KOLEKTOR

www.turboinstitut.com

Turbine R&D

We provide best-in-class solutions

- Development of new top-performance water turbines
- Refurbishment of all types of water turbines
- Independent model testing
- Site testing
- CFD Analysis

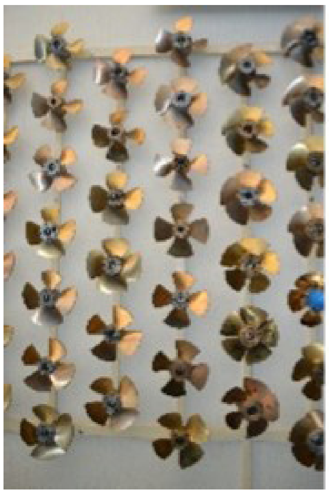
turboinštitut

Decisions in Hydro Power

To build new HPPs?

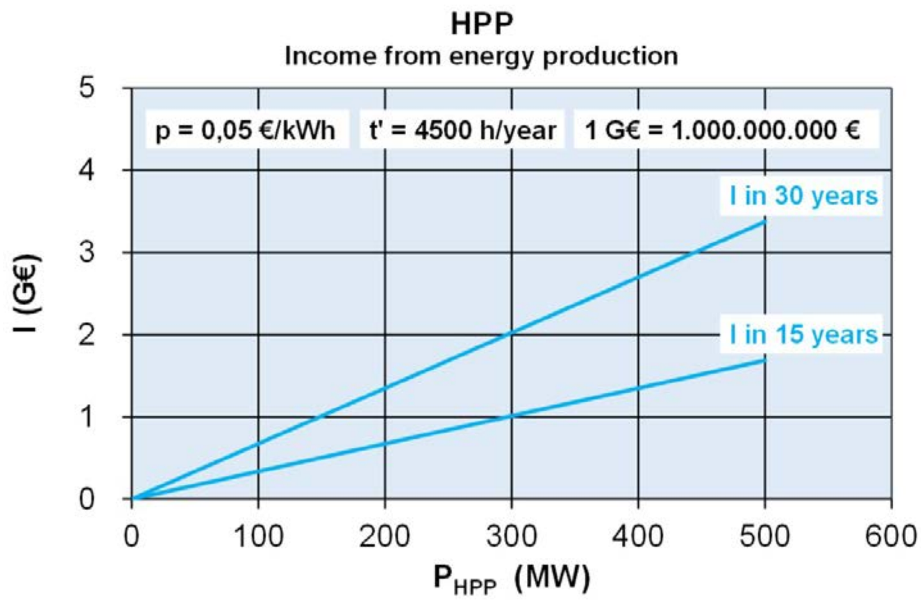
Large investment costs should be counterbalanced by high-efficiency design to shorten the payback period and to increase profit.

Kolektor Turboinštitut offers the following options for R&D and testing in our hydraulic laboratory:
- In-house R&D of a hydraulic shape and testing,
- Independent testing of customer's hydraulic shapes,
- Independent testing of two or three producer's hydraulic shapes – comparative test.




Hydraulic Design → **CFD** → **Model Testing** → **Site Testing**

Simplified estimation of income for a HPP



E.g., for a HPP, operating for 4500 h/year at an average power of 300 MW, with electricity price 0.05 €/kWh, the income is equal to 1.01 billion € in 15 years

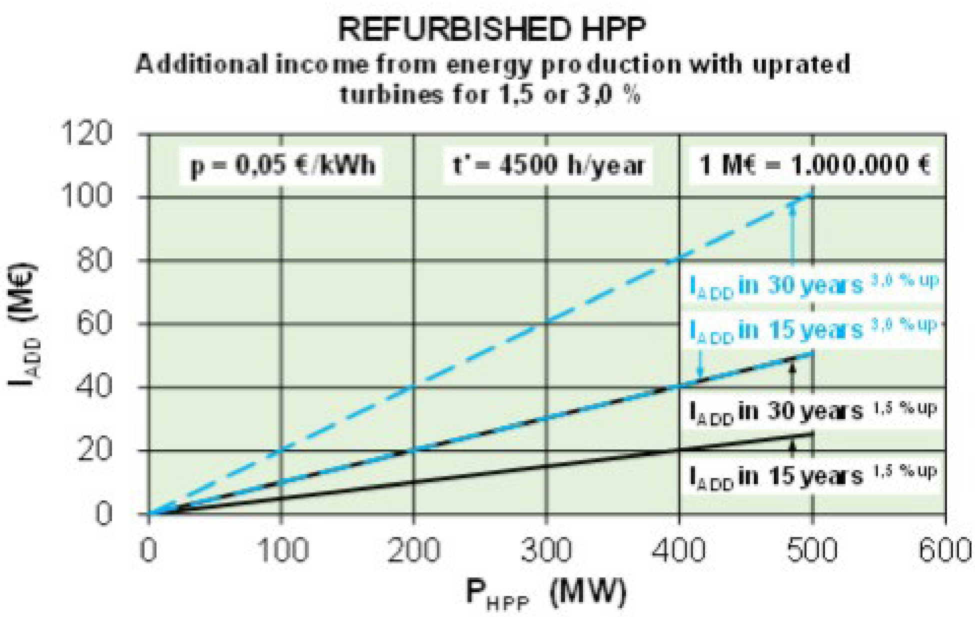
To refurbish old HPPs?

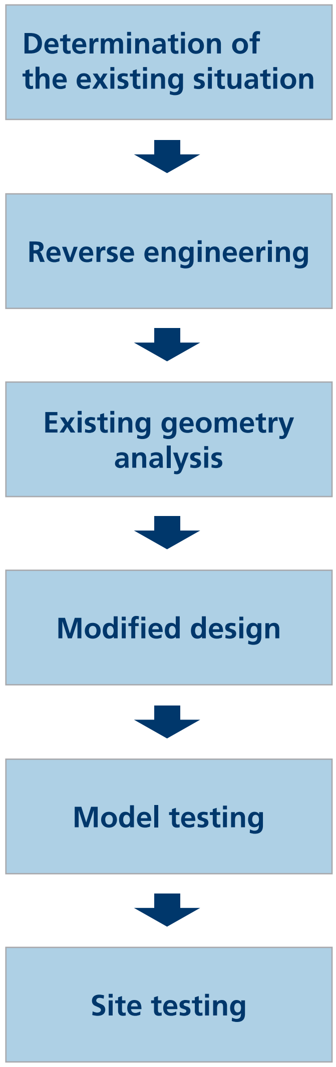
The decision to refurbish is always based on a cost-benefit analysis, and is site-specific.

Our team of experts can:

- Determine the existing situation of the power plant (site testing, reverse engineering, geometry analysis)
- Propose tailored solutions and/or perform independent model testing of proposed solutions:
  - In-house R&D of a hydraulic shape and testing
  - Independent testing of customer's hydraulic shapes
  - Independent testing of two or three producers' hydraulic shapes – comparative test
- Perform site testing

Simplified estimation of additional income for a refurbished HPP (because of e.g. efficiency improvement, improved turbine characteristics, etc.)





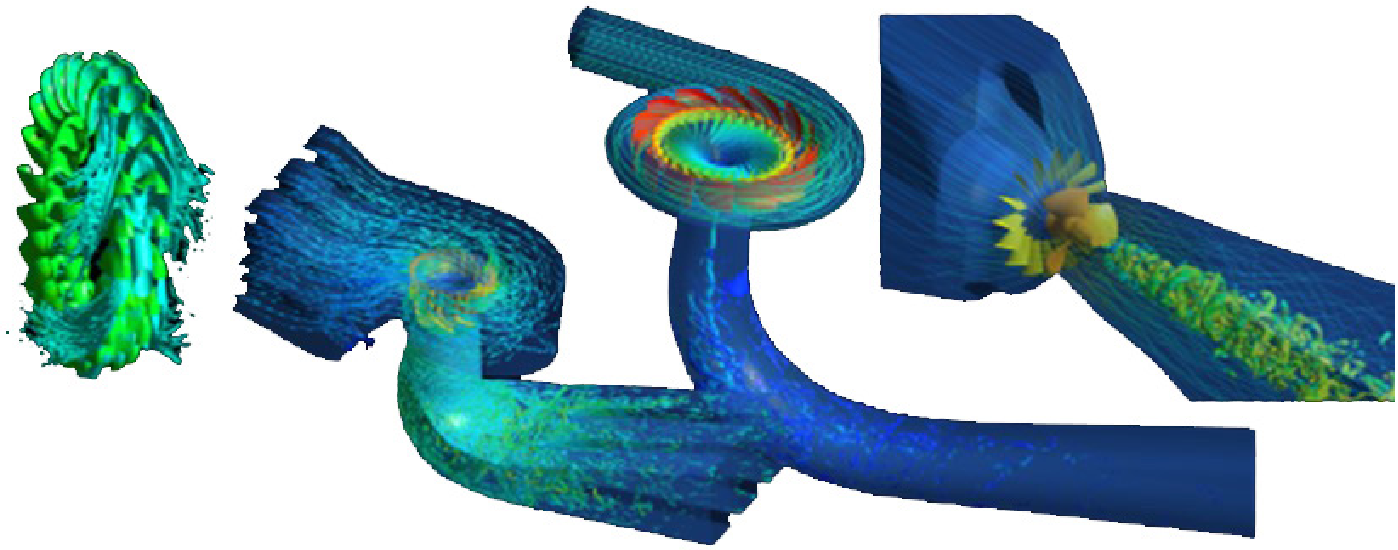
Conclusion: 3% increase in turbine efficiency over a period of 15 years, will result in over 30M EUR increase in revenue!

(at an average HPP power of 300 MW)

R&D with Computational Fluid Dynamics

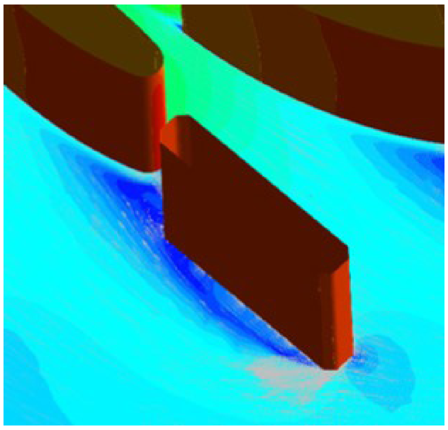
R&D with CFD in Kolektor Turboinštitut

- **Based on more than 65 years of experience, Kolektor Turboinštitut offers the high-efficiency design of water turbines for our customers**
- **More than 30 years of experience in computational fluid dynamics (CFD)**
- **Numerical analysis has become an indispensable tool in Kolektor Turboinštitut's design process**
- **CFD enables a shorter design cycle, less experimental work and, finally, machines with better characteristics**
- **Our research findings are instantly applied to our design process**

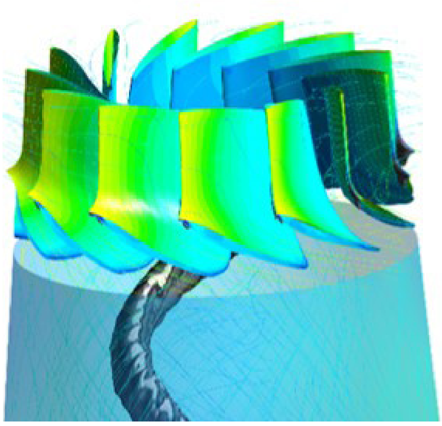


CFD Analysis of an Existing Turbine

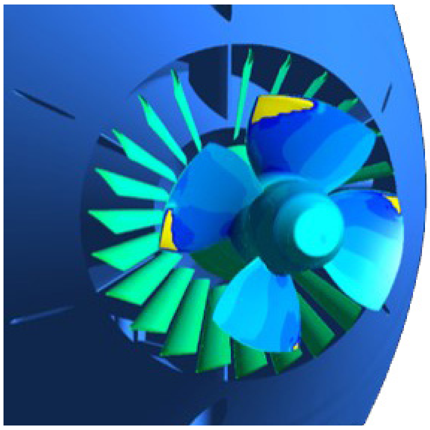
Numerical analysis gives insight into the flow in all turbine parts. On the basis of numerical results it is easier to find the reasons for low efficiency and/or cavitation, and to make improvements to the hydraulic shapes.



Flow separation along stay vanes



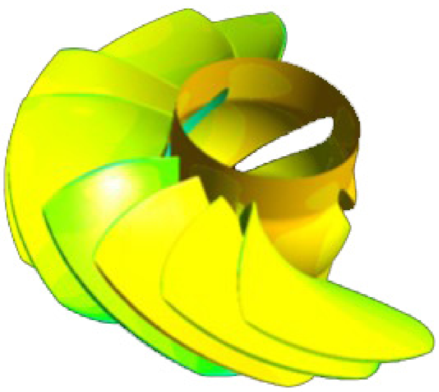
Leading edge cavitation and cavitating vortex rope in a Francis turbine



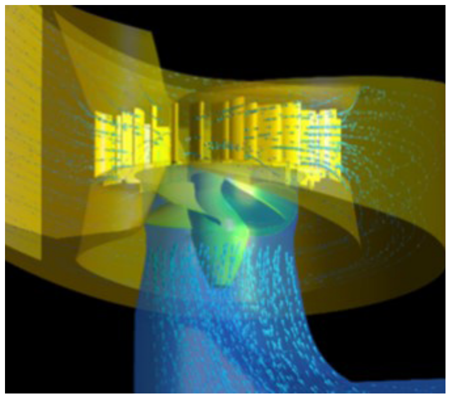
Cavitation in a prototype of a bulb turbine

CFD in a Design Process and Detailed Analysis of the Final Geometry

- **CFD enables the analysis of a large number of hydraulic shapes**
- **Only one or two models of the best designs are manufactured and examined on the test rig**



Several shapes of runner blades analyzed numerically during the design process

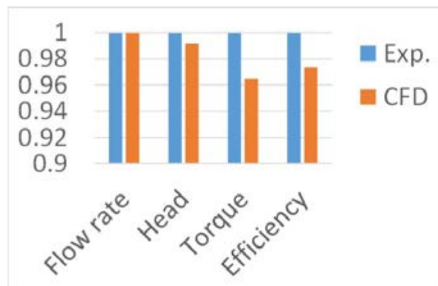


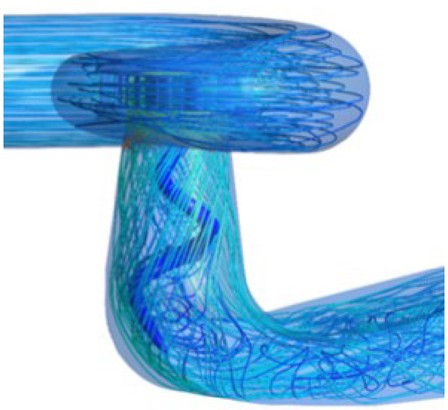
Detailed analysis of the final design

Recent Progress in CFD

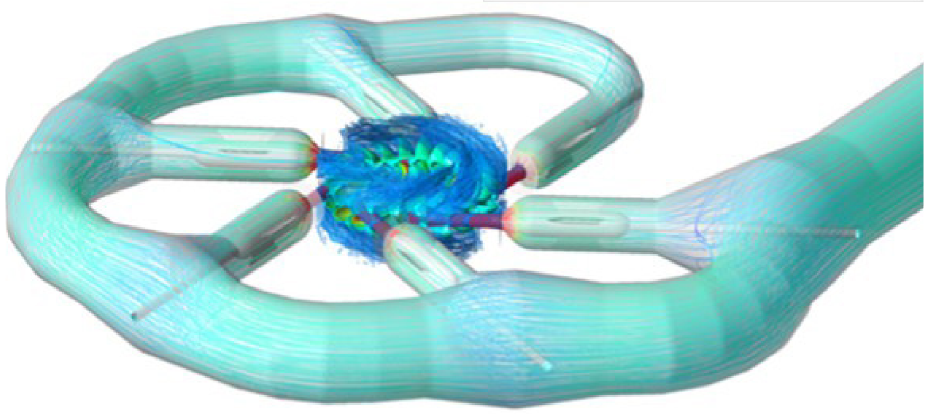
In the last ten years there has been much progress in CFD predictions, which is confirmed by our numerous research papers and our EU project ACCUSIM (Accurate Simulations in Hydro-Machinery and Marine Propellers)

- Accuracy of predicted efficiency and cavitation has improved considerably due to transient simulations with advanced turbulence models
- Transient phenomena, such as rotating vortex rope in the draft tube of Francis turbines, can be accurately simulated
- Even for Pelton turbines, where multiphase flow has to be modelled, efficiency and cavitation can be predicted



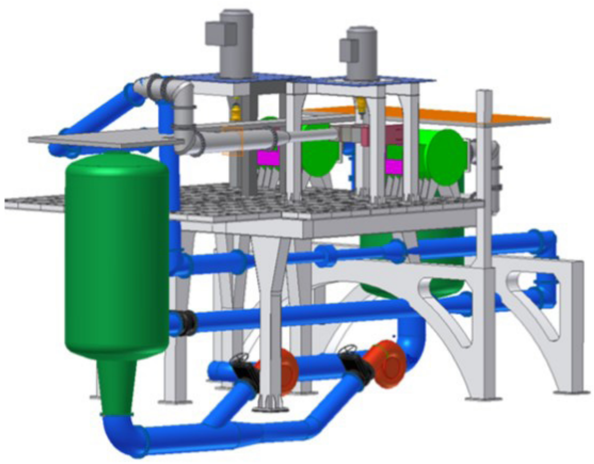


Cavitating vortex rope in a Francis turbine



Efficiency prediction for a 6-jet Pelton turbine

Independent Model Testing

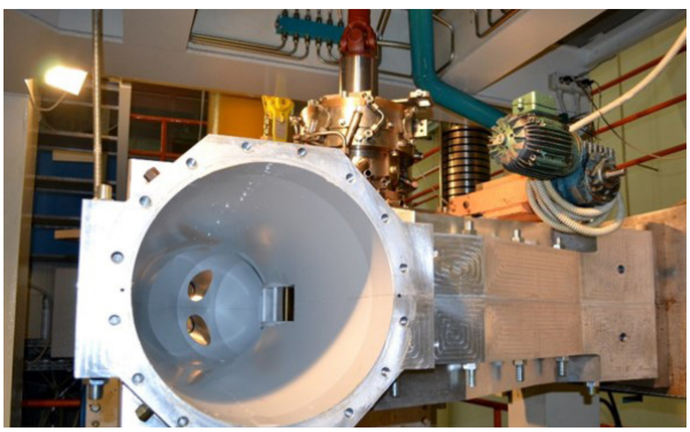


Model testing at Kolektor Turboinštitut:
- In accordance with IEC 60193 standard
- Over 230 model acceptance tests performed
- Over 1000 development tests performed for various producers and users of hydraulic turbines

Four test rigs available for:
- Francis, pump or Kaplan turbines
- Kaplan turbines
- Pelton turbines (horizontal and vertical)
- Bulb turbines
- Test rigs are completely independent of each other
- All four test rigs can operate simultaneously

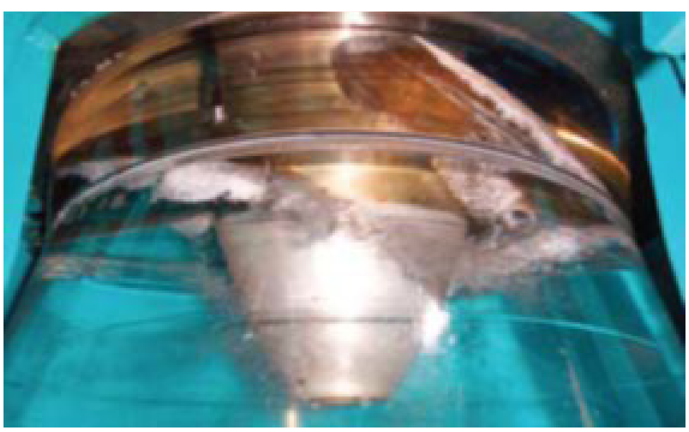
The following options can be observed:
- Energetic performances (efficiency)
- Cavitation characteristics
- Dynamic performances

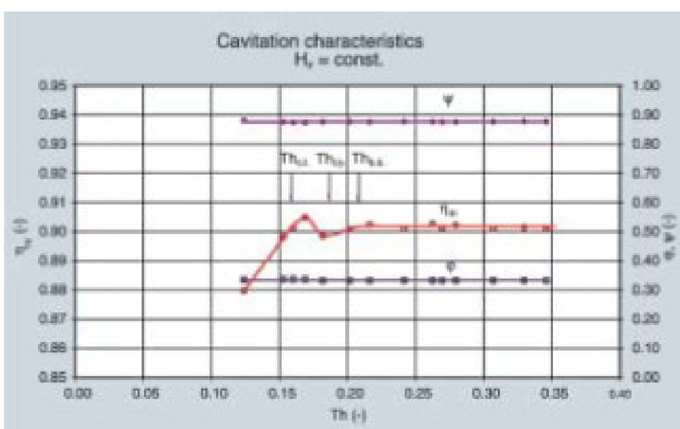
Equipment:
- Modern control and acquisition system
- Calibrated measurement equipment
- Modern control rooms

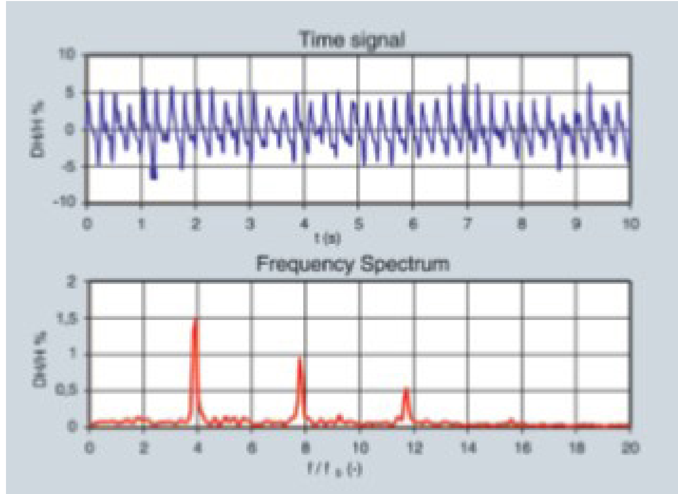


Model materials and manufacturing:
- Spiral casing: CNC manufactured from aluminium blocks
- Draft tube: stainless steel, using welding technology
- Runner blades, guide vanes and stay vanes are usually made of bronze using CNC technology
- All wet surfaces are smooth finished
- Carbon steel components are protected with anticorrosive paint

Model dimensions:
- Defined by the runner outlet diameter - typically 350 mm, only in exceptional cases between 300 mm and 400 mm
- Model dimensions and test rig operating parameters allow Reynolds numbers as required by the IEC 60193

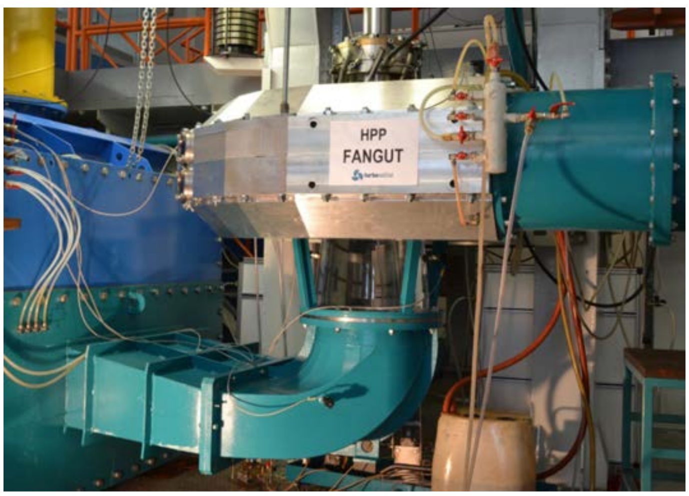






Main parameters of turbine test rigs:

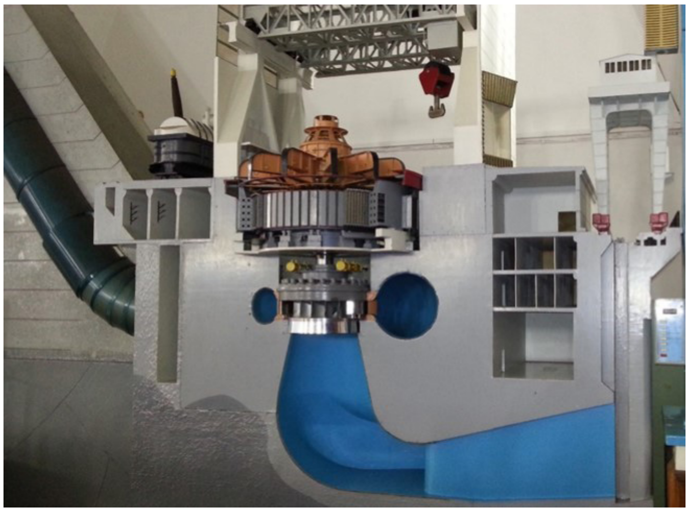
	Francis	Kaplan	Bulb	Pelton
Head H_{max}	60 m	32 m	32 m	110 m
Flow rate Q_{max}	0.7 m^3s-1	0.9 m^3s-1	1.0 m^3s-1	0.25 m^3s-1
Torque T_{max}	1500 Nm	700 Nm	700 Nm	1000 Nm
Power P_{max}	150 kW	150 kW	90 kW	150 kW
Rot. speed n_{max}	1500 rpm	1500 rpm	1500 rpm	2000 rpm



Site Testing

Measurement of Energy and Dynamic Characteristics

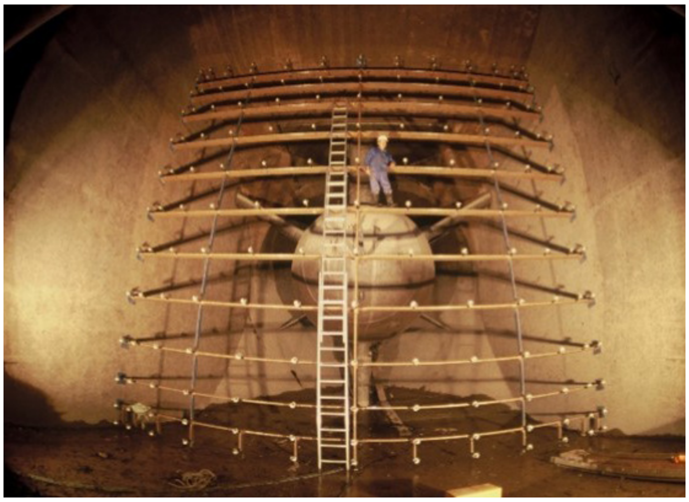
- According to IEC 60041 and IEC 62006
- We have performed 72 on-site measurements on 50 power plants since 1996
- Flow measurement methods can be chosen depending on power plant configuration and customer requirements

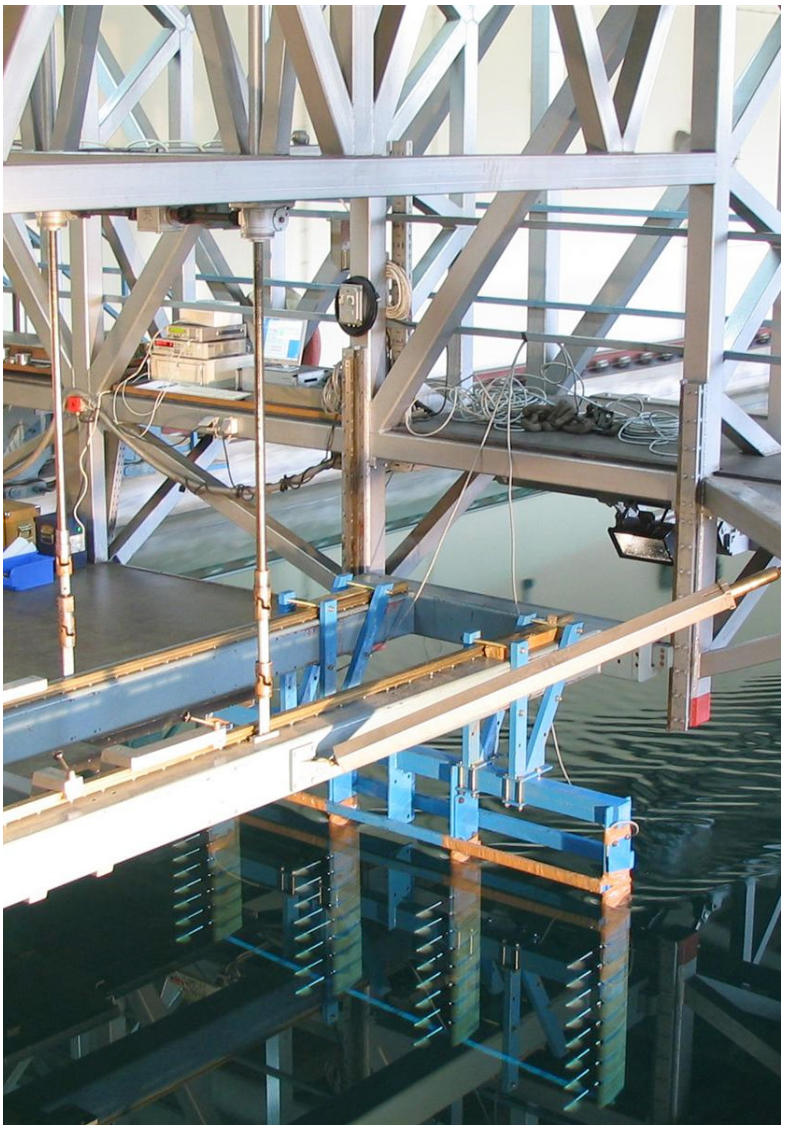


Flow Measurement by Current Meters

- Measurement and calibration in accordance with standards IEC 60041, ISO 3455, ISO 3354 and ISO 7194
- We have performed 56 current-meter flow measurements on 37 power plants since 1996
- Current-meters are manufactured at Turboinštitut according to our own design and technology
- Signals from current-meters are connected to Turboinštitut's proprietary hardware connected to a computer and processed with software developed at Turboinštitut.
- Velocity profiles are immediately visually checked before the on-site integration of the flow is performed

Based on our experience we conclude that the repeatability of our flow measurement is in the range of ±0.2 % and always has an uncertainty less than IEC recommended levels.

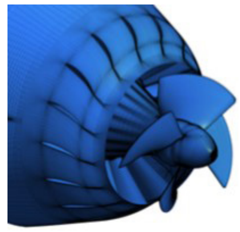


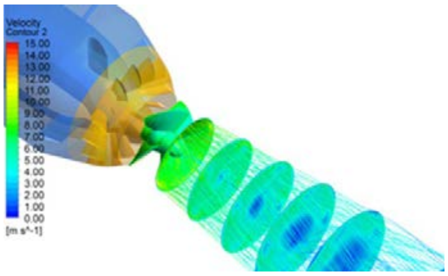


Reference Cases

Bulb turbine
Development with model acceptance test

HPP in Serbia on the river Danube, with a bulb turbine having one of the biggest diameters in the World, was refurbished after about 30 years of operation. New runner was developed using the advanced CFD technique and model testing in 2012.

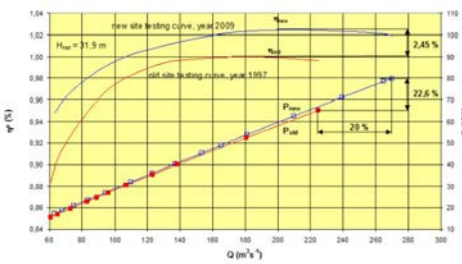




		Old	New
Head	m	7.8	7.8
Flow	m^3/s	475	475
Capacity	MW	30.5	33.3
Speed	rpm	62.5	62.5
No. of units		20	20

Kaplan Turbine
Site pre-testing, turbine R&D with model & site testing

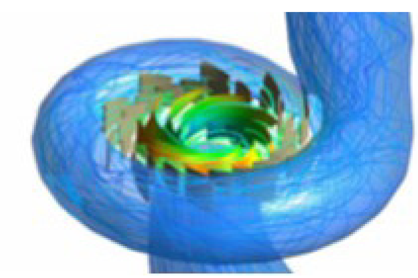
The biggest HPP in Slovenia was refurbished after about 40 years of operation. Site testing before refurbishment was finished in 1998. New runner and new guide vanes were developed using CFD technique and model testing in 2005. Site testing after refurbishment was performed in 2009.



		Old	New
Head	m	32.1	31.9
Flow	m^3/s	225	270
Capacity	MW	65.4	79.4
Speed	rpm	125	125
No. of units		2	

Pump turbine
Development with model testing

A new runner/impeller with 9 blades was designed to replace the old one with 7 blades. Stay and guide vanes were also modified. An advanced CFD technique of nonstationary flow field calculation through complete pump-turbine in pump and turbine modes was performed. A complete series of model tests were performed in four quadrant operation modes.

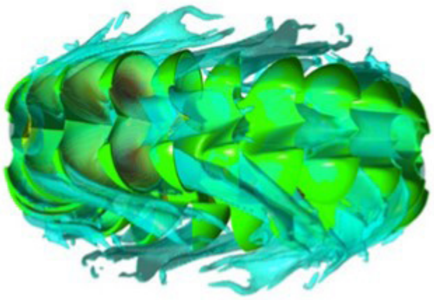


		Old	New
Head	m	32.1	70.0
Flow	m^3/s	151.4	143.0
Capacity	MW	121.3	106.7
Speed	rpm	136.36	
No. of units		1	

6-jet Pelton turbine
Development with model acceptance test

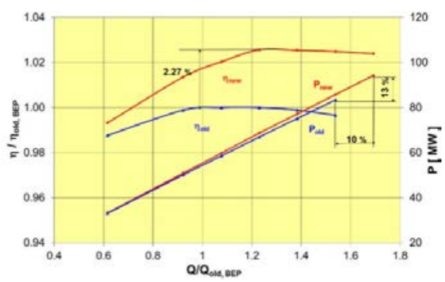
This development was performed for a new HPP with two Pelton turbines. High turbine efficiency was achieved

Head	m	390.5
Flow	m³/s	4.5
Capacity	MW	15.5
Speed	rpm	720
No. of units	2	

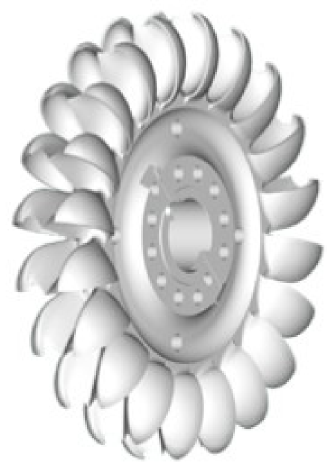


2-jet Pelton turbine
Development with model acceptance test

The power plant operates at very high head – 1000 m, with 3 turbines, each with two runners on the shaft. The owner required turbine refurbishment with a 10% increase of the discharge and with unchanged servomotor stroke. The requirements were met by increasing the nozzle diameter, changing the needle shape, increasing the bucket width and using the protection plates.

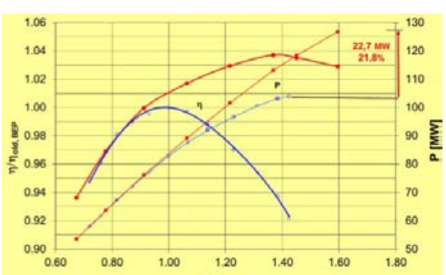


		Old	New
Head	m	1000	1000
Flow	m³/s	10	11
Capacity	MW	83	94
Speed	rpm	600	600
No. of units		3	

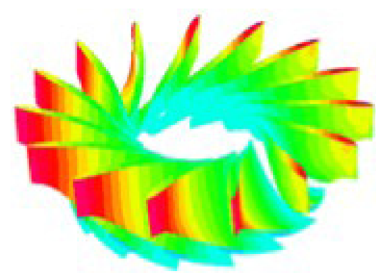


Francis turbine,
feasibility study, model development with testing, site testing

Running more than 4000 h/year at full load the turbines operated at unfavourable conditions. New runner and guide vanes were developed using CFD technique and model testing. Significant improvement in efficiency and maximum flow has been achieved.



		Old	New
Head	m	261	261
Flow	m³/s	47.5	52.5
Capacity	MW	105	127
Speed	rpm	300	300
No. of units		2	



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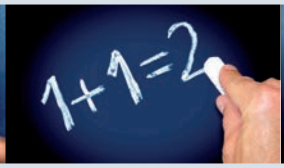
26. 4. 2018

We live our values and we foster them through our work

Responsibility



Fairness

Passion for Success

Customer Proximity

Inventiveness

Team Spirit