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North American Interconnection Requirements: Regional Differences and Emerging Changes

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Interconnection Requirements (Grid Code)

- Existing Requirements
- Regional Differences
- Emerging Changes

Interconnection Requirements: Impacts on Stakeholders

- Owners/Developers: Initial capital costs, O&M, retrofit, compliance reporting; want standardization
- Turbine Manufacturers: Drives design and technology choices; costs for capability; want standardization
- System Operators: Responsible for Reliability and Economics; - Real differences between systems, so differences in requirements – not standardization
- Regulators: Competing interests – interconnection requirements are factors in level playing field or advantages

Important Interconnection Requirements

- Voltage and Frequency Operating Ranges
- Reactive Power
- Voltage Control
- Power Quality
- Frequency Response
- Stability (fault ride-through)
- System Operation

- Emerging Requirements
  - Extended Fault Ride-Through
  - Extended Reactive Capability
  - Ramp Rate Control
  - Delta Control

Voltage and Frequency Operating Ranges

- Objective: Keep generators on line

- Voltage: 0.9 – 1.1 p.u.

- Frequency: 59.4 Hz to 60.6 Hz – Normal Operation
- 57 to 61.7 Hz – Short Periods

- Future
  - Turbines could operate at lower frequencies
  - There is cost: must be rewarded, and benefits demonstrated

Reactive Power and Voltage Control

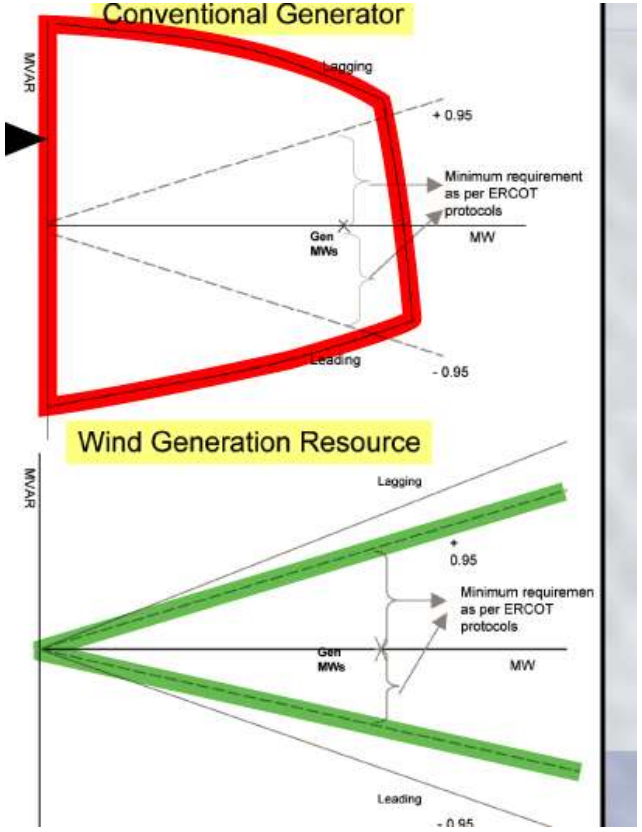
- Constant power factor or within defined range

- Modern wind turbines can provide:
  - Very rapid and precise control of reactive power
  - Wide reactive power range (wider if you want it)
  - Control of voltage, at the wind farm terminals or at some remote point (‘line drop compensation’)
  - Even when not generating

- Cost for capability: must be rewarded

Reactive Power: ERCOT PRR 830

- Requires nameplate reactive capability at all plant output levels
- Has been appealed to PUCT
- Questions on technical justification, fairness (conventional exemptions) and retroactive requirement



Power Quality – Harmonics

Turbines generally not source of harmonic issues, however:

- Pre-existing levels of harmonics, i.e. before the connection of a wind farm, may already be above or close to the permitted levels;
- Transmission owners generally do not know the levels of harmonic distortion on their networks, until they look.
- Is there a market for harmonic filtering services?

Power Quality – Voltage Steps (flicker)

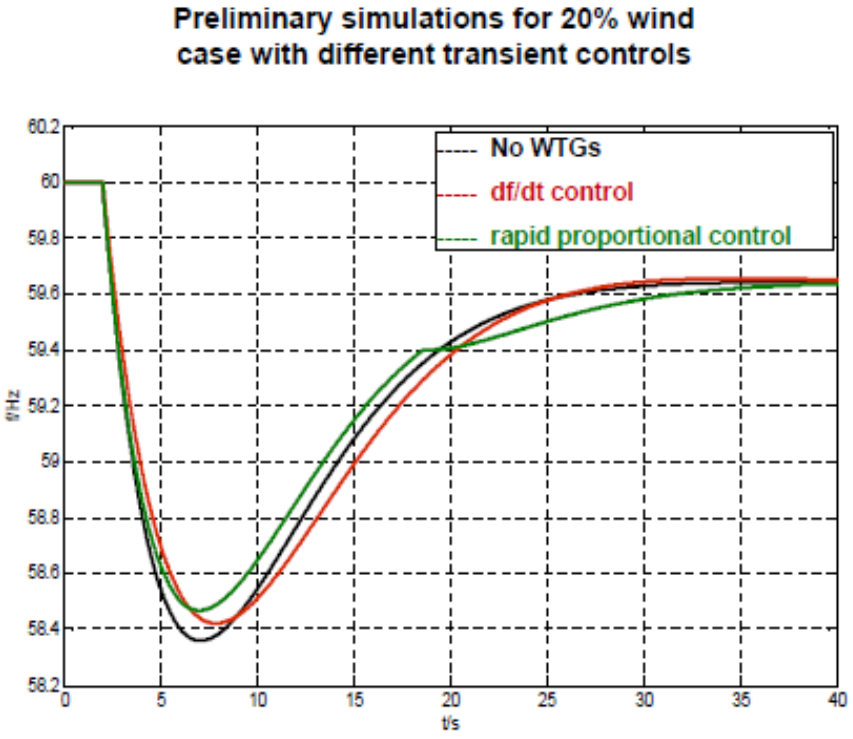
- An issue mostly for small wind farms (distribution connected) but also large transmission connected projects
- The most severe flicker is generally produced by energizing transformers
- Future: fully integrated automatic sequential switching in the wind farm control

Frequency Response

- A clear requirement, well specified in several grid codes, and implemented by many manufacturers
- No significant further development expected
- Future:
  - Steady state: reg up/reg down
  - Required elsewhere
  - Costs for capability: reward and benefit

Frequency Response – Inertial response

- Wind turbines could also provide transient ‘inertia effect’: in the event of a sudden frequency drop, the wind turbine can extract energy from the spinning rotor, to mimic a very large inertia.
- Limited only by torque on drive train, and energy stored in rotor
- Clear benefits especially for island or weak grid systems
- Costs for capability: reward and benefit

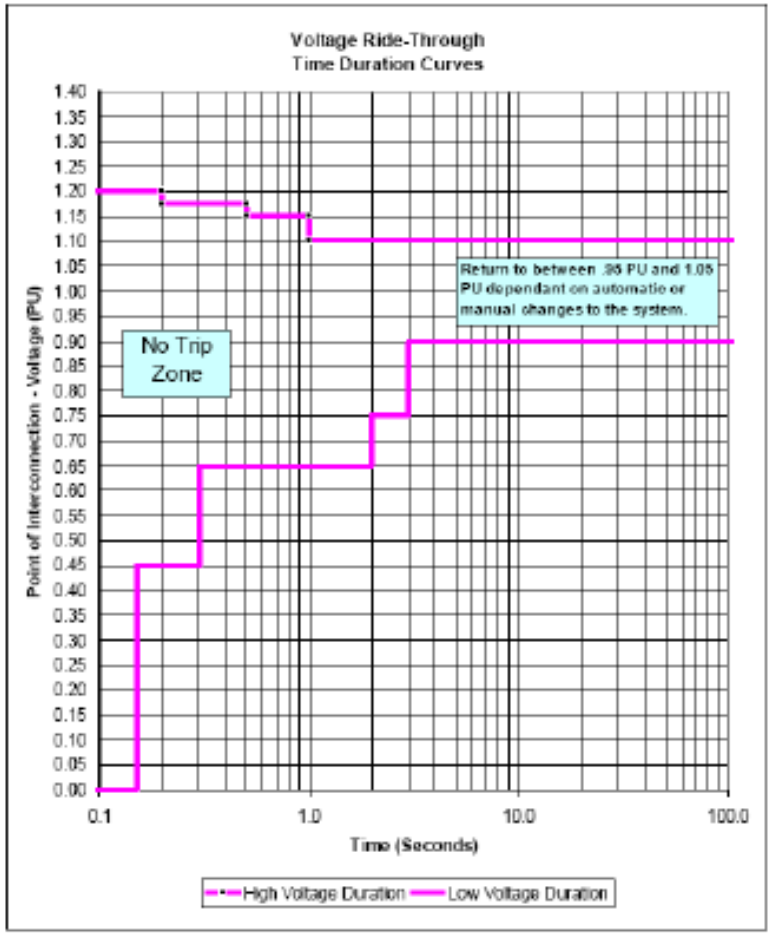


Stability - Fault Ride-Through

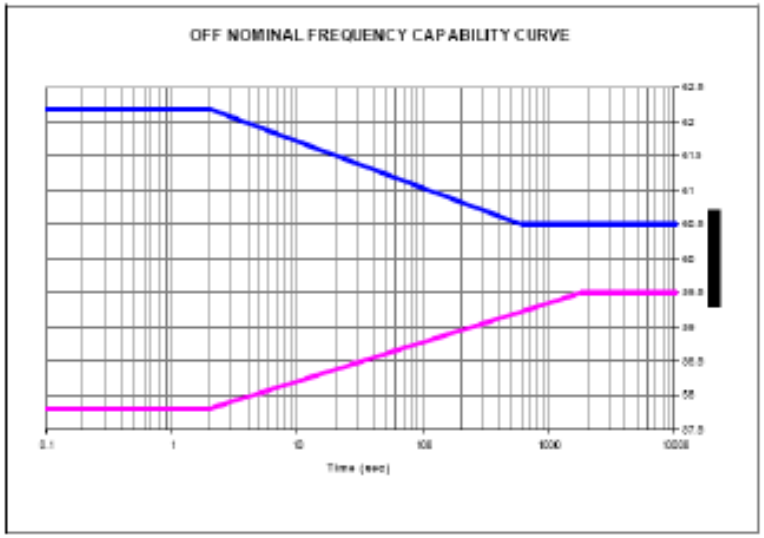
- Zero Volt Ride-Through now standard in most regions

- Extended low voltage ride-through requirements are expected in future
  - NERC PRC-024
  - ERCOT
  - WECC

NERC PRC-024 proposed requirements



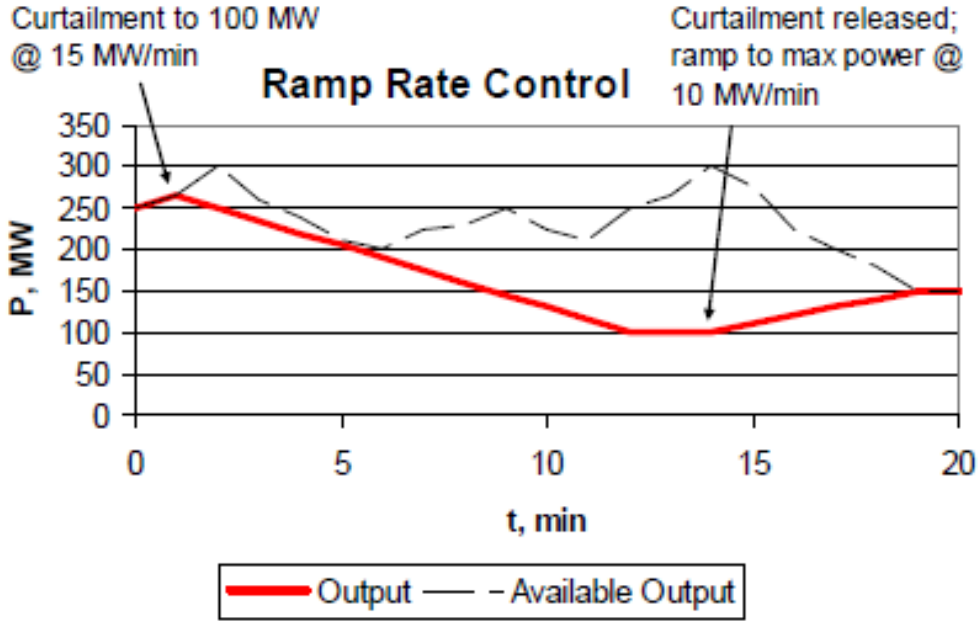
Voltage Ride Through



Frequency Ride Through

Ramp Rate Control

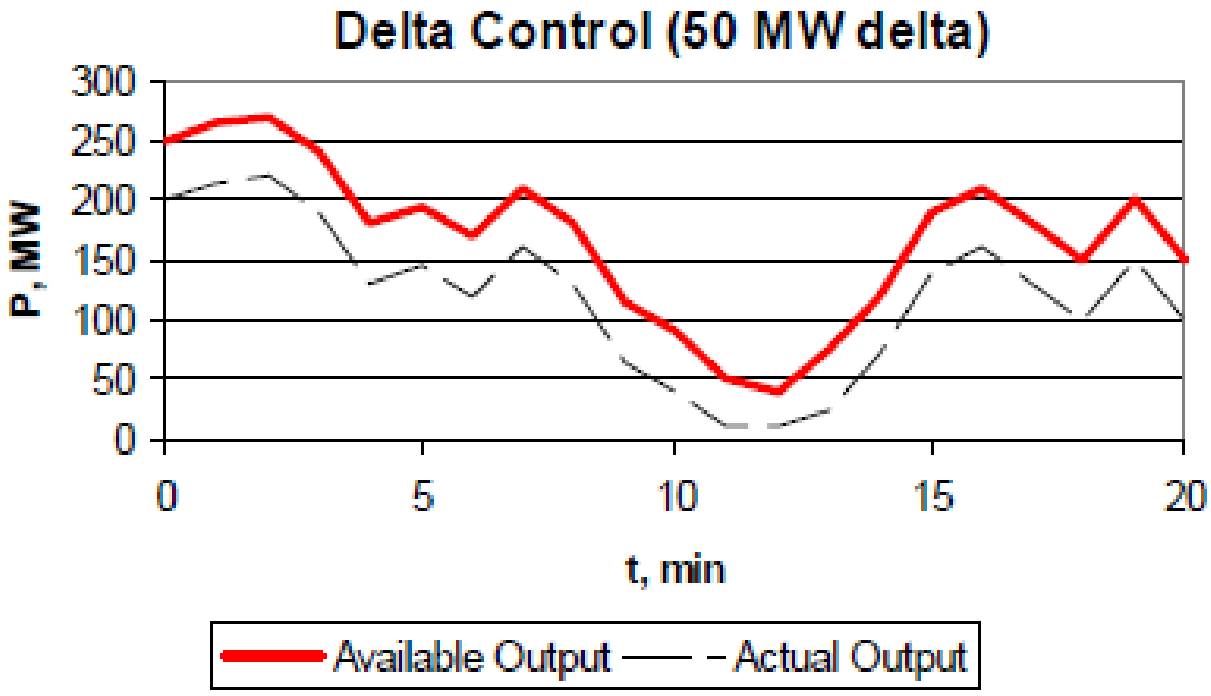
- Ramp events are recognized issue in high penetration regions, especially in island/weak grids
- Some ISOs require (up) ramp rate control
  - Example: ERCOT: 10% of plant nameplate per minute



Siemens Net Converter Information

Delta Control

- Operate with constant delta below max
- Spilling wind – but may allow least cost reg up and spinning reserve



Siemens Net Converter Information

Substation Reactive Power Equipment

DVAR, etc. – common where turbines don't have dynamic capability

Capacitors – common (most plants)

Reactors – uncommon

Interconnection Requirement Implementation

- Some requirements are not needed immediately:
  - E.g. Fault ride-through: only needed when installed wind capacity approaches the size of the biggest generator or in-feed.
  - E.g. Frequency response: only needed when synchronous generation capacity reduces below a certain level

- So maybe some requirements should not be implemented for early projects:
  - Easier job for fledgling industry
  - Possibly cheaper turbines
  - Easier for local turbine manufacturing to get established
  - Need a clear timetable for when the requirements will be activated for new projects.

Interconnection Requirement Standardization

- Very tempting to aim for a standard grid code, BUT:
  - There are real differences between electricity systems, which leads to different requirements
  - Ideally would standardize for all technologies, not just wind: a huge job
  - Danger of ‘lowest common denominator’: very onerous.

- So: standardize the definitions, terminology, test methods and reporting
  - ‘Structural harmonization’
  - IEC and ANSI standards work in testing and validation for Fault Ride-through.

Conclusions

- Modern wind turbines could do more for the network operators:
  - Effectively, a lot of free dynamic reactive capacity, measurements, and fast controller capability, all out on the weak parts of the network
  - Need to specify what is wanted
  - Payment for the service?

- In new markets, get the Grid Codes agreed very early.
  - But maybe some of the requirements should not be activated immediately

- Technical issues now generally well understood
  - ‘Structural harmonization’ will come
  - Attention now moving to testing and validation

Thank you for your attention

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