ENERGETICS

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STATE AND POSSIBILITIES OF COAL-FIRED POWER PLANTS MODIFICATION FOR INCREASING GENERATION EFFICIENCY

Abstract. *The article considers issues related to the modernization of coal-fired power technologies. In order to increase the efficiency of energy resources, operational reliability, reduce losses and improve environmental safety the possibilities of cogeneration and trigeneration, as well as fuel cell technologies with RES, which is expedient to use for production of additional electric energy, are considered. The possibilities of innovative energy components for their integration into traditional power generation systems are shown, and technological schemes are given.*
Keywords: *energy, coal-fired thermal power plant, efficiency, modernization, cogeneration, trigeneration, fuel cells*

Problems and the state of Kazakhstan's energy facilities. According to "Electric Power Industry of Kazakhstan" (http://gbpp.org/ru/2016/ 12/15682), Kazakhstan has large reserves of energy resources (oil, gas, coal, uranium) and is a resource country. At the same time, electricity generation by type of power plants is distributed as follows. Thermal power plants - 87.7%, including: condensing power plants CHP - 48.9%; combined heat and power plants - 36.6%; gas turbine power plants GTPP - 2.3%. More than 72% of electricity in Kazakhstan is generated from coal. The power plants of national importance include large coal-fired thermal power plants: Ekibastuz SDPP-1 LLP; Ekibastuz SDPP-2 JSC; Euroasian Energy Corporation JSC (Aksu SDPP); Kazakhmys Corporation SDPP LLP; Zhambyl SDPP JSC. TPPs with combined production of electricity and heat, which are used to supply electricity and heat to large industrial enterprises and nearby settlements, belong to the stations of industrial importance. The total installed capacity of power plants in Kazakhstan is 20 million kW. TPPs account for 88% of the capacity structure. The largest TPPs supplying heat and electricity to large industrial enterprises and nearby communities include, for example: Pavlodar CHP-3, Balkhash CHP, CHP-3 of Karaganda-Zhylu LLP; PVS CHP, CHP-2 of Arcelor Mittal Temirtau JSC; Rudnenskaya TPP (SSGPO JSC), Zhezkazganskaya TPP of Kazakhmys Corporation LLP; Pavlodarskaya TPP-1 of Aluminium of Kazakhstan JSC; Shymkentskaya TPP-1,2 (Yuzhpolymetal JSC) and others.

Problems and directions of innovative development and increase of efficiency of coal-fired thermal power engineering. Meeting the needs of the thermal power industry is possible in two ways: (a) construction of new generating capacities and (b) reduction of energy consumption of existing and under construction facilities, by applying energy efficient technologies and optimization of equipment operation modes. Releasing additional energy capacities by reducing the energy consumption of existing facilities has lower capital costs compared with the construction of new energy sources; in addition, the negative impact on the environmental situation is reduced.

The relevance of the formation of technical proposals and targeted measures to reduce energy costs is caused by a significant projected increase in the cost of energy resources, the permanent growth of regional energy shortages, the unsatisfactory state of the environment from generating coal-fired thermal power facilities.

Information data, which are taken from officially published sources - Energy Saving and Energy Efficiency Improvement Program of RK - illustrates extremely negatively the technological level of use of energy resources by RK facilities. This requires radical technological and innovative modernization of coal-fired thermal power facilities. Therefore continuous implementation of energy-saving measures with significant amounts of financing, 1-2 years period of implementation and expectation of return on investments for 3-10 years.

The main project activities carried out in the thermal energy sector until 2020 can be conditionally divided into the following groups (A), (B), (C) and (D).

(A) Projects on introduction of energy efficient technologies and equipment: introduction of automated process control system for power engineering (APCS) and software complex (PC) "energy efficiency"; reconstruction and replacement of pumps; introduction of valve drives for auxiliary mechanisms (ACM).

(B) Projects to switch energy supply to more economical sources of energy; optimize energy-consuming equipment according to the load; introduce VFDs; increase the efficiency of electricity distribution equipment; introduce energy-saving equipment; optimize the capacity of boilers and their automation depending on weather conditions and temperatures in heated rooms; reduce heat losses from consumers; heat recovery at plants; measures to optimize equipment and process schemes, including introduction of new equipment and technical solutions to use secondary energy sources with heat recovery in technological processes and for heating buildings; introduction of LED lighting sources, installation of energy-saving starting devices; introduction of reactive power compensation devices, replacement of transformers, load redistribution, etc.

(B) Reconstruction of existing and construction of new generation facilities with high energy saving effects; reconstruction of heat supply systems; introduction of tank induction heating units in winter time instead of using steam; introduction of technological processes automation systems and technical and commercial electricity, heat and fuel metering devices for individual processes and equipment; transfer of boiler houses to automatic operation modes - introduction of weather-dependent automatics; reduction of heat losses of consumers; introduction of heat pumps.

(D) Management of technical policy on energy efficiency through implementation and development of energy management system.

Basic technological schemes of coal-fired thermal power. Due to the fact that the actual detailed technical and economic data of existing coal-fired thermal power generating facilities are commercially proprietary, we will use the data published in the open press, most typical for coal-fired thermal power plants. In particular, figure 1, as an example are typical functional generalized schemes of coal-fired thermal power plants on the example of the plant 500 MW. Similar technological schemes with a certain degree of approximation can be taken as a functional basis for further research.

Figure 1 (left) shows the "subcritical" technology of pulverized coal combustion without carbon dioxide - CO2 sequestration. Input parameters are: coal - 208,0 t/hour; process air - 2450,0 t/hour. The output parameters are: the useful power (electric) - 500MW net, and the products of the plant's activity: emissions of combustion products into the atmosphere - 2770,0 t/hour, temperature 55C and pressure 0,10MPa; technological ash and slag.

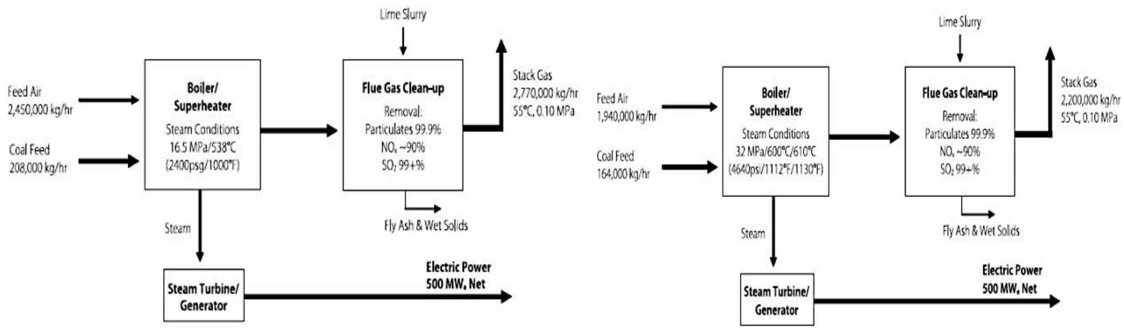

Fig. 1 **Functional diagrams of a coal-fired thermal power plant without CO2 capture using "subcritical" technology (left) and "ultra-supercritical" technology (right)**

The internal parameters of this technological scheme of the coal-fired plant are: the thermal part - the system of technological steam preparation; the system of energy generation - the steam turbine/generator; the system of cleaning of combustion products. The process steam preparation system has the following parameters: steam pressure of 16.5 MPa and temperature of 538C. From this steam through the "steam turbine/generator" system the power of 500 MW is obtained. The combustion products cleaning system has the following characteristics: cleaning degree from combustion solids - 99.9%; purification from nitrogen oxides NOx - about 90%; purification from sulfur oxides - SO2 - more than 99%.

Figure 1 (right) shows the "ultrasupercritical" technology of pulverized coal combustion without carbon dioxide - CO2 sequestration. Input parameters are: coal - 164,0 t/hour; process air - 1940,0 t/hour. Output parameters are: the useful power (electric) - 500MW net, and the products of the plant: the emissions of combustion products into the atmosphere - 2200.0 t / h, at a temperature of 55C and pressure of 0.10MPa; technological ash and slag.

The internal parameters of the given technological scheme of the coal-fired plant are also: the thermal part - the system of technological steam preparation; the system of energy generation - the steam turbine/generator; the system of cleaning of combustion products. The system of technological steam preparation has the following parameters: steam pressure of 32.0 MPa and temperature of 600-610C. From this steam through the "steam turbine/generator" system the power of 500 MW is obtained. The combustion products cleaning system has the following characteristics: cleaning degree from combustion solids - 99.9%; purification from nitrogen oxides NO_x - about 90%; purification from sulfur oxides SO_2 - more than 99%.

Such technological schemes of thermal coal-fired plants are the most typical for the majority of plants that have been in operation for a long time. Such schemes are not perfect from the standpoint of modern economic and environmental requirements.

Therefore, below are other more advanced technologies that require consideration and potentially have prospects for application to coal-fired plants in operation in Kazakhstan, in terms of reducing the cost of primary fuel, including, for own needs.

Tasks and possibilities of increasing technological efficiency of coal-fired thermal power plants. Improvement of efficiency of thermal energy, first of all - at operating TPPs and TPPs under construction, is possible by solving fundamental problems:

(1) Solving energy and environmental problems by replacing traditional energy with renewable energy is one direction of energy potential development. The second direction is to improve the energy efficiency of conventional CHP through innovative modernization. Maximum capacity limitations occur due to insufficient industrial heat consumption, the amount of cooling water and high values of its temperature.

(2) Qualitative structuring of the selected areas of modernization of energy infrastructure. Increase in GDP by 6% requires commissioning 4% per year in installed capacity. This is with the preservation of the QRM of 50% and the need to replace morally and physically obsolete equipment is inefficient and insufficient.

(3) Reduction of specific fuel consumption by introducing technologies that reduce dependence of power plants operation on changes in atmospheric parameters and bring the temperature of chilled water closer to the theoretical cooling limit.

(4) Elimination of the use of natural water sources as technical coolers, implementation of highly efficient technologies of gas cleaning, water treatment and steam and gas removal.

(5) Implementation of technologies for the use of low-potential heat of service water and flue gases. The total amount of unused heat reaches 70% of all heat received during fuel combustion, so it is important to use rational mechanisms for its use. Even now it is vital to find and implement energy-efficient controlled technologies that reduce the technogenic impact on the environment.

(6) Implementation of technologies to provide own needs of TPP from RES, including energy of movement of removed gases and air will increase useful output of electric energy up to 5%.

(7) Creation of effective strategic plans, ensuring control of their implementation, introduction of innovations, solving personnel, financial and infrastructure problems; effective innovation infrastructures, legislative framework, intellectual property protection system. Implementation of innovations is episodic in nature. Promising technologies remain unclaimed because of the payback period (2 to 5 years), which is rarely achievable in the energy sector.

(8) Creation of high-tech system of monitoring the reliability of equipment and structures, determining their residual life, introduction of a system of preventive inspections and repairs; comprehensive comprehensive comprehensive energy audit, based on engineering surveys.

The main typical solutions to improve the efficiency of CHPP. The measures are presented on five systems of energy and resource supply: 1) the power supply system; 2) the heat supply system; 3) the fuel supply system; 4) the water supply and sanitation system; 5) the compressed air supply system and compressor equipment.

Perspective equipment and technologies. It is recommended to use semiconductor devices of power electronics together with resonant filters and active harmonic filters. Promising equipment and technologies in the lighting system. Organization of energy saving monitoring with measurements, data collection and processing. Application of heat exchangers. Application of heat pumps. Application of cogeneration plants, including heat recovery for the needs of heating, ventilation and air conditioning systems. Reuse of wastewater, treated and decontaminated; use of treated water to feed the circulating water supply system. Application of rational schemes of compressor cooling and utilization of heat from cooling systems. Reduction of compressed air consumption through decentralization of compressed air supply to consumers.

Modernization of energy generation facilities. Objectives are to increase energy efficiency of TPPs by reducing specific fuel consumption; increase reliability and efficiency of power supply of facilities by creating local generation; obtain synergy effect from use of own fuel resources at TPPs; develop activities in the field of renewable energy sources.

The technical modernization policy being developed concerns the sphere of operation of the following types of equipment: 1) Heat and mechanical equipment; 2) Heat networks; 3) Hydraulic engineering structures and water management; 4) Electrical equipment; 5) Territory, production buildings and structures; 6) Operational dispatch management; 7) Operation management; 8) Equipment reliability management.

One of the tasks of activity is implementation of energy projects based on RES with priority development of wind, bio- and solar energy.

Design recommendations to improve the energy efficiency and environmental safety of coal-fired CHPP. The measures recommended for implementation are divided into two categories: organizational and technical and investment.

Organizational and technical - strict compliance with nominal modes of operation, ensuring the optimal level of loading of units, timely performance of adjustment and repair and restoration work, improving production culture, establishing proper order in the energy economy;

Investment - introduction of modern energy-efficient equipment, modernization of processes and technologies, replacement of obsolete production facilities, etc.

The above list of typical measures to improve energy efficiency and environmental safety can be expanded with other typical measures.

Use of low-potential waste heat from energy sources for the purposes of industrial zones adjacent to CHP plants. Deep heat utilization of flue gases of boiler units with installation of automation systems. Reconstruction of water treatment facilities of heat sources, modernization of heat exchangers. Use of mixed fuels at power sources of different capacities. Using the energy of water, wind, earth, solar energy.

Application of heat pumps and renewable sources of low-potential heat in heat supply systems (trigeneration). Increase of electric and heat energy generation by combined cycle. Reduction of energy carrier costs for CH sources. In addition, we recommend the use of other, non-traditional, alternative technical solutions, such as: using the heat of formation waters and geothermal sources for heating and hot water; using solar collectors for additional hot water and heating of buildings as well as CHP; creating a system of seasonal and daily heat accumulation; using efficient heat exchangers for utilization of low potential heat; using heat pumps for heating and hot water with extraction of low potential heat from sewage and industrial water discharges; heat of building basements; heat of solar collectors; warm exhaust of exhaust ventilation; return network water of heating system; water of open ponds.

Global technological trends for improving energy efficiency and environmental sustainability are: RES components and technologies in modernization systems of coal-fired plants; creation of components of distributed and autonomous RES-, SMART- and "H&C"-technologies of coal-fired TPPs; modern technologies of cogeneration and trigeneration.

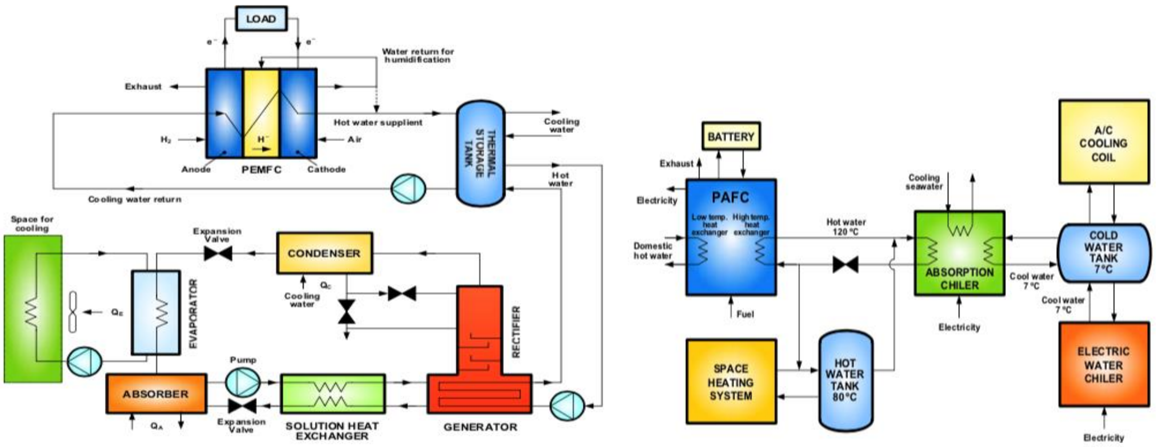

Fig. 2 **Schematic diagram of PEMFC technology in trigeneration mode, which can be used for own needs of TPP (left) and PAFC technology to obtain chilled process water (right)**

By applying specially developed scientific and technological solutions the efficiency of energy resources utilization is significantly increased and can reach from 85% to 93%. In particular, the FLU-ACE® technology can recover up to 90% of the heat at temperatures between 50°C and 70°C. And fuel cells give them a high overall efficiency of about 85%. Also, for example, the configuration adopted with Siemens-Westinghouse SOFC technology has an electrical efficiency of 43.3%, thermal efficiency: in heating - 43.7%, in cooling - 52.6%, in hot water production - 46.7%. The overall efficiency results in the three operating modes are up to 87.95%, 95.9% and 90%, respectively.

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