 245 (here)
- Was unable to present at the May 10 TAC Workshop
- This presentation…

Covers	Does NOT Cover
• Fundamentals of performance requirements enhancements • Technical basis for Elevate comments • Educational comparison of requirements • Educational background and information • Ideas for effective path(s) forward	• Historical back-and-forth on NOGRR 245 • Economic analysis • Advocating for exemptions

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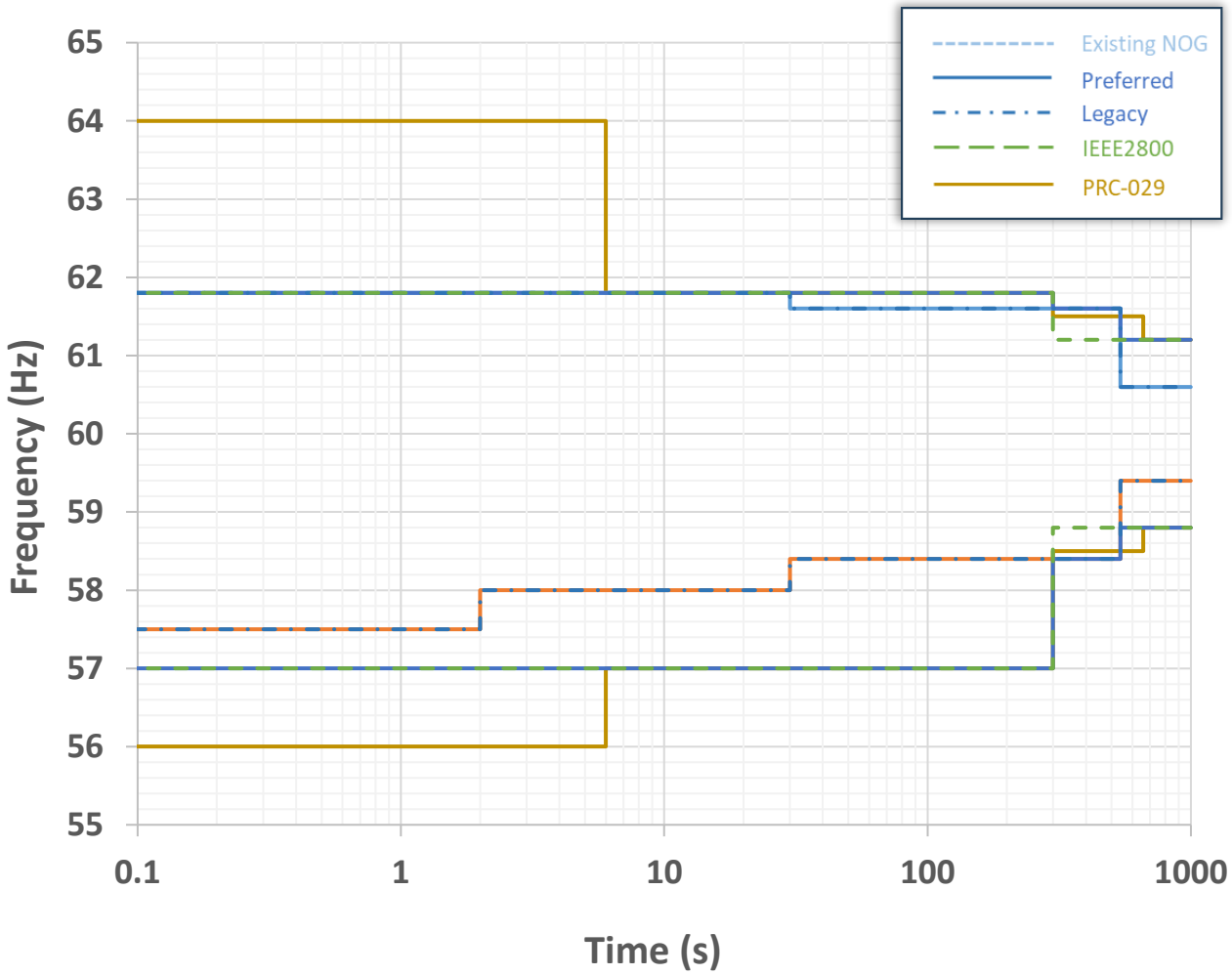
Frequency Ride-Through Curves



Key Takeaways:

- **NOGRR moves from relay settings to performance-based requirement**
  - Existing NOG and New Legacy match
  - New Preferred exceeds IEEE 2800
- PRC-029 is misaligned *(~25% approval)*
- Frequency-related tripping to-date?
  - "Instantaneous frequency" tripping in inverters (CA events) and feeder protection (Odessa events)
    - ***Unrelated to curves***

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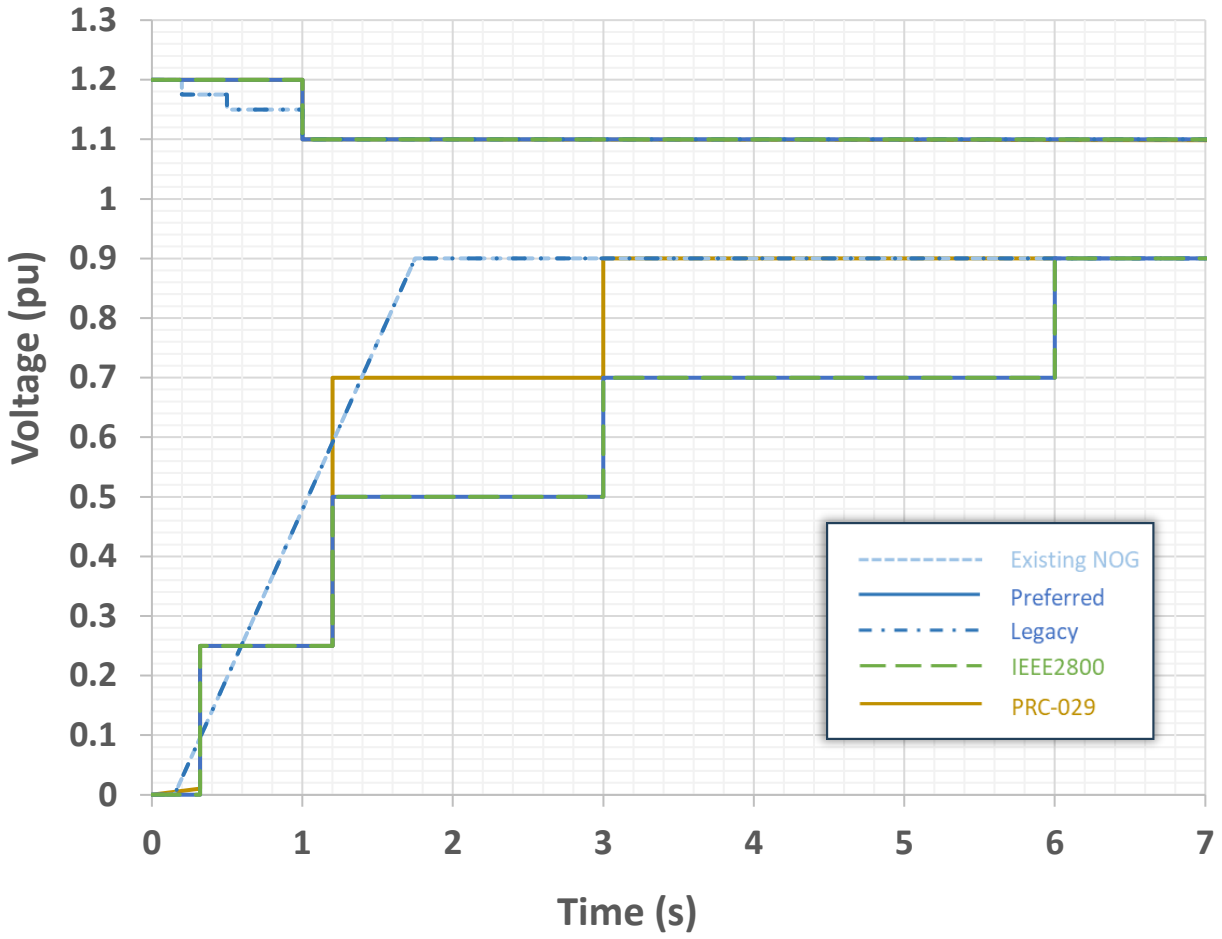
Voltage Ride-Through Curves



Key Takeaways:

- **NOGRR clarifies confusion with relay setting versus performance-based requirement**
  - Existing NOG and New Legacy match
- Preferred VRT requirements in TAC version of NOGRR 245 ***exceeds*** IEEE 2800-2022 requirements
- Aligns with PRC-029 *(~25% approval)*
- Voltage tripping to-date?
  - Inst. AC overvoltage (most prominent)
  - AC undervoltage (unexplained, non-BES)
  - ***Both unrelated to curves***

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Requirements Addressing Causes of Tripping

(3) If protection systems (including, but not limited to protection for over-/under-voltage, rate-of-change of frequency, anti-islanding, and phase angle jump) are installed and activa Type parag

(3) If protection systems (including, but not limited to protection for over-/under-frequency, rate-of-change-of-frequency, anti-islanding, and phase angle jump) are installed and activated to trip the IBR or Type 1 WGR or Type 2 WGR, they shall enable the Resource to ride through frequency conditions beyond those defined in paragraph (1) above to the maximum extent equipment allows.

(4) An IBR or Type 1 WGR or Type 2 WGR shall inject electric current when required to ride-through voltage conditions. When the POIB voltage is outside the continuous operating voltage range, an IBR shall continue to deliver pre-disturbance active current unless reduction is needed for voltage support or otherwise specified by ERCOT or the inte cur red wit sett IBR interconnects and ensure sufficient active current is available for protection system sensing. An IBR or Type 1 WGR or Type 2 WGR shall return to its pre-disturbance level

(5) Plant controls, turbine controls, or inverter controls of an IBR or Type 1 WGR or Type 2 WGR shall not disconnect the Resource from the ERCOT System or reduce its output during voltage conditions where ride-through is required unless necessary for providing appropriate frequency response.

(6) If instantaneous over-current or over-voltage protection systems are installed and activated to trip the IBR or Type 1 WGR or Type 2 WGR, they shall use filtered quantities or sufficient time delays to prevent misoperation while providing the desired equipment protection. Any instantaneous over-voltage protection that could disrupt power output shall use a measurement period of at least one cycle (of fundamental frequency).

(8) An IBR or Type 1 WGR or Type 2 WGR shall not use measurements of quantities such as phase angle jump and rate-of-change-of-frequency to trip or reduce the output of the Resource during fault conditions where the POIB voltage remains within the ride-through profiles specified in paragraph (1) above, unless the Resource has an approved exemption or extension under Section 2.13.

Location		Identified Issue	Odessa Events?	Software Fixable?
Inverter	☑	Momentary Cessation*	X	Yes
	☑	Inst. Frequency		Yes
	☑	Inst. AC Overvoltage	X	Yes
	☑	DC Reverse Current		Yes
	☑	PLL Loss of Sync/Phase Jump	X	Yes
	☑	Slow Active Power Recovery	X	Yes
	☑	AC Undervoltage		Yes
	☑	Inst. AC Overcurrent	X	Yes
	☑	DC High/Low Voltage		Yes
	☑	DC Voltage Unbalance	X	Yes
	☑	Ride-Through Misconfiguration	X	Yes
	☑	DC Overcurrent		Yes
	?	Auxiliary Equipment		Maybe
	?	Subsynchronous Oscillation		Maybe
	☑	AC Current Unbalance		Yes
Plant-Level	☑	Inverter-PPC Interactions	X	Yes
	☑	Feeder Underfrequency	X	Yes

*Except for some legacy inverters

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Alignment with Draft NERC PRC-029

R6. Each Generator Owner and Transmission Owner with a documented equipment limitation that would prevent an applicable IBR that is in-service by the effective date of this standard from meeting voltage ride-through requirements as detailed in Requirements R1 and R2 shall communicate each equipment limitation to the associated Planning Coordinator(s), Transmission Planner(s), and Reliability Coordinator(s). *[Violation Risk Factor: Lower] [Time Horizon: Long-term Planning]*

6.1. Each Generator Owner and Transmission Owner shall include in its documentation:

6.1.1 Identifying information of the IBR (name, facility #, other)

6.1.2 Which aspects of voltage ride-through requirements that the IBR would be unable to meet

6.1.3 Identify the specific piece(s) of equipment causing the limitation

6.1.4 Information regarding any plans to repair or replace the limiting equipment that would remove the limitation (such as estimated date of repair/replacement)

6.2. Each Generator Owner and Transmission Owner with a previously communicated equipment limitation that repairs or replaces the equipment causing the limitation shall document and communicate such equipment change to the associated Planning Coordinator(s), Transmission Planner(s), and Reliability Coordinator(s) within 30 days of the equipment change.

** Disclaimer: NERC PRC-029 still in development and receiving low ballot scores*

- PRC-029 allows for exemptions
  - **No negotiation of exemption; GO documents and communicates**
    - Equipment information
    - Parts unable to meet
    - Specific equipment causing limitation
    - Plans to repair or replace equipment *(if any)*
    - Communicate changes *(if any)* that affect equipment causing limitation
  - Voltage ride-through only
    - Major confusion given the frequency ride-through curve and existing known frequency challenges particularly for wind

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Explanation of Comments

Elevate Comments on NOGRR 245

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#1: ERCOT Event Analysis Process

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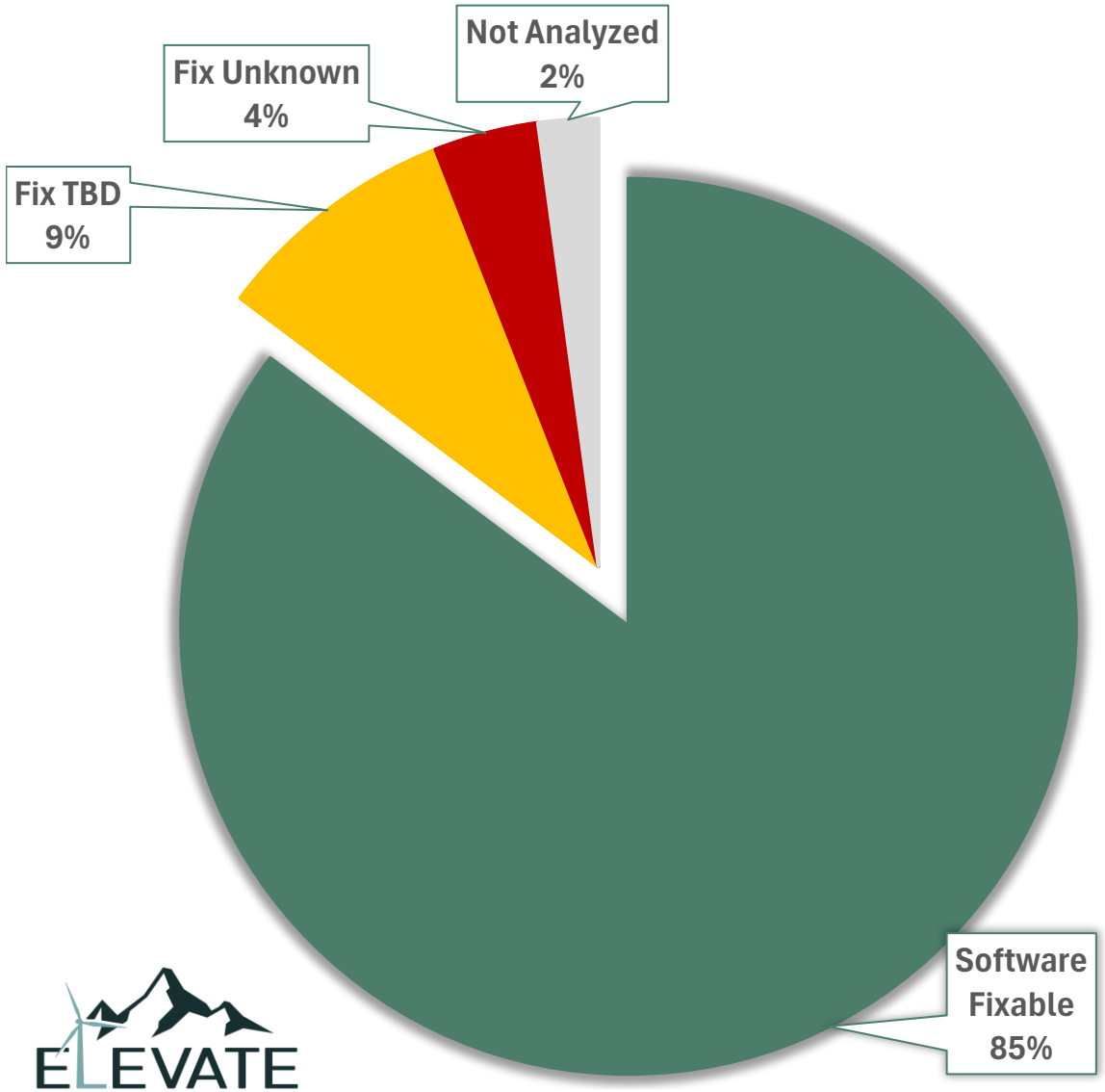
#2: Software Updates Address System Risk



Location	Identified Issue	Odessa Events?	Software Fixable?
Inverter	Momentary Cessation ☑	X	Yes
	Inst. Frequency ☑		Yes
	Inst. AC Overvoltage ☑	X	Yes
	DC Reverse Current ☑		Yes
	PLL Loss of Sync/Phase Jump ☑	X	Yes
	Slow Active Power Recovery ☑	X	Yes
	AC Undervoltage ☑		Yes
	Inst. AC Overcurrent ☑	X	Yes
	DC High/Low Voltage ☑		Yes
	DC Voltage Unbalance ☑	X	Yes
	Ride-Through Misconfiguration ☑	X	Yes
	DC Overcurrent ☑		Yes
	Auxiliary Equipment ?		Maybe
	Subsynchronous Oscillation ?		Maybe
	AC Current Unbalance ☑		Yes
Plant-Level	Inverter-PPC Interactions ☑	X	Yes
	Feeder Underfrequency ☑	X	Yes

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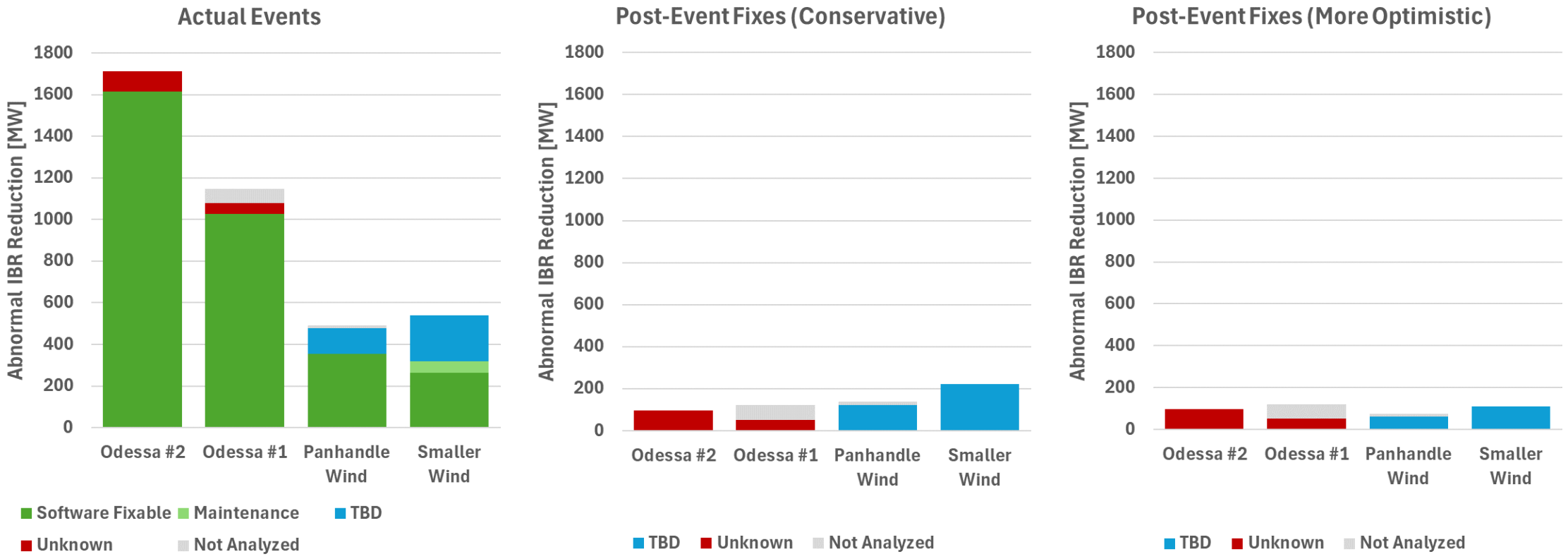
#2: Software Updates Address System Risk



- ***85% of affected capacity (from past NERC-analyzed events) is fixable with software***
- Remaining ~100-200 MW of residual "risk"
  - ***Does not pose risk of "widespread cascading" on its own***
  - Event analysis was still ongoing, these numbers *may* be lower

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#2: Software Updates Address System Risk

- Software fixes mostly deployed at ***all*** applicable existing IBR facilities
  - Included in TAC version of NOGRR 245 presently
- Software fixes part of standard package from OEMs for new inverters

From Joint Commenters:

Equipment Manufacturer	IBRs in ERCOT[65]	IBRs in 2022 Odessa Event	Deployed Solutions[66]
TMEIC	32% (36 facilities)	65% (8 facilities)	• 4 systemic issues; all now have software, settings, or firmware solutions • Solutions largely deployed at the 8 Odessa projects. (6 of 8 have all 4 changes made; remaining 2 have 3 out of 4 changes made to-date and plan to deploy remaining changes) • For the 28 projects not involved in Odessa events, solutions are either deployed (11), planned for 2024 (9), or plan is under development (7), except for 1 generator in construction
Power Electronics	22% (23 facilities)	29% (5 facilities)	• 1 systemic issue – has a firmware solution • Some non-systemic, project-specific issues and limitations at the 5 affected facilities • 5 facilities involved in Odessa events appear to be working with ERCOT to maximize capability and document remaining limitations • Outside Odessa, 16 of 18 projects have fixed the systemic issue through a firmware upgrade; ERCOT is following up with remaining 2 facilities
KACO	7% (8 facilities)	6% (4 facilities)	• At the 4 Odessa projects, limited corrective actions identified; 3 of 4 implemented • No data provided on the remaining 4 projects (not involved in previous disturbances) • KACO no longer in service

From ERCOT:

TMEIC Facilities Update

- Corrective actions identified and implemented for systemic issues
  - PLL Loss of Synch – Disable (Odessa 2021)
  - Volt Phase Jump – Disable or increase threshold to 35º
  - AC Overvoltage – Increase threshold to 1.4pu; decrease k- factor
  - AC Overcurrent – Implement overcurrent mitigation firmware update developed by TMEIC
- All the above
  - Plant B – H
  - Plant C/D – work (did n
- Only 2 out of
  - Per Plannin
  - ERM includ
  - ERCOT will

Power Electronics Facilities Update

- Issues identified in Power Electronic facilities were not as systemic as those with TMEIC inverters
- Plant K/L has legacy inverters that continue to have ride-through performance issues
  - ERCOT continued to work with RE after multiple events with similar ride-through performance issues
  - RE has continued to attempt to improve performance for these events; appears to be limitations on the capability of these inverters
  - Only facility in ERCOT with this inverter model
  - RE has resubmitted models to reflect performance issues
- Plant M also has older inverters and RE has adjusted LVRT and protection settings and facility has shown improved performance during subsequent events
  - Only facility in ERCOT with this inverter model
  - RE has resubmitted models
- Plant Q had small number of inverters trip to AC overcurrent and high inverter temperature during Odessa 2022
  - Unable to perform in depth root cause analysis due to inverter logs being overwritten during event
  - Replaced SD cards with higher capacity to prevent logs from being overwritten during future events
  - No model updates required
- Plant S and Plant V had all inverters trip due to Vdc Bus Unbalance during Odessa 2022 event
  - Power Electronics developed firmware update to improve DC side regulation and ride-through performance
  - Firmware update implemented at both sites
  - PE informed ERCOT DC side is not modeled in positive sequence nor EMT model; therefore, no model updates were required by REs

Risk Dramatically Minimized✓

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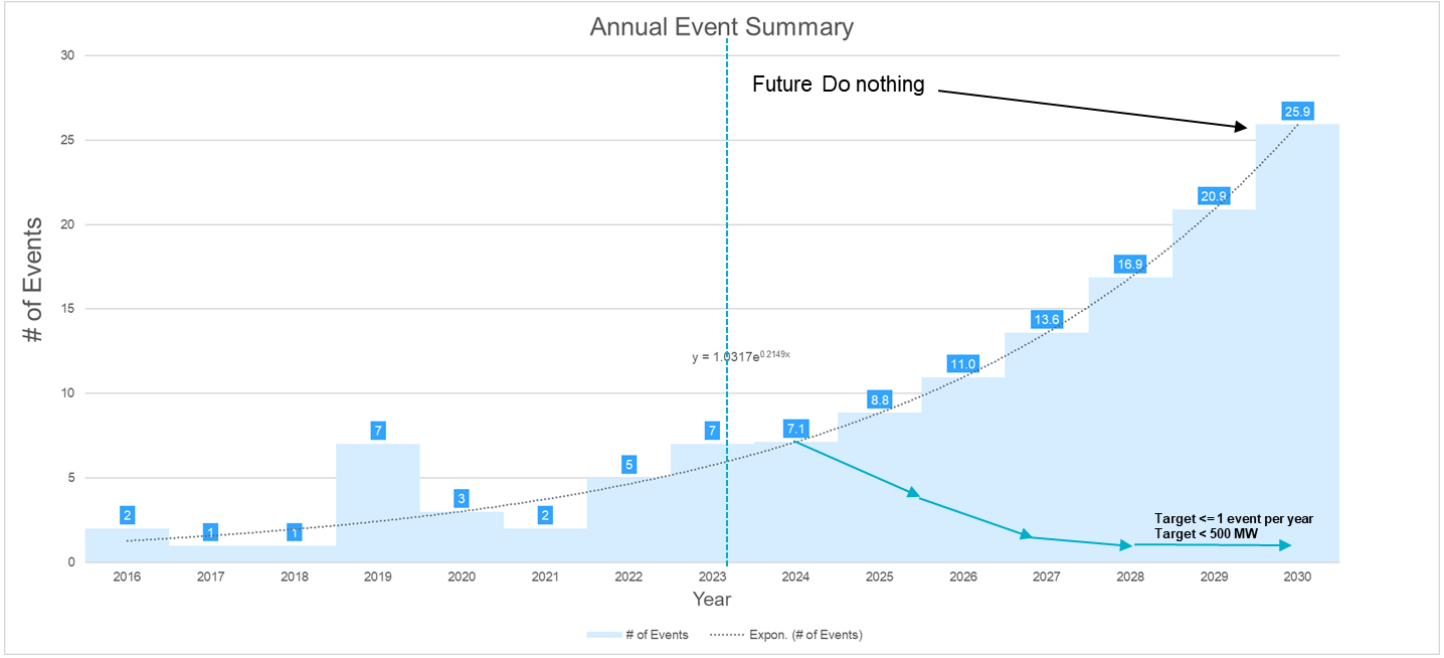
#2: Software Updates Address System Risk

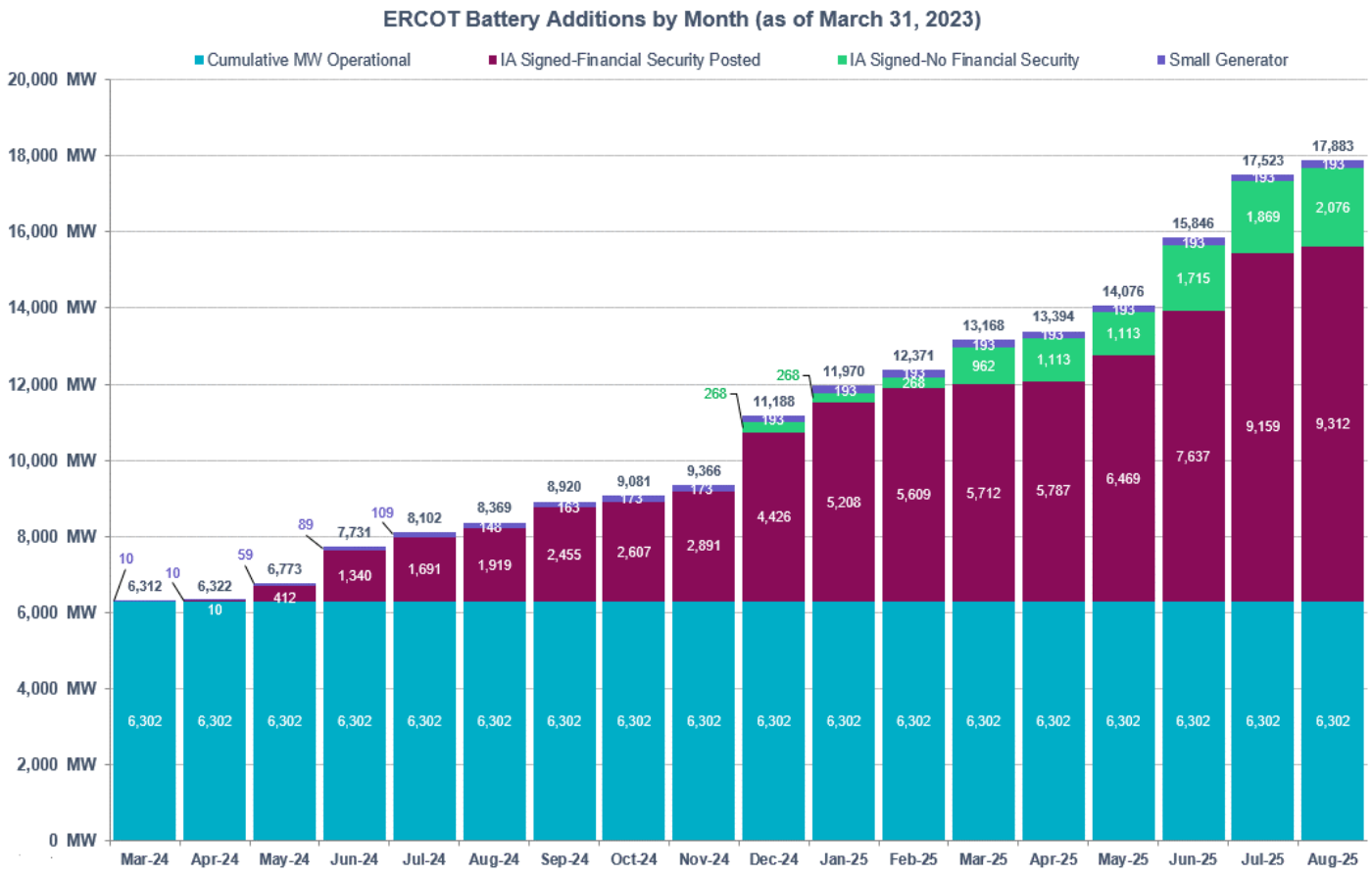
- ERCOT and stakeholder event analysis puts us on the downward trajectory
- TAC version of NOGRR 245 puts us on the downward trajectory
  - Technical differences and exemption differences likely have minimal impact
- More information needed on "#/size of events"

- These types of graphs are a "curve fitting exercise"
- Forecasting these events with "do nothing" out to 2030+ is not credible



Source: May 10 NOGRR 245 Workshop

#2: Software Updates Address System Risk



- Ride-through is an ***essential*** reliability service
- But are we overburdening the ***existing*** resources to fix new grid problems?
  - Battery boom: How many will be grid forming (by default)?
  - What stability (frequency, weak grid, transient, etc.) benefits are gained?
  - Where are the studies and subsequent actions taken?
- Why remove existing exemptions? To gain system-side benefits that help fix these issues…

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#3: Retroactive Date for Preferred Req's

- Dates are relatively arbitrary – arguing for the sake of argument
- Retroactive date for new requirements, removal of existing exemptions, uncertainty with IEEE 2800 (no flexibility in requirements) – all appears to go against standard precedents
- Where are the reliability studies (or technical analyses) that justify this is needed?
  - Physical modifications should not be mandated if the need is not analytically justified
    - Grid codes are updated for "needs" and not "wants"

SGIA Before June 2023	SGIA June 2023 to June 2024	SGIA After June 2024
• Truly legacy resources with known equipment limitations • Resource-specific limitations beyond software • Previous exemptions may have been given, should be respected	• Signed interconnection agreement before NOGRR 245 completed; using rules applicable at time of signing • 97+% solar PV and BESS • Highly capable devices, known risks mitigated • Unknown whether can meet IEEE 2800; requires exemptions	• Signed interconnection agreement (intended) after NOGRR 245 completed; using rules applicable at time of signing • Vastly solar PV and BESS • Can prepare to meet IEEE 2800 • Minimizes exemptions

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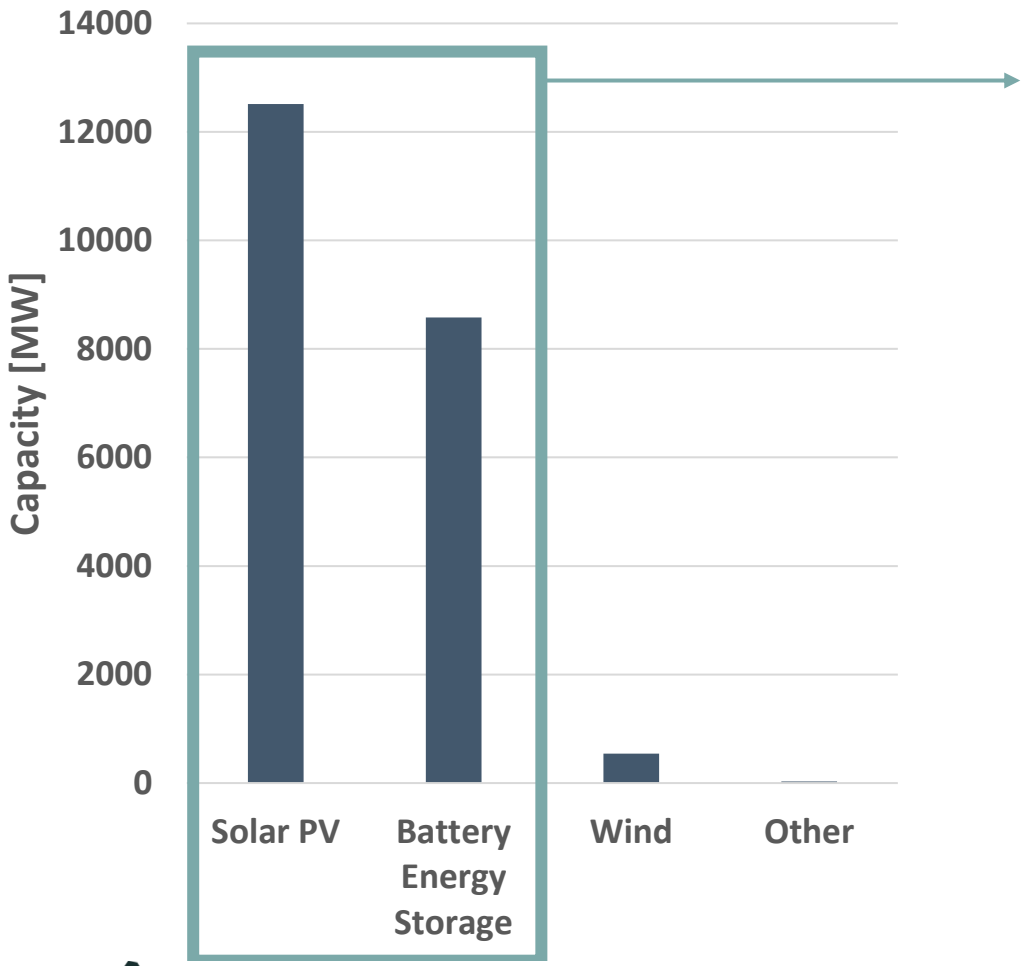
#4: 20-30 GW of IBRs June 2023 to June 2024



- 97+% of these resources are solar PV and battery energy storage
  - Past risks fixed with software updates to newly installed equipment
- Can they meet legacy requirements? Yes.
- Can they meet preferred requirements? Likely, with one big caveat.
  - IEEE 2800-2022 conformance and OEMs waiting for IEEE 2800.2 approval and adoption

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#4: 20-30 GW of IBRs June 2023 to June 2024

- Causes of tripping are unrelated to curves, as discussed
- Which issues would still be allowed by legacy but not by preferred?
  - **None of them…**
- No notable reliability benefit in moving the date backwards
  - Increased compliance risk
  - Need for exemptions for IEEE 2800

Location	Identified Issue	Odessa Events?	Software Fixable?
Inverter	Momentary Cessation[1]	X	Yes
	Inst. Frequency		Yes
	Inst. AC Overvoltage	X	Yes
	DC Reverse Current		Yes
	PLL Loss of Sync/Phase Jump	X	Yes
	Slow Active Power Recovery[1]	X	Yes
	AC Undervoltage		Yes
	Inst. AC Overcurrent	X	Yes
	DC High/Low Voltage		Yes
	DC Voltage Unbalance	X	Yes
	Ride-Through Misconfiguration[1]	X	Yes
	DC Overcurrent		Yes
	Auxiliary Equipment[2]		Maybe
	Subsynchronous Oscillation		Maybe
	AC Current Unbalance		Yes
Plant-Level	Inverter-PPC Interactions[1]	X	Yes
	Feeder Underfrequency	X	Yes

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#5: Commercial Reasonability

- **Existing NOG Requirements**
  - ✗ FRT: Relay setting requirement
  - ⚠ VRT: Mixed relay and performance requirements
  - ✗ Speed of response: nothing

- **NOGRR 245 Requirements**
  - ✓ FRT: Performance-based requirement
    - Equal and/or better curves
  - ✓ VRT: Performance requirements
    - Equal and/or better curves
  - ✓ Speed of response: both legacy and preferred

- All proposed requirements are a notable increase in performance expectations
  - Rightfully require flexibility and possible exemption for existing resources with physical limitations
- Options:
  - Allow reportable exemptions with technical basis
  - ***Increase*** expectation by assessing commercial reasonability

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#6: Stop Delaying Requirements Updates

“New requirements for new resources”

- Preferred requirements, including IEEE 2800 adoption, for new SGIAs
- Everyone agrees
- Bifurcation of what is agreed upon and what is stuck in limbo
- Should have been done in early 2023
- Letting perfect be the enemy of good

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#7: Defense in Depth / Maximizing Capability

- Elevate proposed a “defense in depth” approach as a bridge to IEEE 2800 adoption
- Closer review uncovered additional ***important*** details
- Requirements in TAC version of NOGRR 245 ***require maximizing*** to equipment capability

2.6.2.1 FRT for IBR

(3) If protection systems (including, but not limited to protection for over-/under-frequency, rate-of-change-of-frequency, anti-islanding, and phase angle jump) are installed and activated to trip the IBR or Type 1 WGR or Type 2 WGR, they shall enable the Resource to ride through frequency conditions beyond those defined in paragraph (1) above to the maximum extent equipment allows.

2.6.2.1.1 Temporary FRT for IBR

(1) This Section applies to IBRs and Type 1 and Type 2 WGRs with an SGIA executed prior to June 1, 2024 that have not implemented modifications to satisfy paragraphs (1) through (5) of Section 2.6.2.1, Frequency Ride-Through Requirements for Transmission-Connected Inverter-Based Resources (IBRs) and Type 1 and Type 2 Wind-Powered Generation Resources (WGRs).

2.9.1.2 Legacy VRT for IBR

(3) If protection systems (including, but not limited to protection for over-/under-voltage, rate-of-change of frequency, anti-islanding, and phase angle jump) are installed and activated to trip the IBR or Type 1 WGR or Type 2 WGR, they shall enable the IBR or Type 1 WGR or Type 2 WGR to ride through voltage conditions beyond those defined in paragraph (1) above to the maximum extent the equipment allows.

2.9.1.1 Preferred VRT for IBR

(3) If protection systems (including, but not limited to protection for over-/under-voltage, rate-of-change-of-frequency, anti-islanding, and phase angle jump) are installed and activated to trip the IBR, they shall enable the IBR to ride through voltage conditions beyond those defined in paragraph (1) above to the maximum extent equipment allows.

2.11 Commercially Reasonable Effort

(1) “Commercially reasonable efforts” means that the Resource Entity must evaluate its facilities and available modifications it can make to its equipment, if any, to maximize its frequency and/or voltage ride-through capability up to the frequency and voltage ride-through requirements set forth in Section 2.6.2.1, Frequency Ride-Through Requirements

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Importance of Modeling

Need for Accurate Modeling to Justify Forward-Looking Reliability Risks

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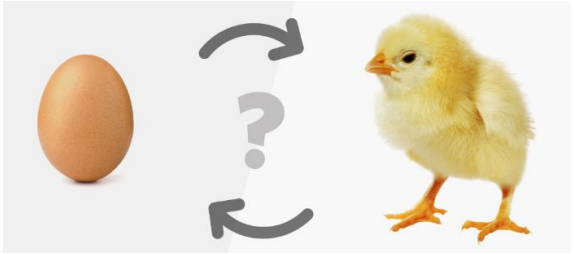
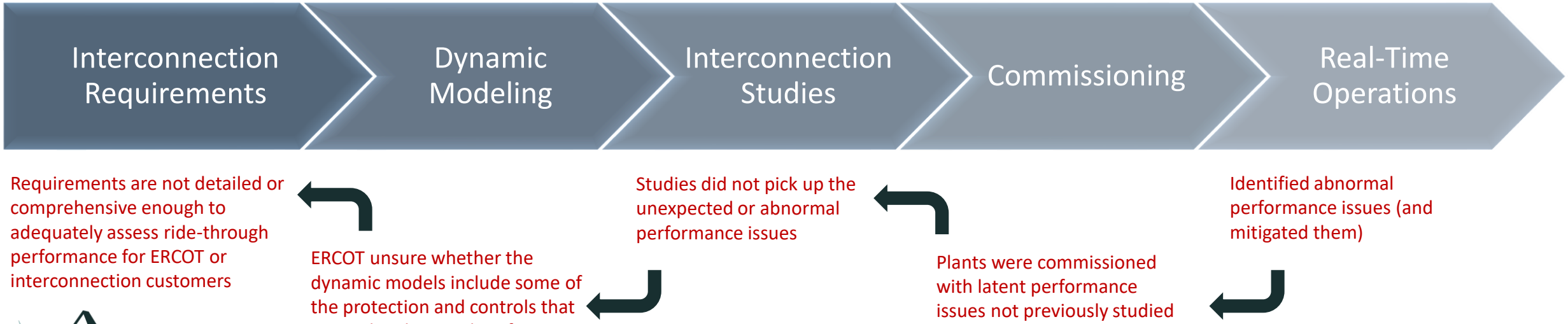
Modeling Improvements Needed



- ERCOT comments from past meetings:*
  - “Unfortunately, a lot of the models we've received haven't accurately represented the actual characteristics of the units.”
  - “Right now, the models that the generators have provided to us don't even show these trips should happen because the models don't accurately reflect what the protection systems and some and other parameters are set to in the field.”
  - “Knowing whether something is an acceptable reliability risk or not is going to require us doing simulations.”
  - “[Without accurate resource models], we’re not going to be able to evaluate how much reliability risk we really have."

* From April ERCOT R&M Meeting and May NOGRR 245 TAC Workshop



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Modeling vs. Eliminate Issue

Location		Identified Issue	Odessa Events?	Software Fixable?	Modeling "Fix"
Inverter	☑	Momentary Cessation*	X	Yes	Eliminate issue otherwise model correctly
	☑	Inst. Frequency		Yes	Eliminate issue; only model if cannot eliminate
	☑	Inst. AC Overvoltage	X	Yes	Ensure max capability, model correctly
	☑	DC Reverse Current		Yes	Eliminate issue
	☑	PLL Loss of Sync/Phase Jump	X	Yes	Eliminate issue; only model if cannot eliminate
	☑	Slow Active Power Recovery	X	Yes	Eliminate issue, model correctly
	☑	AC Undervoltage		Yes	Eliminate issue
	☑	Inst. AC Overcurrent	X	Yes	Eliminate issue
	☑	DC High/Low Voltage		Yes	Eliminate issue
	☑	DC Voltage Unbalance	X	Yes	Eliminate issue
	☑	Ride-Through Misconfiguration	X	Yes	Eliminate issue
	☑	DC Overcurrent		Yes	Eliminate issue
	?	Auxiliary Equipment		Maybe	Model correctly (if possible)
	?	Subsynchronous Oscillation		Maybe	Eliminate issue, model correctly (if possible)
	☑	AC Current Unbalance		Yes	Eliminate issue
Plant-Level	☑	Inverter-PPC Interactions	X	Yes	Eliminate issue
	☑	Feeder Underfrequency	X	Yes	Eliminate issue

*Except for some legacy inverters

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High-Level Process

- ERCOT has interconnection requirements *(including modeling requirements)*
  - Interconnection customer submits models to ERCOT
    - Models must pass ERCOT model quality requirements and checks
    - Largely at the mercy of black box models from OEMs (for protection and controls)
- Interconnection customer and ERCOT assess proposed facility performance using models provided
- Interconnection customer given green light for interconnection; signs GIA
- Facility constructed, commissioned, and interconnected

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Modeling Priorities

- Model fidelity gaps (e.g., missing protections) = improve requirements
  - Model inaccuracy is not the same issue; blatant model errors are not okay, and should be fixed

- Priorities
  1. **Fix software issues (performance) (eliminate need to model)**
     - DC bus protections, AC overcurrent, phase jump/PLL loss of sync, inst. frequency protection, etc.
     - PPC/inverter interactions, slow dynamic recovery, etc. (re-tuning)
  2. **Ensure models match equipment, where they can**
     - Momentary cessation, AC over/undervoltage, etc.
  3. **Assess whether more extensive model updates are required**
     - Use engineering judgment and collaboration to continue to address hardware-related issues
     - Pitch controller limitations, UPS failures, SSO protection issues

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