Promising methods of compressor station efficiency increase of the main pipe lines

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Abstract. This article deals with promising methods of compressor station efficiency increase of the main pipe lines – creation of own gas turbine energy plants with gas turbo-expander energy plant as well as combined energy plants utilizing heat of exhaust gases of gas turbine units.

1. Introduction
One of the main tasks of Plc “Gazprom” is increase of the durability and economic efficiency of compressor stations of main pipe lines which gas compressor stations (GCS) have low economic efficiency. There more than 4000 GCS with total power capacity of 50 million kW. From total number of GCS more than 87% have gas-turbine, and about 12% have electric drive of chargers [1].

New types of GCS are put into operation with higher gas temperature before the turbines. For example, new GCS “GPA-Ts-16A” have COP equal to 38%. Meanwhile, old GCS have same value less than 24%. About 38% of used GCS surpass overhaul period and have total operation time up to 180000 hours. Enormous amount of heat is rejected to atmosphere with exhaust gases which have temperature about 400-550 °C. That’s why necessity to utilize exhaust gases heat of the gas-turbine unit is one of the most important problems.

Most GCS of the main pipe lines are supplied by electricity from power lines with high voltage. Electricity is used for plant own needs as well as for drive of electricity-driven GCS. Electricity losses in long power lines are 12–14% from consumed electricity. Not once, not-enough durability of the power lines causes emergency shutdowns of GCS. “Concept of Plc “Gazprom” energy development on the base of application of own energy units” is developed considering tendency of electricity cost increase. Corresponding to this document, several energy units are constructed in the North and North-East areas, where their electric supply is performed from power lines with length of 500-700 kW. For example, GTES-12 energy plant is built in Vuktyl GCS. But its electric COP is quite low (22.77%). In the same time, building the own energy plants in GCS with small capital costs and creation time promote increase of their efficiency. Decrease of the electricity cost in this case can be achieved either by utilization of the exhaust heat or by using potential energy of the gas in the pipelines in turbo-expander.

2. Turbo-expander application in Gas compressor stations
There are different options to use gas turbo-expanders during their application within gas-turbo-expander energy plant of GCS. To increase power output and economic efficiency it is worthwhile to put fuel gas through the turbo-expander. This fuel gas is consumed by GCS gas-turbine units. For example, in patent [2] it is suggested to heat fuel gas from the pipe line before turbo-expander of
regenerative gas-turbine-expander energy plant by means of utilization of the exhaust gas heat from the GCS. Turbo-expander is used to drive compressor of gas-turbo-expander energy plant. Fuel gas cooled in turbo-expander is used to cool gas compressed in GPS heater. Compressed gas is preliminary cooled in the air refrigeration unit. Partially heated in gas-cooler fuel gas is charged in fuel gas heater where it is heated up to 100–150 ºС before its direction to combustion chambers of gas-turbine GCS and combustion chamber of gas-turbo-expander energy plant. Calculation sows that dependently on gas parameters in pipe lines, number, types and power of mounted GCS, electric output of the energy plant can reach 15–20 MW with its electric COP reaching 60–65%. Building of the own energy plant with such unit allows to significantly decrease exploitation costs.

Figure 1. Gas-turbo-expander energy plant of compressor station of main pipelines 1 – turbo-expander; 2 – compressor; 3 – regenerator; 4 – gas turbine; 5 – gas-turbine GCS; 6 – heater; 7 – air refrigeration unit; gas cooler.

This energy plant can use generated cheap electric energy for energy supply of energy plant own needs, to drive aforementioned GCS as well as support external power lines with electricity. Important direction for increase of the GCS economic efficiency is utilization of the exhaust gases heat of gas-turbine GCS for electricity generation in combines utilization plants [3].

Figure 2. Principal scheme of the cogeneration gas-turbine unit (ČGTU).
CGTU consists of GCS 1 and energy gas turbine unit 2. In exhaust duct of the power turbine of GCS additional heat exchanger is mounted which serve to heat compressed air. Compressed air can be charged either directly into turbine or in its combustion chamber 4. Performed thermodynamic analysis [3] of such unit on the base of NK-14 gas turbine unit showed that in configuration without combustion chamber with regeneration degree of heat exchanger equal to 0.8–0.85, optimal compression ratio is equal to 3.5–4.5.

Calculation for GCS where gas-turbine units are mounted showed that in case of compressed air heating, electric power output will increase only from 0.5 to 1 MW. Consequently, without application of combustion chamber there is possibility to increase compression ratio up to 8–9 and gas temperature. Electric power of the CGTU in this can reach 6–8 MW if gas temperature before turbine is increased up to 1100 K.

3. Application of Combined Cogeneration gas-turbine unit

Technical solution is suggested [4] which shows practical possibility and practicability of application of the Combined cogeneration gas-turbine unit (CCGTU). As in [3] in this unit there is an opportunity to apply GCS and CGTU but in this case additional regenerative air heater is mounted. Air, compressed in compressor of energy gas-turbine unit is separated on two flows. First flow of the compressed air is heat in heat exchanger of GCS power turbine and second flow is directed to regenerative air heater, mounted in CGTU exhaust duct where it is heated by exhaust gas heat. Then both flows of compressed air are mixed and charged to combustion chamber where additional amount of fuel is burnt.

Figure 3 showed principal heat scheme of own electric plant with CCGTU.

![Figure 3. Principal scheme of the cogeneration gas-turbine unit (CGTU)](image)

1 – turbocompressor, 2 – power turbine, 3 - GCS charger, 4 – heat exchanger, 5 – CGTU compressor, 6 – CGTU gas turbine, 7 – CGTU electricity generator, 8 – CGTU combustion chamber, 9 – air flow after compressor, 10,11,13 – separated air flows, 12 – regenerative heat exchanger.

Suggested CCGTU allow to significantly increase electric power and economic efficiency of electric plant itself. This is achieved by the fact that utilization of the same types of gas turbine compressor stations in both CCGTU and CGTU as well as application of combustion chambers in CGTU, CCGTU utilize more powerful energy plant. Larger amount of air is compressed in CCGTU than in CGTU [3]. Heating in additional regenerative air heater of compressed air provides with moderate compression ratio and significant increase of electric power and CGTU COP.

CCGTU calculation analysis was performed for the plant which contains “GPA-Ts-16” and CGTU with electric power 25.5 MW at air temperature 288 K, gas temperature before turbine 1373 K, heat exchanger regeneration degree and CGTU compression ratio. Calculation was performed at varied value of compressed air flow rate, which is directed heated in regenerative heat exchanger.

Figure 4 and 5 shows additional parameters obtained during calculation of CCGTU and their influence on CGTU COP.
Electric power of own needs of most GCS which are equipped by gas-turbine stations is not usually exceed 2–2.5 MW. In the same time about 14% of compressor stations of main pipe lines have electricity-driven GCS with power output of 12 MW. Their advantages at gas-turbine GCS are known: higher lifespan, simplicity of technical maintenance and repair. Their main disadvantages is that electricity-driven stations are supplied by expensive electricity supplied by high voltage power lines. During the gas flow rate drop, shutdown of the part of the operation GCS is usually practiced. It is known, that power of frequency converter does not usually exceed 6 MW, that’s why they are usually not used in GCS. Share of electricity driven GCS utilization is decreasing due to electricity cost increase. Considering difference between electricity and fuel gas cost, options of GCS converting by means of replacement of electricity-driven stations on gas-turbine one are currently considering. During CCGTU mounting on own electric plant which electricity power higher than demand of own needs, excess of generated electricity can be redirected to external electric network. This solution causes disappearance
of significant problems caused by connection of own energy plant to external power lines. More promising way is to use electric energy generated in CCGTU for energy supply of electricity-driven GCS.

It was suggested in patent [5] to apply method of compressor station operation with electricity-driven GCS driven by electricity from own electric station. Electricity-driven GCS can be driven by electricity from both external network and own energy plant.

![Figure 6](image_url)

**Figure 6. Principal scheme of technological gas turbine energy plant on compressor station of main pipe lines**

1 – heaters, 2 – electric engines of GCS, 3 – throttle device on fuel gas pipe lines, 4 – gas turbine technological energy plant, 5 – external power lines.

GCS electric engines supply will be executed from own energy plant which allows to perform their frequency regulation by means of electric generator frequency change.

4. Conclusions
It is most promising to build own energy plants with CCGTU with electric power 25.5 and providing electric supply of 2 electricity-driven compressor stations with power up to 12 MW. In this case there is also a possibility to regulate frequency of electricity-driven compressor station load which allows to increase economic efficiency. Cost of generated electricity will be less than price of bought electricity in a factor of 2, because fuel gas costs for energy gas-turbine units is significantly lesser in comparison with acquisition of electricity from external electric network.

References

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