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GAS TURBINE THERMAL POWER STATIONS WITH THERMAL PUMP PLANTS

There had been analyzed the expediency of using the thermal plants with gas turbine thermal power station with more advanced utilization of heat from the combustion products exhausted by GTP.

Key words: *gas driven turbine, utilizing boiler, thermal power station, thermal pump plant, gas cooler, compressor, evaporator, condensator.*

Introduction

Today, when the price for organic fuel, especially for natural gas, goes up, energy efficiency becomes one of the most urgent tasks. The necessity in development of energy efficient technologies is stipulated for by the availability of high potential for introduction of such technologies in Ukrainian industry as well as by the tendency of fuel price increase.

The most efficient energy saving means in heat and power engineering is the combined production of heat and electric energy [1 – 3]. Much attention is paid to the use of gas turbine power plant (GTPP) [4 – 6]. In Ukraine there had been created the necessary material base for application of gas turbine technologies (firm “Zaria”, the city of Nikolaev, SIC “Turboatom”, the city of Kharkiv; JSC “Motorsich”, the city of Zaporizhzhya). These enterprized had developed and manufactured GTPP with the capacity of 2.5 – 135 MW with efficiency factor up to 0.36. The modern GTPP standard sizes stipulate for the operation on both, gas as well as other kinds of fuel.

The experience in construction and operation of first GTPP TPS [2] states that they are reliable, simply operated, have low cost of produced energy. The equipment of these TPS has small dimensions, its assembly is realized without significant financial and labor expenditures. In majority of cases there is the remote control over the operation of equipment as well as programming the mode of its operation.

There two main variants of GTPP-TPS application. The first variant means that the necessity in electric energy is provided by GTPP and the necessity in heat – partially by the utilization of the exhausted by GTPP gas and the rest-by boiler. In the second variant the necessity in heat is totally ensured by the utilization of heat from the exhausted by GTPP gas, and the electric energy, produced by GTPP is used for the own needs and for power network [7].

The peculiarity of the combined production of the electric energy by GTPP-TPS is the fact that thermal capacity, supplied to the consumers, is connected with the electric capacity. It should also be noted that the increase in GTPP efficiency at preset electric power leads to the decrease in production of thermal energy, and decrease in GTPP efficiency under condition N = const leads to the increase in production of heat and to fuel consumption increase. Production of heat depends on the degree of utilization of heat from the exhausted by GTPP gas, which, in turn, depends on the temperature of gas on the utilizing boiler output. Depending on the temperature of the reverse net water, the temperature behind the utilizing boiler may be relatively high and the utilizing factor, correspondingly, small. Therefore the additional gas cooling behind the utilizing boiler favors the increase in heat production and efficiency in use the fuel heat.

The task of the temperature decrease behind the utilizing boiler may be realized by additional gas cooler and thermal pump plant (TPP).

Proceeding from the above -mentioned the task was set to evaluate the efficiency of GTPP-TPS operation with the additional gas cooling in TPP for the native GTPP of small capacity, which are produced in series by the enterprise “Zoria” (the city of Nikolaev). GTPP characteristics are presented in Table 1.

Table 1

GTPP characteristics

Factors	Type of GTPP / № of variant			
	ГТД-2,5	ГТД-6	ГТД-16	ГТД-25
	1	2	3	4
lectric capacity, MW	2,85	6,7	17	27,5
Gas temperature, ^{0}C:				
before the turbine,	950	4000	1100	1250
behind the turbine	445	420	420	490
Efficiency factor	0,285	0,315	0,35	0,36
Consumption of coal equivalent , kg/s	0,3413	0,7260	1,6577	2,6070

Main results

Flow diagram of GTPP-TPS with the additional gas cooling behind the utilizing boiler and TPP is shown in Fig. 1.

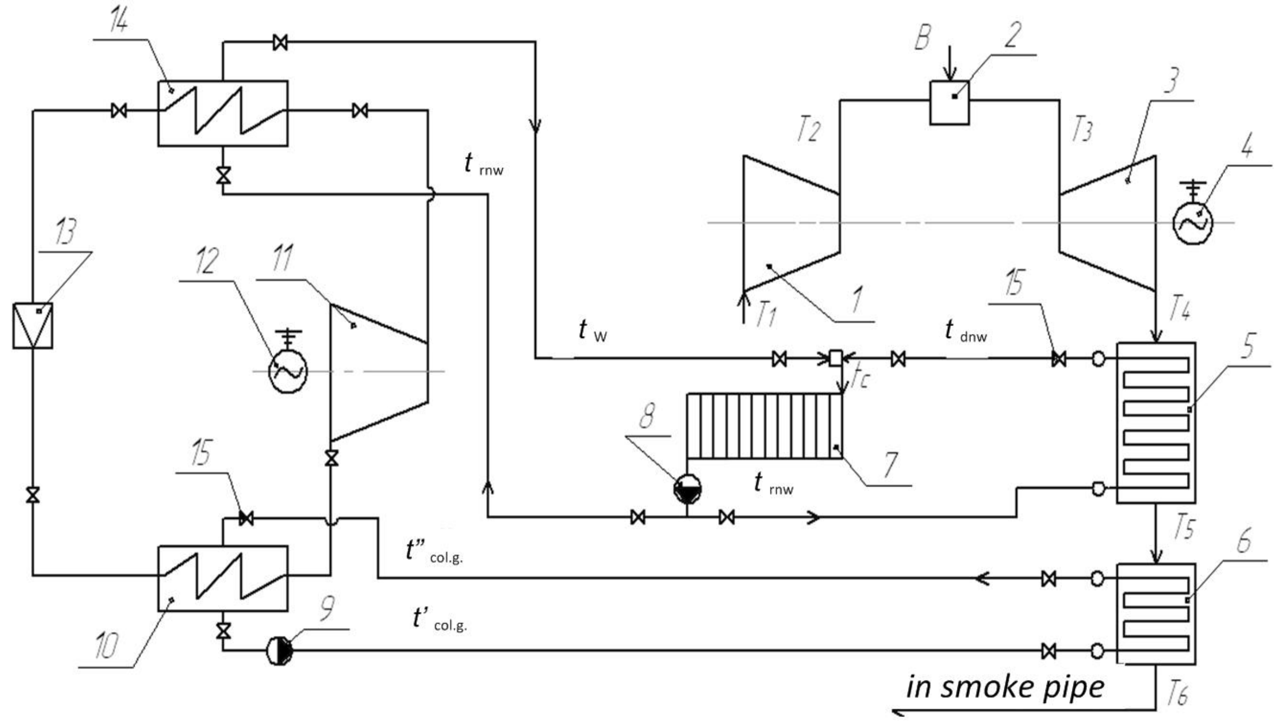

Fig. 1. Heat diagram of GTPP-TPS with thermal pump plant: 1 – compressor ; 2 – combustion chamber; 3 – gas driven turbine; 4 – electric generator; 5 – utilizing boiler; 6 – gas cooler; 7 – heat consumers; 8 – net pump; 9 – circulating pump; 10 – evaporator; 11 – compressor of TPP; 12 – electric motor; 13 – throttle device; 14 – condenser; 15 – stop valve

Water, which cools the smoke gas from temperature T_5 to temperature T_6 is pumped by circulating pump 9 through the additional gas coolant. The circulating water is heated up from the temperature $t^{/}_{col.g.}$ to temperature $t^{//}_{col.g.}$. The heated up water is supplied to evaporator of TPP 10, where it evaporates the cooling agent of TPP. The exhausted in GTPP combustion products (smoke gas) are supplied to utilizing boiler 5, where they warm the net water from temperature t_{rnw} up to the temperature t_{dnw}. The part of reverse net water is supplied to the condenser of TPP 14. In condenser the reverse net water is heated up to the temperature t_{ev}, after which it is directed to the line of direct net water. The mixture of water with temperature t_m is supplied to heat consumers 7. Efficient utilizes are used for the utilization of the heat of smoke gas [8, 9].

It is known [10] that the TPP efficiency operation is evaluated by factor of energy transformation (heating factor) φ, which equals the correlation between capacity of condenser and the capacity of the compressor. Values of φ depend on the average thermodynamic temperature of heat carrier in the evaporator and condenser [10]. Therefore, first there had been analyzed the operation efficiency of ammonia vapor TPP with different temperature of circulating water in evaporator on condition that the temperature of the warm water on the condenser output equals 80 ^{0}C. The calculating values of TPP operating factors are presented in Table 2.

Table 2

Factors of TPP operation

Factors	Variants			
	1	2	3	4
Water temperature, ^{0}C:				
on the evaporator input	35	40	45	50
on the evaporator output	20	25	30	35
Specific heat, supplied to the evaporator, KJ/kg	880	880	880	880
Specific compressor operation, KJ/kg	342	317	293	258
Specific heat, taken from condenser, KJ/kg	1222	1197	1173	1138
Factor of energy transformation	3,573	3,776	4,003	4,41

Table 2 shows that on condition of equal heat, supplied to the evaporator, and equal temperature water on the condenser output, the factor of energy transformation in TPP increases with the increase of water temperature on the evaporator input.

Following the techniques [7] there had been determined the operating factors of GTP-TPS with gas driven turbines, characteristics of which are reduced in Table 1. The calculations are performed for the heating period which lasts for 4500 hours. The calculations accept: fuel – natural gas with heat of combustion 33.4 MJ/m^3; gas temperature behind the utilizing boiler 170 ^{0}C; temperature mode of heating net is 120/60 ^{0}C; fuel price is 2000 Hrs per 1000 m^3 ; the price for the released heat and electric energy, is 250 and 700 Hrs per 1 MW/hour correspondingly. The results of the calculations are shown in Table 3.

Table 3

Operating factors of GTP-TPS

Factors	Variants			
	1	2	3	4
Capacity of utilizing boiler, megawatt	4,571	9,0	19,482	32,929
Discharge of smoke gas, kg/sec	14,67	32,01	69,38	90,38
Released heat, MW/h.	20565	40473	87660	140180
Income for the heat, mln.hrs.	5,141	10,118	21,915	37,045
Electric capacity of own needs, KWatt	31,125	60,346	130,460	151,802
Released electric energy, MW/h.	12684	29878	75913	123067
Income for the electric energy, mln. hrs.	8,879	20,914	53,139	86,116
Fuel discharge, thousand. m^3	4860	10319	23538	37049
Expenditures on fuel, mln. hr.	10,692	20,638	47,076	74,010
Difference between income and expenditures, mln. hr.	3,328	10,380	28,013	49,181
Specific consumption of fuel equivalent per unit of the produced energy, kg/GJ	45,99	46,24	45,43	43,12

The calculations of GTPP-TPS operation with the additional gas coolant and thermal pump plant, which operated according to the variant 3 in Table 2, are shown in Table 4. It was assumed that the gas temperature behind the gas coolant is 105^{0}C.

Table 4

Operating factors of GTPP-TPS with TPP

Factors	Variants			
	1	2	3	4
Capacity of gas coolant , MW	1,028	2,266	4,907	6,610
Released heat,MW/h	25191	50670	109741	178105
Income for heat, mln. hrs.	6,297	12,667	27,435	44,526
Capacity of compressor of TPP, KW	248	555	1377	1701
Electric capacity of own needs, KW	296	654	1601	1968
Released electric energy, MW·/h.	11452	27207	69295	114894
Income for the electric energy, mln. hrs.	8,016	19,045	48,506	80,425
Difference between income and expenditures,mln. hrs.	10,692	20,638	47,076	74,010
Specific consumption of coal equivalent per unit of the	3,621	11,074	28,865	50,911
produced energy, kg/GJ	40,03	40,04	40,0	38,80

Comparing the factors of GTP-TPS operation, shown in Tables 3 and 4, we see that GTPP with thermal pump plants and additional gas cooling behind the utilizing boiler operate more efficiently. Despite the increase in capacity of own needs and decrease in releasing electric energy into the power network, the total income for the released energy increases by 10-11% due to an increase in thermal capacity and income for the released heat. The specific discharge of coal equivalent for the production of energy unit decreases by approximately the same value. The calculations show that when GTPP-TPS operate with thermal pump plan according to the fourth variant in table 2, the operating efficiency increases by 15-16% which allows t economize fuel by the same value.

Conclusions

1. Creation of GTPP-TPS with additional gas cooling and thermal pump plants improves efficiency of fuel usage.

2. Operating efficiency of GTPP-TPS increases with the increase of energy transformation factor in TPP.

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