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Thermodynamics Performance Analysis of Solar-assisted Combined Cooling, Heating and Power System with Thermal Storage

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Abstract

The combined cooling, heating and power (CCHP) system is an energy efficient system that the premium characteristic is the energy cascade utilization. However, there is a mismatch problem between system supply and building demands. This paper proposes a solar-assisted CCHP system with thermal storage so as to effectively reduce the waste of energy. The components including solar heat collector, internal combustion engine and heat storage tank are modeled based their thermodynamic performances. An office building in Beijing is selected as a feasibility case and the impact of solar energy and thermal storage on the thermodynamics performance of the CCHP system is analyzed in detail. The results shows that when this system operates following thermal load, the system energy efficiency and COP decrease with the increase of solar energy, while exergy efficiency appears a slight fluctuation. Additionally, the variations of adjustable cooling compared to the system without thermal storage are discussed. It is concluded that thermal storage involved in the solar-assisted CCHP system contributes to expand the variations of adjustable cooling evidently.

Keywords: Combined cooling, heating and power (CCHP) system; solar energy, thermal storage, adjust strategy

1. Introduction

Combined cooling, heating and power (CCHP) system is widely regarded as an energy efficient system for its high energy efficiency, less pollution and cascade utilization of energy [1]. At present, most of the CCHP system consumes natural gas as fuel. However, China's natural gas resources are extremely limited, and the combustion of fossil fuels also causes environmental problems [2]. Consequently, the renewable energy such as solar energy is

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more and more introduced into CCHP system. Solar energy is not suitable for large-scale use due to its low energy flow density. Thus, the natural gas CCHP system supplemented by solar energy can reduce the fossil fuel consumption, and also make up for the discontinuity and instability of solar energy [3]. CCHP system has an inherent characteristic with the fixed ratio of electricity and heat (cooling). But the demands of heat (cooling) and electricity in buildings vary with people's activities and climate changes. Therefore, it is difficult to match the energy demands from the generated products by the CCHP system [4].In addition, in the case of different energy requirements, the capacity of the CCHP system is usually sized with maximum energy. However, the longtime operation of the system under partial load may reduce the energy efficiency of CCHP system. Also, large sizing configuration will increase investment cost [5].At present, energy storage is considered to be an effective way to adjust the time difference, spatial differences and energy supply and instability of energy demand [6]. To reduce the mismatch between supply and demand, this paper proposed a new distributed CCHP system complemented by solar energy and natural gas with heat storage type.

2. System simulation and design parameters

2.1. System process

Figure 1 shows the flow chart of the new integrated system. Natural gas as fuel drives the internal combustion engine (ICE), and the waste heat from the ICE consisting of high-temperature exhausted gas and low-temperature jacket hot water is used to drive the double-effect lithium bromide absorption chiller with two kinds of heat sources. The high-temperature exhausted gas is introduced into high-pressure generator of absorption chiller to produce the chilled water. The temperature of exhausted gas from chiller is approximately 170 degrees, and the low-temperature heat continues to produce domestic hot water through heat exchanger (HX1). Solar heat energy is collected through the vacuum tube collector, and the hot water from solar collector is mixed with the jacket hot water to be sent to low-pressure generator of absorption chiller. When the heat from the solar collector is excess, the excess heat is stored into heat storage tank. When the recovered heat from jacket water and exhausted gas is insufficient, the stored heat from tank is used to compensate for the heat shortage.

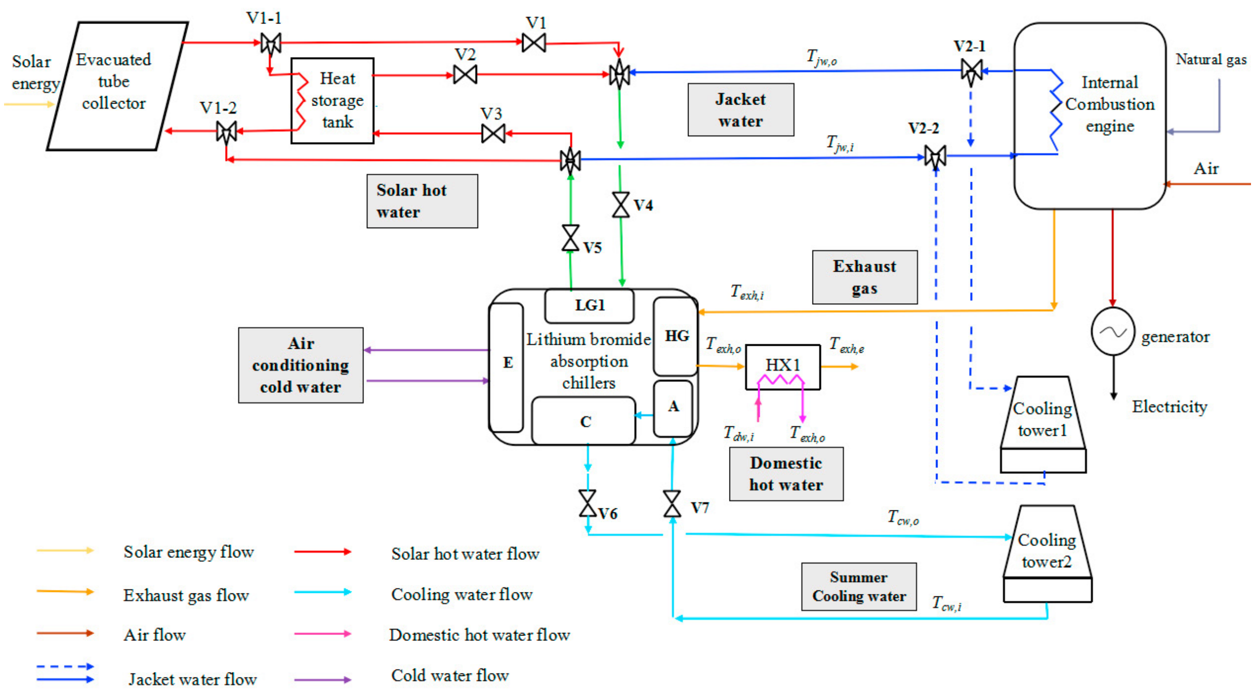

Fig.1 Flow chart of solar-assisted CCHP system with thermal storage