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Energetic and exergetic analysis of integrated energy system based on parametric method

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ABSTRACT

Investigating the relationship between the performance of an integrated energy system (IES) and each influencing factor as well as directly calculating IES efficiency based on relevant parameters are of substantial importance to energy saving. To make the research results applicable to various IES, a typical integrated energy system (TIES) which includes typical energy conversion technologies is proposed. After building energy demands and energy conversion processes in TIES are abstracted and simplified by a typical energy flow map, a dimensionless equation for calculating TIES energy and exergy efficiency is developed. Based on the partial derivatives analysis of TIES's energy and exergy efficiency dimensionless equation, the effects of technological level, demand structure, local renewable energy utilization and IES configuration on energy and exergy efficiency are clarified. Combined with a case study, the usability of the parameter analysis method for IES has been illustrated. The departure phenomenon of energetic and exergetic analysis results in IES are also introduced. Furtherly, we indicate that without proper definition of benchmark environment, it is easy to give perplexing results with an exergetic analysis about IES.

1. Introduction

An integrated energy system (IES) converts various types of energy resource (gas, electricity, solar, wind, etc.) into cooling energy, heat and power to meet the production and living needs of building users. To improve IES's energy efficiency, it is important to determine the factors that affect the system and how they affect the system's energy efficiency [1].

The analysis of various energy conversion and utilization processes in IESs has been a perennial focus of researchers in this field [2].According to Perez-Lombard et al., energy efficiency is a core issue of energy policy and sustainable development, and energy efficiency indicators should be established for building energy systems at four levels (e.g., global, service, subsystem and equipment) to construct an efficiency indicator system to improve the energy efficiency of such systems[3].The energy efficiency of gas-fired boilers by employing a device with integrated functions that uses boiler waste heat to drive absorption heat pumps improved by Qu [4].An energy flow map for heating, ventilation and air conditioning systems, the map depicts the flow of energy from the cooling/heating sources to the transport pipeline network and finally to the terminal air conditioning units created by Perez-Lombard [5].Several common European metrics for measuring the energy efficiency of building energy supply systems introduced by Alves [6]. Alves also provided several common parameters that characterize energy efficiency, including a coefficient of performance and energy efficiency ratio. Kaya analyzed the energy efficiency of heat pumps and determined the relationships between the energy efficiency of a heat pump and the influencing factors (including the flow rate of the refrigerant, pressure and temperature) [7]. Willem reviewed the experimental research on measuring the energy efficiency of heat pump for hot water in practical use and noted that most heat pumps' operated efficiency in a range of 1.8–2.5[8]. Park presented an analytical review of the research on the energy and exergy efficiency of several common renewable energy utilization systems (including solar water heating systems, solar photovoltaic systems and biomass cook stoves), they noted that most of the research was focused on the energy efficiency of these systems, whereas system exergy efficiency was less frequently studied [9].

Research has shown that multiple energy conversion and utilization technologies can be combined to compensate for the deficiency of each conversion and utilization technology, improve a system's total energy and exergy efficiency (η_{total}) and increase the utilization of renewable

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Nomenclature

IES	integrated energy system
TIES	typical integrated energy system
HVAC	heating, ventilation and air conditioning
F	fuel
CHP	combined heating and power system
B	biomass energy
E	electricity
S	solar energy
W	wind energy
R, r	local renewable energy resource
COP	energy coefficient of absorption and mechanical heat pump
EER	energy efficient of heat pump for cooling
D’	system energy demand
D	energy supplied by IES, contain the energy export to external
EX	energy exchange with external
t	the ratio of the cooling energy provided by the electrical cooling technology to the total cooling energy demand
v	ratio of the heat provided by the electrical heating technology (including electrical heating and various types of power-driven heat pump) to the total heat demand
x	the ratio of the amount of fuel consumed by the boiler in a IES to the amount of fuel consumed by the CHP equipment
y	the ratio of the cooling energy demand to the fixed power demand
z	the ratio of the heat demand to the fixed power demand
EX	exergy
T	temperature
Q	the quantity of energy

Subscript

total	the overall system
in	input
boil	boiler
fuel	fuel
e	electricity
CHP,h	combined heating and power system for heating
CHP,e	combined heating and power system for electricity
h	heating
c	cooling
e,0	electricity for non-heating and non-cooling system consumed
en	environment

Greek symbols

η	energy efficiency
θ	the standard coal conversion coefficient for the input fossil fuel and the power
Ω	energy quality, from 0 to 1

energy resources [10]. Duić introduced the strength of IES for islet combined with a case study in Porto Santo [11]. Therefore, IES which employ the combination of multiple energy conversion and utilization technologies have garnered extensive attention. Koirala reviewed the trend and key issues of IES [12]. Lund discussed the impact of IES for district heating and put forward the conception of 4th generation district heating [13]. Hemmes described the characteristics of multi-source, multi-energy product integrated energy systems [14]. Di Somma discussed the operation optimization of a distributed energy system based on the comprehensive optimal of exergy efficiency and cost [15]. Al-Ali analyzed the energy and exergy efficiency of a solar–geothermal–combined heat and power (CHP)-coupled system and found that the coupled system outperformed the CHP system in energy and exergy efficiency [16]. Wang analyzed the energy and exergy efficiency of a biomass gas-fueled combined cooling, heat and power (CCHP) system [17]. Mohammadi studied the energy and exergy efficiency of a wind energy coupled with compressed air energy storage systems for heating, cooling and supply power [18], from sensitivity analysis they indicated that parameters related to gas turbine are the most prominent parameters of the system’s performance.

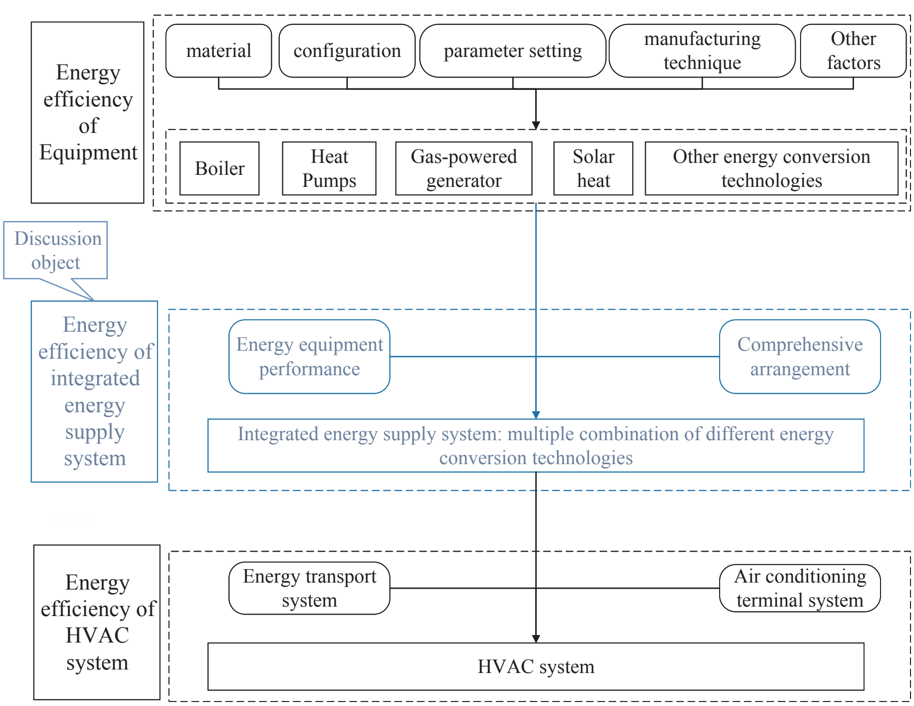

Fig. 1. System level focused on in this article.