Renewable Energy Interconnection Requirements for the US

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Outline of Topics

• Background and Introduction
• NERC Integrating Variable Generation Task Force (IVGTF) Interconnection Tasks
  – Interconnection Requirements
  – Reconciliation of FERC Order 661A with IEEE 1547
  – BA Communication Requirements
• Conclusions
North American Interconnections
NERC IVGTF Report Background

• Broad based industry effort with participation of utilities, ISOs, turbine manufacturers, project developers, research organizations, consultants, trade associations

•Requested by OC/PC in recognition of the increasing large role wind power will play

•Chaired by Warren Frost, AESO with NERC staff support provided by Mark Lauby and John Moura

•Initial report released in April 2009

•Final Phase 2 task report completed in 2014
Guiding Principles – Keeping Reliability in the Balance

• Bulk power system reliability must be maintained, regardless of the generation mix
• All generators must contribute to system reliability within their physical capabilities
• Industry standards and criteria must be fair, transparent and performance-based
Interconnection Recommendations from NERC IVGTF Report

• Task 1.3: Interconnection procedures and standards (i.e. grid codes) should be enhanced and must be applied in a consistent manner to all generation technologies to address:
  • real and reactive power control
  • frequency and inertial response
  • voltage and frequency ride through

• Task 1.7: Existing bulk system voltage ride-through performance requirements (FERC Order 661-A) and distribution system anti-islanding voltage drop-out requirements of IEEE Standard 1547 must be reconciled
Interconnection Task Recommendations from IVGTF Report

• Task 2.2: Balancing Areas must have sufficient communications for monitoring and sending dispatch signals to variable resources
Task 1.3 Objective

• Interconnection procedures and standards should be enhanced to address:
  – real and reactive power modeling and control
  – frequency and inertial response
  – voltage and frequency ride-through

• Must be applied in a consistent manner to all generation technologies
Interconnection Topics

• Reactive Power and Voltage Control
• Performance During and After Disturbances
• Active Power Control
• Harmonics and Subsynchronous Interaction
• Models for Facility Interconnection Studies
• Communications between Variable Generation Plants and Grid Operators
Reactive Power and Voltage Control

- Applicability: Generator interconnection requirement for reactive power should be clearly established for all generator technologies
- Specification of Reactive Range
  - Should be defined over the full output range
  - Q vs. P chart should be used for clarity
  - Baseline capability of +/- 0.95 lead/lag at full output and nominal voltage should be considered
- Specification of Dynamic Reactive Capability
  - Should clearly define what is meant by “Dynamic” Reactive Capability
Performance During and after Disturbances

Applicable plant size

– Scope of existing NERC standard should be broadened to cover smaller plant sizes. The current proposal of 75 MVA is too large.

– Size of 10-20 MW more appropriate
Performance During and after Disturbances

Disturbance ride-through

- Additional clarity should be provided for existing fault ride-through and frequency ride-through standards.
- Ride-through plots should be provided for both high and low voltage ride-through requirements. It is recommended that the zero voltage ride through should be equal to the three phase fault clearing time on the network.
- Performance requirements for balanced and unbalanced faults should be clearly defined.
- Restart expectations of generator following a disturbance should be clarified.
Active Power Control

- Require curtailment capability, but avoid requirements for excessively fast response
- Require capability to limit rate of increase of power output
- Encourage or mandate reduction of active power in response to high frequencies
- Consider requiring the capability to provide increase of active power for low frequencies
- Consider requiring inertial response in near future
Turbine Technology Advances Reduce Impacts

SCADA Control Functions For Improved Grid Operations

- Active power control
- Gradient power control
- Delta power control
- Frequency control
Harmonics and Subsynchronous Interaction

• No need for NERC standard at this time
• However, it would be prudent for transmission owners and/or grid operators to:
  - Request design study reports that assess the harmonic performance of all wind and solar plants
  - Request design study reports that assess the risk, and if necessary mitigation, of wind and solar plant located near series compensated transmission lines
Models for Facility Interconnection Studies

• Preliminary model data may be used for the initial feasibility study of a VG interconnection project

• The best available model should be used for the final System Impact Study or Facilities Study.
  – Models can be user written and may require non-disclosure agreements.

• Detailed dynamic model
  – Must be accurate over the range of 0.1 to 5 Hz
  – Time constants in the model should not be < 5 ms
  – The detailed dynamics model must have been validated against a physical or type test
Communications Between VG Plant and Grid Operator

- Recommendations based on existing policy for conventional generators
- VG plants should send a minimum set of monitoring data to the grid operation via the grid’s SCADA network
- VG plants should receive and execute command signals (power limit, voltage schedule, ramp rate limit, etc.) sent from the grid operator via the SCADA network
- VG plants should have trained on-call plant operators that can receive calls from the grid operator 24/7 and immediately execute verbal commands. The plant operators would not need to be located at the plant provided they have secure remote control capability for the plant.
Task 1.7 Objective

• Existing bulk power system low voltage ride-through requirements of FERC Order 661A and distribution system anti-islanding voltage drop-out requirements of IEEE Standard 1547 must be reconciled.
Interconnection Standards and Requirements for ‘Variable’ Generation

Bulk System Guidelines
NERC, FERC
IEEE, ANSI, IEC
NESC

Plenty of technical and jurisdictional overlap, confusion, contradiction...

Distribution System Guidelines
IEEE 1547, PUC/PRC
IEEE, ANSI, IEC
NEC
Interconnection - Task 1.7
Reconciliation of Order 661-A and IEEE 1547

Recommendations

– In the short-term, NERC should engage in current efforts to revise IEEE Standard 1547 for DER interconnection by providing information, raising awareness and encouraging the adoption of VRT and FRT for DERs

– In the longer-term, NERC should establish a coordination mechanism with IEEE Standard 1547 to ensure that BPS reliability needs are factored into future DER interconnection standards revision efforts

– Recognizing that BES connected VERs are under FERC jurisdiction, and distribution system connected VERs in most cases are under the state utility commission jurisdictions, with their performance requirements in most cases dictated by IEEE Standard 1547, a closely coordinated and cooperative effort between NERC and IEEE is proposed in this area
Interconnection - Task 1.7
Reconciliation of Order 661-A and IEEE 1547

Summary of Conclusions

– Recommended ride-thru and must trip requirements for DER
Task 2.2 Objective

• To ensure that Balancing Areas have sufficient communications for monitoring and sending dispatch instructions to variable resources
Task 2.2 Draft Recommendations – Data and Communications

• Data and communication capabilities which have an impact on the reliability of the BES should be provided by all generation operating in the BA

• Because several smaller wind farms, regardless of the interconnection to the transmission system or the distribution system, can in aggregate have a significant impact on a specific area of the BES, a subset of this information should be provided by all generators greater than 10 MW

• Additional planning and meteorological data should also be required for all generators 10 MW or greater within a BA regardless of interconnection point, if a significant impact has been identified in an interconnection study
Wind and Solar Plants are Power Plants

• Dispatchable
  – Easy if done right, high errors if “fuel characteristics” are ignored

• Ride through disturbances
  – Wind ride-through requirements exceed those of conventional generators per FERC Order 661A and exceed NERC Standard PRC-024 requirements

• Provide fast frequency response and voltage control
  – Implemented for wind in ERCOT and other regions

• Impressive ramping and active power control
  – Very fast and accurate response over entire capability range

VG power plants can provide all the ancillary services as quickly and accurately as conventional plants, and often times more so.
Interconnection Requirements

• Strong grid code is in the best interest of both the manufacturer/developer and the utility
  – Wind and solar power plants are very capable machines
  – Plants must support system reliability requirements

• Grid code should identify the following requirements
  – Real power control
  – Reactive power and voltage control
  – Frequency and inertial response
  – Voltage and frequency ride through
  – Detailed dynamic models for facility interconnection study
  – Communications between power plant and grid operator
General Recommendations

• Require all new power plants to have the capability of providing essential reliability services i.e. voltage regulators and governors
  – All plants should be capable of contributing to system reliability
  – Operational use of plants to provide services will vary based on economics (need for service, value of service, opportunity cost)
  – Not every plant needs to provide every reliability service at all times, but we can’t perfectly predict future needs or values
  – All power plants should ride through disturbances

• We will learn and adapt as the generation mix and load characteristics change
Time of Transition

- Work of the IVGTF is being wrapped up
- Numerous recommendations from the IVGTF are being referred to NERC standards review and development process
- NERC Essential Reliability Services Task Force (ERSTF) has continued some of the work begun by the IVGTF
- This will continue to be an important topic for some time to come
- Complex topic due to technical, economic, market and policy dimensions
## PJM Stakeholder Approved Requirements

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| **Active Power Control** - automatic              | Must have the capability to:  
  1) Have an automated reduction in active power in response to high system frequency with droop characteristics  
  2) Have an automated increase in active power in response to low system frequency with droop characteristics when resource has additional power available |
| **Reactive Power Support / Power Factor Control**  | Must have the capability to autonomously provide dynamic reactive support within a range of 0.95 leading to 0.95 lagging at inverter terminals unless system impact study or TO establishes a need for more conservative limits |
| **Voltage Ride-Through**                         | Must adhere to NERC PRC-024 standard irrespective of generator size                |
| **Frequency Ride-Through**                       | Must adhere to NERC PRC-024 standard irrespective of generator size                |
| **Ramp rate control**                            | Must have the capability to limit ramp rates                                       |
| **Implementation Timeframe**                     | Effective date will apply to new queue requests                                    |
For More Information

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