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Experimental study of large temperature lift heat pump (LTLHP) in CHP system

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ABSTRACT

Combined heating and power (CHP) system is one of most promising ways for district heating, however, more than 20% of heat gained in the boiler is discharged to atmosphere directly by the cooling tower. A new absorption heat pump named LTLHP adopting the lithium bromide aqueous solution as working pair is invented for heat recovery at the thermal power plant, and its temperature difference between the evaporator and condenser could reach 50 °C without risk of crystallization. The concentration difference of lithium bromide solution is 3.58% for a satisfying COP (coefficient of performance) without the risk of crystallization, which is far lower than that of a conventional absorption heat pump. The LTLHP is also experimented at a thermal power plant with double 330 megawatt steam turbines. The mean COP could reach 1.51 during the whole heating period, and 9.5×10^6 kg of coal could be saved annually, and the index of coal consumption for heating at the thermal power plant could be reduced to 14.0 kg/GJ, which is far lower than that of a conventional thermal power plant (18.0 kg/GJ).

1. Introduction

1.1. Conventional CHP system

Energy and environment are two significant issues requiring global attention. CHP system is one of promising aspects for the district heating, which could combine power generation and heat production at the thermal power plant with higher energy efficiency and lower pollutant emission. It is reported that 76% of heating load is afforded by district heating system in China, in which 42% is CHP system [1].

A conventional CHP is shown in Fig. 1. Super-heated steam is utilized step by step in the steam turbine. One part of steam is extracted for heating with a steam-water heat exchanger. Meanwhile, the other steam is exhausted and condensed with the air or water cooling tower, however, this discharged heat is plenty but difficult to be recovered due to its low grade, which is often lower than 40 °C.

1.2. CHP system with absorption heat pump

The heating capacity of the thermal power plant could be increased significantly when recovered its discharged heat, which could reduce coal consumption for heating also. A CHP system with air cooling adopting the absorption heat pump for heat recovery is recommended [2], which is shown in Fig. 2. The absorption heat pump included in HRU (heat recovery unit) is driven by extracted steam from turbine, which could recover discharged heat in its evaporation. Systematic energy efficiency could be lifted significantly, besides, coal consumption and pollutant emission of heating could be decreased obviously.

Besides, many efforts have been put on how to increase the energy efficiency of CHP [3–10]. A natural gas-fuelled system combined in a power plant with a waste heat recovery system was given, and a gas/steam combined cycle was presented to recover condensation heat of exhausted steam [3]. Necessary synergy between gas turbines and thermal engines was emphasized at the power plant, which could increase potential energy efficiency by 10% [4]. ORC (organic rankine cycle) system was adopted for a small CHP, and they found that expander electrical isentropic effectiveness was maximized by 70% for a pressure ratio suitable for the given CHP [5,6]. A CHP system with heat recovery and energy storage was studied, and results showed that thermal energy storage could be used more intensively with more fluctuating CHP load [7].

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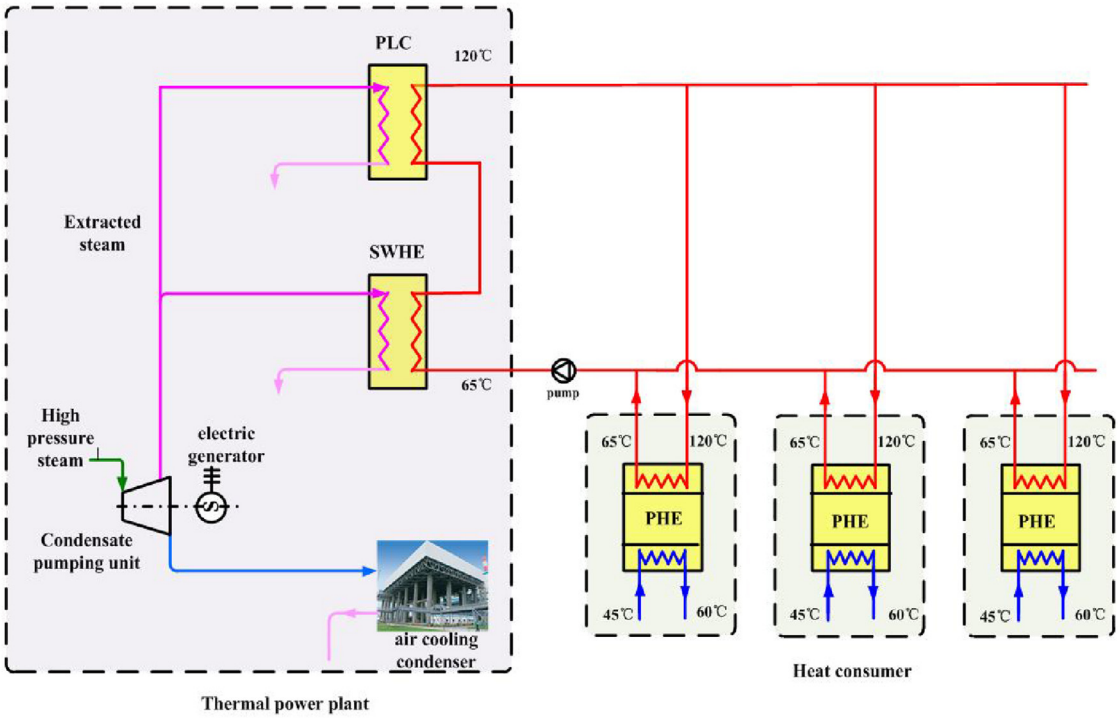

Fig. 1. Principle of conventional CHP system with air cooling [2].

Exergy analysis was recommended for analysis of CHP systems[8], and a CHP-GSHP(ground source heat pump) system was presented and discussed, which could generate more power than the conventional CHP [9].

The EHP (ejector heat pump) was discussed for increasing the heating capacity of heating pipes [10]. Meanwhile, several heat pumps and CCHP(combined cooling heating and power) systems were compared and discussed for the possibility of application [11,12].

Installing the absorption heat pump was found to be an efficient way to recover low grade heat with high COP in different industries [13]. Available working fluids of absorption heat pumps were discussed and compared for different application [13–15]. However, the absorption heat pump is recommended for CHP with air cooling

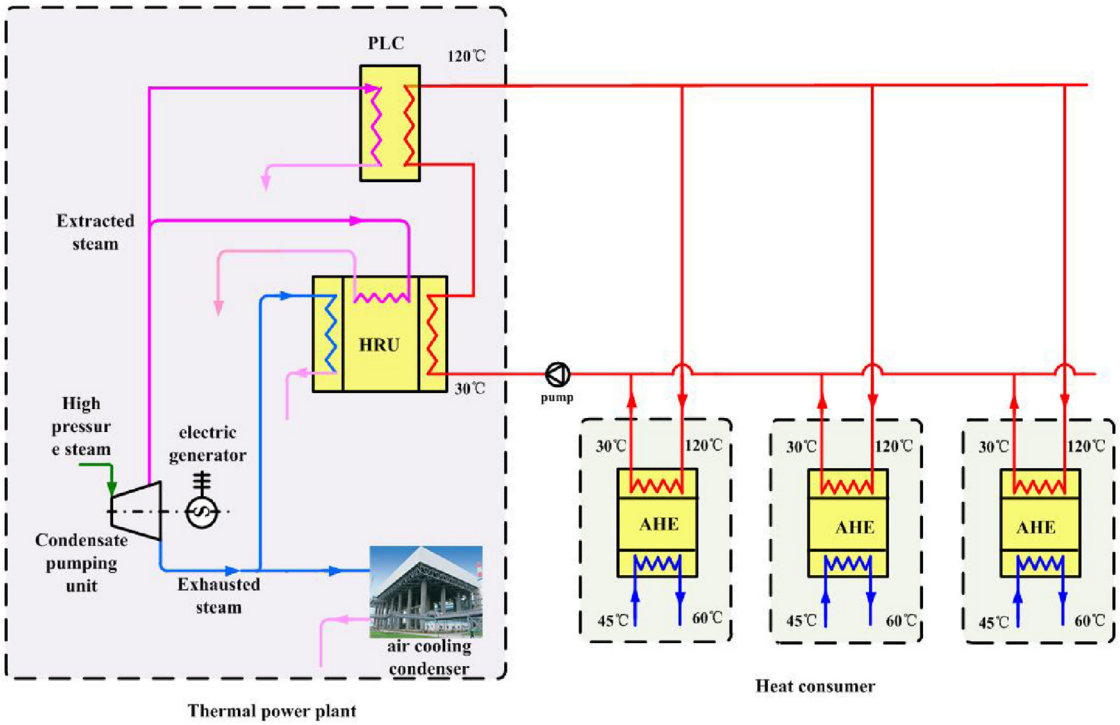

Fig. 2. Principle of CHP system with absorption heat pump [2].