Waste heat utilisation for cogeneration of Energy

Wykorzystanie ciepła odpadowego w procesie skojarzonego wytwarzania energii

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The paper shows the analysis of potential of absorption heat pump (APC) application to increase the efficiency of source energy conversion in the cogeneration power plant, by recuperation of waste heat from oil cooling system. In the presented case, the purpose of APC implementation was to eliminate the number of startup of pick hot water boilers. Obtained results showed that the waste heat may be utilised during the highest heat demand which may lead to delay or even avoiding the pick boiler start up, owing to absorption heat pump implementation.

KEYWORDS: heat recuperation, heat pumps, efficiency increase, cogeneration

Professional energy based on the burning of fossil fuels faces many challenges, which are mainly due to increasingly stringent environmental requirements. At present, the main problem is the reduction of emissions of various pollutants, especially those contributing to the greenhouse effect (e.g. carbon dioxide), and directly affecting the quality of human life (e.g. dust). Additional requirements stem from European directives, which aim to continually improve the efficiency of primary energy use and increase the share of renewable energy sources in the overall electricity and heat production balance.

Due to the increasing share of renewable electricity generation, the key problem of the Polish power industry based on fossil fuel combustion has become the flexibility of work, especially large generators. The amount of energy produced from renewable sources, such as wind or sun, depends on the rapidly changing atmospheric conditions. In turn, because of the unpredictability of the weather, it is impossible to plan the volume of production from renewable sources. At present, power generation units are not designed to work in such fast-changing conditions, when in a very short time the surplus following deficiency (or vice versa) of energy from renewable sources in the power grid may occur. This situation, coupled with the lack of effective energy storage technologies, makes it impossible to provide energy security (understood as supply reliability) based on renewable energy sources. It seems that in the coming years, security will continue to be ensured by fossil fuels.

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Today's electricity production in the thermal cycle of conventional power plant is done with efficiency ranging from 35% to 45% gross and even up to 50% in the case of the latest generation units [1]. The greatest energy losses leading to such efficiency levels are caused by the steam condensation process in the condenser and in the dissipation of condensation heat to the atmosphere in open or closed cooling systems. The minimization of the energy losses in the condenser represents the greatest potential for improving efficiency of primary energy utilization in a conventional steam power plant. Unfortunately, waste heat from the condenser is characterized by low thermodynamic parameters, especially low temperature, which make its direct use for district heating or industrial purposes impossible. However, thanks to the use of modern absorption technologies which allow for increase of the energy potential of waste heat, at least part of it can be effectively recovered [3].

One of utilization methods of such recovered waste heat may be, for example, its use for the production of heat for district heating system or of hot water for industrial purposes. This solution can be applied in the case of power units that only produce electricity - this will result in cogeneration power plant that simultaneously generates electricity and heat (CHP), and in the case of CHP, where it may lead to increase of production of heat. Absorption technologies can be implemented even in a counterbalance power plants, however in a limited scope, in which a certain amount of waste heat may be recovered, for example, from oil cooling systems.

Implementation of the absorption heat pump (AHP)

The absorption heat pump is a device which, by providing external energy in the form of heat, realizes the process of raising the energetic potential of the low temperature heat source [2]. For its proper operation, it is therefore necessary to provide AHP with a heated medium as well as with some amount of heat which may be derived from the turbine steam bleeding. As a result, continuously operated, in the absorber and the heat pump generator, absorption and desorption cycles lead to an increase in the energy potential of the low temperature medium.

Both the amount of heat to be recovered and the potential increase in the heated medium temperature depend on many construction and process parameters of the heat pump [2]. The most important of these are: type of AHP working medium, temperature of the lower heat source (it may be cooling water leaving the turbine condenser or oil cooling system) and inlet temperature of the heated medium. Exemplary characteristics of AHP thermal power - normalized by the nominal values of the temperatures, for which AHP was selected or constructed - depending on these temperatures are shown in fig. 1 and fig. 2.

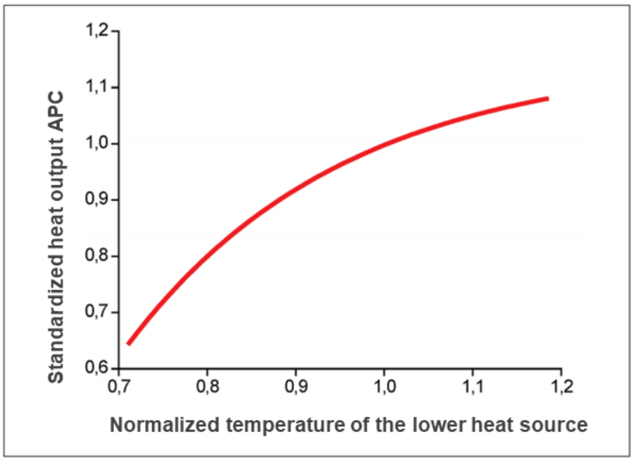

Fig. 1. Normalized thermal power characteristics as a function of the temperature of the lower heat source

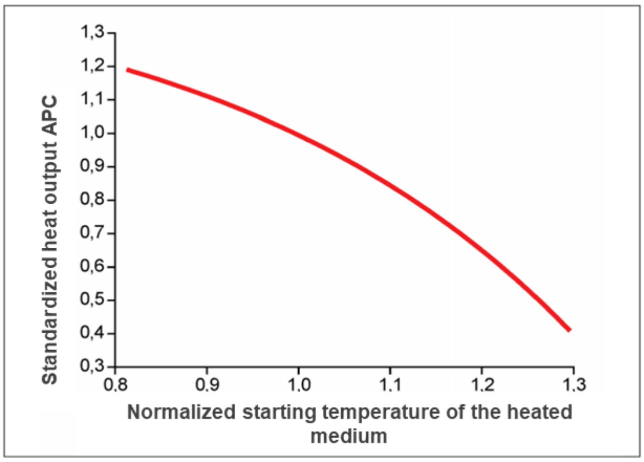

Fig. 2. Normalized thermal power characteristics as a function of the inlet temperature of the heated medium

As the characteristics show, the performance of the heat pump is strongly dependent on the external conditions. Unfortunately, from the point of view of heat demand by the customers, this dependence is not appropriate, because the AHP potential is the higher, when the higher the temperature of the lower heat source is. In the case of heat recovery from the system of cooling of the turbine condenser, this is the case when the ambient temperature is higher and therefore there is smaller heat demand. Nevertheless, proper selection of nominal operating parameters and heat pump design allow for significant recovery of waste heat even under varying conditions.

Properly selected AHP can be integrated into the power plant, however, depending on the turbine, available steam bleeding parameters and heat pump thermal power, the feed steam can be extracted from one of turbine bleedings, plant steam collector or eg. from the pipe between turbine MP and LP part. The method of integration of AHP with the power plant, showing the energy (heat) flows, is schematically illustrated in Fig. 3.

From the point of view of AHP integration with the power plant, it is very important to choose the right vapor collection point, which is the upper heat source for AHP. This is crucial for the size of the AHP - because of the need to transfer the appropriate amount of heat in the AHP generator, which determines the size of the generator. For this reason, the best solution for steam powered AHP is to select a steam extraction location so that only steam condensation heat is received in the pump generator (this means that the steam fed AHP is saturated steam). Unfortunately, in the case of integration of a heat pump with an existing power unit, it is not usually possible to use saturated steam directly from the turbine bleeding. In such a situation, the location of the steam extraction should be chosen in such a way that the energy cost of the bringing superheated steam to the saturation level would be as small as possible. One of possible ways of preparation of the steam for feeding APC can be, for example, direct injection of water from the supply water tank (SWT).

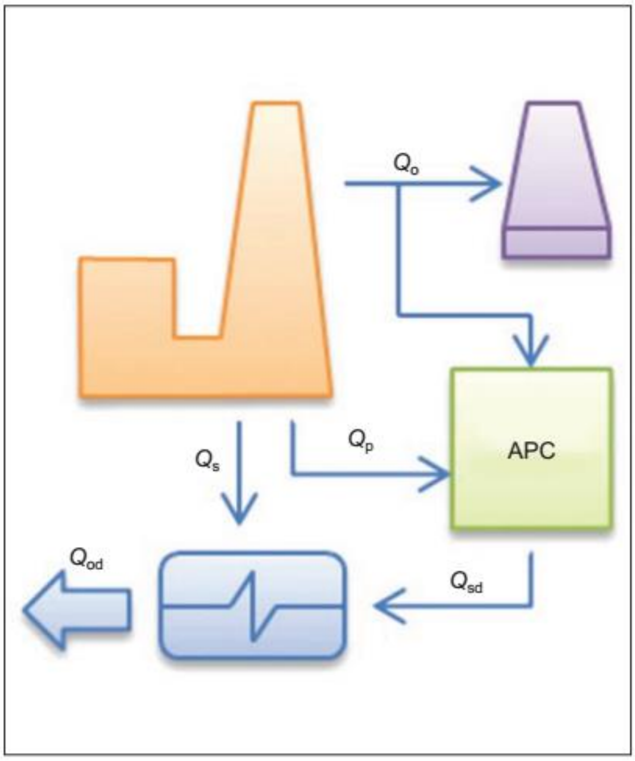

Fig. 3. Diagram of integration of AHP with power plant (Qo - waste heat, Qp - heat from steam, Qs - system heat from power plant, Qsd - additional system heat of AHP, Qod - heat for customers)

Sample calculation results

One of the options for the analysis of the applicability of AHP to waste heat recovery was determination, for selected CHP plant, of a possible reduction of the number of pick hot water boilers (PWB) startups by implementation of AHP. For this purpose, a simulation model of the AHP system integrated with the selected steam power unit was developed and calculations were performed. They were made using SimTech's IPSEpro software. In the simulation environment, a zero-dimensional model (based on mass, energy and momentum governing equations) of a CHP plant was integrated with the AHP simulation model.

Due to the nature of selected steam power plant and especially availability of deriving of the saturated steam from one of turbine bleedings as the AHP power source, the location of the AHP integration with power plant was obvious, and this saturation steam was selected. Due to that, there was no need for special preparation of steam, which could directly be use as an APC power source. The closed oil cooling system was chosen as a lower heat source which waste heat was recovered from.. The analysis was carried out for the selected year of power plant operation and the results of the calculations are presented in the table.

TABLE. Summary of calculation results

Number of hours considered, h	717	
Hours of AHP operation	246	
Number of replaced PWB startups, h	12	
	Sum	Hourly average
Heat production in replaced water boiler, MWh	3500	14,23
Production of heat required according to the regulation table, MWh	31 612	128,51
Real production of heat delivered to the network with CHP and PWB, MWh	34 375	139,73
Heat production with CHP, MWh	30 321	123,26
Heat lack of the block itself (without PWB and AHP), MWh	–1291	–5,25
Excess heat output to the network (with CHP and PWB), MWh	2762	11,23
Production of electricity without AHP, MWh	15436	62,75
Production of electricity with AHP, MWh	15323	62,29
Decrease of electricity production as a result of AHP's work, MWh	113	0,46
Recovered waste heat, MWh	381	1,55
Excess heat production of CHP with AHP (without PWB), MWh	–365	–1,48

As it can be seen, implementation of AHP would eliminate 12 runs of peak hot water boilers, which in this case accounted for about 35% of the total operating time of the PWB.

In the analyzed period, due to the technological minimum power of hot water boilers, the CHP system together with PWB produced an excess of 2762 MWh of heat, which was not demanded by the customers. Application of AHP would avoid this loss, but due to the low power of the AHP (due to the amount of available waste heat from the oil cooling system), the replacement of the PWB by AHP would result in a slight heat deficit of 365 MWh. This amount seems significant, however, in terms of hourly average of only 1.48 MWh - this value is acceptable from the standpoint of keeping parameters of the hot water supplied to the end consumer.

Conclusions

One of the methods of increasing the efficiency of primary energy conversion to electricity and heat is to reduce energy losses to the environment, which in the case of steam power units may be realized by, for example, AHP implementation. Depending on the specific power unit, heat can be recovered from different locations of the system and used for different purposes. In the illustrated example, the AHP implementation was designed to minimize the CHP losses as a result of eliminating peak hot water boiler startups. The results from calculations have confirmed that it is possible to use waste heat during the period of the greatest heat demand, therefore it is possible to delay or completely eliminate the startups of the peak heat source.

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