Modernization and Upgrading of Hydropower plants

The hidden treasures
Hydro Power

Georg Woeber

23.11.1967

Technical Highschool in Moedling: precision engineering

Graduation 1988

Relationship, 1 child

Since 1993 ELIN Energieversorgung resp. legal successor ANDRITZ HYDRO, Senior project manager, IPMA level B

Since 2010 Head of Sales, Service and Rehab International Vienna
Overview

ANDRITZ HYDRO

Requirements and potential

Challenges and benefits

Methodology and achievements

Case studies

Sustainability and Environment
ANDRITZ HYDRO is a global supplier of electromechanical systems and services ("From Water to Wire") for hydro power plants. The company is a leader in the world market for hydraulic power generation.
## Company Profile

A world market leader in most business areas

<table>
<thead>
<tr>
<th>HYDRO</th>
<th>PULP &amp; PAPER</th>
<th>METALS</th>
<th>SEPARATION **</th>
<th>FEED &amp; BIOFUEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ 40-45%*</td>
<td>~ 30-35%*</td>
<td>~ 10%*</td>
<td>~ 10%*</td>
<td>~ 5%*</td>
</tr>
<tr>
<td>Electromechanical equipment for hydropower plants (mainly turbines and generators); pumps</td>
<td>Systems for the production of all types of pulp and of certain paper grades (tissue, cartonboard)</td>
<td>Systems for the production and processing of stainless steel and carbon steel strips</td>
<td>Systems for mechanical and thermal solid/liquid separation for municipalities and various industries</td>
<td>Systems for the production of animal feed and biomass pellets (wood, straw, etc.)</td>
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</table>

* Long-term average share of the Group's total order intake

** The ENVIRONMENT & PROCESS business area was renamed SEPARATION as of October 1, 2011
Facts and Figures

<table>
<thead>
<tr>
<th>Year</th>
<th>Order Intake</th>
<th>Sales</th>
<th>Order Backlog</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>2,590 MEUR</td>
<td>2,045 MEUR</td>
<td>1,870 MEUR</td>
</tr>
<tr>
<td>2009</td>
<td>2,895 MEUR</td>
<td>2,300 MEUR</td>
<td>2,895 MEUR</td>
</tr>
<tr>
<td>2010</td>
<td>3,376 MEUR</td>
<td>2,579 MEUR</td>
<td>3,376 MEUR</td>
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(Proforma figures for ANDRITZ HYDRO)
Our global Presence

[Map showing locations around the world with cities marked as places of presence or set-ups.]
Our Experience

- More than 170 years of turbine experience
- Over 30,000 turbines (more than 400,000 MW) installed
- Over 120 years of experience in electrical equipment
- Complete range up to more than 800 MW
- Leading in Service & Rehabilitation
- World leader for Compact Hydro
Our History

More than 170 years of experience and knowledge in the field of hydropower generation.

The pioneers created the foundation.
Installed Hydropower Capacities

937 GW global installed capacity

≈ 3.900 GW Technical Potential *

187 GW currently under construction

* Technical Potential, considering the region specific Capacity Factors of power plants

Potential for Rehabilitation

≈ 30% of plants older than 40 years 
(263 GW of 887 GW)
~ 37% of plants in Europe
~ 43% of plants in North America

- Value of rehabilitation (turbine + generator) estimated ≈ 10GW p.a.
- But actual ageing process results in 16GW p.a. reaching 40 years age.
- The “10GW p.a.” rate is not sufficient to stop ageing of existing fleet !!
- 30 GW p.a. necessary
  - To face the coming wave and
  - To stop the ageing process and to avoid dramatic incidents.
Worldwide installed capacity and ANDRITZ HYDRO fleet

- ANDRITZ HYDRO supplied 35% of the worldwide installed turbine capacity (320 GW von 926 GW)

Data based on World Atlas Hydro Power and Dams 2010; ANDRITZ references
Europe includes Turkey, Russia, Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
Africa includes Near and Middle East
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Do you see a difference?

The right picture differs from the left picture with additional output of 132 MW!
Multiple reasons for modernizing a Hydro Power Station

- Age of equipment (failure of major components)
- Improvement of plant safety
- Reduced environmental impact

Demands for energy rising dramatically
- Demands for peak load
- Cost-effective opportunities for upgrading
- Commitment towards clean and sustainable energy
- Other reasons (grid stabilization)

HPP in Ural / Russia, >100 yrs, noisy, but working

HPP Sayano–Shushenskaya / Russia, 6400 MW, 2009
3 major options to achieve improvement of plant performance

- Rehabilitation or refurbishment including improved maintenance.
  → This option will bring your systems / components back to original status (only).

- Modernisation with upgrading and/or uprating.
  → This option will generate added value, e.g: higher efficiency / additional MW.

- Re-development of the plant
  → This option opens the opportunity to consider essential changes of the basic design parameters.
The benefits of rehab

- Plant performance and improvement of the return of investment
  - Increased plant availability, reliability, plant lifetime, and safety
  - Reduced operation & maintenance (O&M) costs/risk of standstills
  - Reduced environmental impact
  - Remote control ability

- Costs
  - No additional buildings and quickly implemented
  - Normally no environmental impact assessment requested/no or minor interference with nature

- Additional renewable energy
  - For each 30 GW upgraded per year and for each 5% of increase of performance, rehabilitation programs will create 1,500 MW of renewable and predictable energy
A first class hydro equipment supplier will always compare & optimise various scenarios for improvement of the cost-benefit situation in favour of the customer!
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Sustainability and Environment
The 3 Phase Approach
the ANDRITZ HYDRO Process for Modernisation of HEPPs

**Diagnosis**
- generation
- lifetime

**Analysis**
- availability
- reliability
- safety

**Therapy**
- maintenance
- environment
The 3 Phase Approach

**Diagnosis:**
Register, assess and weigh all project-related parameters.

**Analysis:**
Develop and evaluate suitable modernization scenarios.

**Therapy:**
Implement the optimum modernization solution.

Modernisation Process
The 3 Phase Approach
Tasks, Tools and Services

Modernization Process

- Project planning and management
- State-of-the-art diagnosis engineering
- Economical viability study
- Financial engineering

New hydraulic design by advanced flow analysis
Mechanical safety and risk analysis
State-of-the-art simulation and design engineering
Strong modernization project expertise

Worldwide production centers
Innovative manufacturing technologies
Delegation of supervisors and erection teams
On-site machining equipment

Training programs
Local service centers

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30 years of CAE - From analysis of single component to a joint analysis of a complete system

**CFD**
- 1975: Static analysis of a Spiral Case
- 1985: Stress analysis at Kaplan blade root transition
- 1995: Vaned intake stress analysis based on CFD pressure field
- 2005: Contact analysis of a runner coupling
- 2015: Fluid structure interaction

**FEM**
- 1975: Static analysis of a Spiral Case
- 1985: Stress analysis at Kaplan blade root transition
- 1995: Vaned intake stress analysis
- 2005: Modal analysis in water
- 2015: Forced response analysis

**Key Techniques**
- **CFD**: 2-D Potential, Quasi-3-D Euler, 3-D Potential, 3-D Euler, Navier Stokes, Unsteady Navier Stokes, Free surface flow, Multistage Navier Stokes, Unsteady Navier Stokes, 3-D Potential
- **FEM**: Static analysis, Stress analysis, Vaned intake stress analysis, Contact analysis, Modal analysis in water, Forced response analysis

**Analysis Types**
- **Rotor Dynamic Analysis**: Static analysis of a Spiral Case, Stress analysis at Kaplan blade root transition
- **Fluid Dynamics**: Vaned intake stress analysis based on CFD pressure field, Contact analysis of a runner coupling, Modal analysis in water, Forced response analysis

**Andritz Hydro**
- www.andritz.com
Improvement Potential of Hydraulic Performance

Turbine Peak Efficiency

Year of Equipment Supply

Kaplan
Francis
Pelton

Pelton supplied in 1950

+ 4%
Improvement Potential of Generator components

Potential output increase by replacement of generator components

- Stator winding ~ 5 – 10%
- Stator winding + stator core ~ 7 – 15%
- New stator + new pole winding ~ 10 – 20%
- New stator + new poles ~ 10 – 25%
Achievements
Higher output and efficiency

Akosombo / Ghana

- Customer: Volta River Authority
  - $D = 5,650\ \text{mm}$ Francis Turbine
  - $n = 115.4\ \text{rpm}$
  - $H = 65.0\ \text{m}$
  - $P_{\text{old}} = 139.3\ \text{MW}$
  - $P_{\text{new}} = 173.1\ \text{MW\ (}+25\%\text{)}$

- 6 new runners, adaptation of components

$\Rightarrow$ Additional 200 MW “renewable energy”
Achievements
Higher output and efficiency

INFIERNILLO / Mexico / 2006 - 2010

Customer: Comisión Federal de Electricidad (CFE)
Quantity: 4 Units
Original Supplier: Neyrpic
First Commissioning: 1964
Output: 160 MW > new 205 MW
Francis Runners: DN = 4,550 mm
Weight = 55,910 kg

Modernization of four Francis turbines
- New runners
- Modernization of turbine and generator guide bearings
- Oil cooling systems and instrumentation
- Engineering, CFD study, model test,
- Installation, commissioning

Major features (measured on unit 1):
- Increase of turbine output by 28% (vs. contractual 25%)
Achievements
Higher output and efficiency

PANTABANGAN / Philippines / 2008 - 2010

Customer: First Gen Hydro Power Corporation
Quantity: 2 Units (vertical Francis)
Original Supplier: Mitsubishi
First Commissioning: 1976
Output old: 51.6 MW / 64 MVA
Output new: 60.4 MW / 71 MVA
Head: 70 m > 75 m
Speed: 180 rpm

Refurbishment and upgrade of 2 vertical Francis
- Model test, turbine rehabilitation including new runner, shaft and digital governor
- Stator winding and new generator shaft, rehabilitation of generator auxiliaries, new medium voltage switchgear, new low voltage AC and DC distribution
- New control system with SCADA
- New excitation, protection and online M&D system

Major features:
- Increase of turbine output by 14%
- Delivery time for Francis runner of 18 months
- Very short outage of 5 months
Achievements
Higher output and efficiency

AHVENKOSKI / Finland / 2009

Customer: Oy Mankala Ab
Quantity: 2 Units
Original Supplier: TAMPELTA (ANDRITZ HYDRO)
First Commissioning: 1932
Output: 2 x 15 MW
Head: 11.9 m
Speed: 107.1 rpm
Runner Diameter: 4,560 mm

Upgrading of Kaplan turbines at Unit 1 & 2
- Hydraulic engineering & model test
- Dismantling, erection and commissioning
- New 5 bladed water filled runner, turbine bearing, shaft seal, servomotors
- New discharge ring & guide vanes
- Refurbishment of remaining components
- New turbine governors including high pressure oil units
- Commissioning in 2011 (U1) and 2012 (U2)

Major features:
- Output increase by 25%
- Water filled runner hub
Case Study

ROUNA II
HEPP Rounda 2 / Papua New Guinea
Modernization of Hydro Power Plants

Customer: PNG Power Limited
Order Intake: 2006
31.6 MW River Power Plant
Year of Erection 1969
4x7.9 MW Francis

Major scope
- Automation & Control
- Excitation
- Power Plant Management
- Protection
- Synchronization
- Turbine Governor

Major features:
- Increased Reliability & Availability.
- Increased HS&E Standards.
- Reduced Capital Project Costs due to alternative technical solution
- Community Involvement
- Increase of unit output by 30%.
Challenges and benefits

Location
- Papua New Guinea, power plant in a remote area, one „direct“ flight per week to Port Moresby
- Personal safety, security, travelling

Technical
- Delivery of equipment, limited access required specific design of the new generator
- Logistics, local transportation, reinforcement of bridge and repair of roads

Social aspects
- 700-1000 ethnic groups in PNG
- Support of local community

Benefits
- Increase of output and efficiency
- Plant availability and reliability is important for the power supply of Port Moresby
- Optimized project costs
Transportation and Erection Challenges

Access during Rehab via a vertical shaft ~ 170m

Outlet channel ~ 2 km

Access during construction

Power house cavern

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Technical considerations

Generator

Challenges

- Transportation limitations of weight and dimensions
- Improvement of plant reliability

Benefits

- Compact design - stator to lower through vertical access shaft (2150 x 2300)
- Cylindrical rotor design – No Externally Mounted Rotor Poles
- GD^2 – Combined Brake Ring and Flywheel
- Reducing the external auxiliary systems for the generator (combined braking and jacking system)
Technical considerations
Turbine and auxiliary systems

Benefits Turbine & MIV:
- Additional plant output secures power supply to Port Moresby
- Increase in efficiency – using less water for the same power
- Digital & Hydraulic Governor

Benefits auxiliary systems:
- Increase in reliability – using less external auxiliaries
- Reduced maintenance costs
- Closed loop unit cooling water system is reducing project costs
- New control and monitoring systems secures plant availability
Project social context

Challenges
- Understand and interface with specific social environments effectively to deliver successful projects in an unobtrusive manner
- Respecting local cultures and needs to demonstrate visible local community interaction with the project
- Develop a Project Social Responsibility Policy to engage these responsibilities

Benefits
- Under the Project Social Responsibility Policy, the Rouna II Upgrade Project created and executed support projects in the local community
- Rouna II Upgrade Project promoted PNG cultural diversity, the project features and the project social responsibility policy
Security and Political Risk Forecast
What is Security?

What is Security not?

- It is NOT placing a man at the entrance gate to open it every morning and greet you.
- It is NOT throwing money at some local security company that simply hires a few men in old worn out uniforms sitting around.
- It is certainly NOT giving the man at the entrance gate a big gun in the hope that it scares off bad elements.

Security … from a Management Sense is …

- Ensuring that assets & personal are best protected by …
- Understanding (attempting to) the environment in which we operate …
- Knowing the threat potentials which exists within this environment
- Finding an objective manner to quantify these threat potentials
- Applying threat mitigating measures via a plan
Security assessment process

Threats Identification

- Brainstorm possible security threats.
- Consider the country.
- Consider main & secondary locations of activities.
- Consider transfer routes.
- Consider facts & perceptions.
- Transfer security threats into list.

Categorize & identify Source & Impact of threats

Threats Mitigation Measures

- Physical mitigating measures are always required but it is a reactive approach.
- Controlling environmental influences requires indirect approach.
- Be aware of provocation in poor countries. Openly showing signs of wealth.
- It is recommendable to use professional security people.
- Our behavior has a significant influence toward our own security!
Case Study

EDEA I
EDEA I / Cameroon / 2008 - 2011

Customer: AES Sonel SA
Quantity: 3 Units (propeller)
Original Suppliers: SFAC for units 1 and 2
ACMV for unit 3
(today ANDRITZ HYDRO)
First Commissioning: 1949 - 1955
Original Data: 11.4 MW (U 1&2) / 12.5 MW (U 3)
New Data: 16.4 MW
Head: 25.1 m
Speed: 187.5 rpm

Complete electro-mechanical rehabilitation
- Total replacement of propeller turbines, governing systems, generators, power transformers, control system, electrical equipment, mechanical and electrical auxiliaries
- Supply of new gantry and swiveling cranes
- Refurbishment of power house cranes
- Refurbishment of draft tube stop logs, intake bulkheads and intake radial gates

Major features:
- Output increase by 44% (units 1 & 2)
- Output increase by 33% (unit 3)
Edea 1
Location

The HEPP EDEA, located on the SANAGA River situated halfway from Douala, economic heart, and Yaoundé, Capital of the Cameroon, was built 59 years ago in three phases.

EDEA I, Units 1 to 3, 1949 – 1955
EDEA II, Units 4 to 9, 1954 – 1958
EDEA III, Units 10 to 14, 1969 – 1975
Challenges & benefits

Challenges
- Location in Cameroun, poor developing country, politically unstable, traveling is dangerous, local procurement almost impossible
- Climatic conditions, malaria threats
- Personal safety, security, evacuation plan
- Bureaucratic decisions
- Transportation of equipment difficult due to poor road conditions
- Plant in operation during rehabilitation

Benefits
- Increase of the turbines output will strengthen the power supply in Cameroun
- Increase of efficiency and improve water management
- Increase availability and reliability of Edea 1
Project Description

Intake Equipment

- New gantry cranes
- New swivelling cranes
- Rehabilitation of intake radial gates:
  - inspections of steel structure
  - corrosion protection of steel structure
  - replacement of seals
  - replacement of gates servomotors
  - supply of new pumping units
Project Description

Turbine Equipment

- Dismantling of existing turbine
- Rehabilitation of spiral case and draft tube
- Rehabilitation of runner chamber
- Rehabilitation of embedded bottom ring
- Supply of new propeller turbine consisting of:
  - runner
  - shaft
  - turbine covers
  - bearing
  - shaft and shaft seal
  - distributor assembly incl. servomotors

- Main data: 16.4MW / H=24m / 187.5 rpm

Differences in design between units 1&2 and unit 3
Project Description
Generator Equipment

- Dismantling of existing generator
- New generator consisting of:
  - stator supplied in two halves
    - class F insulation
    - Roebel bar
    - voltage insulation VACUBAND
  - rotor
    - hub spider shrunk to the shaft
  - rotor poles
    - one piece core
    - poles fixed by yoke ring by bolts
  - bearings
    - upper combined bearing
    - lower guide baring

- Main data: 18900kVA / p.f. 0.85 / 187.5 rpm
Project Description
Governor system

- Dismantling of existing governor system

- Supply of new 80bar hydraulic system consisting of:
  - pumping unit with screw pumps
  - piston accumulators
  - nitrogen bottles
  - Servo and safety

- Supply of digital governor MIPREG 600c
Project Description
Control and electrical balance of plant

- New control command system consisting of:
  - Scada system, Control, Monitoring, Synchronization
  - Test platform with control build software
  - Water measurement system

- Electrical equipment consisting of
  - Generator main transformers 20 MVA
  - MV switch gear and power cables
  - LV switchboard and MCCs
  - transformer fire protection

- Brushless excitation system and excitation transformer
Project Description

Mechanical auxiliaries

- Rehabilitation of cooling system consisting of:
  - assessment of global existing system
  - supply of new cooling system pertaining to unit 1 to 3, i.e. piping, backwash filter, bypass filter

- Rehabilitation shaft seal water supply:

- Connection to existing compressed air system

- Rehabilitation of drainage and dewatering systems
  - supply of new sump pumps
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Sustainability and Environment
Environment and Sustainability

Implementation of the Hydropower Sustainability Assessment Protocol

- ANDRITZ HYDRO, via the Hydro Equipment Association (HEA) is a Sustainability Partner of IHA
- Sustainability Partners are participating in the implementation of the Hydropower Sustainability Assessment Protocol
Rehabilitation needs experience

The “best” technology does not exist. It is a matter of value creation and understanding the customers perception of value (and the ability to influence their perception). Such values are not only efficiency, they can also be related to regulation as described here – or other features.

It is the supplier with the best ability to identify, understand, and realize the customers values that will be the winner. Not necessarily the one who fulfills the specification the best.

THANK YOU!
Thank you for Your attention!

Georg Woeber

ANDRITZ HYDRO GmbH
Service & Rehab
Penzinger Strasse 76, A-1141 Vienna
Phone: +43.1.89100-2935
Fax: +43.1.89100 3839
Mobile: +43.664.6154155
georg.woeber@andritz.com
www.andritz.com