Increase of energy efficiency of energy generation due to utilization of waste heat at Krasnoyarsk CHP-2

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Abstract. The relevance of the work is due to the implementation of the Federal law "on energy saving and energy efficiency and on amendments to certain legislative acts of the Russian Federation" and is aimed at reducing environmental pollution from the production of electricity and heat at the CHP.
The aim of the work is to increase the energy efficiency of electric energy generation by upgrading the coal thermal power plant, reducing environmental pollution from the enterprise by reducing the amount of fuel burned at the same capacity.
Research methods: Analysis of existing technologies for utilization of low-potential thermal energy in the energy sector; Thermal, technical and economic analysis of technologies that allow converting low potential thermal energy into electrical energy; Simulation of installation parameters based on the organic Rankine cycle using the Smoweb software package; Analysis of modern manufacturers of organic Rankine cycle technology in order to select the most suitable
Results: a comparative analysis of existing technologies for utilization of low-potential heat energy was carried out and the most effective option for energy efficiency was chosen. Was heat produced and techno-economic analysis of the application of technologies to convert low-grade thermal energy into electrical energy; modeling installation working on the principle of organic Rankine cycle utilizing heat energy from the boiler BKZ-420-140-PT1

1. Choice of heat recovery technology

The rapid growth of electricity needs in the XXI century, the crisis state of the environment, technological problems that need to be addressed to meet these needs, based on modern criteria for a sharp increase in energy efficiency, reducing costs and minimizing the impact on the environment, require a significant expansion of research and development in the power industry. Research, design and design work in the heat power industry should be aimed at the creation of highly efficient and environmentally friendly thermal power plants using advanced technologies and power equipment, providing solutions to the following tasks: improving the efficiency of energy supply by increasing its reliability and reducing the cost of electricity production; maximum reduction of harmful emissions of thermal power plants into the environment; increasing productivity and improving working conditions; reducing the cost of repair and restoration work.

At present, the issue of reducing environmental pollution from enterprises is acute in the city of Krasnoyarsk. The city is located in Siberia where the temperature difference varies from -40 °C to +40 °C, so the rejection of the existing source of generation of thermal power plants is impossible. To reduce the environmental impact of CHP is possible by reducing the burned fuel, by improving the efficiency of production of electricity and heat in the utilization of heat of the exhaust gases.

Currently, the widely distributed four technologies to obtain from low-grade heat energy electric:

- Stirling engine
- Organic Rankine cycle
- Rankine Microcycle
- Thermoelectric converter

As noted in [1] (figure 1) Stirling Engine has a high efficiency and has found its application in industrial samples at temperatures 650-800 and above, but this source of heat network water 95 is not applicable. The Rankine microcycle is effective only in the joint production of heat and electricity, which is not required for this task. Thermoelectric converters have low efficiency below 5%.

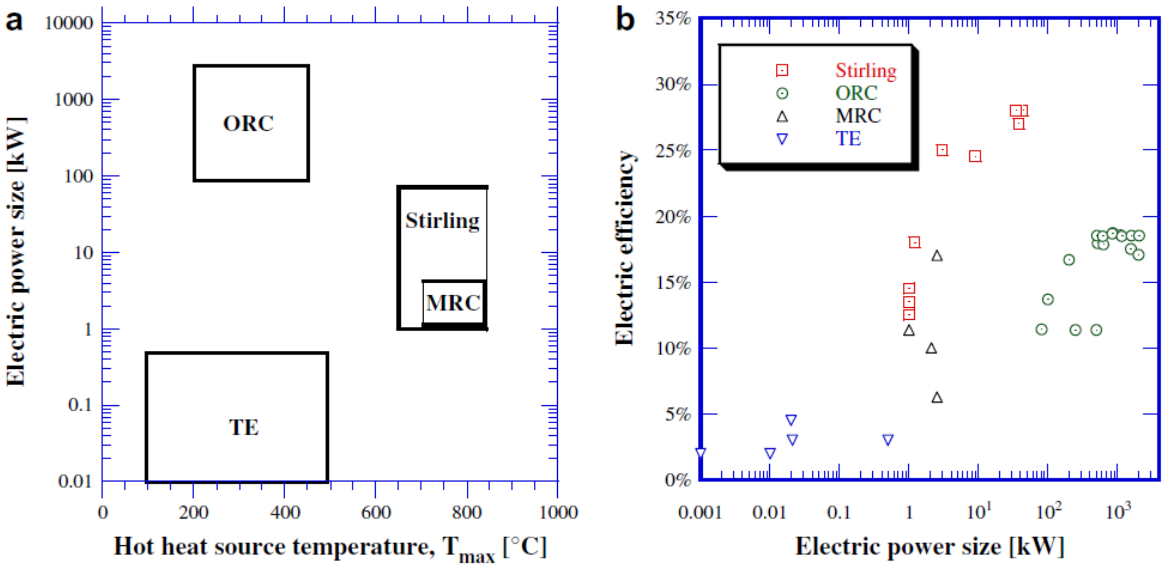

Figure 1. Analysis of technologies for converting thermal energy into electrical energy low power

As shown in the figure and by te authors [2-7] for the utilization of low-potential thermal energy, the most suitable and Mature technology is the organic Rankine cycle (ORC).

2. Inclusion of the installation of organic Rankine cycle in the technological scheme

Recycling the cooling exhaust gases to a temperature below the dew point temperature is called deep. There are two types of ORC installations, the classical Rankine cycle and the regenerative one with the addition of a heat exchanger transferring heat from steam after the turbine to the condensate after the condenser. Given the above, there are four options for including the ORC installation for heat recovery of exhaust gases from the boiler and four options for including the ORC installation that converts low potential thermal energy from hot water (steam) into electric:

- Deep utilization with ORC without regeneration
- Deep utilization with regenerative ORC
- Utilization with ORC without regeneration
- Utilization with regenerative ORC
- Conversion of thermal energy of mains water into electric ORC without regeneration

- Conversion of thermal energy of mains water into electrical energy with regenerative ORC
- Conversion of thermal energy of steam thermal selection into electrical energy without regeneration ORC
- Conversion of thermal energy of steam thermal selection into electrical energy with regenerative ORC

3. Assessment of the technical and economic effect of the implementation of recycling

The valuation of the main equipment is divided into:
- Assessment of the cost of heat exchanger utilization (gas-Air steel or gas-water glass))
- Evaluation of the cost of the heater (Air-water steel in the schemes with the utilization of the heat of gases to a temperature above the dew point)
- Estimate cost of installation of the ORC with screw expander

Assessment of the cost of heat exchangers was taken from the online calculator of the cost of heat exchangers with a dollar exchange rate relevant for 2014.
Estimation of the cost of the UCR module was taken from the price list of the company "infinity turbine Ukraine". The estimation of specific investments was carried out with the help of regressive analysis of cost, $ / kW :

$$K_{\text{ОЦР}} = 1338 \cdot P + 15474{,}18$$

Technical and economic analysis of the implementation of ORC units at the Krasnoyarsk CHPP-2 is presented in table 1 and table 2

Table 1– The main technical and economic indicators of utilization of heat the leaving gases from the boiler of BKZ-420-140-PT1

Parameter	Utilization with ORC without regeneration	Utilization with regenerative ORC	Deep utilization with ORC without regeneration	Deep utilization with regenerative ORC
Gas temperature, °C	145	145	145	145
The temperature of the cooled gases, °C	120	120	80	80
Heat recovery, kW	9000	9000	14000	14000
Efficiency of ORC,%	10,0006	10,3573	10,0006	10,3573
ORC electric power,kW	847,124	877,339	1372,08	1421,02
The R142b flow rate, kg/s	34,132	35,3493	54,178	56,110
The cost of the ORC, $	1149013	1189444	1851459	1916946
The price of the heat exchanger utilization, $	126600	126600	510900	510900
The price of the heater, $	124300	124300		
Capital investments, mln. RUB.	41,997	43,210	70,872	72,837
Operating Costs, mln. RUB. / year	13,199	13,442	18,974	19,367
Cost of energy production, RUB/(kW·h)	1,94	1,91	1,94	1,91
Income of electricity mln. RUB. / year	5,572	5,999	8,025	8,025
Payback period, years	6	6	7	7
Savings, t.t./year	2371,94	2456,55	3411,54	3533,22

Table 2. – The main technical and economic indicators of heat conversion of the t-110/120-130 turbine heat selection.

Parameter	Conversion of thermal energy of mains water into electric ORC without regeneration	Conversion of thermal energy of mains water into electrical energy with regenerative ORC	Conversion of thermal energy of steam thermal selection into electrical energy without regeneration ORC	Conversion of thermal energy of steam thermal selection into electrical energy with regenerative ORC
Water (steam) inlet temperature, °C	120	120	(140)	(140)
Water (steam) temperature output, °C	70	70	(110)	(110)
Heat power, Gcal / kg	750	750	765	765
Efficiency of ORC,%	10,0006	10,3573	11,4815	11,9854
ORC electric power,kW	19946,6	20658,1	23336,7	24393,3
Capital investments, mln. RUB.	801,182	828,744	943,502	985,917
Operating Costs, mln. RUB. / year	919,536	925,248	948,000	956,483
Cost of energy production, RUB/(kW·h)	7,53	7,31	6,63	6,41

Result:

- Deep utilization allows you to remove more heat from the exhaust gases due to condensation of water vapor, but at the same time in the outgoing gases contain sulfur oxides which, when condensed, react with water to form sulfuric acid, which leads to sulfuric acid corrosion. This problem can be solved by using a glass heat exchanger. This lack of devoid of scheme with gas-air utilization.
- The addition of a regenerative heat exchanger increases the cost of installation, but allows to increase the efficiency of the ORC by reducing heat losses in the condenser. The efficiency of the regenerative heat exchanger depends on the freon used and the efficiency of the turbine.
- The inclusion of an ORC using mains water as a heat source allows the production of electrical energy from heat. With this inclusion, the coefficient of use of thermal turbines increases, and as a result, the cost of production of electric energy is reduced, the reliability of operation is improved. The supply to the ORC as a source of heat of the heating steam selection will increase the degree of overheating of freon and efficiency, but will entail an increase in capital costs for individual heat exchangers and a system for regulating the distribution of steam between the network heaters and the ORC.

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