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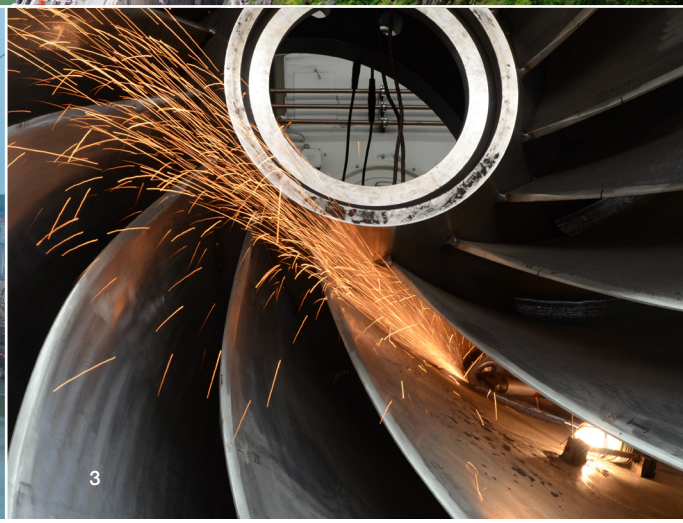
VOITH

Francis turbines



Harnessing the power of water

Generating electricity from the power of water represents large amounts of clean, renewable energy. Seventy-one percent of the earth's surface is covered by water. So far, the installed world´s hydropower potential is 4 million GWh/year. There remains a huge hydropower potential of 16 million GWh/year.

1 Xi Luo Duo, China

2 Omkareshwar, India

3 Voith workshop with Francis runner

Cover picture: Estreito, Brazil

Hydropower is a clean, renewable and environmentally friendly energy source – with low carbon dioxide emissions. Hydropower plants have the highest operating efficiency of all renewable energy generation systems. They are largely automated, and operating costs are relatively low. Hydroelectric power plants also play an important role in water resource management, flood control, navigation, irrigation and in creating recreational areas.

Customer focused and innovative

Voith is a leading full-line supplier as well as trusted partner for equipping hydropower plants all over the world. Our portfolio of products and services covers the entire life cycle and all major components of hydropower plants:

- Generators
- Turbines
- Pumps
- Automation systems
- Spare parts
- Steel structural components
- Maintenance and training services
- Digital solutions for intelligent hydropower

A world-class laboratory

Using state-of-the-art technologies and innovative digital solutions, we are committed to developing customized long-term solutions in hydropower in the years to come. At the Voith Hydro Engineering Center, scientists, engineers and measurement technicians access more than 100 years of know-how and can make use of one of the most modern hydraulic laboratories in the world. Combined with the deep domain knowledge that evolved over decades from more than 40 000 units delivered to customers, this environment paves the way to innovations of the existing product portfolio as well as new technologies.

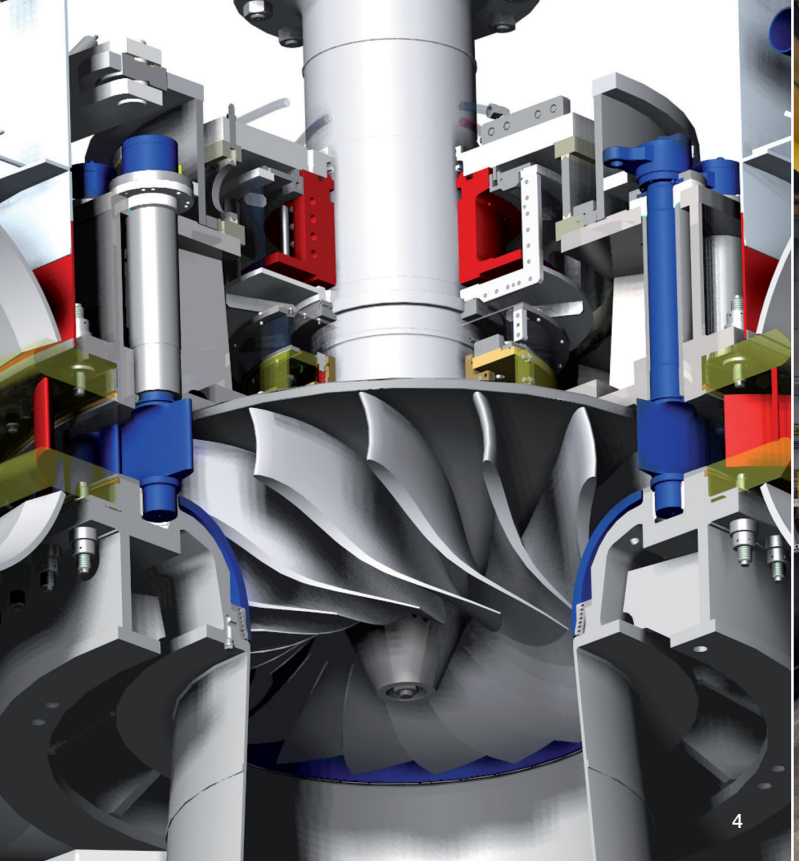
Global experts

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 production 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.

Technical reliability with highest quality standards

Voith has been known for quality right from the start. We strive to continuously meet our own high aspirations in terms of quality: Our global certification is based on well-known international standards (ISO) for quality management environmental protection as well as occupational health and safety. Moreover, we have developed our own methods for quality assurance and work according to them. In this way, future generations will continue to benefit from the quality of our work.



4 Francis turbine 3D model

5 Bratsk, Russia

Characteristics

From the beginning, Francis turbine development has always been synonymous with Voith.

With decades of continuous optimization based on the latest hydro-dynamic research, well over half the turbines manufactured by Voith are of the Francis type.

Our Francis turbines, including the world's largest and most powerful, are in service around the globe. What better testimony to our nearly 150 years of hydropower turbine experience?

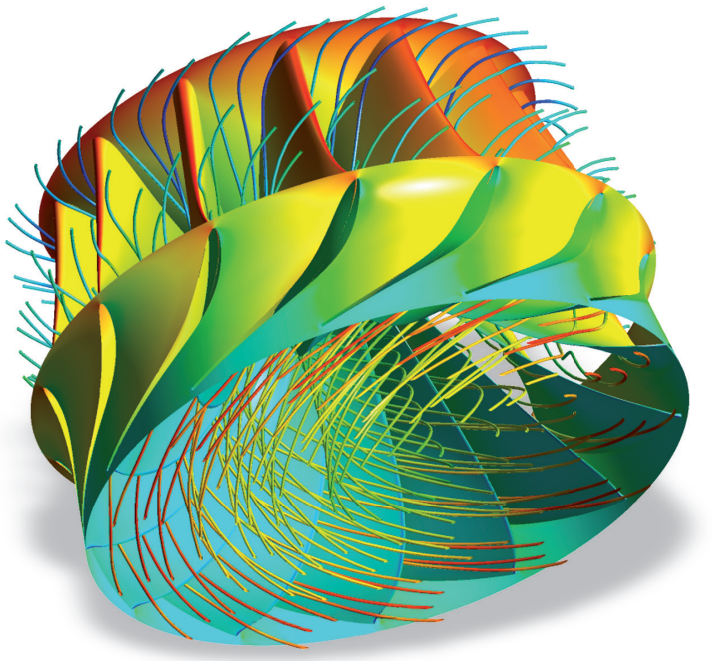
Numerical development methods linked to computer-aided manufacturing methods such as flow simulations and coupled hydro-mechanical calculations processes guarantee optimum hydraulic performance and reliability.

Our state-of-the-art Francis turbine designs are focused to respond on newly market and customer requests with respect to operational flexibility and increased demands on support of grid stability.

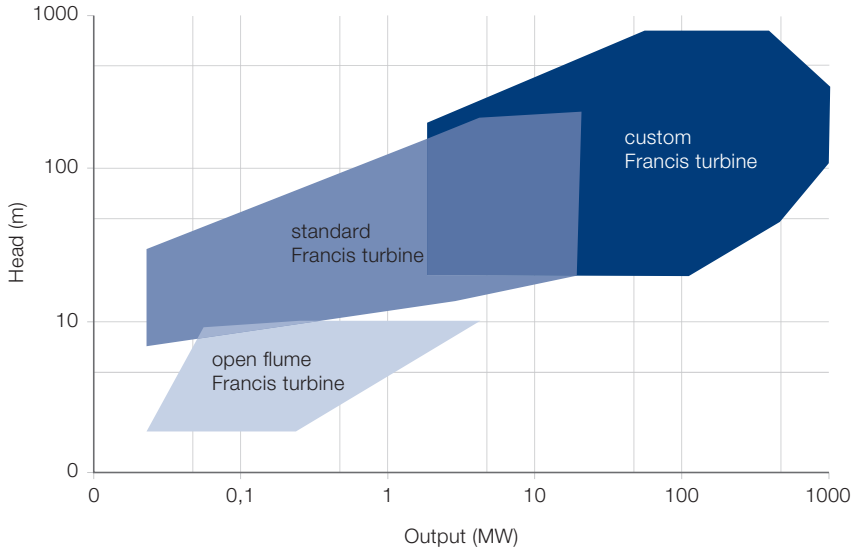
Francis turbines are used primarily for medium heads and large flow applications. Their special hydraulic characteristics result in relatively high-speed compact units, right up to the largest capacities.

Voith also supplies cost-effective Francis units in standardized designs and packages for small hydropower plants.

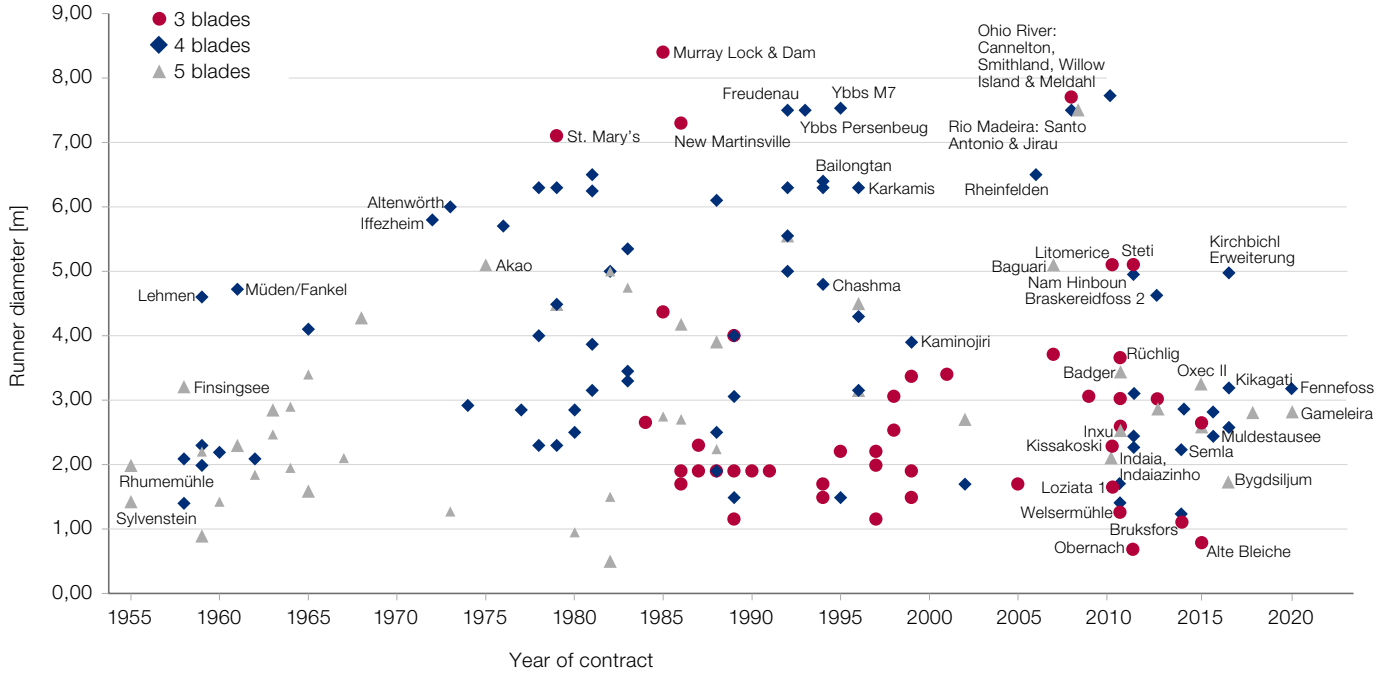
Francis turbine 3D model



Application range

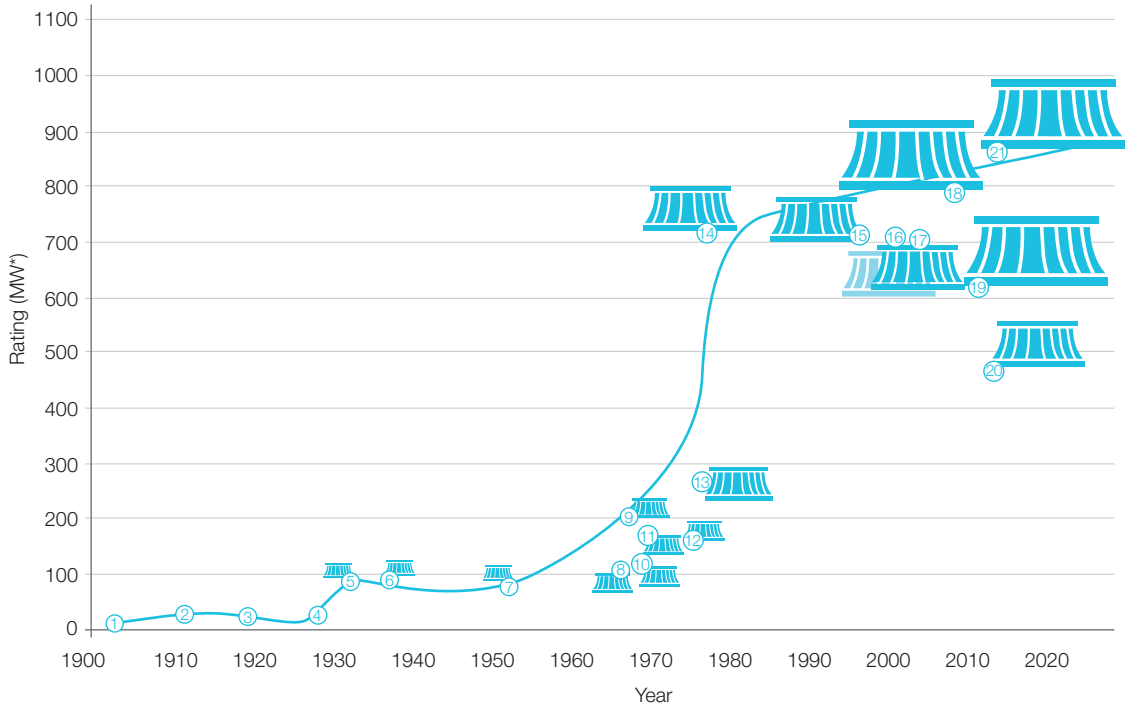


Trend of runner diameter



6 Conowingo, USA

Trend of Francis turbine output



Projects

1 Niagara
2 Niagara
3 Walchensee
4 Häusern
5 Hoover Dam
6 Sungari
7 Chief Joseph
8 Gokcekaya
9 Paulo Afonso III
10 Dworshak
11 Gordon
12 Ilha Solteira
13 Itaparica
14 Itaipu
15 Three Gorges
16 Longtan
17 Xiao Wan
18 Xi Luo Du
19 Belo Monte (Brazil)
20 Tarbela IV (Pakistan)
21 Wu Dong De (China)

Francis turbine

* Megawatt

References in recent years

1870 **Beginning of the hydropower turbine manufacturing.**

1873 **First Francis turbine with a modern distributor.**

1903 **Niagara Falls, Canada:**
Double spiral turbines with an output of 5.2 MW and with an operating head of 79.5 m. Most powerful turbines of their time.

1912 **Niagara Falls, Canada:**
Double spiral turbines with an output of 12 MW and with an operating head of 54.9 m. Most powerful turbines of their time.

1974 **Grand Coulee III, USA:**
An output of 820 MW and with an operating head of 87 m. Most powerful and largest Francis turbines in North America with 9.7 m runner diameter.

1974 **Rovina-Piastra, Italy:**
An output of133 MW at the high head of with an operating head of 554 m.

1978 **Itaipu, Brazil/Paraguay:**
An output of 800 MW and with an operating head of 118.4 m. Overall design and joint supply of turbines and generators for the most powerful hydro plant in South America at 13 300 MW.

1982 **Xingo, Brazil:**
6 x 535 MW; Francis turbines with an operating head of 111.7 m and a runner diameter of 7.2 m.

1991 **Norris Dam, USA:**
First aerating Francis turbine runner increases dissolved oxygen content for enhanced aquatic life.

1997 **Three Gorges, China:**
Participation in the supply of turbines, generators and electrical equipment for the world's largest hydroelectric power plant with a total capacity of more than 18 000 MW.

1997 **Ghazi Barotha, Pakistan:**
5 x 295 MW; vertical Francis turbines with an opera ting head of 69 m and a runner diameter of 6.4 m.

7 Itaipu, Brazil

8 Three Gorges, China

9 Eastmain, Canada

10 Grand Coulee, USA

2002 **Longtan, China:**
7 x 790 MW; Francis turbines with an operating head of 140 m; Runner diameter of 7.9 m.

2003 **Omkareshwar, India:**
8 x 66.3 MW; large low head Francis turbines with operating head in the range of about 30 m.

2005 **Xiaowan, China:**
6 x 714 MW; Francis turbines including 8.7 m outside diameter ring gates.

2006 **Revelstoke, Canada:**
1 x 512 MW; Francis turbine with an operating head of 127.1 m and a runner diameter of 7.1 m.

2007 **Jin Ping II, China:**
8 x 610 MW; high head Francis turbines equipped with ring gates; first application of the splitter blade design for a large runner (runner diameter about 6.5 m).

2007 **Eastmain 1 A, Canada:**
3 x 260 MW; Francis turbines with an operating head of 63 m and a runner diameter of 6.6 m.

2007 **Nuo Zha Du, China:**
3 x 650 MW; Francis turbines with an operating head of 187 m and a runner diameter of 7.3 m.

2008 **Xi Luo Du, China:**
3 x 784 MW; Francis turbines with an operating head of 197 m and a runner diameter of 7.7 m.

2008 **Li Yuan, China:**
4 x 612 MW, Francis turbines with an operating head of 106 m and a runner diameter of 8.2 m.

2008 **Da Gang Shan, China:**
4 x 663 MW; Francis turbines with an operating head of 160 m and a runner diameter of 7.0 m.

2009 **San Esteban II, Spain:**
1 x 177.3 MW, Francis turbine with an operating head of 95 m and a runner diameter of 4.6 m.

2010 **Waneta, Canada:**
2 x 167 MW Francis turbines with an operating head of 61 m and a runner diameter of 5.5 m.

2011 **Bratskaya, Russia:**
Refurbishment and runner replacement for 6 x 255 MW Francis turbines, operating head of 100 m, runner diameter of 5.6 m.

2011 **Belo Monte, Brasil;**
Participation of 4 from 14 total turbine and generator units including electrical equipment; Francis turbines with an operating head of 87 m and 620 MW output each; runner diameter of 8.4 m.

2014 **Tarbela 4th Extension, Pakistan:**
3 x 477 MW; Francis turbines with an operating head of 101 m, runner diameter of 7.9 m.
Project with the world biggest double disc closing valve with a diameter of 7.5 m.

2014 **Gemeinschaftskraftwerk Inn, Austria;**
2 x 51 MW; Francis turbines with an operating head of 132 m; Silt protected turbine design with runner diameter of 2.2 m.

2015 **Wu Dong De, China:**
6 x 862 MW; Francis turbines with an operating head of 137 m, one of the world largest runner diameter of 9.7 m; Project with the highest output supplied by Voith Hydro.

2015 **Wu Nong Long, China:**
4 x 253 MW; Francis turbines with an operating head of 81 m; runner diameter of 6.0 m.

2016 **Site C, Canada:**
6 x 208 MW; Francis turbines with an operating head of 50 m, runner diameter 7.5 m.

2016 **Skjerka, Norway;**
1 x 103 MW; Francis turbine with an operating head of 360 m; Splitter blade runner diameter 2.8 m; High head francis turbine project with splitter blade runner.

2017 **Yang Fang Gou, China:**
4 x 382 MW; Francis turbines with operating head of 99 m; runner diameter 6.9 m.

12

11 Longtan, China

12 Pakal Dul, India

2017 **Ffestiniog, Wales;**
2 x 92 MW, Refurbishment of Francis turbines with an operating head of 279 m, runner diameter of 2.6 m. Project with ternary turbines for frequency and grid control with shaft through draft tube.

2019 **Pakal Dul, India:**
4 x 279 MW; Francis turbines with an operating head of 397 m, runner diameter of 4.2 m.

2020 **La Xi Wa Unit 4, China:**
First 0 to 100 % Power Output Francis turbine with an maximum output of 711 MW at an operating head of 205 m; runner diameter of 6.9 m. Special turbine for grid frequency control to balance wind and solar energy power station.

Voith Group
Voith Hydro Holding GmbH & Co. KG
Alexanderstr. 11
89522 Heidenheim, Germany

Contact:
Phone +49 7321 37-0
www.voith.com/hydro