International Journal of Advanced Science and Technology
Vol. 29, No. 11s, (2020), pp. 1480-1484

Study of efficiency of schemes of fuel-free units of electric power generation in a gas supply system

Mukolyants A.A., Sotnikova I.V., Ergasheva D.K., Karimova N.E.
Tashkent state technical university, 100095, 2 str. University, Tashkent

Abstract

The article discusses the prospect of generating energy appearing from overpressure of natural gas using expander units. Preheating the gas with a heat pump station allows us to solve the problem of insufficient gas temperature in the expander-generator unit in the production of electric energy.
The proposal to utilize excess gas pressure in turboexpander both at gas distribution stations and at compressor stations of gas pipelines without preheating has not yet been widely applied, and therefore the replacement of throttle devices with turboexpander units will be determined by energy and economic efficiency. One of the effective technologies to reduce the consumption of fuel and energy resources is the expander-generator technology. In combination with heat pump units, expander-generator units allow you to create highly efficient energy-generating complexes that can generate electricity without burning fuel. The possibility of generating electricity without burning fuel by expanding high-pressure natural gas at gas distribution stations is being considered. An analytical dependence has been obtained to determine the proportion of electric energy supplied to the electric network based on the expander-generator unit in the gas supply system.
Keywords: *electric power generation, expander generator, main gas pipeline, transported natural gas, differential pressure, heat pump unit.*

1. Introduction

An expander-generator unit (EGU) is used as energy-generating equipment. To convert the heat of a low temperature potential to the heat of an increased temperature potential, a heat pump unit (HPU) is used to heat the gas before EGU. For the operation of HPU, part of the electricity generated by EGU is used. This technical solution to ensure the normal operation of EGU allows to use low potential energy and avoids burning fuel. The remaining energy is supplied to the power grid. The combination of electric generating equipment and HPU in one system allows to efficiently solve the problem of fully supplying consumers with electric energy, depending on their working conditions, without the cost of natural fuel when using EGU and heat pumps. The use of non-fuel units for the production of electricity allows the use of technological pressure differences of the transported natural gas in combination with secondary energy resources and/or the environment.

At the present stage, there are two options for fuel-free systems using EGU. The first consists of EGU and traditional HPU using refrigerant (substances with a low boiling point) as a working fluid. In the second option, an air type heat pump unit (AHPU) is used, atmospheric air in this case serves as a working fluid. Each of the options has advantages and disadvantages. Both systems are fuel-free [1,2,3].

In recent years, a new direction has been outlined in the development of expander-generator technology - fuel-free expander-generator units (FFEGU). The principle of operation of FFEGU provides for the installation of special gas expansion units (turboexpanders) parallel to the gas reduction points of the main gas pipelines. FFEGU reduce the gas pressure to the required consumer, perform the functions of gas distribution points (GDP) and stations (GDS), generate electricity.

In the theoretical solution of the issue, the efficiency of the selected power generation scheme was considered, as well as the feasibility of deploying the equipment.

Operation of the units is determined by the power generation scheme and the equipment used. Several options of schemes and composition of equipment for fuel-free units for generating electricity are possible.

2. Methodology

In this study, the authors investigated four options of schemes of fuel-free units for generating electricity using technological pressure differences of transported natural gas and low-grade heat of secondary energy resources at EGU and heat pumps: a single-stage EHU and a heat pump unit of vapor compression type (VCHPU); two-stage EGU and HPU of vapor compression type; single-stage EGU and air type heat pump unit (AHPU); two-stage EGU and air-type HPU. A low-potential source of heat can be atmospheric air, which is heated both mechanically in AHPU under compression by the compressor, and in the refrigerant circuit in VCHPU [4,5,6].

The disadvantage of the considered VCHPU circuits is a small proportion of (useful) electric power supplied to the grid and a small probability of obtaining the set temperatures (from +60 C) of gas before the expander using a single-stage gas heating. When using a multi-stage scheme, gas heating leads to an increase in the cost of equipment and an even greater decrease in the share of electricity output to the grid. In this connection, to obtain high performance indicators of EGU, the use of a vapor compression heat pump unit was considered (Fig. 1).

The principle of operation of the unit: natural gas is supplied via high-pressure line 1 to the gas distribution system. Throttling device 2 is generally used to technologically lower the pressure of transported natural gas, then the gas enters the low pressure pipe 3. In addition to the throttling device, an expander-generator unit is used in operation to reduce the gas pressure, it includes an expander 6 kinematically connected to an electric generator 8, gas preheater heat exchanger 5.

When pressure decreases, the flow of transported gas expands, and electricity is generated in the generator. 9. One share of electric energy generated by EGU electric generator 8 passes through line 9 to electric motor 12 — HPU compressor 11 drive, the second part goes through line 10 to the power grid.

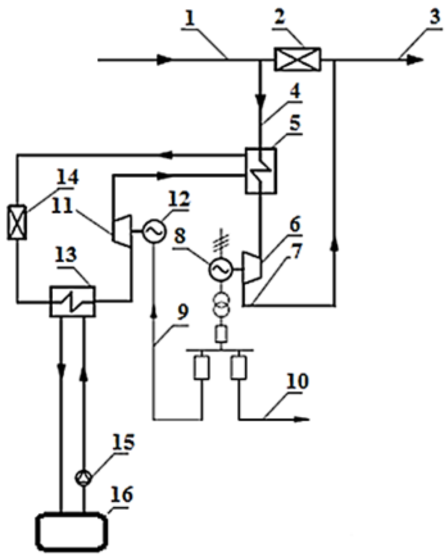

FIGURE 1: Principle diagram of a unit combining EGU and HPU

FIGURE 2: Fragments of a general view of an experimental EGU

Before the expander, a vapor compression heat pump unit is used in the heat exchanger to heat the transported gas, it includes an evaporator 13, a compressor 11 with an electric motor 12, a throttling device 14 and a desuperheater (condenser) 5, which is also a heat exchanger for heating the transported gas 5, a refrigerant in the gaseous state from evaporator 13 is supplied to HPU-1 compressor 11. In the compressor, pressure and temperature of refrigerant increase to the values required by the operating conditions. From compressor 11, refrigerant is sent to the gas heating heat exchanger - desuperheater (condenser) 5 of HPU-1. Natural gas is heated in a gas desuperheater by cooling the refrigerant or by the heat of condensation, depending on the nature of the isobar. From desuperheater (condenser) 5, refrigerant enters the throttling device 14 of the TNU-1. In throttling device 14, refrigerant pressure decreases to what is required by the operating conditions, after which refrigerant is directed to evaporator 13. In evaporator 13, refrigerant evaporates due to the low temperature of air coming from source 16.

Based on the studied materials [7,8,9], the authors proposed norms for choosing the optimal gas heating system. Norms are divided into primary and calculated norms. Primary norms are determined immediately, when selecting the EGU, the calculated ones are determined in the process of designing the unit.

Primary norms include: manufacturing products to meet the needs of the population; power generation; introduction of additional technical measures (such as lowering the threshold of the maximum permissible temperature level at the expander outlet, which will exclude heating of the gas after EGU, so heating the gas before EGU to higher values will become irrelevant); geometric parameters; gas pressure reduction level; ability to heat gas using the heat of secondary energy resources; gas-dynamic parameters.

The calculated norms include: impact of EGU gas heating units on the operation of gas-consuming equipment (difference in gas enthalpies at the outlet and inlet of EGU is the main criterion). To calculate the unit which includes EGU and VCHPU, we used the following conditions: operation of the heat pump in a cycle with deep cooling of the refrigerant after condensation; temperature gas indicator at the gas distribution station inlet; тtemperature gas indicator at the expander inlet t_{ex} = 60 °C; temperature in the evaporator t_{ev} = 5 °C; underheating in the condenser equal to 5°C, and underheating in the evaporator equal to – 4 °C; the temperature of the liquid phase of the refrigerant before the throttle is considered equal to t_{th} =35°C..

3. Result and Discussion

Calculation results are presented in the graph in Fig. 3.

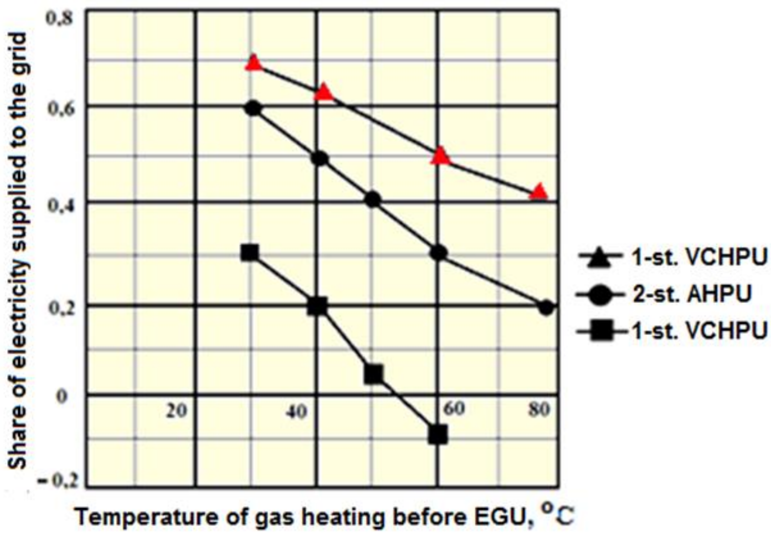

FIGURE 3: Dependence of the share of electricity supplied to the grid on the temperature of gas heating for one- and two-stage AHPU and VCHPU

Conclusion

After comparing the results of calculating the vapor compression type and air type HPU, we can draw the following conclusions:
1. The share of electricity supplied to the grid when EGU and VCHPU are used together is larger by 40-60% (depending on the temperature of gas heating before EGU) than in the case of EGU-AHPU with two-stage gas heating and by 10-25% with single-stage heating.
2. In the scheme of joint operation of VCHPU-EGU in order to minimize equipment costs, the use of HPU air turbines should be abandoned and smaller compressors should be selected.

Thus, the efficiency of EGU circuits for generating electricity at gas distribution stations was studied. The most acceptable methods of gas heating for EGU were identified and a connection was established between a share of the useful electricity that EGU supplies to the grid and gas heating using vapor compression type and air type HPU.

References

1. Urvanov, S.V., Kondrashova, Yu.N., Gazizova, O.V., Skvortsov, D.S. (2017) Development and research of existing possibilities of using an expander-generator unit for a gas distribution station using a heat pump unit as a gas heating system. Bulletin of YuUrGU. "Energy" series. **2**. pp. 5–13.
2. Buranov, M., Mukolyants, A. and Sotnikova, I. (2019) Generation of electrical energy at gas pipelines using a transported natural gas technological pressure drop. J. Phys.: Conf. Ser. 1399 055038 https://doi:10.1088/1742-6596/1399/5/055089
3. Agababov, B.C. (2011) Analysis of the influence of operation parameters of a fuel-free energy generating unit on its efficiency. Energy Saving and Water Treatment.– No. 6 (74). - pp. 26-28.

4. Mukolyants, A.A., Buranov, M.D., Sotnikova, I.V., Makhmudov, H.F. (2020) Operation analysis of expander-generator unit at a gas distribution station. Journal of Physics: Conference Series. Journal of Physics: Conference Series 1515 022053 https://doi:10.1088/1742-6596/1515/2/022053
5. Taslimov, A.D., Berdishev A.S., Melikuziev M.V., and Rakhimov F.M. (2019) E3S Web of Conferences B **139** 010 https://doi.org/10.1051/e3sconf/201913901077
6. Rakhmonov, I., and Niyozov, N. (2019) E3S Web of Conferences B **139**, 010 https://doi.org/10.1051/e3sconf/201913901077
7. Taslimov, A., Rakhmonov, I. (2019) J. Phys.: Conf. Ser. **1399** 055046 doi:10.1088/1742-6596/1399/5/055046
8. Belousov, A.J. (2016) Oil and Gas Technologies B **3** 51-55
9. Taslimov, A.D., Berdishev A.S., Melikuzuev M.V., and Rakhimov F.M. (2019) E3S Web of Conferences B **139** 010 https://doi.org/10.1051/e3sconf/201913901082