THERMAL ELECTRIC POWER STATIONS

ENGINEERING REFIT OF THE DOROGOBUZH HEAT AND ELECTRIC POWER PLANT

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This article discusses the introduction of two gas turbine units with an overall power of 12 MW in 2005 at the Dorogobuzh TÉTs (Heat and Electric Power Plant). This plant provides energy and heat to the Dorogobuzh industrial cluster and the 30000 people living in the Dorogobuzh region. The need to reconstruct and refit the Dorogobuzh TÉTs (Smolensk Oblast’, Russia), which had become noncompetitive in the market, is examined. The engineering state of the Dorogobuzh TÉTs before and after the introduction of two gas turbine units with an overall power of 12 MW in 2005 is described in detail; the consumption and thermal and electrical energy output parameters are compared. The technical characteristics of the new equipment, including GTD-6RM gas turbine power units, TGS-6 turbogenerators, and boiler recovery units, are given.

Keywords: Gas turbine unit; Dorogobuzh TÉTs; engineering refit; gas-turbine power unit; turbogenerator; boiler-recovery unit.

Construction of the Dorogobuzh TÉTs (Heat and Electric Power Plant) was begun in 1957. Its electrical power was 137 MW until the recent engineering refit. The plant includes three rebuilt condensation turbines: R-18-90/2.5 (K-25-90-1 before the refit), T-38-90/1.5 (K-50-90-2 before the refit), and R-21-90/13 (K-50-90-3 before the refit) at stations No. 1, 2, and 3, respectively, a PT-60/90/13 turbine with industrial and heating outlets at station No. 4, and PK-20 power boilers at stations No. 1 – 4, PK-14-2 at station No. 5, and BKZ-220-100F at station No. 6. The fuels were gas and coal.

The main purpose of the Dorogobuzh Plant is to supply heat to the companies in the Dorogobuzh industrial cluster and the 30000 people living in the city of Dorogobuzh and the town of Verkhnednepravskii. In recent years there has been a significant reduction in the heat demand because of the fall in industrial production, which has led to a very large difference between the winter and summer heat loads. During the summer the plant essentially operates in a condensation regime with low engineering and economic performance characteristics. The expenses for repair of physically worn (80.96% worn out on September 1, 2005) and obsolescent equipment have been high.

The Dorogobuzh Plant was no longer competitive with a majority of the power stations in the Central and North-West Integrated Grid. Given the unfavorable prospects for the Dorogobuzh Plant in the electrical energy market, it was decided to carry out an engineering refit of the power plant with installation of two gas turbine systems plus boiler recovery units, with powers of 6 MW each, which would meet the summer industrial and residential heat requirements and, during the winter, would operate in parallel with the steam power plant section of the Dorogobuzh Plant (a PT-60 turbine with two 220-tons/h steam producing boilers). The remaining equipment (four boilers in stations No. 1 – 4 with a steam capacity of 120 tons/h and the three turbines in stations No. 1 – 3 with a total power of 77 MW) was to be retained. These steps ensure a substantial cut in expenditures for the production of electrical energy and heat and ensure a radical shift in the position of the Dorogobuzh Plant in the electrical energy market.

Construction of the foundation of the gas turbine section was begun on October 30, 2003 and its startup was celebrated on September 27, 2005. The structure was completed on the existing site of the Dorogobuzh Plant using in-house facilities, including the water preparation system and the electrical and thermal energy distribution systems.
The main purposes in constructing the gas turbine unit were to change it from an unprofitable into a competitive power station through the use of high efficiency technologies and to improve the ecological conditions in the region of the Dorogobuzh industrial cluster by curtailing the use of coal and ensure a reliable, quality supply to the populations and industrial enterprises of the Dorogobuzh region. These goals were met.

The installed electrical power of the gas turbine — heat and electric power plant is 12 MW and the installed thermal power is 26.2 Gcal/h. The design electrical efficiency of the gas turbine is 25% and the thermal utilization of the fuel is 80%. The design temperature for the gases leaving the outlet of the gas turbine if 423°C, the rate of consumption of gas in the turbine is 46.3 kg/sec, and the working lifetime of the gas turbine unit is at least 120,000 h. Fuel gas is fed to the gas turbine inlet at a pressure of 14 – 18 kgf/cm² and a temperature of 5 – 80°C. The gas turbine unit is maintained by 18 people.

The overall designer of the gas-turbine heat and electrical power station was the firm BelNIPÉnergo and the general project engineering for construction was by the firm JSC RSF “Omega.” Equipment was supplied by the following firms:

- gas turbine unit assemblies: by NPP JSC NPO “Saturn” (Rybinsk, Russia); boiler-recovery units, by UkrpromÉnergo (Kharkiv, Ukraine); automatic (higher level) control systems, by SEALTEK (Moscow, Russia); pressurizer station, by NOÉMI (Moscow, Russia).

The estimated cost of the whole project is 300.4 million rubles, including 158.4 million rubles for equipment, of which 103.8 are for the two gas turbine units, 21.8 for the two boiler-recovery units, and 16.3 for the gas compressor station; and, 97.6 million rubles are for construction and installation work. Ultimately, the capital expenditure through the construction period was 795 dollars/kW.

The design characteristics of the Dorogobuzh Plant before and after the engineering refit are given in Table 1.

### Equipment at the gas turbine unit—heat and electric power station.

The GTD-6/RM gas turbine power unit is a two-shaft unit with a free power producing turbine. Air from the air receiver chamber is fed to the compressor through an inlet structure consisting of a lemniscate, a cowling with a spinner shell, and an inlet housing. The compressor rotor is of the disk type. The working blades are mounted in “swallow tail” grooves and ridges are mounted between the grooves.

The compressor housing consists of front and back housings with a horizontal feedthrough. The directors and rings above the rotors are attached with bolts to the housing. The inlet director system is equipped with a mechanism for rotating the blades. Air is taken from the compressor for pressurizing the labyrinth seals of the leading and trailing bearings of the compressor, the bearing of the turbine that rotator it and the leading bearing of the power turbine, and for cooling the trailing bearing of the power turbine; in addition air is bypassed through the fifth and sixth stages in order to extend the stability range of the compressor operation.

The combustion chamber of the power unit lying between the compressor and the turbine chamber is of the ring-pipe type. It consists of a diffuser, inner casing, 12 heat pipes with fuel sprayers and gas collectors, load shanks, leading and trailing casings, and the diffuser casing. Inner piping for the oil and air systems and for the breather system are mounted in the region of the combustion chamber. The fuel collector pipes are mounted on the outer annular surface of the diffuser.

The installation of the combustion chamber makes it possible to insert an endoscope (fiber optics) through a hatch to survey the flame tubes and gas collectors without taking them apart and to replace the flame tubes and gas collectors by removing the demountable diffuser casing.

The compressor is set to rotating by an axial two-stage reactive turbine compressor.

The nozzle assembly for the first stage is a blade ring assembly consisting of an outer ring, a collector, bearings, 31 cooled blades, and an uncooled slot ring. The nozzle assembly for the second stage is made up of an outer ring, 47 cooled blades, a slot ring, labyrinth flange, diaphragm, and inner ring.

The rotor of the compressor turbine consists of two working wheels with deflectors and labyrinth seal components. It rests on a roller bearing. In the forward section of the turbine shaft there are grooves for coupling the compressor with the rotor and an inner thread for a clamp bushing; in the back section, there is a flange with studs press-fit into it for attaching the disks and transfer of torque from the disk to the shaft. In the axial direction the disks are tightened with nuts.

The four stage power turbine rotates an electrical generator. The nozzle assemblies for the power turbine (3 – 6 stages) contain up to 79 cooled blades each. The rotor of the power turbine consists of four working wheels, and intermediate and hollow shafts. It rests on two roller bearings: front and back.

On the front shaft of the power turbine, to which the disks of the third and fourth stages are attached directly, there are slots for transfer of torque to the electrical generator. In its back portion, this shaft has slots for connection to the

<table>
<thead>
<tr>
<th>Performance indicator</th>
<th>Before refitting</th>
<th>After refitting</th>
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<tbody>
<tr>
<td>Installed power, MW</td>
<td>137</td>
<td>149.0</td>
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<tr>
<td>Annual output:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>electrical energy, million kW · h</td>
<td>205.8</td>
<td>243.2</td>
</tr>
<tr>
<td>heat, thousand Gcal</td>
<td>516.7</td>
<td>545.4</td>
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<tr>
<td>Specific expenditure of nominal fuel for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>electrical energy, g/(kW · h)</td>
<td>397.43/569.0</td>
<td>338.49/268.8</td>
</tr>
<tr>
<td>heat, kg/Gcal</td>
<td>150.93/184.0</td>
<td>149.42/145.0</td>
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**Note.** the numerator is the yearly average expenditure of nominal fuel; the denominator, from May to September.