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Thermodynamic performance analysis and comparison of a combined cooling heating and power system integrated with two types of thermal energy storage☆

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HIGHLIGHTS

- Propose a CCHP system coupled with thermal energy storages according to energy level.
- Construct thermodynamic models and present the coordinative operation strategies of TES.
- Compare the energy performance and adjustable area of building loads of two types TES.

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Combined cooling heating and power (CCHP) system
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Molten salt storage
Operation strategy

ABSTRACT

Energy storage is an effective method to match the incompatibility of the ratio of heat to electricity between a combined cooling heating and power (CCHP) system and its users. This paper proposes an internal combustion engine CCHP system integrated with two types of thermal energy storage, which are accorded with energy levels of the waste heats of jacket hot water and exhausted gas after power generation. Correspondingly, two types of storage technologies including a hot water tank and a molten salt tank are introduced into the CCHP system. Then, the thermodynamic models are constructed, and two operation strategies are established to coordinate the operation of the thermal energy storage tanks. Through a case study, their performances are compared from three aspects: primary energy ratio, adjustable area of ratio of heating/cooling to electricity and application in different building loads. The results in summer work condition indicate that the CCHP system integrated with the jacket water storage tank achieves a primary energy ratio of 83.8% and a ratio of cooling to electricity of 2.24, which are both better than the integration of exhausted gas storage tank. These characteristics show that the CCHP system with thermal energy storage tank is more suitable to adopt the operation strategy in which the exhausted gas is adopted to drive the absorption chiller/heater, while the jacket water is used to store heat when the waste heat is larger than the heat demand.

1. Introduction

Combined cooling, heating and power (CCHP) system is widely regarded as an energy-efficient system because of its prominent feature of the cascade utilization of energy [1]. However, it has a limitation that the output ratio of heat to electricity is generally constant or adjustable in only limited ranges while the thermal and electric demands of buildings vary hourly [2]. This point results in the mismatch between supply and demand sides [3].

Aimed to match CCHP system and building loads, many methods have been proposed and developed, which are generally classified into four categories: supplementary electricity, supplementary heat, electricity/heat transform, and energy storage. The method of supplementary electricity usually adopts central electricity grid [1], photovoltaic system [4], wind power [5] or other available generated power to supplement the shortage of electricity. Similarly, the method of supplementary heat uses boiler [1], solar collector [6] or other heat sources to supplement the heat shortage. Additionally, electricity/heat transform is a suitable method to utilize the excess electricity/heat to produce the heat/electricity outputs, such as electric chiller or Organic Rankine Cycles (ORC). When the ratio of heat to electricity of building is larger than that of CCHP system, electric chiller can utilize the excess electricity to produce chilled water. Based on this principle, the constant operation ratio of electric chiller and absorption chiller proposed

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Nomenclature

CCHP	combined cooling, heating and power
COP	coefficient of performance
HG	high-pressure generator
HX	heat exchanger
ICE	internal combustion engine
LG	low-pressure generator
PER	primary energy rate
TES	thermal energy storage

Symbols

C	refrigerating capacity
C_p	specific heat capacity
E	electricity
F	fuel
h	enthalpy
m	mass
Q	heat
t	temperature
V	volume
w	concentration
η	efficiency
ρ	density
φ	safety coefficient
ε	correlation coefficient

Subscripts

A	absorber
AB	absorption chiller
ab	absorption chiller
AH	absorption heat pump
c	cooling
Con	condenser
e	electricity
esh	exhaust gas heat
ex	exhaust
h	hour
i	import
ICE	internal combustion engine
jw	jacket water
ng	natural gas
o	outlet
s	storage

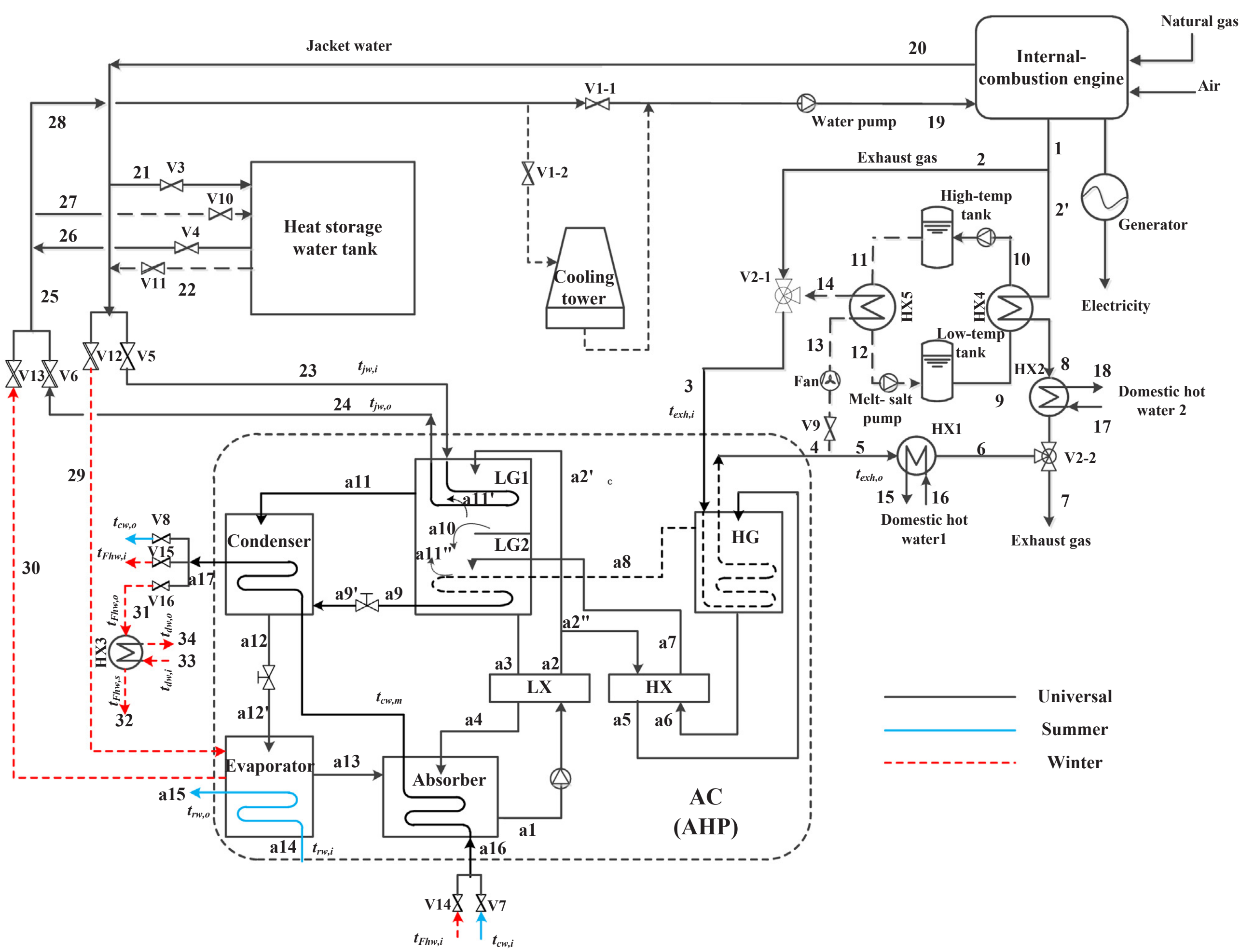

Fig. 1. Flow chart of CCHP system integrated with TES.