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OPERATIONAL EFFICIENCY OF GAS-TURBINE HEAT-ELECTRIC GENERATION PLANT

There had been determined the key figures of gas-turbine heat-electric generation plant operation. There had been given the comparison of operation efficiency of GT-HPP and operation efficiency of boiler plants with equal thermal capacity.

Key words: *gas-turbine plant, heat-electric generation plant, feed-water heater, water boiler.*

Introduction

Combined generation of thermal and electric energy (cogeneration) has been suggested at the beginning of the previous century and realized by manufacturing of industrial steam-turbine heat and power plants (HPP). Cogeneration is a perspective technology, which enables to reduce fuel consumption in energy supply system and to improve ecology. It was also supported legislatively [1].

There are many industrial HPP on the territory of Ukraine. But currently the reduced consumption of technological steam does not allow to reach the planned production capacity. It is a known fact that 90% of all heat-and-power engineering equipment on the existing steam and turbine electric power stations has already exhausted its normative operation resource. The further improvement of economy in the country requires to increase the electric power. The developed system of central heat supply is mainly based upon the use of heating boiler rooms.

Gas and turbine technology has been developing for some decades. Modern gas and turbine plants (GTR) of national production have the efficiency not less then the efficiency of steam-turbine plants. Gas-turbine heat power plants (GT-HPP) allow to produce much electric energy on the base of heat supply, which is one of the components of the energy supply problem, as well as to improve the efficiency of fuel consumption [2 - 4]. The simplest scheme of GT-HPP consists of gas-turbine plant and heat-recovery plant for processed gases in GTP, which acts as gas heater of net water in the heating system.

The peculiarity of heating system operation lies in sharp season changes of thermal loading. In heating season the HPP uses heat for heating and hot water supply. GTP operates with maximum loading. In between - heating seasons the capacity of hot water supply system makes up only 0,2 - 0,3 of thermal loading of heating period. This time the GTP will operate under substantial loading, which sharply decreases its efficiency and causes considerable fuel over consumption. This problem concerns the operation of heating boiler rooms.

In view of the above, we suggest the scheme of GT-HPP with regenerating air heating in between-heating period (fig. 1), which allows to operate with nominal loading within a year due to regenerative air heater. Therefore, there arises a task to determine the main GT-HPP operating factors, which work according to the suggested heat scheme, as well as to compare the efficiency of its work with the operating efficiency of heating boiler rooms under condition of equal heating capacities.

Principal results

Operating principles of the suggested GT-HPP (fig. 1).

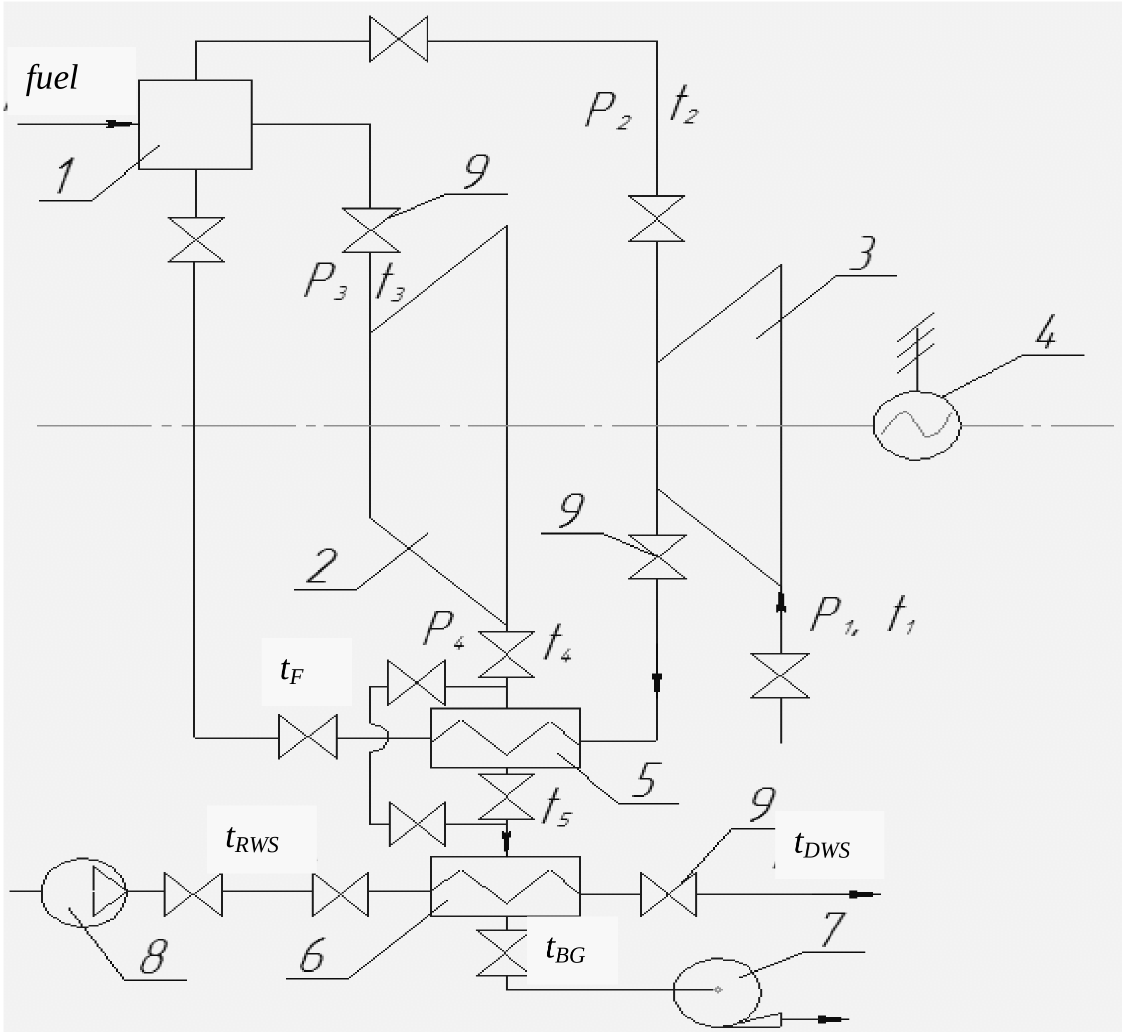

Fig.1. Principal thermal scheme of GT-HPP with heat regeneration: 1- combustion chamber, 2 – gas turbine, 3 – compressor, 4 – electric generator, 5 – regenerative air heater, 6 – heater of system water, 7 – smoke exhauster, 8 – system pump, 9 – stop valve

During the heating season the compressor of GTP (3) compresses atmospheric air with temperature t_1, in the result of which its pressure and temperature increases up to the values P_2 and t_2 correspondingly. Compressed air is fed into the combustion chamber (1) together with as-received fuel. Combustion gases (smoke fumes) with parameters P_3 and t_3 are fed to the gas turbine (2) where they are expanded up to parameters P_4, t_4 , performing mechanical work on shaft rotation, which, in electric generator (4) transforms into electric energy. Burnt-out in GTP gas at temperature t_4 is fed to the system of water heater (6), where, cooling to temperature $t_{b.g.}$, it heats the system water in cogeneration system from temperature t_{RWS} up to temperature t_{DWS} . Effluent gases are evacuated by smoke exhauster (7) to the funnel.

In between-heating season the compressed by the compressor air is first supplied to the regenerative heater (5) in which it is heated up to the temperature $t_{f,}$ and than is fed to the combustion chamber (1). Smoke gases with temperature t_4 are fed to the regenerative heater (5) where they are cooled off to the temperature t_5. Then they are fed to the system heater (6) where they heat water used for hot water supply.

The calculations of thermal schemes were executed for CTP of different capacities, of domestic manufacture, the main characteristics of which are given in table 1.

Table 1

Characteristics of CTP

Factors	GTP type/number of variant				
	ГТД-6001	ГТУ-9,5	ГТД-16	ГТД-25	ГТД-60
	1	2	3	4	5
Electric capacity, MWt	6,7	8,8	17	27,5	60
Degree of pressure increase in compressor	16,6	21,7	17,8	21,8	15
Gas temperature, °C: before the turbine, behind the turbine.	1000 415	1120 480	1000 420	1250 490	1170 490
Efficiency	0,315	0,32	0,35	0,36	0,34

The calculations were done for conditions: natural gas with calorific value of combustion 33,4 MDzh/kg^3; price of fuel – 1400 Uhr per 1000 m^3; price of released and consumed electric energy – 400 and 700 Uhr per 1 MWt·hour, correspondingly; price of released heat– 220 Uhr per 1 MWt·hour; duration of heating and between-heating seasons – 4500 and 3500 hours correspondingly; capacity part of hot water supply from total capacity of heat supply – 0,27; temperature mode of heat system operation in heating and between-heating period – 120/60°C and 80/40°C correspondingly; temperature of exhausting gases – 130°C. The calculations were done according to the methods, presented in [5]. Temperature of gases behind the heater (6) was determined from the thermal balance of the heater. The temperature of the heated air t_f was chosen upon the consideration of temperature differences between the streams (Δ t=70°C) on the gases outcome from the heater (5). The calculating factor of GT-HPP for variants, presented in table 1, are reduced to table 2.

Table 2

Operation factors of GT-HPP by the periods

Factors	Variant				
	1	2	3	4	5
heating period					
Consumption of working fuel, thousand m^3	10316,16	13337,46	23554,03	37049,43	85584,61
Expenses for fuel, Ukr. mln	11,716	18,672	32,976	51,869	119,818
Heating system capacity, MWt	10,385	14,08	22,61	37,04	88,21
Supplied heat, GWT·hour	46,7325	63,36	101,745	166,68	396,90
Income for heat, Ukr. mln	10,281	13,939	22,384	36,669	87,318
Electric energy for own needs, MWt	0,2692	0,319	0,649	0,8068	1,745
Supplied electric energy, GWt·hour	28,938	38,164	73,539	120,119	262,147
Income for electric energy, Ukr. mln	11,575	15,265	29,415	48,047	104,858
Difference between income and expenses, Ukr. mln	10,146	10,536	18,823	32,847	72,358
Between-heating period					
Hot water supply system capacity, MWt	2,8	3,8	6,1	10	23,8
Air heating in heater, °C	60	65	60	70	70
Efficiency of GTP	0,35	0,355	0,386	0,395	0,375
Working fuel consumption, thousand m^3	7219,8	92,61	16608	26,129	60303,6
Expenses for fuel, Ukr. mln	10,11	12,964	23,249	36,575	84,042
Supplied heat, GWt·hour	9,8	13,3	21,35	35,0	83,3
Income for heat, Ukr. mln	2,156	2,926	4,697	7,7	18,326

Electric capacity of own needs, MWt	0,224	0,255	0,5	0,646	1,538
Supplied electric energy, Uhr. mln	22,664	29,908	57,750	93,989	204,617
Income for electric energy, Ukr. mln	9,065	11,632	23,1	37,595	81,846
Difference between incomes and expenses, Ukr. mln	1,111	1,594	4,548	8,72	16,3
Annual difference between income and expenses, Ukr. mln	11,257	12,126	23,371	41,567	88,658

Table 2 shows that heat regeneration in between heating season, increases the GTP efficiency by 3.5%. At the same time, the economy of GT-HPP in this period decreases in the result of less production of thermal energy, so does income for it. In heating season of GT-HPP operation, the income for the supplied electric energy increases the income for heat, which is explained by higher cost of electricity in comparison with the cost of heat. In general, the GTP with higher efficiency and higher electric capacity operate more economical.

Let us compare the operation factors of GT-HPP with operation factors of heating boiler with equal thermal capacity. For an example we quote the values of main factors of heating boiler operation with boiler ПТВМ-20 for heating period, thermal capacity of which equals the thermal capacity of GT-HPP with gas turbine GTD-16 (variant 3 in table 2). During calculation there had been determined the electric power for the own needs of boiler room (vent, smoke exhauster, system pump and auxiliary pumps). Efficiency of boiler equals 0,91. Calculation results are presented in table 3.

Table 3

Boiler room operation factors

Factors	Number values
Thermal capacity, MWt	22,61
Consumption of working fuel, thousand m^3	11985,275
Expenses for fuel, Uhr. mln.	16,779
Supplied heat, GWt·hour	101,745
Income for heat, Uhr. Mln.	22,384
Electric capacity of own needs, MWt	0,308
Consumed energy, GWt·hour	1,386
Expenses for electric energy, Uhr. mln.	0,9702
Difference between income and expenses, Uhr. mln.	4,6348

Comparing operating factors of boiler room and GT-HPP with thermal capacity 22, 61 MWt, we see that the difference between income and expenses in the boiler room is four times less than in GT-HPP. This is due to the fact that in GT-HPP the income for supplied electric energy is proportional to the expenses for fuel. To achieve the similar economy in boiler room operation, the price for supplied heat must be almost doubled. Consequently, in conditions of considerable price increase for fuel and electric energy, the GT-HPP operation becomes more efficient than the operation of boiler rooms. It should also be noted that the use of GT-HPP improves the reliability of electric energy supply in the region, it overcomes the problem of electric energy losses in the electric mains and helps decreases the scarcity of electric control capacities in power supply system.

Conclusions

1. Use of heat regeneration of burnt-out gases in GTP in between-heating operation period allows to improve the GTP efficiency and conduct the operation GT-HTT with full electric loading.
2. In conditions of significant price increase for fuel and electric energy the GT – HPP operation becomes much more economical than the boiler room.

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