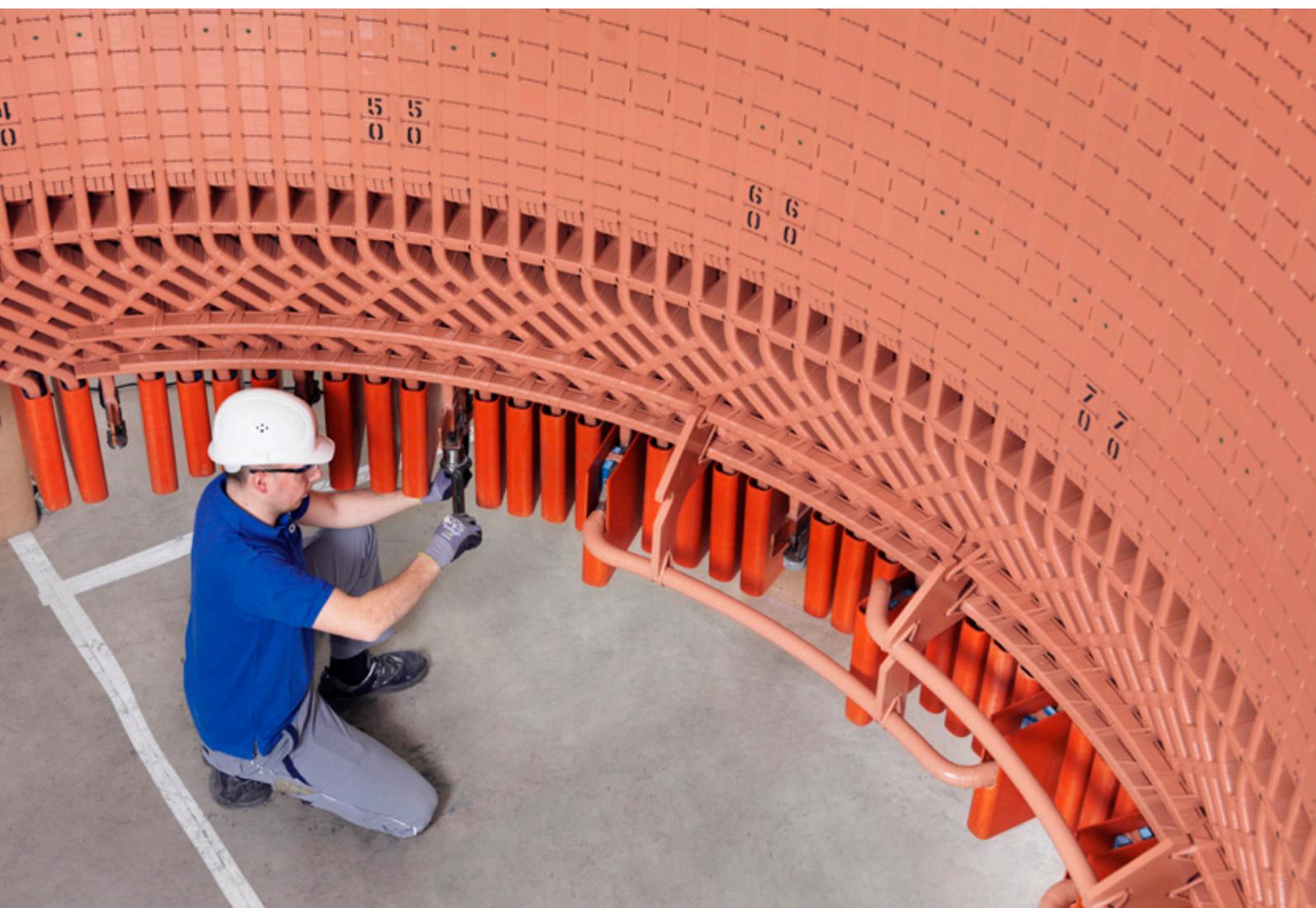


Micalastic insulation





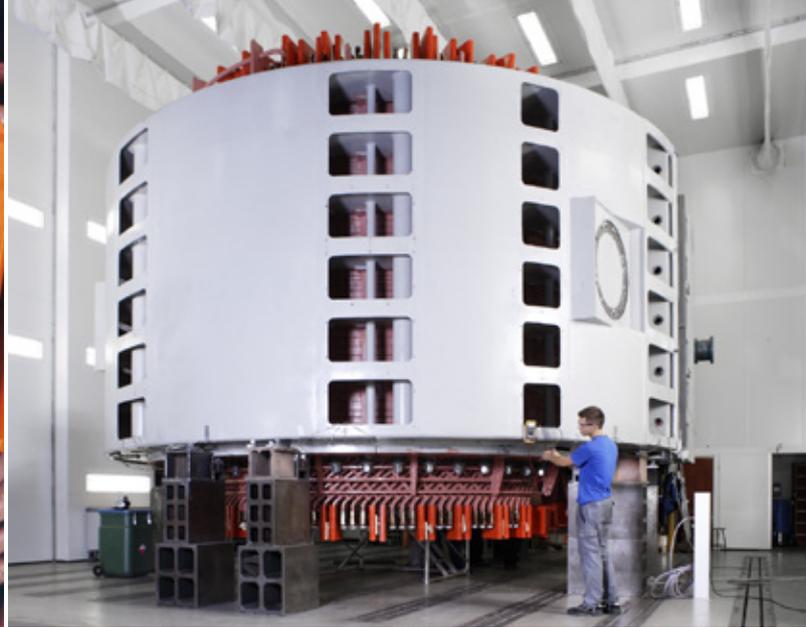
Micalastic insulation

Voith is a global leader in hydropower equipment and services for both new and modernization projects. For nearly 150 years, our name has been synonymous with excellence in the hydropower industry. We have installed more than 40 000 generators and turbines, with capacities that add up to more than 300 000 MW worldwide – one-third of the world’s total installed hydropower capacity.

Throughout its history, Voith has set new quality and performance standards and by continuously upgrading the engineering and manufacturing resources has consistently delivered best-in-class solutions for the hydropower modernization market.

The result is an industry-leading reputation for excellence in engineered reliability, world-class solutions and products.

In a globalized world, the generation of sustainable, emission-free electricity is more important than ever. Hydropower is well positioned as a major contributor within the renewable energy production. With our long history in hydropower products and services, excellent processes and tools for engineering and manufacturing, we offer responsive, creative and cost-effective solutions in the execution of new or modernization projects.



Micalastic insulation for high voltage hydropower generators

Micalastic is Voith standard insulation system within the company's electrical expertise and know-how today.

The common characteristics shared by all types of Micalastic insulation are the use of inorganic fine mica tape as a base material and heat-curing synthetic epoxy resins as a bonding material. This, coupled with state-of-the-art manufacturing techniques, provides high dielectric breakdown strength, long-term resistance to electrical stress and a low power factor ($\tan \delta$).

The mechanical properties of the tape and resin combination also provide excellent resistance to mechanical and thermal stress and different environmental conditions in indoor or outdoor installations, e.g., hydroelectric power plants, pumped storage plants and substations. The Micalastic insulation system is based on Vacuum Pressure Impregnation technology and meets Thermal Class 155 (IEC)/Class F (IEEE) standards.

Thermal resistance to aging

The thermal class is determined according to IEC 60216. Micalastic insulation meets and even exceeds the requirements specified for Thermal Class 155. Thermal Class F represents a maximum weight loss of 3 % after 20 000 hours at 155 °C without any noticeable impairment of the electrical characteristics of the insulation (long-term resistance to electrical stress).

The mechanical stresses that act on the winding are caused by electromagnetic forces during the normal operation, as well as the more severe condition of the short circuit on the main leads. Strong and rigid bracing is applied to the end of the winding to limit the movement within the safe boundaries. This application is especially important during transient phenomena such as short circuits and synchronization failure.



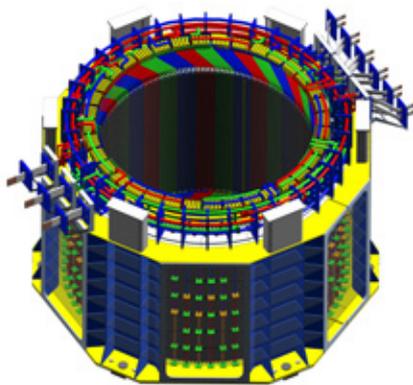
Design

Computerized design tools allow modeling of the performance of the whole generator. Based on extensive test results on completed projects, the calibrated calculation allows the winding performance to be optimized and guaranteed.

Voith approach has always been to provide customers with the best engineered solution for their unique applications. Micalastic offers technological advantages that will benefit customers in many ways.

Leading-edge technology in insulation will ensure continuation of the best engineered insulation systems for customer applications.

Generator frame assembly solid modeling and analysis



Process control

The manufacturing process data are collected on an ongoing basis. This enables a direct comparison of the product performance across all locations using the standard process.

This commitment to best practice and continuous improvement ensures that the products manufactured in the worldwide Voith workshops are consistently produced using excellent processes.



1



2

1 Strand insulation of the Roebel bars

2 Multi-turn coils

Roebel bars

Strand insulation

The strand insulation of the Roebel bars comprises two layers of glass yarn and is impregnated with epoxy, or it comprises one layer of polyester/glass yarn mix and is enameled. During the thermal process in the kiln, the polyester yarn is sintered on the wire surface.

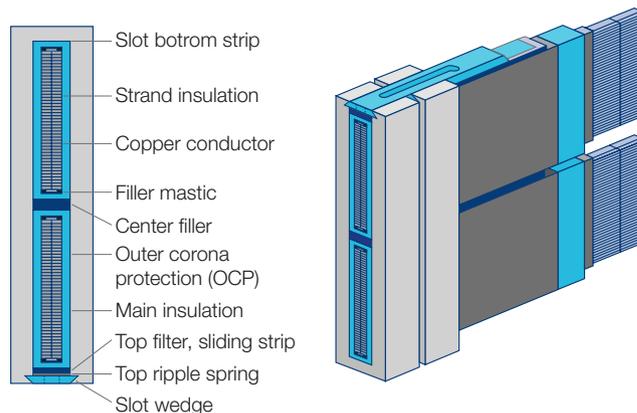
Transposition

The strands bending is performed by a programmable Roebel machine. This allows 360° transposition in the slot portion, as well as 540° transposition under certain conditions.

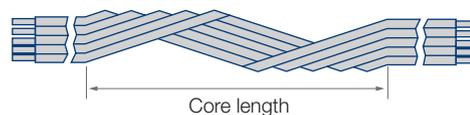
Forming

A B-stage epoxy adhesive strip is placed between the two bar strand columns. The transposed bar is then placed in a heat-press device that aligns and solidly bonds the strands to one another in the slot section. After pressing, the bars are shaped to exact dimensions in a fully programmable bending machine.

Winding concept for bars



Roebel bar



Multi-turn coils

Turn insulation

In Voith design, there are two alternatives for the multi-turn coils turn insulation. In one design, the so-called dedicated turn insulation (DTI), the strands are insulated with double dacron glass, and the set of strands forming the turn are insulated with mica tape. In the other design, layers of mica tape are applied directly on the individual strands. In this design, the mica layers simultaneously play the role of strand insulation and turn insulation. Both designs provide superior performance, increased reliability and extended lifetime for the windings.

Forming

After the coil is looped, a B-stage epoxy adhesive tape is applied on the surface in DTI design, or a B-stage epoxy adhesive strip is placed between the two coil strand columns. The loop is then placed in a heat-press device, which aligns and solidly bonds the coil strands to one another.



Main insulation of the stator winding

The demand for ever-increasing outputs of high voltage hydropower generators without proportional changes in dimensions or weight – e.g., through an increase of the power-per-weight ratio – made it necessary to reduce the volume of the insulation. As a result, the dielectric field strength of the ground wall at rated operating voltage is increased without jeopardizing the lifetime of the winding.

Micalastic insulation is suitable for all types of large and small stator windings. Due to its excellent partial discharge resistance, fine mica paper was an obvious choice as a key insulation component and, with the addition of solvent-free, hot-curing epoxy resin, now represents the base material for the main insulation.

Overlapping wound fine mica tape – the actual number of layers is proportional to the voltage – forms the basic structure of the main insulation over the whole length of the bars and coils (slot and end-winding portions).

The development invested in the materials, insulation system and manufacturing process resulted in a thinner ground wall thickness combined with high dielectric break-down strength and long-term resistance to electrical and thermal stress.

The high performance of Micalastic insulation combined with a state-of-the-art design for hydropower generators results in smaller and more efficient machines. The expected service life of the stator winding is in excess of 40 years.

One of the key improvements of the winding manufacturing process was the introduction of a six-axis controlled taping machine for bars and coils. The taping machine wraps the fine mica tape with an adjustable and consistent overlap and tension around the slot and end-winding portions of the bars and coils, thus ensuring a uniform thickness over the full length of the bar or coil including the knuckle of the coil.



- 1 Forming machine
- 2 Bending machine
- 3+4 Taping machine

Application process of the main insulation

The manufacturing process of the stator winding consists of two consecutive stages and is highly automated and carefully monitored to ensure a high dielectric insulation system.

First process stage

The first step is the Vacuum Pressure Impregnation (VPI), which begins by drying the winding component in an autoclave under vacuum. This process phase is done with extra heating. Moisture and air are removed from the dry tapes (without resin), thus improving the quality of the main insulation.

After that, the resin is pumped to the impregnation vessel and the coils and bars are impregnated with a very low-viscosity resin that fully saturates the mica ground tape. Later, pressure is increased to about 4 bar (0.4 MPa) by means of the injection of nitrogen.

Second process stage

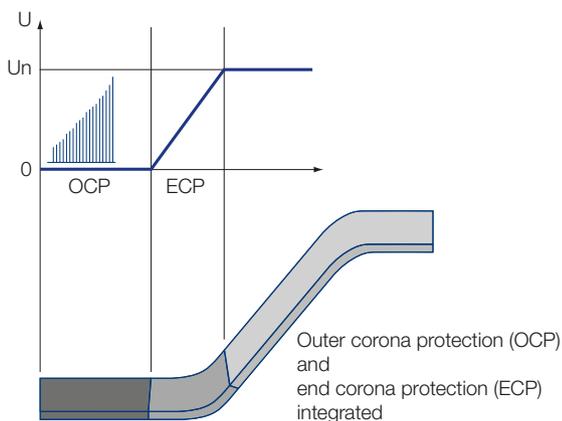
The next step is complete curing of the resin. The ground wall mica tape contains an accelerator. By heating, the accelerator or curing agent accelerates the polymerization until the complete curing. Mobile molds are used to control the shape and size of the finished product. This ensures consistency and repeatability.

This, in conjunction with the fully controlled impregnation and curing process, increases the breakdown strength and service life of the ground wall. These properties are retained even at elevated temperatures and after thermal aging.

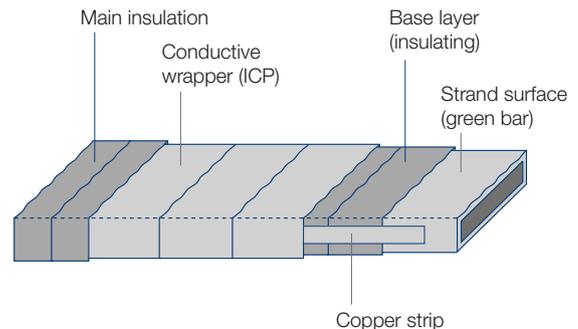
Grading system

Micalastic insulation has been developed to be used in combination with a grading system comprising the three components end-winding corona protection (ECP), outer corona protection (OCP) and inner corona protection (ICP).

Micalastic grading system concept



ICP system



Inner corona protection

The ICP is a grading system that is applied directly to the transposed slot portion of the bars. Its function is to equalize the voltage over the length of the bar's surface to guarantee a homogeneous distribution of electrical field in the ground wall. All bars manufactured by Voith have an incorporated ICP system. In special cases, such as large pump storage machines, where the winding is exposed to extreme cyclical thermal stress, a special execution of the ICP system is equipped to the bars.

Outer corona protection

The surface of the cured insulation of the slot portion of the bar and coil is coated with a conductive varnish or with a conductive tape to act as OCP. OCP equalizes the potential over the coil surface to guarantee uniform consistency of electrical field around the perimeter of a coil/bar and prevents electrical discharges from taking place in between the coils surface and the stator slot.

End-winding corona protection

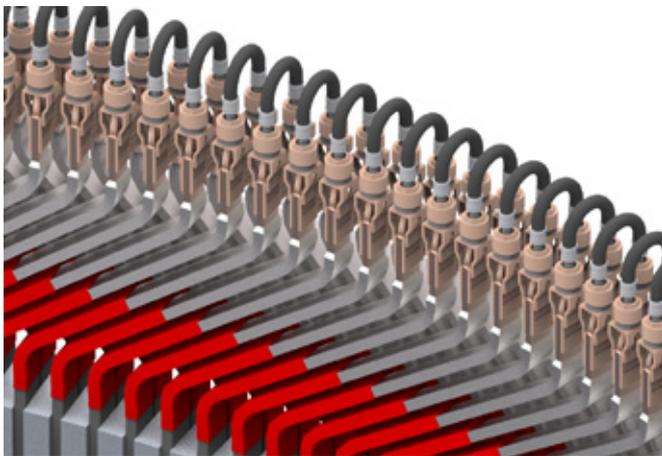
The end-winding corona protection is a semi-conductive coating or semi-conductive tape on a silicon carbide base and is applied to the bars and coils where they exit from the slot portion. The ECP overlaps the graphite-covered section and extends several centimeters into the end-winding section. The ECP serves to control the voltage grading at the transition from the slot portion (grounded) to the end-winding, where full voltage is applied during the tests of individual winding elements or the winding assembly.

Silicon carbide belongs to the group of semi-conductive materials and, thanks to its voltage-dependent conductivity, ensures exceptional potential grading on the insulation surface. The danger of partial discharges during operation and flashovers during high voltage tests is thus ruled out.

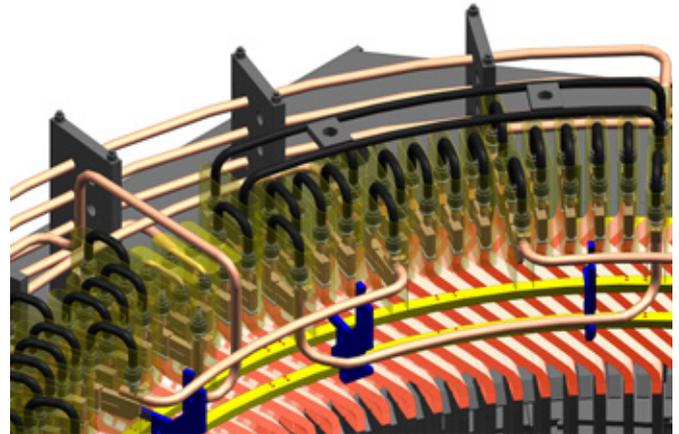
Water-cooled stator winding

The heat losses generated during the operation of conventional hydropower generators are dissipated by the cooling air through the air-water coolers.

Water-cooled stator winding and stator core section



Water-cooled stator winding



Electrical and hydraulic connection “bar-to-bar”



In water-cooled generators, the losses originated in the generator stator winding, the stator circuit rings, the phase connectors as well as some stator core losses are not only dissipated by the traditional air-coolers but also through a direct water cooling.

Pure Water System

The water, which dissipates the heat losses, is designated as Pure Water (PW).

The Pure Water, that is required for cooling the stator winding, circulates in a dedicated closed system, the so-called Pure Water System (PWS)

In order to prevent corrosion, only copper, stainless steel, PTFE or similar corrosion-resistant materials are used throughout the entire cooling system.



Production test and quality control

The quality of Voith winding is assured by well-defined quality procedures in conformance with the ISO-9001.

Each Micalastic winding undergoes a prescribed range of tests to meet IEEE and IEC standards as well as performance requirements of the client's specification.

1. Incoming raw material tests

All materials used in Voith generators are quality controlled, either by a test report from the supplier or by Voith incoming inspection.

2. Strand to strand short circuit test

After pressing and curing the bar/coil when the strands are assembled, 220 V AC is temporarily applied to confirm electrical insulation from strand to strand and long-term resistance to electrical and thermal stress.

3. Turn-to-turn testing (coils only)

To verify the absence of the short circuits between the turns of a coil, a surge test is performed per IEEE 522/IEC 60034-15.

4. Insulation quality inspection

After impregnation and curing, the coils/bars are verified to be free of indentations, scratches, other unusual marks, etc.

5. Dimensional inspection

The size of the bar/coil is verified by use of a caliper.

6. OCP surface resistance measurement

The OCP surface resistance is measured.

7. Tang delta (tip-up) measurement

Test performed per IEEE 286 / IEC 60034.

8. High potential test

After completing the manufacturing process, an AC hipot test is performed as per IEEE 4 / IEC 60034 – 15 for a duration of 1 minute.

9. Voltage endurance test

As per IEEE 1043 and IEEE 1553 or KEMA, a voltage endurance test is performed on the prototype or production coils/bars, as required by the client's specification.



- 1 Chemistry laboratory
- 2 Manufacture laboratory
- 3 Electric laboratory

Insulation technology laboratory

In our state-of-the-art insulation technology laboratory, ongoing research and development takes place to continuously improve our insulation system and support our production sites around the world. The laboratory staff consists of experienced physicists, chemists, engineers and technicians. Thus, all areas of knowledge related to the manufacture, installation and application of the insulation system used for rotating electrical machines are covered.

The insulation technology laboratory is composed of three integrated areas:

Chemistry laboratory

The chemistry laboratory is our central facility for research and development of new materials. In addition, the materials used for our final products in the factories are tested there.

Manufacture laboratory

The equipment in our production laboratory enables simulation of the complete production process at Voith hydropower plants and permits the development of new processes, designs and materials.

Electric laboratory

Our electric laboratory is composed of high voltage cells, a dark room and a dedicated cell to IEEE 1310 thermal cycling test, where all recommended electrical tests defined in the international standards for the insulation system performance evaluation are performed.



1



2

Power plants with Micalastic multi-turn coils

North America:

Gaston

Dominion Generation, Virginia – 1 unit
55.6 MVA, 14.4 kV, 100 RPM, 60 Hz

Moose River

Fortis US Energy Corp., New York – 1 unit
13.26 MVA, 13.8 kV, 327.3 RPM, 60 Hz

Smith Mountain

American Electric Power AEP, Virginia – 2 units
212.5 MVA, 13.8 kV, 100 RPM, 60 Hz

Ohio Falls

Louisville Gas & Electric, Kentucky – 5 units
14.68 MVA, 14 kV, 100 RPM, 60 Hz

Corra Linn

FortisBC, British Columbia – 2 units
20 MVA, 7.2 kV, 85.7 RPM, 60 Hz

Spray

TransAlta Generation Partnership, Alberta – 1 unit
62.2 MVA, 13.8 kV, 450 RPM, 60 Hz

Bay D'Espoir

Nalcor Energy, Newfoundland and Labrador – 4 units
85 MVA, 13.8 kV, 300 RPM, 60 Hz

Wheeler

TVA, Alabama – 1 unit
48.4 MVA, 13.8 kV, 85.7 RPM, 60 Hz

Wyman

FPL Energy Maine
Maine – 1 unit
33 MVA, 13.8 kV, 138.5 RPM, 60 Hz

Safe Harbor

Safe Harbor Water Power Corp., Pennsylvania – 1 unit
36 MVA, 13.8 kV, 109.1 RPM, 60 Hz

Des Cedres

Hydro Quebec, Quebec – 1 unit
11 MVA, 6.6 kV, 52.9 RPM, 60 Hz

Beauharnois

Hydro Quebec, Quebec – 2 units
57 MVA, 13.8 kV, 75 RPM, 60 Hz

Shettisham

US Army Corps of Engineers, Alaska – 2 units
34.5 MVA, 13.8 kV, 600 RPM, 60 Hz

Dardanelle

US Army Corps of Engineers, Arkansas – 4 units
32.63 MVA, 13.8 kV, 75 RPM, 60 Hz

Pensacola

Grand River Dam Authority, Oklahoma – 6 units
19.65 / 22.6 MVA, 13.8 kV, 150 RPM, 60 Hz

High Falls

Great Lakes Power, Canada – 2 units
25 MVA, 12 kV, 276.9 RPM, 60 Hz



- 1 Bath County, USA
- 2 Peixe Angical, Brazil
- 3 Itaipu, Brazil/Paraguay
- 4 Holtwood, USA

South America:

Santa Clara

Brazil – 3 units, 21 MVA, 13.8 kV, 257.1 RPM, 50 Hz

Rio de Peixe

Brazil – 2 units, 5.5 MVA, 6.6 kV, 720 RPM, 50 Hz

Antas II

Brazil – 2 units, 7 MVA, 6.6 kV, 720 RPM, 50 Hz

Pinhal

Brazil – 1 unit, 4 MVA, 6.9 kV, 257.1 RPM, 50 Hz

Elloy Chaves

Brazil – 1 unit, 11 MVA, 6.9 kV, 360 RPM, 50 Hz

Europe:

Rånåsfoss III

Akershus Energi, Norway – 6 units
14.67 MVA, 13.2 kV, 250 RPM, 50 Hz

Uluabat

Akenerji Elektrik Uretim A.S., Turkey – 1 unit
55 MVA, 13.8 kV, 600 RPM, 50 Hz

Akocak

Akenerji Elektrik Uretim A.S., Turkey – 1 unit
46 MVA, 13.8 kV, 750 RPM, 50 Hz

Toeinging

Germany – 6 units, 8.5 MVA, 10.5 kV, 214.3 RPM, 50 Hz

Eitting

Germany – 3 units, 14 MVA, 16.3 kV, 166.7 RPM, 50 Hz

Vohburg

Germany – 3 units, 12 MVA, 6.6 kV, 90.9 RPM, 50 Hz

Goesgen

Switzerland – 4 units, 12.5 MVA, 10 kV, 142.9 RPM, 50 Hz

Tiefencastel

Switzerland – 2 units, 16.1 MVA, 7 kV, 600 RPM, 50 Hz

Frøystul

Norsk Hydro, Norway – 1 unit
50 MVA, 11 kV, 240.3 RPM, 50 Hz

Tevla

Norway – 2 units, 30 MVA, 9 kV, 500 RPM, 50 Hz

Planatovryssi

Greece – 2 units, 68 MVA, 15.75 kV, 200 RPM, 50 Hz

Central America:

Sandillal, Costa Rica – 2 units
17.64 MVA, 13.8 kV, 300 RPM, 50 Hz

Africa:

Steenbras, South Africa – 4 units
50 MVA, 12 kV, 600 RPM, 50 Hz



Power plants with Micalastic bars

Africa:

Gigel Gibe II

EEPCO Ethiopian Electric Power Corp., Ethiopia – 4 units
125 MVA, 15 kV, 333.3 RPM, 50 Hz

Grand Ethiopian Renaissance Dam

Ethiopian Electric Power, Ethiopia – 8 units
444.4 MVA, 18 kV, 125 RPM, 50 Hz

Drakensberg

ESKOM – Electricity Supply Commission
South Africa – 3 units
281.5 MVA, 11 kV, 375 RPM, 50 Hz 2008

Europe:

Vuzenica

Dravske Elektrarne Maribor Slovenia – 3 units
26 MVA, 10.5 kV, 125 RPM, 50 Hz

Wehr

Schluchsee Werr, Germany – 4 units
300 MVA, 21 kV, 600 RPM, 50 Hz

Frades II

EDP – Energias de Portugal, Portugal – 2 units
420 MVA, 21 kV, 375 RPM, 50 Hz

Rodund II

Vorarlberger Illwerke AG, Austria – 1 unit
345 MVA, 21 kV, 375 RPM, 50 Hz

China:

Ji Lin Tai,

Ji Lin Tai Co Ltd. – 4 units
128 MVA, 15.75 kV, 214.3 RPM, 50 Hz

Three Gorges

China Yangtze Three Gorges Develop., Corp. – 6 units
840 MVA, 20 kV, 75 RPM, 50 Hz

Xi Luo Du

China Three Gorges, China – 3 units
855.6 MVA, 20 kV, 125 RPM, 50 Hz

Wu Dong De

China Three Gorges, China – 6 units
944.5 MVA, 22 kV, 90.9 RPM, 50 Hz

Chan Long Shan

CTG – China Three Gorges, China – 2 units
389 MVA, 18 kV, 600 RPM, 50 Hz

North America:

Holtwood

Pennsylvania Power and Light, USA – 2 units
74.3 MVA, 15.75 kV, 85.7 RPM, 60 Hz

Grand Coulee

US Bureau of Reclamation, USA – 3 units
825.6 MVA, 15 kV, 85.7 RPM, 60 Hz



- 1 Gilgel Gibe II, Ethiopia
- 2 Frades II, Portugal
- 3 Raccoon Mountain, USA
- 4 Grand Coulee, USA

Bath County

Virginia Electric and Power Company
USA – 6 units
530 MVA, 20.5 kV, 257.1 RPM, 60 Hz

La Tuque

Hydro Quebec, Canada – 3 units
65 MVA, 13.8 kV, 138.5 RPM, 60 Hz

Raccoon Mountain

Tennessee Valley Authority, USA – 4 units
425 MVA, 23 kV, 300 RPM, 60 Hz

Revelstoke 5

British Columbia Hydro, Canada – 1 unit
532 MVA, 16 kV, 112.5 RPM, 60 Hz,

Site C

British Columbia Hydro, Canada – 6 units
216.5 MVA, 13.8 kV, 72 RPM, 60 Hz

Keeyask

Manitoba Hydro, Canada – 7 units
118 MVA, 13.8 kV, 75 RPM, 60 Hz

Eastmain 1^a

Hydro Quebec, Canada – 3 units
285 MVA, 13.8 kV, 100 RPM, 60 Hz

South America:

El Platanal

Cementos Lima S.A., Peru – 2 units
120 MVA, 13.8 kV, 450 RPM, 60 Hz

Itaipu 50 Hz

Itaipu Binacional, Brazil/Paraguay – 6 units
823.5 MVA, 18 kV, 90.9 RPM, 50 Hz

Itaipu 60 Hz

Itaipu Binacional, Brazil/Paraguay – 5 units
737 MVA, 18 kV, 92.3 RPM, 60 Hz

Irape

CEMIG, Brazil – 3 units
140 MVA, 13.8 kV, 300 RPM, 60 Hz

Peixe Angical

Grupo Rede, Brazil - 3 units
175 MVA, 13.8 kV, 85.7 RPM, 60 Hz

Pedra do Cavalo

Votorantim, Brazil – 3 units
90 MVA, 13.8 kV, 257.1 RPM, 60 Hz

Aimores

Cia. Energetica de Minas Gerais, Brazil – 3 units
116 MVA, 14.4 kV, 105.9 RPM, 60 Hz

Belo Monte

Norte Energia, Brazil – 4 units
679 MVA, 18 kV, 85,7 RPM, 60 Hz

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

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



VOITH