Commissioning of Variable Speed Units in the Linthal PSP

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Variable Speed Units

**Machine Data**

- Number of units: 4
- Power: 250 MW/280 MVA
- Speed: 470–530 rpm
- Rated head: 700 m
- First machine synchronized: Dec. 2015

- Linthal 2015 - the most complex PSP we ever commissioned
- Pump-Turbines operating between 560 and 709 m successfully in operation
- Characteristic of the 250 MW variable speed Motor-Generator in line with calculations
- Grid operator involved to validate primary frequency control and grid code compliance
Validation in Design Stage

Design & Testing at Component Level

**Industrialization**
- Installation of rotor bars
- Brazing of rotor bars
- Assembly of the heating device

**Simulation of operation on component level**
- VET testing on rotor bars
- Real time testing of controller
- Testing of brushes at supplier

Commissioning of variable speed units
# Commissioning

## Overview on Sequence

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activities</th>
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</thead>
<tbody>
<tr>
<td><strong>Dry commissioning</strong></td>
<td>Auxiliaries and instrumentation, protection, diagnostic and monitoring systems, control, AC excitation system</td>
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<tr>
<td><strong>Integral tests</strong></td>
<td>Validation of interfaces, integral tests</td>
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<td><strong>Turbine No load</strong></td>
<td>Mechanical run, short circuit, open circuit</td>
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<tr>
<td><strong>Turbine Load test</strong></td>
<td>Synchronization, protection test, turbine load tests, heat run full load, optimization of governor and variable speed control, grid code capabilities</td>
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<td><strong>Pump condenser</strong></td>
<td>Start-up, synchronization, heat run, reactive power capabilities</td>
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<tr>
<td><strong>Pump mode</strong></td>
<td>Transition from pump condenser to pump mode, heat run, optimization of governor and variable speed control, calibration of operation curves and parameters</td>
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<tr>
<td><strong>Generator condenser</strong></td>
<td>Start-up, synchronization, heat run</td>
</tr>
<tr>
<td><strong>Mode changes</strong></td>
<td>Transition time, vibration, optimization</td>
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</table>
Motor-Generator

Characteristics

Calculated and measured no load curve

Measurements has confirmed the calculated characteristics

Linthal No-load characteristic at 50 Hz

Rotor Design

- Concern: Thermal expansion of the winding overhang support
- Solution: Unique measurement equipment using high-speed optical displacement working with very high sampling rate

Commissioning of variable speed units

Laser measurement and position on the rotor
System Integration

Start-up in Pump Mode

• Criteria for VSI sequence and control
  – Time delay to open the breaker
  – Impact on speed and time during synchronization
  – Stator current with zero crossings and low voltage to enable safe opening of the stator short circuit breaker

• Validation requires a measurement system, capable to detect accurately AC and DC signals
Commissioning

Pump-Turbine (Load Tests)

• Validation of the unit operation range
  – Stability of the hydraulic machine
  – Level of vibration

• Confirm model test on typical P/T characteristics
  – Rotor-stator interaction (vibration)
  – “S” instability (coupling, load rejection)
  – Hump zone (pressure pulsations)
  – Load intake (active power output)

Results from load rejection tests
Commissioning

Variable Speed Control

- Tests at different power and speed to cover complete operation range
- Real time simulations running in parallel to the commissioning
- Fast control vs protection requires specific control functions
- Primary frequency control tests with Swissgrid in pump- and turbine mode

P/F chart
Key Take-Aways

- Characteristic of the 250 MW variable speed Motor-Generator in line with calculations
- Pump-Turbines operating between 560 and 709m successfully in operation
- Linthal 2015 - the most complex PSP we ever commissioned
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