Renewables and Power System Security – lessons from South Australia

Future Grid Symposium 2014

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Presentation outline

> Provide context of high levels of wind energy penetration in South Australia and recent trends

> Present early results of an ElectraNet and AEMO study which is investigating the system security implications of high levels of wind generation in South Australia
SA wind zones

Mid-North region

Major wind zones

Eyre Peninsula region

Yorke Peninsula region

South East region
SA installed wind capacity

Source: Alinta Energy submission to RET review, 16 May 2014
# SA wind penetration metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value for SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total installed wind generation capacity at 30 June 2014</td>
<td>1477 MW</td>
</tr>
<tr>
<td>Maximum instantaneous wind generation (3 July 2014 at 10pm)</td>
<td>1270 MW (86% of capacity)</td>
</tr>
<tr>
<td>Energy penetration – ratio of annual wind energy to annual total energy demand</td>
<td>&gt; 25%</td>
</tr>
<tr>
<td>Maximum instantaneous penetration (excluding exports) – maximum observed ratio of wind energy to demand (Wind generation of 1138 MW, SA demand 1122 MW and SA export 487 MW on 27 June 2014 at 5am)</td>
<td>101%</td>
</tr>
<tr>
<td>Maximum possible instantaneous penetration – ratio of installed capacity to minimum demand (978 MW on 20 April 2014 at 5am)</td>
<td>151%</td>
</tr>
<tr>
<td>Average possible instantaneous penetration – ratio of installed capacity to average demand (1532 MW in 2013-14)</td>
<td>96%</td>
</tr>
</tbody>
</table>

Source: ElectraNet data
SA wind energy trends

- Increasing probability of wind-dominated generation scenarios (>50% of generation mix)
- Expected to increase in the future under favourable market and policy scenarios

<table>
<thead>
<tr>
<th>Year</th>
<th>Probability of Wind &gt; Thermal Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>0%</td>
</tr>
<tr>
<td>2009</td>
<td>0%</td>
</tr>
<tr>
<td>2010</td>
<td>0.02%</td>
</tr>
<tr>
<td>2011</td>
<td>1.55%</td>
</tr>
<tr>
<td>2012</td>
<td>2.2%</td>
</tr>
<tr>
<td>2013</td>
<td>5.69%</td>
</tr>
<tr>
<td>2014</td>
<td>13.25%</td>
</tr>
</tbody>
</table>

Source: ElectraNet data
Wind integration study

Objective:
- Identify potential system security limitations arising from high levels of wind generation in South Australia

Study scope:
- Evaluate power system operation against the following criteria…
  1. Minimum fault levels and short-circuit ratios
  2. Frequency control and fault ride-through assessment
  3. Reactive power support/ voltage control
  4. Small-signal stability/ system damping
  5. Transient stability
- Consider a range of system operating conditions with high levels of wind and low levels of conventional synchronous generation
## Power system security criteria

<table>
<thead>
<tr>
<th>No</th>
<th>Criterion</th>
<th>What is it?</th>
<th>Why does it matter?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minimum fault levels, short-circuit ratio</td>
<td>Measure of power system capability/ strength at various connection points</td>
<td>Load voltage regulation, protection co-ordination, fault ride-through capability</td>
</tr>
<tr>
<td>2</td>
<td>Frequency control (system inertia)</td>
<td>Maintain system frequency within prescribed limits (inertia helps by virtue of stored rotational energy)</td>
<td>Frequency recovery required to maintain system stability</td>
</tr>
<tr>
<td>3</td>
<td>Reactive power support</td>
<td>Required to support real power transfer and stable system voltages</td>
<td>Voltage stability (both steady-state and transient)</td>
</tr>
<tr>
<td>4</td>
<td>Small-signal stability</td>
<td>Adequate damping of small oscillations on electrical network</td>
<td>Mechanical integrity of connected generators and the power system</td>
</tr>
<tr>
<td>5</td>
<td>Transient stability</td>
<td>Ability to recover from large system disturbances</td>
<td>Maintain security of plant and power system</td>
</tr>
</tbody>
</table>
Operating conditions studied

- Power system scenarios:
  - SA light demand (1100 MW to 1400 MW)
  - Low conventional/ synchronous generation (0-5 thermal units) online
  - High wind generation (up to 1500 MW)

- Heywood Interconnector maximum import and export scenarios at current capacity (460 MW) and upgraded capacity (650 MW)

- Range of contingencies considered including loss of the Heywood Interconnector between SA and Victoria
Results – Fault levels

- All fault levels at or above the 2 kA minimum required for effective operation of protection systems even with no thermal units.
- Adequate margins (>4 kA) on most 275/132kV buses, except on Eyre and York Peninsula.
Fault levels and short-circuit ratios

> All short circuit ratios were at the about 4 or above required for effective operation of protection and wind farm control systems
> Good correlation obtained between static (steady-state) and dynamic fault currents

Example comparison between steady-state and dynamic fault current calculations
System inertia and fault ride through

- At least one thermal unit is required on-line to control frequency
- SA is able to survive islanding under high import conditions with at least one thermal unit on-line (and under frequency load shedding);
- Inertia contribution from SA Type 1 & 2 wind farm models observed which limits rate of change as well as depth of frequency excursion

\[
\begin{align*}
\text{Without wind farm inertia (~7000 MWs effective total inertia)} \\
\text{With wind farm inertia (~10000 MWs effective total inertia)} \\
\end{align*}
\]

SA frequency recovery and wind farm inertia contribution for SA islanding contingency at time of high import
Reactive support/ voltage stability

> No reactive support issues under high export conditions

> Worst case condition is high import conditions with no thermal units – additional reactive support needed to maintain voltage stability

Additional 100MVAr reactive dispatched in limiting case with no thermal units to maintain positive Q-V margin
Small signal stability

- Sufficient system damping observed under maximum wind dispatch even with no thermal units – modes disappear with no thermal units
- Inter-regional modes to be investigated further

Left shift in some intra-regional machine modes (improvement in damping) observed when reduce thermal units from 4 to 1

Further work to be undertaken to test and understand this outcome
Summary of findings

> Studies indicate that the South Australian power system can be operated securely at N-1 with high levels of wind generation

> Most system security criteria were satisfied even with no thermal generating units on-line except…
  - Frequency control requires at least one thermal unit
  - Voltage stability under high SA import conditions requires at least one thermal unit or additional reactive dispatched
  - Transient stability/ overvoltage and voltage recovery under islanded conditions

> No network and generation protection co-ordination issues were identified
Summary of findings (cont.)

> For credible contingencies, no issues with system frequency and voltage recovery post-fault (with at least one thermal unit)

> For non-credible contingency involving loss of Heywood Interconnector, local SA frequency controls allow SA system frequency recovery to within Frequency Operating Standards (with at least one thermal unit)

> Sufficient reactive support margins (when utilising all mitigation options including high voltage capacitor bank dispatch)

> Sufficient system damping under maximum wind dispatch
Next steps

> Current studies expected to be concluded within next months with recommendations for further work

> ElectraNet and AEMO to consider how results are communicated
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