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THERMAL POWER STATIONS ON THE BASE OF HEATING BOILER HOUSES AND GAS TURBINE POWER PLANT

There had been determined the main factors of heating boiler house and GTP_TPS created on the base of this boiler house. There had been conducted the comparison of operating factors of boiler house and GTP-TPS.

Key words: *gas-driven turbine, gas turbine power plant, hot water boiler, exhaust- heat boiler .*

Introduction

Issues of energy saving in the process of electric energy and heat generation have become of significant importance, and efficiency of using fuel resources is of great priority, which is reflected on the legislative level [1]. This is stipulated by both, high cost of fuel as well as by low efficiency iof its use. The above stipulates for import of about 50% of required fuel, usually, of natural gas. The solution of this problem is only possible with the use of the latest technologies in the process of energy supply. Following the statistic data, the heat supply requires around 95 mil tons of equivalent fuel and only 35 tonns – for production of electric energy. It becomes obvious that the main attention in the solution of the problem of efficient use of fuel resources will be paid to the sector of heat power supply. The most perspective way of energy saving is the combined production of electric energy and heat. Today the attention is paid to the use of gas turbine power plant (GTPP). In Ukraine there had been created the necessary material base of GTPP with capacity of 2,5 – 135 MWatt, the efficient factor s of which make up 0.32 – 0.36. The modern dimension type of GTP stipulated for their operation on gas as well as on fheed fuel. Creation of gas turbine for thermal power stations (GTP - TPS) on the base of heating boiler houses does not only improve the reliability of electric power supply in the region, but also eliminates the necessity in payments for electric power losses in electric power nets. Apart from that, the creation of GTP-TPS favors the decrease in scarcity of the reserve controlling capacities in power networks. Autonomous GTP -TPS are equipped by some modules.

The equipment is of small dimensions and its installation is done without significant financial labor costs. In the majority of cases there is the remote control over the operation of power equipment as well as programming of operational models in any period. The experience in operating GTP proved that their operation is characterized by simplicity in control and low cost of the produced electric energy [2-6].

The peculiarity in the combined production of thermal and electric energy on GTP-TPS is the factor that the production of some thermal capacity Q is closely related to the production of electric capacity N. And the improvement of gas turbine power plant efficiency under condition N=const leads to the decrease in thermal capacity. The operating conditions of hot water boiler differ with significant disproportions of thermal loading in heating and between-heating periods of operation. Efficiency in GTP operation is achieved in case of its nominal loading. In view of this the expedient variant in creation GTP-TPS is the case, when GTP operates at full electric capacity 24 hours and ensures the constant capacity of hot water supply fro the exhaust boiler.

The above caused the task to determine the operating factors of GTP-TPS for the described variant.

The main results

Fig. 1 presents the principal diagram of GTP-TPS, created on the base of water heating boiler house. The system for thermal supply is a two-pipes one of the closed time. The calculation temperature of the direct and reverse net water is chosen to be equal 120° and 60°C correspondingly. Gas turbine election of the boiler house includes compressor (11) combustion chamber (12), gas turbine (13), electric energy generator (14) and exhausting boiler (15). There had been considered the two-season GTP-TPS operation. The water heating boiler and GTP were operating during the heating period. During the between-heating period there had been operating only GTP with the exhaust boiler. The pomp (9) pumps the reverse net water through the exhaust boiler which is heated from 60° up to 120°C and is directed into the line of the direct net water. This water in heater (8) heats the water supplied to the consumers. The heating and between-heating periods were 4500 and 3700 hours correspondingly. Fuel natural gas with the burning heat of $Q_н^р = 33{,}4$ MDz/m^3 and at price of 1400 Uhr. per 1000 m^3. The cost of the consumed and released electric energy is 700 Uhr and 450 UHr per MWatt/Hour correspondingly. The cost of the released heat is 300 UHr per 1 MWatt/Hour. Electric capacity of the own needs in boiler house and GTP-TPS had been determined according to methodics, presented in [7].

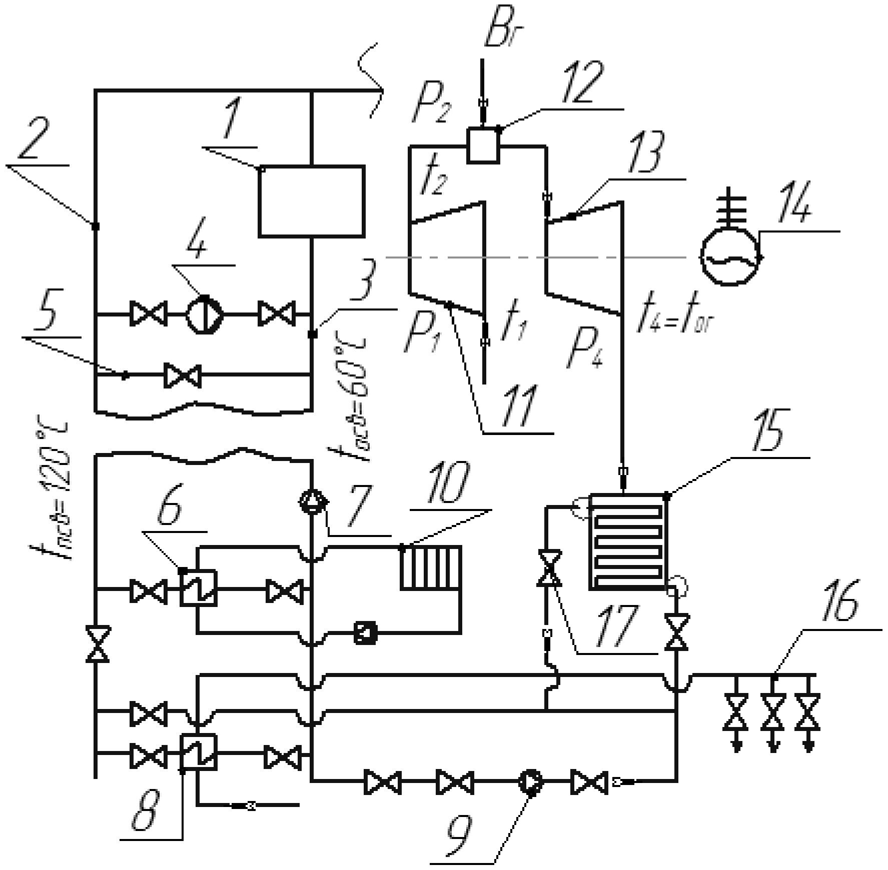

Fig. 1. Principal diagram of the boiler house of GTP-TPS with the closed system of heat power supply:
1 – hot water boiler; 2 – line for direct net water; 3 – line for the reverse net water; 4 – recirculating pump; 5 – line of transfer; 6 – net heator of the heating system; 7 – net pump;
8 – water heater for the hot water supply system; 9 – pump; 10 – heating system consumers;
11 – GTP compressor; 12 – combustion chamber; 13 – gas turbine; 14 – electric generator; 15 – exhaust boiler; 16 – hot water consumers; 17 – stop valve

For an example we consider the operating factors of water heating boiler and GTP-TPS with thermal capacity $Q_{тф} = 48$ MWatt. The heating capacity makes up $Q_{от} = 35$ MWatt and the capacity of hot water supply makes up $Q_{гвс} = 13$ MWatt. The boiler house has typical water heating boilers ПТВМ-30 with nominal capacity of

$Q_н = 34{,}7$ МВт and efficiency factor $\eta_к = 0{,}915$. During the heating period the two boilers with the loading factor $k_з = Q_{тф}/(2 \cdot Q_к) = 48/(2 \cdot 34{,}7) = 0{,}69$ must be operating. In this case the efficiency of boilers decrease and make up 0,89.

In between heating period only one boiler is working with the loading factor $k_з = Q_{гвп} / Q_к = 13/34,7 = 0,37$. The boiler efficiency decreases significantly and equals only 0,7. The factors of boiler operation had been calculated according to [7] and the value are reduced in table 1.

Table 1

Operating factors of water boiling boiler house

Factor	Values
Heating period	
Fuel consumption, thousands m^3	25868,262
Fuel cost, mln. UHr.	36,215
Electric capacity for own needs, MAwtt	1,82
Consumed electric energy, MWatt/Hour	8190
Electric energy costs, Mln. UHr	5,733
Electric energy supply costs, Mln. UHr.	41,948
Released thermal energy, MWatt/Hour	216000
Income for the released heat, Mln. UHR	64,8
Difference between income and costs, Mln. UHr.	22,852
Specific consumption of equivalent fuel for production of the unit of energy, kg/GDz	37,92
Between heating period	
Fuel consumption, thousands m^3	7512,48
Fuel cost, mln. UHr.	10,517
Electric capacity for own needs, MWatt	0,77
Consumed electric energy, MWatt/Hour	2849
Electric energy costs, Mln. UHr	1,994
Electric energy supply costs, Mln. UHr.	12,511
Released thermal energy, MWatt/Hour	48100
Income for the released heat, Mln. UHR	14,432
Difference between income and costs, Mln. UHr.	1,921
Specific consumption of equivalent fuel for production of the unit of energy, kg/GDz	49
Year operating period	
Fuel cost, mln. UHr.	46,732
Costs for consuming electric energy, Mln. UHr.	7,727
Electric energy supply costs, Mln. Uhr.	54,459
Income for the released heat, Mln. UHR	79,232
Difference between income and costs, Mln. UHr.	24,773
Specific consumption of equivalent fuel for production of the unit of energy, kg/GDz	42,9

Table 1 shows the efficiency in boiler house operation during the heating period. This is explained by both, smaller operation period in between-heating period, as well as relative increase in fuel consumption per boiler, which is stipulated by significant decrease in efficiency of the boiler due to its low loading.

Operation of GTP- TPS requires to select the type-size of the gas turbine under condition that the capacity exhausting boiler must be equal to the capacity of hot water supply, that is $Q_{ку} = Q_{гвс}$. We select (with further specification the approximate gas turbine plant of the ГПУ-10-А type with characteristics electric capacity $N_э = 10$ MWatt, gas temperature behind the turbine $t_4 = 450$ °C; efficiency factor $\eta_г = 0,35$. In accordance [7] we determine.

Consumption of operating fuel per turbine, m^3 / sec

$$B_г = N_э /(\eta_г \cdot Q_н^р) = 10/(0,35 \cdot 33,4) = 0,8554. \quad (1)$$

Capacity of the exhausted in GTP gases, MWatt

$$Q_{ог} = (1-\eta_г)\cdot N_э/\eta_г = (1-0{,}35)\cdot 10/0{,}35 = 18{,}5714. \quad (2)$$

Gas temperature behind the exhausting boiler we accept 85°C higher the temperature of the reverse net water, that is $t_{ку} = 60^0 + 85^0 = 145^0 C$.

Factor of gas heat exhaustion in exhausting boiler

$$\psi = (t_4 - t_{ку})/(t_4 - t_{ос}) = (450-145)/(450-15) = 0{,}7014, \quad (3)$$

where $t_{ос}$ – temperature of the environment which, following the international rules makes ups 15°C.

Heat capacity of exhausting boiler, MWatt

$$Q_{ку} = Q_{ог}\cdot\psi = 18{,}5714\cdot 0{,}7014 = 13{,}02. \quad (4)$$

Since the capacity of exhausting boiler equals the capacity of hot water supply, the chosen GTP type suits the creation of GTP-TPS on the base of water heating boiler house, and further specification are not necessary.

Thus, the capacity of hot water supply system in heating and between-heating period of GTP-TPS operation is ensured by exhausting boiler of the chosen gas turbine power plant. During the heating period the capacity of heat power supply of 48 MWatt is provided by the operation of one boiler ПТВМ-30, operating under nominal loading, and operation of ГТУ-10-А with exhaust boiler. Operating factors of GTP-TPS are shown in table 2.

Таблица 2

Factors of GTP-TPS operation

Factor	Числовые значения
Heating period	
Fuel consumption, thousands m^3	32410
Fuel cost, mln. UHr.	45,374
Electric capacity for own needs, MAwtt	36810
Consumed electric energy, MWatt/Hour	16,564
Electric energy costs, Mln. UHr	64,8
Electric energy supply costs, Mln. UHr.	35,99
Released thermal energy, MWatt/Hour	
Income for the released heat, Mln. UHR	39,2
Difference between income and costs, Mln. UHr.	
Specific consumption of equivalent fuel for production of the unit of energy, kg/GDz	
Between heating period	
Fuel consumption, thousands m^3	13834,8
Fuel cost, mln. UHr.	19,368
Electric capacity for own needs, MWatt	34151
Consumed electric energy, MWatt/Hour	15,368
Electric energy costs, Mln. UHr	14,432
Electric energy supply costs, Mln. UHr.	10,432
Released thermal energy, MWatt/Hour	
Income for the released heat, Mln. UHR	42,32
Difference between income and costs, Mln. UHr.	
Specific consumption of equivalent fuel for production of the unit of energy, kg/GDz	
Year operating period	

Fuel cost, mln. UHr.	67,742
Costs for consuming electric energy, Mln. UHr.	31,932
Electric energy supply costs, Mln. Uhr.	79,232
Income for the released heat, Mln. UHR	43,422
Difference between income and costs, Mln. UHr.	
Specific consumption of equivalent fuel for production of the unit of energy, kg/GDz	40,6

Comparing the data in tables 1 and 2 we see that the value of the year specific consumption of equivalent fuel for producing the unit the energy in GTP-TPS is by 5,66 % lower than in the boiling house. The economic efficiency in creation of GTP-TPS is emphasized by the year difference between the income for energy bearers and expenses for fuel which in GTP-TPS is 1,75 times higher, then is boiler house. It mostly concerns the between-heating period, when it 5 times higher. It should be noted that the creation of GTP-TPS on the base of heating boiler houses does not only solve the problem of electric energy scarcity in specific region, but also improves the reliability of electric power supply, since the latter is executes on the place of its consumption and does not concern the electric power losses in electric power lines. For the simplification in choosing the gas turbine power plan t for the creation of GTP-TPS according to the suggested scheme, table 3 presents the main characteristics and thermal capacities of some GTP, which are manufactured by native energy machine engineering enterprises.

Table 3

Characteristics of GTP and capacities of exhausting boilers

Factors	Types of GTP				
	ГТД-2500	ГТД-6001	ГПУ-10-А	ГТД-16	ГТД-25
Electric power capacity, MWatt	2,85	6,7	10	17	27,5
Gas temperature, °C:					
Before the gas turbine;	950	1000	1120	1000	1250
Behind the gas turbine	445	415	450	420	490
Efficiency factor	0,285	0,315	0,34	0,35	0,36
Consumption of operating fuel, kg/s	0,390	0,7259	1,004	1,657	2,607
Factor of heat exhaustion in exhausting boiler					
Capacity of exhausting boiler, MWatt	0,697	0,675	0,7014	0,679	0,726
	5,01	9,834	13,02	21,437	35,508

Conclusions

1. Thermal power stations on the base of water heating boiler house may easily be created from energy equipment, which is manufactured in series by the native energy machine engineering enterprises.

2. Creation of GTP-TPS, which operates within the year within the nominal capacity, is quite appropriate, since it ensures the income 1.75 times higher than that in the boiler houses.

REFRENCES

1. Закон України. Про комбіноване виробництво теплової та електричної енергії (когенерацію) та використання скидного потенціалу // Відомості Верховної Ради, 2005. – № 20. – С. 278 – 285.

2. Котлер В. Р. Мини-ТЭЦ: зарубежный ответ / В. Р. Котляр // Теплоэнергетика, 2006. – № 8. – С. 69 – 72.

3. Евенко В. И. Анализ топливной экономичности газотурбинных ТЭЦ / В. И. Евенко // Теплоэнергетика, 2006. – № 10. – С. 74 – 78.

4. Басок Б. И. Сравнительный анализ решений когенерационных установок / Б. И. Басок, Д. А. Коломейко // Промышленная теплотехника, 2006. – т. 28. – № 5. – С. 77 – 82.

5. Демидов О. И. Использование газотурбинных установок при реконструкции ТЭЦ промышленно-отопительного типа / О. И. Демидов, А. Г. Кутахов, В. М. Корень // Промышленная энергетика, 2004. – № 2. –

С. 19 – 25.
6. Чепурной М. Н. Теплофикационные когенерационные установки на базе ГТУ / М. Н. Чепурной, В. В. Бужинский, В. А. Рейсиг // Промышленная теплотехника, 2002. – т. 24. – № 6. – С. 47 – 50.
7. Чепурний М. М. Енергозбережні технології в теплоенергетиці / М. М. Чепурний, С. Й. Ткаченко. – Вінниця: ВНТУ, 2009. – 114 с.

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