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Experimental research on LiBr refrigeration – Heat pump system applied in CCHP system

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ABSTRACT

A new heat recovery technique for a LiBr refrigeration-heat pump system applied in CCHP(Combined Cooling, Heating and Power system) system is proposed in this paper. The system can recover the heat of the LiBr refrigeration cooling water to heat the demineralized water of the boiler. Experimental research on the operating characteristics of the compound system is carried out and the obtained conclusions are as follows: The LiBr refrigeration-heat pump system is able to perform stably and flexibly. The heat pump system has a relative large coefficient of performance (COP_P) which can be as high as 6.13. When the outlet temperature of the demineralized water is 67.8 °C, the CCHP system brings 26.6% decrease in primary energy rate consumption compared with the combined heat and power production system (CHP) plus electricity-driven refrigeration. It is suggested that heat pumps should be used in CCHP system to heat the demineralized water of the boiler by recovering the exhaust heat of the LiBr refrigeration system.

1. Introduction

In a world of continuously growing scarcity of primary energy as well as of an insurmountable irreversible environmental impact, due to human activity onto the biosphere, it is of utmost importance to look for alternatives to traditional energy sources [1]. Obviously, the best energy source is the energy that has been saved by the means of the increase in energy conversion efficiency. Combined cooling, heating and power(CCHP) system, which has already been applied in many industrial and commercial sections, shows a great potential in energy saving and emission control, and thus attracts investigator's attention extensively [2–5].Compared with the traditional large centralized power plant and local air-conditioning system, distributed CCHP systems possess some unique advantages, such as improved overall fuel energy utilization ratio, reduced CO_2 emission, and increased reliability of the energy supply network [6,7].

CCHP system was first used in the United States. CCHP form of district cooling in China late start in 1992, at present, CCHP system has not been applied in large scale. Such as in the central Hospital of Huangpu District in Shanghai and Shanghai Pudong International Airport, CCHP system is basically in the shutdown status or as a backup energy. The reasons could be manifold. The first is the coordination of heat and cooling and electric power. Enough heat and cold load need a reasonable match. Through theoretical analysis, it shows that the steam-driven refrigeration is not energy-efficient compared with the electricity-driven refrigeration. However, the cooling water of the absorption refrigeration contains a mass of lower quality exhaust heat, it is a better choice for the recovery of the exhaust heat of the LiBr refrigeration system to heat the demineralized water of the boiler by using pump system. This can raise the energy efficiency and diminish the energy consumption of human society. CCHP system needs to combine with the waste heat utilization and the optimization of the thermal systems. The LiBr refrigeration-heat pump system applied in CCHP system is proposed in this paper. The operating characteristics of these compound systems were studied.

2. System and equipment

Thermal system diagram of the CCHP system using the cooling water of the LiBr refrigeration system to heat the demineralized water of the boiler was shown in Fig. 1. Coal was burned in the fluidized bed boiler and was used to generate heat and the heat transforms the demineralized water to steam. The steam was sent into steam turbine to generate electricity. Some of the back-pressure steam was sent into the heat consuming installation to

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Nomenclature

CCHP	Combined cooling, heating and power
CHP	Combined heating and power
COP_R	Refrigeration coefficient of LiBr refrigeration system
COP_P	Heating coefficient of heat pump system
PER_{CCHP}	Primary energy rate of CCHP system
PER_S	Primary energy rate of CHP system and plus electricity-driven refrigeration
Q_{PC}	Primary energy demand of CCHP system
Q_{PS}	Primary energy demand of CHP system plus electricity-driven refrigeration
Q_{HCCHP}	Consumption heat of CCHP system
Q_{HS}	Consumption heat of CHP system and plus electricity-driven refrigeration
P_{CCCHP}	Consumption electric power of the CCHP system
P_{CCCHP}	Consumption electric power of CHP system plus electricity-driven refrigeration
η_b	Thermal efficiency of the boiler
Q_h	Acquisition heat capacity
η_e	Power generation efficiency
Q_c	Acquisition cold capacity
Δq	Primary energy saving rate
P_C	Acquisition electric power capacity

supply heat, the others was sent into the LiBr refrigeration machine to generate refrigerating effect. In the refrigeration process, cooling water with a temperature of 38 °C was produced. The 38 °C cooling water worked as the heat source to heat the 26 °C demineralized water. The compression power is consumed to heat the demineralized water to 65 °C. The heated demineralized water was sent into the deaerator to evacuate oxygen. The deoxygenation water was sent into the boiler to be heated. This is the thermal cycle process of the system.

Table 1 lists the main equipments of the system. In addition to the pump system, the compressor is an outsourcing component, other major components of the pump system are self-designed,

Table 1
Main equipment list.

Equipment	Mode
Boiler	YG-75/5.29-M12 (circulation fluidized bed boiler)
Turbine	C15-4.9/0.98-III (Single-cylinder condensing turbine)
Refrigeration	SXZB-5BDHZM (refrigeration load: 580 kW)
Pump system compressor	RC-2-8308-H-S (displacement: 825 m^3/h)

R134a acted as the working fluid in the cycle of the heat pump system. Fig. 2 is the flow chart of the CCHP system equipment.

3. Experiment conditions and results

3.1. Experiment conditions

The key problem for the recovery of the cooling water of the LiBr refrigeration system to heat the demineralized water of the boiler through the heat pump system is the match between the refrigeration system and the pump system. The heat pump system requires adequate heat source, that is, the LiBr refrigeration system must have adequate cooling load. But the cooling load changes with the change of the weather. When the cooling load is low, the temperature of the cooling water is low and as a result the heat pump system absorbs too much heat from the cooling water of the LiBr refrigeration system. This will result in crystallization of the lithium bromide solution. The lowest temperature of the cooling water for keeping the lithium bromide solution from freezing is 32 °C. When the temperature of the cooling water increases to 32 °C, the heat pump is activated. When the temperature of the cooling water is lower than 32 °C, the heat pump system is stopped. Through monitoring the heat pump system by observing the current, it can be determined whether the system is stable. After the system reaches stability, the data is recorded for every 20 min.

3.2. Experimental system

Fig. 3 shows the measuring points of the LiBr refrigeration system. Fig. 4 shows the measuring points of the heat pump system. In the experiment, temperatures of the water (including heating water,

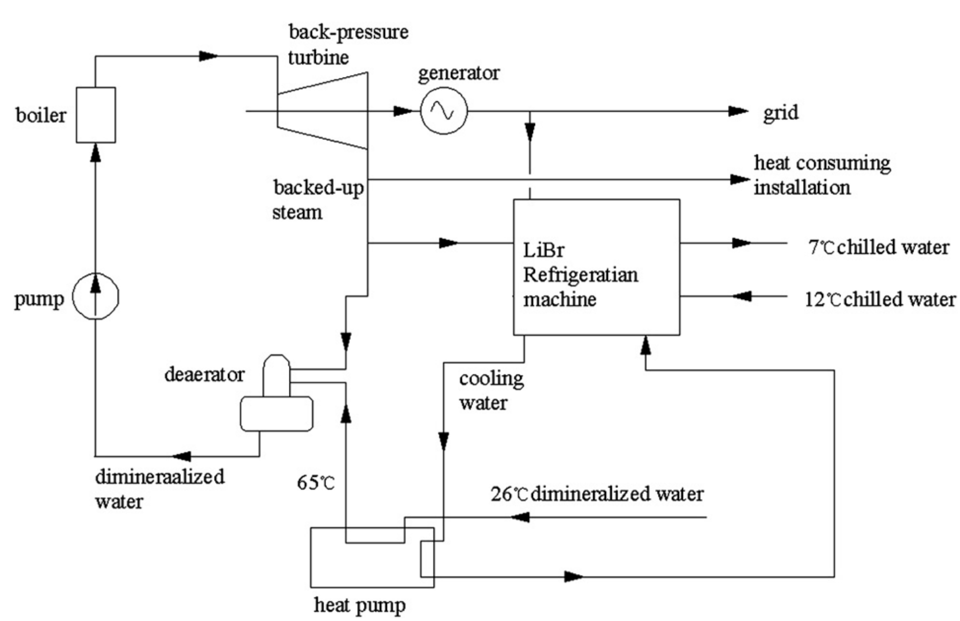

Fig. 1. Schematic diagram of the CCHP system.