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Exploitation of the waste-heat from hydro power plants

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ABSTRACT

This paper presents the possibility of exploiting low-temperature heat from the generators' cooling system within a hydro power plant, using a HTHP (high temperature heat-pump) that enables heating at up to 85 °C.

The results based on theoretical calculations are presented for heat-flows, the powers of the compressors, and COP (coefficient of performance) values for the cases when using the refrigerant R717 and a single stage high pressure compressor (up to 50 bar) under varying operational conditions.

Real possibilities are presented for heat production based on measurements of a closed cooling system of generators, thus showing that the total efficiencies of generators can be enhanced by up to 1% whilst reducing the electricity consumption during the electric heating of buildings. In addition, the simulations of cost and revenue, and cumulatively discounted cash-flows of the investment in HTHP are presented using the MS Excel computer program.

The payback period for the investment in a 500 kW high-temperature heat-pump for exploiting low-temperature heat of the generators' cooling system would be approximately 2 years for the case of heating the commercial buildings of the hydro power plant, and 7 years for the case when heating the fluid within the nearby district heating systems of urban settlements.

1. Introduction

World oil and fossil fuel supplies are rapidly dwindling [1] and over the last decade energy demand has doubled [2]. More research and developments are needed for engaging energy problems and to reduce the emissions of greenhouse gases [3]. Consequently environmental and spatial planning for renewable energy sources are becoming increasingly important values; therefore environmental problems need to be considered, even at the international level, regarding the fields of heating buildings, and the development of common approaches and new attitudes towards the natural environment. It is for these reasons that one of the principally agreed measures is the reduction (or at least slowdown of the growth) of energy-demand, especially through its efficient usage and the usage of renewable-energy, whilst ensuring the same or a higher quality of life. One of the possible measures for reducing CO_2 emissions is exploiting the waste-heat from electrical generators within a hydro power plant that produces renewable electricity.

Recently, more attention has been paid to the integration of high-temperature heat pumps within energy systems with the goals of enhancing their efficiencies, and reducing the CO_2 emissions. Integration of a heat pump into existing ammonia refrigeration units is reported in Refs. [4,5]. However, they considered the high performance compressor with the maximum ammonia pressure of 40 bar. Additional scientifically applied research has brought [6] higher performance single stage compressors with maximum ammonia pressure of 50 bar. High temperature heat pumps integrated within a cogeneration unit can also help towards a better coexistence between cogeneration and intermittent renewables [7], because the overall cogeneration efficiency increases from 88.9 to 95.5% [8].

The generators waste-heat have a low-temperature potential and in the case of a hydro power plant it is usually released into river water using a cooling system. However, the low-temperature potential can be exploited for the production of high temperature water for high-temperature heating using a high temperature heat pump.

It is easy to see that the overall efficiencies of generators would increase because of the development of new technologies for waste heat utilisation, whilst meanwhile decreasing the electricity consumption of electric boilers for the heating of office buildings. This

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work presents the summary of a scientifically applied study that is presently in the implementation phase. The main focus is the possibility of using low-temperature-heat that is released by the cooling of generators within a hydro power plant by integrating an HTHP (high temperature heat-pump) within the plant.

The design of the system only became possible after 2009, when the efficient HTHPs emerged on the global market, and they are now manufactured on the basis of the results of the EUREKA research project [6]. The expedience of the presented system for exploiting the low-temperature heat from the generators' cooling system using HTHP, is supported by the following facts:

- the proposed innovative reconstruction of generators' cooling systems has not been presented until now,
- the efficiency of the renewable energy source is enhanced,
- the waste-heat obtained by cooling the generators is practically free,
- the investment in a high-temperature heat-pump is small, with a short-term return,
- it is possible to integrate HTHP within the heating systems, and
- meets the requirements regarding the rational usage of energy and the environmental protection.

2. Cooling system of generators

Two cooling systems for regulated cooling of three synchronous generators (SIEMENS, type 1HD 7339-3WE24-Z) were installed in the hydro power plant Mariborski otok. A closed system for the regulated cooling of the generators was implemented for low-temperature heating. Now the system would be upgraded with the HTHP to meet the needs of high-temperature heating of the plant's office buildings. Additionally, any excess heat produced would be transferred into the nearby district heating system (2 km away) in order to extend the exploitation time of the HTHP into the summer months. An open cooling system would be used in the event of a HTTP failure or in the case of any excess of low-temperature heat.

A cooling water volume flow of 7.5 l/s (27 m^3/h) with a temperature regime of 30–40 °C is available per single generator. The released heat can be partly used in the high-temperature heat-pump at the highest temperature level and the remainder stored in two heat storage tanks of 50 m^3 each – Fig. 1

The air which cools the synchronous generator windings is cooled by water-cooled coolers on the outer side of the stator housing.

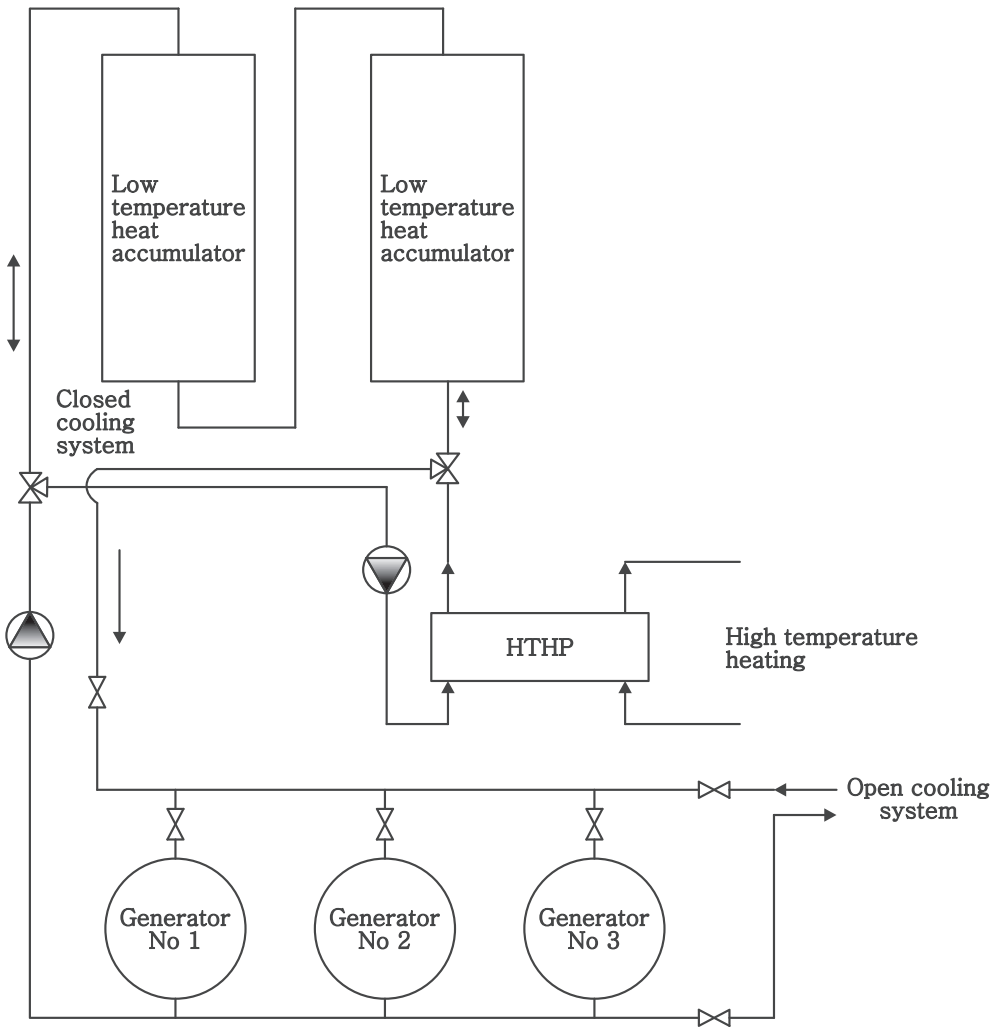

Fig. 1. Schematic representation of exploiting the potential of low-temperature generators' cooling system using HTHP.

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