Hydropower Measurements
Machine measurements.

Status and commissioning
Measuring machine characteristics before/after build/rebuild/refurbishment etc.

Index tests
Ensure that Kaplan machines have the correct cam curve design

Vibrations
Do harmful vibrations occur?

Hydraulics
Measurements of pressure, flow-rate, leakage, pump capacity, etc.

Balancing
Measurement of mechanical imbalance and correction

Diagen
Measurement of geometric parameters of shaft, rotor and stator, including check for deviations

Custom measurements
Identification of problems or potential enhancements. We arrange installation of equipment for measurements, troubleshooting and monitoring.

Status and commissioning.

During commissioning, and before build/rebuild, measurements are made to ensure that the machine will run within its specified limits.

Measurements before disassembly of a machine are made to determine the “status quo”, or settings that are proven to work.

The following parameters that are typically measured during the commissioning of hydropower units.

WATERWAYS

Hydraulic transients in spiral, draft tube and its cone
- Shows if the hydraulic transients exceed the limits of the machine’s design during sudden regulations, such as shut-off.

Oscillating/surging pressures in the penstock and draft tube
- Calculates the time it takes for water levels to stabilize after flow regulation of the hydraulic unit

HYDRAULICS

Regulation pressures, pump pressures, system pressures, etc.
- Indicates pump capacity
- Indicates accumulator capacity
- Regulation forces, friction and hydraulic load

- Indicates at which flow rate, load and water level oscillating pressures occur that can cause damage to the machine, facility or both.
WHAT IS MEASURED AND WHY

**ROTATION SPEED**

Runaway speed at load discharge and fast shut off

- Shows peak runaway speed. Machines have a design limit for runaway speed.

**VIBRATIONS**

Shaft displacement and vibrations on bearing housings are measured and compared to standard limits.

**LEVELS AND MOTIONS**

Shaft lifts

- Indicates the vertical level and motion of machines. The measured levels fluctuate as water is regulated through the machine.

**Servomotor motion**

- Records regulation speed of guide vanes and runner blades
- The parameters can be plotted at any measured guide vane level or motion, steady state or transient time.

**OTHER PARAMETERS**

- Balancing
- Diagen
- Friction track of brakes
- Shaft straightness
- Shaft plumb

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**SURGE LEVEL**

LEVEL

**STEADY FLOW AT VELOCITY** $v$

**RESERVOIR LEVEL**

INSTANTANEOUS VELOCITY $v(-v_c)$

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National Instruments

DASYLab
Index tests.

Index tests are performed to ensure that machines have the optimal combined regulation of flow (guide vanes) and load (runner blades) with respect to transforming efficiency. Sometimes the tests are also used to compare the efficiency curve of different turbines.

LEVELS

Upstream water level (UWL)
- Is measured with underwater pressure sensors in the pipe. The surface should be kept as stable as possible throughout the test.

Downstream water level (DWL)
- Is measured with underwater pressure sensors in the pipe. The surface should be kept as stable as possible throughout the test.

FLOW RATE (WINTER-KENNEDY)
- The flow rates are measured through the differential pressure in two pressure taps located on the inner and outer sides of the spiral case.
- The flow measurement is relative, which means the efficiency is also relative. The efficiency can be combined with an additional test where the absolute flow has been measured in order to provide a more accurate result. The secondary test is usually a model test performed in a lab.

POWER
- Power is measured on the power plant’s measurement transformers.

AUXILLIARY SIGNALS
- Besides levels, power and flow, at least one reference signal is taken as a verification to confirm that both our own sensors and those located at the power plant are functioning correctly.

MEASUREMENT PROCEDURE
- The runner blades are set at a fixed angle. The gateway opening is set to a lower value than the value for expected peak. The first point is measured. One point takes about 5 minutes to measure. Then the guide vane openings are gradually increased and new points are measured until the efficiency peak is found.
- Various runner blade angles are tested depending on the requirements, usually 6 to 7 different runner blade angles.

CALCULATIONS
- Flow rate: 
  \[ Q = \text{konstant} \times \Delta P^{1/2} \]
- Efficiency:
  \[ \eta_{\text{turbine}} = \frac{P_{\text{generator}} + \text{Loss}_{\text{generator}}}{\rho \times g \times H_{\text{net}} \times Q} \]
Vibrations are measured to prevent material exhaustion in heavily loaded mechanical parts.

**SHAFT DISPLACEMENT MEASUREMENT**
- The relative displacement of the shaft is measured with non-touching sensors with an angle normal to the shaft separated by 90 degrees. This is measured at all guide bearing locations and orbits are drawn where peak-to-peak displacement can be observed.

**ANALYSIS – SHAFT DISPLACEMENT**
- The shaft displacement is drawn in a circular plot. The peak-to-peak displacement is checked at various loads.
- Standard ISO 7919-5 applies.

**BEARING HOUSE VIBRATION MEASUREMENT**
- The vibrations on the bearing houses are measured angled normal to the houses/shaft.

**ANALYSIS – VIBRATIONS**
- FFT analysis is made on the measured vibrations. It shows at which frequencies the highest amplitudes occur for different loads.
- Standard ISO 10816-5 applies.
Hydraulics.

Hydraulics are usually measured if there appears to be suboptimal operation, or if information is missing that is required. Hydraulics are usually checked/measured as well during turbine inspections.

**HYDRAULICALLY DRIVEN COMPONENTS**
- Intake gate
- Intake shut off valve
- Guide vanes
- Runner blades
- Draft tube gate

**MEASURED PARAMETERS**

**Pressure**
- Regulation pressure, pump pressure, system pressure etc.

**States and motions**
- Servo motors
- Bearing clearances

**Levels**
- Accumulator etc.

**RESULT**
- Regulation speed
- Regulation forces
- Bearing clearances
- Inner leakage
- Pump capacities, pressure guards
- Load diagrams: water load, friction, regulation forces.
Balancing.

Machine balance is measured if unbalance is suspected through loud noise, vibration, etc. The impact from an imbalanced machine gets worse with mass, speed and eccentricity. The source of imbalance can be mechanical or magnetic, i.e. the machine mass distribution or the magnetic pull force between stator and rotor is not symmetric. The imbalance can be reduced by placing a counter weight opposite to the mass or force that causes the imbalance.

SETUP SENSORS

1-plane balancing
- 2 non-contact sensors are placed 90 degrees apart with normal angle to the axis, preferably parallel to the Cartesian coordinates of the station.
- A trig is setup that sends a pulse to the logger as the first pole passes Y+, keeping track of the imbalance position.

2-plane balancing
- 4 non-contact sensors are installed. 2 and 2, 90 degrees apart from each other similar to 1-plane balancing, in two horizontal planes along the axis.
- A trig is used the same as when performing 1-plane balancing.

MEASUREMENT PROCEDURE

1st Measurement
- Machine run is logged and the direction of imbalance is found (imbalance-vector).
- A known weight is applied at an known angle.

2nd Measurement
- The known weight from “1st Measurement” reveals the magnitude of the 1st imbalance.
- With the imbalance theoretically known, a correction weight can be placed to eliminate most of the imbalance.

3rd Measurement
- The imbalance is measured once again to check the result. The imbalance should now be small if properly corrected.
- The remaining imbalance is presented as “kilogram*meter”.

RESULT/DOCUMENTATION
- The report can be generated immediately.
Diagen/Shaft straightness.

Diagen measurements are usually performed when parts of a generator are replaced or as a routine measurement when the machine is stopped for regular service. The measurements show the general state of the machine and is a good way to check if physical changes have occurred.

When a new generator is purchased, it is of interest to confirm that it is superior to the one being replaced.

**ROTOR MEASUREMENT**

Air gap is measured between rotor and stator. The sensor is placed on the stator. The generator is rotated 360 degrees and the coordinate system is located through the rotor poles.

Measurement yields:
- Air gap
- Roundness (rotor)
- Concentricity/eccentricity (rotor)

**STATOR MEASUREMENT**

Air gap is measured between rotor and stator. The sensor is placed on the rotor. The generator is rotated 360 degrees and the coordinate system is located through the stator teeth.

Measurement yields:
- Air gap
- Roundness (stator)
- Concentricity/eccentricity (stator)

**SHAFT STRAIGHTNESS**

Sensors are set up along the shaft on the same radial plane. The sensors are directed normal to the shaft. The generator is rotated 360 degrees, the rotation is stopped 8 times for the measurement points (45 degree increments).

The measurement yields relative straightness of the shaft, i.e the shape.

**EVALUATION**

Standard IEEE 1095 is applied that refers to CEATI guidelines regarding roundness.

![Diagram of shaft straightness](image-url)
Do you want to measure something unique?
Maybe you want to measure something out of the ordinary, the vibrations on a pump, effectiveness of coolers or hydraulic regulation pressure on the intake gate, etc.

Describe to us what you need to have measured, what mechanical problems you are facing or what may require some tweaking.
Our experienced specialists can provide you with optimal solutions for achieving accurate measurements.

1. PROBLEM DISCOVERED
2. DESCRIBE PROBLEM
3. PLAN MEASUREMENTS
4. MEASURE, IDENTIFY PROBLEM
5. SOLVE PROBLEM
6. DOCUMENTATION, FOLLOW-UP
Contact:

Mikael Lindberg
T +46 10 505 14 47
M +46 70 388 36 45
mikael.lindberg@afconsult.com

Marcus Larsson
T +46 10 505 75 23
M +46 72 537 72 86
marcus.x.larsson@afconsult.com

Johan Berglin
T +46 10 505 56 67
M +46 72 719 40 65
johan.berglin@afconsult.com

Daniel Litström
T +46 10 505 24 32
M +46 70 384 82 40
daniel.litstrom@afconsult.com

Ambjörn Gillsäter
T +46 10 505 24 56
M +46 76 838 27 72
ambjorn.gillsater@afconsult.com

Klaus Adler
T +41 56 483 17 12
M +41 79 239 58 63
klaus.adler@afconsult.com