Dynamic Study of Bonaire Island Power System
Model validation and project experience

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Agenda

- Background info
- Model Validation
- Project Experience
- Conclusions
Background Info – Bonaire Island

Background Info – Bonaire Island Power System Overview
Model Validation – three-phase fault event

- 12 kV 3ph-fault cleared
- Frequency calculated based on 20ms averaging window
- Good match
- 1 kHz sampling resolution
- Relay transient record
- Dedicated Airco model

Airco model

- Dedicated airco model was developed:
  - via analysis of fault recordings
  - reactive power and voltage impact during and after fault clearance

- Reactive power:
  - during fault increases 7Q₀
  - after fault clearance 10Q₀
- Due to increase reactive power:
  - voltage can not recover
  - airco motor stalls (lack of torque)
  - Network voltage remains low and the wind power output can not recover
  => wind power trips on under voltage after 5s.
Project Experience – High wind system configuration

Bonaire island power system installed capacity

- 5 Diesel Generators – 14 MW
- 12 Wind Turbines – 10.8 MW
- 1 Battery Energy Storage – 3 MW (100 kWh)

<table>
<thead>
<tr>
<th>Event, Wind, 12kV, 1 phase, 1 ph-ground</th>
<th>Frequency (Hz, %)</th>
<th>Voltage (12 kV, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HighWind, 2010</td>
<td>57.5%</td>
<td>103.0%</td>
</tr>
<tr>
<td>HighWind, 2011</td>
<td>57.5%</td>
<td>103.0%</td>
</tr>
<tr>
<td>HighWind, 2012</td>
<td>57.5%</td>
<td>103.0%</td>
</tr>
<tr>
<td>HighWind, 2013</td>
<td>57.5%</td>
<td>103.0%</td>
</tr>
</tbody>
</table>

12 kV 1ph-ground fault

Nadir - 47.75 Hz

Larger frequency drop?

2 Diesel Generators

3 Diesel Generators

=Energy • Short circuit current
Project Experience – Voltage stability in high wind scenario

12 kV 1ph-ground fault

- Undervoltage – load shedding

2 Diesel Generators

<table>
<thead>
<tr>
<th>High 12kV Grid Voltage (pu)</th>
<th>Diesel 1 (Generator Power)</th>
<th>Diesel 2 (Generator Power)</th>
<th>Voltage 12kV Grid Voltage (pu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
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<tr>
<td>0.94</td>
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</tbody>
</table>

- Changed 12 kV load shedding scheme via under voltage setting and under frequency.

<table>
<thead>
<tr>
<th>Bay</th>
<th>Proposed U-shedding (%/s)</th>
<th>Proposed f-shedding (Hz/s)</th>
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<th>Proposed U-shedding (%/s)</th>
<th>Proposed f-shedding (Hz/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10AKD7</td>
<td>85% / 1.1</td>
<td>48.0 / 0.4</td>
<td>10AKB04</td>
<td>85% / 0.7</td>
<td>47.3 / 0.1</td>
</tr>
<tr>
<td>10AKD5</td>
<td>90% / 1.3</td>
<td>48.0 / 1.0</td>
<td>10AKC05</td>
<td>85% / 0.8</td>
<td>47.1 / 0.1</td>
</tr>
<tr>
<td>10AED04</td>
<td>85% / 0.5</td>
<td>47.7 / 0.1</td>
<td>10AEC04</td>
<td>85% / 0.9</td>
<td>46.9 / 0.1</td>
</tr>
<tr>
<td>10AKB03</td>
<td>85% / 0.6</td>
<td>47.5 / 0.1</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Conclusions

- Short circuit fault with fault impedance (representing an overhead line) causes active power consumption rise as short circuit current flow through fault path.

- In low inertia island power system, the fault current could already produce significant power losses.

- Load shedding scheme shall consider both under frequency as well as under voltage as the airco load in the tropical island could delay the voltage recovery and in the extreme case could lead to voltage collapse.

Thank you

Ir. Yin Sun
ym.sun@dnvgl.com
Mobile: 0031 615 861217