SERVICE OF THERMAL POWER PLANTS

POWER MACHINES
MISSION
Provide reliable and effective integrated solutions in order to meet the needs of the global energy system, continuously improving its technologies and business processes.

VISION
Occupy the first place in the market of power engineering of Russia and the CIS and to be a key player in the world market.

VALUES

ATTENTION TO CLIENTS
The company exists only due to our clients.

SAFETY
No goal can justify violation of labor protection requirements or neglecting people’s life and health.

TEAMWORK
We are a team of like-minded people who share common values.

PRODUCTIVITY AND EFFICIENCY
It is the ability and desire to do the right thing quickly and correctly on the first try.

FOCUS ON INNOVATION
We strive to introduce innovations and continuous improvements based on the best practices, outdo them and create the new ones.

RESPECT FOR PEOPLE
The ability to create an attractive work place and atmosphere depends on the joint efforts of both the organization as a whole and the leaders and individual employees.
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Dear Client!

You are looking at the catalog of the Power Machines, which presents service solutions for each stage of the life cycle of the Thermal Power Plant power-generating equipment.

Our service offers allow to reduce operating costs, to increase efficiency, reliability and safety of equipment operation, as well as to extend its service life. Any solution can be adapted to the needs of a specific customer and equipment features.

What Are Our Advantages?

For many years our own scientific school and high-technology production base have been satisfying the growing needs of the Russian and world energy with advanced technologies. Power Machines has factories that have become symbols of the domestic power plant engineering.

Leningradsky Metallichesky Zavod, the Electrosila Plant were at the origins of the creation and rapid growth of the Russian energy industry. Here the first sets of Russian turbine and generator equipment were made, unique technologies were created, which are now widely used in the global energy industry. Every second power unit in Russia is fitted with the equipment of enterprises which are a part of Power Machines.

Today our production capacities allow us to produce up to 8.5 GW of turbine equipment per year, and the same amount of generators. Power Machines is developing intensively, introducing the best world practices in production and management. All this allows us to adapt as much as possible to the needs of the market and to offer a number of competitive offers for comprehensive modernization of equipment.

Due to the knowledge of the characteristics of almost all energy facilities in Russia, technical experts of the company offer their clients modernization options optimal in terms of scope, efficiency and costs. The company has worked out in detail the projects for modernization of the equipment of its own production.

Simultaneously solutions for the replacement and modernization of third-party equipment have been developed.
New Approaches to Design

Power Machines uses modern design tools that allow designers and technologists to perform their processes not one after the other as before but simultaneously. We are making a transition to the design technology using an electronic model of the product. The same solid-state model of the turbine element is used by the design engineer during design process, by the technologist in writing control programs for machines, in tooling design, and in part control during the manufacturing process.

The capabilities of modern computational programs and computing complexes allow us to continuously improve the elements of the equipment being produced. We optimize new projects of turbines, generators and boilers using the finite-element method, solve adjoint strength problems and apply their solutions in practice. We test the long turbine blades on our own experimental base. We have learned to improve the body geometry by the so-called topological optimization method, which we use for welded and cast structures. We optimize the gas dynamics of the exhaust pipes, steam distribution facilities. The complex of research and design work carried out by us to improve the burner devices of boiler equipment is aimed at achieving the level of European standards for specific emissions. Various combustion technologies are also being developed.

Service Backup

In order to ensure the unity of service solutions, the company has a Service Center where all services are centralized: adjustment supervision, engineering supervision, inspections and diagnostics, commissioning and start-up, technical support and consulting.

Today, the service in Power Machines is a multi-level organization of technical re-equipment, from replacing morally obsolete and physically exhausted units to full replacement of power-generating equipment.

Along with technical offers for renovation, modernization and reconstruction of equipment, Power Machines offers a range of activities in the field of technical diagnostics, prognostics and vibration alignment. The measures are aimed not only at improving the operational reliability of the units, but also at providing repair, commissioning and start-up of new and previously installed equipment. At the request of the customer, any equipment can be fitted with an automation system that allows you to react in a timely manner and to prevent the failure of any unit at the earliest stages. All of the above allows Power Machines to be a reliable partner for generating companies and to offer modern solutions based on increased requirements for equipment efficiency, its safety and environmental friendliness.

Timur Lipatov,
the CEO of PJSC “Power machines”
UNITY OF SERVICE SOLUTIONS

Service solutions offered to our clients allow to reduce operating costs, to increase efficiency and reliability and safety of equipment operation, as well as to extend its service life.

Power Machines provides services for each stage of the life cycle of power-generating equipment.
When supplying new equipment, Power Machines performs:

- technical guidance and quality control of installation work;
- technical management of commissioning, start-up and coordination of work programs for adjustment and commissioning;
- engineering support of start-up operations.

The advantages of equipment post warranty service from the supplier:

- conducting high-quality repair of equipment in accordance with the requirements of regulatory documentation;
- use of original spare parts;
- development of repair procedures for a specific type of equipment;
- increase of equipment design characteristics;
- recommendations for extending the service life of equipment and increasing its efficiency;
- detection of hidden equipment damage at an early stage.

The main objectives of PJSC “Power machines” technical re-equipment:

- extending the service life of equipment, having its economic life expired, by replacing high-temperature structural elements;
- improving economical efficiency, reliability, maneuverability and repair capability parameters of equipment;
- full or partial bringing of equipment characteristics in compliance with the modern consumer market of heat and electricity.
STEAM BOILERS

MANUFACTURER
Taganrog Boiler-Making Works
Krasny Kotelshchik (TKZ)

> 100 years
in the market of power plant engineering

80%
of installed fleet of boiler equipment
in the Russian Federation

60%
of power plants in the CIS

60%
of boilers for coal power plants
in the Russian Federation

43%
of HRSGs for CCGT

> 30 COUNTRIES
IN THE WORLD
use TKZ equipment
Types of boilers manufactured:

Steam boilers:
- boilers for 800 MW power units (steam generating capacity of 2650 t/h)
- boilers for 600-660 MW power units (steam generating capacity of 1900-2225 t/h)
- boilers for 300-350 MW power units (steam generating capacity of 1000-1080 t/h)
- boilers for 200-225 MW power units (steam generating capacity of 640-670 t/h)
- boilers with steam generating capacity of 420 t/hour
- boilers with steam generating capacity of 230-270 t/hour
- boilers with steam generating capacity of 50-150 t/hour

HRSGs for the combined cycle plants
- Water-heating HRSGs and gas-and-oil-fired boilers from 40 Gcal/hour

Boiler equipment for TPP design execution is characterized by:
- high efficiency and availability of technical capabilities to improve it;
- technological solutions to reduce harmful emissions into the atmosphere;
- possibility of further increasing the unit capacity of steam boiler units;
- tried and tested design and technological base of high pressure, SSP and super SSP boilers;
- the potential for further development in promising areas (circulating fluidized bed (CFB), etc.), combined with other technologies (combined-cycle units, gas generation);
- the use of new technologies for combustion chamber and other boiler processes.
BOILER
EQUIPMENT
SERVICE
1. Boiler Equipment Service

1.1 General Solutions

For newly introduced equipment:
• technical support of installation, commissioning and start-up;
• warranty and service maintenance;
• comprehensive equipment service maintenance throughout the life cycle based on:
  – short-term and long-term service agreements;
  – introduction of systems for remote monitoring of equipment state;
  – development and implementation of standards for service and maintenance of equipment based on the actual operation time and the degree of criticality of failures;
  – equipment inspections during scheduled shutdowns;
  – formation of a “service warehouse” of spare parts, materials and parts according to the manufacturer’s nomenclature within the framework of a service agreement.

For equipment operated within a specified service life, as well as for equipment with a service life coming to an end:
• Comprehensive technical inspection and diagnostics of the boiler island equipment state.
• Research, monitoring and testing of boilers and boiler accessories.
• Technical management of repairs, consulting services.
• Delivery of spare parts and reconstruction within routine maintenance and repair.
• Development of offers for the modernization of boiler units in order to improve the efficiency of the power unit, reducing emissions of harmful substances.
• Equipment design as part of the modernization.
• Supply of large nodes of the boiler island in the framework of modernization programs.

1.2 Experience in Providing Integrated Services for Boiler Equipment on the Example of Zhezkazgan TPP

The purpose of service maintenance:
• reduction of negative consequences associated with the transfer of TP-10 and TP-13 boilers to the burning of non-standard fuel;
• planning of a step-by-step boiler repair campaign;
• increase of boiler design characteristics.

Service of boiler equipment, as a rule, consists of three areas – inspection, repair and adjustment, and is aimed at implementing an integrated approach to the restoration and modernization of equipment.

The first stage of work:
• external and internal equipment inspections, analysis of actual mean time between failures;
• identifying the causes of these failures;
• determination of the actual technical and economic performance of the equipment operation.
Results:
- the following multiple deviations of the design characteristics of the components of the boiler units were identified:
  - corners of burner package;
  - characteristics of pulverized-coal feeders;
  - non-standard steam extraction from the boiler drum for emulsifiers;
- revealed components of boiler units, the wear of which impeded the reliable operation of the boiler units;
- studied and analyzed nature and extent of damage, which resulted in recommendations for the replacement or repair of components.

The second stage of work:
- engineering certification of the bearing structures of boilers in order to determine the actual condition and to develop repair measures for restoring their bearing capacity;
- adjustment work in order to achieve optimal economic performance of boilers operation;
- audit of technological operations performed during the kindling of boiler units, sampling of fuel, dust, water and steam.

Results:
- recommendations were given in order to eliminate errors during technological operations that entail measuring results falsification of dust fineness and feed water and steam salinity;
- a number of defects was revealed in the process flow diagrams and ancillary equipment, that limit the nominal load and worsen the economical efficiency and reliability of the boilers;
- a reliability of operation of boilers was increased due to adjustment activities: modernization of burner devices and dust supply path were performed.

The third stage of work:
- determination of the list of modernized elements in order to increase the reliability and economical efficiency of the boilers;
- development of equipment overhaul project;
- detailed design and manufacture of boiler elements to be replaced.

The advantages of the integrated service from the Supplier in comparison with the traditional approach to the repair of boiler equipment:
- qualified analysis of the operation of the boiler and ancillary equipment;
- identification of weaknesses in the operation of equipment and process flow diagrams;
- offering various solutions to the identified inconsistencies: repair, replacement, modernization;
- increasing the reliability of operation of equipment due to adjustment activities;
- phasing of work, the possibility of optimal planning and resource allocation.

1.3 Offer for the Long-Term Service of HRSGs of CCGT

The complex of works includes:
1) regular monitoring of compliance with the operational parameters:
  - compliance with the operating conditions and operation mode of the equipment in accordance with the manufacturer’s instructions;
  - equipment loading in accordance with data sheets, prevention of equipment overload, except for the cases specified in the instruction manual;
  - strict observance of the operation modes of the boiler and all piping systems set under these operating conditions;
  - maintaining the necessary cooling mode for parts and equipment components subject to increased heat;

2) periodic inspection of equipment during its operation, including:
  - planned inspection of operating equipment in order to check the condition of the boiler unit;
  - detection of overheating, fire, clogging, violations of safety rules and fire regulations;
  - checking the state of thermal insulation and corrosion protection;
  - checking the presence of steaming, gaps in flange connections, fittings;
  - inspection of welds near supply and other nozzles;
  - detection of leaks in safety valves, drain valves and air valves, intermittent blowdown valves;
  - checking the feed water network of the boiler;
  - checking the absence of irregular noise in the furnace;
• checking the status of sites, fences;
• supervision over support, fastenings, indicators of positions of pipelines;
• preventive inspection and check of backup equipment in order to eliminate deviations from the normal state, defects and breakdowns;

3) inspection (equipment inspection) during the scheduled shutdown of GTU*;

4) equipment state monitoring;

5) equipment state diagnostics;

6) scheduled preventive maintenance on equipment in accordance with the Rules for organizing the maintenance and repair of equipment, buildings and structures of power plants and networks, including*:
   • cleaning of all components from dust and dirt;
   • tightening of fitting glands; elimination of steaming, leaks, gaps in flange connections;
   • identifying the degree of depreciation of components and parts readily accessible for inspection and the possibility of their timely replacement;
   • checking the status of non-metallic compensators (at least 1 time in 3 months);
   • elimination of flue gas emissions, especially through non-metallic compensators;
   • repair of inspection hatches, furnace doors and manholes with replacement of hinges, bolts, studs and gaskets;
   • checking and cleaning nozzles and pipes towards water-gauge columns;
   • checking and eliminating (if possible during the maintenance period) the absence of pinching of the drums, collectors and water-wall tubes, which impede the free expansion of the boiler elements;
   • inspection and check of control mechanisms, bearings, valve actuators;
   • check and adjustment of safety valves including the replacement of defective parts;
   • monitoring the health of measuring systems and measuring instruments, including their calibration;
   • repair of stairs and platforms;
   • troubleshooting of logged defects;

7) formation and access to the “service warehouse” of spare parts, materials and parts according to the nomenclature of the manufacturer of the HRSG;

8) equipment state diagnostics (based on the information obtained during the execution of paragraph 1. and the operation of the (Automated System for Boiler Technical Diagnostics) software and hardware complex);

9) service maintenance program management;

10) consulting services (without a specialist visit to the site);

11) maintenance of measuring instruments, automation, interlocks and alarms (I&CE).
* Scope of scheduled inspections of the HRSG:

inspection (external and internal inspection of the steam and gas paths of the boiler); frequency – during the scheduled shutdown of the gas turbine;

1) inspection of the boiler gas path and body:
   • inspection of the inlet diffuser and compensator between HRSG and GT;
   • inspection and assessment of the state of the cladding and insulation elements of the HRSG gas flue;
   • assessment of the state of gas-dynamic and noise-suppression devices of the HRSG gas flue;
   • assessment of the state of seals of the HRSG gas flue;
   • removal of dirt and dust deposits from the outer surface of a non-metallic compensator by wiping with a damp cloth;
   • control of tightening of nuts and clamps of non-metallic compensators (using torque wrenches);
   • inspection of the output confuser and compensator between the HRSG and the chimney;

2) inspection of steam-water path:
   • external visual measuring control of heating surfaces;
   • endoscopic control of collectors and pipes of heating surfaces;
   • monitoring the state of the hanger-support system of heating surfaces;
   • visual and measuring control of the boiler pipelines;
   • monitoring the state of the hanger-support system of pipelines;
   • monitoring the state of the metal of heating surfaces and pipelines (according to the regulations);
   • determination of the degree of contamination of internal surfaces and the need for chemical washing (at least 1 time a year);
   • assessment of the state of parts made of austenitic steel, in particular, i-shaped inter-module partitions, and the possibility of replacing them when in an inappropriate condition;
   • selective inspection and monitoring of the components of shear-resistant connections of the HRSG elements on high-strength bolts with controlled tension, with selective control of the tightening torque of the bolts;
   • blowing of heating surfaces, elimination of slagings, dusting, steaming;
   • technical diagnostics of tubular elements, including those made from P91 steel grade, is made within the estimated service life (after its expiration) and after any accident, within the “Standard Instructions for Monitoring the Metal and Extending the Service Life of the Main Elements of Boilers, Turbines and Pipelines of TPPs” RD 10-577-03 and HRSG Operating Manual P-133 R-92403RE;

3) inspection of the boiler structure metalwork:
   • visual and measuring control of metalwork;

4) inspection of the boiler drums (at least 1 time in 6 years):
   • inspection of the state of the internal drum separation devices (fastening, cleanliness, presence of cracks on the edges of the holes, pock-holes on the drum body);
   • external visual and measuring control;
   • endoscopic control;
   • metal state monitoring;

5) elimination of individual defects identified as a result of state monitoring, inspection (testing) for serviceability (operability);

6) drawing up a report on the state of the equipment on the results of the inspection;

7) composition of the team performing the HRSG inspection:
   • field service engineer;
   • design engineer;
   • metallographist;
   • water chemistry specialist;
   • non-destructive testing specialist.
List of installed HRSGs:

- steam HRSG E-38.3/8.1-5.5/0.63-521/230 (EMA-021-KU, EMA-022-KU) of Omskaya TPP-3 (unit PGU-90);
- steam HRSG E-236/41.9.3/1.5-512-298 (EMA-031-KU) Vladimirskaya TPP-2 (unit PGU-230);
- steam HRSG Ep-264/297/43-13.0/3.0/0.47-558/558/237-11.6vv (EMA-028-KU) construction of PGU-410T (Salavat);
- steam HRSG Ep-264/297/43-13.0/3.0/0.47-558/558/237-11.6vv (EMA-024-KU) PGU-420T TPP-16 of a branch of OAO Mosenergo;
- steam HRSG Ep-264/297/43-13.0/3.0/0.47-558/558/237-11.6vv (EMA-025-KU) PGU-420T TPP-20 of a branch of OAO Mosenergo;
- steam HRSG E-20-0.7-170 for GTU-TPP of OOO Mayak-Energiya;
- steam HRSG E-65-4.0-440 (Tuapsinsky Refinery);
- steam HRSG Ep-270/316/46-12.5/3.06/0.46-560/560/237 (Serovskaya SDPP);
- steam HRSG Ep-227/50-10.6/1.64-515/291-15.1vv (Permskaya TPP-9);
- steam HRSG Ep-160/14-9.0/0.7-552/210 (Novobereznikovskaya TPP);
- steam HRSG Ep-274/320/44.6-12.69/3.08/0.46-566/561/237 (Permskaya SDPP);
- steam HRSG E-65-4.0-440 (Tuapsinsky Refinery);
- water-heating HRSG KUV-38.1-185 for Yakutskaya SDPP-2 (second priority);
- water-heating HRSG KUV-46.4-130 for GTU-TPP unit at the central steam water boiler house (CSWBH) site (Vladivostok);
- water-heating HRSG KUV-38.1-185 for Yakutskaya SDPP-2 (second priority);
- water-heating HRSG KUV-46.4-130 for GTU-TPP unit at the central steam water boiler house (CSWBH) site (Vladivostok).
TECHNICAL
RE-EQUIPMENT
OF BOILERS
PJSC “Power machines” offers a multi-level organization of technical re-equipment – from replacing morally obsolete and physically exhausted units to full replacement of boilers. Re-equipment can be carried out step-by-step depending on the specific conditions.

Projects have been developed for modernization of life-expired boilers with a steam generating capacity of 170 to 420 t/h, as well as boilers for power units of 200 and 300 MW (TP-42, TP-80, TP-87, TP-100, TPP-210). They meet the modern technical level and provide for the preservation of the existing buildings of boiler rooms, foundations and basic elements of the structure.

Goals of boiler modernization

- Improving technical and economic and environmental indicators
- Compliance of the boiler with modern requirements (current regulatory documents, current trends)
- Restoration of resource of the heating surfaces

Power Machines guarantees to the customer:

- increase in steam generating capacity up to 10% due to replacement of components and elements of the boiler unit;
- increase of boiler efficiency up to 2% of the specified efficiency in the boiler data sheet;
- reducing emissions of NOx and COx to regulatory ones in accordance with the requirements of the regulatory documents of the Russian Federation;
- resource restoration of the heating surfaces (when replacing the components operating under pressure).

1. Restrictions on Boiler Modernization

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</table>
| 1   | The steam parameters (pressure and temperature) at the boiler outlet shall remain unchanged | Increasing these values makes the following necessary:  
• replacement of all superheating components of the boiler using more expensive metal;  
• mandatory replacement of the drum;  
• replacement of all connecting pipelines not only of the boiler, but also of the whole plant;  
• increase of the design time;  
• recalculation and possible replacement of equipment for the power unit regeneration;  
• partial fittings replacement |
| 2   | The actual state of the structure                                           | During preparation process of the initial modernization proposal, it is assumed that the boiler structure is in perfect condition. At the time of the offer, the customer has no information about the state of the structure. In fact, during the period of operation, many elements of the structure are exposed to external influences, the foundations settle, which leads to the need to replace the elements or strengthen them. The customer issues this data after a special inspection |
2. Step-by-Step Modernization of Boilers

<table>
<thead>
<tr>
<th>No.</th>
<th>Limitation</th>
<th>Justification/clarification of limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>The maximum increase in the boiler steam generating capacity is not more than 10%</td>
<td>Boiler steam generating capacity is limited by the size of the boiler furnace. With an increase in power, it is required to enlarge the furnace (fuel burnup conditions, conditions of slagging of heating surfaces, etc.). Since in Russia, the boiler equipment is installed indoors, the increase in the size of the boiler, as a rule, is limited by the size of the building and the size of the selected boiler house foot-print between adjacent boilers. Usually, for a coal boiler, without sacrificing the reliability of the heating surfaces, it is possible to increase the steam generating capacity by 5%</td>
</tr>
<tr>
<td>4</td>
<td>Frequent customer requirements are the following: to increase the range of regulation of the boiler and to start the power unit at the “variable pressure”</td>
<td>Increasing the range of regulation while maintaining steam parameters cannot be implemented for technical reasons. For a drum boiler, this is limited by the circulation conditions for direct-flow steam production. The possibility of starting the power unit at “variable pressure” is determined individually, depending on the specific packaged equipment and the necessary scope of its change</td>
</tr>
<tr>
<td>5</td>
<td>The connecting dimensions for steam and water should be kept unchanged</td>
<td>Changing the connecting dimensions will lead to the need of changing the plant pipeline route location. The connecting dimensions shall be maintained in order to minimize the cost of modernization</td>
</tr>
</tbody>
</table>

Scope of step-by-step modernization of boilers

<table>
<thead>
<tr>
<th>No. of stage</th>
<th>Replaceable boiler components</th>
<th>Solved problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Burners, air ducts (partially), furnace screens (partially), economizer, steam superheater (partially)</td>
<td>Bringing the level of emissions of harmful substances into the atmosphere to the standard. Increase of boiler efficiency. Increase steam generating capacity</td>
</tr>
<tr>
<td>2</td>
<td>Furnace screens (100%), downflow pipes, steam discharge and steam supply pipes of the drum</td>
<td>Furnace screens are made in gas-tight design: • reduced load on the structure due to the replacement of solid brick setting; furnace screens for insulation by mats; • reduced level of uncontrollable suckers in furnace; • replacement of the pipeline allows you to restore their economic life</td>
</tr>
<tr>
<td>3</td>
<td>Overhead steam superheater, convective and platen steam superheaters with manifolds, rotary gas flue screens</td>
<td>Manufacture of an overhead screen in gas-tight design makes it possible to apply light brickwork on the ceiling, to exclude suckers in furnace. When replacing steam superheaters, their economic life is restored</td>
</tr>
<tr>
<td>4*</td>
<td>Connecting pipelines, air heater, boiler fittings, slag remover, heating surface cleaning equipment, fittings</td>
<td>Equipment replaced without design changes (only resource recovery)</td>
</tr>
</tbody>
</table>

* the scope of the stage can be redistributed between stages 1-3
2.1 Plan of Activities for the Project Execution on the Step-by-Step Modernization of Boilers

**Stage Goal:**
Inspection of the boiler and ancillary equipment, collection of input data.

**Activities carried out:**
- collection of data on the state of equipment, the residual life of boiler components, the repairs performed;
- process flow tests of the boiler;
- analysis of results, comparison of operational data with those in data sheet. Issue of a report on the status of the equipment to the customer.

**Stage Goal:**
Development of measures for the modernization of boiler equipment.

**Activities carried out:**
- development of recommendations for the replacement of boiler components including improved performance (increased maneuverability, reduced emissions of harmful substances into the atmosphere, increased steam generating capacity, increased efficiency);
- development of an offer with a breakdown into the stages of replacement of the boiler units (taking into account the schedules and plans for the plant repair);
- development of the technical assignment for the whole complex of works.

**Stage Goal:**
Providing customer with TCO for the development of the working design, manufacturing and supply of equipment.

**Activities carried out:**
- coordination of the proposed procedure for the manufacture and supply of equipment including plans for repairs and financial capabilities of the customer;
- when planning/partitioning works, taking into account single-type equipment operated at the plants, it is possible to implement the approach consisting of various stages (“puzzles”) that are performed on several boilers. In addition, the stage number is conditional, not ordinal for execution.

**Stage Goal:**
Signing a contract for the design and manufacture of equipment.

**Stage Goal:**
Manufacture and supply of equipment in accordance with the signed contract.
2.2 Scope and Order of Step-by-Step Modernization of Drum Boilers

First stage
Modernization of the combustion system (furnace units and burning devices).

Stage Goal:
• increasing the economical efficiency of the boiler;
• improving the stability of fuel combustion;
• reduction of slagging of the furnace and convective heating surfaces to ensure the design performance (if necessary);
• improving the reliability of the boiler;
• increase (prolongation) of the estimated life of the operation of the elements.

Stage Scope:
• replacement of combustion chamber non-gas-tight screens with gas-tight ones;
• replacement of existing outmoded burners with modern low-toxic burners;
• installation of the top, side and bottom blowing nozzles (if necessary);
• replacement of downcomers (for drum boilers) in order to achieve the optimal resistance value of the boiler’s circulation system;
• partial reinforcement of individual elements of the boiler structure (if necessary).

Second stage
Modernization of convective heating surfaces of the boiler.

Stage Goal:
• improving the reliability of the boiler;
• increase (prolongation) of the estimated life of the operation of the modernized boiler elements;
• increase of the economical efficiency of the boiler.

Stage Scope:
• replacement of non-gas-tight screens of the transition (horizontal) gas flue and convection shaft with gas-tight ones;
• replacement of water economizer;
• replacement of steam discharge and water supply pipes;
• replacement of boiler crossover pipes;
• installation of additional injection steam superheaters (if necessary);
• replacement of morally obsolete fittings of the steam-water path with modern high-speed electrified (or pneumatic) fittings.
Third stage
Modernization of boiler air heaters.

Stage Goal:
- increase of the economical efficiency of the boiler by reducing losses with mechanical underburning of fuel (by increasing the hot air temperature) and with the heat of the exhaust flue gases, reducing the flows and suction of air in the air heater;
- expansion of the burned fuel range (with a deterioration in its quality);
- increase (extension) of air heater service life;
- improvement of the boiler reliability.

Stage Scope:
- replacement of combustion chamber non-gas-tight screens with gas-tight ones;
- replacement of existing outmoded burners with modern low-toxic burners;
- installation of the top, side and bottom blowing nozzles (if necessary);
- replacement of downcomers (for drum boilers) in order to achieve the optimal resistance value of the boiler’s circulation system;
- partial reinforcement of individual elements of the boiler structure (if necessary).

Fourth stage
Replacement of the drum with inner separation devices.

Stage Goal:
- increasing the steam generating capacity of the boiler;
- increasing maneuverability;
- increase (prolongation) of the estimated life of the boiler drum operation;
- possibility of the boiler operation with modern APCS.

Stage Scope:
- replacement of the boiler drum;
- replacement of drum inner separation devices;
- replacement of instrumentation with a modern one.
2.3 Examples of Drum Boilers Implemented Modernizations

The TP-85 (TP-85М) boiler, TPP of Magnitogorsk Metallurgical Complex.


Purpose of reconstruction:
New modernized boiler in the previous dimensions with modern indicators while preserving the structure, drum and foundations.

Achieved Result:
• actual boiler efficiency increased by 3%;  
• emissions of nitrogen oxides are reduced from 300 mg/m³ to the standard 125 mg/m³.

Scope of reconstruction:
• combustion chamber screens were replaced with gas-tight ones;  
• burner devices were replaced;  
• convective heating surfaces were replaced;  
• water economizer was replaced;  
• boiler structure, drum and foundation are preserved.

The TP-109 boiler, Kurakhovskaya TPP

Productivity: 640 t/h, fuel – black coal.

Purpose of reconstruction:
• increased efficiency;  
• improved environmental performance;  
• improved burning process.

Achieved Result:
• boiler efficiency increased by 3.5%;  
• emissions of nitrogen oxides are reduced by 100 mg/m³;  
• reduced slagging of the combustion chamber.

Scope of reconstruction:
• burner devices were replaced by advanced ones;  
• combustion schemes were improved;  
• furnace screens were partially replaced;  
• heating surfaces were partially replaced.

TGME-464 boilers, Nizhnekkamskaya TPP (stage of installation and configuration)

Productivity: 500 t/h, fuel – natural gas.

Purpose of reconstruction:
• ensuring the burning of petroleum coke in the gas-and-oil-fired boiler;  
• ensuring European environmental performance (using special cleaning equipment behind the boiler).

Achieved Result:
• ensuring the burning of petroleum coke with efficiency of 89%, of gas with efficiency of 94%;  
• ensuring European environmental performance (using special cleaning equipment behind the boiler).

Scope of reconstruction:
• replacement of burner devices;
3.1 Replacement of Burner Devices

TPP-201A boiler, TPP-22 Mosenergo (stage of manufacture and installation)

Productivity: 1000 t/h, fuel – black coal.

Purpose of reconstruction:
- increased steam generating capacity;
- improved environmental performance;
- operation and start-up at variable pressure;
- replacement of fuel with natural gas.

Achieved Result:
- increasing steam generating capacity from 960 to 1030 t/hour;
- reducing emissions of nitrogen oxides down to 125 mg/m³;
- operation and start-ups at variable pressure.

Scope of reconstruction:
- replacement of burner devices;
- change of burning process;
- replacement of furnace screens with gas-tight ones using Ramzin coiling;
- partial replacement of steam superheaters.

3. Modernization of Third-Party Steam Boilers

Power Machines provides solutions for the modernization of any type of boilers from other manufacturers, based on the wishes of the client and the experience of modernizations and reconstructions. Below are examples of such modernizations for BKZ-320-140, BKZ-420-140-5 boilers.

3.1 Replacement of Burner Devices

Purpose of reconstruction:
Additional increase in the boiler steam generating capacity. Improving technical, economic and environmental indicators of the equipment operation. Transfer to non-standard fuel.

Brief scope of modernization works:
Installation of new burner devices and bottom blowing nozzles.

References:
Increase in the steam generating capacity from 420 to 460 t/h and from 320 to 400 t/h. Type of boilers: BKZ 420-140-3 and BKZ 420-140-5 (Ekeiastuz coal). Aluminy Kazakhstan TPP.

Factors limiting reconstruction:
The condition of maximum preservation of the boiler structure and the invariance of ancillary equipment. Restriction on heat liberation rate in the combustion chamber. Restriction on the drum strength and the work of inner drum separation devices. Restriction on fly ash erosion of convective heating surfaces (economizer and air heater).

Term of the project works performance:
3-4 months.
3.2 Transfer of the boiler furnace from non-gas-tight execution to gas-tight one

Purpose of reconstruction:
Improving the reliability and economical efficiency of the equipment. Reducing harmful emissions into the atmosphere (N0x).

Brief scope of reconstruction works:
Replacing non-gas-tight furnace with gas-tight one. Partial reconstruction of the boiler structure. Partial reconstruction of platforms and stairs (in the area of installation of burner devices). Installation of new burner devices and bottom blowing system. Partial change of furnace hangers. Partial reconstruction of the water supply system. At the request of the Client, it is possible to remove the entire downtake and water supply system from the screen insulation (repair and maintenance are simplified). Partial reconstruction of the steam discharge system of the furnace screens. Implementation of lightweight insulation of the furnace screens.

Implementation experience:
Reconstruction of BKZ 210-140-5 st. No. 7 and BKZ 210-140-8 st. No. 9 boilers of the Vladivostokskaya TPP-2. Transfer of the combustion chamber of boilers to gas-tight design:
- including replacement of bare-tube furnace;
- including preservation of overall and mounting dimensions for supply and discharge pipes;
- including preservation of the boiler structure.

Factors limiting reconstruction:
Lack of space of the boiler structure dimensions.

Term of the project works performance:
4-5 months.

3.3 Replacement of steam coolers and condenser units

Purpose of reconstruction:
Improving the reliability of the equipment.

Brief scope of reconstruction works:
Replacement with a modern, more reliable spray desuperheater with injection unit calculation. Replacement with a modern, more reliable installation for obtaining own condensate.

Implementation experience:
Application on BKZ-420-140-3; BKZ 320-140-1 boilers.

Factors limiting reconstruction:
Limited space.

Brief description:
The steam superheaters use a more reliable design that reduces the separation of the internal protective jacket and the damage to the attachment points of the injection nozzles. Nozzles have lower hydraulic resistance. Condenser units are made more reliably in comparison with old samples due to the constructive solution of the thermal points of the metal interface between the hot medium (steam) and the cold one (water).
3.4 Replacement of the drum with inner drum devices

Purpose of reconstruction:
- replacement of the drum with outspent estimated operational life;
- replacement of the drum according to the condition of strength;
- replacement of the drum according to the condition of repair of cracks;
- replacement of inner drum devices due to wear conditions.

Brief scope of reconstruction works:
Drum replacement including: drum body, inner drum devices and drum supports.

Implementation experience:
Type of boilers: BKZ 320-140-1 (st. No. 1-2) (Ekibastuz coal). Aluminy Kazakhstan TPP.

Factors limiting reconstruction:
Limitations are related to:
- the restriction on lifting capacity of lifting mechanisms;
- the lack of space during installation.

Term of the project works performance:
4-5 months.

3.5 Replacing convective heating surfaces (economizer)

Purpose of reconstruction:
Replacement of economizer heating surfaces:
- which outspent their estimated operation life;
- in order to reduce its fly ash erosion;
- in order to increase heat absorption.

Brief scope of reconstruction works:
Replacement of the bare tube heating surfaces of the economizer, on the surfaces made of spiral-finned tubes or membrane (bare tubes with intertube strip penetration).

Implementation experience:
Type of boilers: BKZ 420-140-3; BKZ 420-140-5 (Ekibastuz coal), BKZ 320-140-1 (st. No. 1-2) (Ekibastuz coal). Aluminy Kazakhstan TPP.

Factors limiting reconstruction:
Spiral-finned tubes can not be used when:
- fuel oil is burned (continuous fuel oil operation for more than 5 days);
- shot cleaning application is performed.

Brief description:
Spiral-finned or membrane economizers are installed within the dimensions of the old gas flues. Economizers are supplied in separate packages and manifolds. At the request of the Client, package supply of economizer is possible. The use of spiral-finned economizers provides the necessary heat removal associated with an increase in the boiler steam generating capacity, and at the same time allows it to fit into the dimensions of the gas flues.
limited by the previous boiler structure and also to sustain acceptable gas velocities (for example, according to the conditions of fly ash erosion of 7–9 m/s).

Term of the project works performance: 3-4 months.

3.6 Replacement of Convective Heating Surfaces (Tubular Air Heater)

Purpose of reconstruction:
Replacement of the tubular air heater:
• that outspent its estimated operation life;
• in order to reduce its fly ash erosion;
• in order to increase heat absorption;
• instead of regenerative air heater.

Brief scope of reconstruction works:
Dismantling the reconstructed units of the air heater. Installation of new cubes of a tubular air heater, if necessary, with replacement of support frames and air bypass ducts between cubes.

Implementation experience:
Type of boilers: BKZ 420-140-3; BKZ 420-140-5 (Ekibastuz coal), BKZ 320-140-1 (st. No. 1-2) (Ekibastuz coal). Aluminy Kazakhstan TPP.

Factors limiting reconstruction:
Restrictions associated with the lifting capacity of the lifting mechanisms and the lack of space during installation.

Brief description:
Old cubes of an air heater are completely dismantled and new ones are installed. New cubes have enlarged heating surfaces and sections for the passage of gases and air. Optimized gas and air velocities are selected.

Term of the project works performance: 3-4 months.

3.7 Replacement of Convective Heating Surfaces (Steam Superheater)

Purpose of reconstruction:
Replacement of steam superheater:
• that outspent its estimated operation life;
• in order to reduce pollution and to organize steam cleaning;
• in order to increase steam generating capacity;
• for the organization of a gas-tight steam superheater instead of a bare-tube overhead one;
• for the organization of the replacement of a non-gas-tight guard plate of the rotary gas flue between the furnace and the convection shaft with a gas-tight screen guard.
Brief scope of reconstruction works:
Dismantling of old heating surfaces of the steam superheater, guard plate of the rotary gas flue. Installation of new heating surfaces. Reconstruction of steam bypass pipes. Change of the steam superheater suspension system if necessary.

Implementation experience:
BKZ 320-140-1 (st. No. 1-2) (Ekibastuz coal). Aluminy Kazakhstan TP.

Factors limiting reconstruction:
Adaptation of the new steam superheater to the boiler design.

Brief description:
The steam superheater is designed taking into account the optimization of the diagram and thermal absorption according to the heating stages, taking into account measures for accelerated start-up and shutdown to ensure reliable operation of the heating surfaces of the steam superheater in all boiler operation modes.

Term of the project works performance:
4-5 months.
**4. Reconstruction of Gas-and-Oil-Fired Boilers with a Superstructure of the Gas Turbine Plant (GTP) Boiler-Turbine-Generator**

**Purposes of reconstruction:**
- increase of power unit efficiency (values are indicated in the table of the catalog);
- reducing emissions of nitrogen oxides.

**Scope of the boiler reconstruction:**
- replacement of burners;
- replacement of surfaces in a convection shaft – economizer (fully or partially), convective low pressure steam superheater (partially) – with high and low pressure gas heaters (regeneration replacement) – pos. 9, 10 in the diagram;
- elimination of the air heater.

Optionally, autonomous operation of the boiler in steam-power mode, with the gas turbine stopped, is possible.

Changes in performance when the boilers operate in a block with a discharge diagram with GTP

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter name</th>
<th>TGMP-314 before</th>
<th>TGMP-314 after</th>
<th>TGMP-114 before</th>
<th>TGMP-114 after</th>
<th>TGM-206 before</th>
<th>TGM-206 after</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electrical power, MW</td>
<td>300</td>
<td>410</td>
<td>300</td>
<td>430</td>
<td>200</td>
<td>265</td>
</tr>
<tr>
<td>2</td>
<td>Gas turbine, MW</td>
<td>110</td>
<td>2×65</td>
<td>110</td>
<td>2×65</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Efficiency, electrical unit, gross</td>
<td>39.5</td>
<td>46.4</td>
<td>39.5</td>
<td>46.9</td>
<td>37.8</td>
<td>44</td>
</tr>
</tbody>
</table>

**Parameters of main steam at the boiler outlet:**
- rated steam generating capacity, t/h
- temperature, °C
- pressure, MPa

<table>
<thead>
<tr>
<th>Parameters of main steam at the boiler outlet:</th>
<th>CG-314 before</th>
<th>CG-314 after</th>
<th>CG-114 before</th>
<th>CG-114 after</th>
<th>CG-206 before</th>
<th>CG-206 after</th>
</tr>
</thead>
<tbody>
<tr>
<td>rated steam generating capacity, t/h</td>
<td>1000</td>
<td>1000</td>
<td>670</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature, °C</td>
<td>545</td>
<td>545</td>
<td>545</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pressure, MPa</td>
<td>25.5</td>
<td>25.5</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Parameters of reheated steam at the boiler outlet:**
- rated steam generating capacity, t/h
- temperature, °C
- pressure, MPa

<table>
<thead>
<tr>
<th>Parameters of reheated steam at the boiler outlet:</th>
<th>CG-314 before</th>
<th>CG-314 after</th>
<th>CG-114 before</th>
<th>CG-114 after</th>
<th>CG-206 before</th>
<th>CG-206 after</th>
</tr>
</thead>
<tbody>
<tr>
<td>rated steam generating capacity, t/h</td>
<td>800</td>
<td>800</td>
<td>590</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature, °C</td>
<td>545</td>
<td>545</td>
<td>545</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pressure, MPa</td>
<td>3.7</td>
<td>3.7</td>
<td>2.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 6   | Feed water temperature, °C              | 275            | 275           | 235           |              |               |              |
| 7   | Fuel                                   | gas/fuel oil   | gas           | gas/fuel oil  | gas          | gas/fuel oil  | gas          |
| 8   | Exhaust gas temperatures                | 100            | 100           | 100           |              |               |              |
5. Modernization of the Regenerative Air Heater

Advantages of modernized regenerative air heaters:
- advanced stuffing packages;
- modernized circumferential, radial and axial seals, providing flows of no more than 15%;
- soft starter;
- two gear-motors with the ability to shutdown one of them for repair without stopping regenerative air heaters;
- installation on existing foundations;
- fire extinguishing, steam blasting and water washing devices;
- possibility of installing gas pulse cleaning (GPC).
every second Russian TPP is fitted with steam turbine equipment of Power Machines enterprises

> 110 years
of experience in the design and production of equipment for thermal power plants

235 kW-1200 MW
power range

> 2300
of steam turbines of medium and high power manufactured by LMZ

> 3000
of low power steam turbines manufactured by KTZ

50%
every second Russian TPP is fitted with steam turbine equipment of Power Machines enterprises

STEAM TURBINES
Types of steam turbines manufactured:

- Condensing turbines for subcritical and supercritical steam parameters up to 1200 MW
- Condensing turbines with a heat extraction up to 330 MW
- Cogeneration turbines with production and heat extraction up to 80 MW
- Back pressure turbines
- Turbines for CCGT
- Low and medium power turbines
- Drive turbines (condensing and backpressure ones)
- Steam geothermal turbines and power units

Optional equipment

- Condensers, oil coolers, gland-steam condensers
- Check valves on steam extractions, filters, etc.

Advantages of steam turbines:

In terms of characteristics of wheel space parts, our turbines provide a level of efficiency equal to that of turbines by the leading global manufacturers. Long-term experience of turbine operation makes it possible to guarantee reliable turbine operation for more than 40 years and a mean time between failures of at least 6 years. High rates of economical efficiency and reliability of steam turbines by Power Machines are provided by:

- aerodynamic pilot testing of blades in order to confirm both their reliability and efficiency;
- smooth meridian contours of the flow part;
- blade design checks using CFD methods;
- 3D profiling of stationary blades;
- optimization of steam admissions, withdrawals and exhausts using CFD methods;
- new improved seal designs;
- implementation of advanced design methods, as well as technologies and equipment from leading Russian and global manufacturers.
DIAGNOSTICS AND INSPECTION
The scope of work for the inspection of steam turbines includes:

1. Inspection of pipelines and hanger-support system (HSS)
2. Inspection of thermal expansion system of the turbine-generator set
3. Integrated Vibration Inspection of the turbine-generator set
4. Inspection to extend the service life of steam turbines beyond the steam resource

The results of a comprehensive inspection of steam turbines:
- improved reliability;
- extension of service life;
- increase of power and resistance to operating conditions;
- increase in the time between repairs;
- optimization of the repair cycle structure;
- reduction of maintenance and repair costs.

1. Inspection of pipelines and hanger-support system (HSS)

Inspiration purposes are the following:
- establishing the possibility of further safe operation and giving recommendations for the repair and adjustment of the system;
- determining the terms and conditions for further operation of the HSS.

The following works are performed in the course of inspection:
- inspection of pipeline routes and HSS; determination of compliance with the requirements;
- characterization and compilation of spring support and suspension forms;
- measurement of the actual displacements of pipelines at the places where the thermal displacement indicators are installed; compilation of thermal displacement forms;
- fault detection; determination of the causes of faults detected during operation;
- carrying out calculations for strength and self-compensation of temperature expansions, identification of off-design loads.
- development of recommendations for the adjustment, reconstruction and/or repair of the HSS.
2. Inspection of thermal expansion system of the turbine-generator set

**Inspection purposes are the following:**
- to improve thermal and mechanical characteristics;
- to improve the reliability of the turbine unit operation.

**The following works are performed in the course of inspection:**
- Characterization of thermal displacements of cylinders in the longitudinal and transverse directions, including the control of gaps along transverse keys.

Characterization of transverse thermal expansions of high-pressure cylinder during start-up and heating

- Measurement of thermal vertical and angular displacements of the bearing supports of the turbine unit. Determination of operational and seasonal misalignments, calculation of the optimal centering of the shafting rotor along the coupling halves.

Vertical thermal displacements of the bearing supports Nos. 1-5

**Recommended values of centering values, taking into account the floating-up of rotors on the oil wedge.**

Vertical thermal displacements of the turbine unit shafting supports caused by the cold state and resulting rotors misalignments (mm*10^-3) along the coupling halves, taking into account the floating-up of shafting on the oil wedge.
- Measurement of high and medium pressure cylinders bearing loads in a cold state and during the turbine unit operation. Determination of the influence of the reactive moment created by the rotor rotation. Optimization of the supporting loads.

- Development of measures for the selection of the optimal centering of the rotors on the coupling halves, optimization of the cylinder supporting loads, compensation for off-design efforts from the attached pipelines, reduction of the friction coefficient on the sliding surfaces.

Evaluation of efforts from the steam supply pipeline transmitted to the turbine cylinder
3. Integrated Vibration Inspection of the Turbine-Generator Set

- Inspection purposes are the following:
  - normalization of the vibration state;
  - improving the reliability of the turbine unit.

- The following works are performed in the course of inspection:
  - analysis of vibration characteristics according to the indications of standard equipment.
  - measurement of vibration by a portable device when stopping, turning the unit and at modes: \( P = P_{\text{nom}} \) and \( P = 0.5 P_{\text{nom}} \) of idle running;
  - vibration and dynamic studies using an exciter, removing the contour characteristics of the shafting supports before and after tightening;
  - machine balancing of the rotors of the turbine unit;
  - balancing the turbine unit shafting in its own bearings. Ensuring the vibration state of turbine units in accordance with the requirements of international standards ISO 10816-2 and ISO 7919-2.

![Vibration exciter](image1)

<table>
<thead>
<tr>
<th>Vibration control and thermal control of the turbogenerator bearings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bearing vibration</strong></td>
</tr>
<tr>
<td>Vertical, mm/s</td>
</tr>
<tr>
<td>Transverse, mm/s</td>
</tr>
<tr>
<td>Axial, mm</td>
</tr>
</tbody>
</table>

| **Rotor vibration in the bearing**                          |
| Vertical, µm       | 59  | 32  | 34  | 29  | 31  | 32  | 34  | 36  | 38  | 40  | 42  | 44  | 46  | 48  | 50  | 52  | 54  |
| Transverse, µm     | 37  | 30  | 37  | 34  | 36  | 38  | 38  | 40  | 42  | 44  | 46  | 48  | 50  | 52  | 54  | 56  | 58  |
| Axial rotor displacement, mm | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 |

| **Temperature control of support bearings**                 |
| Temp. of babbitt support bearings, °C                      | 71  | 67  | 77  | 74  | 70  | 66  | 73  | 76  | 79  | 76  | 73  | 70  | 66  | 62  | 59  | 58  |
| Temp. of oil (drain), °C                                   | 68  | 64  | 61  | 62  | 55  | 51  | 61  | 63  | 65  | 63  | 62  | 59  | 58  | 62  | 63  | 65  |

| **Active power, MW**                                       |
| 123.0            | 123.0|

| **Rotor Speed, rpm**                                       |
| 3960            |

| **Time of oil on bearing lubrication, °C**                 |
| 60  | 62  | 64  | 66  | 68  | 70  | 72  | 74  | 76  | 78  | 80  | 82  | 84  | 86  | 88  | 90  |

| **Max temp. of babbitt support bearings**                 |
| 90  °C          |
| 95 °C          |
4. Inspection to extend the service life of steam turbines beyond the steam resource

Inspection purposes are the following:
- to determine the possibility of extending the service life of the turbine beyond the established one;
- to give recommendations on measures aimed at extending the steam turbine economic life.

The following works are performed in the course of inspection:
- calculated and experimental assessment of the stress state of the rotors and turbine shells;
- studies of metal samples (or replicas) from high-temperature zones, estimates of accumulated damage and residual life;
- collection and analysis of data according to the mechanical characteristics of the applied heat-resistant steels of rotor and cases taking into account their long terms of operating time at working temperatures;
- determination of the actual state of turbine parts, obtained during the inspection of the turbine wheel space part in the repair campaign;
- periodic inspection of the turbine wheel space part using an endoscope in specially prepared places;
- thermal rapid tests in the period between repairs, according to the standard measurement points in the turbine wheel space part.

Zones of maximum stress in the steam turbine (ST) rotor when starting-up from the cold position

Temperature field in the ST rotor at the time of maximum stress

Change in temperature stresses in the ST rotor when starting-up from the cold position

Change in rotor temperature when starting-up from the cold position
REPAIR
AT THE MANUFACTURING PLANT
Factory repair methods allow you to perform complex repair operations, most commonly, not feasible in the conditions of TPP. Works on the modernization of cylinders, rotors and other large assemblies or on the elimination of serious defects in them are performed at the factory.

LMZ has a powerful production and testing base. The plant processes materials, semi-finished products and components using mechanical processing and welding methods, and also assembles and ships finished turbine and other products. The company has a cutting and blank production for thermal cutting of sheet metal; unique metal-cutting equipment, machining centers, welding, forging and pressing thermal, testing equipment and stands.

The level of technological processes of manufacturing products corresponds to the global level in similar industries. At the enterprise the equipment of the advanced foreign machine-tool companies of France, Germany, Austria, Sweden, Italy, Switzerland, etc. is widely used.

• Specialized equipment for processing parts of hydraulic and steam turbines (impeller blades, guide vane blades, submersible hubs, hydraulic turbine submersible propeller blades, cast cylinder bodies of steam turbines).

• Turning-and-boring lathes of a wide range with a diameter of machined parts up to 19 m – machining of impellers and stators of hydraulic turbines in the assembly, welded body parts of steam and gas turbines.

• A wide range of specialized boring, milling- boring machines with a spindle diameter of up to 210 mm (including CNC portal milling machines) – for machining of turbine body parts.

• Boring machines, including specialized ones for drilling holes with a maximum diameter of 50 mm (in carbon steel) in tube plates and partitions of heat exchanging equipment.
- Equipment for thermal cutting – thermal cutting of sheet metal with a thickness of 200 mm.
- Thermal equipment for stress relief after welding.
- Complexes for hot forging of turbine blades.
- Correct and bending equipment (presses, rollers) on sheet blanks up to 60 mm thick for the manufacture of spatial sheet metal turbine parts (spiral chambers, bypass pipes, gas turbine housings, etc.).
- Small mechanical equipment – machining turning and turning milling centers – for the manufacture of small parts such as a rotation body, fasteners.
- Load-lifting electric bridge cranes with a carrying capacity of up to 320 tons (PPK), LMZ 250 tons.
- Spark-erosion equipment.
- Hammers with a mass of falling parts up to 3300 kg for free forging.
- Testing base.

- CNC machining centers for machining turbine blades with a maximum length of 2400 mm.

- Specialized turning equipment for mechanical processing of steam, gas and hydraulic turbine rotors with diameters up to 5,000 mm, length up to 20,000 mm and weight up to 250 tons.

- Welding installations for welding thick plates (impellers and stators of hydroturbines, cast cylinders of steam turbines) with thermal means; specialized welding installations for welding heat exchanging equipment.
An example of the technological procedure in the repair of steam turbine rotors.

For re-blading, the rotor arrives at the entrance flaw detection, according to the results of which the decision is made to replace the blades. The blades are removed mechanically on the turning lathe (blades with fir-tree roots are disassembled by the metalworking method).

The form is made according to the slot geometry; on the basis of this form the decision is made on the manufacture of standard blades or blades with the form roots. After the manufacture of rotating blades, the blading is done with new blades. Next is the dynamic balancing of the rotor with the performance of acceleration tests with a maximum rotor speed of 115% of the working one (3450 rpm).
MINOR MODERNIZATIONS
In addition to the programs for the technical re-equipment of steam turbines, which implies significant capital expenditures (see the relevant Section), PJSC “Power machines” is developing minor modernization packages.

**Directions of minor modernizations**

- **Economical efficiency**
- **Maneuverability**
- **Industrial heating**
- **Reliability**
- **Repair capability**

Minor modernizations are measures to improve individual structural assemblies, as well as steam turbine operation technologies that can be implemented during the overhaul of power equipment.

Below are the main solutions used for minor modernizations of equipment of steam turbines of K-50-90, PT-60-90 (13), PT-80-130, K-100-90, K-200-130, K-300-240 type.

**1. Minor Modernizations Packages Aimed at Improving the Economical Efficiency of Steam Turbines**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>K-50</th>
<th>PT-60(80)</th>
<th>K-100</th>
<th>K-200</th>
<th>K-300</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Increase in the rated capacity of steam turbines up to 10% of the rated capacity without replacing the rotors</td>
<td>+</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Technology for checking the density of the vacuum system of the turbine plant by gage pressure of low-grade steam</td>
<td>+</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Reconstruction of steam turbine end seal diagrams</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Very leak-tight seals of high pressure cylinder control valves stems</td>
<td>+</td>
<td>+</td>
<td>—</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Sealing of pipe connectors and low pressure cylinders</td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>Honeycomb shroud seals for steam turbine rotating blades</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>Modernizations of steam turbine condensers</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**1.1 Increase in the rated capacity of steam turbines up to 10% of the rated capacity without replacing the rotors**

Based on the design and engineering studies and carried out tests, it has been established that the existing throughput capacity of steam turbines and the available strength margins allow to increase the consumption of fresh steam per turbine without significant structural changes to the wheel space part.

In order to prepare a technical proposal, a complete revision of the turbine is necessary. As a result of the modernization, the internal efficiency of the cylinder will slightly decrease, and the economic effect can be achieved by certifying more power to the System Operator.

<table>
<thead>
<tr>
<th>$P_{nom}$ before modernization</th>
<th>50</th>
<th>100</th>
<th>200</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{nom}$ after modernization</td>
<td>58</td>
<td>121</td>
<td>225</td>
<td>335</td>
</tr>
</tbody>
</table>

**1.2 Technology for checking the density of the vacuum system of the turbine plant by gage pressure of low-grade steam**

The technology allows you to increase the economical efficiency of the turbine plant. The density of the turbine plant vacuum system is checked by the gage pressure of low-grade steam without filling the condenser with water. At the same time, through the leakiness of the vacuum system, the steam is throttled into the atmosphere with visualization of this process.
Periodic application of a new technology of checking the density of the turbine plant vacuum system will allow to detect and eliminate places of air suction, thereby reducing the pressure in the condenser by at least 0.005 atm. Additional annual electricity generation per year, approximately 750,000 kWh, can be achieved by certifying more power to the System Operator.

1.3 Reconstruction of steam turbine end seal diagrams

The use of the self-sealing diagram allows to reduce the consumption of steam when extracting it for the deaerator by 1.1...1.2 t/h, which gives an additional power generation of about 2,500,000 kW*h per year.

1.4 Very leak-tight seals of high pressure cylinder control valves stems

The straight-through (labyrinth) arrangement of stem sealing has a number of drawbacks, which are eliminated with the help of the very leak-tight seal with liquid metal inserts. The use of such seals allows you to completely eliminate the steam leakages along the stem and, as a consequence, the possibility of their arcing due to the labyrinth clogging with salt of steam. The level of longitudinal vibrations of the stems is significantly reduced and their transverse vibrations in the area of the valve suspension are excluded. The seal assembly is placed in a special boring, performed at the top of the steam chest lid. Mechanical treatment of the steam chest lid is carried out during the installation of the very leak-tight seal at the plant.

As a result:
- the economical efficiency of the turbine plant increases (for example, on a K-300 turbine, when using the very leak-tight seal, the economical efficiency increases by 0.2% without loss of the reliability and maneuverability of the turbines);
- increase of the valves operational reliability and their service life;
- steam leakage exhaust is turned off;
- the cost of modernization of control valve (CV) stem seals pays off in a period of 3 to 6 months.
1.5 Sealing of pipe connectors and low pressure cylinders

The horizontal connector is under the action of various types of loads, including static ones, from pressure drops, as well as from temperature effects, especially at low emission conditions at idle. The specified impact may cause buckling of the connector surface and reduce the density. Leaks in the horizontal connectors lead to increased air suction and performance deterioration of the vacuum systems.

As a result of the reconstruction, the air density of the vacuum system increases.

1.6 Modernizations of steam turbine condensers

In the course of modernization, the tube plates are replaced with preservation of the remaining components of the condenser.

There are two options for basic materials:
• tubes and tube plates – stainless steel;
• tubes – titanium VT1-0, tube plates – carbon steel with titanium coating.

The tubes are fixed in the holes of the tube plates by forming and welding. The tube plates are additionally equipped with a lens compensator.

Duration of works:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Terms</th>
</tr>
</thead>
</table>
| 1   | Increase in the rated capacity of steam turbines up to 10% of the rated capacity without replacing the rotors | Start – 4 months before the next overhaul  
Ending – 2 months after the completion of overhaul |
| 2   | Technology for checking the density of the vacuum system of the turbine plant by gage pressure of low-grade steam | Development of design documentation – 1 month  
Installation supervision during the repair period – 2 weeks  
Adjustment supervision after repair – 2 weeks |
| 3   | Reconstruction of steam turbine end seal diagrams                      | The term is determined by the results of the analysis of the client’s initial request |
| 4   | Very leak-tight seals of high pressure cylinder control valves stems    | Development of design documentation – 1 month  
Installation work in the process of repair – 2 weeks |
| 5   | Sealing of pipe connectors and low pressure cylinders                   | Development of sketches of the horizontal connector machining  
and the cord installation – 1 week  
Installation and adjustment supervision in the process of repair when opening the LPC |
| 6   | Honeycomb shroud seals for steam turbine rotating blades               | Development of design documentation – 2 months  
Installation supervision during the repair period – 1 month |
| 7   | Modernizations of steam turbine condensers                             | The term is determined by the results of the analysis of the client’s initial request |
2. Minor Modernizations Packages Aimed at Improving the Operational Reliability of Steam Turbines

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Improving the operational reliability of the turbine blading of the last stages by modernizing the recirculation system</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Preservation of turbine plant equipment by heated air</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Preservation of turbine plant equipment by the formation of a hydrophobic film on the protected surfaces</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Reduction of oil leakage through shaft oil seals using oleophobic coatings</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Modernization of steam turbine oil supply system</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>Modernization of bearings</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>Modernization of centrifugal throwers of bearings</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>Modernization of control valves</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>Modernization of steam distribution system with tappet valves</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>Modernization of the MPC frontal end seal</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>Use of gland condenser in steam turbines</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>Use of bellows expansion joints in boiler-turbine-generators</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>Automation of final injections into steam receivers of a turbine condenser</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>Moisture removal system in the last stages of LPC</td>
<td>—</td>
</tr>
<tr>
<td>15</td>
<td>LPC barrier cooling system</td>
<td>+</td>
</tr>
<tr>
<td>16</td>
<td>LPC cooling system</td>
<td>+</td>
</tr>
<tr>
<td>17</td>
<td>Reconstruction of the MPC shut-off valve (SDV) body support</td>
<td>—</td>
</tr>
<tr>
<td>18</td>
<td>Restoration of erosion-worn rotating blades of the last stages of the LPC</td>
<td>+</td>
</tr>
</tbody>
</table>

2.1 Improving the operational reliability of the turbine blading of the last stages by modernizing the recirculation system

The modernization is aimed at improving the operational reliability of the turbine blading of the last stages of the turbines, operating according to the diagram with cross links.

The modernization provides an acceptable thermal state of the turbine and reduces the erosion wear of the rotating blades of the last stages, which increases their reliability and service life, as well as reduces the costs and time required to repair the turbine. The service life of the blades of the last stages increases – by 1.3 times.
2.2 Preservation of turbine plant equipment by heated air

Preservation of turbine plant by heated air is carried out in order to protect the metal of the turbine cylinders, shut-off and control valves, condenser, pipelines and regenerative heaters from stand still corrosion.

Application of the turbine plant preservation with heated air allows to provide reliable protection of stopped equipment against stand still corrosion during the whole period of preservation.

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2.3 Preservation of turbine plant equipment by the formation of a hydrophobic film on the protected surfaces

Preservation of turbine plant equipment by the formation of a hydrophobic film on the protected surfaces is one of the ways to protect steam turbine equipment from stand still corrosion and is recommended when the planned shutdown lasts over six months. Both the turbine plant equipment and the boiler equipment can be subject to preservation (if the boiler and turbine are separated into the unit during the preservation process).

---

2.4 Reduction of oil leakage through shaft oil seals using oleophobic coatings

One of the important problems in the operation of power plant equipment is the elimination of oil leaks through the oil seals of the rotating shafts.

Oleophobic coatings retain their properties for 1.5-2 years. Their application allows:
• to practically stop or significantly reduce oil leakage through seals;
• to reduce oil consumption for lubrication;
• to reduce fire risk;
• to eliminate softening of the generator’s brush current collectors;
• to reduce sludging of treated surfaces.

---

2.5 Modernization of steam turbine oil supply system

The projects provide for a change in the turbine oil supply scheme using new design and circuit solutions applied by Power Machines based on accumulated experience, including the selection of equipment to replace morally, physically obsolete equipment and equipment withdrawn from production, including:
• selection of oil pumps to replace them for new manufactured by LMZ or other manufacturers;
• replacement of oil coolers with high-density oil coolers with a stainless steel pipe system, which allow for any ratios of oil and water pressure within acceptable values;
• replacement of a single-stage injector with a two-stage injector to stabilize the oil pressure for lubricating bearings of the turbine-generator set and the operation of the control system (for turbines with a capacity of up to 215 MW);
• installation of an air separator in the oil tank, which decreases air content in the clean tank compartment at the suction of the oil pumps to 0.5%;
• replacement of the drain valve with a pressure reducing valve that performs proportional-plus-integral maintenance of the oil pressure “downstream” on the axis of the turbine-generator set and does not have a “parasitic” consumption of oil discharged into the oil tank (for turbines with a capacity up to 215 MW);
• equipping the turbine-generator set with a system for suctioning oil vapors from bearing housings and a fan to improve the sanitary and hygienic state of the atmosphere in the power plant’s machine hall;
• improving the reliability of emergency oil supply from an emergency oil pump by changing the oil supply scheme to ensure emergency lubrication of bearings in case of erroneous actions of personnel with oil coolers, as well as in case of loss of auxiliary voltage;
• selecting filters and designing the installation of oil filters for fine gage stainers supplied by Power Machines or other manufacturers, providing mesh size from 6 to 30 microns;
• equipping the turbine-generator set with a system of centralized hydrostatic lifting of the rotors to reduce wear of babbit of bearings during start-up and shutdown;
• separation of the regulation oil supply system and bearing lubrication system;
• issuing recommendations on the selection of turbine oils and conclusions on the possibility of using turbine oils from various manufacturers.

2.6 Modernization of bearings

In order to reduce power friction losses and oil consumption, modernized designs of support and journal-and-trust inserts have been introduced.

2.7 Modernization of centrifugal throwers of bearings

Modernization involves the replacement of existing centrifugal throwers of bearings with new ones with spring-actuated segments and anti-friction insert. Presence of the insert and the spring-actuated segments allows to pass the critical frequency of the shafting at the start-up and shutdown of the turbine without damaging the brass sealing inserts.

Effect of modernization:
• excluded oil emissions from bearings in the machine hall;
• increased repair capability;
• increased service life of the centrifugal throwers of bearings.
2.8 Modernization of control valves

New valves have less aerodynamic resistance compared to the existing ones by about 1-1.5%. A decrease in valve resistance is achieved both by increasing the bore diameter and by making a special shape of the valve plate and diffuser (seat). Vibration resistance is ensured by the adopted system of steam inlet to the valve and the size of the clearance between the parts. The use of a splined connection of parts instead of the former threaded one provides easy assembly and disassembly of the valve during repair to check the condition of the stem or to replace it.

2.9 Modernization of steam distribution system with tappet valves

The actuators for closing the control valves in steam distribution systems with a cam mechanism are spring blocks. The main parts of the blocks (body and frame) are traditionally made of gray cast iron. The experience of operating the blocks has shown that valves sometimes stick due to the “growth” of the cast iron and jamming of the block details. Wear of key grooves on the frame was noted, as well as the destruction of cast-iron parts due to the material fragility.

New blocks have the same mounting dimensions and power characteristics, but at the same time:
- they have reinforced keyed connection between the body and the frame;
- the friction surfaces between the body and the frame are nitrated;
- the blocks are equipped with a valve stem position indicator – dial;
- blocks can be supplied in two versions: for bushing and for ball valve suspension.

The use of steel drive blocks of control valves creates the following advantages over cast iron ones:
- eliminated valve failure due to the growth of cast iron;
- reduced labor intensity of repairs;
- eliminated risk of splitting parts, typical for cast iron, increased repair capability;
2.10 Modernization of the MPC frontal end seal

The modernization project was developed with the aim to prevent the MPC frontal end seal assemblies from buckling, leading to steaming and air suction in the vacuum system, and to improve repair capability.

The modernization includes the reconstruction of the existing seal box No. 2 and the installation of a new more rigid seal box No. 3, as well as a new chimney chamber without a compensating ring. The suction of the air-steam mixture from the chimney chamber is made in the upper and lower halves.

In addition, the reconstruction of the seal diagram is performed including cooling of the MPC frontal end seal by the steam from the HPC rear end seal.

Due to the change in the design and seal diagram, the “hot” zone is “moved back” into the depth of the MPC, where there are massive and little deformed parts. The temperature of the metal in the zone of connection of the chimney chamber body and the MPC is reduced by 100-110 °C compared to the existing one. This allows to install the chimney chamber without connecting compensating ring, which increases the repair capability of the seal.

2.11 Use of gland steam condenser (KPU) in steam turbines

The KPU-50-2.5 type gland steam condenser is designed for condensing steam sucked from the end seals and can be produced in three versions:

- KPU-50-2.5-1. Manufactured together with the remote water-jet ejector of the EV 7-200 type for air removal from the KPU.
- KPU-50-2.5-2. Manufactured together with the steam-jet ejector of the EP 1-400 type, placed directly on the KPU body.
- KPU-50-2.5-3. Manufactured together with the remote water-jet ejector of the EV 7-200 type and the condensate collector to maintain the regulation of the condensate level in the KPU.
The use of this type of the KPU allows:
- to ensure almost complete tightness of the KPU;
- to exclude buckling of the flange connector;
- to significantly reduce the likelihood of air suction in the KPU;
- to prevent the removal of copper into the condensate-feed pipeline of the turbine, thereby improving the quality of water and steam;
- to improve the reliability, service life and mean time before failure period of the KPU.

2.12 Use of bellows expansion joints in boiler-turbine-generators

In order to modernize the old compensating devices, which have a number of shortcomings, as well as those that have exhausted their service life, new multilayer and single-layer bellows expansion joints manufactured using modern technologies are introduced.

Advantages over traditional compensators:
- significantly greater flexibility of the multilayer bellows with respect to the lens of a single-layer sheet;
- degree of freedom: axial, shearing and rotatable;
- significantly fewer number of welds, their shorter length and high welding quality.

2.13 Automation of final injections into steam receivers of a condenser

Automation of final injections into steam receivers of a turbine condenser is carried out in order to reduce erosive wear of the exit edges of the rotating blades of the last stages of the LPC.

Automation of final injections is carried out by implementing a special control algorithm of the control valve, additionally installed on the pipeline for supplying cooling condensate to the SR.

Automation of final injections in the condenser SR allows optimizing the flow rate of the cooling condensate, ensuring both the acceptable thermal state of the LPC exhaust parts and the absence of an excessive amount of erosion-hazardous moisture in the exhaust nozzles.

The use of metered condensate flow rate for final injections will increase the service life of the blades of the last stages by 1.3 times.
2.14 Moisture removal system in the last stages of LPC

The moisture removal system is used in welded diaphragms designed for stages with a rotating blade with a length of 960 mm, and provides suction of moisture from its concentration zone in the interface area of stationary blades with peripheral bypass and from the surface of peripheral bypass behind the stationary blades.

About 1.3% of the steam is sucked into the moisture removal system along with the moisture, with most of it being sucked off in the trailing vortex zone, which as a result increases the efficiency of the stage. The use of a moisture removal system allows to increase the reliability of the turbine blading of the last stages of the LPC.

2.15 LPC barrier cooling system

The use of the LPC barrier cooling system (BCS) allows:

- to protect the exit edges of the rotating blades of the last stages from erosion caused by the movement of reverse cooling flows from the condenser by creating a swirling annular jet of wet steam, crushing erosive moisture into a fine fraction;
- to preserve the adhesion of the brazed stellite plates by cooling the medium in the rim clearance of the last stages with wet cooling steam.

Use of the BCS allows to increase the service life of the blades of the last stages in 1.5-2 times.

2.16 Reconstruction of the MPC shut-off valve (SOV) body support

Wear of the supporting surfaces under the shock absorbers of the MPC shut-off valve supports impairs the thermal displacement of the bodies of shut-off valves, which leads to an uneven thermal movement of the cylinder and to a decrease in the values of its absolute thermal displacement.

The new design of the supports eliminates the emergence of efforts that adversely affect the thermal displacement of the MPC. In addition, it allows to freely change the load on the supporting surfaces at all stages of operation of turbines, which increases the reliability and maneuverability of the turbine.

Modernization of the construction of supports suggests the following:

- removal of existing shock absorbers;
- installation of existing springs in shock absorbers as a hanger-support system.
2.17 LPC cooling system

A special system of water injection cooling is provided to prevent excessive heating of the exhaust nozzles and blades of the last stages of the turbine when operating at low emission conditions, due to ventilation losses. This solution allows for efficient cooling of the exhaust nozzle, eliminating the presence of erosion-hazardous moisture in it. The erosion wear of the rotating blades of the last stage does not occur, respectively.

2.18 Restoration of erosion-worn rotating blades of the last stages of the LPC

The technology of restoring rotating blades can be implemented both without unblading the rotor stage being repaired, and with blading.

When using the technology without unblading the rotor stage, the scope of work includes:

• mechanical removal of the eroded part of the leading edge of the blade;
• surfacing of the blade profile under controlled thermal cycle conditions, its machining, polishing and control;
• welding of stellite plates under controlled thermal cycle conditions;
• polishing of places of welding, control by non-destructive methods.

The effectiveness of the technology is estimated on the basis of the cost of performing the full volume of the above-said technological operations, which is about 40% of the cost of new blading.

When using rotor unblading technology, all operations are performed similarly to the variant without unblading (surfacing and welding of stellite plates), as well as additionally performed deep thermal tempering and ion implantation with the application of multi-layer vacuum plasma coating by titanium nitride. When carrying out repair of the rotor stage with unblading, the fatigue limit on the blades is 15% higher than the fatigue limit without unblading, and with additional ion implantation the fatigue limit rises another 18%.

The effectiveness of the technology with unblading and using ion implantation is estimated based on the cost of performing the full scope of work, which is about 50% of the cost of new blading.
3. Minor Modernizations Packages Aimed at Improving the Maneuverability of Steam Turbines

3.1 Reconstruction of heating system of cylinder flanges

During the reconstruction, the existing “box” heating system of the cylinder flanges is replaced with a “box-free” one. The “box-free” system has the following advantages:

- significant simplification of the design. Heating steam taken from the main steam pipeline to the main steam valve (MSV) is supplied only to the lower parts of flanges of the horizontal cylinder connector. The heating boxes of the cylinder flanges can either be dismantled or left. The number of valves is reduced by 8 units, including 2 safety valves. This improves the vacuum density of the turbine plant by eliminating air suction through the safety valves. The number of pipelines is reduced, it also eliminates the heating collector;
- simplified system operation as a result of reduced number of valves;
- the possibility of putting the system into operation before turbine start from rest in order to equalize the relative expansion of the turbine rotor, which significantly reduces the start-up time.

The use of a reconstructed heating system reduces the cold and warm turbine start-up time by an average of 20 minutes. The annual fuel economy at eight cold and warm start-ups per year will be approximately 20 tons of standard fuel, while the turbine operates in a maneuverable schedule (50 start-ups per year) – 120 tons of standard fuel.

3.2 Reconstruction of drainages of crossover pipes

During the reconstruction, additional drainage is performed from the ascending sections of the cylinder crossover pipes or from the control valve boxes. The proposed drainage scheme allows, during the start-up of the turbine, to warm both the descending and ascending sections of the crossover pipes, to improve the conditions for the warm-up of the control valves. This reduces the likelihood of moisture entering the steam inlets of the
3.3 Motoring operation conditions of steam turbines

When using steam turbines to control the unevenness of the daily load curve of the power system, the most optimal is the motor mode, that is, the mode of operation without supplying fresh steam to the turbine through the steam inlets when the generator is not disconnected from the network and works as an engine, rotating the rotor with a synchronous frequency. At the same time, the HPC is in a steam-free vacuum mode, and steam is supplied to the MPC from an external source in order to cool the last stages of the turbine (see diagram for a K-200 type turbine). The special cooling system is used to cool the exhaust nozzles of the LPC. When operating in motor mode, the thermal state of the turbine is maintained close to the thermal state when operating under nominal load. When switching to the active mode of operation, this allows a fast loading of the turbine to the nominal load or to the load determined by the dispatch schedule.

The use of the motor mode increases the reliability of the turbine compared with the start-stop modes of the turbine, since:
- shafting does not pass through critical frequencies;
- there is no cooling down and subsequent heating of the wheel space part (as when the turbine start-ups), which eliminates cyclic temperature stresses;
- reduced wear of turbine seals, which increases the economical efficiency of the turbine;
- in addition, when the turbine operates in motor mode, the generator can operate as a synchronous compensator, in other words, participate in regulation of cosΦ in the power system.

cylinders, and also reduces the heating time of the crossover pipes, which reduces the turbine start-up time by an average of 10 minutes.

3.4 Pre-jerk heating up technology of the MPC rotor

The technology provides for the MPC heating to a temperature of 100-120 °C when cold start-up before starting operations on the turbine. This allows to reduce to a minimum (up to 5-10 min) the delay at an intermediate speed (1200 rpm), which is provided for heating the rotor of the MP (medium pressure) turbine before going to idle up to a temperature of 120 °C. The total start-up time of the turbine is reduced by 40-50 minutes, and, accordingly, the starting losses of fuel are reduced.
3.5 Installation of steam receivers in condensers to enable operation of turbines in a unit with a boiler

To ensure the operation of the turbine in the unit with the boiler, the discharge pipeline is re-routed from the ignition desuperheating and pressure reducing system (DPRS) to the condensers. The steam is discharged to the condenser adapters under both turbine exhausts. On the steam discharge into the adapters, the second stage of cooling of the boiler’s ignition steam – steam receivers – is installed. Steam is cooled by condensate from the pressure line of the condensate extraction pump (ECP). The design of the steam receivers ensures the efficient spray of the cooling condensate and its fine dispersion.

3.6 Measures to normalize the thermal expansion of steam turbines

To improve the expansion of the turbine, it is proposed to install metal-fluoroplastic tapes (MFT) on the base frames of the front and middle bearings with their mechanical fastening to the support.

Normalized thermal expansion of the turbine can reduce the time of cold and warm start-up of turbines by an average of 20-25 minutes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Organization of controlled steam extraction behind the steam turbine</td>
<td>Development of design technical documentation – 4 months;</td>
</tr>
<tr>
<td></td>
<td>MPC</td>
<td>Production of necessary equipment – 4 months;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision during the overhaul period – 3 months;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after overhaul – 3 months</td>
</tr>
<tr>
<td>2</td>
<td>Organization of additional unregulated steam extraction from turbines</td>
<td>Development of design documentation – 2 months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation and adjustment supervision during the repair period – 2 months</td>
</tr>
<tr>
<td>3</td>
<td>Electro-hydraulic overpressure protection system of turbine heat</td>
<td>Development of design documentation – 2 months;</td>
</tr>
<tr>
<td></td>
<td>extraction</td>
<td>Production of the necessary equipment – 2 months;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The duration of the contract, as well as installation and adjustment supervision – by agreement of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>parties, taking into account the planned repair time</td>
</tr>
<tr>
<td>4</td>
<td>Increase of hydraulic gates on drains of main steam-jet ejectors</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td>up to 11 m</td>
<td>Installation supervision during the repair period – 1 month;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision after repair – 15 days</td>
</tr>
<tr>
<td>5</td>
<td>Sealing of the rotatable diaphragm, which increases the economical</td>
<td>Development of design documentation – 4...5 months;</td>
</tr>
<tr>
<td></td>
<td>efficiency of the turbine plant when operating according to a heating curve</td>
<td>Installation supervision during the repair period – 2 months;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after repair – 2 months</td>
</tr>
<tr>
<td>6</td>
<td>Reconstruction of the steam extraction pipeline to the HDVH-2 with</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td>the exception of the thermal diagram of the check valve KDS-1200</td>
<td>Installation supervision during the repair period – 15 days;</td>
</tr>
<tr>
<td></td>
<td>(only for turbines of PT-80-130 type)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Reconstruction of the steam suction pipeline from the rods of the</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td>shut-off valve and control valves of the HPC including the transfer</td>
<td>Installation supervision during the repair period – 15 days;</td>
</tr>
<tr>
<td></td>
<td>of steam leaks into the inside turbine pipelines instead of the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deaerator</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Reconstruction of the turbine plant with the exception of the LPH-1</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td>from the thermal diagram</td>
<td>Installation supervision during the repair period – 15 days;</td>
</tr>
<tr>
<td>9</td>
<td>Replacement of flexible coupling half of the high pressure rotor/</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td>flow-medium pressure rotor (for turbines of PT-66 type)</td>
<td>Installation supervision during the repair period – 15 days;</td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

The term is determined by the results of the analysis of the client’s initial request.
4. Minor Modernizations Packages Aimed at Improving the Repair Capability of Steam Turbines

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Turbines K-50</th>
<th>PT-60/80</th>
<th>K-100</th>
<th>K-200</th>
<th>K-300</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The shutdown technology for shaft-turning gear and lubrication systems at cylinder metal temperatures in the steam inlet zone of 250-270 °C</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Technology of forced cooling down of shutdown turbine with air</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Modernization of the bolted connection of the flanges of the coupling halves of steam turbines</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Loadometers</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>IU-20, IU-35 stud elongation meter</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.1 The shutdown technology for shaft-turning gear and lubrication systems at metal temperatures in the steam inlet zone of 250-270 °C

On the basis of thermal and strength calculations and subsequent commissioning work, a permit is issued to stop (if necessary) the shaft-turning gear and the lubrication system at a temperature of metal of the steam admission of the HPC and the MPC 250-270 °C. The temperature control of babbitt of bearings is carried out both in the existing and in the additional regular thermal monitoring.

Thus, increasing the temperature at which the shaft-turning gear and the lubrication system can be shut down by 80-100 °C reduces the time taken for the turbine to be released for repair after the shutdown to three and a half days.

4.2 Technology of forced cooling down of shutdown turbine with air

The technology is designed to reduce the cooling time of a stopped turbine to temperatures that allow stopping the shaft-turning gear and the lubrication system.

The turbine is air-cooled by means of organizing its movement through the wheel space part of the cylinders and the heating system of the cylinder flanges using ejectors that create a vacuum in the condenser. The combined use of the technology of an earlier shutdown of the shaft-turning gear and the technology of forced air cooling down with the help of a special additional ejector reduces the time taken for the turbine to be released for repair to 20-24 hours.

4.3 Modernization of the bolted connection of the flanges of the coupling halves of steam turbines

The main way to connect the coupling halves of the rotors of turbines is the connection by cylindrical fitter bolts. Fitter bolts are installed in the holes of the coupling halves with a clearance of 0.02-0.04 mm.
4.4 Loadometers

Loadometers (LM) are designed to measure bearing loads on bearing housings and foundation frames from the weight of cylinders and pipelines connected to them during assembly and to determine the total effort during the heating and operation of turbines in the entire range of the power generated.

In order to improve the measurement accuracy and ensure acceptable weight and size indications of the loadometer, its elastic element is made of high-strength titanium alloy VT-5. Measurement accuracy is ± 1% of the maximum load value.

Based on the measurement results, measures to optimize loads and normalize thermal expansions of steam turbine cylinders are determined and implemented.

The principle of operation is based on the measurement of the elastic deformation of the elastic element (2) that is deformed when the body (1) is screwed into the hole in the foot of the turbine cylinder, or based on the object to be weighed. The deformation of the elastic element (2) through the rod (3) is recorded by the I410 dial gauge of 0 class of GOST 577-68.

4.5 IU-20, IU-35 stud elongation meter

Traditionally, the control of fasteners for flange connections of horizontal connectors of steam turbine cylinders is monitored along an arc of rotation of cap nut. The experience of installation and repair work, as well as calculation and experimental studies show that this method of tightening is not accurate enough. For high-quality tightening of fasteners for flange connections, it is proposed to use a stud elongation meter. This method of measuring the stud elongation (through the center hole) determines the actual elongation when tightening as the difference between the readings before and after tightening the nut.

The device consists of a tube with a lower foot welded to it, a body with a dial gauge attached to it with a scale of 0.01 mm, and a slider with the top foot.
## Duration of works:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reconstruction of heating system of cylinder flanges</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision during the overhaul period – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after overhaul – 2 weeks.</td>
</tr>
<tr>
<td>2</td>
<td>Reconstruction of drainages of crossover pipes</td>
<td>Development of design documentation – 2 weeks.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision during the repair period – 2 weeks.</td>
</tr>
<tr>
<td>3</td>
<td>Motoring operation conditions of steam turbines</td>
<td>Development of design documentation – 2...3 months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Production of the necessary equipment – 3 months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision during the overhaul period – 2 months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after overhaul – 3 months.</td>
</tr>
<tr>
<td>4</td>
<td>Pre-jerk heating up technology of steam turbines</td>
<td>Development of design documentation – 2 months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision during the repair period – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after repair – 1 month.</td>
</tr>
<tr>
<td>5</td>
<td>Installation of steam receivers in condensers to enable operation of</td>
<td>Development of design documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td>turbines in a unit with a boiler</td>
<td>Installation supervision during the overhaul period – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after overhaul – 1 month.</td>
</tr>
<tr>
<td>6</td>
<td>Measures to normalize the thermal expansion of steam turbines</td>
<td>Development of technical documentation – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Production of loadometers to determine the supporting forces of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>turbine cylinder – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inspection of the turbine before overhaul – 1 month.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Installation supervision during the overhaul period – 2 months.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjustment supervision after overhaul – 1 month.</td>
</tr>
</tbody>
</table>

## 5. Minor Modernizations Packages for Steam Turbines Operating according to the Heating Curve

### No. | Name                                                                 | Turbines | K-50 | K-100 | K-200 | K-300 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Organization of controlled steam extraction behind the steam turbine MPC</td>
<td></td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Organization of additional unregulated steam extraction from turbines</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>Electro-hydraulic overpressure protection system of turbine heat extraction</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Increase of hydraulic gates on drains of main steam-jet ejectors up to 11 m</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>Sealing of the rotatable diaphragm, which increases the economical efficiency of the turbine plant when operating according to a heating curve</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>Reconstruction of the steam extraction pipeline to the HDVH-2 with the exception of the thermal diagram of the check valve KOS-1200 (only for turbines of PT-80-130 type)</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>Reconstruction of the steam suction pipeline from the rods of the shut-off valve and control valves of the HPC including the transfer of steam leaks into the inside turbine pipelines instead of the deaerator</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>Reconstruction of the turbine plant with the exception of the LPH-1 from the thermal diagram</td>
<td></td>
<td>—</td>
<td>+</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>Replacement of flexible coupling half of the high pressure rotor/low-medium pressure rotor (for turbines of PT-60 type)</td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

### 5.1 Organization of controlled steam extraction behind the steam turbine MPC

The proposed modernization of the turbine plant allows to obtain a heat load up to 200 Gcal/hour at the temperature of heating of the delivery water up to 120 °C. The maximum steam consumption for industrial heating is 360 tons/hour.
The solution does not require the installation of a rotatable diaphragm. The organization of controlled heat extraction of steam is carried out by installing special control valves on the crossover pipes of the MPC-LPC. Maintaining the steam pressure required for the industrial heating is carried out by covering the heat extraction control valves. Heat extraction of steam is carried out from the crossover pipe of the MPC-LPC. As a protection against unacceptable increase in steam pressure during heat extraction, two direct-acting safety valves are installed on the steam extraction pipeline. The delivery water heating is single-stage and carried out in the HDVH-4600 type heater.

5.2 Organization of additional unregulated steam extraction from turbine

Depending on the magnitude of the pressure and steam consumption required for the additional consumer, additional unregulated extraction can be organized from the overload valve chamber (at a pressure of 33-50 kgf/cm²) or from the extraction to the last HPH (at a pressure of 27-30 kgf/cm²).

In both cases, a KOS-type check valve, an electrically operated gate valve and a shut-off valve of the boiler power control (BPC) are installed in series on the additional extraction pipeline. The check valve is equipped with a hydraulic servomotor and the shut-off valve is equipped with an oil one.

Hydraulic servomotor of the KOS check valve is connected to the power supply system of check valves on the regenerative extractions from the turbine. Servomotor of the BPC shut-off valve is included in the turbine control system. All of the specified valves on the additional extraction pipeline are closed when closing the shut-off valve (SV) of the turbine.

5.3 Electro-hydraulic overpressure protection system of turbine heat extraction

The modernization is aimed at improving the reliability and economical efficiency of a turbine plant with the possibility of reducing its metal consumption by organizing automatic effects on steam supply to the heat extraction with an unacceptable increase in pressure during this extraction.

The introduction of this system eliminates the use of large diameter safety valves of LSV (lever safety valve) 600/800 type and associated bulky pipelines.

5.4 Increase of hydraulic gates on drains of main steam-jet ejectors up to 11 m

During operation of the turbine in various modes, especially starting ones, with sectional switching on of the main ejectors, as well as when switching from one section of the ejector to another, stalling phenomena in the ejector and,
as a result, loss of vacuum in the condenser are possible. For the stable operation of the ejectors in the thermal diagram of the turbine plant, hydraulic locks on the drains from ejectors are provided, which create additional resistance.

To ensure the stable operation of ejectors in all operating modes, the following modernization options are possible:
1. Increasing the hydraulic lock depth by increasing the depth of the well.
2. Insert of the ejector discharge pipeline into the steam part of the condenser (instead of the existing insert at the bottom of the condenser).

5.5 Sealing of the rotatable diaphragm, which increases the economical efficiency of the turbine plant when operating according to a heating curve

The rotatable diaphragm is sealed to improve the economical efficiency of the turbine plant when operating in the mode with a fully closed rotatable diaphragm by reducing non-production steam leakage into the condenser. This leakage was provided for cooling the rotating blades of the last stage of the turbine and the exhaust nozzles, heated by friction and ventilation losses. Steam entering through the leakage of the rotatable diaphragm in the last section of the turbine, does not produce neither electric nor useful thermal power.

Sealing of the rotatable diaphragm reduces the amount of leakage to a minimum by sending additional steam to the delivery water heater. This is done by reducing the axial clearance between the movable and fixed rings of the rotatable diaphragm, as well as by providing a more complete overlap between the openings of the mentioned rings.

Sealing of the rotatable diaphragm when operating according to a heating curve reduces the ventilation vapor flow into the turbine condenser by approximately 15 t/h.

This allows further increase the heat load by 7 Gcal/hour.

Cooling of the blades of the last stage and the exhaust nozzle is carried out by a special water spray refrigeration system.

5.6 Reconstruction of the steam extraction pipeline to the HDVH-2 with the exception of the thermal diagram of the check valve KOS-1200 (only for turbines of PT-80-130 type)

When performing the reconstruction, the KOS-1200 valve and the electrified gate valve on the extraction pipeline to the HDVH-2 are dismantled (as an option, the gate valve can be left for repair purposes). To ensure effective drainage of the extraction pipeline, its horizontal section is lifted and the displacement of the condensate collector of the turbine condenser in the horizontal plane to a distance of 1 m is caused by this.

In order to stop the return flow of the wet-steam medium from the horizontal delivery water heater (HDVH) condensate collectors to the HDVH bodies arising during load shedding, special funnels are installed in them.
5.7 Reconstruction of the steam suction pipeline from the rods of the shut-off valve and control valves of the HPC including the transfer of steam leaks into the inside turbine pipelines instead of the deaerator

The reconstruction improves the reliability of the turbine operation by eliminating the danger of moisture ingress into the HPC steam inlets by a countercurrent from the deaerator and the associated probability of bend of the HP rotor. During the reconstruction, the pipeline for removing leakage from valve stems to the deaerator, which is under the jurisdiction of the Gosgortekhnadzor, is excluded from the thermal diagram. In addition, due to the use of high-potential steam leakages from the valve stems in the wheel space part of the turbine, its economical efficiency is increased.

5.8 Reconstruction of the turbine plant with the exception of the LPH-1 from the thermal diagram

Steam extraction to the built-in LPH-1 is located downstream the rotatable diaphragm. In modes with a fully closed rotatable diaphragm, the LPH-1 is not loaded and not used. Therefore, for turbines, most of the year operating according to heating curve (with a closed rotatable diaphragm), it is possible to disassemble the built-in LPH without sacrificing economical efficiency.

This solution allows:
- to eliminate the danger of entering wet-steam medium into the turbine in case of rupture of the LPH-1 tubes. The condensate of the heating steam from the LPH-1 is drained through the hydraulic lock into the condenser, the level in the LPH-1 is not monitored. In case of rupture of the heater tube, the throughput capacity of the drain pipeline may not be enough and the heater body will be filled with water. In this case, it is possible both the direct entry of water into the wheel space part and the entry of wet-steam medium into the turbine during load shedding and condensate boiling-up in the LPH-1 body;
- to simplify the thermal diagram and to reduce maintenance of the turbine plant;
- to reduce the resistance of the path of the main condensate and, accordingly, the cost of electricity for the ECP operation;
- to use nodes of dismantled LPH-1 for the needs of the power plant.

5.9 Replacement of flexible coupling half of the high pressure rotor/low-medium pressure rotor (for turbines of PT-60 type)

Replacing the flexible coupling with a rigid one:
- eliminates the possibility of misalignment of the shafting and the violation of the ability of the flexible coupling to compensate for axial movement during wear of the teeth;
- increases the operational reliability of the high pressure rotor/low-medium pressure rotor connection.

Duration of works:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The shutdown technology for shaft-turning gear and lubrication systems at cylinder metal temperatures in the steam inlet zone of 250-270 °C</td>
<td>Calculation and development of design documentation – 1 month. Installation supervision during the repair period – 15 days Adjustment supervision after repair during shutdown at a time convenient for the customer – 1 month.</td>
</tr>
<tr>
<td>2</td>
<td>Technology of forced cooling down of shutdown turbine with air</td>
<td>Development of design documentation – 2 weeks Installation supervision during the repair period – 2 weeks Adjustment supervision after repair – 2 weeks</td>
</tr>
<tr>
<td>3</td>
<td>Modernization of the bolted connection of the flanges of the coupling halves of steam turbines</td>
<td>The term is determined by the results of the analysis of the client’s initial request</td>
</tr>
<tr>
<td>4</td>
<td>Loadometers</td>
<td>The term is determined by the results of the analysis of the client’s initial request</td>
</tr>
<tr>
<td>5</td>
<td>IU-20, IU-3S stud elongation meter</td>
<td>The term is determined by the results of the analysis of the client’s initial request</td>
</tr>
</tbody>
</table>
6. Modernization of Ancillary Equipment

Also, in the course of minor modernizations, work can be performed on the selection and replacement of auxiliary equipment of a steam-turbine plant.

### Oil coolers

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Oil consumption, m³/h</th>
<th>Water consumption, m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MP-80-60-1</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>MP-165-150-1...4165</td>
<td>165</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>330MP-330-300-1</td>
<td>330</td>
<td>300</td>
</tr>
</tbody>
</table>

### Heaters

<table>
<thead>
<tr>
<th>No.</th>
<th>Purpose</th>
<th>Heating surface, m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regenerative heaters</td>
<td>30 to 3200</td>
</tr>
<tr>
<td>2</td>
<td>Line vertical heater</td>
<td>200 to 2400</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal delivery water heaters</td>
<td>1300 to 5000</td>
</tr>
<tr>
<td>4</td>
<td>Gland steam condenser</td>
<td>30 to 340</td>
</tr>
</tbody>
</table>

### Filters

<table>
<thead>
<tr>
<th>No.</th>
<th>Purpose</th>
<th>Dn, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manual drive</td>
<td>250, 400, 600</td>
</tr>
<tr>
<td>2</td>
<td>Mechanical drive</td>
<td>1000, 1200, 1600, 2000, 2400</td>
</tr>
</tbody>
</table>

### Valves

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Dn, mm</th>
<th>Ps, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check valves</td>
<td>100 to 1400</td>
<td>0.1 to 15</td>
</tr>
<tr>
<td>2</td>
<td>Electrically operated water-regulating valves</td>
<td>100 to 50 mm</td>
<td>2.5 to 10</td>
</tr>
<tr>
<td>3</td>
<td>Hydraulic-operated steam-regulating valves</td>
<td>100 to 800 mm</td>
<td>0.63 to 6.3</td>
</tr>
<tr>
<td>4</td>
<td>Safety valves</td>
<td>200/400 and 250/400</td>
<td>0.8 to 5.4</td>
</tr>
</tbody>
</table>

### Ejectors

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Rated steam consumption, kg/h</th>
<th>Rated water consumption, m³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steam-jet ejector</td>
<td>EP-3-750 750</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP-1-400 400</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP-1-1100 1100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP-1-2200 2200</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP-1-4700 4700</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Water-jet ejector</td>
<td>EV-1-50 50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EV-1-100 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EV-7-200 200</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EV-13-450 450</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP-13-900 900</td>
<td></td>
</tr>
</tbody>
</table>
TECHNICAL RE-EQUIPMENT PROGRAMS FOR STEAM TURBINES
Power Machines has considerable experience in solving complex design problems, developing and creating various power equipment, therefore, in the course of carrying out technical re-equipment projects, it can implement the individual options necessary in each particular case.

Programs of technical re-equipment of steam turbines include the following areas:

- Renovation is a replacement of equipment, having its economic life expired, restoration of equipment parameters to the design level.
- Modernization in an equipment parameters’ enhancement beyond design levels, including the replacement of major units and components.
- Reconstruction is a significant increase in design parameters including the replacement of all major components and mechanisms and the state examination of project documentation.

The main objectives of the technical re-equipment:

- extending the service life of equipment, having its economic life expired, by replacing high-temperature structural elements;
- improving economical efficiency, reliability, maneuverability and repair capability parameters of equipment;
- full or partial bringing of equipment characteristics in compliance with the modern consumer market of heat and electricity.

Programs of technical re-equipment have been developed for the entire fleet of steam turbines of PJSC “Power machines”, including low-power steam turbines by KTZ, as well as third-party turbines.

1. Modernization of Low Power KTZ Steam Turbines

The production of low-power steam turbines is focused at the Kaluga Turbine Works (KTZ). For the more than 70-year history of its existence, KTZ has manufactured, tested and successfully put into operation more than 3000 power steam turbines of various standard sizes and purposes.

KTZ steam turbines are distinguished by simplicity of design, workmanship, compactability, optimal weight and size characteristics, high efficiency and economical effectiveness, ease of assembly, installation and operation, as well as a high level of reliability.

In addition to civilian usage steam turbines, the plant has enormous experience in creating power plants for Russian naval vessels, including nuclear ones, as well as for large vessels (icebreakers) operating in the extreme conditions of the northern seas.

The established service life of steam turbines manufactured by KTZ is 40 years. After this period, it is necessary either to perform the major modernization of the steam turbine in order to increase reliability, extend the life and increase power, or replace the turbine with a new one.

Modernization packages are designed for the most common and mass-produced steam turbines from the factory model range. As part of the KTZ special design bureau, there is a bureau of general engineering and power parts, which works out about 150 applications from customers per year for the supply of spare parts.

Summary table of modernization measures for steam turbines manufactured by KTZ

<table>
<thead>
<tr>
<th>Turbine type</th>
<th>Modernization measures</th>
<th>Purpose of modernization</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-6-35/5/1,2</td>
<td>Installation of the second flexible tower in the area of the front bearing</td>
<td>Improvement of vibration characteristics of the bearing</td>
</tr>
<tr>
<td>PR-6-35/10/1,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-6-35/5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-6-35/10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-10-35/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT-25 family</td>
<td>Replacement of the regulating stage turbine blading with an integrally-machined shrouds and a welded package blades</td>
<td>Increase of the economical efficiency and efficiency of the plant by reducing the profile losses and parasitic leakages in the wheel space part</td>
</tr>
<tr>
<td>R-12-90/18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-12-90/31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-12-1,0PA</td>
<td>Replacement of the brand of the condenser tubes material with 08KH18N10T or VT-1-0</td>
<td>Fulfillment of new requirements for NPP equipment, as well as an increase in the capacitor service life</td>
</tr>
<tr>
<td>K-11-1,0P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT-12 family</td>
<td>Replacement of the KP-540 condenser with KP-1000</td>
<td>Increase of the produced capacity of the plant</td>
</tr>
<tr>
<td>PT-25 family</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-12-90/18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-12-90/31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-12-1,0PA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-11-1,0P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbine type</td>
<td>Modernization measures</td>
<td>Purpose of modernization</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>PT-25/30-90/10</td>
<td>Replacement of the KP-935 condenser with KP-1200</td>
<td>Increase of the produced capacity of the plant</td>
</tr>
<tr>
<td>“R” type turbines</td>
<td>Modernization of the diagram of the steam suction pipelines. Installation of exhaust ejectors instead of jet heater</td>
<td>Elimination of steaming from seal bodies</td>
</tr>
<tr>
<td>For all types of turbines</td>
<td>Modernization of the sealing scheme. Exclusion of oil or slide valves with installation of control valves</td>
<td>Convenience of operation and maintenance</td>
</tr>
<tr>
<td>For all turbines with high pressure heaters (HPH)</td>
<td>Replacement of old design (with coils) PV-60, PV-70, PV-30 HPH with a new design with I-tubes PV-125</td>
<td>Ensuring repair capability (old design was non-serviceable)</td>
</tr>
<tr>
<td>For all “K” type turbines</td>
<td>Replacement of safety diaphragms on exhaust parts with diaphragms of a new design with self-sealing rubber seals</td>
<td>Improvement of the reliability of the assembly</td>
</tr>
<tr>
<td>For all types of turbines</td>
<td>Modernization of diaphragms with a vertical centering key</td>
<td>Exception of centering of the upper halves of the diaphragms. Convenience of assembly and installation of the wheel space part</td>
</tr>
<tr>
<td>manufactured before 1970</td>
<td>Replacement of the old design (with coils) EO-30 and EO-50 ejectors with new straight-tube design</td>
<td>Ensuring repair capability (old design was non-serviceable)</td>
</tr>
<tr>
<td>For all “K” type turbines</td>
<td>Manufacture and supply of devices for the revival of inserts</td>
<td>Elimination of the operation to remove the oil throwers when assembling and disassembling the machine</td>
</tr>
<tr>
<td>For turbines with old seal designs</td>
<td>Modernization of end and diaphragm seals with installation of coil springs instead of leaf ones</td>
<td>Increase of the economical efficiency of the wheel space part by reducing steam leakages through seals</td>
</tr>
<tr>
<td>For T-50 type turbines</td>
<td>Installation of thrust bearings with increased bearing capacity and individual supply of oil to each block. Increase of the diameter of the frontal end seal (dummy)</td>
<td>Ability to increase power by 5 MW. Reduction of axial forces acting on the thrust bearing. Reduction of operating temperature of the thrust bearing shoes</td>
</tr>
<tr>
<td>R-4-18/2TK</td>
<td>Supply of a new 6MW generator manufactured by Ruselprom and a new turbine-generator interface node coupling. Issue of technical characteristics and definition of new equipment operation modes. Examination of the state of the equipment, revision of the wheel space part and main turbine assemblies in order to determine the scope of repair and supply the necessary spare parts</td>
<td>Increase of the electric power from 4 to 6 MW</td>
</tr>
</tbody>
</table>

Reconstruction of the automatic control system

One of the promising areas for the modernization of turbines of the PR-12, PR-6, PT-12, PT-25, R-12, T-12, T-25, K-17 types is equipping the steam turbines with automated control systems – ECP EHACS (Electromechanical Control Part of the Electronic and Hydraulic Automatic Control System).

The reconstruction of the turbine automatic control system consists in its transformation into a modern microprocessor electronic and hydraulic system (EHACS) in order to improve the accuracy of the rotational speed, as well as the quality of joint control from the APCS of turbine units of power units.

The EHACS modernization consists of two functional parts: electromechanical control and hydraulic executive. Hydraulic executive part of EHACS (control unit) is being modernized. The design of the control unit is developed with the application of the electromechanical drive – model Exlar, series GSX30.

The electromechanical control part (ECP) is based on an electronic controller using an electromechanical drive (EMD) of the cut-off pilot-valve.

Purpose of the ECP is:

1. Automatic maintenance of a given rotation frequency of the TG rotor and assurance of the possibility of its change in the mode of the TG starting at nominal and starting steam parameters and when operating in an individual electrical network.
2. Automatic maintenance of a given electrical power and assurance of the possibility of its change when the TG parallel operation in a common electrical network.
3. Automatic maintenance of given steam pressures in regulated extractions and (or) delivery water temperature downstream of the delivery water heater when the TG parallel operation in a common electrical network.
4. Keeping the turbine rotor speed below the setting level of the safety automatic actuation when the electrical load instantaneously drops to zero (including when the generator is disconnected from the network), which corresponds to the maximum steam consumption at its nominal parameters and maximum steam passage to the low pressure part of the turbine.

5. Automatic warm-up and cold, warm and hot start-up of a turbine according to a given algorithm with the turbogenerator (TG) switch to idle conditions at a nominal speed with a subsequent synchronization and connection to the network.

6. TG normal automatic shutdown by reducing the load and closing the control valves according to a given algorithm.

7. Ensuring the required accuracy of setting, maintaining and limiting of parameters of turbine operation modes.

8. Ensuring the TG participation in the normalized primary and secondary regulation of the current frequency and power flows in the power system when the generator parallel operation in a common electrical network.

9. Integration of EHACS into the upper level TPP APCS and attracting the boiler to participate in the normalized primary and automatic secondary frequency control.

Examples of modernizations of the KTZ steam turbines:

1. Turbine modernization for Ust-Ilimsky Forest-Industry Complex Production Association R-12-35/5M with R2=10 kgf/cm² req. No. 9265 (1977 manufacture year) with the aim of increasing the output power when operating at R2=12 kgf/cm². The power reached NEL=7900 kW instead of 6000 kW.

2. Modernization of the rotatable diaphragm of the PT-25/30-90/10M turbine for TPP-28 Mosenergo for pressure in the production extraction of 15 kgf/cm² (abs). Changing the method of unloading the rotatable ring of the diaphragm from axial to radial eliminated its jamming.

3. Modernization of the OK-18PU turbine drive control system for Surgut SDPP-2. Instead of a hydrodynamic system, an electric-hydraulic system was used. Modernization was performed for all four units of the SDPP. This system allows to provide a dead zone for speed control ± 0.01 Hz.

4. The PT-25-90/10M turbine was modernized for Donetskstal with the manufacture of low and high pressure heaters, ejectors, with the replacement of KP-935 condenser with KP-1650 one with circulating water pressure of 6 kgf/cm². Modernization provided an increase in technical and economic indicators of the plant.

Summary table of the most mass series of steam turbines manufactured by KTZ

<table>
<thead>
<tr>
<th>Name</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-11-10P</td>
<td>43</td>
</tr>
<tr>
<td>K-12-10PA</td>
<td>20</td>
</tr>
<tr>
<td>OK-3S</td>
<td>34</td>
</tr>
<tr>
<td>P-6-35/5</td>
<td>59</td>
</tr>
<tr>
<td>PR-12/15-90/15/7</td>
<td>20</td>
</tr>
<tr>
<td>PR-6-35/10/1,2</td>
<td>17</td>
</tr>
<tr>
<td>PR-6-35/10/5</td>
<td>24</td>
</tr>
<tr>
<td>PT-12/15-35/10</td>
<td>61</td>
</tr>
<tr>
<td>PT-25/30-90/10</td>
<td>24</td>
</tr>
<tr>
<td>R-1,5-15/3</td>
<td>27</td>
</tr>
<tr>
<td>R-11-15/3P</td>
<td>68</td>
</tr>
<tr>
<td>R-12-35/5</td>
<td>68</td>
</tr>
<tr>
<td>R-12-90/31</td>
<td>18</td>
</tr>
<tr>
<td>R-2,5-15/3</td>
<td>26</td>
</tr>
<tr>
<td>R-6-3,4/0,5-1</td>
<td>24</td>
</tr>
<tr>
<td>R-6-35/10</td>
<td>45</td>
</tr>
<tr>
<td>R-6-3,4/1,0-1</td>
<td>13</td>
</tr>
<tr>
<td>R-6-35/5</td>
<td>116</td>
</tr>
<tr>
<td>TG 0,5/0,4 R13/4</td>
<td>17</td>
</tr>
<tr>
<td>TP-1100</td>
<td>12</td>
</tr>
<tr>
<td>TP-1250</td>
<td>11</td>
</tr>
</tbody>
</table>
2. General Technical Solutions for Modernization of Wheel Space Parts of LMZ Steam Turbines

2.1 Improvement of HP stages

Turbine blading is designed using modern methods of parametric three-dimensional modeling. The cross sections of the blade profiles have a spline representation in order to eliminate the possibility of breaking the second derivative and reducing the profile losses. The designed stages were subjected to complex three-dimensional gas-dynamic modeling, taking into account the geometry of the seals.

Improvements also affected the configuration of the stage bypass of the nozzle boxes. Due to their optimization, the coefficient of energy loss is reduced and the uniformity of steam supply to the impeller of the regulating stage is improved.

For the new design of the labyrinth-type shroud seal, gas-dynamic analysis has been performed in the Fluent package.

Thanks to the calculations, it was possible to improve the initial section of the HP compartment – the regulating stage.

Efficiency increased +2%
Power increased up to 0.25 MW
Advantages of the new design:

• excluded damage;
• increased economical efficiency;
• increased repair capability.

Also, the standard solution for turbines of a new generation is the active type stage with a honeycomb shroud seal of the rotating blade and the multi-ridge diaphragm seal using coil springs.

2.2 Improvement of LP stages

Improvements affected the configuration of the stage bypass. Due to their optimization, the coefficient of energy loss is reduced and the uniformity of steam supply to the impeller of the regulating stage is improved.

The last stage before the modernization

Radial clearance is 1.5 mm

HPC efficiency +1.4%

Power +0.8 MW

Radial clearance is 0.5 mm

Advantages of the new design:

• excluded damage;
• increased economical efficiency;
• increased repair capability.

After improving the LP stages

Also, the standard solution for the modernization of steam turbines is the use of LP stationary blades with tangential offset.

Before modernization

Power +0.76 MW,

LPC efficiency +2.1%

After modernization
3. Modernization of Steam Turbines of K-50-90, K-100-90 Types by LMZ

Technical offers for the modernization of turbines

- Modernization of K-50-90 turbines with full replacement of stages.
- Renovation (replacement) of K-100-90 steam turbines, having their economic life expired, with KT-115-8,8-2 (K-120-8,8) steam turbines.

3.1 Modernization of K-50-90 turbines with full replacement of stages

As part of this modernization, the entire wheel space part is replaced in the existing body, which makes it possible to extend the service life of the turbine, increase power and reduce specific heat consumption.

Description

Modernization of the wheel space part includes complete delivery of the solid-forged rotor, diaphragms of all stages with the necessary accessories for their installation and fastening.

New rotating and stationary blades have aerodynamically developed profiles that are optimized in each section for thermal gradient and flow contact angle. All rotating blades have T-shaped roots, integrally-machined shrouds with inserts, which increase the reliability and efficiency of the wheel space part.

New types of shroud seals are used, which allows minimizing steam leakage.

All diaphragms are welded, which provides high precision manufacturing and possibility of meridional conical profiling of the wheel space part. Axial forces acting on the rotor are within acceptable limits.

Modernization efficiency

If the steam consumption is kept at the rated level, the increase in capacity to the rated one will be 1.2 MW.

Duration of works:

During the overhaul.

Comparative table of technical and economic indicators

<table>
<thead>
<tr>
<th>Turbine type</th>
<th>Rated capacity, MW</th>
<th>Rated parameters of fresh steam</th>
<th>Rated consumption of fresh steam, t/h</th>
<th>Pressure in the condenser, kgf/cm²</th>
<th>Feed water temperature, °C</th>
<th>Specific heat consumption, kcal/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-50-90 before modernization</td>
<td>50</td>
<td>90</td>
<td>535</td>
<td>192.8</td>
<td>0.08</td>
<td>217</td>
</tr>
<tr>
<td>K-50-90-3M after modernization</td>
<td>51.2</td>
<td>90</td>
<td>535</td>
<td>192.8</td>
<td>0.08</td>
<td>220</td>
</tr>
</tbody>
</table>

3.2 Renovation (replacement) of K-100-90 turbines, having their economic life expired, with KT-115-8,8-2 (K-120-8,8) turbines

The proposed renovation (replacement) of K-100-90-(2,5,6) turbines, having their economic life expired or being on the verge of its expiration, with KT-115-8,8-2 turbines (K-120-8,8) allows to achieve two purposes: to restore steam turbine equipment service life and to improve technical, economic and operational indicators of the turbine-generator set.
Comparative characteristics of K-100-90 and KT-115-8,8-2 (K-120-8,8) turbines

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated parameters of fresh steam</th>
<th>Con-</th>
<th>Specific consumption of heat in the condensing mode is gross, at cool water t 12°C kcal/kWh</th>
<th>Power at generator terminals in the condensing mode, MW</th>
<th>Maximum heat load, Gcal/h</th>
<th>Max. steam sampling for production needs, t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pressure, MPa</td>
<td>temperature °C</td>
<td>consumption of fresh steam, t/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-100-90</td>
<td>8.8</td>
<td>535</td>
<td>420</td>
<td>2140</td>
<td>110</td>
<td>—</td>
</tr>
<tr>
<td>KT-115-8,8-2</td>
<td>8.8</td>
<td>500 (535)</td>
<td>446 (435)</td>
<td>2105</td>
<td>120</td>
<td>146</td>
</tr>
<tr>
<td>K-120-8,8</td>
<td>8.8</td>
<td>500 (535)</td>
<td>446 (435)</td>
<td>2095</td>
<td>120</td>
<td>100</td>
</tr>
</tbody>
</table>

Description
The KT-115-8,8 is a two-cylinder (HPC, LPC) condensing turbine with a single-stage adjustable steam extraction for industrial heating and unregulated steam extraction for production. It is installed on the old foundation with its partial reconstruction. Number of extractions is 8. Number of exhausts is 2.

The KT-115-8,8-2 turbine utilizes modern technical solutions, such as the modernization of the regulation system, the replacement of the main oil pump, the modernization of steam distribution valves, the modernization of the oil supply system and others, which make it possible to increase the reliability and maneuverability of the equipment, and to reduce the costs of scheduled repairs.

The K-120-8,8 steam turbine is a modification of the KT-115-8,8-2 turbine and can be used at facilities where there is no need to generate thermal energy. At the same time, control valves on crossover pipes and a line heater are excluded from the delivery set, corresponding changes are made in the turbine automatic control system, and as a result, the specific heat consumption is reduced by 10 kcal/kWh.

Modernization efficiency
Installation of KT-115-8,8 turbine instead of K-100-90 allows generating up to 120 MW of electrical power in the condensing mode while reducing the gross specific heat consumption by 35 kcal/kWh and also to 146 Gcal/h of thermal power for industrial heating needs.

Duration of works:
- the project of reconstruction of the foundation and turbine plant ~ 6 months;
4. Modernization of Steam Turbines of K-200-130 Types

Technical offers for the modernization of turbines

- Renovation of the wheel space part of the HPC, MPC and LPC of 200 MW steam turbines.
- Replacement of the K-200-130 turbine with a new K-225-12.8 turbine with installation on an existing foundation.
- Modernization of the K-200-130 turbine HPC using reactive blading.
- Modernization of the K-200-130 turbine MPC using a new design of the wheel space part, consisting of 12 stages.

Examples of modernization of the K-200-130 type steam turbines

<table>
<thead>
<tr>
<th>Name of offer</th>
<th>Result</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modernization of the LP wheel space part (using the last stage rotating blade LSB = 960 mm)</td>
<td>Power increased by 5 MW</td>
<td>Verkhnetagilskaya SDPP (Russia) Tahkoluoto TPP (Finland)</td>
</tr>
<tr>
<td>Partial modernization of the HPC wheel space part (4 stages) and modernization of the LP part (according to p.1) with a rated main steam consumption of 628 t/h</td>
<td>Power increased by 6.7 MW</td>
<td>Eesti TPP (Estonia) Balti TPP (Estonia)</td>
</tr>
<tr>
<td>Partial modernization of the HPC (4 stages), MPC (5 stages), modernization of the LP part (according to p.1) and increase in steam consumption from 637 to 665 t/h</td>
<td>Power increased by 16 MW</td>
<td>Maritsa-Vostok-3 TPP (Bulgaria)</td>
</tr>
<tr>
<td>Partial modernization of the HPC (4 stages), MPC (5 stages), modernization of the LP part (according to p.1) and increase in steam consumption from 637 to 700 t/h</td>
<td>Power increased by 25 MW</td>
<td>Bitola TPP (Macedonia) st. No. 1, 2, 3 Maryskaya SDPP (Turkmenistan)</td>
</tr>
<tr>
<td>Complete modernization of the HPC (including the outer cylinder replacement) using the reactive wheel space part</td>
<td>Power increased by 4 MW</td>
<td>Maritsa-Vostok-3 TPP (Bulgaria)</td>
</tr>
<tr>
<td>HPC of reactive type, new MPC, modernization of the LPC with the replacement of the last two stages (liquidation of the Bauman’s stage) at a steam consumption of 640 t/h</td>
<td>Power increased by 10 MW</td>
<td>Lugansk TPP, st. 13 (Ukraine) Verkhnetagilskaya SDPP at. No. 10 (Russia)</td>
</tr>
<tr>
<td>Modernization of the LPC with the replacement of the last two stages (liquidation of the Bauman’s stage) at a steam consumption of 661 t/h</td>
<td>Power increased by 4.1 MW*</td>
<td>Beloyarsk NPP st. No. 4, 5, 6 (Russia)</td>
</tr>
<tr>
<td>Complete replacement of the LPC wheel space part (liquidation of the Bauman’s stage) at a steam consumption of 640 t/h</td>
<td>Power increased by 5.7 MW, specific heat consumption reduced by 53.6 kcal/kWh</td>
<td>Kurakhovskaya TPP st. No. 5 (Ukraine)</td>
</tr>
<tr>
<td>Partial modernization of the HPC (1, 2-4 st.), MPC (1-3, 10, 11 st.) at a steam consumption of 640 t/h</td>
<td>Power increased by 3.5 MW, specific heat consumption reduced by 21.0 kcal/kWh</td>
<td>Kurakhovskaya TPP st. No. 5 (Ukraine)</td>
</tr>
<tr>
<td>HPC of reactive type, repair of MPC, complete replacement of the LPC wheel space part (liquidation of the Bauman’s stage) at a steam consumption of 640 t/h</td>
<td>Power increased by 10 MW</td>
<td>Lugansk TPP st. 13 (Ukraine)</td>
</tr>
<tr>
<td>Complete modernization of the HPC (including the outer cylinder replacement using reactive blading), MPC and LPC (with an increase in steam consumption from 637 to 700 t/h)</td>
<td>Power increased by 30 MW</td>
<td>In development</td>
</tr>
</tbody>
</table>

4.1 Renovation of the wheel space part of the HPC, MPC and LPC of 200 MW steam turbines

Renovation of the wheel space part of the 200 MW steam turbines consists in replacing the first four stages of the HPC, as well as the first three and last two stages of the MPC.
As a result of renovation, the generation of electric power increases, economic efficiency increases by reducing the specific heat consumption of the turbine plant, and the operational performance of the turbine improves.

Description
Renovation of the HPC is carried out with preservation of the outer body and the partially processed rotor when replacing the first four stages of blading, the shroud and diaphragm seals of all stages, the first diaphragm box and the frontal end seal box. Sealing rings with an increased number of ridges are installed to reduce steam leakages in the frontal and rear end seals, in the diaphragm seals of 5-12 stages. Rotating blades of 1-4 stages are made with integrally-machined shrouds. To reduce losses associated with peripheral leakages, developed shrouds seals are used. The performance index of the HPC renovation is achieved by increasing its efficiency and, accordingly, increasing the generation of electric power by ~ 3.3-5.4 MW, depending on the specific conditions of the power plant, including extent of wear of wheel space part, scope of modernization, etc.

Renovation of the MPC provides for the preservation of the outer body and the partially processed rotor with the replacement of 1-3, 10-11 stages, the last two disks, the diaphragm No. 3 box and the frontal end seal box, as well as diaphragm and end seals. The rotating and stationary blades of the modernized stages have improved aerodynamic characteristics of the profiles, ensuring high economical efficiency of the wheel space part. Rotating blades of 1-3, 10-11 stages are used with integrally-machined shrouds and trapezoidal damping inserts, as well as with developed shroud seals minimizing steam leakages (Fig.). All new diaphragms are welded. This ensures higher dimensional accuracy of manufacturing. Sealing rings are replaced with rings with an increased number of ridges to reduce steam leakages in the frontal and rear end and diaphragm seals. The performance index of the MPC renovation is achieved by increasing its efficiency and, accordingly, increasing the generation of electric power by ~ 18.-3.9 MW, depending on the specific conditions of the power plant, including extent of wear of wheel space part, scope of renovation, etc.

The renovation of the LPC consists in replacing the wheel space part with multiehaust stages (Bauman’s stages) with new ones with 960 mm rotating blades of the last stages including corresponding reconstruction of the exhaust parts of the outer body.

The performance index of the LPC renovation is achieved by increasing its efficiency and, accordingly, increasing the generation of electric power by ~ 4.5-6.7 MW, depending on the specific conditions of the power plant, including extent of wear of wheel space part, scope of modernization, etc.

Modernization efficiency
Modernization of high, medium and low pressure cylinders leads to an increase in electric power generation by ~ 16 MW, the economical efficiency of the turbine plant increases to ~ 6%.

Duration of works:
• development of design technical documentation ~ 5 months;
• production of the necessary equipment ~ 5-11 months depending on the configuration;
• installation and adjustment supervision ~ 3 months.
4.2 Modernization of the K-200-130 turbine high pressure cylinder using reactive blading

The proposed modernization of the high pressure cylinder wheel space part is the complete replacement of the old wheel space part with active blading with a new wheel space part with reactive blading.

**Description**

Considering that the K-200-130 turbine is used together with a boiler unit operating at constant pressure, the nozzle steam distribution with a regulating stage is retained in the new modernized HPC. The outer body of the HPC is replaced by a new one installed on the same foundation.

The wheel space part with reactive blading is performed with a constant root diameter with blades of variable height. The stationary blades are mounted in the boxes. The rotating and stationary blades are made of aerodynamically developed profiles, have a T-shaped roots, and integrally-machined shrouds. Damping inserts are installed in the rotating blades.

A developed radial seal was applied over the shrouds of the rotating blades and in the stationary blades, which consists of canted whiskers on the rotor, inserts in the boxes, and also turned whiskers on the shrouds. Seal boxes are supplied of the bushing type, which ensures that they are not buckled during operation, reduces maintenance and repair costs, and allows to keep leakages in the design state.

The axial force of the high pressure shafting is maintained within acceptable limits.

**Modernization efficiency**

When installing a new HPC with reactive blading, a reconstruction of the heating system of the HPC flanges is carried out to improve the reliability and economical efficiency of the turbine, as well as to simplify operation.

As a result of the HPC modernization with the replacement of the wheel space part, the HPC efficiency in the nominal mode will increase by 6-9% depending on the actual state of the HPC wheel space part with a corresponding increase in power (3.3-5.0 MW).

**Duration of works:**

- Development of design documentation – 4 months;
- Installation and adjustment supervision during the repair period.

Modernization can be carried out at the time of the unit shutdown for overhaul. In the process of modernization, it is advisable to carry out reconstruction of auxiliary systems of the turbine plant.

**Supplied equipment:**

- HPC body;
- Rotor with blading;
- Boxes Nos. 1, 2 and 3 with stationary blades;
- Frontal and rear seal boxes;
- Segments of nozzles.

**Implemented projects:**

- Obra TPP, India.
4.3 Modernization of the MPC using a new design of the wheel space part, consisting of 12 stages

Modernization of the MPC provides for the replacement of the old wheel space part with a new wheel space part (consisting of 12 stages) in the existing body, including the new rotor, diaphragms and boxes, as well as the guide vane.

Advantages of the new design:
- applied rotating blades with integrally-machined platforms;
- eliminated damping wires from the wheel space part of the last two stages;
- cast diaphragms replaced by welded ones;
- applied frontal end seal of bushing type.

Effect of modernization:
- Power increased up to 0.6-5.0 MW
- Increased economical efficiency up to 0.5-4.0%
- $G_0 = 630-700$ t/h

Implemented in turbines:
- K-200-130 Lugansk TPP st. 10, Ukraine.

4.4 Replacement of the K-200-130 turbine with a new K-225-12,8 turbine with installation on an existing foundation

The Power Machines company has developed a highly economical modern multi-purpose turbine K-225-12,8, which can be successfully used to re-equip power plants with 200 MW turbines of various modifications.

Main characteristics:
The K-225-12,8 turbine is designed for operation at the following steam parameters:
- pressure upstream the high pressure shut-off valves – 130 kgf/cm²;
- temperature upstream the high and medium pressure shut-off valves – 540 °C;
- rated throughput capacity of the high pressure cylinder – 670 t/h;
- rated capacity at the generator terminals – 225 MW.

The K-225-12,8 turbine is a single-shaft unit consisting of single-flow HPC and MPC and double-flow LPC. Resuperheating between the HPC and the MPC.

In K-225-12,8, developers have eliminated the K-200-130 turbine design solutions that are outdated today:
- Bauman’s stage was eliminated;
- the main oil pump with a coupling connecting it to the turbine shaft was replaced by an electrically driven pump;
- high pressure control valves were removed from the HPC, which simplified the HPC casting and discarded the camshaft, etc.
Design features
The automatic control system (ACS) of the turbine is made electro-hydraulic with a microprocessor electronic part (ECHSR-M2). ACS performs the functions of controlling power, frequency, fresh steam pressure, position of control valves during turbine start-up and operation under load. Electrical pumps are used in lubrication and regulation systems. In the control system, OMTI fire-resistant oil is used as a working fluid. The lubrication system is designed to work on both mineral and OMTI fire-resistant oil.

The turbine is equipped with a centralized system of hydraulic lifting of the rotors, it is possible to turn the turbine shafting manually. The high pressure cylinder has two bodies – inner and outer. The medium pressure cylinder is single-body. The low pressure cylinder has an outer and inner bodies of welded structure. The outer body consists of three parts – the middle and two exhaust.

The bodies, boxes and diaphragms of the HPC and MPC are made of heat-resistant chrome-molybdenum and chrome-molybdenum-vanadium steels. The LPC body is made of carbon steel. The diaphragms of all stages are steel with welded structures.

Rotating blades of all stages have shrouds; damping connections in the wheel space part are left only at the last stage of the MPC and LPC. The estimated life of the main parts and assembly units made of heat-resistant steels has been increased to 200 thousand hours.

At the turbine, the steam receiver of the condenser has been modernized and the cooling water supply restriction scheme has been changed, which makes it possible to improve the LPC thermal condition when starting-up and operating at low emission conditions, to reduce the erosion wear of the exit edges of rotating blades of the turbine last stages, and to increase the service life of the rotating blades.

Modernization efficiency
Replacement with the K-225-12.8 turbine leads to an increase in reliability, maneuverability, repair capability, durability, economical efficiency and rated capacity.
After replacement, the turbine economical efficiency increases by 4-5%, depending on the actual state of the replaced turbine.

Modernization conditions
The K-225-12.8 turbine is installed in the old cell of the machine hall on the existing foundation. Main service marks and connection dimensions are retained.

The main equipment of the turbine plant (condenser, heaters, pumps, piping, etc.) can be left in operation.

In addition to replacing the turbine, Power Machines modernizes the condenser, which consists in reconstructing the tube bundle in order to increase its surface from 9,000 to 12,000 m² and to increase its efficiency. In the process of modernization, tube plates, tube partitions with steam shields, and water chamber partitions shall be replaced. Also, the dimensions of the supplied condenser tubes change and their quantity by weight increases from 80 to 115 tons.

Also, Power Machines, at the request of customers, provides a ball cleaning system for condenser tubes.

Implemented projects:
The K-225-12.8 turbine was manufactured and supplied to Dobrotvorskaya SDPP (Ukraine).

5. Modernization of Steam Turbines of K-300-240 Types

Technical offers for the modernization of turbines
• Modernization of the K-300-240(170) turbine HPC using reactive blading.
• Modernization of the K-300-240(170) turbine MPC and LPC.
• Transfer of a 300 MW unit to operation with a gas turbine superstructure as part of a combined cycle plant.
Efficiency of modernization of the K-300-240 steam turbines

<table>
<thead>
<tr>
<th>Name of offer</th>
<th>Result</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modernization of the LP wheel space part</td>
<td>Power increased by 7.5 MW</td>
<td>Lukomlskaya SDPP st. No. 3 Konakovskaya SDPP st. No. 4</td>
</tr>
<tr>
<td>Modernization of the HPC using reactive blading</td>
<td>Power increased by 7 MW</td>
<td>Konakovskaya SDPP st. Nos. 1, 2, 3 Lukomlskaya SDPP st. Nos. 1, 2, 4</td>
</tr>
<tr>
<td>Modernization of the HPC, MPC, exhaust part of the LPC (replacement of blading the last steps of the low pressure rotor) and an increase in steam consumption from 930 to 990 t/h</td>
<td>Power increased by 27.5 MW</td>
<td>Konakovskaya SDPP st. Nos. 2, 1</td>
</tr>
<tr>
<td>Modernization of the LPC, the entire LP wheel space part with the installation of a shortened blade of the last stage L=755 mm and an increase in steam consumption from 930 to 1050 t/h</td>
<td>Power increased by 30 MW</td>
<td>Azerbaijan SDPP st. No. 5</td>
</tr>
<tr>
<td>Modernization of the HPC, MPC, exhaust part of the LPC (replacement of blading the last steps of the low pressure rotor) with a steam consumption of 937 t/h</td>
<td>Power increased by 15 MW</td>
<td>Lukomlskaya SDPP st. No. 1, 2, 4</td>
</tr>
<tr>
<td>Modernization of MPC wheel space part and LP part, located in the MPC</td>
<td>Power increased by 4 MW</td>
<td>Karmanovskaya SDPP st. No. 3</td>
</tr>
<tr>
<td>Complete modernization of the HPC (with a reactive type HPC, MPC (replacement of 13, 19-24 stages, rotor), LPC (replacement of the entire wheel space part) and an increase in steam consumption from 930 to 1050 t/h</td>
<td>Power increased by 46.5 MW</td>
<td>Lukomlskaya SDPP Kostromskaya SDPP</td>
</tr>
</tbody>
</table>

5.1 Modernization of the K-300-240(170) turbine HPC using reactive blading

The proposed modernization consists in the complete replacement of the old wheel space part with active blading with a new wheel space part with 19 pressure stages of the reactive type. Modernization can be performed both with the use of the existing outer body of the HPC and with its replacement.

Description

The increase in the HPC efficiency due to the use of reactive blading is caused by the following factors:

- an increase in the number of stages, which leads to an increase in the reheat factor;
- a decrease in the steam velocity in the wheel space part due to a decrease in the enthalpy drop per stage and, accordingly, a decrease in losses in the nozzles and rotating blades;
- a decrease in the diameters of the wheel space part and an increase in the height of the blades (especially of the first stages), which reduces additional losses in the turbine blading;
- a reduction of steam leakages in the turbine stages due to the use of developed diaphragm seals and a reduction of radial clearances due to a more rigid rotor design;
- a significant decrease in the thermal adiabatic drop per regulating stage (in ~ 1.5 times). The redistribution of the thermal drop on the HPC allows to increase the pressure in the chamber of the regulating stage and to increase its throughput capacity, which contributes to the increase in economical efficiency.
Modernization efficiency

The internal efficiency of the high pressure cylinder with a modernized wheel space part can be increased by 5-6% and will be approximately 89.6%, which corresponds to an increase in the power of the entire turbine plant with the same fresh steam consumption by 5.5-6.5 MW.

Improving the economical efficiency of the wheel space part is also due to the use of a number of design solutions:
• the tangential offset of stationary blades of 17-20 stages contributes to a more uniform velocity field along the height of the rotating blades;
• variable cross-section of stationary blades of 18-20 stages contributes to a good coincidence of flow and skeleton angles of cross-sections of profiles;
• stationary and rotating blades are made with integrally-machined shrouds, and the rotating blades have damping inserts in their shrouds;
• guaranteed contactless developed radial seals of rotating and stationary blades with a large number of whiskers are applied. This design provides minimal leakage and allows to maintain them in conditions of prolonged use almost unchanged.

The modernization option with the replacement of the existing outer body of the HPC will further increase the internal efficiency of the cylinder by 0.7%.

Characteristics of the modernized outer cylinder:
• high flange connections, which have a high rate of heating and cooling while maintaining the permissible temperature difference;
• aerodynamic perfection of the nozzle boxes, the turning channel after the 11th stage and the exhaust part of the cylinder with a significant reduction in losses and a more uniform flow inlet;
• single-box design of the high pressure cylinder end seals with high axial and radial rigidity, which allows minimization of clearances in the end seals;
• modernized system of the HPC feet resting on the keys of the bearing housing to increase the rigidity of the system and facilitate assembly operations;
• modernized HPC steam distribution system by replacing the seven-valve HPC steam distribution with a four-valve one. In this case, the supply includes two valve blocks, each of which consists of one shut-off and two control valves – 150 mm. Each valve has its own spring-hydraulic servomotor. Valve blocks are located on both sides of the turbine. The use of a new HPC valve block with high throughput capacity gives an increase in the HPC efficiency by 0.3%.

Efficiency of the wheel space part of the modernized HPC will be approximately 90.3%, which is 7% higher than the rated efficiency of the existing design and corresponds to an increase in the power of the entire turbine plant with the same fresh steam consumption of 7-7.5 MW.
5.2 Modernization of the K-300-240(170) turbine MPC and LPC

The proposed modernization is aimed at improving the economical efficiency and reliability of the turbine. It includes replacing the wheel space part of the middle and three low-pressure flows while preserving the existing bearings and bodies of the MPC and the external LPC. In this case, there are options for modernizing including both the replacement of existing rotors, and the installation of new blading on the old rotors in the plant. The new rotors of PJSC “Power machines” are delivered balanced on a Schenck type installation, which eliminates the need for additional start-ups and stops for sub-balancing the shafting and will significantly reduce the scope and duration of repair work at the plant.

Description
The low pressure rotor can be manufactured both with capped disks or solid-forged. In the latter case, the Y-shaped root connections of the rotating blades of the 3rd stage are replaced with T-shaped ones, and of the 4 and 5 stages – with the end-type (fish-bone) ones, which facilitates assembly and blading and improves repair capability. Modernization of the wheel space part was carried out on the basis of studies on the full-scale stand of PJSC “Power machines” and on full-scale gas-dynamic tests at Karmanovskaya and Kostromskaya SDPPs, as well as during new rated aerodynamic and vibration studies.

During modernization, new design and technological solutions are implemented: The use of rotating blades with integrally-machined shrouds, including in the last LP stages.

In this case, the rotating blades with shrouds are made of one blank-stamping. This design allows to:
• eliminate the spin-up of blade airfoils under the action of centrifugal forces;
• significantly reduce the negative impact of steam leakage on the main flow and improve steam flow over the entire height of the blades, especially in the peripheral zone of the stage;
• remove the damping wires from the wheel space part to the shroud body in all stages except the last ones;
• apply special high-performance shroud seals.

The use of new, more efficient profiles of stationary and rotating blades, including stationary blades with tangential offset, taking into account the alignment of flow and skeleton profile angles and the effect of the curvilinearity of the blades on energy losses in root clearances.

Improvement of the upper and root bypass of the LP wheel space part with a smoother contour near the periphery and in the root zone.

Replacement of cast diaphragms with steel diaphragms and diaphragm boxes of welded construction, which provides higher precision of manufacturing. The new design uses new effective diaphragm seals.

Modernization of exhaust nozzles by optimizing the diffuser behind the last stages of the wheel space part. To this end, a special fairing is welded to the periphery of the exhaust nozzle, which leads to a significant decrease in the resistance of the steam outlet tract and a reduction in losses in it by at least 25%.
The use of moisture removal system in welded diaphragms of the last LP stages provides suction of erosion-hazardous moisture from its concentration zone in the interface area of stationary blades with peripheral bypass and from the surface of peripheral bypass behind the stationary blades.

The high technical level of the developed design is confirmed by patents and copyright certificates, as well as reliable operation at the Tahkoluoto TPP in Finland.

Modernization of the seal of the LPC horizontal connector and the MPC exhaust part. The horizontal connector works in conditions of prolonged exposure to static loads from pressure drops, as well as from temperature effects, especially in the low emission conditions and idling modes. This effect leads to buckling of the connector surfaces and a decrease in density, which, in turn, leads to increased air suction and performance deterioration of the vacuum systems.

To eliminate this phenomenon, along the entire length of the connector, in the lower half of the body, there is a groove in which the silicone temperature-resistant rubber cord is laid. When the connector is tightened, the rubber deforms and seals the cylinder connector securely over the entire length of the contour.

Modernization of the MPC frontal end seal in order to prevent buckling of the assemblies, which leads to steaming and air suction in the vacuum system, as well as to improve repair capability (see the corresponding offer).

5.5 Transfer of a 300 MW unit to operation with a gas turbine superstructure as part of a combined cycle plant

One of the most effective ways to increase the economical efficiency of steam-power cycles of power plants is the transfer of blocks to the gas-steam cycle. The CCGT cycle efficiency depends on the CCGT diagram type (discharge or disposal), as well as on the parameters of the gas upstream the gas turbine. Modern CCGTs operating according to the disposal diagram have an efficiency of 50-55% (gross). For comparison, the steam cycle efficiency with a 300 MW turbine reaches 44-45% (gross) and 37-38% (net).

Offer for the reconstruction of 300 MW units with the organization of a highly economical binary CCGT cycle, developed by Power Machines company, assumes maximum use of the existing equipment of the units including their partial reconstruction and modernization.

As an option of using the existing equipment, the gas-steam cycle can be implemented in a standard unit with a K-300-240 turbine by raising its height with a 30–160 MW gas turbine according to the scheme with discharge of gases into the boiler and with a feed water partial bypass of high and low pressure regenerative heaters. Since part of the feedwater will be bypassed and heated by the exhaust gases of the gas turbine in the boiler, the consumption of fresh steam per turbine and its electrical capacity can be increased.

In the process of this reconstruction of the steam turbine, the volume of supplied parts and assemblies will depend on the actual state of the turbine wheel space part and the turbine plant auxiliary equipment.

The K-300-240 turbine is designed for a maximum pass of fresh steam in the amount of 975 t/h. After carrying out low-cost modernization, steam consumption per turbine can be increased up to 1050 t/h, which will provide additional electricity generation.
### Steam consumption per turbine, t/h

<table>
<thead>
<tr>
<th>LPH bypass, t/h</th>
<th>HPH bypass, t/h</th>
<th>Capacity*, MW</th>
<th>Capacity increase*, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>975</td>
<td>585</td>
<td>500</td>
<td>344</td>
</tr>
<tr>
<td>975**</td>
<td>580</td>
<td>500</td>
<td>335</td>
</tr>
<tr>
<td>1000</td>
<td>590</td>
<td>500</td>
<td>351</td>
</tr>
<tr>
<td>1000**</td>
<td>585</td>
<td>500</td>
<td>341</td>
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<tr>
<td>1050</td>
<td>595</td>
<td>500</td>
<td>364</td>
</tr>
<tr>
<td>1050**</td>
<td>590</td>
<td>500</td>
<td>355</td>
</tr>
</tbody>
</table>

Note:
* only the electric capacity of the steam cycle turbogenerator is indicated. Capacity of the gas cycle turbogenerator is assumed nominal, in this case it is 160 MW.
** heat-extraction mode with a thermal capacity of 50 Gcal/h.

In the scope of the turbine plant reconstruction, it is recommended to modernize the HP, MP and LP wheel space parts. For more information on possible modernization options see the relevant sections of the offer.

#### Scope of work
- inspection work, which includes a visual inspection of the turbine rotors, disk rims, rotating and stationary blades, nozzles and diaphragms, shut-off and control valves, end and internal seals. Magnetic powder and dye penetrant inspection, ultrasonic testing of individual parts and assemblies are also carried out;
- determination of the residual life of the main parts and assemblies, obtaining the conclusion and recommendations of the LMZ manufacturers of the boiler and auxiliary equipment of the turbine plant according to the scope of reconstruction;
- modernization of the HP, MP and LP wheel space parts (if necessary).

#### Modernization efficiency
In case of using the CCGT discharge diagram, in addition to obtaining additional capacity it is possible to increase the cycle efficiency to 48-50% (gross) depending on the type of gas turbine and the scope of modernization of the steam turbine.

### 6. Modernization of the steam turbines of K-150-130 (KhTZ), K-300-240 (KhTZ), T-110-130 (UTZ) types being in operation

#### Technical offers for the modernization of turbines
- replacement of the K-150-130 steam turbine manufactured by the Kharkov Turbine Plant (KhTZ), having its economic life expired, with the K-165-130 steam turbine manufactured by Power Machines;
- renovation (replacement) of the T-110/120-130 steam turbine manufactured by the Ural Turbine Plant (UTZ), having its economic life expired, with the T-120/140-12,8 steam turbine manufactured by Power Machines;
- renovation (replacement) of the K-300-240 steam turbine manufactured by the Kharkov Turbine Plant, having its economic life expired, with the K-330-240 steam turbine manufactured by Power Machines.

#### 6.1 Replacement of the K-150-130 turbines manufactured by KhTZ with K-165-130 turbines
Replacement of the K-150-130 turbine of the Kharkov Turbine Plant, having its economic life expired, with the K-165-130 turbine manufactured by Power Machines while maintaining the initial steam parameters, significantly improves the technical, economic and operational indicators of the turbine-generator set.
Comparative characteristics of K-150-130 by KhTZ and K-165-130 turbines at the nominal mode

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated parameters of fresh steam</th>
<th>Consumption of fresh steam, t/h</th>
<th>Turbine weight, t</th>
<th>Turbine specific weight, kg/kW</th>
<th>Specific gross heat consumption, kcal/kWh</th>
<th>Power at the generator terminals, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-150-130, KhTZ</td>
<td>12.8</td>
<td>540</td>
<td>480</td>
<td>390</td>
<td>2.6</td>
<td>2051</td>
</tr>
<tr>
<td>K-165-130</td>
<td>12.8</td>
<td>540</td>
<td>480</td>
<td>337</td>
<td>2</td>
<td>1949</td>
</tr>
</tbody>
</table>

**Description**

The K-165-130 turbine is condensing, single-shaft, with nozzle steam distribution, one intermediate superheating, without adjustable steam extraction is installed on the existing foundation after a minor reconstruction of the front and middle cross-beam.

The wheel space part of the turbine is designed taking into account the latest theoretical and experimental studies. New turbine blading profiles were developed using modern three-dimensional methods of gas-dynamic calculation and design, allowing to achieve maximum performance of internal efficiency of the turbine cylinders.

All compartments of the HP, MP and LP of the wheel space part are single-flow. In total, there are 28 stages in the wheel space part, 12 of them are in the HPC, 13 of them are in the MP part, and 3 of them are in the LP part. A reinforced rotating blade of the last stage of 1000 mm is used in the LP part. High pressure rotor is solid-forged, low-medium pressure rotor is forged together with the front coupling half and the disks of thirteen stages, the last three disks are mounted.

All stages have developed shroud seals of the labyrinth radial type with six whiskers.

Selections for the regeneration of the K-165-130 turbine correspond to the existing scheme, but it is possible in principle to use the new equipment of the regenerative scheme, which will increase the economical efficiency of the turbine plant. The technical and economic indicators presented in the table are confirmed by warranty tests at the Maritsa-Vostok-2 TPP. The scope of supply includes the K-165-130 turbine with the corresponding ancillary equipment.

**Modernization efficiency**

Installation of the K-165-130 turbine by Power Machines instead of the K-150-130 by KhTZ allows to additionally produce 18.3 MW of electrical capacity and to reduce the specific gross heat consumption by 102 kcal/kWh.

With the same dimensions of the turbine, the specific metal content is reduced by ~ 16%, which improves the maneuverability of the turbine-generator set.
Duration of works:
- delivery of equipment ~ 10-12 months from the date of signing the contract;
- installation and adjustment supervision ~ 4-6 months.

Implemented projects:
- Maritsa-Vostok-2 TPP, Bulgaria.

6.2 Replacement of the K-300-240 turbines manufactured by KhTZ with K-330-240 turbines

Replacement of the K-300-240 turbines of the Kharkov Turbine Plant, having their economic life expired or being on the verge of its expiration, with the K-330-240 turbine manufactured by Power Machines ensures the recovery of service life of the steam turbine equipment and the improvement of the technical, economic and operational parameters of the turbine-generator set.

Description
The K-330-240 turbine is condensing, single-shaft turbine; it has three cylinders: HPC, MPC (MP part + LP part), LPC. Number of extractions is 8. Number of exhausts is 3. Selections for the regeneration of the K-330-240 turbine correspond to the existing scheme; upon the request of the customer, it is possible to use the new equipment of the regenerative scheme, which will increase the economical efficiency of the turbine plant.

The wheel space part of the turbine is designed taking into account the latest theoretical and experimental studies. New turbine blading profiles were developed using modern three-dimensional methods of gas-dynamic calculation and design, allowing to achieve maximum performance of internal efficiency of the turbine cylinders.

The turbine is installed on the old foundation with a slight reconstruction of it. The scope of supply includes the K-330-240 turbine with the corresponding ancillary equipment.

Features of K-330-240 turbine:
- wheel space part with stationary blades with tangential offset;
- integrally-machined shrouds, welded diaphragms;
- smooth meridional bypasses;
- film moisture evacuation;
- modernization of the exhaust nozzle;
- developed diaphragm seals;
- new design of shroud seals.

Features of the reactive HPC blading:
- new design of shroud seals;
- spatial profiling of grids (new profiles);
- new design of diaphragm and end seals;
- stationary blades of variable cross-section;
- use of integrally-machined shrouds;
- reducing the regulating stage head;
- new outer body.

Modernization efficiency
New technical solutions were applied in the design of the K-330-240 turbine. All measures allow to increase the efficiency of the HPC by 5.0-8.0%, the MPC by 1.0-1.5%, and the LPC by 6.0-8.5%, depending on the condition of the equipment being replaced.

Installation of the K-330-240 turbine manufactured by Power Machines instead of the K-300-240 by KhTZ allows to produce 348.5 MW of electrical capacity and to reduce the specific gross heat consumption by 39 kcal/kWh.

Power Machines also proposes to carry out a set of measures aimed at improving the reliability and maneuverability of equipment, reducing the costs for scheduled repairs, namely:
- modernization of the control system;
- replacement of the main oil pump;
- modernization of the steam distribution valves;
- modernization of the oil supply system, etc.

**Duration of works:**
- the project of reconstruction of the foundation and turbine plant ~ 6 months;
- equipment manufacturing ~10-12 months;
- installation and adjustment supervision ~ 4-6 months.

**Implemented projects:**
- replacement of K-300-240 by KhTZ turbines with K-330-240 turbines manufactured by Power Machines was carried out at the following plants:

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Turbine</th>
<th>Modernized wheel space parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Konakovskaya SDPP</td>
<td>K-300-240 st. No. 2</td>
<td>HP part</td>
</tr>
<tr>
<td>Azerbaijan SDPP</td>
<td>K-300-240 st. No. 5</td>
<td>MP part</td>
</tr>
<tr>
<td>Lukomlskaya SDPP</td>
<td>K-300-240 st. No. 3</td>
<td>LP part*</td>
</tr>
<tr>
<td>Konakovskaya SDPP</td>
<td>K-300-240 st. No. 4</td>
<td>LP part</td>
</tr>
</tbody>
</table>

* according to warranty tests, increase in electrical capacity by 8.7 MW, including a project guaranteed rated 7.5 MW, was confirmed

6.3 Replacement of the T-110/120-130 turbines manufactured by UTZ with T-120/140-12,8 turbines

Replacement of the T-110/120-130 turbines of the Ural Turbine Plant, having their economic life expired or being on the verge of its expiration, with the T-120/140-12,8 turbines manufactured by Power Machines ensures the recovery of service life of the steam turbine equipment and the improvement of the technical, economic and operational parameters of the turbine-generator set.

**Comparative characteristics of T-110/120-130 by UTZ и T-120/140-12,8 turbines at the nominal mode**

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated parameters of fresh steam</th>
<th>Specific heat consumption in gross condensing mode, kcal/kWh</th>
<th>Power at generator terminals in the condensing mode, MW</th>
<th>Maximum heat load, GJ/h</th>
<th>Maximum steam extraction for production needs, t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-110/120-130, UTZ</td>
<td>12.8 555 516</td>
<td>2167</td>
<td>120</td>
<td>770</td>
<td>—</td>
</tr>
<tr>
<td>T-120/140-12,8, with 2-flow LPC</td>
<td>12.8 555 500</td>
<td>2010</td>
<td>146,4</td>
<td>762</td>
<td>50</td>
</tr>
<tr>
<td>T-120-12,8, with 1-flow LPC</td>
<td>12.8 555 500</td>
<td>2157</td>
<td>127</td>
<td>725</td>
<td>50</td>
</tr>
</tbody>
</table>

**Description**

T-120/140-12,8 turbine is heating, single-shaft, two-cylinder (HPC, MLPC) with two-stage adjustable steam extraction for industrial heating; it is installed on an old foundation with partial reconstruction. Number of extractions is 7. Number of exhausts is 2 or 1, depending on the modification of the turbine ordered.

The wheel space part of the turbine is designed taking into account the latest theoretical and experimental studies. New turbine blading profiles were developed using modern three-dimensional methods of gas-dynamic calculation and design, allowing to achieve maximum performance of internal efficiency of the turbine cylinders.
**HPC modernization measures:**

- Replacement of the cylinder body with the boxes of stationary blades
- Replacement of the HPC wheel space part with a new one with reactive blading
- Reduction of heat drop and modernization of the regulating stage
- The use of high-performance end seals of bushing type

**The effect of HPC modernization:**
- Power increased by 3 MW;
- Increased efficiency by 10%.

**MPC modernization measures:**

- Use of rotating blades with integrally-machined shrouds;
- Eliminate damping wires from the wheel space part of the last stages;
- Use of new effective profiles of stationary and rotating blades;
- Use of high-performance frontal end seal of bushing type.

**The effect of MPC modernization:**
- Power increased by 7 MW;
- Increased efficiency by 8%.

**LPC modernization measures:**

- Replacement of the low pressure rotor with a new one with mounted disks and a blade of the last stage with a length of 560 mm;
- Measures to improve the efficiency of heat extraction;
- Installation of diaphragms of the last stages with moisture removal system;
- Use of stationary blades with tangential offset.

**The effect of LPC modernization:**
- Power increased by 1 MW;
- Increased efficiency by 3%.
Modernization efficiency

Installation of the T-120/140-12,8 turbine by Power Machines (option with 2-flow LPC) instead of the T-110/120-130 by UTZ allows generating up to 146.4 MW of electrical power in the condensation mode and reducing the specific gross heat consumption by 157 kcal/kWh. Other modern technical solutions, such as the modernization of the regulation system, the replacement of the main oil pump, the modernization of steam distribution valves, the modernization of the oil supply system and others, make it possible to increase the reliability and maneuverability of the equipment, and to reduce the costs of scheduled repairs.

Duration of works:
• the project of reconstruction of the foundation and turbine plant ~ 6 months;
• equipment manufacturing ~10-12 months;
• installation and adjustment supervision ~ 4-6 months.

7. Modernization of LMZ Thermalclamping Steam Turbines

Technical offers for the modernization of turbines

• renovation of steam turbine of the PT-60/75-90(130) type in terms of high pressure;
• modernization of the PT-60-90(130) steam turbine MLPC in order to increase the throughput capacity of the MLP part for the use of steam of production extraction;
• modernization of the PT-80/100-130/13 turbine in order to use steam of production extraction in the MLP part;
• modernization of the PT-80/100-130/13 steam turbine in order to increase the throughput capacity of the MLP part by reducing steam consumption for production needs;
• installation of attached turbines operating on a steam of production extraction of the PT-60-90(130), PT-80-130, R-50-130 turbines.

Examples of modernization of PT-60-130 (90), PT-80-130 steam turbines (as of 1/1/2010)

<table>
<thead>
<tr>
<th>Turbine type</th>
<th>Name of offer</th>
<th>Capacity gain</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>electrical, MWh</td>
<td>thermal, Gcal/h</td>
</tr>
<tr>
<td>PT-60-130(90)</td>
<td>Renovation in terms of high pressure in order to restore the service life and increase the generation of electrical power (replacement of HPC with a 180° turn with the removal of BB coupling)</td>
<td>5</td>
<td>—</td>
</tr>
<tr>
<td>PT-60-130(90)</td>
<td>Modernization of the MLPC in order to increase the throughput capacity of the MLP part for the use of steam of production extraction (replacement of the wheel space part of the MLP part)</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>PT-80/100-130</td>
<td>Modernization of the MLPC in order to increase the throughput capacity of the MLP part for the use of steam of production extraction (replacement of the wheel space part of the MLP part)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>PT-60-130(90), PT-80-130, R-50-130</td>
<td>Organization of additional unregulated extraction in the HPC with a flow rate of up to 60 t/h for production needs with pressures of 33÷50 kgf/cm² abs or 27÷30 kgf/cm² abs</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

35 renovations were carried out in the period of 1997-2007, including: Ufimskaya TPP-4, Chitinskaya TPP-1, Yaroslavskaya TPP-3, Kurskaya TPP-1, etc.
7.1 Renovation of the PT-60/75-90(130) turbine in terms of high pressure

The purpose of renovation is to replace equipment that has its life expired. Modernization of the high-pressure part is made on the basis of unified and spent elements of the wheel space part structure, its blading with the use of new technological and design solutions that increase the reliability, economical efficiency and maneuverability of the turbine plant.

Description

The high pressure cylinder is installed on the existing foundation with a 180° turn. The use of a new HPC improves operational reliability by:

- exclusion of the BB coupling from the HP and LP connection design;
- replacement of the seal box of the regulating stage with the modernized box No. 1 with the implementation of the seal on the deflector;
- replacement of the main oil pump coupling sleeve, with the turbine shaft, with the modernized design;
- removal of the journal-and-trust insert of the high pressure rotor (the journal-and-trust insert of the high pressure rotor remains);
- installations of modernized HP control valves.

Comparative table of technical and economic indicators

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated capacity, MW</th>
<th>Max. capacity, MW</th>
<th>Rated parameters of fresh steam</th>
<th>Max. consumption of fresh steam, t/h</th>
<th>Max. consumption of coolant water through the cond-r, t/h</th>
<th>Max. performance of heat extraction, GJ/h</th>
<th>Max. consumption of production extraction, t/h</th>
<th>Max. pressure of product extraction, MPa</th>
<th>Specific heat consumption, kcal/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT-60-90 before modernization</td>
<td>60</td>
<td>75</td>
<td>8.8</td>
<td>535</td>
<td>402</td>
<td>8000</td>
<td>335</td>
<td>0.07-0.25</td>
<td>250</td>
</tr>
<tr>
<td>PT-60-90 after modernization</td>
<td>65</td>
<td>75</td>
<td>8.8</td>
<td>535</td>
<td>398</td>
<td>8000</td>
<td>355</td>
<td>0.07-0.25</td>
<td>250</td>
</tr>
<tr>
<td>PT-60-130 before modernization</td>
<td>60</td>
<td>75</td>
<td>12.8</td>
<td>555</td>
<td>390</td>
<td>8000</td>
<td>335</td>
<td>0.07-0.25</td>
<td>250</td>
</tr>
<tr>
<td>PT-60-130 after modernization</td>
<td>65</td>
<td>75</td>
<td>12.8</td>
<td>555</td>
<td>396</td>
<td>8000</td>
<td>355</td>
<td>0.07-0.25</td>
<td>250</td>
</tr>
</tbody>
</table>

Modernization efficiency

As a result of the renovation, the rated capacity of the turbine is increased to 65 MW. Economical efficiency of the turbine plant is increased by transferring the end seals to the self-sealing scheme. Maneuverability properties of the turbine plant are improved due to the implementation of a box-free heating of the HPC flanges. After replacing the set of assemblies and parts, the turbine will be designated as PT-65/75-90(130).

Indicators of reliability of the PT-65/75-90/13 (PT-65/75-130/13) turbine

- The readiness coefficient of the HPC of the PT-65/75-90(130) turbine will be at least 0.98.
- Average time to failure is not less than 8000 hours.
- Mean time before failure period is not less than 6 years.
- Service life of the modernized HPC is 220 000 hours.
- Life time till discarding is 40 years.

Duration of works:

- development of design documentation – 1 month;
- installation and adjustment supervision during the repair period – 100 days.

Supplied equipment:

- complete HPC with end seals, rotor, boxes, diaphragms and parts of the wheel space part;
- middle bearing;
- front insert of the high pressure rotor;
- coupling sleeve between high pressure rotor and low pressure rotor;
- assembled automatic shutter valve with box;
7.2 Modernization of the PT-60-90(130) turbine MLPC in order to increase the throughput capacity of the MLP part for the use of steam of production extraction

Modernization of the MLPC wheel space part provides for replacing the MLP part wheel space part on the existing rotor in order to use steam of production extraction and to increase the throughput capacity of the MLPC up to ~240 t/h at a pressure of 13 at upstream the MLPC, as well as to increase the heat extraction up to 200 t/h. Maximum steam consumption to the condenser will be 160 t/h.

Comparative table of technical and economic indicators

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated capacity, MW</th>
<th>Max. capacity, MW</th>
<th>Rated parameters of fresh steam</th>
<th>Max. consumption of fresh steam, t/h</th>
<th>Max. steam consumption in the MLPC, t/h</th>
<th>Max. performance of heat extraction, t/h</th>
<th>Max. steam consumption to the condenser, t/h</th>
<th>Max. consumption of production extraction, t/h</th>
<th>Specific heat consumption, kcal/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT-60-130 before modernization</td>
<td>60</td>
<td>60</td>
<td>12.8</td>
<td>555</td>
<td>387</td>
<td>170</td>
<td>140</td>
<td>160</td>
<td>230</td>
</tr>
<tr>
<td>PT-70-130 after modernization</td>
<td>67.2</td>
<td>86.4</td>
<td>12.8</td>
<td>555</td>
<td>387</td>
<td>240</td>
<td>200</td>
<td>160</td>
<td>76</td>
</tr>
</tbody>
</table>

Description

The new elements of the wheel space part are designed to pass more steam flow and provide greater economical efficiency. Shroud seals of rotating blades are performed with developed labyrinth and integrally-machined shrouds, which allows to increase the efficiency of seals and to reduce steam leakages.

Radial and axial clearances on the wheel space part are set optimal in terms of economical efficiency and assurance of reliable operation during thermal displacements.

Modernization efficiency

Modernization of the medium-pressure wheel space part allows to increase the MP part efficiency by 2.0%.

At the same time, by improving the economical efficiency of the wheel space part and increasing the steam consumption through the MP part, the turbine capacity after modernization will be:

- in the condensing mode – 60.5 MW with a steam consumption of 223.9 t/h (determined by the maximum allowable steam consumption in the condenser – 160 t/h);
- with steam consumption per turbine – 337.5 t/h, and maximum extractions of Gp=40 t/h and Gt=200 t/h – 67.2 MW (determined by the maximum allowable steam consumption in the MLPC – 240 t/h);
- with steam consumption per turbine – 387 t/h, and extractions of Gp=76 t/h and Gt=34 t/h – 86.4 MW
- (determined by the maximum allowable steam consumption in the condenser – 160 t/h, maximum capacity mode).

The capacity values are given for the conditions of the simultaneous modernization of the MLPC and HPC (installation of honeycomb seals and modernization of end seals).

Duration of works:

- development of design documentation – 6 months;
When performing the modernization of the MLPC, the following works are carried out:

- a new nozzle diaphragm for the MLPC is installed;
- new diaphragm boxes No. 1, 2 and 3 are installed;
- new diaphragms of 2-9 stages of the MLPC completed with sealing rings are installed;
- new rotating blades of 1-9 stages of the MLPC with integrally-machined shrouds are installed;
- the MP control valves are modernized to provide acceptable steam rates and to reduce valve losses when steam is passed with a flow rate of 240 t/h.

Modernization of the MP control valves includes the replacement of the valves and seats themselves, as well as the operating cams of the control valves.

Diaphragms are supplied completed with boxes that are installed in existing borings. A new box of the frontal end seal is also installed in the existing boring. New rotating blades are designed for installation on existing disks.

Implemented projects:

- TPP-9 Mosenergo st. No. 5 on the PT-70-130/13 turbine;
- TPP-22 Mosenergo st. No. 1 on the PT-60/70-130/13-1M turbine.

7.3 Modernization of the PT-80/100-130/13 turbine in order to use steam of production extraction in the MLP part

Modernization of the PT-80/100-130/13 turbine is performed in order to increase the throughput capacity of the MLPC up to 380 t/h while maintaining pressure control during the production extraction with reduced steam consumption for production needs and increasing the additional generation of heat and electric power.

Comparative table of technical and economic indicators

<table>
<thead>
<tr>
<th>Name</th>
<th>Steam consumption for production, t/h</th>
<th>Rated capacity, MW</th>
<th>Max. consumption of fresh steam, t/h</th>
<th>Max. steam consumption for production, t/h</th>
<th>Max. performance of heat extraction at 13/16.7 kgl/cm² in the production extraction, Gcal/h</th>
<th>Max. steam passage in the MLPC at 13/16.7 kgl/cm² in the production extraction, t/h</th>
<th>Turbine capacity in the cond. mode, MW</th>
<th>Specific steam consumption, kg/kWh</th>
<th>Specific heat consumption in the cond. mode, kcal/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT-80/100-130/13 before modernization</td>
<td>200</td>
<td>80.7</td>
<td>470</td>
<td>300</td>
<td>120/150</td>
<td>218/280</td>
<td>81.5</td>
<td>5.82</td>
<td>2264</td>
</tr>
<tr>
<td>PT-80/100-130/13M after modernization</td>
<td>76</td>
<td>92</td>
<td>470</td>
<td>300</td>
<td>130/168</td>
<td>302.5/383</td>
<td>83.3</td>
<td>5.1</td>
<td>2200</td>
</tr>
</tbody>
</table>

Description

In the process of modernization, a new rotor, new diaphragms and boxes are installed in the existing outer MLPC cylinder. The following activities are also implemented:

- installation of new diaphragms of 29 and 3 stages with tangential offset. This design can significantly improve the economical efficiency of the last low pressure stages without replacing the rotating blades due to the redistribution of parameters and their alignment along the height of the wheel space part, streamlining of the flow structure (an increase in electric power generation in the condensing mode up to 3 MW);
- rotatable diaphragm seal with exhaust cooling system installation. Made with the aim of improving the economical efficiency of a turbine plant when it is operating in a mode with a fully closed rotatable diaphragm by reducing unproductive steam leakage into the condenser, which reduces the leakage to a minimum by sending additional steam to the delivery water heater (this measure will increase the heat load by 7 Gcal/hour).

Power Machines proposes, simultaneously with an increase in the throughput capacity of the MLPC, to modernize the high pressure cylinder in order to improve the technical and economic characteristics with minimal scope of reconstruction.
Modernization of the HPC involves the following works:

- replacement of shroud seals of the HPC 2-17 stages with modernized ones. Wherein, the diaphragm deflectors are refined to install the box with honeycombs. The use of honeycomb seals allows reducing clearances in seals for up to 0.5 mm and increasing the economical efficiency of the HPC and, accordingly, the generated power;
- modernization of the rotating blades of the first (regulating) stage of the HPC provides for the installation of honeycomb shroud seals, which provide a significant increase in economical efficiency by reducing leaks. At the same time, the seal box is modernized with additional processing for installation of honeycomb units. It also provides for the installation of optimal radial (1.5 mm) and axial clearances, ensuring the effective operation of the seals while maintaining reliability in all modes.

**Modernization efficiency**

Implementation of the abovesaid measures on the HPC increases the efficiency of the turbine plant up to 0.8%. The results of the entire complex of modernization:

- increasing turbine plant efficiency by at least 2.8%;
- ensuring maximum electrical load of the 110 MW turbogenerator in the combined heat and power generation mode;
- ensuring increase in the maximum heat extraction up to 168 Gcal/h.

**Duration of works:**

- development of design documentation – 6 months;
- installation and adjustment supervision during the repair period ~ 3.5 days

**Supplied equipment:**

- a set of units for the MLP part modernization, including a low-medium pressure rotor, a guide vane, a box of frontal seal, diaphragms, diaphragm boxes, LPC control valves, etc.;
- set of spare parts for turbine units.

**Implemented projects:**

- in terms of increasing the throughput capacity of steam in the MLPC, work was carried out at TPP-12 of Mosenergo st. No. 9 on the PT-80/100-130/13-1M turbine;
- TPP-26 Mosenergo st. No. 1 on the PT-80/100-130/13-1M turbine;
- in terms of increasing the throughput capacity of steam in the MLPC and increasing the HPC efficiency, work was carried out at Minusinskaya TPP st. No. 1 on the PT-80/100-130/13 turbine.

**7.4 Modernization of the PT-80/100-130/13 turbine in order to increase the throughput capacity of the MLP part by reducing steam consumption for production needs**

Modernization of the turbine was performed in order to increase the throughput capacity of the MLPC up to 340-350 t/h while maintaining pressure during the production extraction of 13 at with reduced consumption for production needs and increasing the additional generation of electric power.
Comparative table of technical and economic indicators

<table>
<thead>
<tr>
<th>Name</th>
<th>Rated capacity in the comb. el/power generation, MW</th>
<th>Rated parameters of fresh steam</th>
<th>Consumption of fresh steam, t/h</th>
<th>Consumption of cool. water through the cond-r, t/h</th>
<th>Max. performance of heat extraction, GJ/h</th>
<th>Max. consumption of produc. extraction, t/h</th>
<th>Max. steam consumption in the MLPC at 1.3 MPa</th>
<th>Electric power in the condens. mode, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT-80/100-130/13 before reconstruction</td>
<td>100</td>
<td>12.8</td>
<td>555</td>
<td>470</td>
<td>8000</td>
<td>100</td>
<td>300</td>
<td>215</td>
</tr>
<tr>
<td>PT-80/100-130/13 after reconstruction</td>
<td>97</td>
<td>12.8</td>
<td>555</td>
<td>410</td>
<td>8000</td>
<td>120</td>
<td>100</td>
<td>340</td>
</tr>
</tbody>
</table>

* With the steam consumption of Gt=305 t/h to the turbine head
** The maximum steam consumption per turbine at rated parameters can be 470 t/h at the combined electric power generation

Description

As a result of modernization, the regeneration system changes:

• no steam is extracted to the deaerator from the turbine;
• LPH-1 should be removed and can be dismantled;
• in order to ensure optimal operation of the deaerator at the maximum steam consumption in the LPC, the LPH-4 is removed and can be dismantled.

This modernization option allows to save the existing cylinder and the MLPC rotor. The following measures are provided for the turbine:

• the existing nozzle steam distribution of the MPC is replaced by a throttle one;
• reconstruction of the existing LP cylinder body (front cast section);
• reconstruction of the existing LP rotor;
• manufacture of new structural elements of the stator, forming a scroll of the steam admission, as well as new boxes of control valves, a new front seal box, a 1st stage guide vane and a 6th stage diaphragm (due to the replacement of profile of the stationary blades). Box No. 1 is canceled, box No. 2 is reconstructed (new).

Due to the fact that the consumption in the MLPC increases by ~ 1.5 times, the first 3 stages are cut off (regulating and 2 stages of pressure); 4 nozzle and 2 side steam boxes are cut off (to limit the consumption rate) and replaced with two side boxes of control valves of the MPC. As a result, a smooth supply from the side boxes is ensured, a rotor section is closed, a camera and a box configuration are designed. The horizontal connector fastener is replaced with a new one, enlarged by size. The MPC is processed again.

The following changes are foreseen for the regulation:

• installation of side valves with a new design, a lower steam supply, improved vibration characteristics and lower pressure losses;
• two new operating cams are installed on a shaft of the kept cam distribution device;
• columns that have a more repairable welded structure are installed on the side valves. The wear surfaces of the frame and the column body are made in the form of changeable bushings of special steels with hardened surface layer;
• the existing upper control valves are dismantled and the corresponding plugs are installed in the steam boxes. The existing servomotor is retained as a valve actuator. In the system of steam supply, to supply steam to the new lower side valves of the MLPC, the design of the crossover pipes from the HPC to the MLPC changes. New crossover pipes are routed similar to existing ones.

Modernization efficiency

As a result of the modernization, additional generation of 1800 kW is ensured due to the internal streamlined scroll and the replacement of steam boxes.

Duration of works:

• development of design documentation ~ 8 months;
• installation and adjustment supervision during the repair period ~ 100 days.
Supplied equipment:
- a set of assemblies for the modernization of MLP part, including a guide vane and diaphragms of the 6th stage with boxes, a frontal seal boxes, rotating blades with a reconstructed low pressure rotor and front part of the LPC;
- MP control valves;
- columns of the MP part control valves;
- levers of the MP part side valves;
- operating cams of the MP part CV;
- magnetic circuit breakers;
- details of the servomotor modernization;
- details of the front bearing assembly;
- gear coupling;
- set of spare parts for turbine units.

Implemented projects:
- PT-80/100-130 Minusinskaya TPP, Russia;
- K-255-162-2 Alholma TPP, Finland.

7.5 Installation of attached turbines operating on a steam of production extraction of the PT-60-90(130), PT-80-130, R-50-130 turbines

The design of R-50-130, PT-80/100-130, PT-60-130(90) steam turbines provides for the extraction of steam for production needs: in the R-50-130 turbine – from the cylinder exhaust; in the PT-80/100-130 and PT-60-130(90) turbines – from the HPC exhaust (table 1).

Now at many power plants, the need for a steam of production extraction has significantly decreased (7-21 kgf/cm²).

The most effective way to use steam of production extraction is to install attached turbines with different technical characteristics (condensing, industrial heating, back pressure).

The attached turbine can also operate from the production manifold, to which several turbines having production extractions are connected.

Steam turbines with production extractions

<table>
<thead>
<tr>
<th>Turbine type</th>
<th>Rated capacity, MW</th>
<th>Max. capacity, MW</th>
<th>Rated parameters of fresh steam</th>
<th>Pressure range of steam of production extraction, kgf/cm²</th>
<th>Steam consumption at the turbine output, t/h</th>
<th>Consumption of steam of production extraction, t/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-50-130</td>
<td>50</td>
<td>57</td>
<td>12.8</td>
<td>555</td>
<td>470</td>
<td>7+21</td>
</tr>
<tr>
<td>PT-80/100-130</td>
<td>80</td>
<td>109</td>
<td>12.8</td>
<td>555</td>
<td>470</td>
<td>10+16</td>
</tr>
<tr>
<td>PT-65-130 (PT-60-130)</td>
<td>65 (60)</td>
<td>75 (65)</td>
<td>12.8</td>
<td>555</td>
<td>396</td>
<td>10+16</td>
</tr>
</tbody>
</table>

* Steam consumption on exhaust from the HPC

Flow diagrams of connection of attached turbines
Possible nomenclature of attached turbines powered by steam of production extractions

<table>
<thead>
<tr>
<th>Turbine type</th>
<th>Rated consumption of steam, t/h</th>
<th>Rated parameters of fresh steam</th>
<th>Heat extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pressure, MPa</td>
<td>temperature, °C</td>
<td>capacity, MW</td>
</tr>
<tr>
<td>K-70-15</td>
<td>400</td>
<td>15</td>
<td>275</td>
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<tr>
<td>K-50-15</td>
<td>300</td>
<td>15</td>
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<td>T-45-15</td>
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<td>15</td>
<td>275</td>
</tr>
<tr>
<td>K-30-15</td>
<td>155</td>
<td>15</td>
<td>275</td>
</tr>
<tr>
<td>PTR-27-15/1.9</td>
<td>300</td>
<td>15</td>
<td>275</td>
</tr>
<tr>
<td>K-25-2.5</td>
<td>190</td>
<td>2.5</td>
<td>200</td>
</tr>
</tbody>
</table>

** line heater is installed at the turbine exhaust

- **Duration of works:**
  - design works – 6 months;
  - manufacturing – 11 months.

- **Supplied equipment:**
  - steam turbine with auxiliary equipment.

- **Implemented projects:**
  - K-25-2.5, Uralmetprom Company, Russia.
The production of electricity in Russia is produced by turbogenerators manufactured by the Electrosila Plant. More than 2700 turbogenerators are manufactured with a total capacity of more than 280 GW (330 GVA). The power range is 6-1200 MW. All turbogenerators meet GOST, IEC and other national standards and are distinguished by high efficiency and reliability. Of the electricity produced in Russia, 84% is generated by Electrosila Plant-manufactured turbogenerators.
Types of turbogenerators manufactured:

- Hydrogen conductor-cooled turbogenerator (TVF);
- Hydrogen-water cooled turbogenerators (TVV);
- All water-cooled turbogenerator (T3V);
- Turbogenerators with full air cooling (TA, TF, T3F, T3FA, T3FAU);
- Turbogenerators with combined air-water cooling (T3FSU).

Advantages of turbogenerators:

- High reliability;
- Low heating and vibration;
- High efficiency;
- Operation in reactive power consumption modes;
- Availability of emergency oil supply and removable brush blocks;
- Noise protective covers, stator core spring mounting and rotor hydrolift.
DIAGNOSTICS
AND INSPECTION
The scope of work for turbogenerator inspection includes:

1. **Turbogenerator Technical Condition Information Analysis**
2. **Turbogenerator Heat Testing**
3. **Turbogenerator Special Technical Control**
4. **Conclusion on the Generator Technical Condition and Recommendations**

Comprehensive turbogenerator inspection results:
- improved reliability;
- extended service life;
- increased power and resistance to operating conditions;
- increased time between repairs;
- optimized structure of the repair cycle;
- reduced maintenance and repair costs.

1. **Turbogenerator Technical Condition Information Analysis**, including the Regulated Control Completeness and Results Analysis carried out during Scheduled Repairs

   Inspection purposes are the following:
   - identifying the most likely areas of defect occurrence before scheduled repairs in order to optimize production schedules, as well as labor and material resources involved in repairs;
   - detecting periodically occurring defects and issue recommendations on the optimal mode of generator operation, on changing and adjusting the repair methods, their terms and scope, the need to upgrade the generator equipment.

2. **Turbogenerator Heat Testing**

   Testing purpose:
   - determining thermal characteristics of active elements of the generator;
   - assessing the state of the gas and water cooling system of the turbogenerator;
   - verifying compliance of the obtained turbogenerator thermal characteristics with the requirements of regulatory documentation.
3. Special Technical Control of the Turbogenerator Structure Components

**Stator core:**
- technical inspection using endoscopes in hard-to-reach areas;
- core tooth area pressing tightness ultrasonic testing;
- electromagnetic control of intersegmental insulation of active steel sheets (ELCID Test);
- testing active steel for heating and losses.

**Stator winding:**
- technical inspection using endoscopes in hard-to-reach areas;
- checking the tightness of wedging of the stator winding slotted area;
- measuring the intensity of partial discharges in insulation;
- measuring leakage currents through the insulation of end windings and connecting buses;
- measuring distillate flow rates in hydraulic branches using an ultrasonic flow meter with attachable sensors.

**Rotor winding:**
- technical inspection of winding, turn insulation and main insulation using endoscopes in hard-to-reach areas, inspection of ventilation ducts;
- rotor winding turn insulation testing.

**Rotor shaft:**
- technical inspection;
- rotor shaft necks hardness control for supporting and stuffing box bearings, rotor teeth hardness control in the place of installation of the retaining rings on the rotor body and in the joints of slot wedges;
- rotor shaft and retaining rings intense sections dye penetrant testing.

**Turbogenerator auxiliary systems:** gas and oil system, cooling system, etc.; technical inspection (not shown in the figure).
3.1 Technical inspection

- **Control purposes:**
  - identifying deviations in technical condition of the generator.

- **Equipment used:**
  - technical video endoscopes;
  - viewing mirrors;
  - magnifying glass.

3.2 Checking the wedging tightness of stator winding slotted part

- **Control purposes:**
  - revealing the weakening of wedging tightness of the slot wedges in the stator winding.

- **Control method advantages:**
  - objective determination of wedging tightness;
  - building a visual and easy-to-analyze wedging map with an indication of the relative tightness index for each wedge;
  - ability to track the dynamics of wedging tightness weakening.

- **Equipment used:**
  - a portable device for checking the tightness of wedging.

3.3 Measuring leakage currents through the insulation of end windings and connecting buses

- **Control purposes:**
  - identifying local areas of stator end windings insulation and connecting buses insulation with a dielectric barrier fault (abrasion, pollution, moistening).

- **Control method advantages:**
  - non-destructive type of testing that reliably detects insulation damages remote from the grounded parts of the stator.

- **Equipment used:**
  - a portable testing complex.
3.4 Measuring the intensity of partial discharges in insulation

Control purposes:
• assessing the state of electrical machine stator windings insulation.

Control method advantages:
• early detection of the beginning of insulation aging process;
• control of insulation aging process over time.

Equipment used:
• portable monitoring systems for partial discharges in electrical machine stator windings insulation.

3.5 Measuring distillate flow rates in hydraulic branches

Control purposes:
• identifying the stator winding bars with reduced distillate permeability.

Control method advantages:
• no need to disassemble the cooling system to measure the distillate consumption.

Equipment used:
• portable ultrasonic flow meters with attachable transducers.
3.6 Determining the dynamic characteristics of end turns and connecting buses

Control purposes:
• identifying the weakening of fastening of the stator winding end turns and connecting buses.

Equipment used:
• a vibration analyzer.

3.7 Core tooth area pressing tightness ultrasonic testing

Control purposes:
• assessing the residual pressing tightness and identifying local weakening in the teeth of active steel packages.

Control method advantages:
• high accuracy of identification of teeth areas with pressing tightness weakening which are not visually detectable;
• evaluation of the effectiveness of measures to increase the core zones resistance to operational impacts.

Equipment used:
• a portable low-frequency ultrasonic flaw detector.
3.8 Electromagnetic control of intersegmental insulation of active steel sheets

Control purposes:
- assessing the interlayer insulation of electrical machine stator cores.

Control method advantages:
- automatic test result recognition;
- possibility of conducting a local test to clarify the location of core insulation defects and assess the success of their elimination;
- low labour costs, low power consumption and relatively short monitoring time;
- no potential risk of damage to the stator.

Equipment used:
- an electromagnetic system for interlayer electrical machine stator core insulation control (BShS).

3.9 Testing active steel for heating and losses

Control purposes:
- assessing the interlayer insulation of electrical machine stator cores.

Control method advantages:
- obtaining reliable information on the state of interlayer isolation.

Equipment used:
- a thermal imager;
- an electric power quality analyzer (for recording electrical parameters of a measurement circuit and determining specific losses in steel).
3.10 Testing the rotor winding turn insulation

Control purposes:
• assessing the interturn insulation of the electrical machine rotor windings.

Control method advantages:
• the most reliable method for assessing the state of interturn insulation of windings on stopped equipment.

Equipment used:
• a device for conducting surge tests of the windings of electrical machines.

3.11 Control of the rotor metal and its structural elements

Control purposes:
• determining the deviations in the technical condition of the rotor shaft metal and its structural elements (metal incandescence zones, cracks and other damages).
MODERNIZATION AND REPAIR AT THE PLANT
1. Replacing the stator winding

Modernization purpose:
- improving the reliability of the turbogenerator. After inspecting the stator core and issuing a conclusion on its technical state, modernization can be limited to only replacing the stator winding to a winding with thermosetting insulation of the “elmicaterm” type with temperature characteristics of class B, and strengthening the end winding supports.

Works can be performed:
- in the repair zone of the plant’s machine hall (the stator is installed on a tilting unit);
- on a regular workplace of a turbogenerator (without using a tilting unit).

Duration of works:
- from 30 to 60 days depending on the turbogenerator type.
2. Modernization of the Stator Active Steel End

**Modernization purpose:**
- expanding the range of the power diagram of the turbogenerator operation in the under-excitation mode, restoring the operational state of the core.

During turbogenerator operation in the under-excitation mode (with reactive power consumption), the end zones of the stator core are affected by the magnetizing axial component of the alternating magnetomotive force (MMF) of the armature reaction, which causes an increase in heating of the end packages of the core end zones and pressure plates of the stator. To strengthen the end zones of the stator core and increase the intensity of their cooling, the end packages of the stator core end zones are replaced with baked packages of new configuration, which together with copper shunting screens reduce the effect of the axial component of the MMF on the stator core end zones. The core assembly is pressed with a horizontal hydraulic press. After testing the core, the stator winding bars are installed.

**Works can be performed:**
- in the repair zone of the plant’s machine hall (the stator is installed on a tilting unit);
- on a regular workplace of a turbogenerator (without using a tilting unit).

**Duration of works:**
- from 80 to 120 days depending on the turbogenerator type.

---

3. Replacing the Stator Core Active Steel

**Modernization purpose:**
- Manufacturing a new stator of modern design using the old body.

In the process of modernization, the stator is installed in vertical position. The procedure is as follows: the stator core and the keybars are disassembled; new keybars are spread and welded; the stator core packages are arranged and pressed with a vertical hydraulic press (intermediate and main pressing). After the core active steel is assembled, the stator is positioned into a horizontal position, and the stator winding bars are installed.

**Duration of works:**
- from 120 to 180 days depending on the turbogenerator type.
4. Stabilizing the Compressing Force of Active Steel of Turbogenerators of types TVV-165, TVV-200, TVV-320

**Modernization purpose:**
- Restoring the pressing tightness of turbogenerator stator active steel.

During the operation of turbogenerators, the pressing force of the active steel core, especially in the end zone, can decrease. An effective way to restore the pressing force of active steel is to install special spring devices with preset and adjustable pressure instead of core keybar nuts. Spring cartridges (pressure accumulators) are installed without removing the stator winding but requires rendering additional works that provide access to the device’s installation location and mobility of the core pressure plates. Works are rendered directly at the plant.

**Duration of works:**
- From 20 to 40 days depending on the turbogenerator type.

5. Modernizing the Ventilation Systems for Turbogenerators of types TVV-200, TVV-320

**Modernization purpose:**
- Increasing the capacity up to 10–15%.

A distinctive feature of the turbogenerators of the TVV series is that the stator winding is cooled via distillate, and the active steel and the rotor winding are cooled via hydrogen. TVV-type turbogenerators allow to increase the power output (capacity) without increasing the temperature of the active parts by intensifying ventilation. For this purpose, special wedges protruding into the clearance are installed between the rotor and the stator. These wedges prevent hydrogen from rotating in the clearance and increase the speed of the cooling gas in the ventilation channels of the rotor winding. The gas velocity in the ventilation channels of the stator active steel also increases. The proposed modernization ensures the reduction of operating temperatures of active parts, thus increasing their service life. Works are rendered directly at the plant.

**Duration of works:**
- Up to 20 days depending on the turbogenerator type.
6. Installing the Guide Ducts for Cooling the Stator Pressure Plate of the T3FP(G)-160(180) Turbogenerators

Modernization purpose:
- improving the cooling system efficiency, reducing heating of pressure plates.

In the course of modernization, guides are installed on the stator frame for distributing cooling air from the side of the turbine and slip rings.

Duration of works:
- up to 5 days.

7. Key References for the Modernization of Turbogenerator Stators

Hydrogen cooled turbogenerators

<table>
<thead>
<tr>
<th>No.</th>
<th>Power plant</th>
<th>Generator type</th>
<th>Quantity</th>
<th>Year</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>TVF-120-2U3</td>
<td>1</td>
<td>2001</td>
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<td>2</td>
<td>Permskaya SDPP, Russia</td>
<td>T3V-800-2U3</td>
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<td>3</td>
<td>Konakovskaya SDPP, Russia</td>
<td>TVV-320-2U3</td>
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<td>4</td>
<td>Kazanskaya TPP4, Russia</td>
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<td>5</td>
<td>Yuzhno-Ukrainskaya NPP, Ukraine</td>
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<td>8</td>
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<td>13</td>
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<td>TVV-200-2U3</td>
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<td>15</td>
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<td>16</td>
<td>Dobrovorskaya TPP, Ukraine</td>
<td>TVV-165-2</td>
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<td>19</td>
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<td>TVV-800-2E</td>
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### Air-cooled turbogenerators

<table>
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<th>Generator type</th>
<th>Quantity</th>
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### 8. Replacing the Rotor Winding and Retaining Rings

**Modernization purpose:**
- improving the reliability of the turbogenerator.

The goal of replacing or rewinding rotors is to reduce operating temperatures, as well as to improve the insulation resistance to operating temperatures. This is achieved via changing the configuration of the rotor winding cooling layout in the slotted part and using new insulation materials.

During the modernization of the turbogenerator rotor, the retaining rings are also replaced with corrosion-resistant ones. For turbogenerators with corrosion-resistant steels, the periodicity of routine inspections of retaining rings can be significantly increased, and the use of retaining rings fixing them on the rotor of the turbogenerator without a nut allows to inspect retaining rings using ultrasonic testing, without removing them from the rotor shaft.

**Duration of works:**
- from 30 to 60 days depending on the turbogenerator type.
9. Replacing End Seals of Hydrogen Cooled Turbogenerator Rotor Shaft with Radial (Ring Type) Seals

Modernization purpose:
• improving the reliability of the turbogenerator.

Radial (ring) type shaft oil seals with hydrodynamic insert centering, partial unloading from axial forces and intensified insert cooling are easier to operate, as the supply system uses only one oil pressure regulator instead of two. These seals also have high mobility and therefore are not sensitive to various changes in the operating modes of the generator and shafting thermal expansion. Works are rendered directly at the plant.

Duration of works:
• up to 20 days depending on the turbogenerator type.

10. Key References for Replacing, Repairing and Modernizing the Rotors

<table>
<thead>
<tr>
<th>No.</th>
<th>Power plant</th>
<th>Type of work</th>
<th>Generator type</th>
<th>Quantity</th>
<th>Year of modernization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pervomayskaya TPP, Lenenergo, Russia</td>
<td>Winding modernization including transfer from indirect to direct hydrogen cooling</td>
<td>TV-60</td>
<td>5</td>
<td>1966,1984-85, 1987,1991</td>
</tr>
<tr>
<td>2</td>
<td>Orskaya TPP-1, Russia</td>
<td>Winding modernization including transfer from indirect to direct hydrogen cooling</td>
<td>TV-60-2</td>
<td>1</td>
<td>1998</td>
</tr>
<tr>
<td>3</td>
<td>Novovoronezhskaya NPP, Russia</td>
<td>Rotor replacement including transfer from water to direct hydrogen cooling</td>
<td>TVV-500-4</td>
<td>2</td>
<td>1998, 2000</td>
</tr>
<tr>
<td>4</td>
<td>Konakovskaya SDPP, Russia</td>
<td>Rotor replacement including intensified hydrogen cooling of winding</td>
<td>TVV-320-2</td>
<td>1</td>
<td>1998</td>
</tr>
<tr>
<td>5</td>
<td>Piedra Buena TPP, Argentina</td>
<td>Rotor repair including the restoration of turn and frame insulation and replacement of retaining rings</td>
<td>TVV-320-2</td>
<td>1</td>
<td>2000</td>
</tr>
<tr>
<td>6</td>
<td>Kirshskaya SDPP, Russia</td>
<td>Rotor repair including the restoration of turn and frame insulation and replacement of retaining rings</td>
<td>TVV-320-2</td>
<td>2</td>
<td>2004, 2009</td>
</tr>
<tr>
<td>7</td>
<td>Surgutskaya SDPP-2, Russia</td>
<td>Rotor repair including the restoration of turn and frame insulation and replacement of retaining rings</td>
<td>TVV-800-2</td>
<td>1</td>
<td>2009</td>
</tr>
<tr>
<td>8</td>
<td>Kostromskaya SDPP, Russia</td>
<td>Rotor repair including the restoration of turn and frame insulation and replacement of retaining rings</td>
<td>TVV-320-2</td>
<td>1</td>
<td>2007</td>
</tr>
<tr>
<td>No.</td>
<td>Power plant</td>
<td>Type of work</td>
<td>Generator type</td>
<td>Quantity</td>
<td>Year of modernization</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>9</td>
<td>Kostromskaya SDPP, Russia</td>
<td>Installing (replacement with) a rotor with brushless excitation with an increase in power up to 350 MW.</td>
<td>TVV-320-2</td>
<td>1</td>
<td>2006</td>
</tr>
<tr>
<td>10</td>
<td>Bitola TPP, Macedonia</td>
<td>Rotor winding with central cooling channels replacement and retaining rings replacement</td>
<td>TVV-200-2</td>
<td>2</td>
<td>2011, 2012</td>
</tr>
<tr>
<td>11</td>
<td>Tyumenskaya TPP-2, Russia</td>
<td>Rotor repair including the restoration of turn and frame insulation and replacement of retaining rings</td>
<td>T3FP-160-2</td>
<td>1</td>
<td>2014</td>
</tr>
<tr>
<td>12</td>
<td>Sirdarya TPP, Uzbekistan</td>
<td>Rotor winding with central cooling channels replacement and retaining rings replacement at the plant</td>
<td>TVV-320-2</td>
<td>2</td>
<td>2014, 2015</td>
</tr>
</tbody>
</table>

Rotor retaining rings replacement

<table>
<thead>
<tr>
<th>No.</th>
<th>Power plant</th>
<th>Generator type</th>
<th>Year of modernization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Piedra Buena TPP, Argentina</td>
<td>TVV-320-2T3</td>
<td>1996, 2000</td>
</tr>
<tr>
<td>2</td>
<td>Konakovskaya SDPP, Russia</td>
<td>TVV-320-2U3</td>
<td>1998</td>
</tr>
<tr>
<td>3</td>
<td>Severnaya TPP of Lenenergo, Russia</td>
<td>TVF-120-2U3</td>
<td>2001</td>
</tr>
<tr>
<td>4</td>
<td>TPP-15 of Lenenergo, Russia</td>
<td>TVF-120-2U3</td>
<td>2002</td>
</tr>
<tr>
<td>5</td>
<td>Kalininskaya NPP, Russia</td>
<td>TVV-1000-2U3</td>
<td>2002</td>
</tr>
<tr>
<td>6</td>
<td>TPP-17 of Lenenergo, Russia</td>
<td>TVF-120-2U3</td>
<td>2003</td>
</tr>
<tr>
<td>7</td>
<td>TPP-7 of Lenenergo, Russia</td>
<td>TVF-60-2U3</td>
<td>2003</td>
</tr>
<tr>
<td>8</td>
<td>Yuzhno-Ukrainskaya NPP, Ukraine</td>
<td>TVV-1000-2U3</td>
<td>2003</td>
</tr>
<tr>
<td>9</td>
<td>Kostromskaya SDPP, Russia</td>
<td>TVV-320-2U3</td>
<td>2007</td>
</tr>
<tr>
<td>10</td>
<td>Kirishskaya SDPP, Russia</td>
<td>TVV-320-2U3</td>
<td>2009</td>
</tr>
<tr>
<td>11</td>
<td>Surgutskaya SDPP-2, Russia</td>
<td>TVV-800-2U3</td>
<td>2009</td>
</tr>
<tr>
<td>13</td>
<td>Iriklinskaya SDPP, Russia</td>
<td>TVV-320-2</td>
<td>2016</td>
</tr>
</tbody>
</table>

Shaft seal modernization

<table>
<thead>
<tr>
<th>No.</th>
<th>Power plant</th>
<th>Generator type</th>
<th>Quantity</th>
<th>Year of modernization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tuzla TPP, Bosnia and Herzegovina</td>
<td>TVF-100-2</td>
<td>1</td>
<td>1998</td>
</tr>
<tr>
<td>2</td>
<td>Keratsini TPP, Greece</td>
<td>TVV-200-2</td>
<td>1</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>Kozloduy NPP, Bulgaria</td>
<td>TVV-220-2A</td>
<td>1</td>
<td>2001</td>
</tr>
<tr>
<td>4</td>
<td>Armyanskaya NPP, Armenia</td>
<td>TVV-220-2A</td>
<td>2</td>
<td>2001</td>
</tr>
<tr>
<td>5</td>
<td>Leningradskaya NPP, Russia</td>
<td>TVV-500-2</td>
<td>2</td>
<td>2001</td>
</tr>
<tr>
<td>6</td>
<td>Kurskaya NPP, Russia</td>
<td>TVV-500-2</td>
<td>2</td>
<td>2001</td>
</tr>
<tr>
<td>7</td>
<td>Novovoronezhskaya NPP, Russia</td>
<td>TVV-220-2A</td>
<td>1</td>
<td>2002</td>
</tr>
<tr>
<td>8</td>
<td>Kolskaya NPP, Russia</td>
<td>TVV-220-2A</td>
<td>1</td>
<td>2002</td>
</tr>
<tr>
<td>9</td>
<td>Smolenskaya NPP, Russia</td>
<td>TVV-500-2</td>
<td>4</td>
<td>2000-2003</td>
</tr>
<tr>
<td>10</td>
<td>Lithuania SDPP, Lithuania</td>
<td>TVV-320-2</td>
<td>1</td>
<td>2003</td>
</tr>
<tr>
<td>11</td>
<td>Kostromskaya SDPP, Russia</td>
<td>TVV-350-2</td>
<td>2</td>
<td>2006-2007</td>
</tr>
<tr>
<td>12</td>
<td>Bitola TPP, Macedonia</td>
<td>TVV-200-2U3</td>
<td>3</td>
<td>2010-2012</td>
</tr>
<tr>
<td>13</td>
<td>Sirdarya TPP, Uzbekistan</td>
<td>TVV-320-2</td>
<td>2</td>
<td>2014, 2015</td>
</tr>
<tr>
<td>14</td>
<td>Iriklinskaya SDPP, Russia</td>
<td>TVV-320-2</td>
<td>1</td>
<td>2016</td>
</tr>
</tbody>
</table>
11. Additional Measures to Improve the Reliability of Turbogenerators

Modernization of the brush-contact apparatus (BCA):
- the BCA’s ease of maintenance can be achieved by upgrading it, which provides for the replacement of the brush yoke to the yoke with removable brush brackets;
- the upgraded brush-contact apparatus can be equipped with a diagnostic system that provides current distribution measurement across the brushes;
- for effective cooling of the BCA, the air intake pipe with filter can be placed outside of the noise-protective casing;
- to increase the reliability of sliding contact operation and to prevent the sparking of the brushes when using the BCA in a dry climate or in winter, a humidification system is installed.

Modernization of the pressurization system:
To improve the efficiency of cleaning the cooling air and to simplify operation, replace the pressurization system by installing additional fine gage stainers with a louver system, allowing replacement of filters during unit operation.

Installation of a partial discharge monitoring system:
The partial discharge monitoring system allows timely detection of stator winding bars insulation defects and monitoring the dynamics of their development.

Capacitive sensors (80 pF, 16 kV, 6 pcs.) permanently installed in the conductor of the generator

Continuous or periodic monitoring device
12. Requirements for the Modernization or Repair Location

The equipment of Power Machines is adapted to the conditions of work at SDPP, TPP or in a workshop and allows for modernization of turbogenerators with a capacity of 60 to 1000 MW. The works necessary for modernizing and repairing the turbogenerators can be rendered at a power plant under the following conditions.

Stator modernization:
• repair area of 350 sq. m with foundations for installing the equipment;
• availability of lifting cranes in the repair area;
• provision of water, compressed air, sources of electricity, including high power ones, for testing the stator core for losses and heat.

Full repair and modernization of the turbogenerator:
• balancing and turning machines for rotor machining;
• ability of heating the rotor winding from a DC source;
• ability to connect an inductor for heating the retaining rings, etc.
RECONSTRUCTION
AT THE MANUFACTURING PLANT
1. Reconstruction of the TVV-165-2 Turbogenerator with an Increase in Power up to 180 MW and a Transition to the TVF Type

Cooling medium:
- stator winding – indirect hydrogen cooling;
- rotor winding – forced hydrogen cooling (“internal” ventilation ducts);
- core – indirect hydrogen cooling.

Single-jet exhaust ventilation configuration.

### Shaft seal modernization

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter name</th>
<th>Before reconstruction of TVV-165-2</th>
<th>After reconstruction of TVF-180-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Active power, MW</td>
<td>165</td>
<td>180</td>
</tr>
<tr>
<td>2</td>
<td>Power factor</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>3</td>
<td>Voltage, kV</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>Stator current, A</td>
<td>6040</td>
<td>6800</td>
</tr>
<tr>
<td>5</td>
<td>Rotor current, A</td>
<td>2110</td>
<td>2270</td>
</tr>
<tr>
<td>6</td>
<td>Cooling water temperature in gas coolers, °C</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>7</td>
<td>Hydrogen pressure, kg/cm²</td>
<td>3.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

2. Scope of reconstruction

**Stator:**
- complete replacement of core active steel and ribs including the modernization of the end zone (end core packages in the form of a “magnetic shunt”);
- installing short-circuiting buses on the core ribs;
- completely replacing the stator winding including an increase in the copper cross-section while maintaining the existing stator slot;
- modernizing the design of brackets for end turns, mounting the outlet buses, wedging the bars in the slot by folding wedges, using elastic sub-wedge gaskets, installing thermal resistance transducers with Pt100 nominal static characteristic into the stator slots using 4-wire or 3-wire hardwiring;
- equipping the end parts of the stator winding with vibration control sensors (optional).

**Rotor:**
- rewinding the rotor including manufacturing a new winding with “internal” ventilation channels instead of “side” channels;
- replacing the retaining rings with corrosion-resistant rings including modernizing the assembly for fixing the rings in the axial direction;
- replacing the existing yoke to the yoke with removable brackets.

**Inspection, repair, testing, documentation:**
- inspection of the generator and its systems, refurbishment procedure according to the results of the inspection of equipment not participating in the modernization;
- correction of operational documentation.

After the proposed reconstruction is complete, the turbogenerators rated capacity value will equal to 180 MW at cosφ=0.85.
End core packages in the form of a “magnetic shunt”

Stator core end zone

Such a design of the end zone allows reducing losses via intensifying the cooling and optimizing the shape of the end packages.

Stator winding with an increased cross section of copper conductors in existing slots

Wedging of the rods in the slot using folding wedges, application of elastic sub-wedge gaskets

Fastening of the stator end winding (to reduce the vibration of the end turns)
To improve the operational reliability of turbogenerators, it is proposed to replace the shaft end sealings with ring seals.

In o-ring seals, a sealing ring (insert) encloses the shaft with a small clearance. No insert movement in the axial direction is required. Axial movement of the rotor does not affect the operation of the seal, and therefore does not depend on the generator’s mode of operation (maneuverable or stationary).

The winding conductors will be manufactured using a new technology with internal channels, which will increase the area of the cooled surface of the conductors.

Fastening of the stainless steel retaining ring on the rotor body with a spring ring (without nuts).

Simplified design (excluding the retaining ring nut) and increased reliability.
Rotor retaining rings suitability for control testing

Retaining ring fastened on the shaft by a nut

Inner seating surface is not tested with ultrasound. Retaining rings are removed every 4 years.

Retaining ring fastened on the shaft by a key

Inner seating surface is ultrasonic tested. Retaining rings are removed every 8 years.

Replacing the shaft seal

Axial (end) seal

Radial seal

Installation of vibration control sensors on the bar head ring and the pressure ring (optional)

Two sensors are installed at three points of each assembly on the “excitation” side and on the turbine side.
Experts of Power Machines examined TGV-200 type turbogenerators with direct hydrogen stator winding cooling. During the examination, the basic dimensions of the active parts were determined, the generator operation was analysed and the maintenance and repair documentation was studied.

To analyze the cooling efficiency of the active parts of the generator and estimate the scope of modernization, a ventilation calculation of its cooling path and thermal calculation of the winding and stator core were performed.

The results of thermal and ventilation calculations allowed to identify the following reasons for the low efficiency of stator ventilation:

- Hot hydrogen released at high speed from the axial channels of the rotor winding into the clearance between the stator and the rotor in the middle part of the machine creates significant back pressure on the radial channels of the stator core in this zone, and prevents hydrogen from moving in these channels towards the clearance;
- Lack of good sealing between the air clearance between the stator and the rotor and the location of the stator end winding on the side of the centrifugal compressor leads to a significant recirculation of hydrogen in the end zone of the stator core and prevents this part of the core from cooling;
- Insufficient pressure developed by the axial fan, and low consumption of hydrogen through the generator.

A concept for generator modernization was developed based on the survey results. It includes:

- Replacing the existing stator winding to direct hydrogen cooling with a winding with high thermal conductivity insulation;
- Improving the efficiency of the generator hydrogen cooling system (barrier);
- Improving the axial fan productivity;
- Modifying the generator air clearance seal.

3. Modernization of Third-Party Turbogenerators Using the Example of Electrotyazhmash TGV-200 Type Turbogenerators

PJSC “Power machines” also has references regarding the modernization of TVV-320-2 type turbogenerators with an increase in power up to 350 MW, and TVV-200-2A type turbogenerators with an increase in power up to 250 MW depending on the scope of modernization.

<table>
<thead>
<tr>
<th>No.</th>
<th>Power</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>220-225 MW</td>
<td>- Stator winding replacement; &lt;br&gt;- Rotor winding cooling intensification via installing wedge barriers</td>
</tr>
<tr>
<td>2</td>
<td>230-235 MW</td>
<td>- Activities under item No. 1; &lt;br&gt;- Replacement of end packages (magnetic shunt) of the stator core; &lt;br&gt;- Replacement of the rotor winding at the manufacturing plant including changing the configuration of the cooling circuit in the slotted part of the winding; &lt;br&gt;- Strengthening the fastening of the stator end winding; &lt;br&gt;- Installation of short-circuiting rings on the stator ribs</td>
</tr>
<tr>
<td>3</td>
<td>245-250 MW at cosφ = 0.9</td>
<td>- Activities under items No. 1 and 2; &lt;br&gt;- Increasing the hydrogen gage pressure in the body including replacing the generator shaft end seals with ring seals</td>
</tr>
</tbody>
</table>
4. Replacement of Hydrogen-Cooled Turbogenerators, having their Economic Life expired, with New Air-Cooled Turbogenerators

Main advantages of turbogenerators with full air cooling:
- simplified design: no preparation systems for cooling water, hydrogen, carbon dioxide or nitrogen, no oil seals, other certain structural elements removed;
- increased reliability: no water leaks and hydrogen leaks in the generator cooling system;
- extended mean time before failure up to 10 years;
- ease of maintenance and preventive repairs;
- fire and explosion safety.

<table>
<thead>
<tr>
<th>No.</th>
<th>Hydrogen-cooled turbogenerator</th>
<th>Air-cooled turbogenerator</th>
<th>Foundation modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TGV-200-2</td>
<td>T3FP-220-2</td>
<td>Not required</td>
</tr>
<tr>
<td>2</td>
<td>TVF-100(120)-2</td>
<td>T3FP-130-2U3</td>
<td>Not required</td>
</tr>
<tr>
<td>3</td>
<td>TVF-60 type</td>
<td>T3F-80-2M</td>
<td>Not required</td>
</tr>
<tr>
<td>4</td>
<td>TVF-50 type</td>
<td>T3F-63-2M</td>
<td>Partial modification</td>
</tr>
</tbody>
</table>

The offered air-cooled turbogenerators can be integrated into existing machine halls of power plants with minimal modifications of the building part.

Turbogenerators are designed in a three-dimensional design system. It allows to improve the quality of the design and reduce the time this process takes.

The use of three-dimensional design made it possible to create an efficient cooling system that ensures a low level of heating of the active elements at a high efficiency value and a low turbogenerator noise level of 80 dB(A).
Computational packages that make it possible to carry out electromagnetic, mechanical, aerodynamic and thermal calculations in a three-dimensional formulation are also used in designing turbogenerators.

- **Mechanical stresses**
- **Airflow around guide ribs and guide vane blades in the feed channel to the rotor**
- **Airflow around centrifugal fan blades**
- **Stator winding and core thermal state**
Power Machines develops, manufactures, implements and maintains a wide range of energy machine excitation systems, as well as software and hardware complexes for automating the main equipment control.

The advantages of using Power Machines automated process control systems:

- ensuring personnel safety;
- increasing the reliability of the main equipment;
- optimizing operating modes of the main equipment;
- improving the quality of information support in production management processes.
PJSC “Power machines” supplies generating equipment together with control and automation systems.

Main solutions:
- automating main equipment of TPPs, including: frequency and power regulators for turbine units, thermal control systems, vibration control systems, process automation systems, auxiliary equipment control systems;
- automating turnkey machine halls, including automatic control systems for units and auxiliary equipment, protection systems (hydromechanical and electrical), vibration control systems;
- automating a turnkey thermal power plant, including automatic control systems for turbine units, monitoring and control systems for general station systems, switchgear control systems, top control level, including general station active and reactive power regulators.

1. Excitation Systems of the Turbogenerator

The main types of manufactured excitation systems:
- thyristor self-excitation systems (TSS);
- independent thyristor systems (ITS);
- standalone diode systems (SDS);
- brushless diode systems (BDS);
- backup systems (TSS-R).

Preventive maintenance

Preventive maintenance is aimed at identifying and correcting faults and defects that can lead to disruptions in the operation of the excitation system during normal operation, allows minimizing the flow of failures and extending the service life of the equipment.

The company implements the following solutions:
- automating main equipment of TPPs, including: frequency and power regulators for turbine units, thermal control systems, vibration control systems, process automation systems, auxiliary equipment control systems;
- automating turnkey machine halls, including automatic control systems for units and auxiliary equipment, protection systems (hydromechanical and electrical), vibration control systems;
- automating a turnkey thermal power plant, including automatic control systems for turbine units, monitoring and control systems for general station systems, switchgear control systems, top control level, including general station active and reactive power regulators.
Plan of diagnostic measures for servicing the excitation system

Work description:
• external inspection, checking equipment and documentation completeness, checking the excitation system circuit insulation resistance without disconnecting cables or buses;
• updating microprocessor devices software (if necessary);
• checking secondary power supplies;
• checking the automatic excitation control mode parameter sensors;
• checking the automatic excitation control input and output discrete signals;
• checking the protecting microprocessing relay protection unit (if any);
• checking the time delay relay protection devices (if any);
• checking the rotor protection against over-voltages;
• checking the rotor protection against earth fault at one point;
• checking the field suppression breaker and other switching devices;
• checking the current and voltage relays (if any);
• checking the time delay relay;
• checking the rectifier transformer temperature control unit (if any);
• joint checking all assemblies and circuits of the excitation system in the complete circuit, testing the protection of the excitation system;
• checking the interaction of the excitation system with the control, protection and alarm circuits of the unit;
• testing the excitation system when the generator is in short circuit mode;
• testing the excitation system when the generator is idling;
• testing the thyristor excitation system when the generator operates in the grid at two steps of active power.

Modernization

Replacement of the analog excitation controller (for systems with EPA panels)

Modernization purpose:
• replacing an obsolete analog excitation controller with a modern AVR-45M;
• extending the service life of obsolete excitation systems.

Description:
• AVR-45M excitation controller is by far the most modern. This model is optimized for projects in modernization of obsolete and worn-out analog excitation controllers and voltage correctors. Due to the monolithic form of analog and discrete interfaces, the AVR-45M controller is positioned as a cost effective technical solution for generators of medium and low capacity. The controller supports all modern exchange protocols with top-level automated systems based on the Ethernet interface;
• a series of thyristor rectifier units with natural air cooling is tailored for reconstructing excitation systems with EPA panels;
• in addition to the excitation controller and thyristor rectifiers, high-frequency diode rectifiers with natural cooling and a thyristor arrester can also be supplied.

Duration of works:
20 days.
Replacing the control and regulation section (retrofit solution)

Modernization purpose:
- replacing the control and regulation sections with ARM-M with a new one based on the ARV-3M controller;
- extending the service life of obsolete excitation systems.

Description:
Since 2017, the support for excitation controllers of the ARV-M type has been discontinued. To extend the service life of the excitation systems with ARV-M, PJSC “Power machines” proposes the replacement of the control and regulation section with a modern one, made on the basis of an excitation controller of the AVR-3MT type, preserving the power and relay parts. The AVR-3MT third-generation excitation controller is designed taking into account the long-term experience of operating excitation systems and is characterized by increased reliability, noise immunity and functionality. AVR-3MT is equipped with a built-in alarm recorder and provides communication with the data acquisition system via Ethernet or RS-485 using the Modbus Plus protocol. Also, the use of these controllers greatly simplifies operational maintenance and integration of the excitation system in SCADA.

Duration of works:
20 days.

Complete replacement of equipment

Modernization purpose:
- increasing the reliability of excitation systems;
- increasing the stability and accuracy of voltage regulation;
- ensuring the operation of the excitation system in the automated control systems of the power plant.

Description:
To improve reliability, modern thyristor excitation systems with microprocessor excitation controllers are designed according to a two-channel scheme. Each channel is equipped with its own autonomous power supply system, measurement of operating parameters, a system of phase-impulse control of the thyristor converter. Implementation of the proportional-integral-derivative (PID) law of voltage regulation at the program level eliminates the influence of aging active and passive elements of the electrical circuit on the accuracy of voltage regulation. To interface with automated control systems of power plants, modern excitation systems are equipped with RS-485 and Ethernet communication interfaces. The presence of diagnostic functions allows to reduce the time for diagnosing possible malfunctions and the time spent on restoring the operation capability of the excitation system.

Duration of works:
30 days.
The standby exciton circuit shall be connected to the generator rotor winding through the input cabinet for standby hardware. At that, the current measuring shunt, discharger, and damping resistors of the rotor circuit shall be common for working and standby excitation of the generator.
2. Start-up Frequency Converter

A series of start-up frequency converters is designed for frequency starting, braking and cranking, washing and ventilation of turbine-generator sets with a capacity of up to 160 MW, as well as for frequency starting of large synchronous electric motors with a capacity of up to 10 MW, powered via a 6 (10) kV network.

Start-up frequency converters are designed according to the frequency converter scheme with a DC link, both with matching transformers and without transformers. The input unit of the converters is a thyristor controlled rectifier. It's design includes a three-phase bridge connection. As an output element of the converter, a thyristor dependent inverter is used, which is structurally similar to a rectifier.

The scope of maintenance work on start-up frequency converters, conducted by experts of Power Machines:

- external equipment inspection;
- checking the installation status, operating conditions, cleaning, blowing;
- checking the tightening force of power thyristors in the circuits of start-up frequency converters;
- checking the insulation resistance of the cubicle (power cabinet, control cabinet);
- high-voltage testing, checking the electrical strength of the insulation of power cabinets;
- checking the insulation resistance of a smoothing reactor, high-voltage testing;
- checking the insulation resistance of current-limiting reactors, high-voltage testing;
- checking relay equipment;
- checking switching equipment;
- updating and checking the software of the protection and control unit;
- checking power and RC-blocks;
- lighting and cooling systems inspection;
- checking power supplies;
- checking the device’s digital inputs and outputs;
- checking discrete and analog inputs of the protection and control unit;
- checking voltage sensors;
- checking the external links with the automatic control system and the excitation system;
- checking the protection and control circuits in/out;
- checking the pulses, control angle, pulse phasing;
- adjusting of the coefficients of the generator’s accelerating characteristics;
- checking the start-up frequency converters in operating modes of operation (“Start”, “Venting”, “Flushing”, “Cross Controlling”).

Oscilloscope patterns of amplitude and duration of inverter thyristor pulses

Oscilloscope patterns of amplitude and duration of rectifier thyristor pulses
3. Replacement of the Turbogenerator Protection Relay

Modernization purposes:
• increasing reliability;
• increasing noise immunity;
• adding a possibility of self-diagnostics of protection units;
• installing emergency oscilloscopes;
• reducing maintenance costs for relay protection units.

Description:
In order to improve the reliability, modern microprocessor protections consist of two independent units, each with its own power supply system, measurement circuits, output relays. Adding emergency oscilloscopes to protection terminals provides information for investigating the causes of emergency shutdowns. Self-diagnostics of the protection terminal ensures timely failure detection and prevents developing emergencies. The implementation of electrical protection at the software level allows to implement complex protection algorithms for electrical equipment and improve noise immunity, thereby reducing the likelihood of false shutdowns.

Duration of works:
30 days.

The scope of maintenance work on turbogenerator protection cabinets, conducted by experts of Power Machines

Work description:
• external inspection of equipment, cleaning from dust and dirt, blowing with compressed air;
• checking bus-bolt and screw contact and fastening connections of protection cabinets;
• checking resistance and electric strength of insulation of the power supply circuits, current and voltage measuring circuits, checking input-output interface;
• checking power supplies of protection cabinets;
• software adjustment (if necessary);
• checking current and voltage measuring channels from an external source, RELAY-TOMOGRAPH 51 (61), Omicron 356;
• checking protection settings and protection logic from an external source, RELAY-TOMOGRAPH 51 (61), Omicron 356;
• checking interaction of the protection system with other aggregate systems (comprehensive testing);
• checking current circuits of the generator-transformer unit from an external source, or conducting an experiment of a 3-phase short circuit of the unit including the removal and analysis of vector diagrams;
• conducting an experiment of idling the generator-transformer unit for checking voltage circuits;
• conducting experiments of single-phase short circuits in the circuits of the generator voltage on the HV side of the unit transformer;
• testing the protection system when the main equipment is operating under load;
• analysing the information received, preparing and transferring the report and the testing protocols to the customer.
4. Replacement of the Turbogenerator Heat Control System

**Modernization purposes:**
- increasing the reliability of thermal control systems;
- improving the stability of the equipment;
- improving the measurement accuracy.

**Description:**
- the process control systems are based on modern microprocessor controllers by Siemens, Omron, etc. and allow continuous and automatic monitoring of parameters of turbogenerators, displaying parameters in a form convenient for analysis, transferring information to the “upper” level of the APCS. The scope of the monitoring system allows to change the approach to the periodicity of preventive repairs and overhauls and only schedule them based on the results of sensor readings analysis and diagnostics of the state of the turbogenerator. The use of three- or four-wire thermal transducers can significantly improve the measurement accuracy by taking into account the actual current resistance value of the connecting wires for a three-wire diagram, or by excluding this value from measurement for a four-wire diagram. Compared to copper, platinum thermal transducers are more stable over time. They also have a wider range of measured temperatures (up to 400 °C instead of 150 °C);
- the following is carried out in the process of turbogenerator modernization: replacement of information processing and display facilities; transfer of thermal transducers from the stator winding insulation to the distillate discharge from all the cooling circuits of the stator winding; when the stator is rewound, thermal transducers that are installed at the bottom of the slot and between the bars or on the stator insulation at 12-24 points are also replaced.

**Duration of works:**
in accordance with the terms of replacement of the stator winding.

The scope of maintenance work on process control systems, conducted by experts of Power Machines

**Work description:**
- carrying out planned preventive measures;
- checking the internal mounting of the rack;
- broaching the contact connections, terminals;
- checking the secondary power supplies;
- checking the functioning of the uninterruptible power supply;
- checking the sound and light alarm;
- checking the operation of the cooling system;
- checking the discrete inputs/outputs;
- checking the insulation resistance of internal circuits;
- checking the contactors and relays using trigger simulation;
- checking the contactors and relays using test facility;
- checking the integrity of the panel computer software;
5. Replacement of Mechano-Hydraulic Systems for Regulating the Steam Turbines

Modernization purposes:
- simplifying the hydraulic part of the regulation system;
- improving the reliability of the automatic control system (ACS) operation and the accuracy of maintaining controlled parameters;
- ensuring compliance with the operational regulation (OR) requirements in terms of primary frequency control of the grid;
- reducing the repair costs for the ACS;
- adding a possibility for the ACS to communicate with upper level APCS;
- visualizing and archiving events.

Description:
PJSC “Power machines” modernizes steam turbine automatic control systems, as well as replaces the existing hydraulic controllers with electronic controllers. The reconstruction is carried out using digital serial industrial automation equipment based on the hardware and software complex (HSC) of Siemens, Valmet, Emerson, HIMA companies.

<table>
<thead>
<tr>
<th>Station</th>
<th>Platform</th>
<th>Capacity, MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belovskaya SDPP, Russia</td>
<td>Valmet DNA</td>
<td>225</td>
</tr>
<tr>
<td>Belovskaya SDPP, Russia</td>
<td>Valmet DNA</td>
<td>225</td>
</tr>
<tr>
<td>Tom-Usinskaya SDPP, Russia</td>
<td>Valmet DNA</td>
<td>115</td>
</tr>
<tr>
<td>Tom-Usinskaya SDPP, Russia</td>
<td>Valmet DNA</td>
<td>115</td>
</tr>
<tr>
<td>Raahé TPP, Finland</td>
<td>Valmet DNA</td>
<td>120</td>
</tr>
<tr>
<td>Belovskaya SDPP, Russia</td>
<td>Valmet DNA</td>
<td>225</td>
</tr>
<tr>
<td>Belovskaya SDPP, Russia</td>
<td>Valmet DNA</td>
<td>225</td>
</tr>
<tr>
<td>Blagoveshchenskaya TPP, Russia</td>
<td>Emerson Ovation</td>
<td>120</td>
</tr>
<tr>
<td>Severstal, TPP-TBS, Russia</td>
<td>Siemens PCS7</td>
<td>65-80</td>
</tr>
</tbody>
</table>

Examples of the turbine operator’s AWS screen
HSC EEC&PS

The electronic elements of control system (EECS) are an integral part of the electro-hydraulic system of automatic regulation of steam turbines, which ensures the characteristics of the turbine unit as a control object, guaranteed by PJSC “Power machines”.

Purpose:
- surveying primary sensors and measuring transducers;
- implementing turbine control algorithms in all modes of operation by controlling the steam flow into the turbine;
- generating control actions and transferring them to the hydraulic part of the control and turbine protection system;
- ensuring interaction with the upper level APCS and other control and monitoring systems of the power unit, as well as with the means of dispatching and emergency control of the power system.

Application purposes:
- maintaining stable operation and regulating the turbine in all modes of operation by controlling the control valves (CV);
- ensuring the compliance with frequency regulation standards in power systems;
- ensuring regulatory quality;
- visualizing and archiving;
- improving labour conditions, preventing erroneous actions.

The system of technological protections (EEPS) serves to prevent emergency situations associated with the conduct of the technological process on the equipment of turbine-generator sets. In an emergency situation, EEPS forms control actions to the hydraulic part of the turbine regulation and protection system through protection devices – electromagnetic switches (EMS), as well as a turbine valve control device – a turbine control mechanism (CM).

Protections implemented in the EEPS:
- from increase in turbine rotor rotation frequency;
- from unacceptable axial shift of the rotor;
- from lowering the oil pressure on the lubricant;
- from increasing the pressure in the condenser;
- from lowering the fresh steam temperature;
- from increasing the vibration of bearings;
- from increasing the pressure in heat extraction;
- from increasing the rotor rotation acceleration;
- regarding the turbine controller failure (EECS);
• regarding the generator, unit and other equipment protection operation, fire alarm systems, regarding emergency shutdown of the turbine by personnel.

6. Installation of Modern Vibration Monitoring Systems

Modernization purposes:
• increasing the vibration reliability of the turbine plant.

Description:
A vibration monitoring system (VMS) is designed to measure, monitor and analyze vibration parameters, mechanical values of a steam turbine and a generator with the subsequent issuance of data, and warning and alarm signals to other subsystems of the APCS.
2014
start of series production of transformers

Full production cycle

Own automated testing center

HIGH-VOLTAGE TRANSFORMERS
Products and services:

- 110-750 kV power transformers with a capacity of up to 630 MVA;
- 220-750 kV autotransformers;
- comprehensive service.
Information on the company

Power Machines – Toshiba. High-Voltage Transformers Plant (PMTT LLC) is located in the industrial zone of Metallostroy village, St. Petersburg.

Full-cycle production includes procurement and welding, assembly, storage, insulation and winding workshops, as well as a testing center.

The technological level of production, complete with equipment from leading manufacturers, meets the highest standards.

The joint venture allows solving the tasks of complex modernization regarding the long-distance power grid facilities of Russia and the CIS countries on the basis of the most progressive and innovative technologies.

The company has its own testing center and laboratory, which are accredited by the Federal Accreditation Service for compliance with the requirements of GOST ISO/IEC 17025-2009.

Fully automated testing center allows typical and acceptance testing of transformers of voltage class up to 750 kV in full.

The company’s laboratory is equipped with the latest measurement tools that provide research at an advanced technical level, with highly automated processes.

Basis of activities


2. Ensuring warranty and post-warranty service for products manufactured in Russia and in all regions of supply.

3. Optimizing the customers’ costs and time for transformer equipment maintenance.

Service maintenance:

- Diagnostics and inspections.
- All types of repairs.
- Supply of original spare parts.
- Long-term service.
- Services for supervision installation.
- Supervision control during repair.
Diagnostics and maintenance

Types of services:
• comprehensive and specific diagnostics;
• diagnostics in cooperation with laboratories of power systems and regional partners;
• applying the design knowledge and operating experience to diagnosing each type of equipment;
• computer analysis of diagnostics results;
• residual resource determination and development of necessary measures to extend the equipment’s service life;
• optimization of consumer costs for assessing the condition of the equipment.

Equipment condition faults, detected by existing diagnostic methods:
• Developing defects accompanied by overheating and partial discharges.
• Various problems in the active part:
  – reduced pressing forces of windings and magnetic system;
  – deformation of the windings;
  – moisture, contamination and aging of paper insulation;
  – defects of contact connections.
• Deterioration of oil
• Various defects of transformer constituent parts:
  – input defects;
  – disturbances in switching devices operation;
  – defects of the cooling system assemblies;
  – problems in instrumentation operation.

All types of repairs

• On-site repair technical guidance based on modern technical solutions and new technologies.
• Development of programs and special technological processes for repairs of varying complexity.
• Types of repairs:
  • scheduled overhauls;
  • emergency repairs in the field;
  • factory repair.
• Supply of necessary components and materials for repair.

Supplying original spare parts

In order to ensure reliable and trouble-free operation, timely maintenance and use of original spare parts that can be delivered to the site are necessary.

List of main components and spare parts
• Control cabinets for cooling systems of any type and control algorithm configuration.
• Winding tap changers and their components.

Cooling systems of all types and their components:
• fans of different types;
• centrifugal and continuous-flow oil pumps;
• finned radiators;
• assembled ODTs coolers.
Supervision installation of power transformers is a compulsory condition for the quality of installation work, as well as for trouble-free operation of the equipment.

Chief (supervision) control of repairs and any kind of maintenance ensures the necessary level of quality and control of technological processes.

The scope of services of supervision control over repairs includes:
- developing repair programs, including the description of technologies and materials, the drawing-up of technical certificates of work performed;
- assessing the condition of the equipment in order to determine the scope of repair and reduce the cost of its implementation;
- technical guidance on site repair based on modern technical solutions and new technologies;
- participation in the development of programs and special technological processes for repairs of varying complexity in conjunction with the customer;
- determination of the residual life and recommendations for further operation of the equipment.

Chief control services can be provided during all types of repairs:
- scheduled overhauls;
- emergency repairs in the field;
- factory repair.
Modern diagnostic methods

The SFRA method is regarded the most modern and most sensitive method of detecting mechanical deformations and makes it possible to very accurately assess the condition of a power transformer and, based on the results obtained, develop further diagnostic procedures. This allows to increase the reliability of the transformer in operation, to improve the quality of service and maintenance, to minimize the costs associated with the need for unscheduled repairs.

Thermal-imaging inspection performed at the plant and then repeated during the operation of transformers allows, without taking electrical equipment out of operation, to check the reliability of the transformer, to identify possible defects while they yet develop, to reduce maintenance costs by predicting the timing and scope of repair work.
LONG-TERM SERVICE
Long-term service from the supplier:

- term – 3 to 25 years;
- full range of services under a single long-term contract;
- controlling supply chains of spare parts and materials;
- service price projected by years for the convenience of budgeting;
- rapid response to emerging needs during operation and maintenance of equipment.
PJSC “Power machines” offers long-term service solutions for all types of main power equipment of thermal power plants:

- Gas turbines
- Steam turbines
- Turbogenerators
- Unit-type transformers
- Steam (hot water) boilers
- HRSGs
- Automation systems

2. Examples of service packages

Package “A” is aimed at providing the Client with continuous technical support during the operation and maintenance of power equipment.

Package “B” is aimed at improving the reliability of power equipment via providing original spare parts and supervision control of repairs.

Package “C” is aimed at carrying out repairs of power equipment based on its technical condition via using advanced predictive diagnostic systems.

Package “O” is aimed at providing comprehensive maintenance of power equipment and providing the required readiness characteristics.

<table>
<thead>
<tr>
<th>Service name</th>
<th>Package “A”</th>
<th>Package “B”</th>
<th>Package “C”</th>
<th>Package “D”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate contract time</td>
<td>3 years</td>
<td>6 years</td>
<td>8 years</td>
<td>12 years</td>
</tr>
<tr>
<td>Remote support for the Supplier’s engineering services</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Operating personnel training</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Maintenance personnel training</td>
<td>—</td>
<td>—</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Developing regulations for repairs of power equipment</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>On-site consultations during scheduled and emergency repairs</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Supervision support of scheduled and emergency repairs</td>
<td>—</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Supply of spare parts for scheduled repairs</td>
<td>—</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Permanent representative of the Supplier at the site</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>✗</td>
</tr>
<tr>
<td>Emergency service warehouse for parts having long production cycle</td>
<td>—</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Diagnostics and inspection</td>
<td>—</td>
<td>—</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Installation of predictive diagnostic system</td>
<td>—</td>
<td>—</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>
1. Advantages of Long-Term Service Contracts

<table>
<thead>
<tr>
<th>Service name</th>
<th>Package “A”</th>
<th>Package “B”</th>
<th>Package “C”</th>
<th>Package “D”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair according to technical condition</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>&quot;Turnkey&quot; overhaul</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Responsibility for ensuring the required readiness characteristics</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Long-term service offers are developed individually for each client, taking into account the specifics of the operation of power equipment and its performance indicators necessary for the client.
3. Key References for Long-Term Service

Pervomayskaya TPP, St. Petersburg, Russia

Contract time:
2011-2025

Equipment:
- four V64.3A gas turbines;
- two T-50/64-7.4 steam turbines;
- four WY18Z-066LL turbogenerators;
- two T3FP-63-2M turbogenerators;
- excitation systems and start-up frequency converters;
- APCS units.

List of services:
- remote monitoring;
- chief control and technical support;
- supply of spare parts and restoration of program parts;
- diagnostics and inspection;
- scheduled and unscheduled maintenance (inspections, repairs);
- constant presence on the site.

Yuzhnaya TPP, St. Petersburg, Russia

Contract time:
2011-2023

Equipment:
- two GTE-160 gas turbines;
- T-125/150-7.4 steam turbine;
- three type T3F-160 turbogenerators;
- excitation systems and start-up frequency converters;
- APCS units.

List of services:
- remote monitoring;
- chief control and technical support;
- supply of spare parts and restoration of program parts;
- diagnostics and inspection;
- scheduled and unscheduled maintenance (inspections, repairs);
- constant presence on the site.
Appendix No.1
to the rules of the organization of maintenance and repair of electric power facilities, approved by Order of the Ministry of Energy of Russia dated October 25, 2017, No. 1013.

Repair cycle, types, duration of repair of 150-1200 MW power units of thermal power plants

### Table 1
150 MW power units
- Type of fuel burned — gas
- Types of boilers — TGM-94 (outdoor design)
- Standard time between overhauls — 40800 hours
- Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T1T2</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>K1T2</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>K1T2</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>13+8</td>
<td>13+8</td>
<td>18+8</td>
<td>13+8</td>
<td>18+8</td>
<td>49+8</td>
<td>13+8</td>
<td>18+8</td>
<td>13+8</td>
<td>51+8</td>
<td>13+8</td>
<td>13+8</td>
<td>18+8</td>
<td>13+8</td>
<td>13+8</td>
<td>54+8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2
150 MW power units
- Type of fuel burned — gas
- Standard time between overhauls — 40800 hours
- Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T1T2</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>K1T2</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>C1</td>
<td>T1T2</td>
<td>K1T2</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>13+8</td>
<td>13+8</td>
<td>25+8</td>
<td>13+8</td>
<td>24+8</td>
<td>42+8</td>
<td>13+8</td>
<td>24+8</td>
<td>13+8</td>
<td>46+8</td>
<td>13+8</td>
<td>13+8</td>
<td>24+8</td>
<td>13+8</td>
<td>13+8</td>
<td>54+8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3
200-215 MW power units
- Type of fuel burned — gas
- Standard time between overhauls — 40800 hours
- Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years

| Repair cycle year | 1       | 2       | 3       | 4       | 5       | 6       | 7       | 8       | 9       | 10      | 11      | 12      | 13      | 14      | 15      | 16      | 17      | 18      |
|-------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Repair type       | T1T2    | T1T2    | C1      | T1T2    | T1T2    | C1      | T1T2    | C1      | T1T2    | K1T2    | T1T2    | C1      | T1T2    | C1      | T1T2    | C1      | T1T2    | K1T2    |
| Repair duration, calendar days | 13+8 | 13+8 | 25+8 | 13+8 | 25+8 | 44+8 | 13+8 | 25+8 | 13+8 | 48+8 | 13+8 | 13+8 | 25+8 | 13+8 | 13+8 | 56+8 |
### Table 4

**200 MW power units**

**Type of fuel burned** — gas до 75%, мазут и уголь — свыше 25%

**Types of boilers** — all types of boilers

**Standard time between overhauls** — 34000 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours** — 5 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>13</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
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<td>13+8</td>
<td>44+8</td>
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<td>25+8</td>
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<td>25+8</td>
<td>13+8</td>
<td>56+8</td>
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</tr>
</tbody>
</table>

### Table 5

**200 MW power units**

**Type of fuel burned** — coal

**Types of boilers** — all types of boilers

**Standard time between overhauls** — 34000 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours** — 4 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
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<td>K₁T₂</td>
</tr>
<tr>
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<td>44+8</td>
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<td>48+8</td>
<td>13+8</td>
<td>25+8</td>
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<td>56+8</td>
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</table>

### Table 6

**200 MW power units**

**Type of fuel burned** — coal

**Types of boilers** — PK-40-1

**Standard time between overhauls** — 34000 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours** — 5 years

<table>
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</tr>
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<tbody>
<tr>
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<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
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<td></td>
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</tbody>
</table>

### Table 7

**300 MW power units**

**Type of fuel burned** — gas

**Types of boilers** — PK-41, TGMP-114, TGMP-314, TGMP-314A, TGMP-324

**Standard time between overhauls** — 40800 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours** — 6 years

<table>
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<tbody>
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<td>T₁T₂</td>
<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
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<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
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<td>51+8</td>
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<td>16+8</td>
<td>16+8</td>
<td>68+8</td>
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</tr>
</tbody>
</table>
### Table 8

300 MW power units

- **Type of fuel burned** — gas (up to 70%), fuel oil (over 30%)
- **Type of boilers** — gas-and-oil-fired
- **Standard time between overhauls** — 34000 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 5 years**

<table>
<thead>
<tr>
<th>Repair cycle year</th>
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<th>2</th>
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<th>15</th>
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</thead>
<tbody>
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<td>CT₂</td>
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<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₂T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₃T₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
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<td>25+8</td>
<td>16+8</td>
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<td>16+8</td>
<td>16+8</td>
<td>25+8</td>
<td>16+8</td>
<td>68+8</td>
</tr>
</tbody>
</table>

### Table 9

310 MW non-serial power unit

- **Type of fuel burned** — gas
- **Type of boilers** — P-74
- **Standard time between overhauls** — 40800 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years**

<table>
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<tr>
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<th>1</th>
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</thead>
<tbody>
<tr>
<td>Repair type</td>
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<td>CT₂</td>
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<td>K₁T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₂T₂</td>
<td>T₁T₂</td>
<td>CT₂</td>
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<td>K₃T₂</td>
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<td></td>
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</tr>
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<td>16+9</td>
<td>82+9</td>
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</tbody>
</table>

### Table 10

300 MW power units

- **Type of fuel burned** — fuel oil
- **Type of boilers** — gas-and-oil-fired
- **Standard time between overhauls** — 27200 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 4 years**

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
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<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
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<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₃T₂</td>
</tr>
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<td>Repair duration, calendar days</td>
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<td>24+8</td>
<td>16+8</td>
<td>65+8</td>
</tr>
</tbody>
</table>

### Table 11

300 MW power units

- **Type of fuel burned** — coal
- **Types of boilers** — PK-39, P-50, P-59, TPP-110, TPP-210, TPP-210A
- **Standard time between overhauls** — 27200 hours

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 4 years**

<table>
<thead>
<tr>
<th>Repair cycle year</th>
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<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₁T₂</td>
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<td>T₁T₂</td>
<td>CT₂</td>
<td>T₁T₂</td>
<td>K₃T₂</td>
</tr>
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<td>Repair duration, calendar days</td>
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<td>50+9</td>
<td>18+9</td>
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<td>18+9</td>
<td>27+9</td>
<td>18+9</td>
<td>60+9</td>
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</table>
### 325-330 MW power units

Type of fuel burned — gas  
Types of boilers — all types  
Standard time between overhauls — 40800 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years

<table>
<thead>
<tr>
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<th>5</th>
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<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
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<td>$T_1T_2$</td>
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<td>$T_1T_2$</td>
<td>$T_1T_2$</td>
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<td>$CT_2$</td>
<td>$T_1T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$CT_2$</td>
<td>$T_1T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
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</table>

### 500 MW power units

Type of fuel burned — coal  
Types of boilers — P-57, P-49  
Standard time between overhauls — 27200 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 4 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
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</thead>
<tbody>
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</table>

### 800 MW power units

Type of fuel burned — gas  
Type of boilers — TGMP-204  
Standard time between overhauls — 40800 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
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</table>

### 800 MW power units

Type of fuel burned — gas (up to 70%), fuel oil (over 30%)  
Type of boilers — TGMP-204  
Standard time between overhauls — 34000 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 5 years

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</tr>
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<td>62+$10$</td>
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</table>
### Table 16

**800 MW power units**  
Type of fuel burned — coal  
Type of boilers – P-67  
Standard time between overhauls — 40000 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years

<table>
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<td>T_1 T_2</td>
<td>K_T</td>
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<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>64+12</td>
<td>64+12</td>
<td>86+12</td>
<td>64+12</td>
<td>64+12</td>
<td>114+12</td>
<td>64+12</td>
<td>64+12</td>
<td>86+12</td>
<td>64+12</td>
<td>64+12</td>
<td>121+12</td>
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<td>64+12</td>
<td>86+12</td>
<td>64+12</td>
<td>64+12</td>
<td>133+12</td>
</tr>
</tbody>
</table>

### Table 17

**1200 MW power units**  
Type of fuel burned — gas  
Type of boilers — ТГМП-1202  
Standard time between overhauls — 34000 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 5 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td></td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>24+12</td>
<td>24+12</td>
<td>45+12</td>
<td>24+12</td>
<td>72+12</td>
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<td>24+12</td>
<td>24+12</td>
<td>45+12</td>
<td>24+12</td>
<td>84+12</td>
</tr>
</tbody>
</table>

### Table 18

**180 MW power units**  
Type of fuel burned — gas  
Types of boilers — TG-104, TPE-215, TRGE-215, TGME-206  
Standard time between overhauls — 34000 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 5 years

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
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<th>3</th>
<th>4</th>
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<th>7</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td></td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>13+18</td>
<td>13+18</td>
<td>25+8</td>
<td>13+18</td>
<td>44+8</td>
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<td>13+18</td>
<td>25+8</td>
<td>13+18</td>
<td>48+8</td>
<td>13+18</td>
<td>13+18</td>
<td>25+8</td>
<td>13+18</td>
<td>56+8</td>
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### Table 19

**180 MW power units**  
Type of fuel burned — coal  
Types of boilers – TPE-214, TPE-215  
Standard time between overhauls — 27200 hours  
Estimated overhaul periodicity with an average annual operating time of 6800 hours — 4 years

<table>
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<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>C_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
<td>K_T</td>
<td>T_1 T_2</td>
<td>T_1 T_2</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>13+18</td>
<td>25+8</td>
<td>13+18</td>
<td>44+8</td>
<td>13+18</td>
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<td>13+18</td>
<td>25+8</td>
<td>13+18</td>
<td>56+8</td>
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</table>
### Table 20

**250 MW power units**

<table>
<thead>
<tr>
<th>Type of fuel burned — gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of boilers — TPP-210A, TGMP-314Ts, TGMP-314P</td>
</tr>
</tbody>
</table>

**Standard time between overhauls — 40800 hours**

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years**

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
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<th>9</th>
<th>10</th>
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<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>$T_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>16+8</td>
<td>16+8</td>
<td>25+8</td>
<td>16+8</td>
<td>16+8</td>
<td>51+8</td>
<td>16+8</td>
<td>25+8</td>
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<td>25+8</td>
<td>16+8</td>
<td>16+8</td>
<td>68+8</td>
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</tr>
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</table>

### Table 21

**250 MW power units**

<table>
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<th>Type of fuel burned — gas</th>
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</thead>
<tbody>
<tr>
<td>Type of boilers — TGMP-344A</td>
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</table>

**Standard time between overhauls — 40800 hours**

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 6 years**

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$C_T_2$</td>
<td>$K_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>16+8</td>
<td>16+8</td>
<td>32+8</td>
<td>16+8</td>
<td>16+8</td>
<td>69+8</td>
<td>16+8</td>
<td>16+8</td>
<td>32+8</td>
<td>16+8</td>
<td>16+8</td>
<td>78+8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 22

**250 MW power units**

| Type of fuel burned — газ до 75%, уголь и мазут — свыше 25%  |
| Type of boilers — TPP-210A |

**Standard time between overhauls — 34000 hours**

**Estimated overhaul periodicity with an average annual operating time of 6800 hours — 5 years**

<table>
<thead>
<tr>
<th>Repair cycle year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair type</td>
<td>$T_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$C_T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
<td>$T_1T_2$</td>
<td>$K_1T_2$</td>
</tr>
<tr>
<td>Repair duration, calendar days</td>
<td>18+9</td>
<td>18+9</td>
<td>27+9</td>
<td>18+9</td>
<td>58+9</td>
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<td>27+9</td>
<td>18+9</td>
<td>62+9</td>
<td>18+9</td>
<td>18+9</td>
<td>27+9</td>
<td>18+9</td>
<td>18+9</td>
<td>69+9</td>
</tr>
</tbody>
</table>

**Note:**

the following abbreviations are used in the tables of this Appendix:

- K1 – category 1 overhaul;
- K2 – category 2 overhaul;
- K3 – category 3 overhaul;
- C – medium repairs;
- T1 – current repair of category 1.
Appendix No. 2
to the electric power facilities maintenance and repair organization rules approved by Order
of the Ministry of Energy of Russia dated October 25, 2017, No. 1013

Standards for the duration and periodicity of scheduled repair of cross-connection thermal power plants power facilities

Table 1. Standards for the duration of scheduled repair and the periodicity of scheduled overhaul of steam boilers; coal-fueled

<table>
<thead>
<tr>
<th>Steam pressure, MPa (kgf/cm²)</th>
<th>Steam capacity, t/h</th>
<th>Time between overhauls, years</th>
<th>Standard life between overhauls, hours</th>
<th>Repair type C - medium K - overhaul</th>
<th>in overhaul</th>
<th>in the current repair</th>
<th>total</th>
<th>in the medium repair</th>
<th>in the current repair</th>
<th>total</th>
<th>in the year of the scheduled repair only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Up to 35 inclusively</td>
<td>5</td>
<td>34000</td>
<td>T-T-CT-T-KT</td>
<td>16</td>
<td>6</td>
<td>22</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Over 35 up to 100 inclusively</td>
<td>5</td>
<td>34000</td>
<td>T-T-CT-T-KT</td>
<td>18</td>
<td>7</td>
<td>25</td>
<td>7</td>
<td>7</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Over 100 up to 150 inclusively</td>
<td>5</td>
<td>34000</td>
<td>T-T-CT-T-KT</td>
<td>20</td>
<td>8</td>
<td>28</td>
<td>8</td>
<td>8</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Over 150 up to 200 inclusively</td>
<td>5</td>
<td>34000</td>
<td>T-T-CT-T-KT</td>
<td>23</td>
<td>9</td>
<td>32</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Over 6.5 (65) up to 12.5 (125) inclusively</td>
<td>Over 70 up to 120 inclusively</td>
<td>4</td>
<td>24200</td>
<td>T-CT-T-KT</td>
<td>23</td>
<td>9</td>
<td>32</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Over 6.5 (65) up to 12.5 (125) inclusively</td>
<td>150–170</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
<td>25</td>
<td>11</td>
<td>36</td>
<td>10</td>
<td>9</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>Over 6.5 (65) up to 12.5 (125) inclusively</td>
<td>200–300</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
<td>33</td>
<td>13</td>
<td>46</td>
<td>13</td>
<td>13</td>
<td>26</td>
<td>20</td>
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<tr>
<td>14 (140)</td>
<td>210</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
<td>35</td>
<td>14</td>
<td>49</td>
<td>15</td>
<td>13</td>
<td>28</td>
<td>22</td>
</tr>
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<td>14 (140)</td>
<td>320</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
<td>38</td>
<td>16</td>
<td>54</td>
<td>17</td>
<td>14</td>
<td>31</td>
<td>24</td>
</tr>
<tr>
<td>10–11 (100–110)</td>
<td>420–430</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
<td>40</td>
<td>16</td>
<td>56</td>
<td>18</td>
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<td>34</td>
<td>24</td>
</tr>
<tr>
<td>14 (140)</td>
<td>400–420</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
<td>44</td>
<td>18</td>
<td>62</td>
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<td>38</td>
<td>27</td>
</tr>
<tr>
<td>14 (140)</td>
<td>480–500</td>
<td>4</td>
<td>27200</td>
<td>T-CT-T-KT</td>
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<td>20</td>
<td>66</td>
<td>24</td>
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Table 2. Standards for periodicity and duration of the scheduled repair of steam boilers when burning fuel oil over 30%

<table>
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<th>Steam pressure, MPa (kgf/cm²)</th>
<th>Steam capacity, t/h</th>
<th>Time between overhauls, years</th>
<th>Standard life between overhauls, hours</th>
<th>Repair type</th>
<th>Repair duration, calendar days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T – current</td>
<td>in the overhaul year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C – medium</td>
<td>in the current repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>K – overhaul</td>
<td>total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in the medium repair</td>
<td>in the current repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>only</td>
<td>total</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>in the current repair only</td>
<td>total</td>
</tr>
<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Up to 35 inclusively</td>
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<td>34000</td>
<td>T-T-CT-T-KT</td>
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<td>9</td>
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<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Over 35 up to 100</td>
<td>5</td>
<td>34000</td>
<td>T-T-CT-T-KT</td>
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<tr>
<td>Up to 6.5 (65) inclusively</td>
<td>Over 100 up to 150</td>
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Table 3. Standards for the duration of scheduled repair and the periodicity of scheduled overhaul of steam boilers; fuel is gas

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<th>Steam capacity, t/h</th>
<th>Time between overhauls, years</th>
<th>Standard life between overhauls, hours</th>
<th>Repair type</th>
<th>Repair duration, calendar days</th>
<th>in the overhaul year</th>
<th>in the current repair</th>
<th>total</th>
<th>in the medium repair year</th>
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Table 4. Standards of periodicity and duration of steam turbine scheduled repair

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<th>Steam capacity, t/h</th>
<th>Time between overhauls, years</th>
<th>Standard life between overhauls, hours</th>
<th>Repair type</th>
<th>Repair duration, calendar days</th>
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<td>T-T-T-T-K</td>
<td>27</td>
</tr>
<tr>
<td>R-100-130/15</td>
<td>13 (130)</td>
<td>100</td>
<td>5</td>
<td>34000</td>
<td>T-T-C-T-K</td>
<td>29</td>
</tr>
<tr>
<td>PT-135/165-130/15</td>
<td>13 (130)</td>
<td>135</td>
<td>5</td>
<td>34000</td>
<td>T-T-C-T-K</td>
<td>38</td>
</tr>
<tr>
<td>T-175/210-130</td>
<td>13 (130)</td>
<td>175</td>
<td>5</td>
<td>34000</td>
<td>T-T-C-T-K</td>
<td>42</td>
</tr>
<tr>
<td>Turbine type</td>
<td>Steam pressure, MPa (kgf/cm²)</td>
<td>Steam capacity, t/h</td>
<td>Time between overhauls, years</td>
<td>Standard life between overhauls, hours</td>
<td>Repair type</td>
<td>Repair duration, calendar days</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------</td>
<td>--------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------</td>
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<td>--------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in overhaul</td>
<td>in the overhaul year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in the current repair</td>
<td>total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in the medium repair</td>
<td>total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>in the current repair</td>
<td>total</td>
</tr>
<tr>
<td>T-50/60-130</td>
<td>13 (130)</td>
<td>50</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>35 – 35 – 9</td>
</tr>
<tr>
<td>PT-50/60-130/7</td>
<td>13 (130)</td>
<td>50</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>35 – 35 – 9</td>
</tr>
<tr>
<td>R-40-130/31</td>
<td>13 (130)</td>
<td>40</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>23 – 23 – 6</td>
</tr>
<tr>
<td>R-50-130/13</td>
<td>13 (130)</td>
<td>50</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>25 – 25 – 7</td>
</tr>
<tr>
<td>PT-60/75-130/13</td>
<td>13 (130)</td>
<td>60</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>36 – 36 – 9</td>
</tr>
<tr>
<td>PT-80/100-130/13</td>
<td>13 (130)</td>
<td>80</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>36 – 36 – 9</td>
</tr>
<tr>
<td>T-100/120-130/15</td>
<td>13 (130)</td>
<td>100</td>
<td>6</td>
<td>40800</td>
<td>T-T-C-T-K</td>
<td>40 – 40 16 – 8</td>
</tr>
<tr>
<td>PR-25-90/10/09</td>
<td>9 (90)</td>
<td>25</td>
<td>6</td>
<td>40800</td>
<td>T-T-T-K</td>
<td>27 – 27 – 7</td>
</tr>
<tr>
<td>R-100-130/15</td>
<td>13 (130)</td>
<td>100</td>
<td>6</td>
<td>40800</td>
<td>T-T-C-T-K</td>
<td>29 – 29 16 – 8</td>
</tr>
<tr>
<td>PT-135/165-130/15</td>
<td>13 (130)</td>
<td>135</td>
<td>6</td>
<td>40800</td>
<td>T-T-C-T-K</td>
<td>38 – 38 16 – 8</td>
</tr>
<tr>
<td>T-175/210-130</td>
<td>13 (130)</td>
<td>175</td>
<td>6</td>
<td>40800</td>
<td>T-T-C-T-K</td>
<td>42 – 42 17 – 9</td>
</tr>
</tbody>
</table>

Note:
1. The duration of the repair is set in calendar days, including weekends, but excluding holidays.
2. The list of works performed during the overhaul is developed by the electric power industry subject independently.
3. The standards for the duration of repair of steam boilers, given in Table 1, are established for the conditions of powdered coal combustion with ash content of up to 35% with an average abrasiveness. The following ratios are applied to the given standards for the duration of repair: when burning powdered coal with ash content higher than 35% and (or) high abrasiveness – 1.2; when shale combustion – 1.4.
4. Annual (total) duration of current repairs is given.
5. The overhaul, medium and current repairs of turbogenerators are carried out at the same time as for steam turbines.
6. The periodicity, duration, scopes and list of maintenance and types of scheduled repair of gas turbine plants are established in accordance with the manufacturers’ regulations.
Table 5. Standards for duration of scheduled repair of transformers

<table>
<thead>
<tr>
<th>Voltage class, kV</th>
<th>Transformer capacity, kVA</th>
<th>Repair duration, calendar days in overhaul</th>
<th>Repair duration, calendar days in the current repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 4000</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4001-10000</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>10001-16000</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16001-25000</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>25001-40000</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>40001-80000</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>110–150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 16000</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16001-25000</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>25001-40000</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>40001-80000</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>80001-160000</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>160001-250000</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>250001-400000</td>
<td>38</td>
<td>5</td>
</tr>
<tr>
<td>220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 25000</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>25001-40000</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>40001-80000</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>80001-160000</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>160001-250000</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>250001-400000</td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>400001-630000</td>
<td>46</td>
<td>8</td>
</tr>
<tr>
<td>330</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 80000</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>80001-160000</td>
<td>38</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>160001-250000</td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>250001-400000</td>
<td>46</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>400001-630000</td>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Over 630000</td>
<td>54</td>
<td>11</td>
</tr>
<tr>
<td>330</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 80000</td>
<td>38</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>80001-160000</td>
<td>42</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>160001-250000</td>
<td>46</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>250001-400000</td>
<td>50</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>400001-630000</td>
<td>54</td>
<td>12</td>
</tr>
</tbody>
</table>

Note:
1. The repair duration is given for power transformers and general purpose autotransformers with on-load tap changing and shunt reactors based on single-shift operation.
2. The duration of the repair of transformers does not include the time required for drying the active part. The overhaul of 110-150 kV transformers with a capacity of 125 MW and more, 220 kV and above transformers, main auxiliary transformers at power plants is carried out no later than 12 years after commissioning, taking into account the test results, and after that – as necessary depending on the test results and technical condition. For the rest of the transformers – depending on the test results and their technical condition.
Table 6. Standards for duration of scheduled repair of synchronous compensators

<table>
<thead>
<tr>
<th>Compensator capacity, MVA</th>
<th>Repair duration, calendar days</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>with rotor removal</td>
<td>in overhaul</td>
<td>without rotor removal</td>
<td>in the current repair</td>
</tr>
<tr>
<td>Up to 6 inclusively</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Over 6 up to 10 inclusively</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>20</td>
<td>9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>37.5 (hydrogen-cooled)</td>
<td>25</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>50 (hydrogen-cooled)</td>
<td>30</td>
<td>12</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>75 (hydrogen-cooled)</td>
<td>35</td>
<td>12</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>100 (hydrogen-cooled)</td>
<td>40</td>
<td>12</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Note:
1. For the first time the rotor is removed no later than after 8000 hours of operation after commissioning.
2. During subsequent repairs, the rotor is removed as needed or in accordance with the requirements of regulatory and technical documents.