CoDiS protection and diagnostic system
BENEFIT EXAMPLES
**Monitored values:** CoDiS system is configured to detect faults

- **Air gap, Magnetic Field**
- **Stator core vibrations**
- **Stator windings vib.**
- **Stator core temp.**
- **Stator windings temp.**
- **Rotor monitoring:** Insulation Resistance, AG/MX, Exciter voltage and current, Rectifier diode failure detection
- **Rotor Pole temperatures**
- **Monitoring of electrical values**
  - Active/Reactive power
  - Process parameters: Lead angle, Phase symmetry
- **Quasi-static parameters**
  - DC
- **Hydraulic quantities**
  - Caviation, Water levels, Flow, Fall, Pressures

**Alarm management, analog/relay output**
Fault detection— List of typical faults on hydro turbine and generator

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<th>Measurement</th>
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**Data base:** Data recorded to highlight some typical errors
Increased stator core vibrations – HPP /Vertical Kaplan/ 2 bearings /45 MW unit.

**Problem**
- High vibrations of stator core
- Vibration maximum reached at certain stator core temperature and then amplitudes reduce as the heating continues
- Temperature where maximum is achieved is becoming lower as the loosenes progresses and after few months reached the 20% of nominal

**Detection**
- Stator core loosened after 15 years, probably due to bad assembly
- Stator core change stiffness with temperature
- Resonance of core is at 100 Hz as the core is loosened

**Objective:**
- Stator core exposure to high vibrations as short as possible

Core vibrations (upper diagram)
Active and reactive power (middle diagram)
Stator core and winding temp. (lower diagram)
Increased stator core vibrations – HPP /Vertical Kaplan/ 2 bearings /45 MW unit.

Solution proposal
• Regulation of load level and cooling of stator using vibration feedback in order to cross over critical frequency as fast as possible and get out of resonant area

- Load level regulation (measured vibration feedback) significant influence on vibration level
- Stator cooling off
  - In function of measured vibrations
  - Faster heating exposure time minimized
Increased stator core vibrations – HPP /Vertical Kaplan/ 2 bearings /45 MW unit.

**Permanent solution** - Dedicated stator core permanent monitoring system connected to control system (ASEA ProMaster) - **FIRST CoDiS INSTALLATION – 1993.**

**BENEFITS**
- system eliminated critical temperature changes
- generator was operational for following 3 years
- after three years (1996) stator core was changed due to a lightning protection failure

- total investment cost:
  - expert measurements cost ~ 35,000 US$
  - monitoring system 1993 costs ~ 40,000US$
  - generated energy > 350 GWh
  - > 9.500.000,00 US$
Quick statistical condition estimation – CoDiS-QSCE

**Estimation of stationary operation conditions**

- Selecting representative period of operation (typically 1 – 2 months before and 1 – 2 months after overhaul) – evaluation of results

- Selecting values for analysis, significant for condition estimation (typically vibration Smax, s1n, AirGap minimum etc)

- Determining data filters (real and imaginary power levels, rotational speed, temperature etc.)

- Applying statistical data distribution analysis – histograms

- Performing histogram comparison

Histogram’s area, x and y maximum and minimum differences are basics for condition stability estimation.
Quick statistical condition estimation module – CoDiS-QSCE

Estimation of conditions based on RunDown&StartUp data

- Behaviour repeatability during RunDown and StartUp analysis
- Selection of data significant for condition evaluation (relative and absolute vibrations – Smax, RMS, s1n amplitudes and phases)
- Data filtering – only data recorded during variable speed are submitted to analysis
- Additional to histograms regression analysis is performed
- Comparison of regression curves for various periods is performed

Smax regression analysis (Vibration vs Rotational speed)

Regression curves comparison (Vibration vs Rotational speed)
Quick statistical condition estimation module – CoDiS-QSCE

CoDiS-QSCE analysis results application
- applied for quick condition estimation in order to plan overhaul procedures – overhaul reduction if conditions are stable (no changes), further analysis if some fault (changes) are indicated

HPP 2x108MW
- Bearing opening on condition change or every 3rd year
- overhaul reduction for ~ 15 days
- overhaul cost reduction ~ 180.000 €
- generated energy ~ 28000MWh

HPP 2x45 MW
- Bearing opening on condition change or every 2nd year
- overhaul reduction for ~ 18 days
- overhaul cost reduction ~ 216.000 €
- generated energy ~ 8500 MWh

HPP 2x35MW
- Bearing opening on condition change or every 2nd year
- overhaul reduction for ~ 15 days
- overhaul cost reduction ~ 180.000 €
- generated energy > 3000 MWh
HPP 2x 108 – Shaft alignment

**Problem**
- Increased relative vibration level after overhaul measured by CoDiS system

**Detection**
- irregular shaft centerline
- irregular shaft collar assembly on upper generator combined bearing

Run out compensation analysis

2D and 3D shaft alignment and Run-Out analysis
HPP 2x 108 – Shaft alignment

Solution
Irregular thrust collar assembly repair:
- inserting thin metal plates between thrust collar and collar plate
- checking shaft centerline after each metal plate insertion

Result
• Reduced repair cost as OEM demanded to dismount the collar and transport 500km to the factory for repairs
• Reduced downtime cost for at least 10-12 days
  • 2 days for shaft centerline assembly due to automated procedure for run out detection
  • 10 days for transport and repair in the factory

RESULT: Metal plates installed on site, no vibro-dynamical behaviour changes reported for 11 years of unlimited operation.
HPP 2 x50 MW, Vertica Kaplan – Turbine cover vibrations

Problem
- High vibration of generator (AC) in axial direction and high statical (DC) deflection
- Unstable in operation – vibrations occur suddenly in stationary operation
- New machine was out of operation for 2 months

Detection
- Low stiffness of turbine cover

Initial state – axial displacement of rotor

Axial displacement of rotor
- Vs structure
  - DC ~ 1.7 mm
  - AC~ 1mm

Axial displacement of rotor
- Vs turbine cover
  - AC~ 1mm
HPP 2 x50 MW, Vertica Kaplan – Turbine cover vibrations

Solution
- Increase the turbine cover stiffness applying the rigid elements to the construction

Result
- Stiffness increased ~ 2 X
- Deflection reduced by ~ 2X
- No more unstable operation and AC vibrations
- MACHINE AVAILABLE FOR OPERATION 2 WEEKS AFTER MEASUREMENTS

After correction – axial displacement of rotor

Axial displacement of rotor Vs structure
Axial displacement of rotor Vs turbine cover

DC ~ 0.9 mm

Benefits of installed Machine Condition Monitoring system
Thank you for your attention!

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