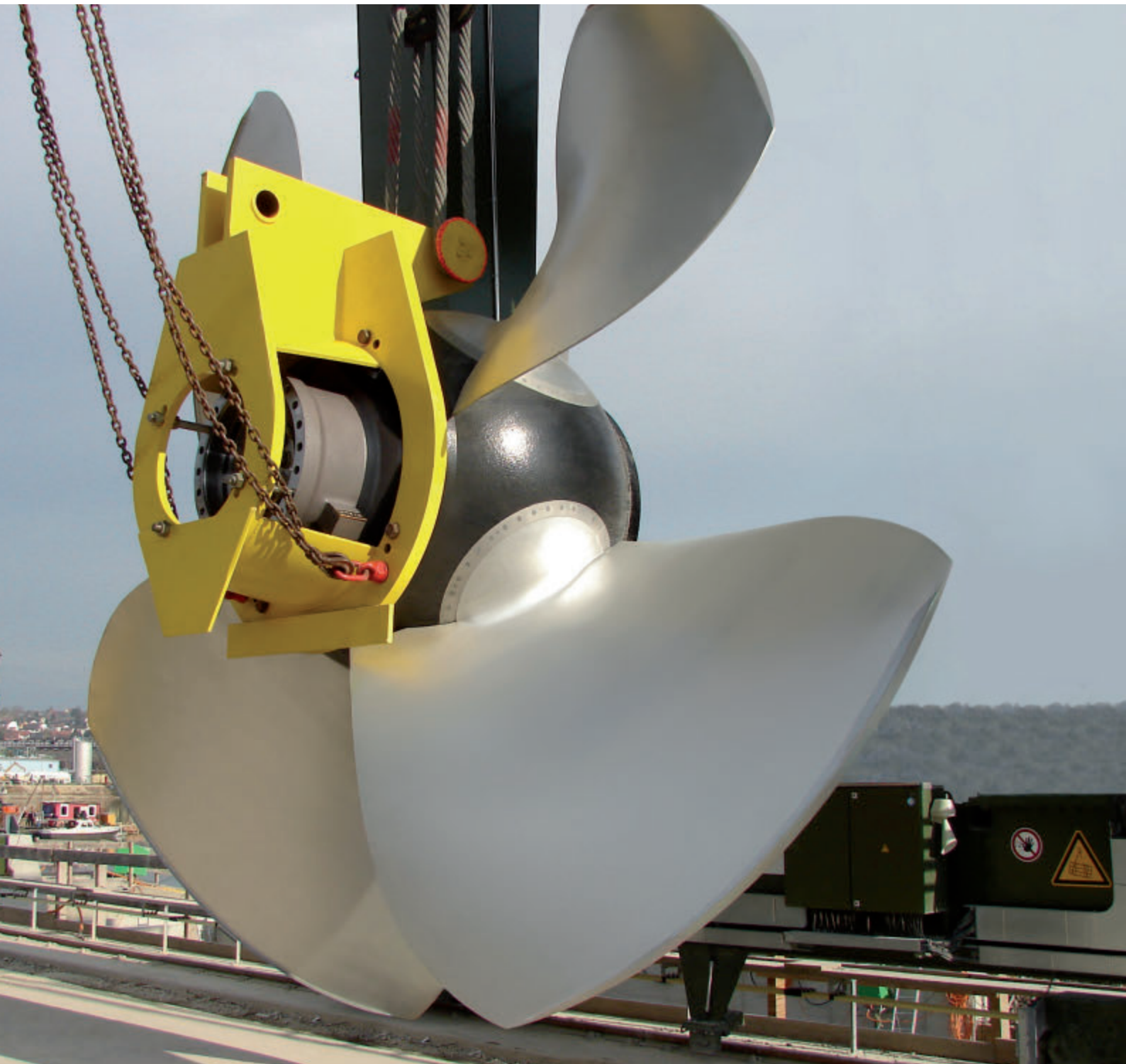


Bulb/Pit/S-Turbines and Generators





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 hydropower potential amounts to 20 billion Mega Watt hours per year and only 30 percent of this has been developed so far.

Hydropower is not only environmentally friendly, but also cost-effective. Hydropower plants have the highest operating efficiency of all renewable 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 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 one of the world's leading hydropower product and service provider.

As part of our international network each Voith 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 pro-

duction facilities for electrical and hydraulic machines and components in Europe, Asia, North and South America we are close to our customers and active in all major hydropower markets worldwide.

With more than 140 years' experience in the field of hydropower and high annual spending for research and development, Voith is well equipped to continue delivering excellence in hydropower in the years to come.



Cover picture:

Rheinfelden, Germany

1 Meldahl, Ohio River, USA

2 Rheinfelden, distributor

3 Karkamis, Firat - Euphrates, Turkey

Engineered reliability

Is our promise to our customers. Our products and services are designed specifically for our customers' needs. Always efficient and economical and, above all, following our values and visions for sustainable hydropower solutions.

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/Pit/S-turbines, pump-turbines, standard and customized products
- 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 hydropower plants and cascades, including plant management and diagnostic systems
- Shut-off valves
- Integrated Management System to safeguard excellence and quality

Turbine characteristics

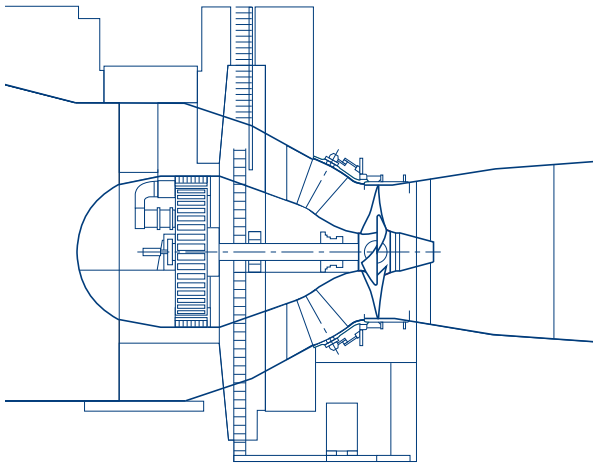
For decades, the hydraulic development, design and manufacture of bulb and pit turbines has been significantly influenced by Voith.

Characteristics

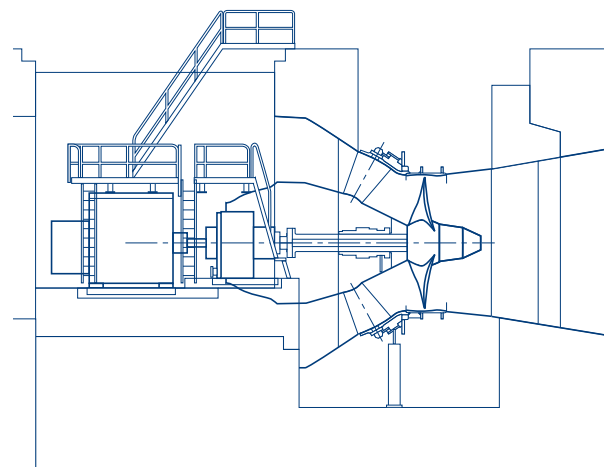
While the bulb turbine is the most common solution for high outputs at low headsites, S- and pit turbines are frequently favored for economic solutions in small hydro applications with outputs up to about 10 MW. Specific project requirements determine, which hydroelectric equipment is favorable on a case by case basis.

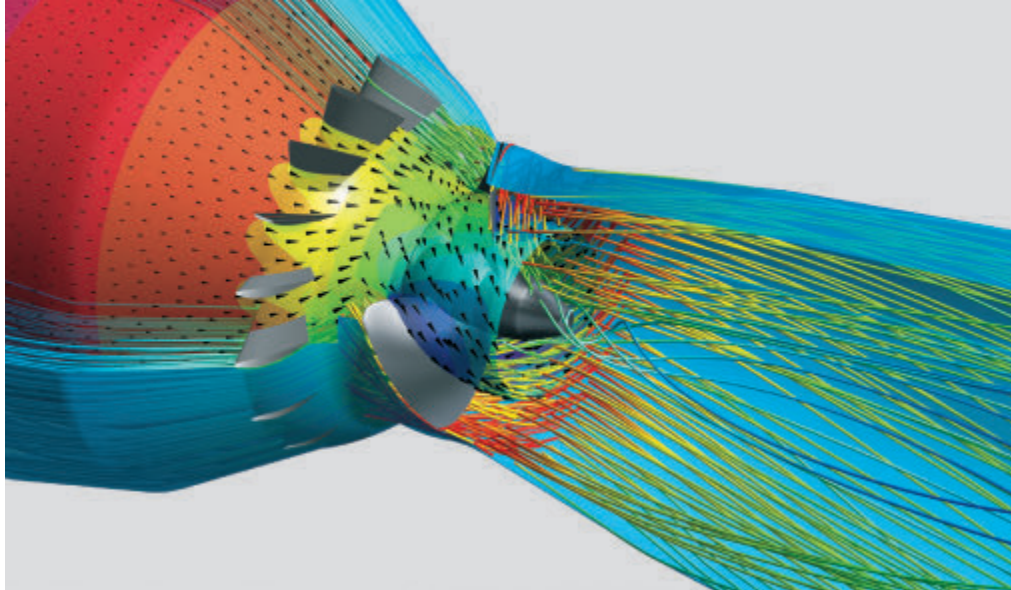
The application of pit and S-turbine units provides unique advantages. Their design provides good accessibility of various components and assures reliability and long service life.

Cross section of a bulb turbine and generator



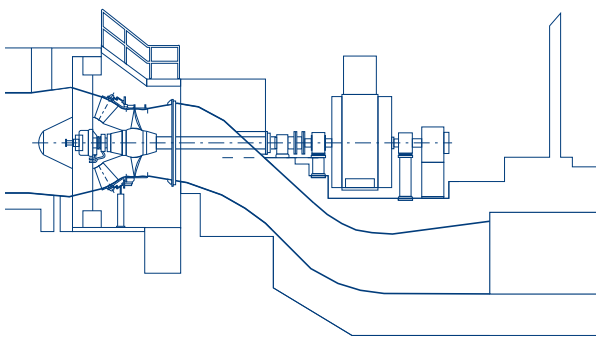
Cross section of a pit turbine, gearbox and generator



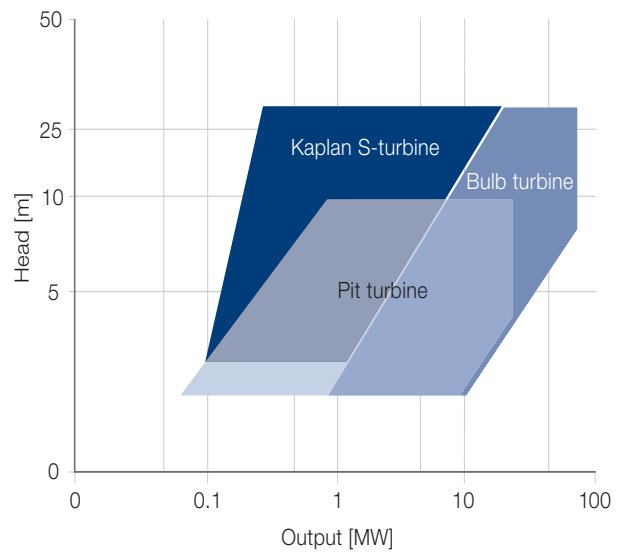


CFD illustration:
Pressure and velocity distribution in a bulb turbine

Cross section of an S-turbine and generator



Application range



Advantages of the bulb design

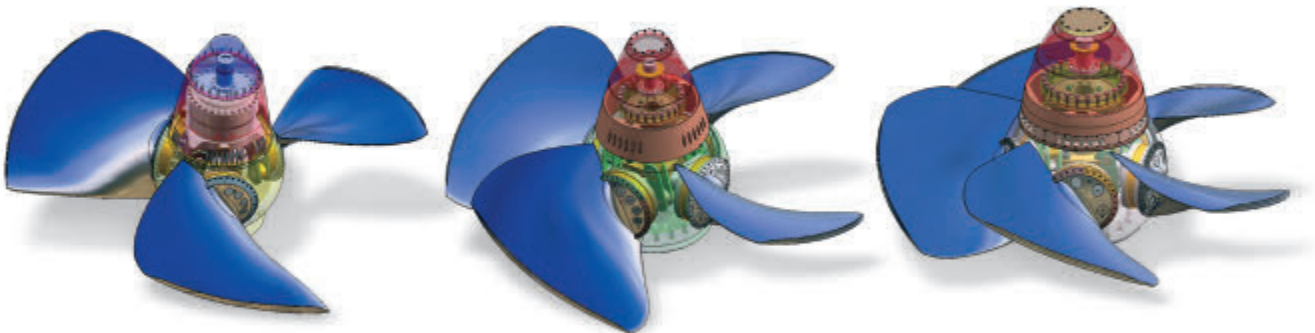
Higher full-load efficiency and higher flow capacities of bulb and pit turbines can offer many advantages over vertical Kaplan turbines.

In the overall assessment of a low head project, the application of bulb/pit turbines results in higher annual energy and lower relative construction costs.

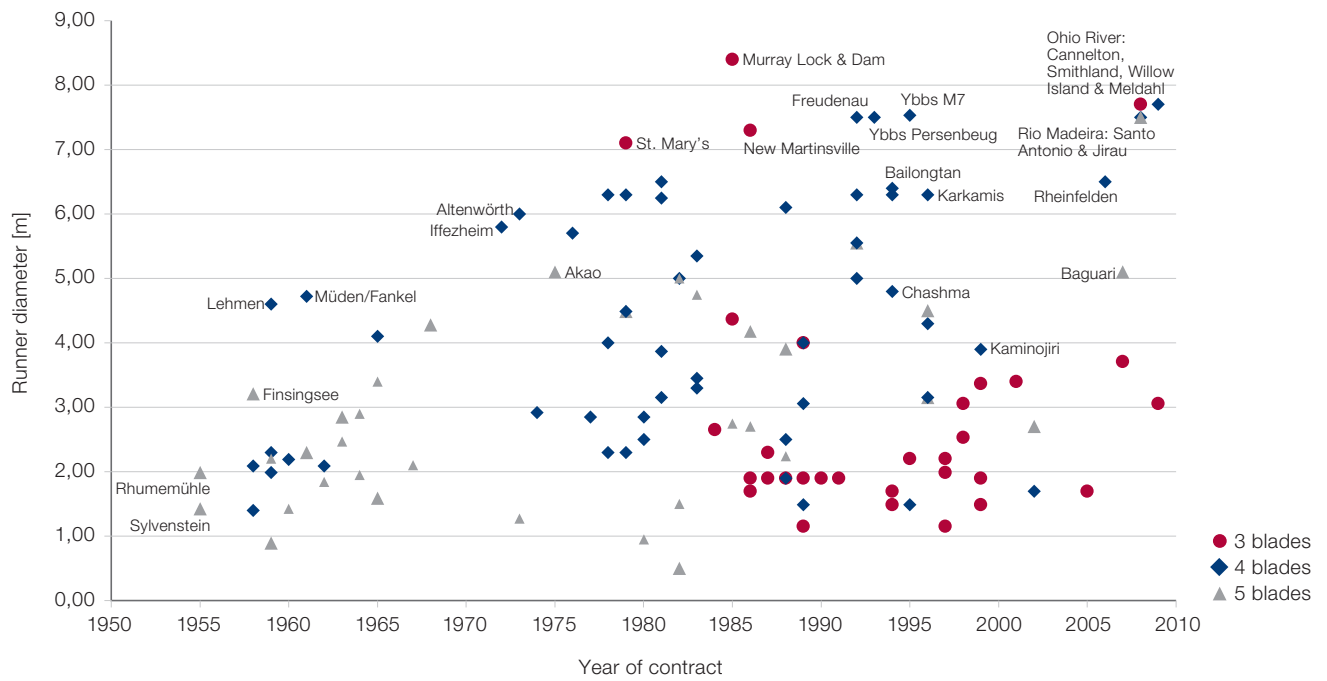
Pit-type turbines with a speed increaser located between the runner and generator are used for projects with heads lower than 10 meters. Since 1955 over 180 machines have been installed all over the world with outputs ranging from 50 kW to nearly 50,000 kW and with runner diameters between 800 mm and 8 400 mm.

Currently, units with outputs of up to 75 MW are in operation.

3-, 4-, 5-blade bulb turbine runners



Trend of runner diameter



Generator characteristics of bulb

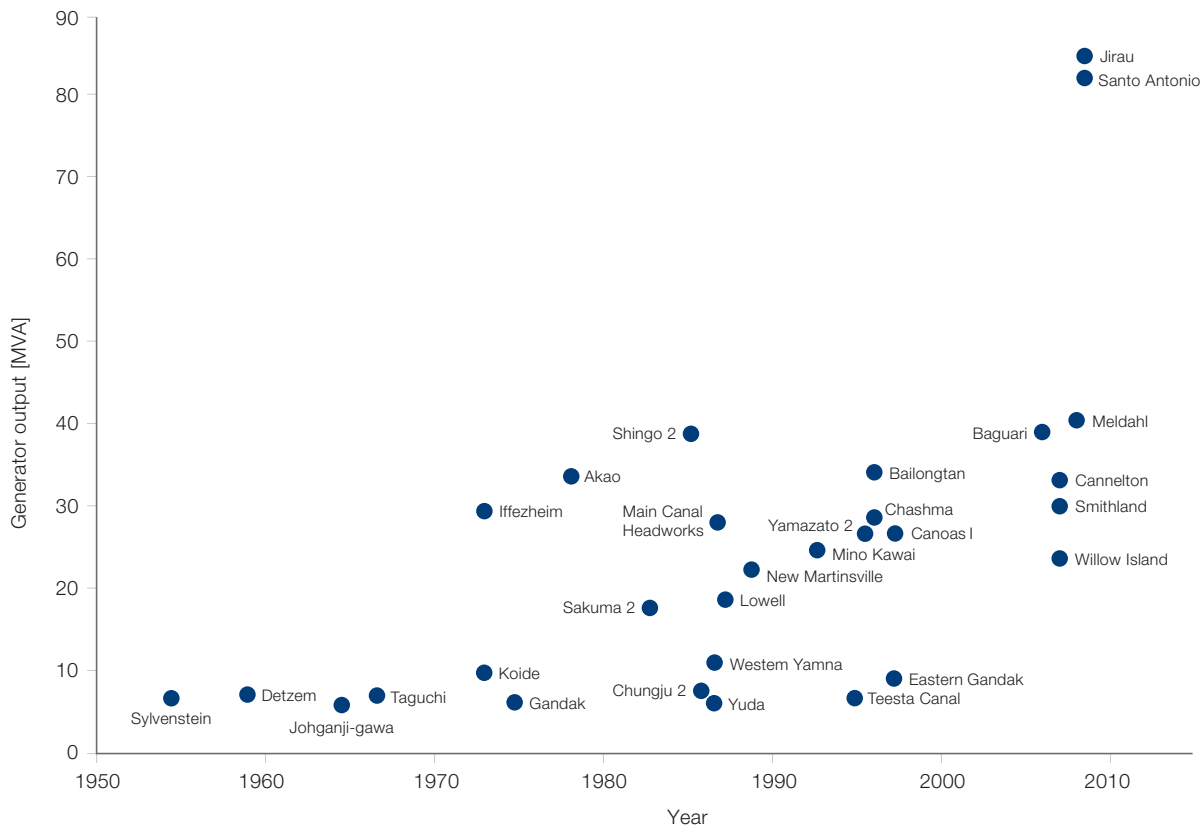
Since the mid 1950s Voith has supplied bulb generators, with new designs approaching high outputs in excess of 80 MVA.

As bulb units grew in size, generator voltage also grew from initially 3.3 and 6.6 kV to 11.0 kV or even 13.8 kV on higher capacity units. Cooling systems evolved from originally separate heat exchangers to maintenance-free closed loop systems, providing heat dissipation directly into the river water passing the bulb unit. For very high capacities and high speed units pressurized air can also be used to improve heat dissipation.

Most bulb units are arranged with two bearings: a guide bearing near the overhung turbine runner, and a combined guide and thrust bearing supported by the stay column just downstream of the generator.

The bearing systems of horizontal machines, whether for bulbs, pit-turbines or S-type machines, are arranged to handle the counter thrust associated with load rejections of such units.

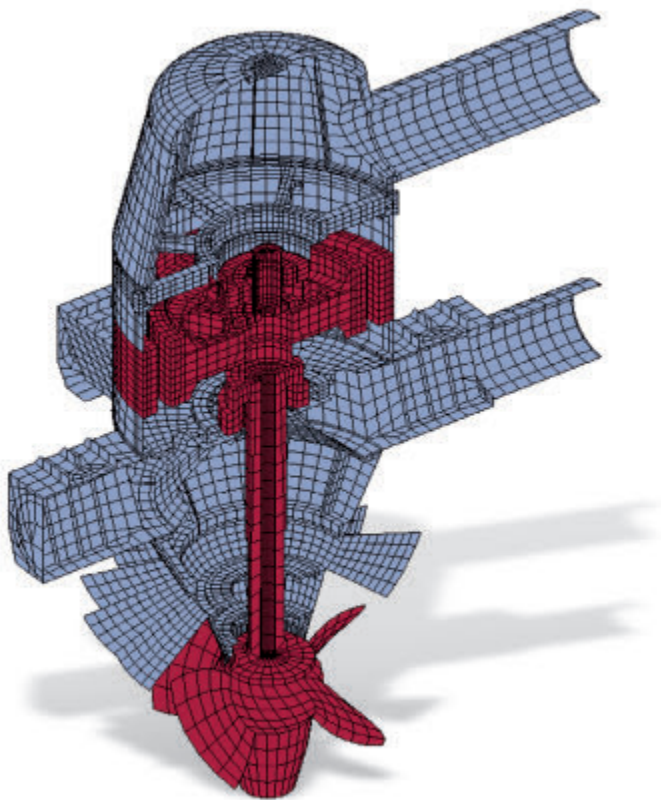
Trend of bulb generator output



Three-bearing systems are provided for certain high capacity machines, optimized for specific project requirements. The challenge in modern bulb unit designs is to achieve maximum reliability and availability, with minimum maintenance of the main units and associated auxiliaries.

With its broad experience in hydro generators for the world's largest hydroelectric facilities, and fifty years of experience in the design, manufacture and installation of bulb generators, Voith can provide fully optimized bulb, pit and S-type units for any installation.

3D section of a vertical bulb unit





- 1955** Sylvenstein, Germany:
First compact design bulb turbine.
- 1961** Fankel/Lehmen/Müden, Germany:
Four pit machines each with runner diameters between 4.6 m and 4.7 m for the Mosel River.
- 1973** Altenwörth, Austria:
Most powerful bulb turbines at the time at 44 MW output, runner diameter 6 m.
- 1978** St. Mary's, Ontario, Canada:
18 MW 3-bladed bulb turbines, runner diameter 7.1 m.
- 1978** Ma Ji Tang, Hunan, China:
First modern bulb turbine units in China at 18 MW and runner diameter 6.3 m.
- 1982** Shingo 2, Japan:
Largest bulb turbine/generator unit in Japan at the time at 40.6 MW/40.9 MVA, 5 blades and 5 m runner diameter.
- 1985** Murray Lock and Dam, AR, USA:
Largest pit turbine/generator units in the world with runner diameters of 8.4 m, rated at 20.5 MW/22.8 MVA with two-stage epicyclic speed increases.
- 1993** Ybbs-Persenbeug, Austria:
Large bulb unit at 48 MW and runner diameter of 7.5 m.
- 1994** Chashma, Pakistan:
Largest bulb power station in Pakistan equipped with eight bulb turbine/generator units each rated at 23.7 MW/21.6 MVA and 6.3 m runner diameter.
- 1994** Bailongtan, China:
Largest bulb power station in China at the time equipped with six bulb turbine/generator units each rated at 33 MW/33.7 MVA with 6.4 m runner diameter.
- 1995** Karkamis, Turkey:
Largest bulb power station in Turkey, with six 35.5 MW bulb turbines with 6.3 m runner diameter.



- 1 Shingo, Japan
- 2 Rheinfelden, Germany
- 3 Baguari, Brazil
- 4 Ohio River/Cannelton, USA

1999 Kaminojiri 2, Japan:
Vertical bulb turbine/generator
at 14 MW/14.3 MVA and runner diameter of 3.9 m.

2002 Kisköre, Hungary:
The hydraulic turbines of this power station were modernized with new runners and guide vanes. The four units have runner diameters of 4.3 m and operate at 10 m of rated head.

2004 Lower Olt, Romania:
This large project has five power houses and each is equipped with four reversible axial pump-turbines. These bulb type machines have been completely modernized. They generate 14.5 MW and have a runner diameter of 4.5 m.

2005 Toyomi, Japan:
This contract includes the largest vertical bulb turbine/generator in the world at 32 MW and runner diameter of 4.4 m.

2006 Rheinfelden, Germany:
This contract is for four new 25 MW bulb turbine units with 6.5 m runner diameter. The new Rheinfelden hydropower plant is the largest investment in renewable energies in Germany.

2007 Baguari, Brazil:
Four new 36 MW/39 MVA bulb turbine/generator units with 5.1 m runner diameter. The units are designed for heads up to 20 m.

2008 Ohio River, USA:
This contract includes four power stations: Cannelton, Meldahl, Smithland and Willow Island. Combined, these projects have an expected capacity of 321 MW/357 MVA with eleven bulb turbine/generator units altogether. The large turbines with 7.7 m runner diameter will operate at very low speed.

2008/2009 Rio Madeira, Brazil:
Two projects: Santo Antonio with 13 units each generating 75,55 MW/82,25 MVA and Jirau with ten units operating at 76,5 MW/83,33 MVA each. Both have runner diameters of 7.5 m.

2012/2016 Nam Hinboun, Laos:
2 x Bulb Turbine/ Generator Units of a rated output of 15.4 MW.

Voith Hydro Holding GmbH & Co. KG
Alexanderstraße 11
89522 Heidenheim, Germany
Tel. +49 7321 37 0
Fax +49 7321 37 7828
www.voith.com

A Voith and Siemens Company

VOITH
Engineered Reliability