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COGENERATION POWER PLANT WITH GASIFICATION OF CARBON-CONTAINING FUEL FOR DECENTRALIZED AREAS OF THE KRASNOYARSK TERRITORY

Boiko E.A., Strashnikov A.V.

Keywords: small-scale distributed generation, cogeneration, gasification of coal, electric and thermal energy, electricity, cost price, tariffs, energy efficiency.

Abstract. The article analyzes the structure of energy supply to consumers in decentralized areas of the Krasnoyarsk territory. The consumers receiving the electric power from diesel power plants, and thermal energy from boiler houses are allocated. A promising technology to meet the needs of consumers of decentralized areas, a cogeneration gas-piston power plant based on the gasification of carbon-containing fuel, is considered. One of possible variants of realization of cogeneration power installation at the level of pilot sample with possibility of modernization to the level of perspective industrial installation is offered. The scheme and design of the pilot installation with the results of its commissioning and thermal tests, as well as the estimated technical and economic characteristics of its industrial counterpart are presented.

КОГЕНЕРАЦИОННАЯ ЭНЕРГЕТИЧЕСКАЯ УСТАНОВКА С ГАЗИФИКАЦИЕЙ УГЛЕРОДСОДЕРЖАЩЕГО ТОПЛИВА ДЛЯ ДЕЦЕНТРАЛИЗОВАННЫХ РАЙОНОВ КРАСНОЯРСКОГО КРАЯ

Бойко Е.А., Страшников А.В.

Ключевые слова: малая распределенная энергетика, когенерация, газификация угля, электрическая и тепловая энергия, энергоснабжение, себестоимость, тарифы, энергоэффективность.

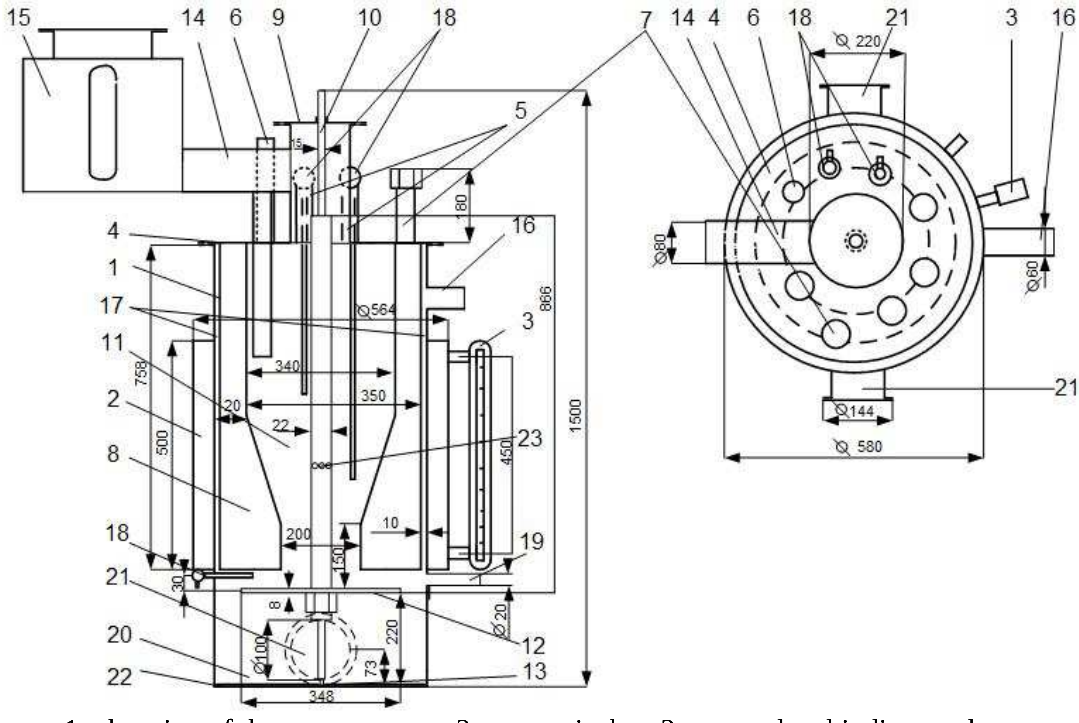
Аннотация. В статье проведен анализ структуры энергообеспечения потребителей в децентрализованных районах Красноярского края. Выделены потребители, получающие электроэнергию от дизельных электростанций, а тепловую энергию от котельных. Рассмотрена перспективная технология для обеспечения нужд потребителей децентрализованных районов, когенерационная газопоршневая электростанция на основе газификации углеродсодержащего топлива. Предложен один из возможных вариантов реализации когенерационной энергетической установки на уровне пилотного (опытного) образца с возможностью модернизации до уровня перспективной промышленной установки. Представлены схема и конструкция пилотной (опытной) установки с результатами ее пуско-наладочных и тепловых испытаний, а также расчетные технико-экономические характеристики ее промышленного аналога.

In the Krasnoyarsk territory, only 10 regional cities are covered by centralized power supply with heating. At the same time, the thermal energy produced at the CHP and GRES is about 3000 Gcal/h (81%) of the required volume, the remaining thermal energy of about 700 Gcal/h (19%) is produced at urban boilers.

Settlements of 44 districts of the region are mainly provided with centralized power supply of 600 MW (86%), the rest of the electricity is generated by diesel power plants (DES) of 100 MW (14%). Thermal energy in the volume of about 3150 Gcal/h is produced at the boiler houses. In the centralized part, 3000 Gcal/h (95%) is produced, in the non-centralized part 150 Gcal/h (5%).

The tariff for electricity in areas with centralized power supply for the population within the social norm is about 2.0-2.5 rub./kW*h, in excess of the social norm of electricity consumption is about 3.0-4.0 rub./kW*h, for single-rate tariffs, without differentiation by zones of the day, on average 4.0-5.0 rub./kW*h with a maximum of 8.5 rub./kW*h, the tariff for electricity from DES is already 25-45 rub./kW*h. The tariff for heat energy generated centrally at CHP and GRES, averages about 1400-1600 rub./Gcal, the tariff from the boiler is 3000-24000rub./Gcal with a maximum of 70000 rub./Gcal. In this situation, the state is forced to subsidize municipalities in energy-deficient areas, and in the Krasnoyarsk region, the amount of such subsidies is about 5.5 billion rubles per year [1-10].

To solve the problem of energy supply in decentralized regions of the Krasnoyarsk territory, where electricity is generated by DES and heat energy on the boilers, department of TPP SFU was established in the pilot cogeneration power plant with a capacity of 5.5 kW based on gasification of solid fossil fuels (Fig. 1 and 2), conducted commissioning tests and investigated the various modes of its operation with the determination of technical and economic indicators.



1 – housing of the gas generator; 2 – water-jacket; 3 – water level indicator glass; 4 – cover; 5 – pipe for the installation of temperature sensors; 6 – the first outlet; 7 – inlet flow gasification agent; 8, the second annular space; 9 – a cylindrical shell; 10 – blower rod; 11 – working area; 12 – grate; 13 – stop; 14 – fuel line; 15 – bunker coal; 16, the second outlet; 17, the first annular space; 18 – temperature sensors; 19 – nozzle for ignition of coal; 20 – area to collect ash and slag, and ignition of the gas generator; 21 – hatches for ignition of coal and cleaning of ash and slag; 22 – bottom; 23 – blow holes

Fig. 1. Design of gas generator on carbon-containing fuel

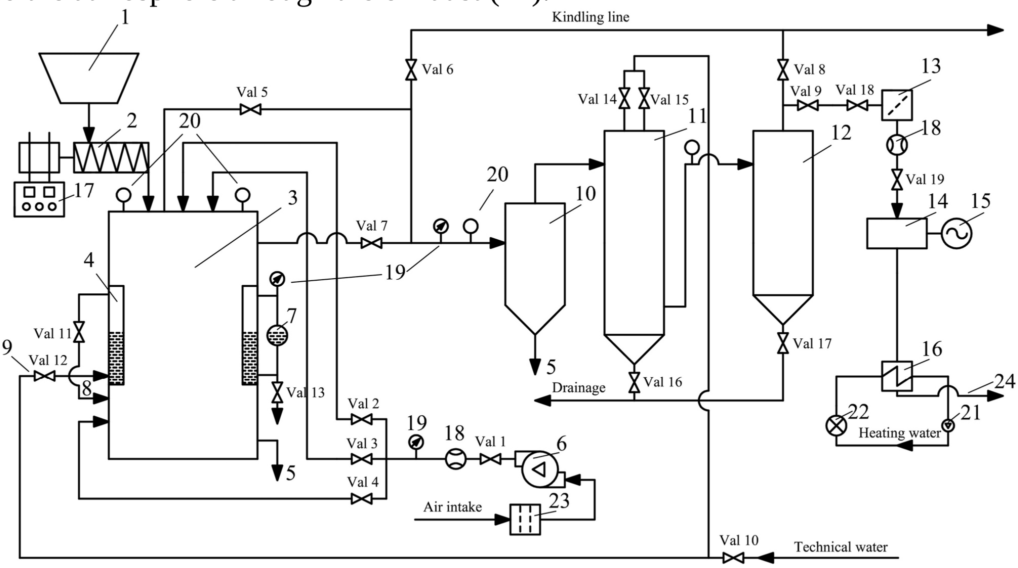
Gasification of the fuel in the plant is carried out by converting the organic part of the solid fuel into combustible generator gas under high temperature heating in an oxygen-deficient environment. At the same time, the device of this gas generator allows to realize both direct and reverse gasification process in different environments [11]. The gas generator can work on air, oxygen or steam-air, steam-oxygen blowing, as well as their mixtures in any proportion. Water vapor with a temperature of 120 °C and a pressure of 3 kgf/cm2 is formed in the water jacket of the gas generator. The process of gasification of solid fuel is carried out at a pressure above atmospheric P = 1.2-2 at, a temperature of 400-700°C in the gasification zone, a lack of oxygen α = 0.2 - 0.3 and solid slag removal.

During operation of the gas generator (see Fig. 1) fuel is loaded from the coal bunker (15) through the fuel pipeline (14). Ignition of the gas generator is carried out through hatches for ignition of coal and cleaning of ash and slag (21) in the zone for collecting ash and slag, and ignition of the gas generator (20). To organize a direct gasification process, the gasifying agent is fed through the gasifying agent supply pipe (7) into the second annular space (8), and the generator gas is removed from the working area (11) through the first outlet pipe (6). In this case, heat exchange occurs between the outcoming generator gas and the incoming gasifying agent. To organize the reversed gasification process, the gasifying agent is fed into the blow rod (10) and through the blow holes (23) enters the working zone (11), where the gasification process takes place, while the generator gas is removed from the first annular space (17) through the second outlet pipe (16). In this case, the incoming gasifying agent moving down the blast rod (10) is heated from the heat of the working zone (11) propagating upwards, and heat exchange between the outcoming generator gas and the water jacket (2) occurs to form steam. Ash and slag from the grate (12) are collected in the zone for collecting ash and slag, and ignition of the gas generator (20) and removed through hatches for ignition of coal and cleaning of ash and slag (21).

Pilot cogeneration power plant (see Fig. 2) contains a coal hopper (1) connected to a screw feeder (2) which loads the fuel into the gas generator (3). From the gas generator (3) leave the gas line for the output of the generator gas by direct gasification with installed on it valve Val5 and a gas pipe for output gas generator when the reversed process of gasification with the valve Val7. For the process of kindling through the set tee, these trunks have access to the ignition line with the valve Val6, and for installation through the set tee, these trunks have access to the filter-cyclone dust collector (10).

Next is the generator gas purification system, consisting of a filter-ash collector cyclone type (10), scrubber (11), dehumidifier (12) interconnected gas lines. After the dehumidifier (12), through the installed tee, for the kindling process there is an exit to the kindling line with the valve Val8 installed on it, and in the operating mode of the installation, the generator gas is supplied to the fuel line through the installed valve Val9.

The fuel line includes a fine filter (12) inside the housing of which is installed a cassette with a flow filter element, a gas meter (10) and a ball valve Val19 for supplying generator gas to the internal combustion engine (14) of the ZUBR ZESG-5500 electric generator. The electric power is generated on the generator (15), and thermal energy is provided at the expense of utilization of the spent exhaust gases of the internal combustion engine (14) on the heat exchanger TVT-1500. Removal of heat energy is made on radiators of heating of the heating consumer (22) and goes for providing own needs of laboratory of Department of TPP of SFU. Regulation of the heat removal process is carried out by means of a frequency-controlled drive of the network pump (21). The cooled exhaust gases are discharged into the atmosphere through the exhaust (24).



1 – raw coal hopper; 2 – screw feeder; 3 – gas generator; 4 – water jacket; 5 – ash pit; 6 – blow fan; 7 – water level indicator glass; 8 – steam injection line; 9 – water supply line to the water jacket of the gas generator; 10-filter – ash collector cyclone; 11 – wet scrubber; 12 – dehumidifier; 13 – filter fine gas cleaning; 14 – internal combustion engine; 15 – electric generator; 16 – heat exchanger; 17 – control Board; 18 – rotary counter; 19 – pressure gauge; 20 – temperature sensor; 21 – network pump; 22 – heating consumer; 23 – air filter; 24 – exhaust

Fig. 2. Principal schema of cogeneration power plant with gasification of carbon-containing fuel

In the course of this work, a pilot version of the cogeneration power plant with gasification of carbon-containing fuel (coal, pelettes, peat, solid waste) was designed and installed, and testing and commissioning works were carried out. The installation showed stable, stable operation at different modes of 600, 900, 1200 watts of electrical load of the generator. The obtained technical and economic indicators of the pilot plant show compliance with the lower indicators of coal steam turbine stations operating at a pressure of 3.4-4.0 MPa and a temperature of 400-440°C with an exergetic efficiency of 15 - 20%. According to the results of testing, the exergetic efficiency of the pilot installation was 10-15%.

The results of the pilot plant testing and the parameters of the prospective industrial design installation, our target, are given in Table. 1.

Tab. 1. Specific characteristics of the cogeneration plant

Name of parameter	Pilot cogeneration plant, (experimental value)	Prospective industrial cogeneration plant (calculated value)
Specific consumption of equivalent fuel for electric power generation, g.e.f/kW*h	976	332
Specific consumption of equivalent fuel for thermal energy generation, kg.e.f./GJ	39	17
Cost of electric energy, rub./kW*h	8	5
Cost of thermal energy, rub./Gcal	2500	1750
The overall exergy efficiency, %	12	34

Work with the pilot plant revealed a number of problems and shortcomings that prevent the improvement of performance and increase the exergy efficiency to 30-35%. The solution of these problems and shortcomings is possible at creation of industrial plant. Experimental estimates show the possibility of obtaining the exergy efficiency installation of up to 35%, which corresponds to the average indicators of russian coal steam turbine stations operating at a pressure of 14-17 MPa and a temperature 545-560°C with the exergy efficiency 30 - 35%.

The unit was installed in the laboratory of the Department of thermal power plants of the Polytechnic Institute (Fig. 3).

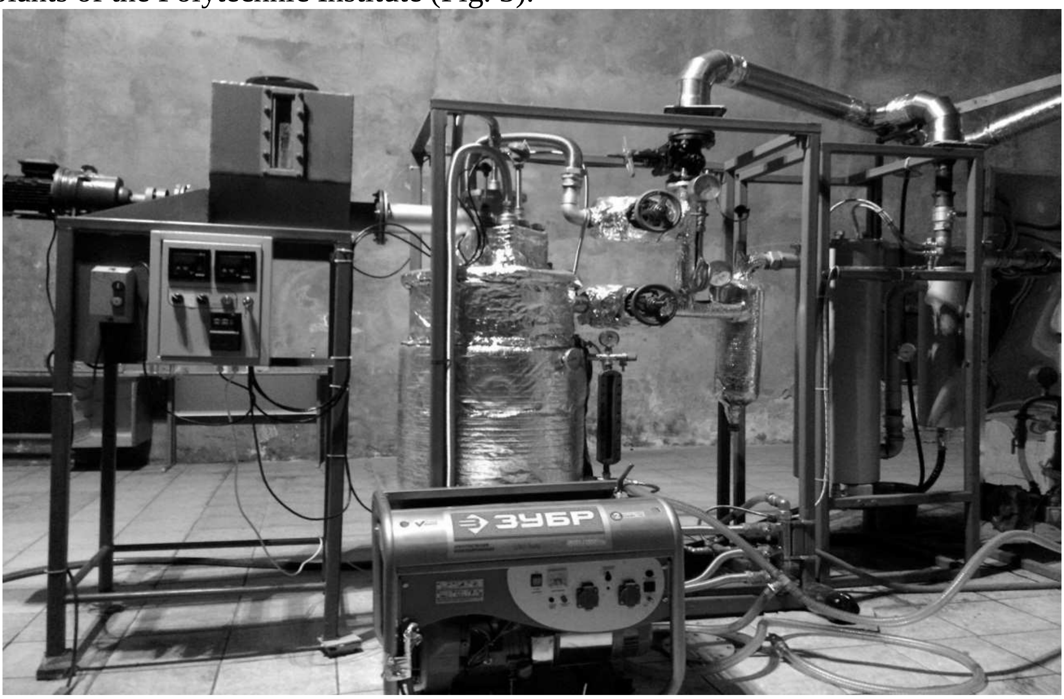


Fig. 3. Pilot sample of cogeneration plant with gasification of carbon-containing fuel (dimensions W×L×H-800×6000×2000 mm)

The need for technical re-equipment of installed DES and boilers in the Krasnoyarsk territory is such that about 100 MW of diesel generation due to the reduction in the cost of production of electric energy by 10 times and boiler plants with a total thermal capacity of 3850 Gcal/h should be replaced by industrial plants [12]. Given that the situation with the power supply of other regions of the Russian Federation is approximately the same, the experience of introducing industrial plants to replace the installed DES and boilers of the Krasnoyarsk territory may be of interest to other regions of the Russian Federation, as well as other countries.

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Бойко Евгений Анатольевич – доктор технических наук, профессор, заведующий кафедрой «Тепловые электрические станции», EBoiko@sfu-kras.ru	**Boiko Evgeny Anatolyevich** – doctor of technical sciences, professor, head of the department "Thermal power plants", EBoiko@sfu-kras.ru
Страшников Александр Викторович – аспирант, savtr@mail.ru	**Strashnikov Aleksandr Viktorovich** – postgraduate, savtr@mail.ru
Сибирский Федеральный Университет, г. Красноярск, Российская Федерация	Siberian Federal University, Krasnoyarsk, Russian Federation

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