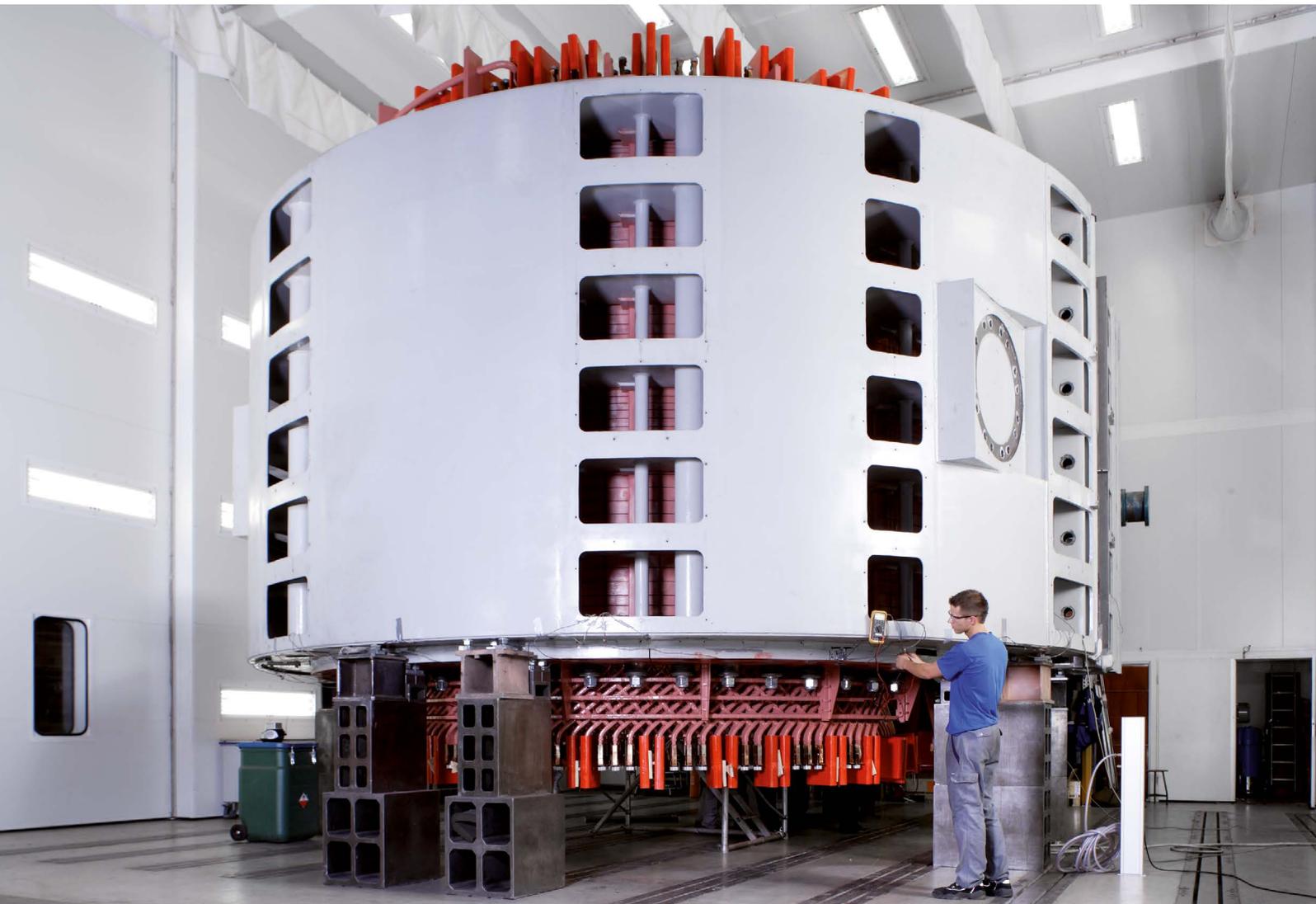


Generators





Revelstoke, Canada

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.

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 and an industry leader in the production of generators 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.



Characteristics

For well over a century, Voith has supplied the world's largest and most powerful hydroelectric units with respect to both performance and size. As we push the envelope in hydropower technology, Voith focuses on customized solutions for utilities.

Power demand increases with the expansion of the economy and improved living standards. Following this trend, the capacity of generating units has also increased, growing from 6.25 MVA at Necaxa in 1903 up to 840 MVA at Three Gorges in 1997 and now to more than 855.6 MVA at the Xi Luo Du and even 944.5 MVA at the Wu Dong De power station. These are the most powerful generators designed and manufactured by Voith today.

To improve optimum project economics, higher unit capacity machines are often used in order to reduce the number of units at each plant. For compact machines, direct water cooling is very effective. Within the renewable energies, pumped storage plants play a new role with the use of variable speed technology to directly support grid control.

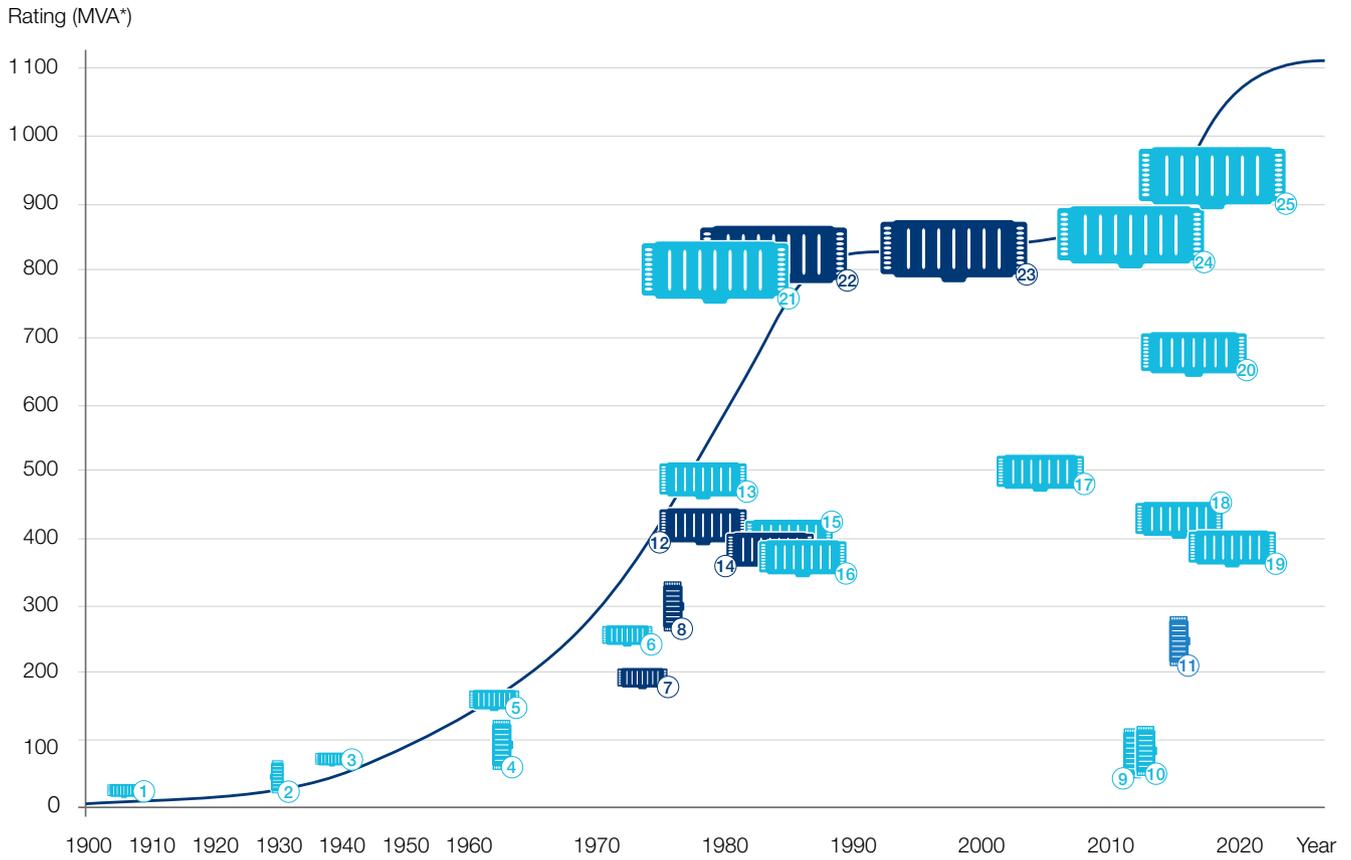
Frades II is a milestone in hydropower: thanks to their variable speed based of DFIM (Doubly Fed Induction Machine), the pumped storage units designed and supplied by Voith can adapt their number of revolutions continuously and take or provide power from and to the grid.

Above this, the asynchronous motor generators can also be utilized for frequency stabilization of the grid. The highly sensitive control systems react to grid variations within milliseconds, can tap the kinetic energy of the flywheel masses of the motor generators, and provide immediately energy to the grid, or respectively absorb energy from it. Facing variations in the grid, the motor generators react extremely fast and in the case of faults can compensate voltage drop accordingly – and thus enhance security of power supply.

With a maximum continuous output of 433 MVA and a speed range from 350 rpm to 381.2 rpm, those are the most powerful variable speed motor generators in Europe built so far.

Another milestone in hydropower is the powerhouse at Limberg I in Austria. The built-in synchronous full inverter machine provides a maximum continuous output of 81.5 MVA and a speed range from 400 rpm to 750 rpm.

History of generators and motor generators



Projects

- | | |
|----------------------------|----------------------------------|
| 1 Necaxa, Mexico | 14 Helms, USA |
| 2 Herdecke, Germany | 15 Bath County, USA |
| 3 Suiho, China | 16 Samrangjin, South Korea |
| 4 Vianden, Luxembourg | 17 Bath County MOD, USA |
| 5 Furnas, Brazil | 18 Frades II (DFIM***), Portugal |
| 6 El Chocon, Argentina | 19 Chang Long Shan, China |
| 7 Rottau/Malta, Austria | 20 Belo Monte, Brazil |
| 8 Wehr, Germany | 21 Guri II, Venezuela |
| 9 Santo Antonio, Brazil | 22 Itaipu, Brazil/Paraguay |
| 10 Jirau, Brazil | 23 Three Gorges, China |
| 11 Riel (SC**), Canada | 24 Xi Luo Du, China |
| 12 Raccoon Mountain, USA | 25 Wu Dong De, China |
| 13 Paulo Afonso IV, Brazil | |

-  Water-cooled
-  Air-cooled
-  Hydrogen

- * Mega volt ampere
- ** Synchronous Condenser
- *** Doubly Fed Induction Machine

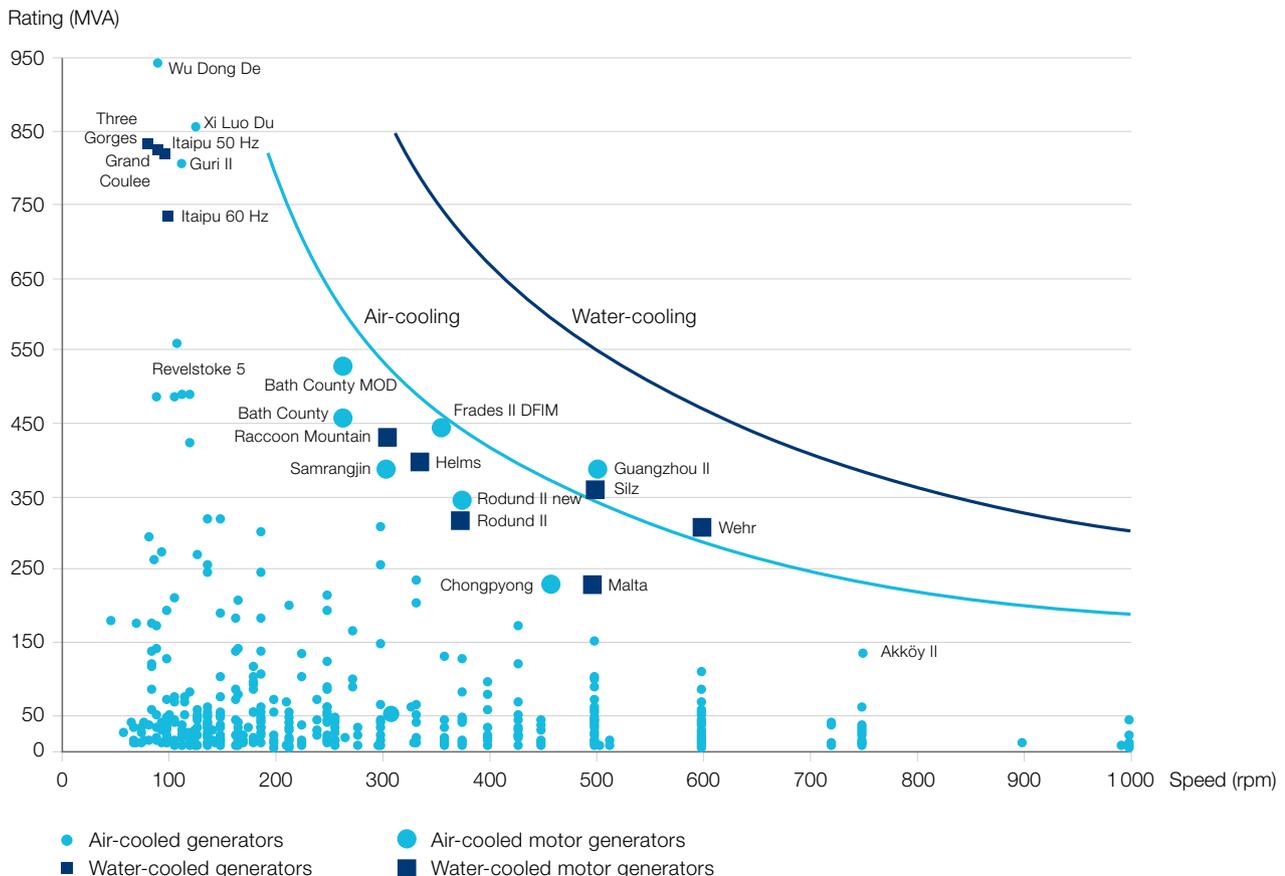
Design criteria

Voith is setting milestones with its generator technology. Customers benefit from our deep understanding of sophisticated engineering and conceptual competence in project execution.

And at the same time, our engineers incorporate the cause and effects of the related components of the entire plant. We master the interplay of thinking outside the box and traditional engineering in order to provide a highly reliable generator that offers the state-of-the-art technology.

We keep in mind what customers are looking for: efficiency, easy handling, absolute reliability. Two of the world's most powerful synchronous generators are part of the Xi Luo Du power plant in China with a maximum output of 855.6 MVA at 125 rpm and the Wu Dong De power plant with a maximum output of 944.5 MVA at 90.9 rpm.

Generators and motor generators





Frades II, Portugal

The following design criteria influence the generator's main dimensions

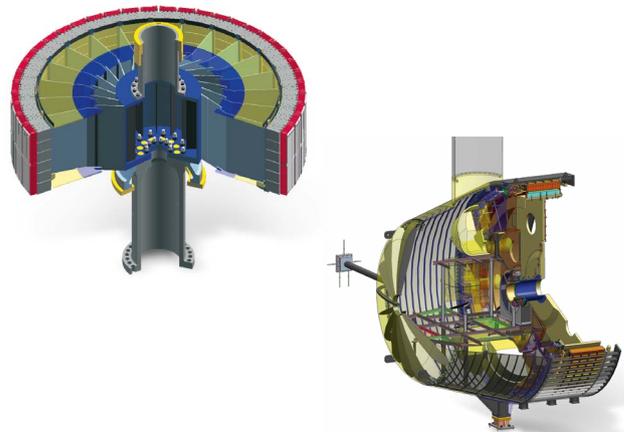
- In order to ensure a long and reliable operation, it is essential that operational temperatures are aligned with the allowable limits of the materials, especially those of the winding with respect to the applied insulation system.
- The required moment of inertia must be provided within the given stator bore dimensions:
 - to enhance the grid stability and improve the LVRT (Low Voltage Ride Trough) characteristic
 - to increase the time until the power unit achieves the runaway speed
 - to reduce the water hammer pressure
 - to guarantee turbine regulation at shutdown
- At runaway speed the mechanical stress incurred by the rotating parts shall be designed within the maximum allowable stresses of the specific material and load universe for static as well as dynamic integrity.
- A safety margin is provided between the first critical speed and the unit's runaway speed. A shorter and lighter rotor helps to achieve this margin.
- For air-cooled machines, a shorter core length and a larger diameter might be suitable for uniform cooling along the entire core length and windings.

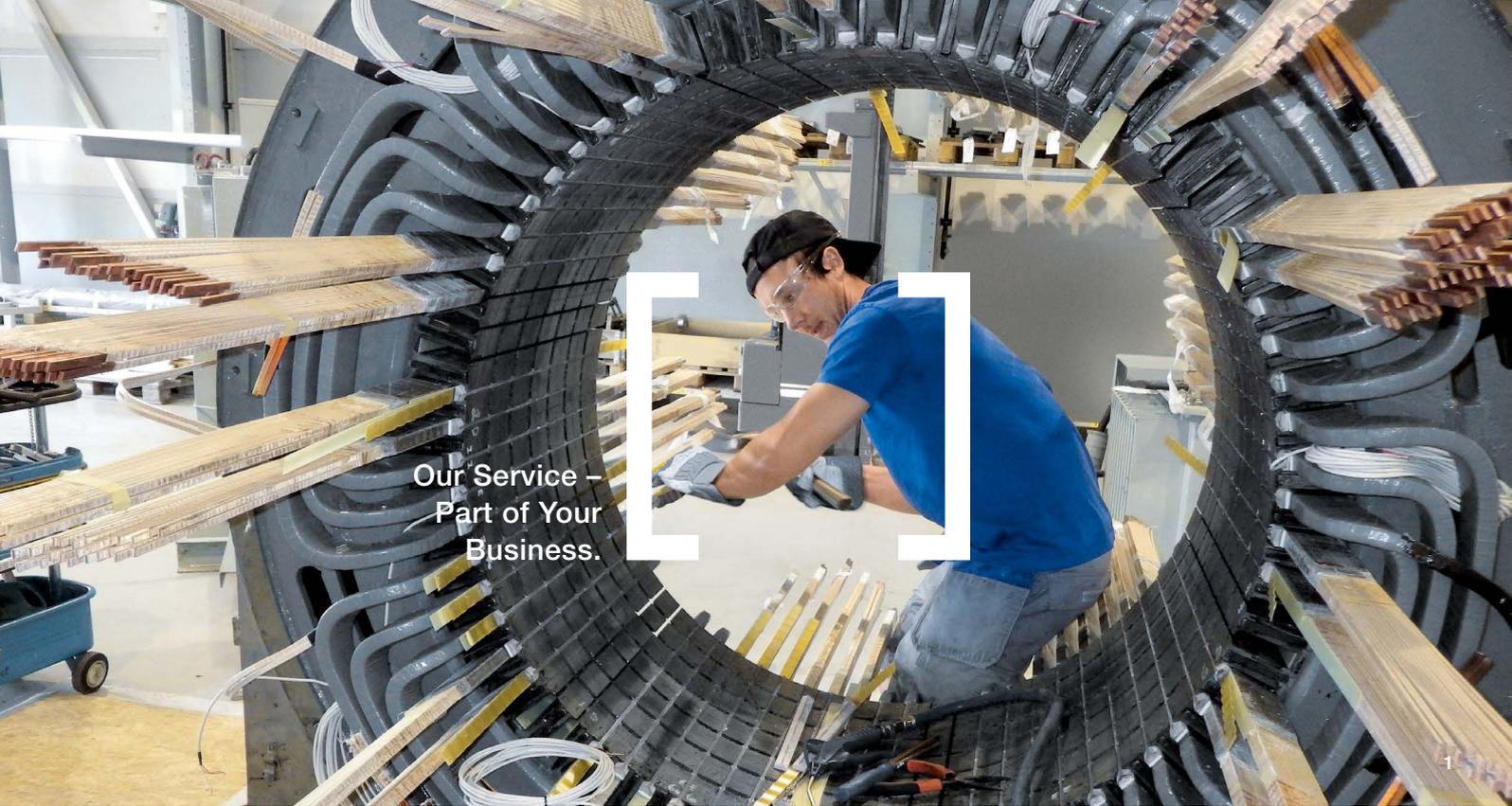
Voith has vast references in water-cooled machines and has designed the world's largest and most powerful air-cooled hydropower generators, including Guri II (Venezuela) rated at 805 MVA and the 672 MVA units at Grand Coulee II (USA), as well as the world's largest and most powerful directly

water-cooled units at Itaipu (Brazil/Paraguay) rated at 823.6 MVA and the 840 MVA units at Three Gorges (China). These records have been broken with the totally air-cooled generators for the Xi Luo Du power station (China) with a rated output of 855.6 MVA and for the Wu Dong De power plant (China) with a rated output of 944.5 MVA.

All Voith generators are designed and manufactured with the latest state-of-the-art technology including the use of Vacuum Pressure Impregnation (VPI) for the stator bars and coils. Rated voltages up to 25 kV are part of our standard production.

3D generator models

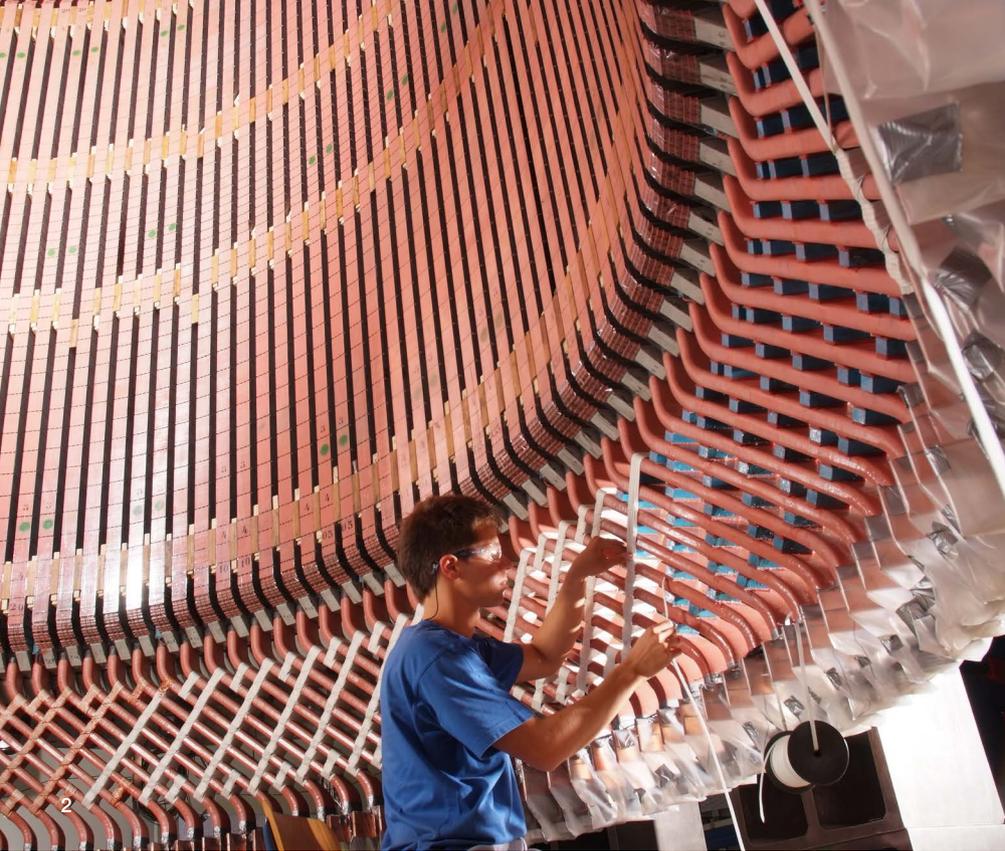




Our Service –
Part of Your
Business.

Keep your energy flowing HyService and modernization

Over decades, generators have been running reliably. To ensure continuous and first-class operation in the future, extensive service and maintenance will be indispensable to prevent or solve your problems effectively.



- 1 Manual bar assembly into a 70-year-old stator with semi-closed slot in a generator workshop of Voith Hydro, Norway
- 2 Application of end-winding reinforcement

Voith offers comprehensive and tailor-made first-class service and modernization solutions. Reliable service management incorporates the idea of thinking forward. Our HyService teams at Voith offer repairs, spare parts, preventive maintenance, inspections and assessments. Our focus is clear: Voith is your partner to extend the lifetime of your hydropower plant at any point of its life cycle. And we want to keep it running smoothly. As an experienced service partner, we support you in any part of the plant's operation. Reliable. Experienced. Available all around the world.

Consider our modernization project of the pumped storage plant Wehr in southern Germany. By completely renewing the motor generators, Voith increased the efficiency and especially the reliability of the machines. This included the refurbishment of the stator and rotor using modern state-of-the-art calculation methods, materials and design features. During the Bath County modernization that started in 2005, we delivered six new state-of-the-art stator windings and later six completely new rotors; each motor generator now has a rated output of 530 MVA instead of the original 389 MVA.

This helped, among other modernization measures, to re-establish Bath County as the pumped storage power plant with the highest power output in the world. For a successful modernization such as these examples, you have to consider the complete design of the plant and at the same time investigate the different options for service, refurbishment and renewal of every single part of your generators. We at Voith develop new, high-quality parts and refurbish existing parts to deliver what you really need. For instance, our engineers think of individual solutions to deliver the outstanding Micalastic insulation from our modern factories in Mississauga (Canada), São Paulo (Brazil) or Shanghai (China).

Get in touch with us! Contact:
HyService@Voith.com

Synchronous generators

References

- 1867** Werner von Siemens invents the direct current dynamo.
- 1881** Start of design and manufacturing of direct current dynamos at Siemens factory in Berlin.
- 1895** **Kuråsfossen, Norway**
First alternating current generator for a hydropower station.
- 1903** **Necaxa, Mexico**
World record: 6.25 MVA generator.
- 1938** **Fengman, China**
The world's first 100 MVA generators.
- 1941** **Grand Coulee I, USA**
The world's first 108 MVA generators.
- 1969** **El Chocon, Argentina**
First generator with a stator bore diameter of 16 m.
- 1976** **Guri II, Venezuela**
Most powerful air-cooled generators with 805 MVA.
- 1978** **Itaipu, Brazil / Paraguay**
Complete mechanical design for the world's most powerful hydroelectric plant (13 300 MW).
Maximum output of each unit: 823.6 MVA.
- 1982** **Xingo, Brazil**
Design and supply of six generators with 555 MVA and rated speed 109.1 rpm.
- 1992** **Grand Coulee III, USA**
New water-cooled stators for the largest hydroelectric generators in the world to date, rated 826 MVA per unit with an outside diameter of 23 m.
- 1997** **Three Gorges, China**
Design and supply of generators and electrical equipment for the largest hydroelectric power plant in the world with an ultimate total capacity of more than 22 500 MW.
- 1998** **Lajeado, Brazil**
Design and supply of five generators with 190 MVA and rated speed 100 rpm.
- 1999** **Baspa II, India**
Design and supply of two generators with 122.1 MVA and rated speed 375 rpm.
- 1999** **Cana Brava, Brazil**
Design and supply of three generators with 163.4 MVA and rated speed 90 rpm.
- 2002** **Irape, Brazil**
Design and supply of three generators with 127 MVA and rated speed 300 rpm.
- 2002** **Peixe Angical, Brazil**
Design and supply of three generators with 175 MVA and rated speed 85.7 rpm.
- 2003** **Omkareshwar, India**
Design and supply of eight generators with 80 MVA and rated speed 107.1 rpm.
- 2005** **Yeywa, Myanmar**
Design and supply of four generators with 230 MVA and rated speed 142.8 rpm.
- 2005** **Gilgel Gibe II, Ethiopia**
Design and supply of four generators with 125 MVA and rated speed 333 rpm.
- 2005** **El Platanal, Peru**
Design and supply of two generators with 120 MVA and rated speed 450 rpm.
- 2006** **Holtwood, USA**
Design and supply of two generators with 64.1 MVA and rated speed 85.7 rpm.
- 2006** **Mazar, Ecuador**
Design and supply of two generators with 100 MVA and rated speed 257.1 rpm.

- 2006 Revelstoke, Canada**
Design and supply of one generator with 532 MVA and rated speed 112.5 rpm.
- 2007 Eastmain 1A, Canada**
Design and supply of three generators with 285 MVA and rated speed 100 rpm.
- 2007 Karcham Wangto, India**
Design and supply of four generators with 340 MVA and rated speed 214.3 rpm.
- 2007 Svartisen, Norway**
Design and supply of one generator with 320 MVA and rated speed 375 rpm.
- 2008 Long Kai Kou, China**
Design and supply of five generators with 400 MVA and rated speed 83.3 rpm
- 2008 Xi Luo Du, China**
Design and supply of three totally air-cooled 855.6 MVA generators. Voith's most powerful generator at the time.
- 2008 Akköy II, Turkey**
Design and supply of air-cooled generators with rated speed of 750 rpm and a rated output of 135 MVA.
- 2009 San Esteban II, Spain**
Design and supply of one generator with 210 MVA and rated speed 166.7 rpm.
- 2010 Waneta, Canada**
Design and supply of two generators with 186.1 MVA and rated speed 112.5 rpm.
- 2010 Embretsfoss IV, Norway**
Design and supply of one generator with 56 MVA and rated speed 93.8 rpm.
- 2010 Ferreira Gomez, Brazil**
Design and supply of three generators with 94 MVA and rated speed 90 rpm.
- 2011 Budarhals, Iceland**
Design and supply of two generators with 45 MVA and rated speed 166.7 rpm.
- 2011 Teles Pires, Brazil**
Design and supply of five generators with 404.45 MVA and rated speed 75 rpm.
- 2011 Belo Monte, Brazil**
Design and supply of four generators with 679 MVA and rated speed 90 rpm.
- 2012 Las Lajas, Brazil**
Design and supply of two generators with 146 MVA and rated speed 300 rpm.
- 2012 Alfalfal II, Chile**
Design and supply of two generators with 145.2 MVA and rated speed 600 rpm.
- 2013 Cambambe II, Angola**
Design and supply of four generators with 195.5 MVA and rated speed 187.5 rpm.
- 2013 Great Millenium, Ethiopia**
Design and supply of four generators with 417 MVA and rated speed 125 rpm.
- 2014 Tarbela IV, Pakistan**
Design and supply of three generators with 522 MVA and rated speed 107.14 rpm.
- 2014 Keeyask, Canada**
Design and supply of seven generators with 117 MVA and rated speed 69.23 rpm.
- 2019 Wu Dong De, China**
Design and supply of six generators with 944.5 MVA and rated speed 90.9 rpm.

Motor generators

References

- 1962 Erzhausen, Germany**
Design and supply of two motor generators with 62.5 MVA and rated speed 428.6 rpm.
- 1964 Roenkhausen, Germany**
First reversible motor generator unit in a German pumped storage station.
- 1970 Raccoon Mountain, USA**
Most powerful reversible pumped storage motor generators in the world at the time, with four 425 MVA units and directly water-cooled stator and rotor.
- 1971 Wehr, Germany**
Design and supply of four motor generators with 300 MVA and rated speed 600 rpm.
World most powerful machines with 600 rpm.
2008 modernization: New stator
2010 modernization: New rotor
- 1972 Rodund II, Austria**
Europe's most powerful reversible motor generator at the time with 310 MVA and water-cooled stator and rotor.
- 1973 Malta Hauptstufe, Austria**
Design and supply of four motor generators with 220 MVA and rated speed 500 rpm.
- 1976 Bath County, USA**
Largest pumped storage reversible motor generators in the world at the time, with six 447 MVA air-cooled units.
- 1976 Chongpyong, Korea**
Design and supply of two reversible motor generators with 220 MVA and rated speed 450 rpm.
- 1979 Leitzach I, Germany**
Design and supply of one reversible reversible motor generator with 60 MVA and rated speed 333.3 rpm.
- 1983 Palmiet, South Africa**
Design and supply of two reversible motor generators with 250 MVA and rated speed 300 rpm.
- 1985 Herdecke, Germany**
Design and supply of one reversible motor generator with 190 MVA and rated speed 250 rpm.
- 1992 Bhira 1, India**
Design and supply of one reversible motor generator with 176.5 MVA and rated speed 500 rpm.
- 1994 Guangzhou II, China**
Design and supply of four reversible motor generators with 380 MVA and rated speed 500 rpm. World most powerful machines with 500 rpm.
- 2000 Venda Nova II, Portugal**
Design and supply of two reversible motor generators with 106 MVA and rated speed 600 rpm.
- 2004 Zhanghewan, China**
Design and supply of four reversible motor generators with 278 MVA and rated speed 333.3 rpm.
- 2002 Taian, China**
Design and supply of four reversible motor generators with 278 MVA and rated speed 300 rpm.
- 2005 Bath County Modernization, USA**
New air-cooled winding for the six world's most powerful reversible motor generators with 530 MVA rated capacity.
- 2006 Waldeck 1, Germany**
Design and supply of one reversible motor generators with 81 MVA and rated speed 500 rpm.
- 2008 Ingula, South Africa**
Design and supply of four reversible motor generators with 373.2 MVA and rated speed 428.6 rpm.

2010 Frades II, Portugal

Design and supply of Europe's largest and most powerful variable speed reversible motor generators (DFIM) with 433 MVA and speed range from 350 rpm up to 381 rpm.

2010 Rodund II new, Austria

Design and supply of totally air-cooled reversible motor generator with 345 MVA and rated speed 375 rpm.

2012 Hong Ping, China

Design and supply of four reversible motor generators with 333 MVA and rated speed 500 rpm.

2014 Lam Ta Khong, Thailand

Design and supply of two motor generators with 282 MVA and rated speed 428.6 rpm.

2017 Chang Long Shan, China

Design and supply of two motor generators with 389.9 MVA and rated speed 600 rpm.

2018 Xia Men, China

Design and supply of four motor generators with 389.9 MVA and rated speed 428.6 rpm.

2018 Limberg I, Austria

Design and supply of two motor generators with full inverter with 81.5 MVA and speed range from 400 rpm up to 750 rpm.

Bulb generators

References

1973 Iffezheim, Germany

Design and supply of four generators with 29 MVA and rated speed 100 rpm.

1988 Oberaudorf-Ebbs, Austria

Design and supply of two generators with 35 MVA and rated speed 93.8 rpm.

1993 Bai Long Tan, China

Design and supply of six generators with 33.68 MVA.

1994 Chasma, Pakistan

Design and supply of eight generators with 26 MVA and rated speed 85.7 rpm.

2007 Baguari, Brazil

Design and supply of two generators with 39 MVA and rated speed 128.6 rpm.

2008 Santo Antonio, Brazil

Design and supply of the world's most powerful bulb generators at the time with a rated output of 82.25 MVA.

2008 Willow Island, USA

Design and supply of two generators with 23.72 MVA and rated speed 58.1 rpm.

2008 Smithland, USA

Design and supply of three generators with 29.9 MVA and rated speed 60 rpm.

2008 Cannelton, USA

Design and supply of three generators with 33.08 MVA and rated speed 62.1 rpm.

2009 Jirau, Brazil

Design and supply of four of the world's most powerful bulb generators at the time with 83.33 MVA and rated speed 94.7 rpm.

2009 Meldahl, USA

Design and supply of three generators with 40.3 MVA and rated speed 64.3 rpm.

2012 Nam Hinboun, Laos

Design and supply of two generators with 16.3 MVA and rated speed 107.1 rpm.

2017 Kirchbichl, Austria

Design and supply of one generator with 20 MVA and rated speed 100 rpm.

Synchronous condensers

References

2015 Riel, Canada

Design and supply of four units with 250 MVAR and rated speed 1200 rpm.

2017 Janaúba 3, Brazil

Design and supply of two units with 150 MVAR and rated speed 900 rpm.

2017 Terminal Rio, Brazil

Design and supply of two units with 150 MVAR and rated speed 900 rpm.

2017 Ariquemes, Brazil

Design and supply of one unit with 150 MVAR and rated speed 900 rpm.

2017 Ji-Paraná, Brazil

Design and supply of one unit with 150 MVAR and rated speed 900 rpm.

2017 Tapajós, Brazil

Design and supply of one unit with 150 MVAR and rated speed 900 rpm.

2017 Rurópolis, Brazil

Design and supply of one unit with 110 MVAR and rated speed 900 rpm.

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

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



VOITH