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Abstract of the doctoral dissertation

„OPTIMIZATION OF ELECTRICITY AND HEAT GENERATION IN A COMBINED HEAT AND POWER PLANT (CCGT) COOPERATING WITH COAL BOILERS AND A THERMAL ENERGY STORAGE UNIT"

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This thesis is a comprehensive overview of a method of economic efficiency optimization of electricity and heat generation in a combined heat and power (CHP) plant composed of a gas-steam module, a gas module, coal boilers and a thermal energy storage unit. It defines a general mathematical model of the energy market consisting in the elements of technology, economy and the law. The study presents the scheme and working parameters of the studied CHP plant and the impact of a change in the source structure, the time of electrical energy generation, the time of gas purchase, the sequence of heat source activation, the prices of electricity and generated electrical power etc. on the gross profit.

It further describes the goal function for optimization and maximisation of the net profit on the energy market and the limitations of the goal function, which include, among other things, correction curves of gas turbines, structured external system heat load curves, legal restrictions governing access to certificates of origin for electricity and economic limitations in the form of energy prices. Moreover, it demonstrates solutions of the optimization task on the basis of a few selected days and a complete year. The results obtained show the ability to increase the CHP plant gross profit by around 14% per annum for the year 2016 data and up to 40% for the daily data. It is possible thanks to an alteration of electrical power generated within 24 hours.

For the purpose of appraisal of a financial instrument in the form of the power market, a CHP plant mathematical model was applied using a variable price of carbon dioxide (CO2) allowances, electricity and gas, and known CHP plant operational costs. It was found that the minimum bid per share should be at least 453 000 PLN/MW for 160 PLN/MWh of electricity, 80 PLN/MWh of gas, and 30 EUR/Mg CO2.

Two thermodynamic models of a CHP plant are demonstrated: one using an isentropic and polytropic processes, and a model of gas incineration in a Joule-Brayton cycle. A detailed algorithm of calculations conducted in the models is presented. The comparison of model results with the results of measurements revealed good agreement – the calculation error was between 4% and 20%, depending on the analysed variable in a cycle. It is concluded that the real transformations occurring in a gas turbine are between the isentropic and polytropic processes.

Finally, the dissertation demonstrates the outcomes the of CHP plant economic efficiency optimization carried out in Siedlce over the years 2002-2016. It presents the changes introduced in the source structure and financial performance. An increase in revenues observed over the studied period is from approximately PLN 40 million to around PLN 110 million, primarily thanks to the conversion of a heat plant into a combined heat and power (CHP) gas-steam system plant and the utilisation of available financial instruments dedicated to high-efficiency cogeneration.

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