In booth theater presentations

Wind Turbine Grid Integration Challenge

- Speaker name: Slavomir Seman
- Speaker title: Design manager - Simulations, Grid codes
- Company name: ABB, Drives, Wind AC
Grid Integration Challenges

- # 1: Grid integration requirements – What, Where and How?
- # 2: Fault Ride Through (FRT) – How to support the grid during fault conditions
- # 3: Quick Response - Fast acting voltage control and reactive current during fault
- # 4: Advanced simulation models – Important tool for compliance validation
- # 5: Series compensated lines & DFIG wind farm
Grid Integration Challenge #1

What are the requirements?

- Requirements of the local grid codes are different between countries/regions.
- Today’s grid codes are very diverse and contain many technical “gray areas” (historical reasons, new generation).
- Common specification language, as required for global standardization, does not exist.
- Grid codes are continually changing.

EXAMPLE Germany (11 Grid codes and guidelines):

<table>
<thead>
<tr>
<th>Code</th>
<th>Short term interruption (disconnect)</th>
<th>Fault type FRT</th>
<th>FRT reference voltage (V-profile)</th>
<th>Reactive current injection V-ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC 2007</td>
<td>Not defined but allowed</td>
<td>Symmetric</td>
<td>Largest L-L</td>
<td>Voltage – effective value</td>
</tr>
<tr>
<td>MV 2008</td>
<td>Not defined but allowed</td>
<td>Symmetric</td>
<td>Lowest L-L</td>
<td>Undefined (U limited to 1.1 p.u)</td>
</tr>
<tr>
<td>SDL WindV</td>
<td>Not defined</td>
<td>Symmetric</td>
<td>Positive seq. voltage</td>
<td>Positive seq. voltage (U limited to 1.1 p.u)</td>
</tr>
</tbody>
</table>
Where to Comply

- Defines what the performance requirement is for power plants connected to power system
- Grid code reflects the structure and status of transmission system
- The content of grid code depends on the region
  - US FERC Order 661
  - E.ON 2006, German
  - R.E.E 12.3. Spain
Grid Integration Challenge #1

How to validate compliance

- Type test of a single wind turbine – typically performed by so-called “container test”.
- Wind power plant compliance assessment – performed by simulation.
Challenge #2: Fault Ride Through (FRT)

Typical FRT curve - not full consistency on how FRT profiles are to be understood and applied

FERC Order 661- LVRT requirements defined at HV side of the plant step-up TR. Wind generation facility remains online during:

- 3-phase fault with normal clearing
- 1-phase to ground fault with delayed clearing
Challenge #2: FRT – Example of Dynamic Performance

**FRT 0% Un, 180 ms – DFIG (Type 3) - LV side**

**FRT 0% Un, 500 ms – Full Converter (Type 4) – MV/LV side**

- **Measured Instantaneous Values at LV Side of TR**
  - urms [V]
  - uvrmsgrid [V]
  - uwrmsgrid [V]

- **Fundamental Positive RMS Voltages (p.u.)**
  - $u_L$ (blue)
  - $u_M$ (green)

- **Instantaneous Phase Currents (21kV Side)**
  - $I_L$ (blue)
  - $I_M$ (green)
  - $I_N$ (red)

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Challenge #3: Quick Response to Grid Faults/Voltage Support

Reactive Current (<100%In) injected within 30 ms during ZVRT
## FRT – Converter Supports Wind Turbine

<table>
<thead>
<tr>
<th>Fault Condition</th>
<th>Double Fed Induction (DFIG) with ABB ACS800-67(LC) *</th>
<th>Full Power Converter (FPC) with ABB ACS800-77/87(LC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVRT - Symmetrical Fault</td>
<td>Down to $V_{L-L} = 0% U_{Nom}$ at MV side</td>
<td>Down to $V_{L-L}$ (rms) = $0% U_{Nom}$ at MV side</td>
</tr>
<tr>
<td>LVRT-Unsymmetrical Fault</td>
<td>Down to $V_{L-L} = 0% U_{Nom}$ at MV side (limited time duration)</td>
<td>Down to $V_{L-L}$ (rms) = $0% U_{Nom}$ at MV side</td>
</tr>
<tr>
<td>Reactive Current Support – Symmetrical Fault</td>
<td>$I_Q = 100% I_{Nom}$ within 50-150ms (depending on severity) Down to approx $V_{L-L} = 15% U_{nom}$ (MV side)</td>
<td>$I_Q = 110% I_{Nom}$ within 30-40ms, down to $V_{L-L} = 0% U_{nom}$ (MV side)</td>
</tr>
<tr>
<td>Reactive Current Support – Unsymmetrical Fault</td>
<td>$I_Q =$possible down to $V_{L-L} = 20% U_{nom}$</td>
<td>$I_Q = 100% I_{Nom}$ within 50ms, down to $V_{L-L} = 0% U_{nom}$ (MV side)</td>
</tr>
</tbody>
</table>
Challenge #4: Advanced Simulation Models

Detailed model “black box” (EMT) of WT 4 type model – Full power converter

Generic model “open source” (RMS) of WT 4 type model – Full power converter

- Electrical Control Model
- Generator/Converter model
Challenge #4: Advanced Simulation Models – Validation

WT 4 model against full power test - 2,5 MW, Full converter under 3-ph dip , Generic model Ts = 5 ms
Challenge #5: Series compensated lines & DFIG wind farm

Voltage dip, 55% compensated line, $R_{SC}$ about 1.6 at the point of connection

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