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HEAT RECOVERY OF EXHAUST GAS FROM GAS AND STEAM PLANT ON GAS-COMPRESSOR UNITS

There had been determined the conditions for creation of thermoelectric power stations (TEPS) with gas power generating units on gas – compressor units. There had been considered their operation efficiency factor.

Key words: *gas turbine,steam turbine, gas and steam plant, boiler-utilizer.*

Introduction

The prospects of using gas and steam plants (GSP) in heat – and – power engineering has recently become generally recognized [1 – 5]. Creation of GSP on the base of gas turbine plants (GTP) allows to increase the production of electric energy, improve the use of fuel and decrease the amount of emission into the atmosphere. In Ukraine there had been created the necessary material base for implementing gas and stem technologies into power sector of national economy. The material engineering enterprises in the cities of Mykolaiv, Kharkiv, Zaporozhia have developed and manufacture, GTP with capacity ranging from 2,5 up to 135 MW with efficiency factor from 0,3 up to 0,36, which allow to ensure the necessary efficiency, small specific cost, operating expenses and concentration of harmful emissions into the environment. The operation of modern GTP is characterized by rather high (400 – 500 ^{0}C) temperatures of the exhaust gas from gas turbines. Therefore the use of such GTP in power engineering stipulates first of all for heat utilization of exhaust gas from GTP, which allows to achieve the significant saving on the fuel.

Gas industry is one pf the largest consumer of natural gas, the cost of which constantly grows. Therefore the issues, relating to its efficient use need adequate attention. Today the heat of exhaust gas in GTP on gas-compressor units in practically not used [6]. One of the ways for saving gas with simultaneous increase in electric capacity of power supply system as well as decrease in price cost for gas transportation is to apply the gas and steam plants, which operate according to the binary cycle. The gas-compression units operate aggregates manufactured in 80s of the previous century, which are now replaced by modern. The characteristics of the latter are given in table 1. GSP on the base of gas- compressor unit may be created in case of heat recovery from the exhausted in GTP gases in utilizing boilers (UB) which generate water steam with certain pressure P_{UB} and temperature t_{UB}. Types and designs of UD are shown in [7].

Table 1

Characteristics of some GTP for gas – compressor installations

Indices	Type of gas –pumping unit		
	GSP-10A	ГПА-Ц-16А	GSP-25
Net power, MW	10	16	25
Degree of pressure increase in compressor	17	18,1	21,8
Efficiency factor	0,34	0,34	0,35
Gas temperature, ^{0}C:			
before the turbine;	1120	1183	1220
after the turbine	480	480	485

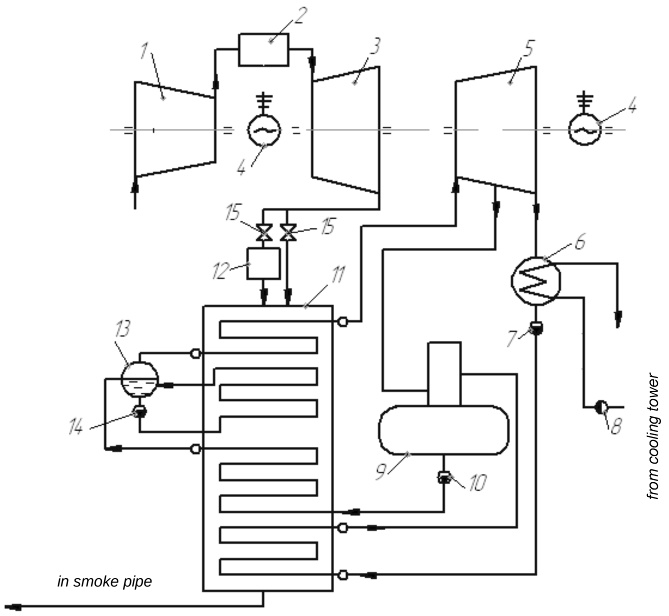

Fig. 1. Principal thermal diagram of GSP: 1 – compressor; 2 – combustion chamber; 3 – gas turbine; 4 – electric generator; 5 –steam turbine; 6 –condenser; 7 –condensate pump; 8 – circulating pump; 9 – deaerator; 10 – feeding pump; 11 – boiler- utilizer; 12 – device for additional fuel burning ; 13 –separator drum; 14 – recirculation pump; 15 – gate

Utilizing boiler is fit with the device – block for additional fuel burning (BAB) which, if necessary, helps increase the temperature of the exhausted in GTP gases in the utilizing boiler input. Final burning is done without the additional air supply to the environment of the used products of fuel burning. The latter [3 – 6] are known to be balassed by combustion products oxidizer, which contains from 13 to 15% of oxygen. Such a method for additional burning of gas like- fuels considerably decreases the formation of nitric oxide [8].

Water steam, produced in utilizing boiler, enters the steam turbine, where it expands up to the final pressure P_f performing the mechanical work on rotating the shaft with electric power generator. Steam, exhausted from the turbine is fed to the condenser where it is condensed and pumped to the utilizing boiler by the condensing pump. Thus, the combined gas and steam plants with binary (gas and steam) cycle is created on the base GTP, the principal diagram of which is presented in Fig. 1.

The aim of the given research was to determine the indices of GPU, developed on the base of GTU, used at gas-pumping stations, their characteristics are given in Table1.

Main results

For the utilization of heat from the exhaust in GTP gases and generation of water steam there had been chosen the utilizing boiler of the КГТ-50/39-50 type, which generates the overheated steam with parameters P_{UB} = 3,9 MPa, t_{UB} = 440 ^{0}C. The turbine К-11-10 П with electric capacity of 12 MW is chosen as steam-turbine drive of electric power generator. Steam parameters before the turbine equal P_0 = 3,5 MW, t_0 = 435 ^{0}C. The system of technical water supply system – reverse with cooling tower. The final steam pressure on the condenser input makes up 5 кPa. Deairation of the feeding water is done in the deairator of atmospheric type, which is fed by steam from turbine with pressure 0,12 MPa. To provide the recommended temperature difference between heat transfer agents [7], the temperature of gas from BAB on the input of utilizing boiler is 540^{0}C, and on the output from utilizing boiler – 133 ^{0}C. It is clear, that to achieve temperature of 540 ^{0}C, it is necessary to burn additional fuel D_A in BAB, or certain portion of $\delta = D_A/D_{GTP}$, where D_{GTP} – fuel expenditure for GTP. The value D_A was determined from the balance equation of BAB.

$$G_{DG} \cdot h_{EG} + D_A \cdot Q_н^p = \left(D_A + G_{DG}\right) \cdot h_{UB}^{/}, \qquad (1)$$

where G_{DG} –expenditure of the exhausted gas in GTP; h_{EG} and $h_{UB}^{/}$ - enthalphy of the exhausted in GTP gases and combustion products after BAB (on the input of utilizing boiler) correspondingly; $Q_{н}^{р}$ - burning heat of fuel.

The right part (1) is thermal power of combustion products in the input to utilizing boiler $Q_{UB}^{/}$. Thermal power, utilized in utilizing boiler (capacity of utilizing boiler) equals

$$Q_{ut} = Q_{UB}^{/} \cdot \psi \ , \tag{2}$$

where $\psi = \left(t_{UB}^{/} - t_{UB}^{//}\right) / \left(t_{UB}^{/} - t_{EA}\right)$; $t_{UB}^{/}$ and $t_{UB}^{//}$ - gas temperature on the input of utilizing boiler and on its output correspondingly; t_{EA} - temperature of environmental air, which, in accordance with ISO-23-14 equals 15 ^{0}C.

Fuel – natural gas with combustion temperature 33,4 MJ/m^3. The methods for calculation of GSP without the additional burning of fuel and with additional burning of fuel in BAB is presented in [3]. Calculation results of GSP for selected types of GTP, utilizing boiler and steam turbine are given in the table 2. Calculations of nitric oxide and carbon dioxide emissions are performed according to techniques [9, 10].

Table2

Operational indices of gas steam plants

Indices	Type of GTP		
	GSP-10A	ГПА-Ц-16А	GSP-25
Fuel consumption on GTP, m^3/c	1,00	1,608	2,44
Exhausted gas expenditure in GTP, kg/c	36,91	57,5	82,1
Exhausted gas power in GTP, MW	19,41	31,06	46,428
Additional fuel expenditure in BAB, m^3/c	0,128	0,182	0,211
Portion of additional fuel expenditure (δ)	0,128	0,114	0,0866
Total fuel expenditure in GSP, m^3/c	1,128	1,788	2,651
Total consumption of equivalent fuel in GSP , kg/c	1,285	2,038	3,02
Gas power at the input to utilizing boiler,MW	23,578	36,738	52,444
Heat utilization factor of combustion product (ψ)	0,775	0,775	0,775
Thermal capacity of utilizing boiler, MW	18,36	28,61	40,80
Steam expenditure in utilizing boiler, t/hour	23,04	35,82	46,8
Electric capacity of steam and turbine plants (STP), MWt	5,9	9,1	12,9
STP efficiency	0,34	0,34	0,34
Specific consumption of equivalent fuel for producing electric energy in GSP, kg/(kW·hour)	0,291	0,292	0,285
STP efficiency	0,4226	0,4212	0,4315
Efficiency increase relating to STP efficiency, %	8,26	8,12	9,15
Annual saving of equivalent fuel, t	10145	16510	25240
Annual saving of oxygen, t	13695	22230	33932
Annual decrease in emission of nitric oxide, t	2205	3588	5486
Annual decrease in emission of greenhouse gas, t	925,1	1485,9	2271,6

The obtained results show that the usage of thermal electric power stations (TEPS) with gas and steam plants, created on the base of gas pumping units with gas and turbine plants is quite expedient. Such TEPS allow to generate the significant electric capacities with the efficiency factor that 8 – 9 % exceeds efficiency factor of thermal electric power stations. Gas pumping stations are usually equipped with three (two operating and one reverse) gas pumping units driven by gas turbine. TEPS with two units of ГПА-10 А type allow to produce 11,8 MW of electric capacity; TEPS with ГПА-Ц-16 А – 18,2 Mw and TEPS with ГПУ-25 – 24 MW. The portion of additional fuel burning does not exceed 0,13, which, in accordance with [3], corresponds to its optimal values.

Increase in efficiency of GSP in comparison with the efficiency of TEPS stipulates for significant economy of conditional fuel , which, in its turn, decrease the emissions of nitric oxide and carbon dioxide into atmosphere. It should also be noted that the increase in electric generating capacities in energy system solves the problem of scarcity of maneuvering capacities and electric energy in the region, as well as improves the reliability of electric power supply, since generation of electricity is performed on the place of its consumption and is not connected with significant losses while its transmission in transmission lines.

Conclusions

1. Creation of thermal electric power stations with gas and steam units is easy to realize on the base of energy equipment, which is manufactured and operated.

2. The usage of gas and steam units on gas pumping stations allow to increase the maneuvering energy generating capacities in energy system.

3.The usage of heat from the exhausted combustion products in gas turbine plants increases the efficiency of its use, stipulates for its economy and decrease in contaminating emissions into the environment.

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