Equipment of OJSC "Power Machines" for new international projects of NPP rated 800 – 1200 MW.

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Contents

1 OJSC “Power Machines” experience in development and manufacture of high-powered high-speed steam turbine for NPP.

“Power Machines” Concern is a leader in manufacture of power generating equipment. Produced were 2300 turbines of power more than 300 mln kW. Among them - 381 pieces of 66 GW total power produced for foreign Customers.

In the paper presented are the advantages of steam turbines of previous generations, of currently supplied turbines and of advanced developments of NPP steam turbines. Information is given about the superheated steam turbines rated 800 MW and about wet steam turbines rated 1000-1200 MW.

If we look at the international market of NPP steam turbines both high-speed and low-speed, one can notice the leadership of OJSC “Power Machines” in high-speed turbines in the 800-1200 MW power segment.

Up to date the Company produced: 1 turbine plant for Beloyarskaya NPP for fast neutron reactor rated 800 MW, 9 turbine plants rated 1000 MW operating at Rovenskaya, Khmelnitskaya, Yuzhno-Ukrainskaya in Ukraine, at Kalininskaya NPP in Russia and at Tianwan NPP in China. Other 3 turbine plants are under commissioning at Kudankulam in India (2) and Bushehr in Iran (1), (see Table 1). Four steam turbine rated 1200 MW were manufactured and shipped to the Customers of Novovoronezhskaya NPP and Leningradskaya NPP in Russia and two turbines of the same class for two units of Belorusskaya NPP are under manufacture.

Table 1

No	Turbine Type	Design scheme	Number of turbines	Place of installation		Year of bringing into service
				Name of power plant	Country	
1	2	3	4	5	6	7
1	K-800-130	HPC + 3 x LPC	1	Beloyarskaya NPP	Russia	Erection
2	K-1000-60/3000	2 x LPC + HPC + 2 x LPC	2	Rovenskaya NPP units 5, 6	Ukraine	1986 2004
3	K-1000-60/3000	2 x LPC + HPC + 2 x LPC	2	Khmelnitskaya NPP units 1, 2	Ukraine	1987 2005
4	K-1000-60/3000	2 x LPC + HPC + 2 x LPC	1	Yuzhno-Ukrainskaya NPP unit 3	Ukraine	1989
5	K-1000-60/3000	2 x LPC + HPC + 2 x LPC	2	Kalininskaya NPP units 3, 4	Russia	2005 2011
6	K-1000-60/3000	2 x LPC + HPC + 2 x LPC	2	Tianwan NPP units 1, 2	China	2006 2007
7	K-1000-60/3000-3	HPC + 3 x LPC	1	Bushehr NPP ст. № 1	Iran	precommissioning tests
8	K-1000-60/3000-2	HPC + 3 x LPC	2	Kudankulam NPP units 1,2	India	precommissioning tests
9	K-1200-6,8/50	2 x LPC + HPC + 2 x LPC	2 2	NV NPP-2 LNPP-2	Russia	2014-2015* 2015-2016*
10	K-1200-6,8/50	2 x LPC + HPC + 2 x LPC	2	Belorusskaya NPP	Belarus	2017-2018*

*Preliminary dates.

2 Operating experience.

The longest operating experience for the turbines K-1000-60/3000 obtained in Ukraine NPP: Rovenskaya NPP units – since 1986, at Khmelnitskaya NPP – since 1987 and at Yuzhno-Ukrainskaya NPP – since 1989, proved high reliability and efficiency indices. Table 2 gives (data as of 2008-2009) general indices of operation of the pilot line of turbines K-1000-60/3000, which have long-standing operating experience at Rovenskaya NPP, Yuzhno-Ukrainskaya NPP and Khmelnitskaya NPP. From the Table 2 one can see that the total operating period of the turbine plant K-1000-60/3000 at Ukraine units comes to 97.5 years. If added with operating period of turbines of units 1 and 2 of Tianwan NPP (since 2006 and 2007 respectively) the total operating time of the turbine plant K-1000-60/3000 will be more than a century.

The idea about the average value of availability factor over the long operating period is given by the analysis of the results of operation of the long-term running units, namely – unit 3 of Rovenskaya NPP, unit 1 of Khmelnitskaya NPP and unit 3 of Yuzhno-Ukrainskaya NPP. The average availability factor of the turbine comes to 99.6%, having reached 100% sometimes. (According to Russian Norms as per State Standard GOST 24277-91 this value must be no less than 98%).

Table 2

<table>
<tr><th>NPP</th><th>Unit No</th><th>Month and year of start-up</th><th>Operating period (years)</th><th>Average availability factor *, %</th></tr>
<tr><td>Rovenskaya NPP</td><td>3</td><td>12.1986</td><td>25</td><td rowspan="6">> 99,6%</td></tr>
<tr><td>Rovenskaya NPP</td><td>4</td><td>10.2004</td><td>7,5</td></tr>
<tr><td>Khmelnitskaya NPP</td><td>1</td><td>12.1987</td><td>24</td></tr>
<tr><td>Khmelnitskaya NPP</td><td>2</td><td>08.2004</td><td>7,5</td></tr>
<tr><td>Yuzhno-Ukrainskaya NPP</td><td>3</td><td>09.1989</td><td>22,5</td></tr>
<tr><td>Kalininskaya NPP</td><td>3</td><td>12.2004</td><td>11</td></tr>
</table>

*Operation indices of NPP units with K-1000-60/3000 turbines (Ukranian units – the data as of 01.07.2009, Russian unit – as of 01.11.2008). Calculated to 2012.

3 Modern steam turbines for operation with VVER-1000 reactor, developed and manufactured by our Company for foreign NPP.

In this Section described are the foreign orders for new equipment which represents the significant part of Company’s production.

The base turbine plant K-1000-60/3000 incorporated a number of design solutions which are conceptual for NPP steam turbines, implemented in almost all NPP turbine projects. The main of them are:

- Rotational speed of 3000 rpm;
- LPC last stage blades of maximum length for high-speed turbines - 1200 mm manufactured of titanium alloy in lots.
- Integrally-forged LP rotors for 3000 rpm, mass of 75 t, having no equivalent in world’s turbine building practice;
- Implementation of a number of passive and active measures to protect the turbine parts against erosion, besides intermediate separation and reheating:

1) turbine HPC, carriers and diaphragms are made of stainless steel that allowed to solve totally the problem of crevice erosion which requires considerable expenses for repair work in operation;

2) HPC blade shrouds are made with inclined inner surface stabilizing the flow of pellicular moisture and its further removal with extracted steam;

3) LPC last stage has increased heat drop, bigger axial clearances and intra-channel moisture removal.

Depending on cooling water conditions and condenser pressure the 1000 MW-powered NPP turbines with VVER-1000 type reactor are made in versions with 4 and 3 LPC, with LPC last stage moving blade 1200 mm long, with the design scheme as 2xLPC + HPC + 2xLPC ("butterfly") and HPC+3LPC respectively.

Tianwan NPP. The heat flow train of the turbine plant rated 1000 MW for Tianwan NPP differs from those operating at the power plants in Russia and Ukraine as follows :

- reduced number of LPH - from 5 to 4;
- instead of mixing type LPH-1 used are the surface type apparatuses built-in into the turbine exhaust connections;
- usage of electrically driven feed pumps (EFP) instead of turbine driven feed pumps (TDFP);
- usage of sliding pressure deaerator.

These and a number of another solutions allowed to reduce the area of the machine hall at Tianwan NPP, as compared to the machine hall of the base turbine plant, by about 40%.

Besides the above-mentioned solutions in the heat flow train, a number of new technical solutions concerning the turbine design were implemented (Fig.1):

- Modernized LPC exhaust hood with improved efficiency, reduced weight and better adaptability to streamlined manufacture;
- New titanium layer (VT-6) implemented for last stage moving blades. Also introduced was ion implantation to strengthen the last stage moving blades.

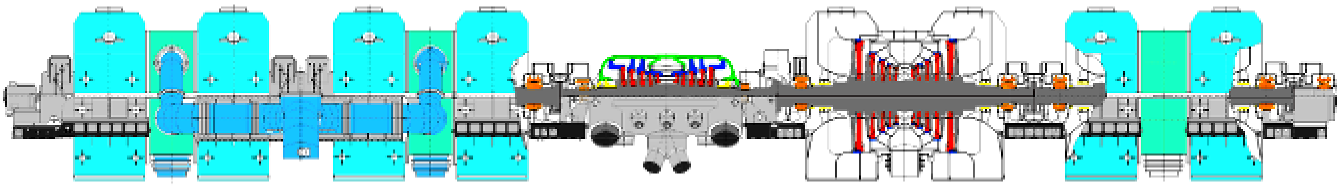


Fig. 1 Steam turbine K-1000-60/3000 for Tianwan NPP in China

Steam turbine technical data:

Main steam pressure, MPa	5.88
Main steam temperature, °C	274.3
Reheat steam temperature (upstream of LPC), °C	250
Vacuum in condenser, bar	~ 0.045
Cooling water temperature, °C	18
LS moving blade height, mm	1200

On the base of high-speed turbine plants the a.m. changes allowed to create one of the most efficient and reliable power units in the world. In 2009 Tianwan NPP with the turbine and the generator make of OJSC “Power Machines” was recognized as the best NPP in China.

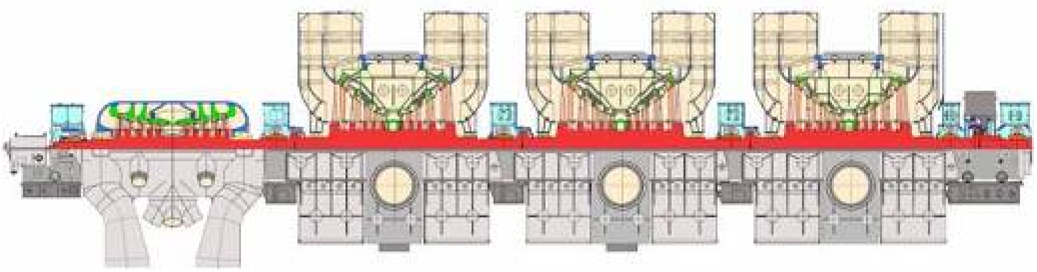
Modified K-1000-60/3000 turbine plants for hot climate regions. Individual approach to each project, to each particular Customer entailed batch production to be left in the past. Customization requires at one hand the design work using modern technical solutions, at the other hand – application of proven referenced solutions.

Among the modern projects of OJSC “Power Machines” for hot climate regions noticeable are the turbine plant projects for Bushehr NPP in Iran and Kudankulam NPP in India. So these 1000 MW turbine projects were made for the regions with high temperature cooling water t_{cw}=33°C, for design vacuum of 0.075...0.08 at(abs). The turbine design features with reduced number of LPC, their arrangement in series between the HP cylinder and the generator. The geometry of HPC flow path was changed keeping intact the dimensions of the cylinder outer casing.

Besides that there is a number of common solutions for the mentioned units:

- Three LPC in answer to the cooling water conditions (condenser vacuum of 0.075 at(abs));
- In LPC the guide vanes of stages 2-5 with tangential lean (scimitar-shaped) are used ;
- New-design shaft end glands used for LPC.

Bushehr NPP. The difference between Bushehr NPP heat flow train and that of Tianwan NPP is significant: the number of high-pressure regeneration stages is reduced; all LPH are of surface type. This solution was associated with the necessity of integrating the auxiliary equipment available at the Customer and it is not subject to duplication.



Fic. 2 Steam turbine K-1000-60/3000-3 for Bushehr NPP in Iran

Steam turbine technical data:

Main steam pressure, MPa	5.88
Main steam temperature, °C	274.3
Reheat steam temperature (upstream of LPC), °C	240
Vacuum in condenser, bar	~ 0.075
Cooling water temperature, °C	28
LS moving blade height, mm	1200

The distinctive design features of the steam turbine for Bushehr NPP (Fig. 2):

- LP rotor design with few supports;
- Hydrosphere is used for rotor journal bearings;
- LPC with reduced axial dimension.

The start-up and adjustment work to bring into operation the unit of Bushehr NPP are at their final stage in 2013.

Kudankulam NPP. Fig. 3 represents the general view of the main equipment arranged in the machine hall (55 x 94 m) of Kudankulam NPP, India. One can see that an additional distinctive aspect of high-speed steam turbines make of OJSC "Power Machines" is main steam supply into the HPC lower half, thus turbine maintainability is improved significantly and the number of flange connections in HPC is reduced (Fig. 3).

HPC steam inlet collector

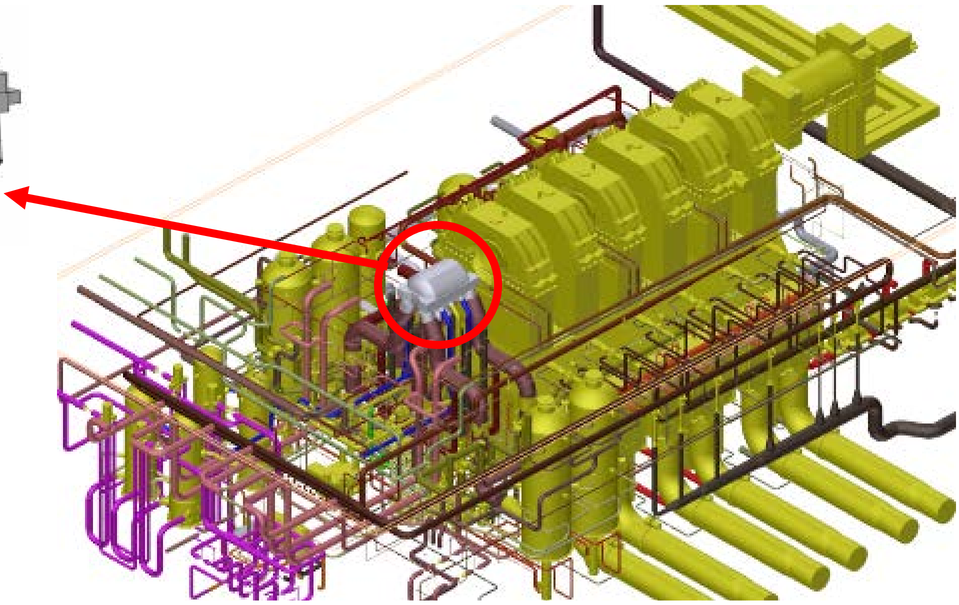


Fig. 3 Arrangement of equipment of K-1000-60/3000-3 turbine plant in the machine hall of Kudankulam NPP, India.

Steam turbine technical data:

Main steam pressure, MPa	5.88
Main steam temperature, °C	274.3
Reheat steam temperature (upstream of LPC), °C	250
Vacuum in condenser, bar	~ 0.08
Cooling water temperature, °C	31
LS moving blade height, mm	1200

For 2013 the start-up and adjustment work is scheduled in order to bring into operation the unit 1 of Kudankulam NPP.

4 Steam turbine K-1200-6,8/50 for “NPP-2006” project.

Let’s proceed to the review of the more powerful steam turbine plants – with a capacity of 1200 MW. Development of the present turbine is due to OJSC “Power machines” participation in the “NPP-2006” project. In accordance with the approved concept a Technical Assignment for the base project “NPP-2006” with the reactor plant VVER-1200 and the full-speed turbine set with a capacity of not less than 1150 MW was developed.

The following units were taken as pilot units:

Novovoronezhskaya NPP – two units (the General Designer – Atomenergoproekt, Moscow). Leningradskaya NPP-2 – two units (the General Designer – Atomenergoproekt, St. Petersburg).

In December, 2010, OJSC “Power machines” successfully tested a pilot model of the new full-speed turbine rated 1200 MW intended for Novovoronezhskaya NPP-2. In May, 2011, OJSC “Power machines” tested a full-speed turbine generator, totally water-cooled, with a capacity of 1200 MW intended for the first power generating unit of Novovoronezhskaya NPP-2.

A heat flow train of the turbine plant K-1200-6,8/50 is a totality of the referenced solutions and the new solutions that improve the efficiency of the whole turbine set. A use of the use-proved components is possible due to close operation conditions of the turbines K-1000-60/3000 and K-1200-60/50 as to main steam parameters and flow rate and pressure in condenser.

The turbine design scheme is 2LPC+HPC+2LPC, the so-called “butterfly”. HPC and LPC are of double-flow design, the last stage moving blades of titanium alloy are 1200 mm long, the total exhaust area is 90.4 sq m. A general view of the turbine K-1200-6,8/50 for NPP-2006 is given in fig.4.

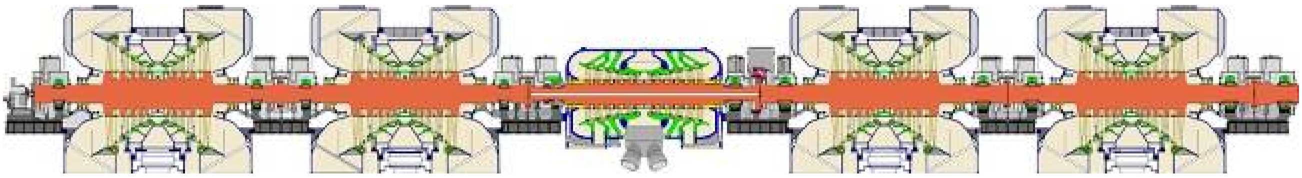
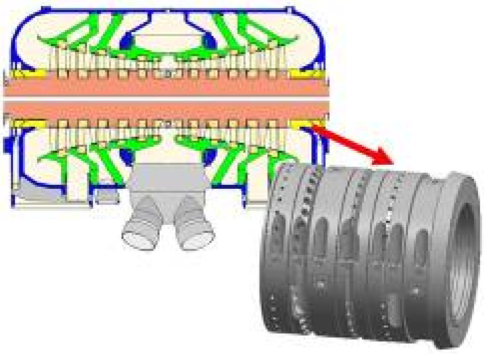


Fig. 4 The longitudinal section of the turbine К-1200-6,8/50

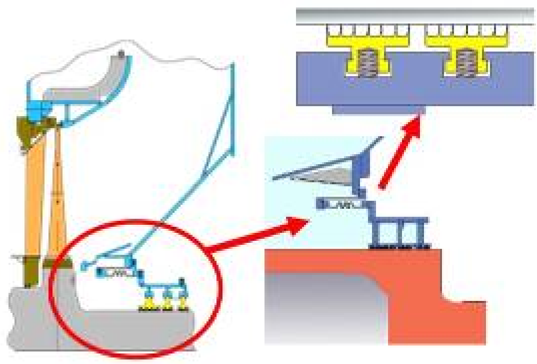
In order to improve the efficiency, the modern end glands are used:

HPC end glands



- Constancy of geometric forms
- Constancy of clearances during operation
- High maintainability – low labour input during erection and operation

LPC end glands



- Insensitivity to misalignment
- High maintainability – replacement of sealing rings without opening LPC and rotor removal
- Reduction of the maintenance downtime

Main technical data of the turbine plant K-1200-6,8/50 are presented in comparison with the turbine plant K-1000-60/3000 for Tianwan NPP in table 3.

Table 3 Comparison of the main technical data of the turbine plants K-1000-0/3000 and K-1200-6,8/50 for NPP with a reactor of VVER type

№	Parameter designation	K-1000-60/3000 Tianwan NPP	K-1200-6,8/50 NPP-2006
1	Heat power of the reactor/nuclear steam generating plant, MW	3000/3000	3200/3212
2	Main steam parameters: - pressure, kg/cm^2 - temperature, ˚C - moisture, %	 60 274,3 0,5	 69,34 283,8 0,5
3	Thermodynamic cycle	MS+RH	MS+RH1+RH2
4	Design scheme	2LPC+HPC+2LPC	
5	Regeneration scheme	4LPH+D+2HPH	
6	The length of the last stage moving blade	1200 mm	

As is seen from Table 3, operation conditions of the turbine plants K-1200-6,8/50 and K-1000-60/3000 are close to each other. The significant difference of the turbine plant with the capacity of 1200 MW is the use of double steam reheat. This solution has improved the efficiency of the turbine plant in comparison with the previous units.

A heat flow train has all characteristics of the heat flow trains that are typical for the turbine plants by OJSC “Power machines” for the NPP with VVER of high capacity: a developed regeneration system (the number of regeneration stages is seven), the presence of one LPH of mixing type, injection of heating steam condensate of the MSR steam reheater into the feed water duct upstream the steam generator.

The design of the turbine plant auxiliary equipment, including LPH, HPH, deaerator, condensate and feed pumps, is the same as that used in the turbine plants K-1000-60/3000 for new NPP.

MSR design, in spite of the two-stage reheat, is based on the reference components of the separator and steam reheater designed by OJSC “ZIO” for the OJSC “Power machines” NPP turbine plants rated 800-1000 MW.

Main condensate injection from the condenser into the deaerator is carried out by the condensate pumps in two steps. Feed water supply from the deaerator through HPH to the steam generator is carried out by motor driven feed pumps (4 operating + 1 standby).

Injection of heating steam condensate of the MSR second stage steam reheater is carried out into the feed water main line by a hydroturbine-driven high-temperature pump, drain of the MSR first stage steam reheater heating steam condensate – into the HPH 5.

LPH-1, 3 and 4 are of

closed-type, LPH-2 – of mixing type. LPH-1 is made in 4 casings, built-in the LPC-condenser transition branches, LPH-2, LPH-3 and LPH-4 are made as one group. HPH-5 and HPH-6 are made as two groups.

All closed-type LPH are manufactured without drain coolers, HPH – with drain coolers.

Main condensate heating is carried out consequently: in the gland steam condenser (GSC), in LPH-1 – LPH-4; feed water heating is carried out consequently in the deaerator, in HPH-5 and 6 and further feed water downstream of HPH-6 is heated while mixing with MSR heating steam condensate.

The turbine plant K-1200-6,8/50 is provided for heating load up to 300 MW (th) under the maximum temperature chart of the district heating network of 150/70°C.

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In Fig. 5 there is a general view of the main equipment arrangement of the turbine plant K-1200-6,8/50 in the turbine hall of Leningradskaya NPP-2, Russia. The turbine hall sizes - 51x121 m (the size is pointed out including the deaerator mezzanine floor). The steam turbine design – “the butterfly” has imposed the arrangement of 4 MSR at both sides of the turbine axis, thus, the effective steam distribution to the low pressure cylinders takes place.

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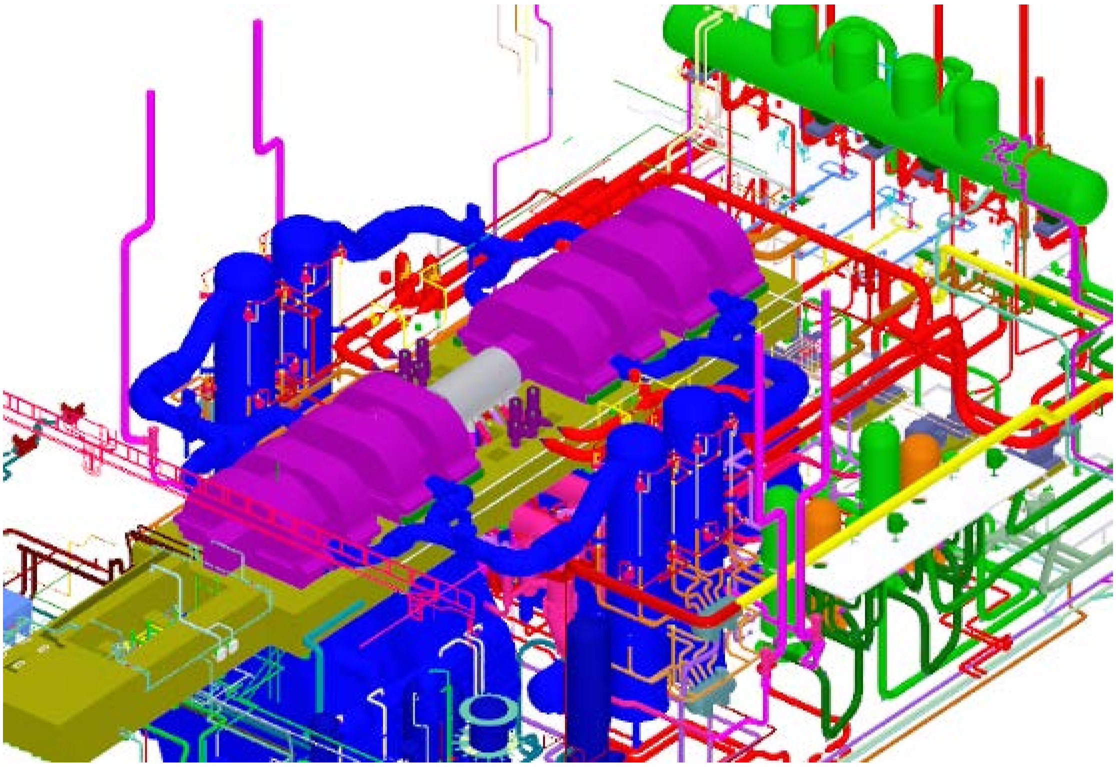


Fig. 5 Arrangement of the turbine plant K-1200-68/3000 equipment in the turbine hall of Leningradskaya NPP-2, Russia

Close operation conditions of the turbines K-1000-60/3000 and K-1200-60/50 as per main steam parameters, as well as pressure in the condenser allowed to use the turbine design solutions similar to those of the base turbine. All differences on individual elements of the HPC and LPC design in the turbines rated 1000 and 1200 MW are of developmental nature and, usually, primarily, are for, steam path efficiency improvement. The main of them are:

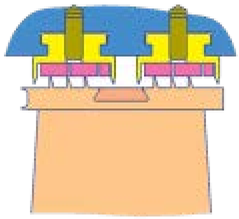
- the **new project of high pressure cylinder** for the turbine inlet advanced parameters has been developed, with increased number of stages (6 stages) that required to design a new high pressure rotor and diaphragms;

- the **honeycomb overshroud seals** (Fig.6) **are used** for turbine steam path efficiency improvement.

Also high and low pressure solid-forged rotors are used, they increase reliability and decrease expenses for the additional inspection in comparison with another constructions. **A special end gland arrangement** gives an opportunity to replace sealing rings without opening the LPC cover .

Overshroud seals of honeycomb type for installation instead of the present inserts X6

Segment of the honeycomb seal



General view of the overshroud seal

Fig. 6 Use of honeycomb overshroud seals in the turbine K-1200-6,8/50

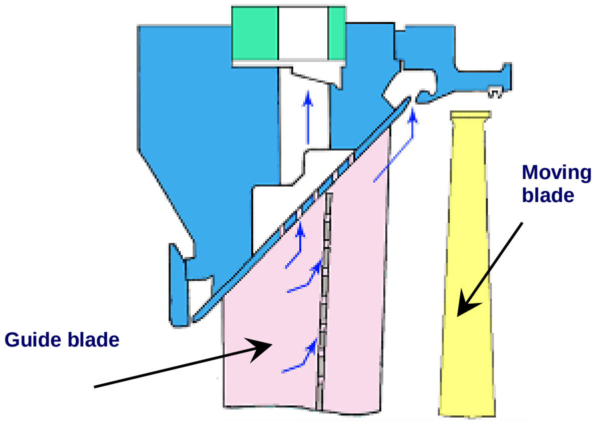
In Fig.7 an example of the effective moisture removal system is shown, which is provided in the following ways:

- Use of the moisture separation from the upper part of the diaphragm;
- Arrangement of the peripheral moisture catcher downstream of the guide blades;
- Intra-channel moisture removal through the narrow slots system on the convex and concave surfaces into the core space of the guide blades;
- Arrangement of moisture breakup and dumping from the concave surface of the guide blades near the trailing edge.

Among the methods of the moving blades erosion passive protection the following can be pointed out – coating the blade of titanium alloy BT-6 by ion-implantation method with titanium nitride deposition, thus a protection of leading and trailing edges, moving blades shrouds is carried out.

The moving blades erosive wear active protection allows to remove up to 25% of coarse particle moisture from the flow path.

Erosive wear passive protection



Erosive wear active protection

Fig. 7 Erosion wear protection of the last stage moving blades.

Besides the enumerated engineering solutions, high efficiency and reliable journal bearings are necessary for providing reliable operation of any horizontally mounted rotary machine. The developed bearings differ by the following:

- Higher vibration resistance
- High maintainability – possibility of rolling off the bearings without rotor removal
- Presence of auxiliary lube tanks of fire-resistant fluid
- High fire safety – use of fire-resistant fluid for bearings lubrication

As to usage of fire resistant fluid, it's worth noting that OJSC "Power Machines" is one of the first companies which declared about usage of fire resistant oil in its turbines. This solution improved NPP fire safety to a great extent. Fire safety is determined first of all by self-ignition temperatures of fire-resistant and mineral oils which are 720˚C and 370˚C.

Below is the reference-list of NPP where this lubrication system was introduced:

- K-1000-60/3000, Rovenskaya NPP, Ukraine, units 5 and 6
- K-1000-60/3000, Khmelnitskaya NPP, Ukraine, units 1 and 2
- K-1000-60/3000, Yuzhno-Ukrainskaya NPP , Ukraine, ст. 5 и 6
- K-1000-60/3000, Kalininskaya NPP, Russia, unit. 3
- K-1000-60/3000, Tianwan NPP, China, units 1 and 2

5 Low-speed steam turbine rated 1200 MW for NPP – new project of OJSC "Power Machines"

In 2008 in order to strengthen its position as one of the world's leader in manufacture of high-speed (3000 rpm) steam turbines for NPP, OJSC "Power Machines" began to develop a project and to prepare production of low-speed (1500 rpm) steam turbine and turbine generator of more than 1200 MW power.

The necessity of creating such equipment is dictated by a will to widen the spectrum of manufactured products and to fix the Company's position in the market as a complete and flexible supplier and by global tendencies in development of nuclear power field.

In September 2009 completed was development of the engineering design of the modern low-speed turbine and turbine generator of 1200 MW, which in their technical characteristics are as good as the best world's models in this segment of power. From the results of performed examination the positive expert opinions were obtained from the leading RF scientific and R&D organizations (VNIIAM, MEI, VTI, CNIITMASH, SPbAEP, PIMash, CKTI, etc).

The turbine consists of high-intermediate pressure cylinder (HIPC) of loop design (9 impulse stages – in HP part and 4 impulse stages – in IP part with intermediate separation and reheating between HP and IP parts) and 2x LPC.

LPC is double-flow, symmetrical, 5 impulse stages in each flow. LP rotor – of welded design.

The heat flow train is totally unified with that of the turbine plant K-1200-6,8/50, which is typical for the turbine plants of high power for NPP units with VVER make of OJSC "Power Machines". The turbine heat flow train and the turbine design provide for additional steam extractions for unit auxiliaries and for district heating.

In 2010 in Russia organized was the work on buildup of conditions for further development of the project "NPP-2006", a new project was created so called VVER TOI (typical, optimized, informational). On September 13, 2010, Rosenergoatom Concern OJSC together with ZAO "Atomstroyexport" generated the main technical-and-economic requirements to the VVER TOI project. Having received the revised technical assignment, OJSC "Power Machines" began to revise available technical documentation developed for NPP-2006 project in order to confirm the possibility of participation in VVER TOI project. Below some results of this work are presented.

Developed was the design of low-speed steam turbine with the design scheme HIPC + 2LPC (Fig. 8), and also of the turbine generator and the auxiliary equipment (Fig.11).

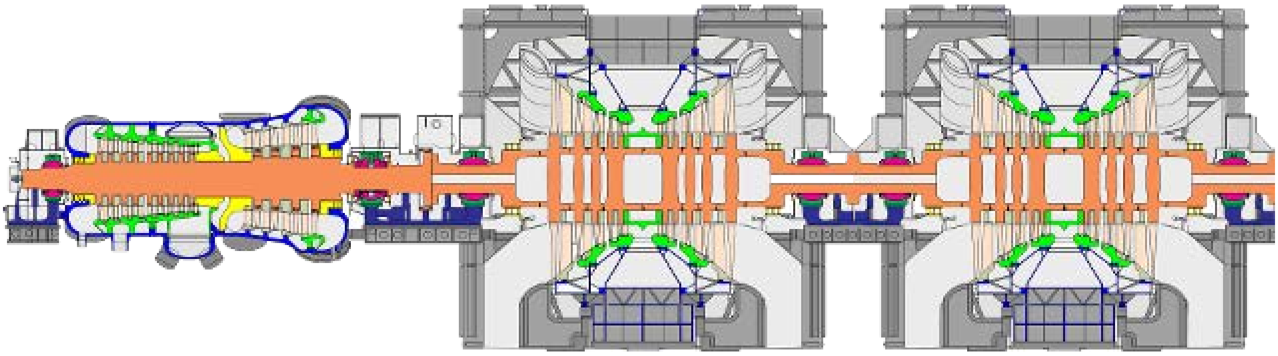
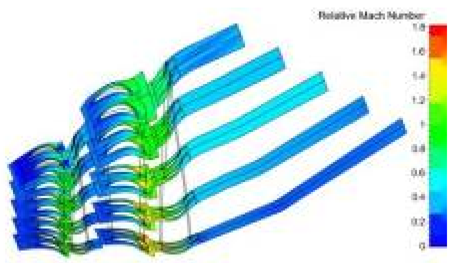


Fig. 8 Low-speed turbine for VVER TOI project

For low-speed turbine it was necessary to design a new last stage moving blade 1760 mm long. To speed up the alternative studies – a variety of blade versions was subject to gas-dynamic calculation experiments. Fig. 9 shows the steps of the gas-dynamic calculation of two las stages of the low-speed turbine with moving blade 1760 mm long. Until recently to obtain the wet steam flow pattern in the last compartment of the steam turbine was possible only with carrying out the expensive tests. Now, using the previously proved turbulent model, it is possible to predict with a particular likelihood ratio the behavior of the 3D working medium flow. Fig. 9b shows the results of relative Mach number in cross-sections throughout the height.

9a. Calculation grid of LPC two last stages made in AUTOGRID 5



9b. Relative Mach number in cross-sections throughout the height of calculation field

9в. Moving blade design

Fig. 9 The cycle of gas-dynamic calculation for the moving blade of LPC last stage of low-speed turbine

Moreover, full scale tests of the 1760 mm moving blade are planned to be performed after finishing the test rig modernization at the Company's factory in Saint-Petersburg. At the full scale test rig was tested a unique moving blade 1200 mm long of titanium alloy used in all the projects of powerful nuclear steam turbines.

The last LPC compartments with new last stages for full- and half-speed turbines of high power will be tested on the modernized test rig.

- Steel moving blade 1220 mm (3000 rpm);
- Steel moving blade 1760 mm (1500 rpm).

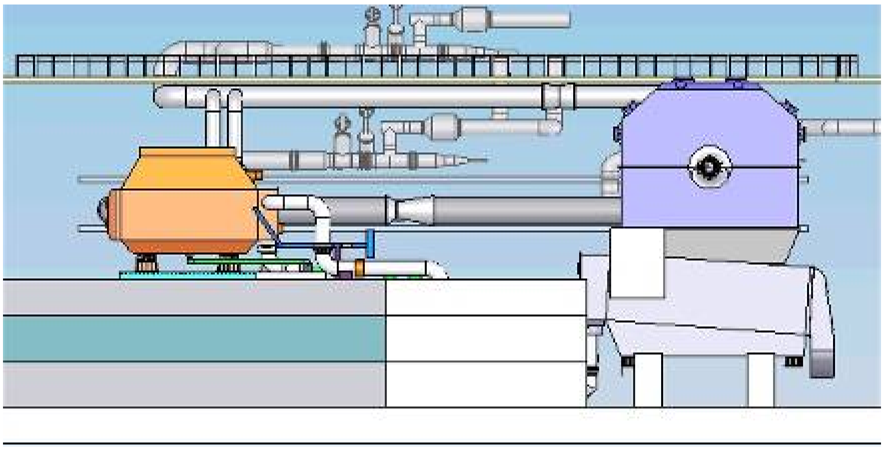


Fig. 10 Overview of the full scale test rig which is under modernization.

Lay-out of the half-speed turbine plant. Designed preliminary lay-out meets requirements of the NPP with VVER TOI project, the following general principals were laid down in its base:

- turbine hall overall dimensions in the plan should not exceed 57.2 m x 92 m;
- turbine hall building is single-bay;
- demineralizing plant, district heating plant and thermal energy storage system are located out of the turbine hall building, in the separate buildings joined up to it ;
- requirements to the turbine set oil systems arrangement;
- turbine generator service floor should be maximum free for laying the TG components during repair works;
- pumps and heat exchangers that have splits of the casing for repair, should be maintained by the lifting equipment.

Fig.11 shows preliminary lay-out arrangements of the NPP turbine hall for the VVER TOI project with applying half-speed equipment manufactured by OJSC «Power Machines».

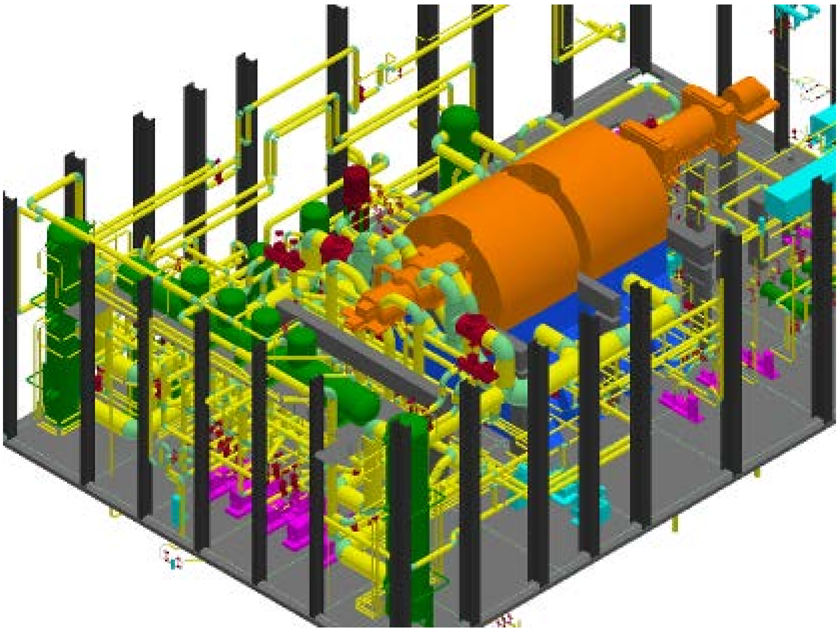
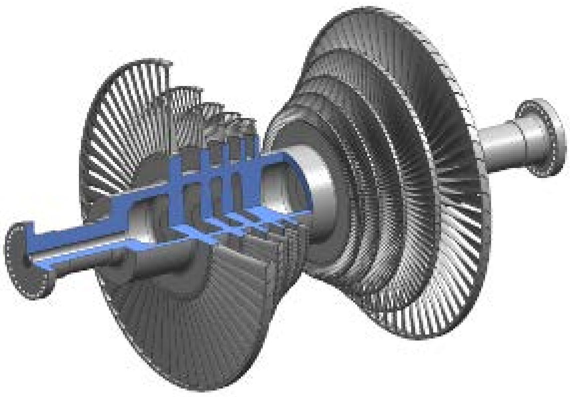


Fig.11 Overview of the half-speed turbine plant lay-out model (without referring to definite turbine plant)

Components of the half-speed steam turbine are planned to be produced at the new manufacturing area of the OJSC «Power Machines» in the industrial zone «Metallstroy», Saint-Petersburg. The new manufacturing complex consists of the site where turbines and high capacity turbine generators for NPP are produced, the site is furnished with modern equipment, overspeed-balancing machine, apparatus manufacturing complex, warehouse complex, engineering infrastructure buildings. Its production capabilities stand for the manufacturing of four sets of half-speed and full-speed turbine sets rated 1000 to 1800MW. At present, construction of the new complex is completed and its pilot operation is carried on. Fig.12 illustrates LP rotor of the half-speed turbine at the modeling stage in the software package and during welding procedure on the welding skid of the new manufacturing complex.



Low pressure rotor of the half-speed turbine

.

Spanning type welding skid for the rotors horizontal welding

Fig. 12 Generation of the welded rotor model of the half-speed turbine plant by OJSC «Power Machines»

6 Turbine plant K-800-130/3000.

Condensing steam turbine of the K-800-130/3000 type is designed for operation in monoblock unit with fast neutron reactor facility БН-800 with thermal output of 2100MW fed with superheated steam, with heat cycle with intermediate separation and single-stage steam superheating. The turbine is adapted to the conditions of the unit 4 site of Beloyarskaya NPP.

Unit 4 of Beloyarskaya NPP includes district heating plant that provides heat supply up to 250 Gcal/h, the temperature chart of the district heating network being 150/70°C.

The General Designer of the Unit 4 of Beloyarskaya NPP is SPbAEP.

Turbine design scheme is: HPC+3LPC.

LPC is applied unified with LPC of the turbine K-800-130/3000 type for NPP of new generation.

HPC is of new design, loop construction, similar to that used in TPP turbines rated 500, 800 and 1200MW. Turbine longitudinal cross section is given in Fig.13.

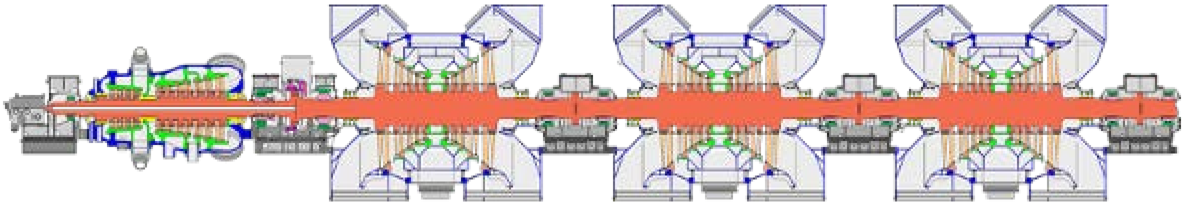


Fig. 13 HPC longitudinal cross sections of the turbine K-800-130/3000

Main steam parameters: Po = 12.8 MPa, To = 485 °C.

Thermodynamic cycle includes intermediate separation and single-stage steam reheating. Regeneration system structure is 5LPH+D+HPH. Heat cycle distinctive features, in comparison with typical scheme, accepted for the turbine plants K-1000-60/3000 for NPP with VVER-1000 are the following:

- as heating steam for separator-reheater the extraction steam from HPC (pressure is ~ 62 kgf/cm^2 abs.) is applied instead of main steam;

- application of 2 LPH of mixing type No2 and No3, but not one No2. Such solution is applied by OJSC “Power Machines” in the NPP turbine plants for the first time and does not have analogue in the world practice.

Fig.14 shows turbine set and auxiliary heat exchange equipment arrangement in the turbine hall.

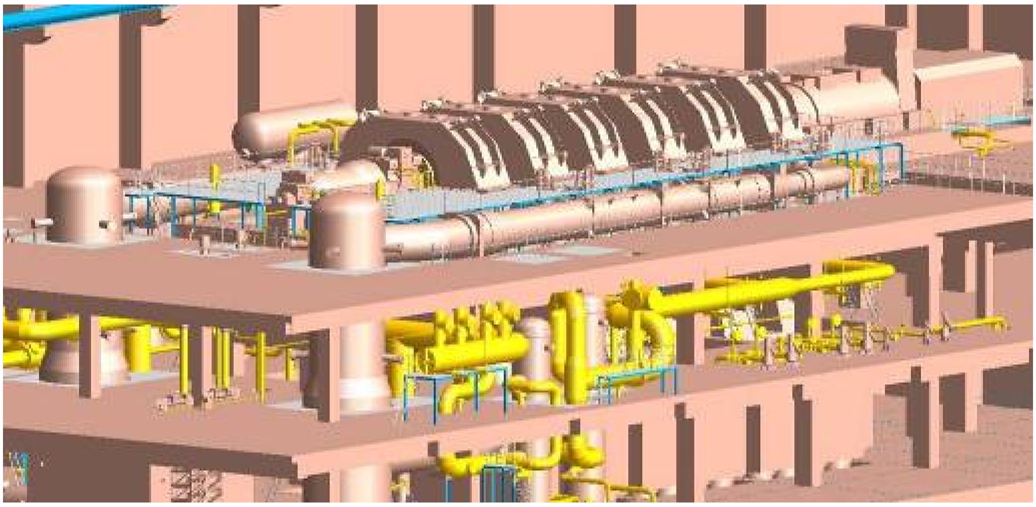


Fig. 14 K-800-130/3000 turbine plant equipment lay-out in the turbine hall of the Beloyarskaya NPP, Russia

At present, turbine mounting work on the unit of Beloyarskaya NPP is carried out. Supposed commissioning period is 2014-2015.

After the unit 4 of Beloyarskaya NPP is brought into operation, reactor unit power as well as of turbine plant will be maximum unit power in the world among operating plants at NPP with fast neutron reactor.

China takes an interest to construction of the units with БН-800 reactor and turbine K-800-130/3000 for the Sanmin NPP. In the nearest future it is supposed to prepare and sign the appropriate intergovernmental agreement between China and Russia concerning construction of two units presumably. In case of favorable decision, OJSC “Power Machines” will design modification of the turbine K-800-130/3000 taking into account the difference between the operating conditions of the turbine plants at Beloyarskaya NPP and Sanmin NPP.

7 Heat exchange and auxiliary equipment for the turbine plants at NPP.

OJSC “Power Machines” offers extended delivery scope of the equipment for the turbine hall, adding a number of equipment of own make. To provide extended scope of equipment delivery, OJSC “Power Machines” use component parts and blank pieces of the world’s leaders and of the companies with good reference in the NPP supplying sphere.

Among manufactured heat exchange and auxiliary equipment we can point out the main condensers of the turbines of 25 … 1200MW, district and regenerative heaters, valves (non-return valves, safety valves, control valves), oil coolers and water-to-water heat exchangers, gland steam condensers, fast-response valves of quick-acting pressure-reducing plant and others.

Main condensers for the high capacity turbine plants.

OJSC “Power Machines” have a long term experience of manufacturing the new and modernizing the existing condensers of the NPP turbine plants.

Reliable and cost-effective condenser operation is achieved due to the following aspects:

- application of titanium alloy as material for tubes;
- insuring reliable and tight tube fixation (tube expansion and seal welding in the main tube sheets);
- elimination of the impact of difference between heat expansions of the cooling tubes and the casing (application of lens compensator) on the condenser leak tightness;
- prevention of the stand-still corrosion at the expense of tube inclination;
- right choice of space between tube partitions for the purpose of vibration reduction;
- application of effective tube bundle modular arrangement, the shape of bundles was tried out by modeling, full-scale tests and modern methods of thermal fluid dynamic analyses;
- organization of admission of steam-water flows injected into the condenser for the purpose of cooling tubes scouring prevention;
- tube bundles supplied in blocks of full factory readiness, the necessary inspection and high quality ensured.

OJSC “Power Machines” perform supply and assembling of the auxiliary equipment, design of which can be optimized following definite Customer requirements. Fig.15 gives an example of block-modular constructions of the 1000MW turbine condenser at Kozloduy NPP in Bulgaria. Such construction allows to perform assembling of relatively large-sized equipment in tight deadlines. This is ensured by the possibility of pre-assembling the tube sheets into modules at the manufacturing factory. Tubes of such condensers can be manufactured of stainless steel as well as of titanium. Fig.16 represents the actual results of modernization of the condenser of the turbine plant Kozloduy NPP in Bulgaria, here is given the condenser pressure – cooling water temperature relationship before and after modernization according to the data from the units 5, 6. Depending on the cooling water temperature the difference in pressure is 0.45 to 1.1 kPa.

Realized projects:
- K-1000-60/3000, Tianwan NPP (China) units 1, 2
- K-1000-60/3000, Kudankulam NPP (India) units 1, 2
- K-1000-60/3000, Bushehr NPP (Iran) unit 1

Projects of modernization:
- K-1000-60/1500, Kozloduy NPP (Bulgaria) unit 5, 2003
- K-1000-60/1500, Kozloduy NPP (Bulgaria) unit 6, 2004

Fig. 15. Block-modular construction of the 1000MW turbine condenser at Kozloduy NPP

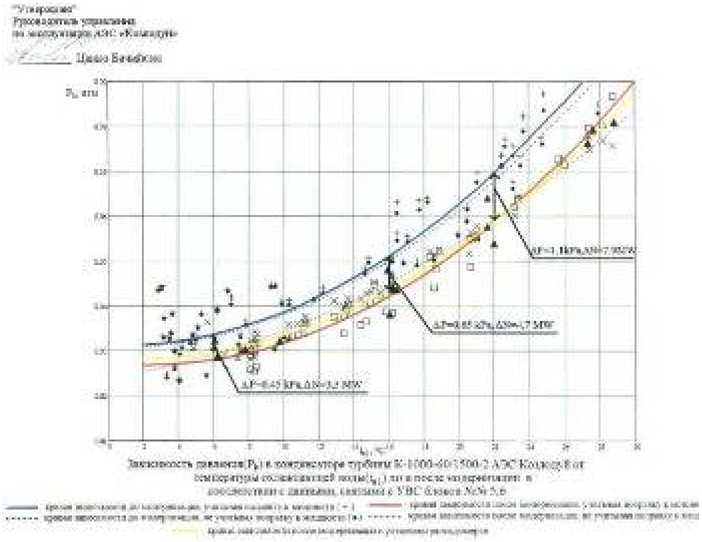


Fig.16. Actual results of modernization at Kozloduy NPP (Bulgaria)

8 Conclusion

At present, OJSC “Power Machines” offers high performance, reliable steam turbines, turbine generators, heat exchange and auxiliary equipment for nuclear power plants with different reactor types with a capacity up to 1200MW and higher.

50-year experience in nuclear power equipment designing and manufacturing has provided the top position among world’s manufacturers of full-speed turbines in the capacity range of 800-1200MW.

OJSC«Power Machines» upgrades own manufacturing by construction of new factory, installation of new processing base, that provides the capability of extension of manufactured equipment product line, in particular, creation of half-speed steam turbines.

Having unique technical and technological experience in designing and manufacturing power plant equipment for Tianwan NPP, Kudankulam NPP, Bushehr NPP, OJSC “Power Machines” confirms its readiness to take part in the projects of new NPP unit construction in the countries with various cooling water conditions, especially in the countries of South-East Asia.