Voith Hydro

VOITH

Pumped storage machines

Harnessing the power of water

with engineered reliability

Generating energy from the power of water represents large amounts of clean, renewable energy. 71 percent of the earth's surface is covered by water. The world's hydro power potential amounts to 20 billion Mega Watt hours per year and only 30 percent of this has been developed so far.

Hydro power is not only environmentally friendly, but also cost-effective. Hydro power plants have the highest operating efficiency of all known generation systems. They are largely automated, and their operating costs are relatively low. Hydroelectric power plants also play an important role in water resource management, flood control, navigation, irrigation and in creating recreation areas.

Voith Hydro is an industry leader in the production of generators, turbines and the associated control systems to put the power of water to work. A range of services, from engineering through manufacturing and project management to commissioning, completes our portfolio as a leading product and service provider.

As part of our international network each Voith Hydro facility operates under the same cutting edge platform and is equipped with consistent best-in-class processes and tools. This network also ensures that we can meet special customized requirements: from individual components to project planning, through project management and plant maintenance. With branches and production facilities for electrical and hydraulic machines and components in Europe, Asia and North and South America we are close to our customers and all major hydro power markets.

Voith Hydro is also a trend-setter in the field of "new renewables". Wave and ocean current power technology from Voith Hydro are amongst the pioneering initiatives for the commercial development of the power of the oceans in the foreseeable future.

Competence and capabilities

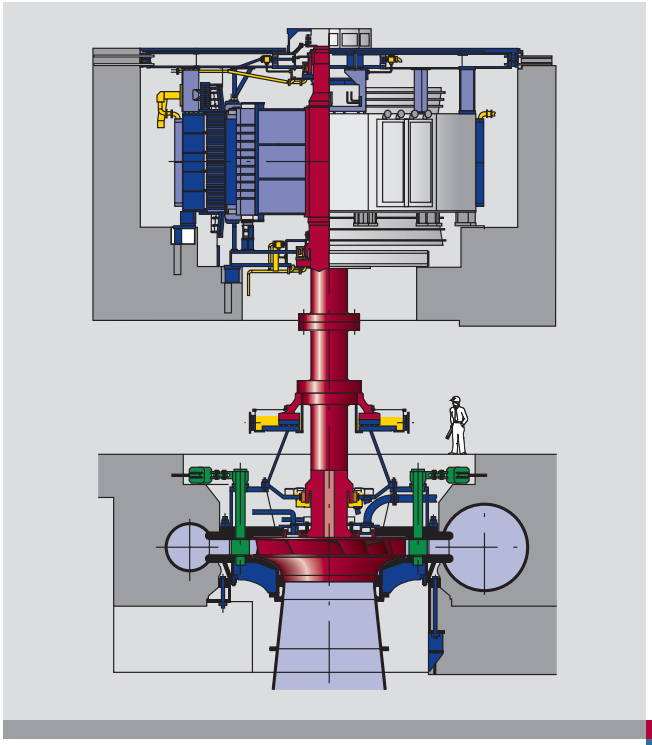
- Consulting, engineering, erection and commissioning
- System/plant assessments
- HyService – global, fast and effective for modernization and rehabilitation of existing hydroelectric power plants
- Complete equipment, installation and services for hydroelectric power plants
- Francis, Pelton, Kaplan, bulb turbines, pump-turbines, standard and custom
- Storage pumps, radial, semi-axial and axial-flow pumps
- Generators and motor-generators for constant and adjustable speed, excitation systems
- Frequency converters, protection systems, switchyards for all voltages, transformers
- Power plant automation, control centers for hydro power plants and cascades, including plant management and diagnostic systems
- Shut-off valves
- Integrated Management System to safeguard excellence and quality

Engineered reliability.

Our promise to the customer. Precise and creative. Our products and services are designed specifically for our customers' needs. Always efficient and economical, and, above all, following our values and visions for a sustainable solution.

Pumped storage development

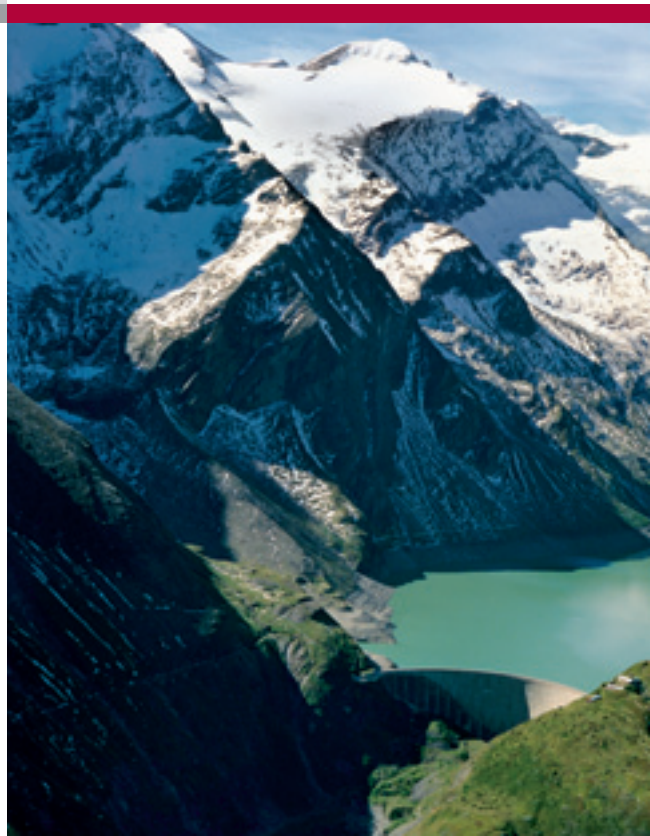
Pumped storage is the economically and environmentally most developed form of storing energy during base-load phases while making this energy available to the grid for peaking supply needs and system regulation. This has been done by Voith since this technology was invented.



Cross section of a variable-speed Francis pump-turbine for Goldisthal, Germany

In 1937 Voith developed the first large pump-turbine, which operated both as a turbine for energy generation and, in the reverse direction, as a pump.

The first pumped storage station in Germany was installed in 1908 in the Voith research and development building, the Brunnenmühle in Heidenheim, Germany.



Today, over 200 Voith Hydro pumped storage units have been installed worldwide with a combined output of well over 24,000 MW. With a wide range of specific speeds, pump-turbines can be installed at sites with heads from less than 50 to more than 800 m, and with unit capacities ranging from less than 10 to over 500 MW.

When supplying equipment and services for pumped storage plants, Voith Hydro can draw on vast experience gained over many years of hydraulic development and a very large number of designs.

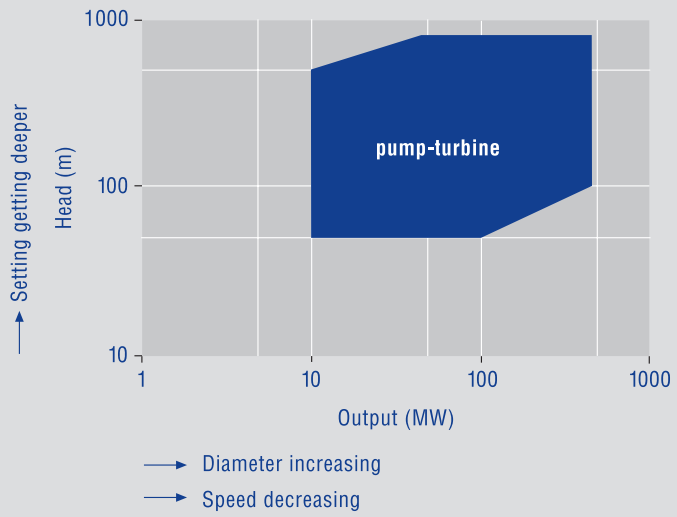
Characteristics of pump-turbines

Advances in technology are constant, including the latest developments on variable-speed and wide head range applications.

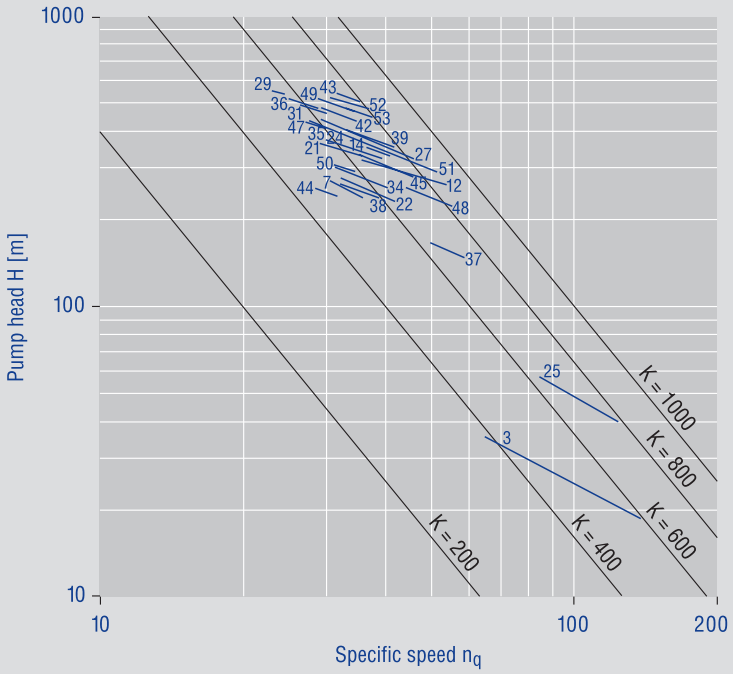
Pumped storage plants can be configured in several different ways. Reversible pump-turbines or separate generating and pumping equipment may be installed. Some are equipped with a fixed or adjustable distributor. In the case of separate machines, a clutch operable at standstill, a starting turbine or a synchronizing torque converter facilitating extremely short change-over times can be provided.

Whether a reversible pump-turbine, or a turbine and pump combination, these machines have proven to be extremely durable. In many cases, they have performed reliably for several decades.

Application range



Selected pump-turbines: operation range in pump mode



$$K = n_q \times \sqrt{H}$$

$$n_q = n \times \frac{Q^{0.5}}{H^{0.75}}$$

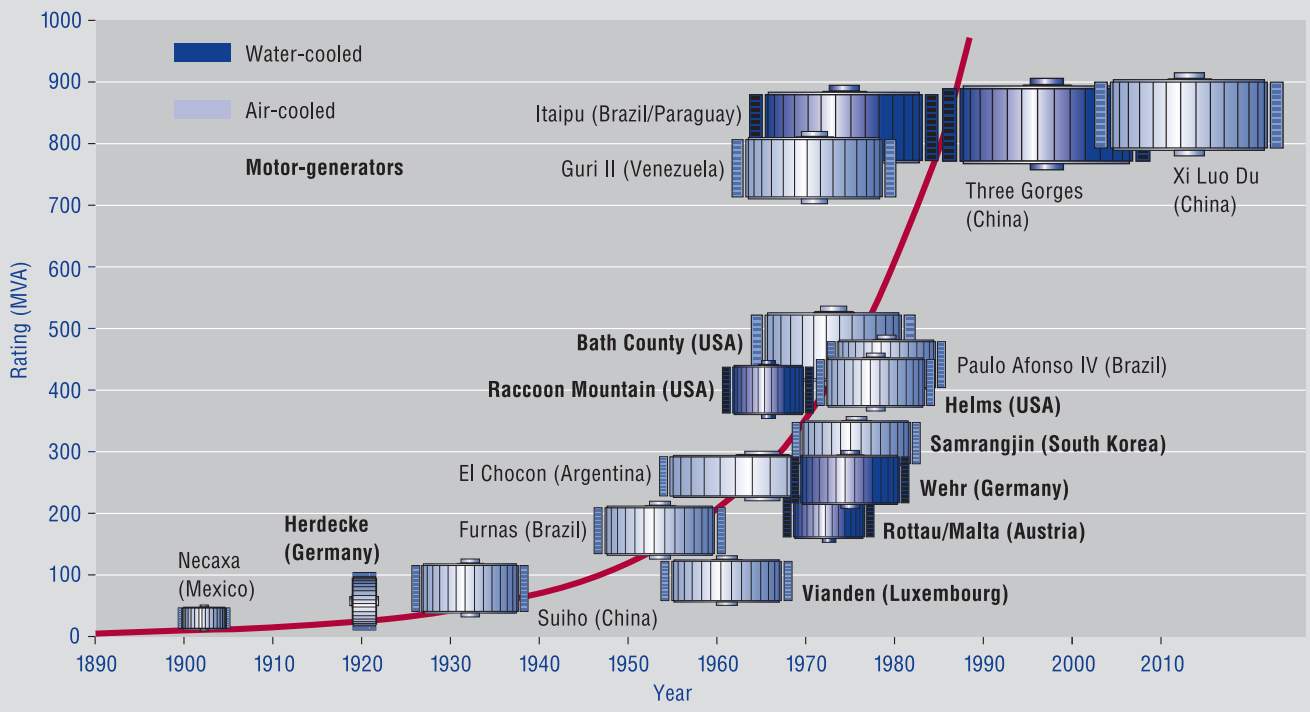
3 *Lewiston*
7 *Coo I*
12 *Raccoon*
14 *Rodund II*
21 *Bath County*
22 *Coo II*
24 *Estangento*
25 *Gabriel y Galan*
27 *Kühtai*
29 *Obrovac*
31 *Presenzano*
34 *Palmiet*
35 *Bad Creek*
36 *La Muela*
37 *Herdecke*
38 *Chiotas (4 stage)*
39 *Mingtan*
42 *Shisanling*
43 *Guangzhou II*
44 *Edolo (5 stage)*
45 *Goldisthal (two variable speed)*
47 *Venda Nova*
48 *Tai An*
49 *Siah Bishe*
50 *Waldeck I*
51 *Limberg II*
52 *La Muela II*
53 *Ingula*

Palmiet, South Africa, runner assembly

Motor-generator characteristics

Since the early beginning Voith Hydro has supplied the world's largest and most powerful units in performance and size at their time, always exceeding the existing limits.

History of generators and motor-generators



Power demand increases with the expansion of the economy and the improvement of living standards. Following this trend, the capacity of power supply units has increased continuously. From the early 20th century, Voith Hydro has manufactured motor-generators.

In 1976, the world's most powerful motor-generators for Bath County (USA) were delivered.

One of the largest capacity high-speed motor-generators were installed at Guangzhou II (China) in 2000.

Our technology sets us apart

- Motor-generator technology by Voith Hydro – including excitation, static frequency converters (SFC) and SCADA systems.
- Well advanced and proven VPI insulation system for optimized design for Class 155 according IEC (formerly Class F) and voltages up to 27 kV.
- Motor-generators are air-cooled by RIM-Ventilation or forced ventilated or direct water-cooling of stator or stator and rotor windings and also stator core.
- Magnetic thrust bearings for reduced torque during pump starts and reduced bearing losses during normal operation.
- Comprehensive system for automation of power station complex as a whole including monitoring, remote supervisory control and data acquisition of the plant with fiber optic cable as required, for control and station networks.
- Static frequency converter systems composed of computer duplex digital controller and optical thyristor of high resistance voltage for high performance and easy maintenance.

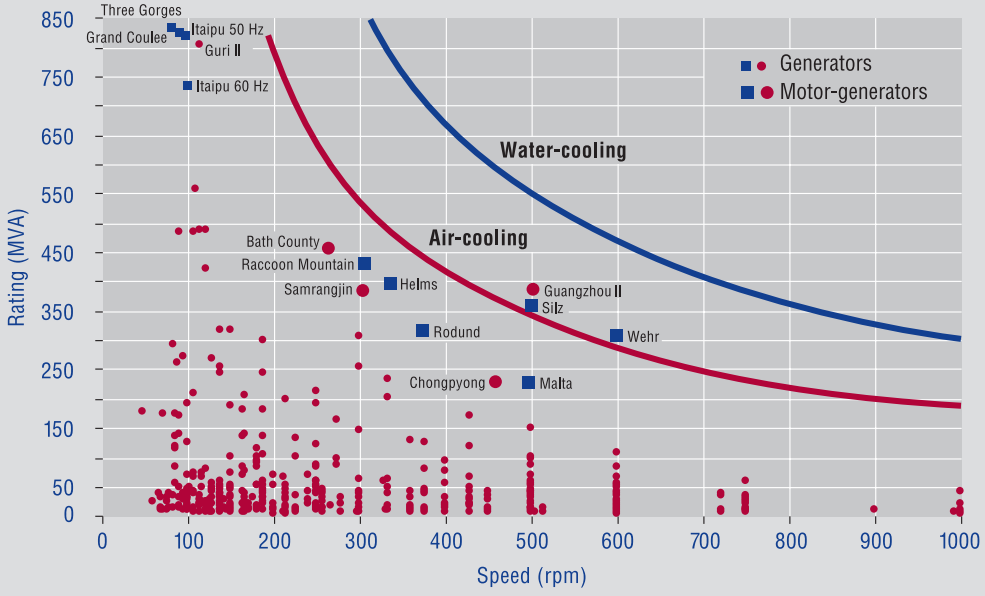
The following design criteria influence the generator's main dimensions:

- The specified output can be produced by the dimensions within the allowable limit of temperature rise of windings and stator core.
- The required moment of inertia must be provided within the given stator bore dimensions.
- The mechanical stress incurred by the rotating parts at runaway speed can be handled within the maximum allowable stresses of the specific material.
- A safe margin is provided between the first critical speed and the unit's runaway speed. Shorter lengths and lighter rotor weights help to determine this margin.
- In case of air-cooling, a shorter core length and a larger diameter are better for uniform cooling along the entire core length.

To achieve optimum economics, larger unit capacity machines are often being designed in order to reduce the number of units at each plant. In addition, high-speed rating is another important factor for smaller volume machines.

Direct water-cooling is a very effective method in compact machines. Voith Hydro has vast references in both air-cooled and water-cooled machines as shown below.

Generators and motor-generators



References and milestones

Raccoon Mountain, USA

Guangzhou, China

1908 First pumped storage plant in Germany in Voith's hydraulic research laboratory.

1937 Pedreira, Brazil:
First reversible pump-turbine in the world with an output of 5.3 MW, 30 m, 212 rpm.

1964 Roenkhausen, Germany:
First reversible motor-generator unit in a German pumped storage station.

1966 Coo-Trois Ponts 1, Belgium:
Three 145 MW, 270 m, 300 rpm pump-turbines and motor-generators.
First reversible pump-turbines in Belgium.

1970 Raccoon Mountain, USA:
Highest capacity pumped storage plant in the world at the time, with four 392 MW/425 MVA, 300 rpm pump-turbines and motor-generators and with directly water-cooled stator and rotor.

1970 Vianden 10, Luxembourg:
One 230 MVA, 333,3 rpm motor-generator.

1971 Wehr, Germany:
Worldwide highest synchronous speed for large motor-generators with four 300 MVA motor-generators and with directly water-cooled stator and rotor at 600 rpm.

1974 Rio Grande, Argentina:
Four 187.5 MW, 178 m, 250 rpm, pump-turbines, inlet valves and 210 MVA motor-generators. First reversible pump-turbines in Argentina.

1976 Bath County, USA:
The world's most powerful pump-turbines and motor-generators, six units with an output of 458 MW/447 MVA, 329 m, 257 rpm.

1977 Helms, USA:
Three motor-generators rated at 343.2 MW/390 MVA, 360 rpm with directly water-cooled stator.

1981 Samrangjin, South Korea:
Two 385 MVA, 300 rpm motor-generators.
The highest capacity reversible units in Korea.

1983 Palmiet, South Africa:
Two 253 MW/250 MVA, 301 m, 300 rpm pump-turbines and motor-generators.

Waldeck, Germany

Wehr, Germany

1992 Shisanling, China:
Four 204 MW, 430 m, 500 rpm pump-turbines and inlet valves, providing reliable peaking power for China's capital.

1994 Guangzhou II, China:
Four 306 MW/380 MVA, 510 m, 500 rpm pump-turbines and motor-generators in the world's largest pumped storage plant with a total output of 2,400 MW.

1997 Ghatghar, India:
Two 139 MW, 445 m, 500 rpm, pump-turbines and motor-generators, enhancing the quality of India's electric energy supply.

1997 Goldisthal, Germany:
Two 270 MW, 307 m, 333 rpm pump-turbines for the most recent German pumped storage plant including variable-speed technology (300-346,6 rpm).

2000 Venda Nova II, Portugal:
Two 106 MVA, 600 rpm motor-generators.

2001 Bath County, USA:
Refurbishment of stator windings and installation of new runners push these units to once again become the world's highest output pump-turbines and motor-generators at 480 MW/530 MVA.

2002 Tai An, China:
Four 278 MVA, 300 rpm motor-generators.

2004 Siah Bishe, Iran:
Four 300 MVA, 500 rpm motor-generators.

2006 Limberg II, Austria:
Two 240 MW pump-turbines with optimum design to meet wide head range application.

2007 La Muela II, Spain:
Four reversible 213 MW, 600 rpm pump-turbines and spherical valves, max. pump head 531 m, to deliver reliable power to the grid.

2008 Ingula, South Africa:
Supply of complete electro-mechanical equipment with four 342 MW/373 MVA, 428,6 rpm pump-turbines and motor-generators.

Voith Hydro Holding GmbH & Co. KG
Alexanderstrasse 11
89522 Heidenheim/Germany
Tel. +49 7321 37 0
Fax +49 7321 37 7828
info.voithhydro@voith.com
www.voithhydro.com

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