Power Machines Company 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 and hydraulic 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’ equipment is installed and operated in 57 countries over the world.
- The company’s share in the domestic market of Russia and the CIS is 70%.
- Total installed capacity of equipment manufactured by the company exceeds 300 GW.
POWER MACHINES - IS A LEADING SUPPLIER OF INTEGRATED SOLUTIONS FOR THERMAL POWER PLANTS

With an extensive experience in development and production and all necessary design and production resources, Power Machines offers effective integrated solutions for main generating equipment supply and maintenance for thermal power plants.

MORE THAN

2300 steam turbines
2700 turbogenerators

were manufactured by Power Machines

MORE THAN 45%
THERMAL POWER PLANTS

and about 40% gas turbine power plants and combined-cycle power plants in Russia are furnished with Power Machines’ steam turbines

QUALITY ASSURANCE

Production quality and reliability are provided due to strict adherence to manufacturing process and company’s quality assurance policy. 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 manufacturing solutions are based on detailed calculations and technological studies. All finished products are subject to final inspection – assembly check and examination at factory test benches.

The company is particularly focused on quality inspection at every production stage. All materials are subject to inspection and the most critical parts and components undergo repeated mechanical tests.

All components are tested by the Technical Inspection Department before they are delivered to the customer. Moreover, main equipment assemblies are subject to assembly check and tests in the presence of the customer. Participation in tests makes it possible for the customer to be assured of high quality of the manufactured equipment.

The Power Machines production facilities are furnished with state-of-the-art manufacturing equipment.
PRODUCT RANGE FOR THERMAL POWER ENGINEERING

Power Machines designs, manufactures and supplies the following:

- steam turbines of various types up to 1200 MW, including NPP turbines;
- turbogenerators of various types up to 1200 MW;
- boiler equipment: utility boilers, heat recovery steam generators, auxiliary heat-exchange equipment, etc.;
- electrical automation systems;
- auxiliary equipment: condensers, oil coolers, gland steam condensers, bleed check valves, filters, etc.

Power Machines implements complete customer service package, including:

- inspections;
- design of wide range of power equipment of various output, as well as control systems based on most advanced technologies;
- procurement, manufacturing and assembling;
- transportation and storage;
- erection and commissioning;
- acceptance tests, putting into operation and safety tests;
- warranty and post-warranty customer service support;
- equipment upgrading;
- customer stuff training.

OVER 100 YEARS OF EXPERIENCE

in design and production of equipment for thermal power plants
Power Machines’ turbine equipment of high and medium power is produced at Leningradsky Metallichesky Zavod (LMZ), which is the main Russian supplier of this type of equipment.

The plant has over 100 years of experience in manufacturing of steam turbines of various types and capacities. The first turbine produced by Leningradsky Metallichesky Zavod was put into commercial operation in 1907.

General characteristics and main advantages of the Power Machines steam turbines

Cost effectiveness and reliability

As to flow path characteristics of produced turbines, they are at the level of turbines made of the world’s leading manufacturers.

Long-term experience of turbine operation makes it possible to guarantee high performance during more than 40 years of operation and a mean time between scheduled maintains not less than 6 years.

Cost effectiveness and reliability of the Power Machines steam turbines are ensured by:

- implementing the advanced design methods, as well as technologies and equipment from leading Russian and global manufacturers;
- 3D profiling of moving and guide vanes;
- optimization of steam inlets, bleeds and exhausts by CFD methods;
- new improved seal designs;
- smooth meridional profiles of flow path;
- aerodynamic pilot testing of blades and flow path elements to confirm both reliability and efficiency;
- check calculations of the flow path elements by CFD methods.
Reduced losses

Losses are reduced by using high-performance blading, state-of-the-art types of seals, advanced water removal from low pressure flow path structure, and improved regenerative heater system.

Blades

Blades of all stages have integrally-machined shrouds improving stage reliability and performance.

Power Machines’ specialists developed and implemented new types of high effective seals, which ensure reduced radial clearances of moving blades and provide reduced leakage. Introduction of these seals into NPP turbines made it possible to increase their efficiency and improve start/stop characteristics.

Meridional profiling allowed to increase efficiency significantly and to reduce erosion damage of blades.

General principles of research and development

Power Machines approaches new equipment development in accordance with basic power engineering trend – constant improvement of efficiency by increasing of initial steam conditions and turbine design improvement.

Steam turbine construction is based on modular design concept using major components: cylinders, group of stages, separate stages, rotors, housings, bearings, etc. Major turbine components have a high level of structural and process optimization and confirmed performance. Such an approach makes it possible to incorporate into new structures all the best solutions accumulated during operation of extensive park of prototype turbines and thus reducing project execution period.

Products

Having significant experience and all the resources required for development and production of competitive steam turbines equipment, Power Machines offers a wide range of proprietary steam turbines of 20 to 1200 MW both for new construction projects and upgrading of existing power plants.

Today Power Machines designs, manufactures and supplies wide range of turbines for various applications:

- Condensing turbines for subcritical and supercritical steam conditions up to 1200 MW.
- Condensing turbines with heat extraction up to 330 MW.

- Extraction turbines with process heat extraction up to 140 MW.

- Extraction reheat turbines up to 210 MW.
- Backpressure turbines up to 85 MW.

- CCGT turbines up to 160 MW.

- NPP turbines up to 1200 MW.
Power Machines' turbogenerators production facilities are located at the Electrosila plant. By now over 2730 turbogenerators with a total output of 283.8 GW or 334 GVA have been manufactured.

Output of turbogenerators produced by the company ranges from 6 to 1200 MW. All turbogenerators meet the requirements of GOST, IEC and other national standards.

Types of turbogenerators:
- hydrogen-cooled turbogenerators (ТВФ);
- hydrogen-and-water cooled turbogenerators (ТВВ);
- fully water-cooled turbogenerators (ТЗВ);
- air-cooled turbogenerators (ТА, ТФ, ТЗФ, ТЗФА, ТЗФАУ);
- combined air-/water-cooled turbogenerators (ТЗФСУ).

Benefits of turbogenerators:
- high reliability;
- low heating and vibration level;
- high efficiency;
- operation in reactive power consumption modes;
- noise enclosures, stator core spring mounting.
Thermal power plant equipment and services

Turbogenerators can be equipped with excitation systems of the following types:
- thyristor self-excitation systems;
- thyristor independent excitation systems;
- brushless diode systems;
- reversible thyristor self-excitation systems – for asynchronized turbogenerators.

Turbogenerators coupled with gas turbines are additionally equipped with static frequency converters (SFC). Equipment installation, adjustment and commissioning are performed by Power Machines representatives.

Turbogenerator retrofitting and modernization provide generator performance improvement: increased power, reduced temperature, improved reliability and extended service life.

ТВΦ series hydrogen-cooled turbogenerators

ТВΦ series turbogenerator ventilation scheme

*generator with noise enclosure;
*excitation system;
*cooling and ventilation;
*automated monitoring and diagnostics system;
*spare parts and installation tool kit;
*set of technical documentation.*
The ТВФ turbogenerator design features:
- stator winding cooling – indirect hydrogen;
- rotor winding cooling – direct hydrogen, self-ventilation;
- stator lamination cooling – direct hydrogen;
- stator winding insulation – using thermoreactive binders, thermal class F;
- rotor winding insulation – thermal class F, based on fiber glass and heat-resistant varnishes.

Upgrading measures:
- stator re-winding, replacement of rotors and excitation systems for active ТВФ-type turbogenerators.

### Types of ТВФ series generators

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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<tr>
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<td>Project</td>
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</tbody>
</table>

**TBB series hydrogen-and-water cooled turbogenerators**

This type of turbogenerators accounts for over 80% of installed TPP and NPP turbogenerators in Russia and the former Soviet Union states. TBB series turbogenerators are designed for coupling with a steam turbine and unit at thermal and nuclear power plants of 160 to 1200 MW power range.
Unified design principles are applied to main components of hydrogen-water-cooled turbogenerators. This allows to optimize the turbogenerator design to the full extent and start the full-scale production with high-level standardization of its components.

**Advantages of TBB series turbogenerators:**

- cost effectiveness;
- flexibility;
- reliability;
- improved vibration behavior;
- high heat resistance;
- easy maintenance and operation under different climatic conditions;
- possible operation in reactive power consumption modes.

**TBB series turbogenerator design features:**

- stator winding cooling – indirect hydrogen;
- rotor winding cooling – direct hydrogen, self-ventilation, gas gap-pickup system;
- stator lamination cooling – direct hydrogen;
- improved design of stator winding water-cooling manifolds due to the use of elastic fastening and vibration-absorbing components;
- stator winding insulation – continuous, thermoreactive, thermal class F;
- rotor winding insulation – based on fiber glass and heat-resistant varnishes, thermal class F;
- fundamental change in stator end winding support system provides vibration reduction by 20-25% from standard requirements, and improved maintainability due to demountable construction;
- improved design of stator core end enables heat reductions by 20-30% and increased reliability during operation.

**Types of TBB series generators**

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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</thead>
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<tr>
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<td>24</td>
<td>3000</td>
<td>2006</td>
</tr>
</tbody>
</table>
T3B series fully water-cooled turbogenerators

Turbogenerators of this series are designed for newly constructed power plants and for replacement of generators with expired service life.

In view of power industry perspectives, Power Machines has developed and launched the mass production of the unrivaled T3B series heavy-duty turbogenerators with fully water-cooled stator winding, rotor windings and stator core laminations (“three waters”).

Advantages of T3B series turbogenerators:

- explosion and fire safety;
- high flexibility and overload capability due to low heating and vibration levels;
- no shaft oil seals, fans or gas coolers built into the stator.
High reliability is ensured by:

- measures preventing cavitation and erosion of hollow conductor walls of stator and rotor windings;
- low lateral vibrations in rotor and bearings;
- bracing of stator slot winding using counter wedges and flexible gaskets;
- self-pumped rotor cooling system without hydraulic connections between rotor windings and shaft;
- complete rotor damping system;
- flat silumin coolers in the form of segments with embedded stainless steel tube coils, installed between cooling stacks of stator core laminations.
- special design of stator end winding support;
- improved compaction of stator core due to the absence of vent spacers between the stacks.

### Types of T3B series generators

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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<td>3000</td>
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</tbody>
</table>

### TA, ТΦ and Т3Ф series air-cooled turbogenerators

The turbogenerators are designed for newly constructed combined-cycle, gas turbine and steam turbine plants and for replacement of hydrogen cooled and hydrogen-water cooled generators with expired service life. Output range is from 6 to 350 MW.

All series use:

- the latest thermosetting insulation for stator and rotor windings;
- electrical steel with low specific loss;
- state-of-the-art structural materials;
- depending on the generator output, stator winding insulation is of the Monolit-2 type using dry glass-mica tapes with subsequent forced vacuum impregnation and curing of winding packed into the stator core. Or Resin Rich insulation using pre-impregnated tapes with subsequent hydrostatic testing.
Advantages of turbogenerators with the state-of-the-art air cooling:

- improved reliability due to simple design;
- reduced amount of auxiliary equipment;
- easy and faster preventive maintenance;
- higher flexibility;
- maintenance safety;
- high operational completeness allowing shipment of a factory tested turbine unit;
- reduced installation time.

### TA series

TA series – includes turbogenerators with indirect cooling of stator and rotor winding and direct air cooling of stator core.

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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<tr>
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<tr>
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<td>98,4</td>
<td>10,5/6,3</td>
<td>3000</td>
<td>2012</td>
</tr>
</tbody>
</table>

### ТФ series

ТФ series - includes turbogenerators with direct air cooling of rotor winding and stator core and indirect cooling of stator winding.

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
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<td>137,5</td>
<td>98,5</td>
<td>13,8</td>
<td>3000</td>
<td>1998</td>
</tr>
</tbody>
</table>
ТЗФ series

The ТЗФ series includes turbogenerators with three-loop air cooling. Turbogenerators of this series represent further developed ТФ series units. ТЗФ type turbogenerators make it possible to increase output of turbogenerators with air cooling up to 350 MW. Reliability and overload output are achieved due to separated air flows for stator and rotor cooling and avoidance of their negative interaction. This makes it possible to reduce heating of active and structural generator components while reducing air flow rate.

Turbogenerators of this series are featured by:
- better and more uniform cooling of active components;
- improved characteristics;
- higher efficiency;
- optimized use of electrical materials;
- use of high-conductivity insulation materials;
- reduced installation weight of stator.

Cross-sectional view (vertical)

Cross-sectional view (horizontal)

Types of ТЗФ series generators

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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<td>411,8</td>
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<td>20</td>
<td>3000</td>
<td>Project</td>
</tr>
</tbody>
</table>
ТЗФА, ТЗФАУ, ТЗФСУ, АСК

ТЗФА, ТЗФАУ and ТЗФСУ type asynchronized turbogenerators with air- and combined air-water cooling

Asynchronized turbogenerators with air- and combined air-water cooling up to 110, 160 and 320 MW and compensators are designed for reactive power control in grids and voltage control at the connection point. Turbogenerators of this type are installed at newly constructed power plants, and also when generators with expired service life are replaced with standard foundations of units with corresponding output.

This series’ generators should be installed in order to drastically and cost-effectively solve the problems in grid operation and make it possible to:

- increase static and dynamic grid stability;
- consume and produce wide range of reactive power;
- regulate the grid voltage level.

Stator core end design version is characterized by increased mechanical strength and enhanced cooling.

Two controlled rotor field windings that are supplied from individual excitation systems and controlled by a common automatic controller ensure increased dynamic stability of power units and the entire grid.

### Asynchronized compensators (ACK)

ACK ensure reactive power control in electric power system, which is especially important during electric energy transmission via long lines and in local systems under the existing periodical variations of the consumed power.

Asynchronized compensators are distinguished from synchronous ones by an additional field winding along the lateral rotor axis. For nonsalient pole ACK, the magnetomotive force (MMF) of this winding can be significantly lower than the main field winding MMF.

<table>
<thead>
<tr>
<th>Generator type</th>
<th>Rated output, MW</th>
<th>Total output, MVA</th>
<th>Efficiency, %</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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<tr>
<td>ТЗФА-110-2UZ</td>
<td>110</td>
<td>116</td>
<td>98,1</td>
<td>10,5</td>
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<td>2003</td>
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<td>15,75</td>
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<td>ТЗФСУ-320-2UZ</td>
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<table>
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<th>Compensator type</th>
<th>Power, MVar</th>
<th>Voltage, kV</th>
<th>Speed, rpm</th>
<th>Year of introduction into full-scale production</th>
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<td>ACK-100-4</td>
<td>-100 … +100</td>
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<td>2008</td>
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</table>
Main types of excitation systems manufactured by Power Machines for thermal power plants:

- Thyristor self-excitation systems;
- Independent thyristor systems;
- Standby thyristor systems;
- Brushless diode systems;
- Reversible thyristor systems;
- Power converters;
- Excitation control system;
- Excitation system protection.

Excitation systems provide the following operation modes of synchronous generators:

- initial excitation;
- idling;
- connection to grid by precision synchronization or self-synchronization;
- operation in power grid under loads and overloads permissible for turbogenerator;
- rotor swing damping (system stabilizer in accordance with Russian and international standards);
- excitation boost with preset ceiling voltage and current factor;
- reactive power shedding up to $\cos \phi = 1$;
- de-excitation in case of power grid faults;
- field suppression in emergency and during normal shutdown;
- switch over from main to standby excitation and back.

Advantages of our excitation system design:

- maximum safety of operating personnel and equipment is ensured by a set of special measures, including optic cables and draw-out thyristor converters (upon customer’s request);
- easy maintenance of excitation boards is achieved by combination of modular configuration, which ensures easy access to any board component, and practical layout of controls, alarms, instruments and measurement points;
- optional design diversity is the opportunity of easy transformation of standardized sections;
- thyristor converter cooling - water, forced air or natural air cooling;
- high degree of completion at works is ensured due to the fact that all electrical connections between sections are located inside the board;
By implementing integrated solutions for thermal power plants, Power Machines supplies generating equipment complete with control systems. The company offers the following services:

- turnkey automation of turbine halls, including power unit and auxiliary equipment control systems, protection systems (hydromechanical and electrical) and vibration control systems;
- TPP main equipment automation, including: turbine set frequency and power controllers, thermal control systems, vibration control systems, process control systems, auxiliary equipment control systems;
- system for monitoring turbogenerator process variables;
- system for monitoring condition of insulation by partial discharge method;
- system for monitoring vibration of structural elements of turbogenerator stator;
- generator protections;
- excitation system protections;
- protection of generator-transformer block;
- generator synchronization systems;
- protections of Unit transformers and auxiliary transformers;
- cubicle for generator circuit-breaker control automatic equipment.

To increase service life of generator equipment, to widen repair intervals and to make forecasts of equipment condition, turbogenerators may be equipped with automatic monitoring and diagnostics system. The following systems may be supplied with the generator:

- system for monitoring turbogenerator process variables;
- system for monitoring condition of insulation by partial discharge method;
- system for monitoring vibration of structural elements of turbogenerator stator;
- system for monitoring turbine set rotor shaft currents (shaftline);
- system for monitoring turn-to-turn short circuit in rotor winding;
- system for monitoring brush contact system.

Specialists of the company are experienced in setting into operation, service and modernization of automatic system and microprocessor-based protection equipment, have Licences and Certificates from the leading Manufacturers entitling to precommissioning work and technical service (OOO NPP "EKRA", Siemens, GE).
Power Machines provides complete service package for installation supervision, adjustment supervision, testing of power equipment to be put into operation, upgrade, repair and refurbishment work, spare part and special material supply.

The customer services provided by Power Machines include engineering supervision of installation, adjustment and commissioning of power equipment, and warranty services, participation in scheduled maintenance, repair process development, training of customer’s personnel and contractors, consulting services and post-warranty services.

**Maintenance of steam turbines from 50 to 1200 MW:**

- full or partial modernization of high, intermediate and low pressure cylinders with or without steam flow rate buildup in order to increase power and efficiency by 2 to 12% and reduce specific fuel consumption by 3 to 10% (depending on the scope of refurbishment, initial equipment condition and local conditions);
- modernization of steam turbine compartments with process steam extraction in order to increase their throughput due to reduced steam consumption for production purposes with the respective gain in generated power;
- turbine modernization in order to adapt the main and auxiliary equipment of the unit to combined cycle;
- provision of additional extractions from high, intermediate or low pressure cylinders of 60 to 300 MW to satisfy customers’ needs in process and heating steam extractions;
- installation of supplementary turbines of 25 to 70 MW, which use unused process bleed steam;
- provision of controlled heating steam extractions for condensing turbines of 200 to 1200 MW to achieve thermal power from 100 to 300 Gcal/h;
- modernization and delivery of advanced monitoring, vibration monitoring and diagnostics systems;
- modernization of control, vibration monitoring and diagnostics systems;
- process control system modernization with changeover to electronic system;
- replacement of condensers and improvement of auxiliary equipment.
Customer service and spare parts for electrical equipment

Own warehouse of standard spare parts and consumables allows express delivery to customers in any region.

Throughout the equipment service life, customers are provided with a wide range of customer services: installation supervision, adjustment supervision, chief supervision, inspection, repair, supply and replacement of required spare parts and components, and at the same time high quality and reliability of supplied equipment are guaranteed.

The customer service program includes a flexible discount system and mutually advantageous customer service procedures such as:

- extended warranty period;
- additional spare parts and materials;
- delivery of required equipment directly from the company’s customer support warehouse;
- full-scale equipment examination and diagnostics services using state-of-the-art testing and diagnostics tools.

The scope of spare part supply includes special components such as retaining rings, current-carrying bolts, PET cords, etc. Special chemical components such as varnishes, enamels and compression materials are provided as well.
Steam boilers are developed by the engineering divisions of the TBW Krasny Kotelshchik, which have extensive and successful experience in research and development. The Taganrog Boiler-Making Works has a long-term experience in production of:

- boilers up to 500 t/h;
- boilers for 200 MW units;
- supercritical pressure boilers for 300 MW units;
- supercritical pressure boilers for 500 MW units;
- supercritical pressure boilers for 660 to 800 MW units;
- supercritical pressure boilers for 1200 MW units.

The production output of the TBW Krasny Kotelshchik is up to 6 GW per year, it is planned to increase the output up to 10 GW per year. During several previous decades, the TBW Krasny Kotelshchik has been the leading supplier of direct-flow supercritical pressure boilers for 1200, 800, 300 MW power units for large size thermal power plants in Russia and worldwide. Basic reliability and cost-effectiveness characteristics of these boilers correspond to the current level of the leading foreign boiler manufacturers that is proven by long-term operation experience. The TBW Krasny Kotelshchik is one of the world leaders in total production of supercritical pressure boilers for 1200, 800 and 250 to 300 MW power units.

Customer service and modernization

- installation and adjustment services for supplied equipment;
- full package of equipment maintenance services throughout the service life based on:
  - long-term customer service contracts (6-12 years);
  - implementing of remote monitoring systems of equipment condition;
  - development and fulfillment of maintenance and repair services based on actual running hours and failure criticality level;
- responsibility for technical and economic performance and equipment availability.

Proprietary maintenance services for newly introduced equipment

- development and fulfillment of long-term equipment maintenance, repair and modernization programs covering the entire service life.

Remote monitoring system implementation

Development, manufacturing, supply, installation, commissioning and personnel training

Warranty and post-warranty maintenance, repair and spare part supply

Refurbishment and modernization

Equipment removal from operation (replacement)