Commissioning of Variable Speed Units in the Linthal PSP

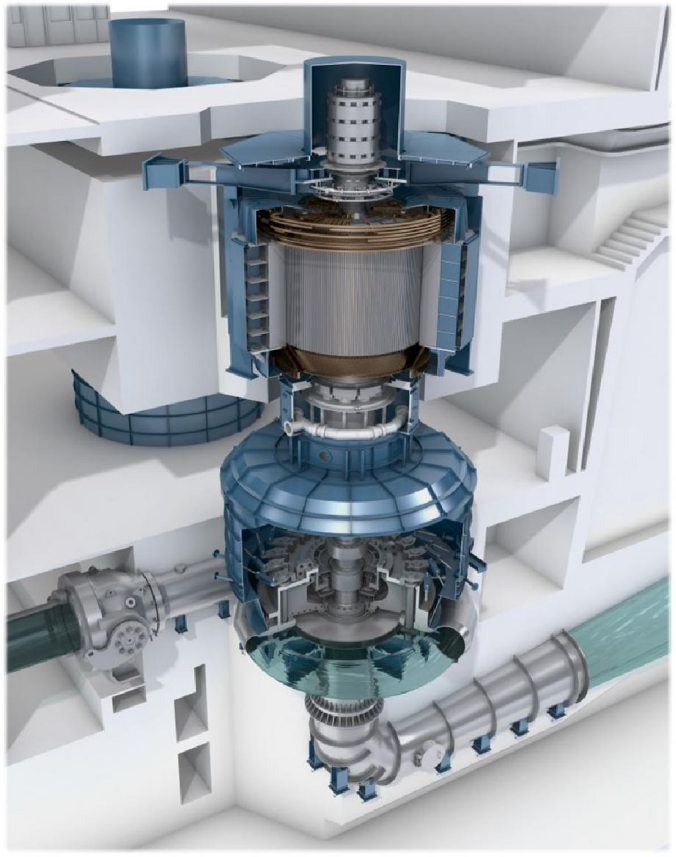
F. Mazzouji, 4 Nov 2016

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

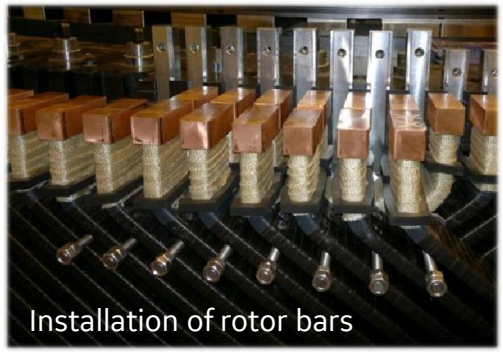
- Linthal 2015 - the most complex PSP we ever commissioned
- Pump-Turbines operating between 560 and 709m successfully in operation
- Characteristic of the 250 MW variable speed Motor-Generator in line with calculations
- Grid operator involved to validate primary frequency control and grid code compliance

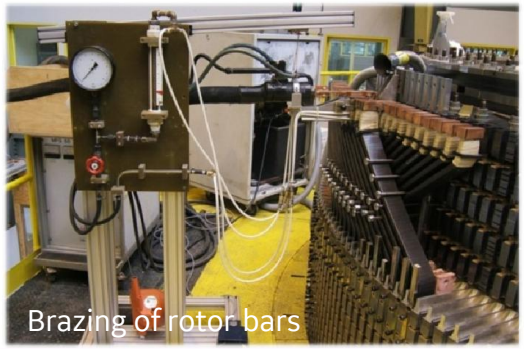


Validation in Design Stage

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

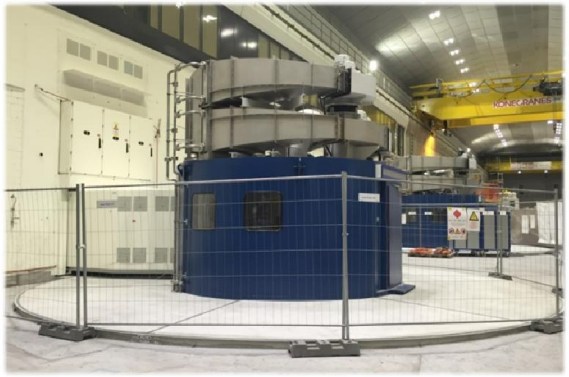

Real time testing of controller


Testing of brushes at supplier

Commissioning

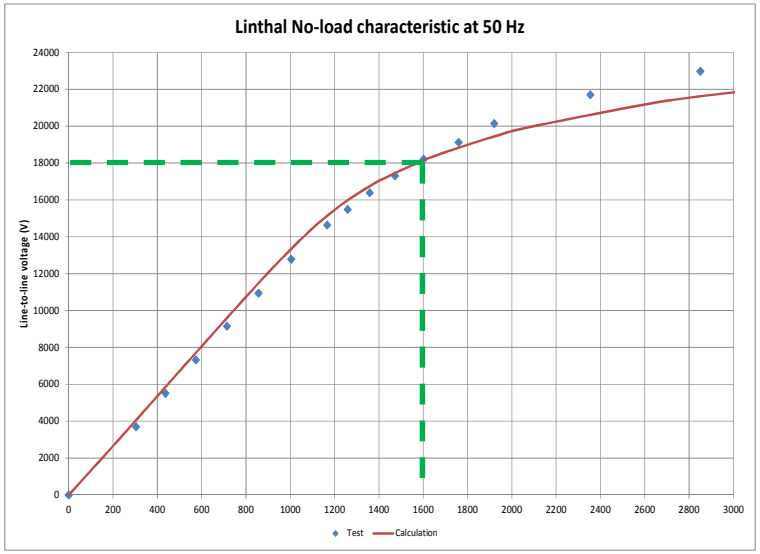
Overview on Sequence

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



Motor-Generator

Characteristics

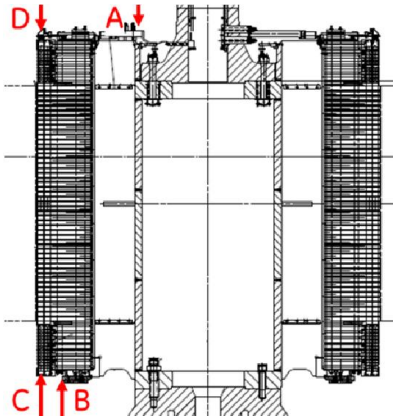


Calculated and measured no load curve

Measurements has confirmed the calculated characteristics

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

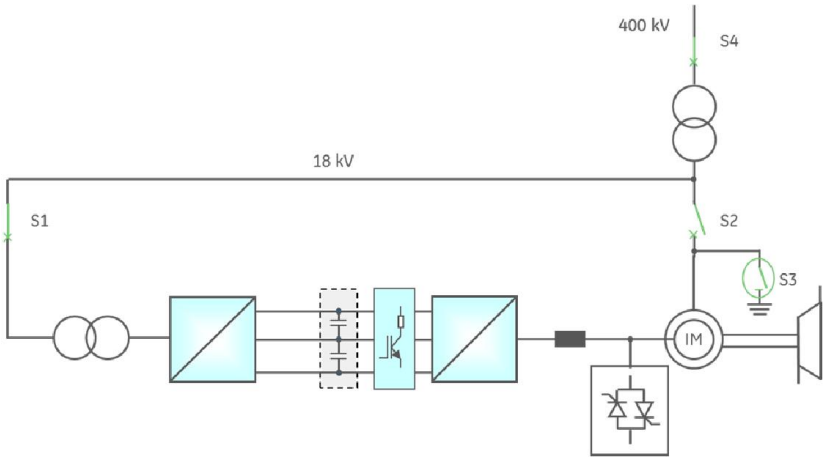


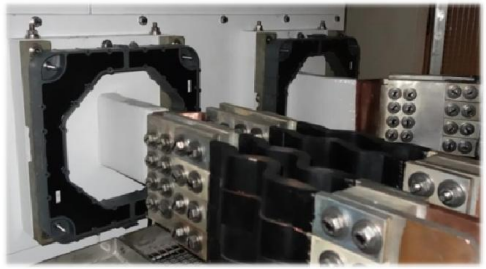
Laser measurement and position on the rotor

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



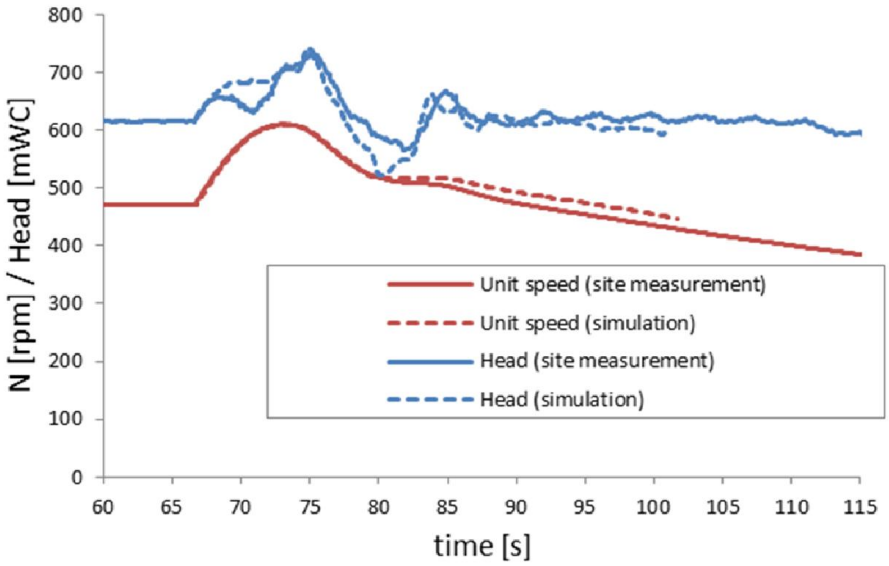


Current sensors on terminals

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)

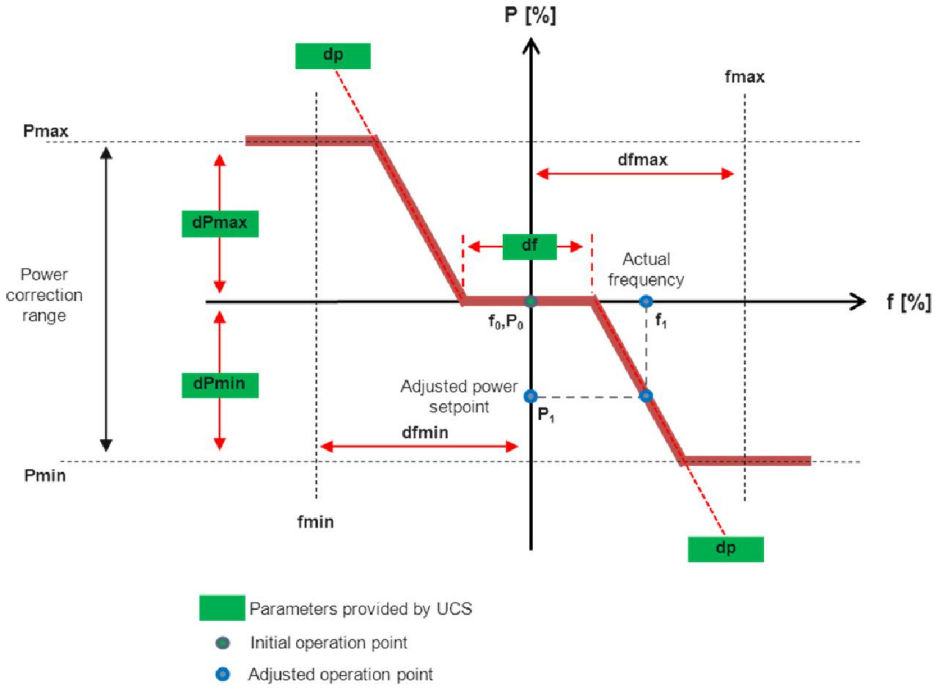


Results from load rejection tests

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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