SECTION XIV. ENERGY AND POWER ENGINEERING

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OPTIMIZATION OF HEAT RECOVERY CIRCUIT PARAMETERS OF COMBINED CYCLES POWER PLANTS IN ENERGY SECTOR COUPLING SYSTEM

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***Abstract**: This study sought to optimize the steam parameters of combined-cycle power plants as a part of the integration of power and gas sectors to enhance the efficiency of the energy system. The potential for decarbonization and integration with storage systems is emphasized. A specific CCPP configuration involving a UGT 6000 DP71 gas turbine is detailed. Simulation results demonstrate CCPP performance at ambient temperature range from -35 to +45 °C, showcasing power and efficiency changes.*

Coupling the power and gas sectors by optimizing existing connections in the production, transportation and distribution of energy and gas is one of the promising ways to improve the efficiency of the EU energy system and compliance with EU Energy Efficiency Directive 2012/27/EU [1, 2].

Significant savings in fuel resources in the power sector are achieved by using cogeneration combined-cycle power plants (CCPP) [3]. CCPP uses the heat of gas turbine (GT) exhaust gases to generate electrical and thermal energy. A feature of cogeneration in the energy sector is that electricity is the basis of production, and thermal energy is an additional product that improves the efficiency of the plant.

In terms of the efficiency and flexibility of integrated heat and power systems, CCPPs have a significant potential to move toward decarbonization by empowering consumers and integrating with gas, heat, and power storage [4].

Figure 1 shows the place of CCPP in the energy sector coupling structure. In addition to the standard Power-to-Heat (P2H) and Heat-to-Power (H2P) links, CCPPs are linked to heat, gas, and energy storages.

Ebsilon Professional 16.0 software was used to generate a thermal diagram, optimize steam parameters in the heat recovery steam generator (HRSG) and determine the effect of ambient temperature on the efficiency of the CCPP.

The paper considers a CCPP with a GT engine UGT 6000 DP71 [5] with a one-pressure HRSG. Initial data for the boiler thermal calculation was taken from [6]. The

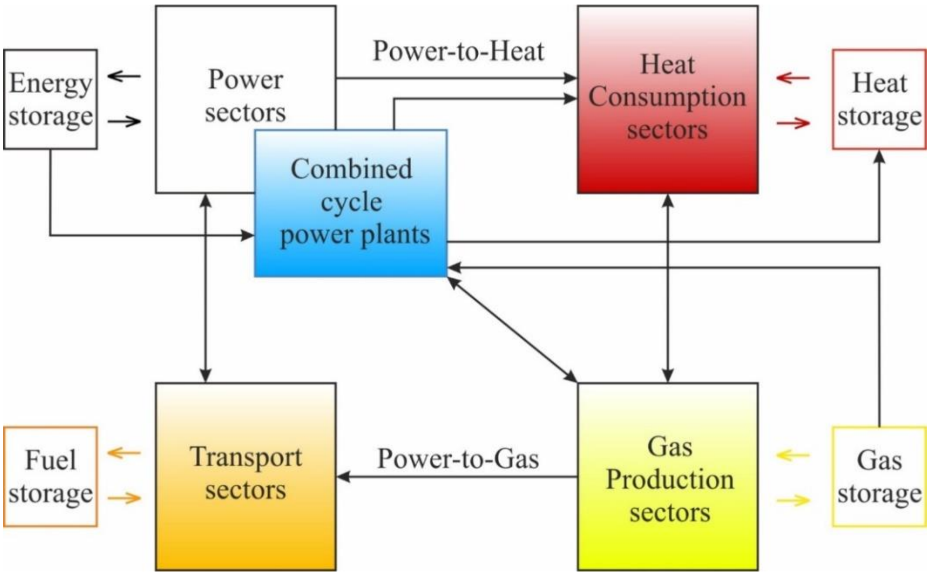


Fig. 1. **Combined cycles power plant as part of energy sector coupling system**

thermal diagram of the installation is shown in Figure 2. The peculiarity of this scheme is an additional stabilization combustion chamber (CC) in front of the superheater (SH), hot water section (HW) in the tail part of the HRSG and a peak-load boiler in the heating network for consumers.

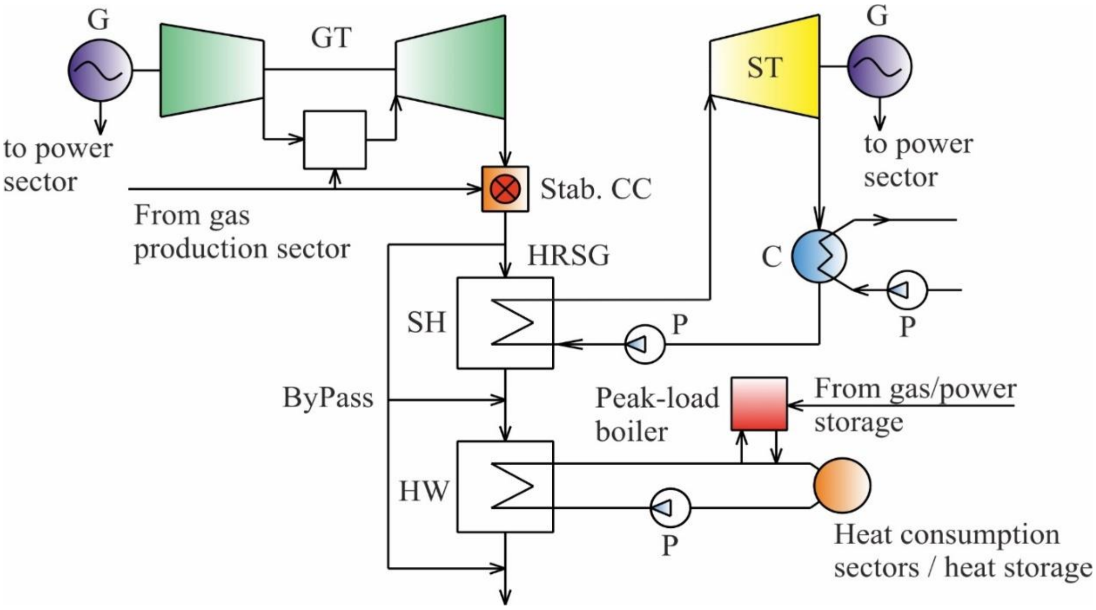


Fig. 2. **CCPP scheme with P2H, H2P and heat, gas, energy storage connections**

To apply mathematical methods for the implementation and analysis of this study, it is necessary to move from a meaningful to a mathematical formulation of the problem.

The target optimization function is the dependence of electrical efficiency on the steam turbine (ST) pressure $\eta_{el} = f(P_{ST})$. The steam pressure P_{ST} is the optimization criterion. That is, the mathematical formulation of this optimization study will be written as follows:

$$\eta_{el}^{CCPP} = f(P_{ST}, t_{ST}, x_2);$$
$$f(P_{ST}, t_{ST}, x_2) \rightarrow extr\ (\eta_{el}^{CCPP} \in Q).$$

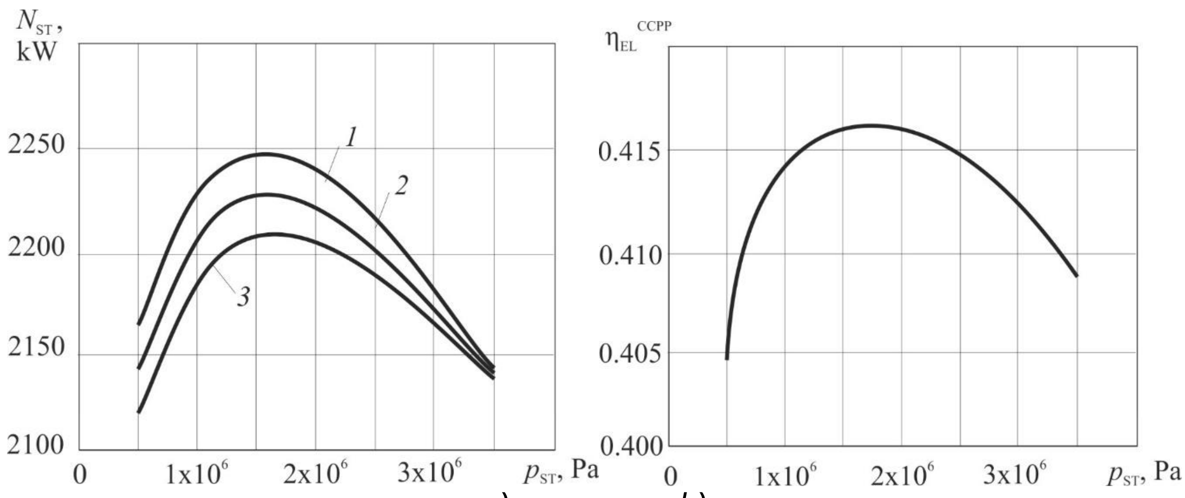
The results of the optimization calculations are shown in Figure 3.

Further, the operation of the power plant was simulated in the ambient temperature range T_{amb} = -35 .. +45 °C. To simplify the mathematical model, the work were carried out under the following assumptions:

– the pressure of superheated steam was P_{ST} = 1.5 MPa (according to optimization results), the coefficient of heat retention in the HRSG φ = 0.97, the percentage of blowing p = 2%;

- the temperature gradient at the hot end of the superheater was Θ_{ST} = 30 ^oC, at the cold end of the evaporating surface Θ_{EVAP} = 10 ^oC, and in the economizer was Θ_{EC} = 10 ^oC;

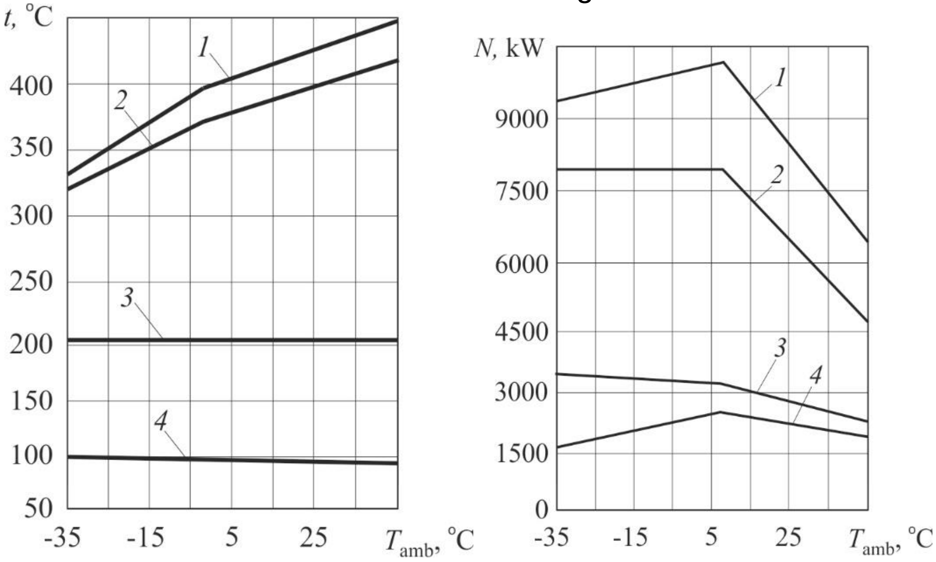
- internal CCPP steam consumption was 4% of the steam productivity of the HRSG.



a) *b)*

Fig. 3. ***a)* ST power from steam pressure $N_{st} = f(P_{ST})$: *1* – Θ_{ST} = 10 ^{0}C; *2* – Θ_{ST} = 30 ^{0}C; *3* – Θ_{ST} = 50 ^{0}C; *b)* electrical efficiency from steam pressure $\eta_{el}^{CCPP} = f(P_{ST})$**

The results of the simulation are shown in Figure 4.



a) *b)*

Fig. 4. ***a)* temperatures: *1* – HRSG inlet; *2* – superheated steam; *3* – saturation in steam drum; *4* – HRSG outlet; *b)* power: *1* – CCPP; *2* – GT; *3* – HW; *4* – ST.**

With an increase T_{amb} from -35 to +45 °C, the HRSG inlet temperature increases significantly from 330 to 454 °C, which causes, despite the decrease in gas mass flow, an increase in the superheat steam temperature from 322 to 419 °C. At the same time, the outlet HRSG gases temperature changes only by a few degrees (from 98 to 92 °C).

The power of the steam turbine and, accordingly, the CCPP increases as the air temperature rises to -3 °C, and then falls (Fig. 4b), which is associated with the same nature of the change in the steam productivity of the HRSG and the adiabatic heat drop.

Conclusion.

The resulting mathematical model can predict the change in the operating parameters of a CCPP in the ambient temperature range T_{amb} = -35...+45 °C. The results showed that in the specified range of ambient temperature changes, the power of the HW section of the boiler changed from 2000 to 3200 kW, and the total electric power of the CCPP from 6500 to 9500 kW. The obtained values can be used as initial data for coupling with heat consumption, power and gas production sector, and gas/power/heat storages as well.

To stabilize the temperature of the superheated steam, the change of which was 100 °C, a stabilization combustion chamber was installed in front of HRSG, which will also allow regulating the electrical and thermal power according to the load. To compensate for the power loss (1200 kW) of the HW section of the HRSG, a peak-load boiler was installed associated with gas/energy storage.

Thus, the proposed plant scheme, its connections with P2H, H2P and heat, gas, energy storage, and the developed mathematical model will allow to form a database of PP output parameters for coupling with the power, gas, and heat energy sector.

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