EQUIPMENT AND SERVICE FOR HYDROPOWER PLANTS
OUR MISSION

To provide reliable and efficient, comprehensive solutions to meet the needs of the global energy system by continuously improving our technology and business processes.

OUR VISION

To take the lead in the power engineering market in Russia and the CIS and to be a key player on the global market.

OUR VALUES

ATTENTION TO CLIENTS
EFFICIENCY AND PROMPTNESS
INNOVATION
SAFETY
TEAMWORK
RESPECT FOR PEOPLE

PJSC “Power Machines” is the largest power plant engineering company in Russia with international experience in the field of design, manufacture and complete delivery of equipment for thermal, nuclear, hydraulic and gas-turbine power plants.

The company creates efficient integrated solutions for the world’s power industry based on the 150 years’ experience of the company’s production assets and implementation of the latest achievements in science and technology.

The equipment produced and supplied by the Company functions in 57 countries around the world and currently has more than 300,000 MW of installed capacity.
POWER MACHINES – A SUPPLIER OF INTEGRATED SOLUTIONS FOR HPPS

With solid experience in developing and manufacturing equipment, and with all necessary design and production resources available to it, Power Machines offers efficient integrated solutions, supplying hydropower enterprises with comprehensive generating equipment and rendering maintenance services.

Power Machines provides a full range of services including:
- survey;
- design;
- procurement and production as well as packing, transportation, and warehousing;
- installation and commissioning;
- acceptance testing, start-up, and guarantee testing;
- warranty and post-warranty service;
- customer personnel training.

Main products for Hydropower Applications

- various types of hydraulic turbines with a capacity of up to 1000 MW including pump turbines with a capacity of up to 300 MW;
- pre-turbine gate valves and turbine gates of 1.5 to 7.5 meters in diameter;
- pre-turbine globe valves of 1 to 4 meters in diameter;
- electrohydraulic governors and oil pressure units rated at 6.3 MPa and higher;
- umbrella, semi-umbrella, and suspension-type vertical hydrogenerators;
- encapsulated hydrogenerators;
- electrical automation systems: hydrogenerator automated control systems and HPP process control systems;
- excitation systems.

Quality assurance

The quality and reliability of our products are ensured by strictly following manufacturing procedures and the quality policy adopted by the company. The quality management system in place at Power Machines PJSC is certified for compliance with ISO 9000 series standards (ISO 9001:2015, GOST R ISO 9001-2015), as well as GOST RV 0015-002-2012.

Design and process solutions are based on detailed calculations and examinations.

The company places special emphasis on quality control throughout the manufacturing process. Such control covers all materials, and mechanical tests are repeated for critical components and parts.

All parts are inspected by the quality control department before being presented to the customer. Furthermore, the trial assembly and testing of the main pieces of equipment are overseen by the customer. By participating in the tests, the customer is assured of the high quality of the manufactured equipment.

Power Machines’ manufacturing facilities are fitted with advanced processing equipment.

MORE THAN

870 hydroturbines
650 hydro-generators
85 gate vales
2000 governors

have been manufactured at the company’s facilities

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650 hydro-generators
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HYDROTURBINES

Power Machines have concentrated their hydroturbine production at Leningradsky Metallichesky Zavod (LMZ) which has nearly a century of experience in manufacturing hydroturbines. The first Russian hydraulic turbine was manufactured at LMZ in 1924.

The design of hydroturbines, automated control systems, and gate valves is provided by Power Machines’ Special Design Bureau (SDB), Gidroturbomash, which was established over 95 years ago. Hydroturbine equipment is designed by Gidroturbomash SDB based on in-house developments.

Benefits of Power Machines’ Hydroturbines

With its extensive experience in finding solutions for design challenges and in developing and creating various types of hydroturbine equipment, Power Machines offers customized solutions for each individual project.

Manufacturing procedures are strictly followed throughout the work process. All these efforts and a case-by-case approach to each and every project ensure:

- reliable operation of equipment for a design life of at least 40 years;
- high performance quantities and cavitation qualities of hydraulic turbines;
- extension of the operating capacity range;
- environmental security of equipment;
- operational reliability of equipment;
- reductions in maintenance costs.
Power Machines’ specialists have developed and introduced advanced materials and components for hydraulic turbines:

<table>
<thead>
<tr>
<th>Implemented Improvement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>New steels for impellers, blades, and guide vanes</td>
<td>Improved cavitation and erosion resistance; compliance with international standards</td>
</tr>
<tr>
<td>New anti-friction lubrication-free materials for bearing bushings in guide vanes and servomotors</td>
<td>Improved reliability and extended life for bearings</td>
</tr>
<tr>
<td>New anti-friction, lubrication-free materials for bearing bushings in adjustable blade impellers</td>
<td>Oil spills from the impeller housing to the river are eliminated</td>
</tr>
<tr>
<td>New anti-friction materials for guide bearings</td>
<td>Improved reliability and reduced friction</td>
</tr>
<tr>
<td>New materials for seals in guide vanes and shaft and impeller blades</td>
<td>Improved structural reliability</td>
</tr>
<tr>
<td>Advanced diagnostic systems have been developed</td>
<td>Emergency situations are avoided</td>
</tr>
<tr>
<td>Adjustable blade impellers and oil receivers have been designed that are rated at control pressures of up to 15 MPa</td>
<td>Less oil in the oil pressure unit and smaller dimensions of motors for the guide vanes and impeller</td>
</tr>
<tr>
<td>Hydroturbine automated control systems have been developed that are rated at a pressure of 15 MPa</td>
<td>Compressors are eliminated that were previously used to add air to oil pressure unit accumulators</td>
</tr>
</tbody>
</table>

Engineering Solutions, Design, Testing

In order to more accurately evaluate the energetic and cavitational properties and structural behavior of hydroturbine equipment, Power Machines’ specialists undertake all of the necessary research and development, using methods of physical and mathematical modeling to simulate the work flow in a hydroturbine, including a three-dimensional CFD method for analyzing fluid flows in supply elements, the impeller, and the suction pipe.
These methods make it possible to calculate optimal equipment parameters and eventually yield results that directly contribute to the growth in HPP economic indicators:

- to reduce hydraulic losses in the impeller;
- to reduce hydraulic losses in the suction pipe by creating flow that is most suitable for the functioning of the suction pipe;
- to improve the cavitation properties of the hydroturbine increasing the maximum capacity at the same hydroturbine depth;
- to reduce unsteady flow effect by optimizing the impeller and installing stabilizing devices.

Critical units are simulated and tested at designated test benches in order to verify engineering solutions. These examinations allow the determination of: efficiency contributors; strength; cavitation damage and vibration.

Acceptance tests are conducted at the Water Turbine Laboratory and are witnessed by the customer in compliance with IEC standards.

Engineering solutions are field-tested for reliability and efficiency on existing hydroturbine equipment by the skilled personnel at the Water Turbine Laboratory.

### Turbine Types and Applications

Today Power Machines design, manufacture, and supply:

- **Radial-axial hydroturbines (Francis)** with a capacity of up to 1000 MW at pressure heads of up to 600 m, with an impeller 1.0 to 8.3 m in diameter.

- **Adjustable-blade hydroturbines (Kaplan)** with a capacity of up to 300 MW at pressure heads of up to 70 m, with an impeller 1.0 to 10.3 m in diameter.
Horizontal bulb-type hydroturbines with a capacity of up to 70 MW at pressure heads of up to 25 m, with an impeller 4 to 7.5 m in diameter.

Pump turbines with a capacity of up to 400 MW at pressure heads of up to 400 m, with an impeller 3.0 to 8.0 m in diameter, and with variable speed in both pump and turbine mode.

The company also manufactures and supplies:

- Butterfly valves 1 to 7 m in diameter at pressure heads of up to 170 m.
- Globe valves 1 to 3.5 m in diameter at pressure heads of 200 to 600 m.
- Governors and oil pressure units for all hydroturbine types.
Governors

Governing equipment from Power Machines is used in Europe, Asia, America and Africa. Advanced governors and oil pressure units are equipped with microprocessor control panels.

Electrohydraulic governors are designed to control the speed and active power of a hydropower set. A governor provides the following operating modes:

- idle speed;
- isolated load;
- powerful opening or power feedback energy system;
- synchronous capacitor;
- group operation from the central selector;
- water flow.

Governors are available for all hydroturbine types:

- radial-axial;
- adjustable-blade;
- water impulse turbine.

Power Machines offers new governors but also replace and renovate existing governors.
Gate valves

Gate valves are installed at the pressure pipeline upstream of the turbine’s spiral chamber and serve as an operation, emergency, and maintenance shutoff device.

Currently, two types of gate valves are designed and manufactured:

- butterfly valves 1 to 7 m in diameter at pressure heads of 45 to 235 m
- globe valves 1 to 3.5 m in diameter at pressure heads of 170 to 800 m

The electrohydraulic valve control system operates automatically, opening and closing a gate valve in normal conditions and closing it if there is an emergency. The control system and actuators are fed with oil from either an independent oil pressure unit or one shared by the hydroturbine and gate valve.

As an option, ring valves can be designed and fitted where requested to substantially decrease the dimensions of the hydropower unit.
Most of Power Machines’ hydro-generators are produced through Electrosila, a leader in the Russian power engineering industry. The first Russian hydrogenerator was manufactured in 1924 and more than 650 hydro-generators with a total output capacity exceeding 65.5 GW have been manufactured by Electrosila.

Power Machines offers a comprehensive range of generators for hydroelectric power stations with low, medium and high water pressure heads. Our wide range of generators have output capacities ranging from 4 to 720 MW and operating speeds of 50 to 750 rpm. The hydro-generators operate at various voltages and frequencies and use different cooling systems and excitation systems.

Our hydro-generators can achieve an availability factor of 0.996, a mean time between failure of 27 000 hours and a service life of 40 years.

All hydro-generators come complete with:
- systems for automatic excitation control and regulation;
- cooling and excitation systems;
- field suppression equipment.

Power Machines specialists can carry out equipment assembly, adjustment and commissioning as well as various testing procedures.

Electrosila, a subsidiary of Power Machines is a leader in delivering new hydro-generator designs. Examples include:

- a forced air cooling system with the lateral ducts in the rotor winding turns; this is as effective as water-cooling systems. The stator winding which is one-layer in the slot portions and a double-layer in the end portions; this principle is used in the bulb-type water-cooled hydrogenerators;
- direct water cooling of the core poles;
- stator featuring a pre-stressed core for high vibration stability and stable structure avoiding residual deformation and loosening of the core packs and loosening of their pressing;
- resilient packing of the stator winding bars in the slots preventing the formation of slot discharges;
- special design of the rotor and stator end zones, lifting all restrictions when operating in the under-excitation conditions.
Vertical-shaft hydro-generators

Power Machines manufactures hydro-generators of different designs: vertical-shaft machines of umbrella, semi-umbrella and suspension types.

Structural features:

- **umbrella type hydro-generators** – the thrust bearing and guide bearing are located below the rotor;
- **semi-umbrella type hydro-generators** – the thrust bearing is located below the rotor, while the guide bearing is arranged above the rotor;
- **suspension type hydro-generators** – the thrust bearing is located above the rotor.

In the case of the umbrella type and semi-umbrella type hydro-generators, the load on the thrust bearing is transmitted via the lower bracket or turbine cover to the foundation. In the case of the suspension type hydro-generators the same load is transmitted via an upper bracket and stator frame to the foundation.

Umbrella and semi-umbrella type designs are used for low-speed hydro-generators, especially for those of large capacities.

The semi-umbrella type hydro-generators may have one guide bearing in the lower bracket, or two guide bearings: one in the upper bracket and the other in the lower one.

The semi-umbrella type modification can be of the shaftless rotor design, where the turbine shaft is attached to the bottom part of the rotor spider, while the extension shaft is attached to the rotor spider top.

Hydro units with generators of this design have two guide bearings – the lower bearing mounted on the turbine shaft and the upper one on the extension shaft.

The suspension-type modification is used mainly for the high-speed and medium speed hydro-generators. The hydro-generators of this type are made with one guide bearing arranged in the upper bracket or with two guide bearings, in this case one guide bearing being located in the upper bracket and the other – in the lower bracket.
Bulb-type hydro-generators

In addition to traditional hydro-generators, Power Machines produces bulb-type hydro-generators with an output capacity up to 54 MW. These hydro-generators have varying designs and cooling systems and feature high operational reliability and durability.

Bulb-type horizontal-shaft hydro-generators are enclosed electric machines placed directly in the water flow. They are used at low-head power plants and tidal plants.

The bulb-type hydro-generators can be offered with direct water-cooling of the stator and rotor winding and pole cores as well as with indirect forced cooling with air at atmospheric pressure.

For the first time in the world hydro-generators with an output of more than 200 MW have been created and manufactured:

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zejskaya HPP</td>
<td>215</td>
</tr>
<tr>
<td>Ust-Ilimskaya HPP</td>
<td>240</td>
</tr>
<tr>
<td>Burejskaya HPP</td>
<td>335</td>
</tr>
<tr>
<td>Bratskaya HPP</td>
<td>250</td>
</tr>
<tr>
<td>Krašnoyarskaya HPP</td>
<td>500</td>
</tr>
<tr>
<td>Sayano-Shushenskaya HPP</td>
<td>640</td>
</tr>
<tr>
<td>El Cajon HPP</td>
<td>375</td>
</tr>
<tr>
<td>La Yeska HPP</td>
<td>375</td>
</tr>
<tr>
<td>Boguchanskaya HPP</td>
<td>333</td>
</tr>
</tbody>
</table>

The bulb-type hydro-generators are manufactured with the thrust bearing and counter-thrust bearing located either at the upstream side (the equivalent of the suspension type vertical-shaft hydro-generators) or between the generator itself and turbine (the equivalent of the umbrella-type or semi-umbrella-type hydro-generators).

Although a supplier of equipment for hydropower stations with large generators, Power Machines can also draw on its experience with small hydro-generators with capacities of up to 30 MW to bring new approaches and up-to-date solutions.

The main principles incorporated from its small hydro-generators include:

- ensuring generator self-sufficiency;
- maximum simplicity of the design;
- high level of availability for assembly and erection.

Thrust bearings with ftoroplast-coated pads

Today, hydro-generators manufactured by Power Machines are fitted with the most reliable thrust bearings in the world.

The distinctive feature of the design lies in the application of an anti-friction layer based on a ftoroplast (polytetrafluorethylene) composition with a metalized spring liner coating the thrust-bearing pads.

Hydro-generator thrust bearings from Power Machines have a number of advantages:

- improved reliability and durability;
- do not require a forced oil supply to the sliding surface;
- they have no restrictions on operating conditions, including start-ups and stops;
- they permit creep speed of rotation, rundowns without braking;
- they allow higher specific pressure of up to 100 kg/cm²;
- they allow a reduction in friction losses and oil reservoir dimensions;
- they do not require the scraping of the surface in the process of erection and operation.
EXCITATION SYSTEMS

The main types of excitation equipment for HPPs are:
- thyristor self-excitation systems (TSES);
- thyristor independent-type excitation systems (TIS);
- power converter equipment;
- excitation control;
- excitation system protections.

Excitation systems provide the following operation modes for synchronous generators:
- initial excitation;
- no load;
- coupling by precision synchronization or self-synchronization;
- operation within the power system with loads and overloads permissible for a generator;
- rotor swing damping (system stabilizer in line with Russian and international standards);
- forced excitation with a settable voltage and current ratio;
- reactive power dropping to $\cos\phi=1$;
- de-excitation in cases of power system disturbances;
- field suppression in cases of emergency operation or normal stop;
- electrical braking of the unit.

Benefits of the excitation systems
- Service personnel and equipment security is maximized through a set of special measures such as the usage of optical cables and draw-out thyristor transmitters (upon Customer request).
- Excitation panels are made to be maintenance-friendly by combining modular configuration, the provision of easy access to any panel element, and the clever arrangement of controls, alarms, instruments, and test points.
- A variety of configurations available at the Client’s request means standardized sections that are easily transformable. Thyristor converters are cooled by water, forced air, or natural air.
- The high degree of prefabrication is attained through all electrical connections being made between sections within the panel.
- Proven quality. Excitation systems are tested on equipment from the world’s leading suppliers.
- The improved panel design, which meets European ergonomics standards, is achieved by using advanced structural materials.
Power Machines offers the following services:

- Replacement (modernization) of instrumentation and automatics of hydropower unit and auxiliary equipment.
- Automation of main equipment of HPP including: frequency and power controllers of hydropower units, heat control systems, vibration control systems, process automation systems, hydro-mechanical and electrical protection systems, auxiliary equipment operation systems (MNU, gate valves, cooling water systems for process water supply).
- Installation and modernization of vibration control and diagnostic systems of hydropower unit.

The vibration control system comprises implementation of the following tasks:

- Vibration control of hydropower unit;
- Meaning acquisition of current values of parameters on absolute and relative vibration in chosen points of hydropower unit;
- Measurement of the air gap between stator and rotor of hydropower unit.

If measured or rated values of vibration in support assemblies of hydropower unit exceed acceptable ones, the following shall be undertaken:

- Formation and transfer of generalized and deciphering warning and emergency signals into automation and alarm systems.

The information is represented in the form of current measured and rated values on display devices as part of APCS.

- Automation of plant-wide systems, distribution devices control systems such as switchyard 220, switchyard 110, switchyard 35, switchgear, hydraulic measurements, drainage and ground water discharge systems, transformer monitoring system etc.
- Automation of the upper control level of HPP: creation and arrangement of the main control panel operator workplace, design and delivery of equipment of data processing and storage servers, equipment systems of sensor panel boards, panels of software-engineering complexes of group control of active and reactive power, voltage adjustment (GRAM, GRNRM, GRARM), systems of rational control of mechanisms and equipment complexes (RUSA).

- Turnkey automation of hydropower plant including systems of automatic control of hydropower units, operation systems and plant-wide control systems, distribution systems control systems, the upper level control including plant-wide controllers of active and reactive power.

Design and production of APCS equipment involves use of components of leading foreign and domestic manufacturers of automation and instrumentation systems.
**SERVICE AND RENOVATION**

Power Machines offers maintenance, renovations, and renewal services for HPPs to improve their reliability, cost effectiveness, flexibility, and ease of use.

When implementing renewal and renovation projects at hydropower plants, Power Machines solves strategic tasks that ensure the clients receive returns on their investments by restoring equipment to working condition and improving its technical and economic performance and reliability.

With its extensive experience in finding solutions to design challenges and in developing and creating various types of hydroturbine and hydrogenerator equipment, Power Machines develops customized solutions for every particular project. Equipment can be renovated and repaired both at the manufacturer’s facility and in the field. When providing renewal services, Power Machines’ specialists do their best to minimize construction work and ensure that renovated equipment is positioned on existing embedded parts and foundations.

**Renovation results**

<table>
<thead>
<tr>
<th>Renovation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renovation of impellers in radial-axial hydroturbines</td>
<td>Turbine efficiency increased of 7% and capacity by 5 to 20% of the level as of renovation; Improved reliability and increased time between impeller overhauls.</td>
</tr>
<tr>
<td>Renovation of impellers in adjustable-blade hydroturbines</td>
<td>Turbine efficiency increased of 7% and capacity by 5 to 20% of the level as of renovation; Improved reliability and increased time between impeller overhauls; No oil spills in the environment.</td>
</tr>
<tr>
<td>Renovation of hydroturbine guide vanes</td>
<td>Reduced water and oil spills; Improved reliability and extended time between equipment failures.</td>
</tr>
<tr>
<td>Renovation of hydrogenerator stators</td>
<td>Power increased by 5% to 40% with the same stator dimensions; Improved reliability and extended time between hydrogenerator failures.</td>
</tr>
<tr>
<td>Renovation of hydrogenerator rotors</td>
<td>Improved reliability and extended time between hydrogenerator failures.</td>
</tr>
<tr>
<td>Renovation of pads and bearings</td>
<td>Improved reliability and extended time between hydrogenerator failures.</td>
</tr>
<tr>
<td>Renovation of excitation systems</td>
<td>Improved reliability and extended time between hydrogenerator failures.</td>
</tr>
<tr>
<td>Modernization of automation systems</td>
<td>Improvement of reliability and informativeness of hydropower unit control systems.</td>
</tr>
</tbody>
</table>