Inverter-Based Interconnection Standards to ensure Grid Reliability

IRTF
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Applied Solutions
Primary Mission: Keeping the Lights On
Frequency Disturbances

High wind 28 March 2009 - average 866 MW

Wind power fluctuations, MW

Frequency fluctuations, Hz

CIGRE Technical Brochure on
Grid Integration of Wind Generation
July 2008
Working Group 08
of Study Committee C6

Ireland
Frequency Control

Primary Frequency Control
[Governor response (and frequency-responsive demand response)]

Secondary Frequency Control
(Generators on Automatic Generation Control)

Tertiary Frequency Control
(Generators through operator dispatch)
Effects of reduced Governing

Frequency Response of a 2550 MW Generation Trip

- **Base case**
- **30% Inertial and Governor Off**
- **40% Inertial and Governor Off**
- **60% Inertial and Governor Off**
- **90% Inertial and Governor Off**
Active Power Frequency control
Required by Grid Codes

Germany: with ramp rate of 10% capacity per Minute (above 50.2 Hz reduce active power with a gradient of 40% of available power per Hz)

Ireland: with ramp rate of 1-30 MW per Minute

Nordic: with ramp rate of 10% of rated power per minute

Denmark: with ramp rate 10-100% rated power per minute

Ireland: Frequency responsive active power control to a prescribed response curve (minimum 1% of rated capacity per second)

Great Briton: wind farms must have a frequency control device capable of supplying Primary and Secondary frequency control

H. Quebec: wind farms with rated power > 10 MW must have a frequency control system (activated only for freq. disturbances >0.5 Hz) with inertial response similar to a conventional generator (3.5 s)

ERCOT wind units are required to provide primary frequency response to high frequencies similar to a thermal unit with a droop of 5%
Voltage Control

Voltage with and without VAR support

Voltage (pu)

MW

Base Case

with VARs
Lack of Voltage Control in an Interconnection
Solar Generation in Germany

![Map of Germany with solar generation data]
50.2 Hz Problem

[T.K. Vrana 2011]
Example of voltage drops below 0.5 pu for a 500 KV fault
<table>
<thead>
<tr>
<th></th>
<th>Reactive Power &amp; Voltage Control</th>
<th>Voltage Disturbance Ride-Through</th>
<th>Frequency Control</th>
<th>Frequency Disturbance Ride-Through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission System Connected</td>
<td>- FERC 661</td>
<td>+ FERC 661A</td>
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<td>+ FERC 661A</td>
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<tr>
<td>Distribution Connected</td>
<td></td>
<td>+NERC IVGTF 1.7</td>
<td>+NERC IVGTF 1.7</td>
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</tr>
</tbody>
</table>
Voltage Disturbance Ride through Requirement
Frequency Disturbance Ride-through Requirements