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STUDY OF THERMAL SCHEMES AND CONSTRUCTIVE CHARACTERISTICS OF ENERGY GAS TURBINE UNITS

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Abstract. The paper studies the thermal schemes and construction characteristics of gas turbine units. The pros and cons of the considered turbines are compared with steam turbine units. At the same time, the amount of nitrogen gas coming out of the gas turbine and a steam turbine of the same power is calculated and a comparative analysis is given. It is found that the amount of nitrogen gas coming out of the gas turbine is 4 times less than that of the steam turbine.

Keywords: gas turbine, thermal schemes, exhaust gases, nitrogen oxide.

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1 Introduction

Modern gas turbine units (GTU) consist of an air compressor, a combustion chamber, a gas turbine, and auxiliary systems. (GTS) together with an electric generator is called a gas turbine unit. There are different types of gas turbine units. A simple scheme of the most used (GTU) in energy is shown in Figure 1.

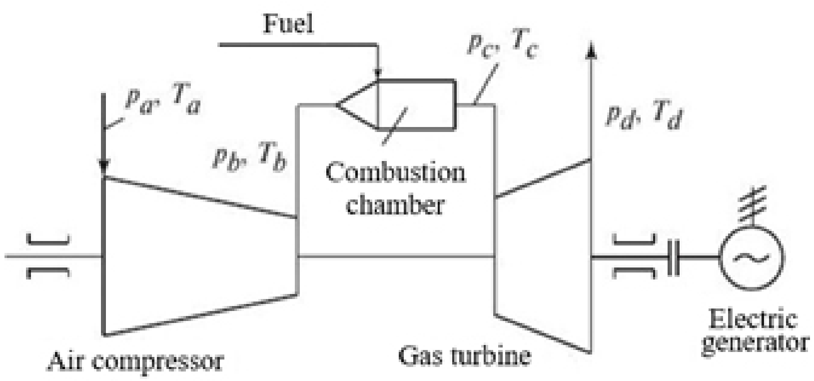

Figure 1: A simple scheme of a gas turbine installation

Air from the atmosphere is blown into the compressor, and compressed, increasing the pressure and temperature, and then it is separated into two streams. The first stream and fuel

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(gas) are fed to the igniters there at the same time. The high-temperature combustion products obtained are mixed with a relatively low-temperature second stream. In this case, the temperature of the gases is taken according to the metal of the gas turbine. In a gas turbine, the kinetic energy of gases is converted into mechanical energy, and in a generator, mechanical energy is converted into electrical energy. Gases from the gas turbine are either injected into the smokestack or used as a secondary resource. Schemes of modern gas turbine units are shown in Figure 2 (Tsanev et al., 2009; Olkhovsky, 1985).

The thermal schemes of GTU depend on the parameters of thermodynamic cycles (Cycle Brayton). That is, air heating, step heating of fuel and its application, regenerative heating of air, etc. In Figure 2 a, the compressor, gas turbine, bar, and generator are located on one shaft, and the electric generator is connected to the cold side of the compressor.

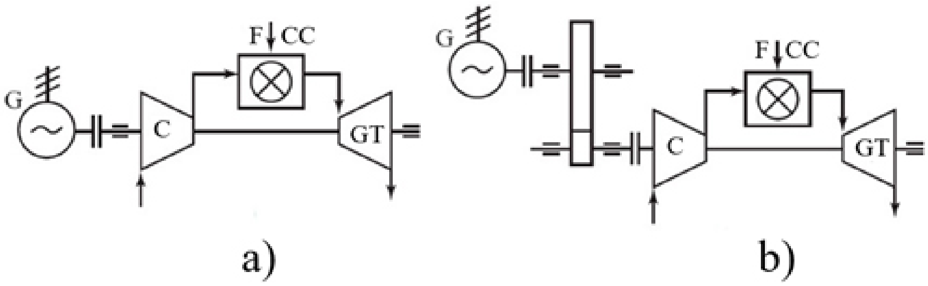

Figure 2: G-generator, F-fuel, CC-combustion chamber, GT-gas turbine, C-compressor, LPC-low pressure compressor, HPC-high pressure compressor, HPE-high pressure engine, LPE-low pressure engine, AI-air intercooling, GT-power gas turbine

In the 2 v scheme, when the power units work with a high number of cycles (n=5000, 10000 cycles/minute), a reducer is installed to connect the devices to the generator.

Schemes of the GTU working with multi-stage compression of air and expansion of gases are shown in figure 2 b,g,e. In this case, high-pressure units (HPC and HPU) are built on a shaft, and the movement from it drives the generator through a power gas turbine (GT) (2.v). The generator is usually connected to the cold side of the compressor (Fig. 2 c,d). Sometimes a generator is connected to the low-pressure part of the gas turbine (Fig. 2.e).

The gas turbine unit has several positive and negative aspects. First, GTU is compact. This unit has no tall steam boiler that requires a separate building. The combustion process in the gas turbine combustion chamber occurs at a pressure of 1.2-2 MPa. The combustion process in the hearth of the steam boiler takes place at atmospheric pressure, which increases the number of hot gases received by 12-20 times. In a gas turbine, the expansion occurs in 3-4 stages, while in a steam turbine, the same power is obtained in 3-4 cylinders and 25-30 stages. Even considering the compressor and the combustion chamber, the length of the 150 MW GTU is 8-12 m. The length of a three-cylinder steam turbine of such power is 1.5 times more than this one.

In addition to these, the steam turbine includes a condenser, a condensate pump, a circulation pump, and a regenerative system.

The gas turbine is in the engine room at the zero point on a concrete foundation, while the steam turbine is built with its auxiliary equipment on a 9-16 m high frame foundation. The gas turbine does not require water for cooling and is air-cooled. Gas turbine cooling is a very complex system. This is a strongly branched system and arranged in so that air must be supplied to each cooling element in such a way that a favorable temperature is created in that part. On the one hand, too much cooling of the parts is also harmful, so a lot of power is required to compress the cooling air into the compressor. On the other hand, when too much air is given to the cooling, the temperature of the gases coming out of the gas turbine decreases, which seriously affects the operation of the equipment. To cool the components of modern gas turbines, air is taken from different stages of the compressor. Water vapor, which is a better cooling agent than air, is used to cool some GTUs.

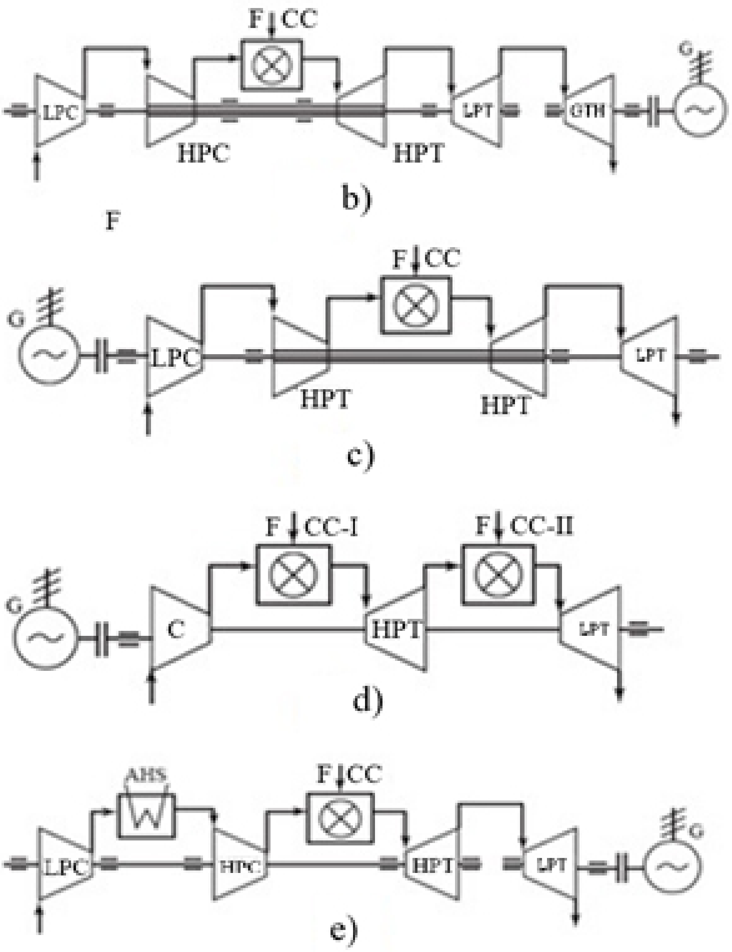

Figure 3: 2.b.c.d.e. Examples of construction schemes of modern energy gas turbine installations. LPC-low pressure compressor, HPC-high pressure compressor, HPE-high pressure engine, LPE-low pressure engine, GT-power gas turbine, IAH-intermediate air heating

Another positive aspect of gas turbines is that the number of harmful gases released into the atmosphere from these turbines or waste steam-gas turbines is less than that of a condensing unit. A catalytic reactor is placed in the middle of the horizontal waste boiler. This reactor consists of a porous catalyst, titanium oxide, tungsten, etc. When you add ammonia to the gas path and the gas mixture passes through the catalyst, nitrogen oxide is converted into nitrogen molecules. This process takes place more actively in the 340-380° C zone. Therefore, the reactor is located in the middle of the boiler. Such reactors are installed in many boilers because modern GTUs meet environmental requirements.

The number of harmful gases released into the atmosphere in gas turbine units is less than in a condensing unit. This is given in the comparative report below.

1) The parameters of the MW701G power inverter of the Mitsubishi firm at nominal load are shown below.

Electric power (gross) $N_g^{gr} = 334\ MVt$.

Efficiency for electricity production $\eta_g^{gr} = 39,5\%$.

Organic fuel consumption B=16,892 kg/sec, 100% methane heat transfer capacity $Q_a^i = 50056\ \frac{kJ}{m^3}$.

The volume concentration of nitrogen oxide in the gas of GTU is 10 PPM. It is necessary to determine the mass concentration of nitrogen oxide in the gases coming out of the GTU at a concentration of 15% of oxygen.

If the concentration of harmful gases is not equal to 15% concentration of oxygen, then it is necessary to bring them to the normative value and calculate them.

$$C^{*} = C_{NO_2}\frac{21-15}{21-Q_2} = 20,53\ mg/m^3$$

$C^{*}_{NO_2} - O_2$ is the concentration of nitrogen (NO2) in the exhaust gases at a concentration of 15%.

When burning 1 m^3 of natural gas, the amount of smoke gases is calculated by the known formula [4].

The amount of smoke gases obtained when 1 m3 of fuel is burned $V_{ng} = 23,409\frac{m^3}{m^3}$; air excess coefficient in the combustion chamber $\alpha_{c.c} = 2,42$; density of dry natural gas $\rho^{g}_{gas} = 0,716\ kg/m^3$.

The mass of nitrogen oxide emitted by exhaust gases

$$M_{NO_2} = \frac{C^{*}_{NO_2}\cdot V_{ng}{\cdot}B_g\cdot 10^3}{\rho^{g}_{gas}} = 20,52\cdot 23,409\frac{16,892}{0,716}\cdot 10^{-3} = 11,33\ g/sec$$

2) Condensing power unit with a power of 300 MW works with a $T\Gamma M\Pi$-314 II type direct-flow steam boiler.

Block settings:

Electric power (gross) Ne=334 MVt; efficiency- $\eta^{gr} = 41\%$.

Mass density of nitrogen oxide - 140 mg/m3.

Fuel gas, 100% methane, heat of combustion - $Q^{i}_{a} = 50056\ \frac{kJ}{m^3}$.

Fuel consumption in the boiler - $B_q = \frac{N_e\ \cdot\ block}{Q^{i}_{a}\ \cdot\ \eta^{br}_{block}} = \frac{334000}{50056\ \cdot 0{,}41} = 16,274\frac{m^3}{sec}$.

1 m^3 the amount of flue gases released when natural gas is burned $Vng = 14,542\ \frac{m^3}{m^3}$; air excess cofficient α=1,4.

The amount of nitrogen oxide emitted by boiler gases

$N_{N_2} = C_{NO_2}\cdot V^{g}_{T}\ \cdot \frac{Bg}{\rho\cdot g}\cdot 10^{-3} = 140\cdot 1542\frac{16{,}274}{0{,}716}\cdot 10^{-3} = 46,27$ g/sec

As it can be seen, the amount of nitrogen oxide emitted from the energetic GTU is 11.39 g/sec; it is 4 times less than the amount of nitrogen oxide emitted from a 300 MW condensing power unit of the same power.

If to assume that the number of annual hours of use is 8,000 hours/year at the determined capacities, then

$\triangle M_{NO_2} = \frac{3600\cdot h_{annual}}{\rho^{g}_{gas}}\left(N_{STU} - M_{GTU}\right) = 28,8\left(46,27 - 11,33\right) = 1006,3$ T/year be the difference in nitrogen oxide emitted during the year in the mentioned devices.

2 Conclusion

1. Thermal schemes and structural features of gas turbine units are investigated; their pros and cons are compared with steam turbines.

2. The amount of nitrogen gas emitted from the gas turbine and nitrogen gas emitted from the steam turbine block of the same power is determined and compared.

3. It is determined that the amount of nitrogen gas emitted from the steam turbine block is 4 times more than the amount of nitrogen gas emitted by the gas turbine.

4. It was determined that the difference in nitrogen gas emitted from the mentioned facilities during the year is 1006.3 t/year.

References

Fedosov, A.A. (2015). *Thermal calculation of boiler units using a computer, methodological instructions.* Kazan State Energy University, Art. 34.

Kagan, G.M. (1998). *Thermal Calculation of Boilers* (Normative Method). St. Petersburg, Russia: Vseross. Teplotekh. Inst.

Olkhovsky, G.G. (1985). *Power gas turbine installations.* M.Energoatomizdat.

Tsanev, S.V.,Burov, V.D., & Romozov A.N. (2009). *Gas turbine and combined cycle thermal power plants.* Under the general editorship of S.V. Tsanev. Moscow. MPEI, 584.

Tsanev, S.V.,Burov, V.D., Dorofeev, S.N. et al. (2000). *Calculation of indicators of thermal circuits and elements of gas turbine and combined cycle power plants.* Moscow, Publishing House, MPEI, 2000.