GE Energy

Asia Development Bank
Wind Energy Grid Integration Workshop:

Wind Grid Codes

Nicholas W. Miller

GE Energy Consulting

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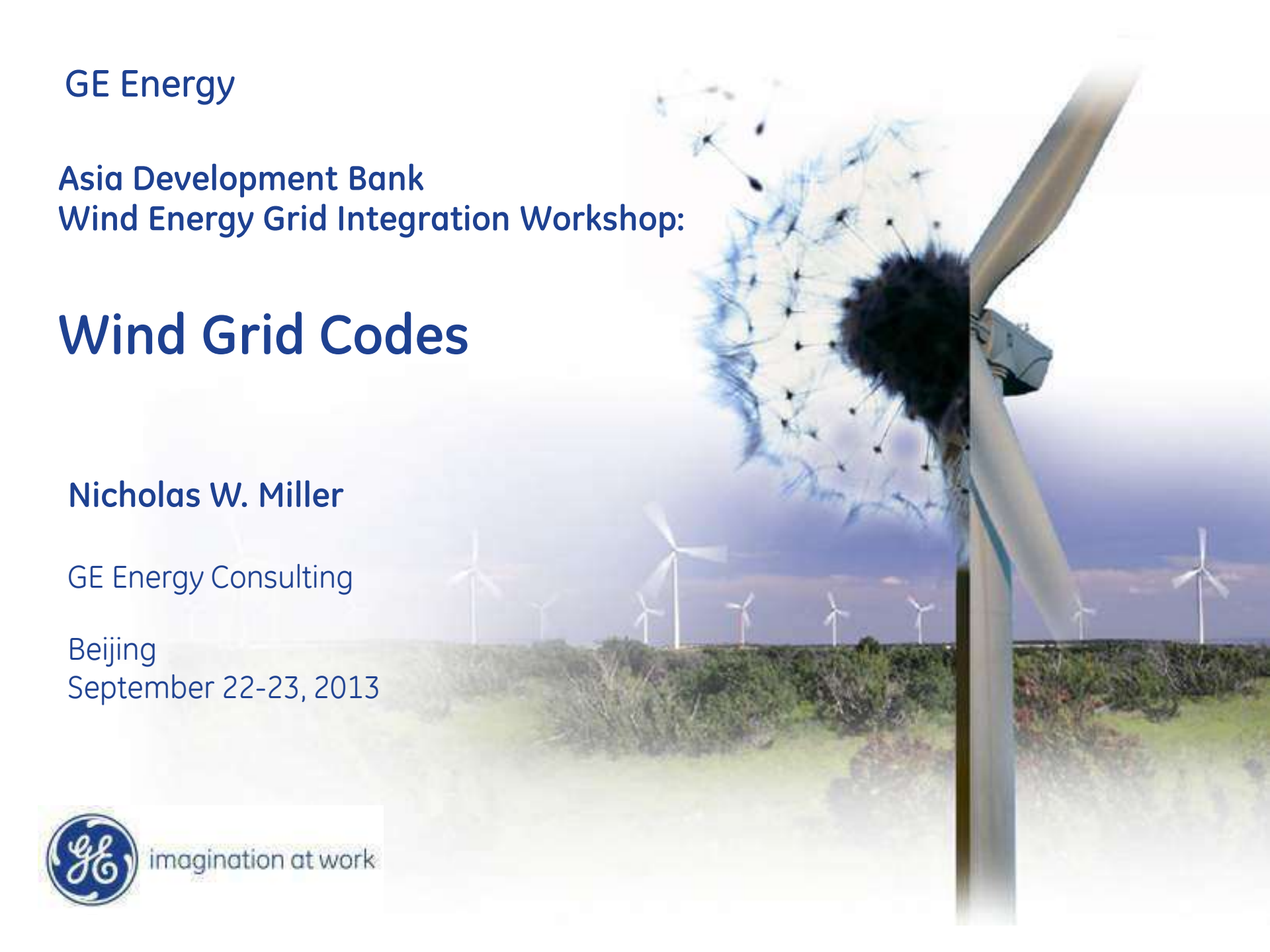

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Grid Code Development

Debate…

- Should wind generation be treated differently?
- What is the obligation of generation to provide voltage control?
- How should generation respond to system disturbances?
- How should generation prove it meets performance requirements?

These questions are still being debated in the industry today.

US Grid Code Development

In the US, relationships between transmission system operators (TSO), generators and users of energy are governed by multiple entities:

- FERC (Federal Energy Regulatory Commission)
- NERC (North American Reliability Council)
- Regional Reliability Councils (e.g.:)
  - WECC (Western Energy Coordinating Council)
  - ERCOT (Electric Reliability Council of Texas)
- State Reliability Councils
- State Regulators
- Standards Organizations (ANSI/IEEE/NESC/NEC)
- A similar Federal/Provincial structure applies in Canada

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North American Grid Code Development

In NA, rules are generally identified in terms of:

- Reliability Standards
- Interconnection Requirements
  - These interconnection requirements correspond approximately to European Grid Codes

The objectives are:

- To make sure generation and transmission is efficient and reliable, and
- To regulate rights and responsibilities of generators, TSO's and energy users.

Note: Interconnection Requirements for Wind Energy in the US are continuing to develop. Regulating groups (FERC) and Reliability groups (NERC) are debating terms of current grid codes.

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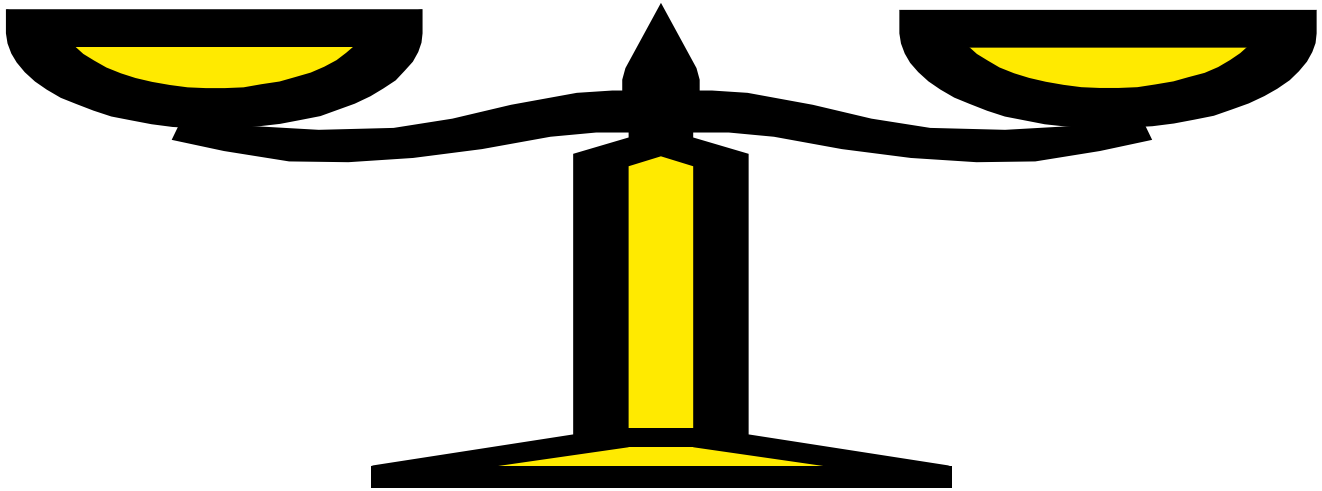
What consensus is emerging NA Grid Codes?

- Reactive Power: +/- 0.95 pf @ POI
- Voltage Control: required, with ISO voltage setpoints
- Frequency Tolerance: +/- 3 hz continuous
- Voltage Tolerance (Low Voltage Ride-Through): ZVRT (FERC 661a), NERC PRC-024 up for ballot
- Models and Data: required cooperation
- Telemetry and Metering: specific minima
- Power Quality: IEEE 519 for Harmonics and Flicker
- Frequency Control: debate just starting
- Validation requirements: NERC MOD Standards up for ballot
- Plant Protection Coordination: NERC PRC-019 up for ballot

Grid Code Development

Tight
More Expensive Equipment
Reduced Efficiency

Loose
Compromised System
Reliability



Grid Code Functional Specifications

Grid Codes should be no more specific than they need to be to avoid over-designed equipment and reduced efficiency of wind generation, but should be specific enough for adequate system reliability.

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Global Renewable Codes & Standards Development

California ISO Interconnection Requirements for Variable Energy Resources

ISO-NE Technical Requirements for Wind Interconnection & Integration

NERC Standards Drafting and Task Forces

- Integration of Variable Generation Task Force **(IVGTF)**
- Generator Verification Standards Drafting Team **(GVSDT)**

FERC now mandates that all new reliability standards address VER

International

- Ontario IESO Amended Market Rules for Generation Facilities
- Chinese State Power Grid Technical Code for Wind Interconnection
- Indian CERC Electricity Grid Code for Wind
- German FGW Technical Guidelines for Wind Energy
- Australian Energy Market Operator (AEMO) Guidelines for Wind Energy

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NERC GVSDT* standards currently in draft

MOD (Model Validation):

MOD-025: Verification of Generator/Plant Real & Reactive capability

MOD-026: Verification of Dynamic Models and Data for Generator Excitation Control and Plant Volt-Var Control Functions

MOD-027: Verification of Dynamic Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions

PRC (Protection & Control):

PRC-019: Coordination of Generating Unit/Plant Voltage Regulating Controls with Unit/Plant Capabilities and Protection

PRC-024: Generator Performance During Frequency and Voltage Excursions

Applicability has been modified to include wind & large solar.
These drafts in various stages of being finalized.

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* Generator Verification Standards Drafting Team

FAULT RIDE-THROUGH

NERC PRC-024: Generator Performance During Frequency and Voltage Excursions

Requirement 1: Frequency Ride-Through

- Each Generator Owner (GO) shall:
  - Set in service frequency protective relaying so that it does not operate to trip the generating unit during frequency excursions within the band described in Attachment 1
  - Conditions and exceptions:
    - Must operate between 59.5 and 60.5 Hz continuous
    - May trip if rate of change >2.5 Hz/sec (Aurora exclusion)

Requirement 2: Voltage Ride-Through

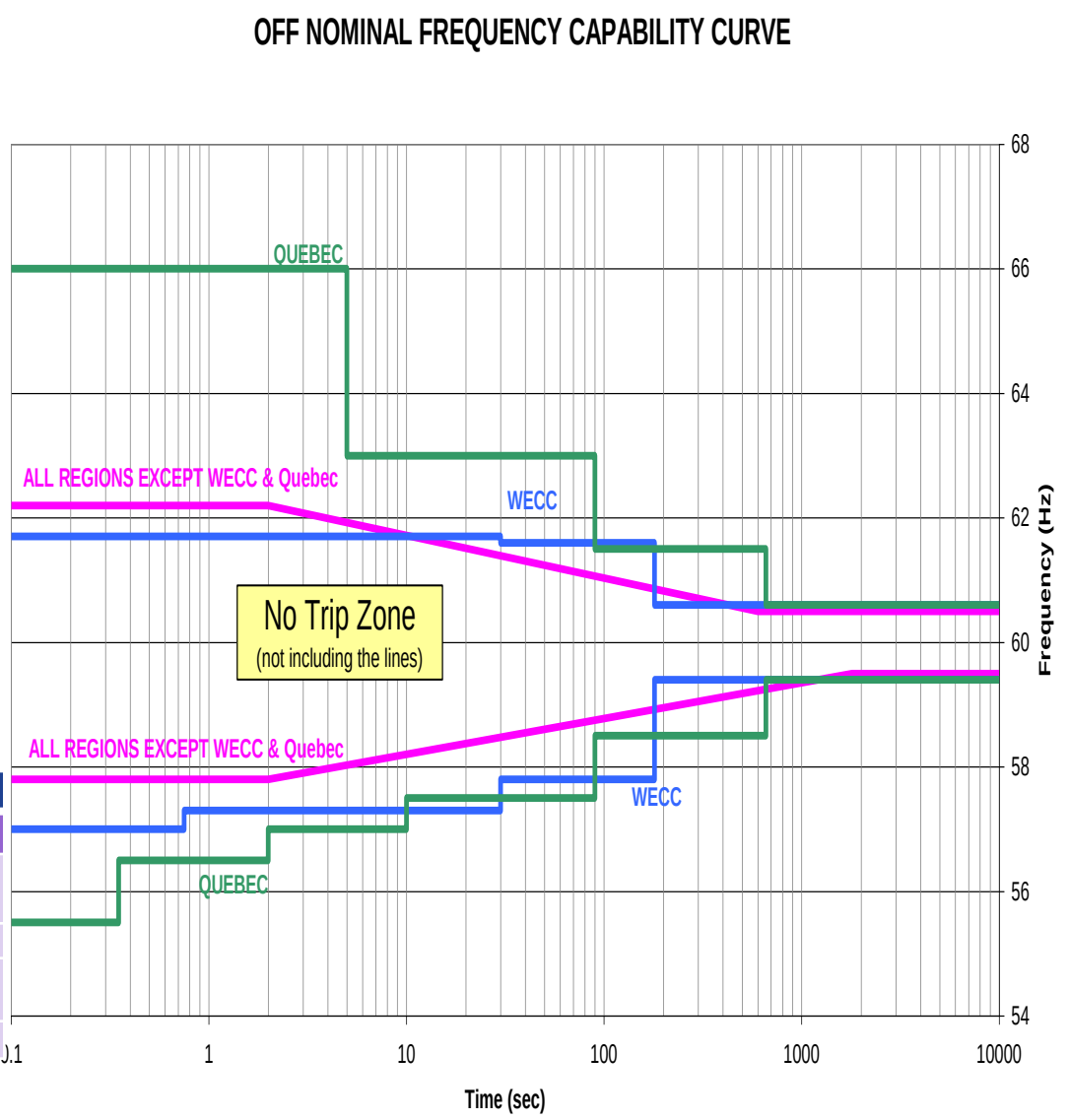
- Each Generator Owner (GO) shall:
  - Set in service voltage protective relaying so that it does not operate to trip the generating unit during voltage excursions within the specified band
  - Conditions and Exceptions:
    - Consider 3-phase Zone 1 faults with normal clearing
    - Site-specific clearing time may be used
    - Generator tripping for SPS, RAS or to clear the fault allowed

NERC PRC-024: Frequency Ride-Through

QUEBEC			
High Frequency		Low Frequency	
Time (Sec)	Frequency (Hz)	Time (Sec)	Frequency (Hz)
0 - 5	66	0 – 0.35	55.5
5 -90	63	0.35 - 2	56.5
90 - 660	61.5	2 - 10	57
> 660	60.6	10 - 90	57.5
		90 - 660	58.5
		> 660	59.4

WECC			
High Frequency		Low Frequency	
Time (Sec)	Frequency (Hz)	Time (Sec)	Frequency (Hz)
0 – 30	61.7	0 – 0.75	57
30 – 180	61.6	0.75 - 30	57.3
>180	60.6	30 - 180	57.8
		>180	59.4

ALL OTHERS			
High Frequency		Low Frequency	
Time (Sec)	Frequency (Hz)	Time (Sec)	Frequency (Hz)
0 - 2	62.2	0 - 2	57.8
2 - 600	62.41 – 0.686 log(t)	2 - 1800	57.63 + 0.575 log(t)
>600	60.5	>1800	59.5



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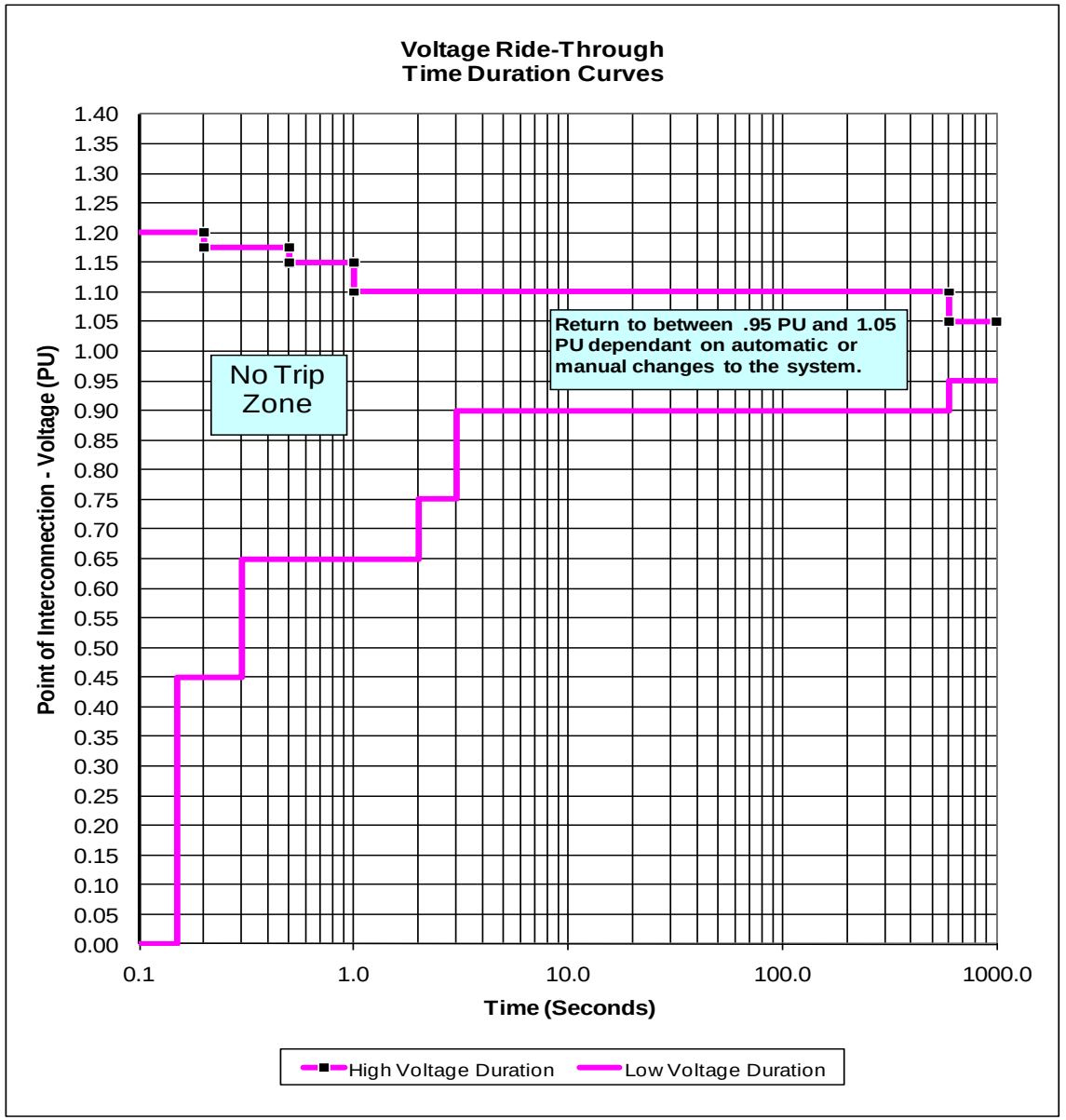
NERC PRC-024: Voltage Ride-Through

HVRT DURATION		LVRT DURATION	
Time (Sec)	Voltage (p.u.)	Time (Sec)	Voltage (p.u.)
0.20	1.200	0.15	0.000
0.50	1.175	0.30	0.450
1.00	1.150	2.00	0.650
600	1.100	3.00	0.750
		600	0.900

Generators / Plant must not trip for credible faults inside the zone unless:

- SPS / RAS requires it
- Generator critical clearing time requires it (synchronous generators)



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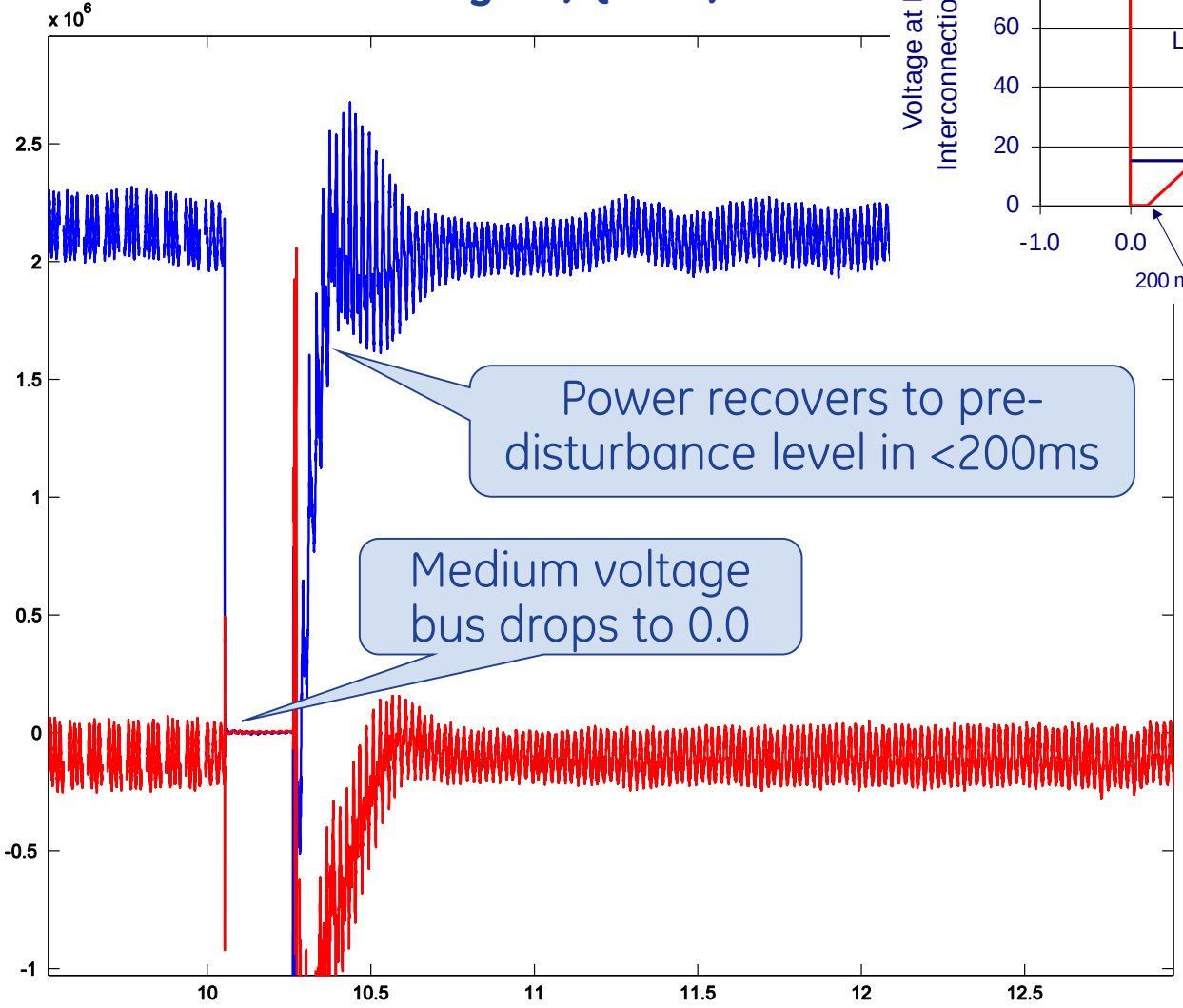
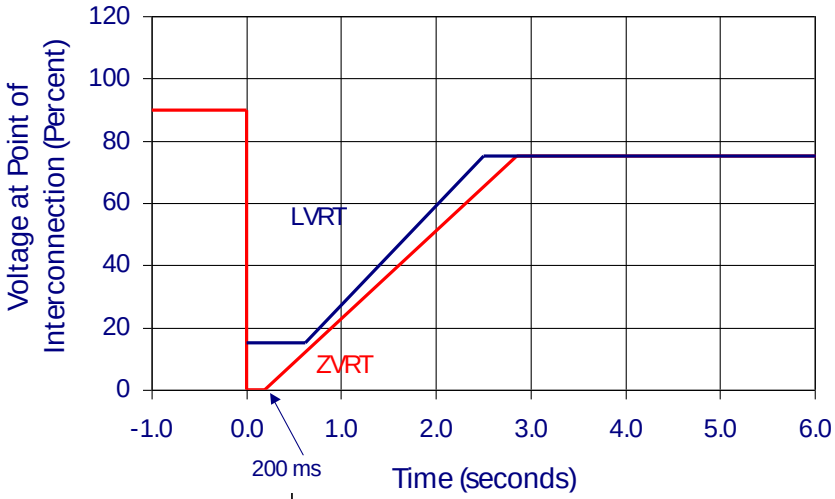
Ride-Thru Capabilities

3-phase zero retained voltage, 200ms fault: (GE Standard ZVRT offering) P, Q (Mw,Mvar)





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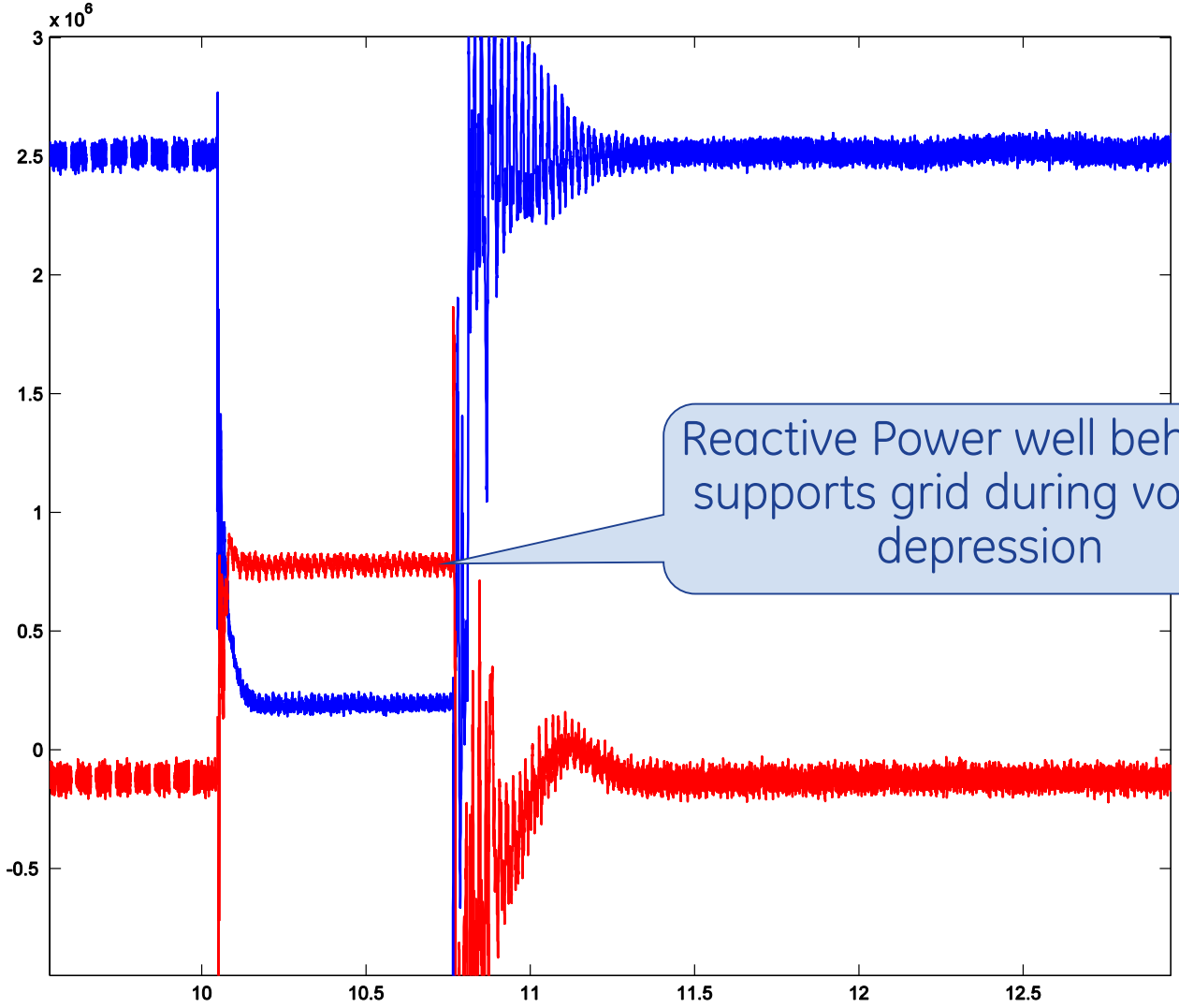
Field Test Results (2.5 unit)

3-phase 18.5% retained voltage, 700ms fault: P, Q (Mw.Mvar)



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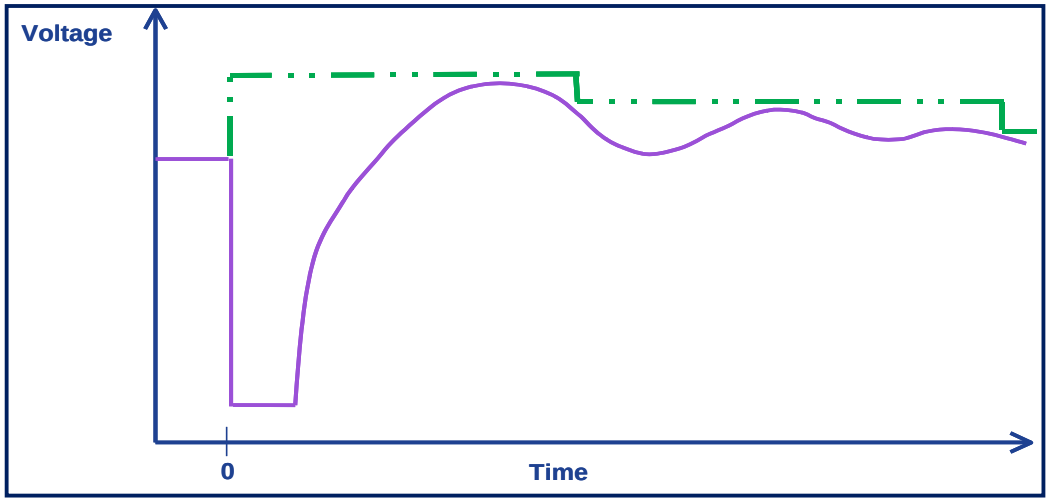
Field Test Results (2.5 unit)

HVRT Requirement: Traditional vs. Severity-Duration

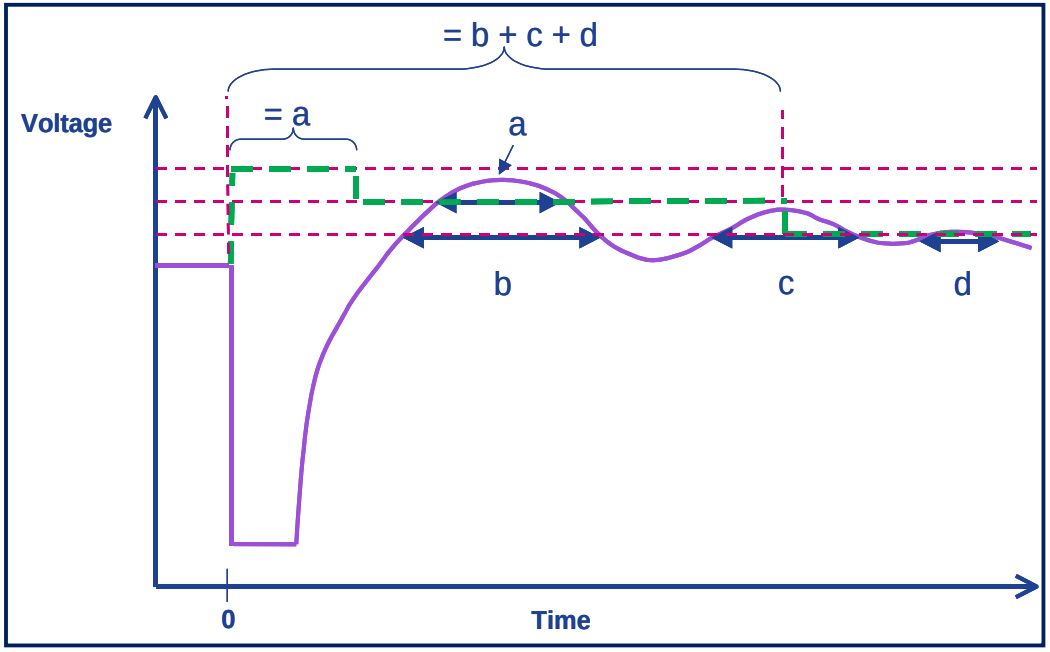
Traditional HVRT Req'mt

- Timer starts at beginning of fault



Recommended HVRT Req'mt

- Timer starts when voltage exceeds high-voltage threshold
- Objective is to align criteria with equipment duties/capabilities



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PROTECTION COORDINATION

NERC PRC-019: Coordination of Generating Unit/Plant Voltage Regulating Controls with Unit/Plant Capabilities and Protection

Coordination

- Verify limiters are set to operate before protection
- Verify protection is set to operate before conditions exceed equipment capabilities

Elements may include (but are not limited to):

- Field over-excitation limiter and associated protective functions
- Inverter over current limit and associated protective functions
- Volts per Hertz limiter and associated protective functions
- Stator over-voltage protection system settings
- Generator and transformer volts per Hertz capability
- Time versus field current or time versus stator current capability
- Converter over temperature limiter and associated protective functions

MODEL VALIDATION

NERC MOD-026: Plant Volt / Var Control

NERC MOD-027: Plant Active Power / Frequency Control

Main Requirements

- Each Transmission Planner shall provide existing model and data to the Generator Owner within 30 days of receiving an information request
- Each Generator Owner shall provide to the Transmission Planner a verified and accurate model in accordance with the standard's periodicity table
- Other requirements that cover special circumstances

Staged test or ambient monitoring is allowed

The GO **"owns"** the model and is responsible for its validity

- Responsible for selecting proper structure and determining parameters
- Responsible for determining if match is "good enough"
- Peer Review process is included to facilitate technical discussions between the Generator Owner (GO) and the Transmission Planner (TP)

Existing NERC Standards Relevant for Renewables

VOLTAGE REGULATION

NERC VAR-001: Voltage and Reactive Control

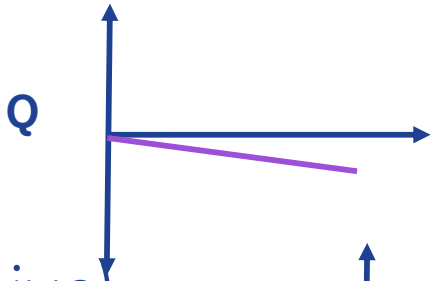
NERC VAR-002 : Generator Operation for Maintaining Network Voltage Schedules

Main Requirements

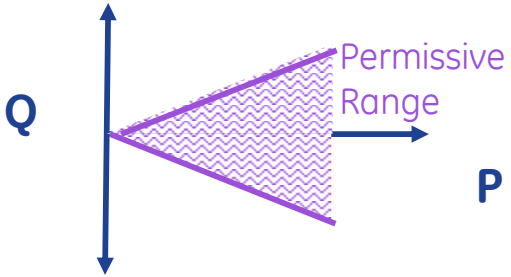
- Each Transmission Operator shall acquire sufficient reactive resources and specify a voltage or reactive power schedule at the POI
- Each Generation Operator shall operate each generator in automatic regulation mode and follow the voltage or reactive power schedule provided by the Transmission Operator or as otherwise directed by the Transmission Operator

Reactive/Voltage Requirement Variations

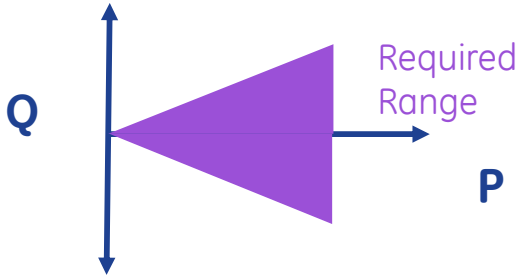
- Fixed power factor



- Power factor range (permissive)



- Dispatched reactive or pf, within pf range



- Voltage regulation, within pf range
  - May regulate local or remote bus

DISTURBANCE CONTROL / FREQUENCY REGULATION

NERC BAL-002: Disturbance Control Performance

NERC BAL-003: Frequency Response and Bias

Main Requirements

- Each Balancing Authority shall have access to and/or operate Contingency Reserve to respond to Disturbances. Contingency Reserve may be supplied from generation, controllable load resources, or coordinated adjustments to Interchange Schedules.
- **Frequency Response Obligation (FRO):** The Balancing Authority's share of the Frequency Response required for reliable operation across the entire interconnected system. This will be calculated as MW/0.1Hz. [Included in BAL-003.1x draft, now in balloting process]

New and highly visible in the US now

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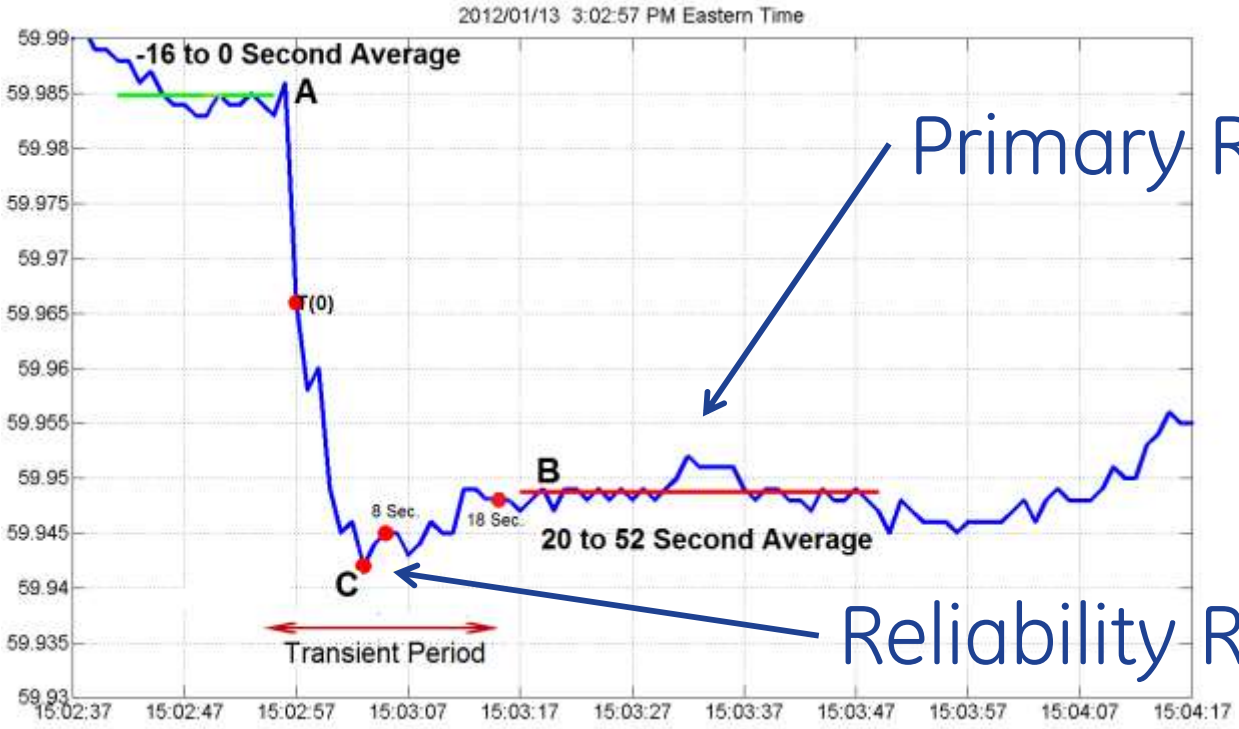
DISTURBANCE CONTROL / FREQUENCY REGULATION

NERC BAL-002: Disturbance Control Performance

NERC BAL-003: Frequency Response and Bias

Frequency Response Measurement and Calculation



$$FRO_{BA} = FRO_{Int} \times \frac{Peak\ Gen_{BA} + Peak\ Load_{BA}}{Peak\ Gen_{Int} + Peak\ Load_{Int}}$$

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NE

- Report was written by a team of industry experts and NERC members
  - Sub-groups worked on individual chapters
- Draft of consolidated document was sent to entire project team for review
- Final version of the report was accepted by NERC in September 2012
  - Various regulatory and technical standards teams now may use this reference for future development

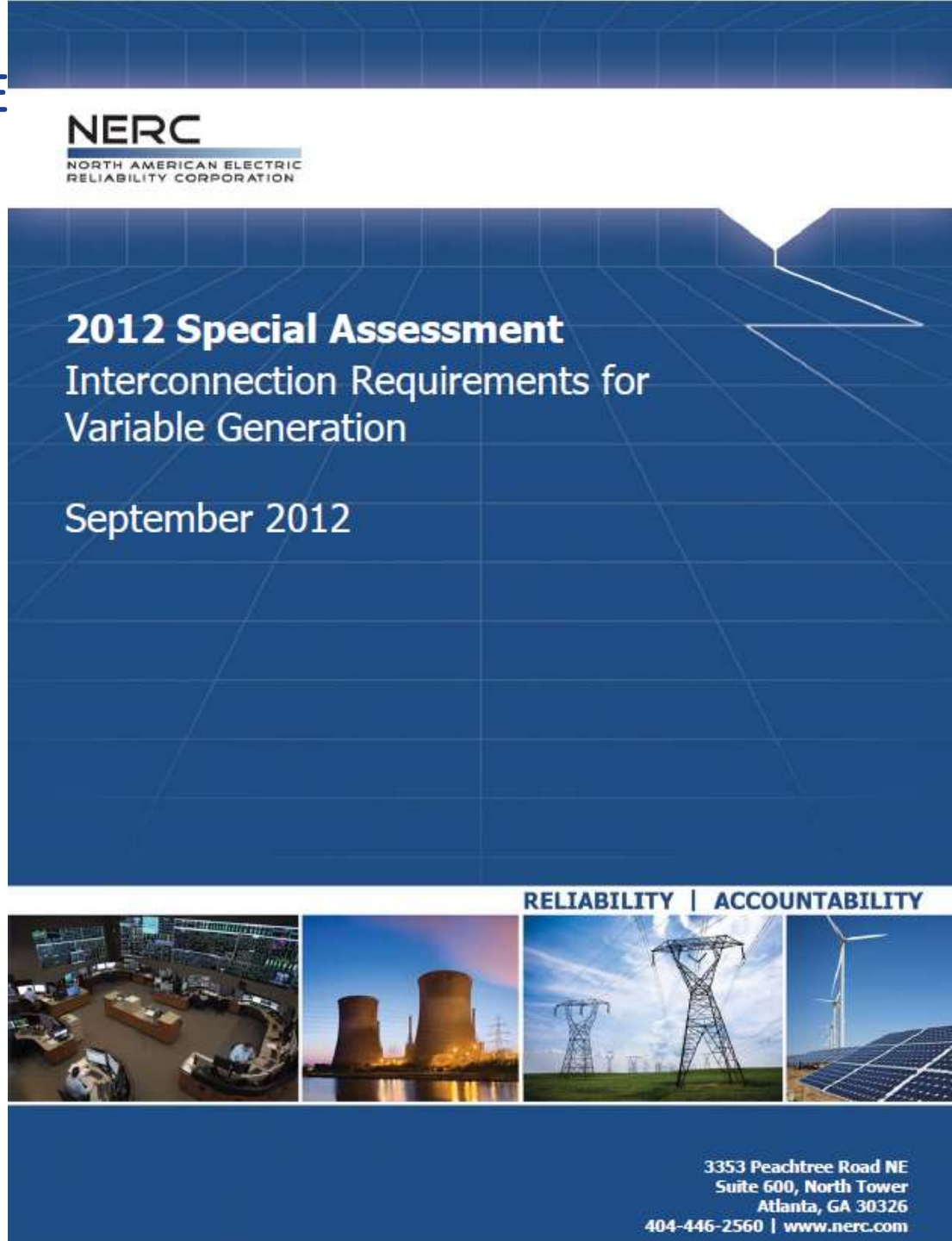

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Table of Contents

Thank you!

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