Voith Hydro is a global leader in hydro power equipment and services for both new and modernization. For more than 140 years, our name has been synonymous with excellence in the hydro power industry. We have installed more than 40,000 generators and turbines worldwide.

Over all these years, Voith Hydro has continuously set new performance and size records, and continuously educated its staff around the world to create the best-in-class designs through engineering and manufacturing expertise. The result is a second-to-none reputation for excellence in engineering standards and products as well as reliability, trust and commitment in long-lasting partnering relationships with owners and operators around the world.

Voith Hydro – by its electric expertise represents the former hydro generator expertise of Allis-Chalmers, Fuji Electric, Westinghouse and Siemens that have all contributed through their merging into Voith Hydro’s organization of today. Based on this history, we have rich references in air-, hydrogen- and water-cooled synchronous generators with vertical or horizontal shafts including motor-generators and synchronous condensers.
Micalastic insulation for high voltage hydro generators

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

The common characteristics shared by all types of Micalastic insulation is the use of inorganic fine mica tape as a base material and heat-curing synthetic resins as bonding material. This, coupled with state-of-the-art manufacturing techniques geared to the various types and size of the machines, makes for its most outstanding features which are high breakdown strength, long-term resistance to electrical stress, and a low power factor ($\tan \delta$), as well as excellent resistance to mechanical and thermal stress.

- Based on VPI (Vacuum Pressure Impregnation) technology.
- Thermal Class 155 resp. Thermal Class F according to international standards.
Design

Computerized design tools allow modeling of the performance of the whole generator. Optimization of the coil/bar design with respect to losses, heating and overall rating is performed. Based on extensive test results on completed projects, the calibrated calculation allows the winding performance to be guaranteed.

The range of applicability for multi-turn coil winding is up to 150 MVA and voltages up to 18 kV. Bar windings up to a rated output of 840 MVA and rated voltage of 23 kV are in service. Soon these records will be broken with the totally air-cooled generator for the Xi Luo Du power station (China) with a rated output of 855.6 MVA. Hydro generators exceeding 1100 MVA and up to 27 kV are considered feasible.
Roebel bars

In the manufacturing process, the crossovers are formed with a 3D bending technique which prevents any contact between the strands in the transposition area and no additional protection against interstrand short-circuits is required. This process allows under certain conditions the transposition of the slot portion to be increased from the usual 360° to 540°.

To maintain strand alignment a “B” stage epoxy bonding strip is placed vertically between the bar strands to solidly bond the bar strands during the pressing in a hot press machine. After pressing, bars are shaped in a fully programmable bending machine to exact dimensions.

Strand insulation

The strand insulation of the Roebel bars comprises double layer braid-ed glass yarn impregnated with epoxy varnish. The rigid layer of insulation between the half bars also carries the bonding resin for solidifying the transposed slot portions in the heat moulds.
Multi-turn coils

Turn insulation
The turn insulation of the multi-turn coils comprises a double layer of fine-mica paper. In the Voith Hydro unique design the layers of mica paper are placed directly at the individual strand. The mica layers play simultaneously the role of strand insulation and turn insulation. Therefore, all strands are insulated to support the requirements of turn insulation. This feature provides superior performance, increased reliability and extended life time for windings.

Forming
After the coil is looped, a “B” stage epoxy bonding strip is placed vertically between the coil strands. The loop is then placed in a heated press which aligns and solidly bonds the coil strands to one another in the slot section. This strand alignment is maintained as the coil is spread in a fully programmable coil forming machine to exact dimensions.
The demand for ever increasing outputs of high-voltage hydro generators without changes in dimensions or weight – as for example through an increase of the power-per-weight ratio – made it necessary to reduce the volume of the insulation. This results in an increase of the dielectric field strength of the ground wall at rated operating voltage.

Micalastic insulation is suitable for all types of large and small stator windings. Because of its excellent discharge resistance, fine mica paper is the obvious choice as a key insulation component and with the addition of solventless, heat-curing epoxy resin now represents the base material of 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 breakdown strength and long-term resistance to electrical and thermal stress.

The high performance of Micalastic insulation coupled with a state-of-the-art design for hydro 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 is the introduction of a 6 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.
Voith Hydro’s manufacturing of stator windings is a highly automated and carefully monitored process to ensure a void free, high dielectric insulation system. The manufacturing process has two stages:

**The first stage**

is VPI (vacuum pressure impregnation) 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) and therefore the quality of the main insulation is improved.

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

**The second stage**

consists of the full cure of the resin. The groundwall Mica tape contains a catalyst. By heating, the catalyzer or cure agent accelerates the polymerization until the full cure. Mobile molds are used to control the shape and size of the finished product, ensuring 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, which are properties retained even at elevated temperatures and after thermal aging.
Grading system

Micalastic has been developed to be used in combination with a grading system comprising the following three components:

- ECP – end corona protection
- OCP – outer corona protection
- ICP – inner corona protection

**Inner corona protection**

The ICP is a grading system which is applied directly to the transposed slot portion of the bars. Its function is to equalize the voltage over the length of the bars surface to guarantee a homogeneous distribution of electrical field in the ground wall. All bars manufactured by Voith Hydro have an ICP system incorporated. 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, with dedicated technological improvements helps to avoid the delaminating between the Roebel bars and the ground wall.

**Outer corona protection**

The surface of the cured insulation of the slot portion of the bar and coil is coated with 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 taking place in between the coils surface and stator slot.
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.

The figure above shows the influence of ECP during a high voltage test. The bars are tested with the same voltage and sparking does not occur at the end of those bars, which are coated with ECP.

End corona protection

The end 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.

The Micalastic® grading system concept

a) Top bar: No ECP at either end
b) Center bar: No ECP on right-hand side and with ECP at left-hand side
c) Bottom bar: ECP applied to both ends
The quality of Voith Hydro’s winding is assured by well defined quality procedures in conformance with ISO-9001.

Production test and quality control

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

1. Incoming raw material tests – all materials used in Voith Hydro generators are quality controlled, either by a test report from the supplier or by Voith Hydro incoming inspection.

2. Strand to strand short circuit test – after the pressing and cure of the bar/coil, when the strands are consolidated together, 220 V AC is applied momentary to confirm strand to strand electrical insulation.

3. Turn to turn testing (coils only) – to verify the absence of the short circuits between turns of a coil, a surge test is performed per IEEE 522/IEC 60034-15.

4. Insulation quality inspection – after impregnation and cure, coils/bars are verified to be free of hollows, porosity, scratches, other unusual marks, etc.

5. Dimensional inspection – the size of the bar/coil is verified by use of a calibrator.

6. OCP surface resistance measurement – the OCP surface resistance is measured.

7. Tan δ (tip-up) measurement – test performed per IEEE 286/IEC 60034.

8. High potential test – after completion of manufacturing process, an AC Hi-pot 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, performed on prototype or produced coils/bars, as required by the client’s specification.
Thermal resistance to aging

The thermal class is determined according to IEC 60216. Micalastic insulation meets and even exceed the requirements specified for Thermal Class 155 resp. Thermal Class F which means, 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).

Mechanical characteristics

The mechanical stresses which 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 power grid.

Strong and rigid bracing is applied to the end of the winding to limit the movement into the safe boundaries. This application is especially important during the short-circuit.