Applied Energy 219 (2018) 179–186

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Advancement of distributed energy methods by a novel high efficiency solar-assisted combined cooling, heating and power system

Na Zhang[a,*], Zefeng Wang[a,b], Noam Lior[c], Wei Han[a]

[a] Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, China
[b] University of Chinese Academy of Sciences, Beijing, China
[c] Department of Mechanical Engineering and Applied Mechanics, University of Pennsylvania, Philadelphia, PA 19104-6315, USA

HIGHLIGHTS

- A solar assisted combined cooling, heating and power (SCCHP) system is proposed.
- Energy recovery improves matches between energy donors and receivers.
- Cascade utilization of input energies enables enhanced specific power generation.
- The fossil energy saving ratio of the proposed system reaches 30.4%.
- The exergy efficiency can be improved 6.18% compared with conventional trigeneration.

ARTICLE INFO

Keywords:
Distributed energy system
Combined cooling, heating and power system
Solar heat
Thermochemical upgrading
Fossil fuel saving

ABSTRACT

To improve the conversion efficiency of renewable energy use in high efficiency novel distributed energy systems, and the match between the energy donors and receivers in them, this paper proposes and analyzes a solar assisted combined cooling, heating and power system which supplies electricity, cooling and heat, with internal energy recovery and thermochemical upgrading, as their core component. The proposed system consists of a chemically recuperated gas turbine cycle, an absorption chiller and a heat exchanger, in which the reformer upgrades the absorbed turbine exhaust heat and solar heat into produced syngas chemical exergy, and rearranges the matches of energy donors and receivers both quantitatively and qualitatively. Based on well-established technologies including trigeneration, steam reforming and low/mid temperature solar heat collection, the system exhibits enhanced specific power generation and efficiency, and it commensurately reduces CO_2 emissions and saves depletable fossil fuel. The net solar-to-electricity efficiency is predicted to be 26–29% for a turbine inlet temperature of 980 °C. Compared with the stand-alone power, cooling and heating generation system, the reduction potential of fossil fuel consumption has been demonstrated to be 30.4% with a solar thermal share of 26%. Moreover, this system produces 33% less CO_2 emission than a conventional combined cooling, heating and power system with the same technology but without solar assistance. An excess electricity storage unit or storage of excess syngas can be considered to balance the difference between the supply and demand quantities.

1. Introduction

Distributed energy systems (DES), which are typically composed of a number of modular and small scale technologies and situated close to the end users, can be regarded as an essential complement to conventional centralized power network [1,2]. They have a number of advantages such as low transmission loss, low environmental emissions, and flexibility with multiple energy resources including fossil fuels, alternative fuels and renewable energy resources. In addition, they also have multiple energy production with cascade energy utilization, in the form of combined cooling, heating and power cogeneration (CCHP) systems [3–5], in which the heating and cooling demand is provided by using the residual heat from electricity generation, and thus achieve better performance in meeting customers' multi-energy demands and in energy saving with overall energy efficiency typically > 80%.

The research publications related to distributed energy systems mainly focus on system design, operation strategy and performance evaluation [6,7]. The CCHP system configuration used is mainly

* Corresponding author.
E-mail addresses: zhangna@iet.cn (N. Zhang), wangzefeng@iet.cn (Z. Wang), lior@seas.upenn.edu (N. Lior), hanwei@iet.cn (W. Han).

https://doi.org/10.1016/j.apenergy.2018.03.050
Received 7 November 2017; Received in revised form 12 March 2018; Accepted 18 March 2018
0306-2619/ © 2018 Elsevier Ltd. All rights reserved.

Nomenclature

A	energy level
CEM	specific CO_2 emission per kWh electricity generation [g/kWh]
COP	coefficient of performance
DNI	direct normal irradiation
E	exergy [kW]
LHV	lower heating value of fuel [kJ/kg]
m	mass flow rate [kg/s]
P	pressure [bar]
Q	heat [kW]
SR_f	fossil fuel saving ratio, Eq. (7)
T	temperature [°C]
TIT	turbine inlet temperature [°C]
W	power output [kW]
$X_{e,sol}$	solar exergy input share, Eq. (5)
X_{sol}	solar heat input share, Eq. (4)
η_b	gas boiler efficiency [%]
η_{col}	collector efficiency [%]
η_e	electrical generation efficiency, Eq. (2)
η_{ex}	system exergy efficiency, Eq. (3)
η_{sol}	solar-to-electricity efficiency [%], Eq. (6)
η_{th}	system thermal efficiency [%], Eq. (1)

Subscripts

c	cooling
col	collector
e	electrical
f	fuel
h	heating
net	net output
ref	reference system
rad	solar radiation
sep	separate generation system
sol	solar heat
0	environment state
1, 2… 18	states on the cycle flow sheet

determined by the available energy resources and energy conversion technologies [8–10]; and operation strategy by the variation of customers' energy demands. CCHP systems can theoretically be made very efficient and cost-effective by cascade utilization of the input energy. Practical systems, however, usually exhibit lower than expected energy efficiency, because the energy demand and supply are not in optimal match, and the distributed energy resources are thus not fully exploited. The application of appropriate operation strategy is an essential requirement to improve the off-design performance of CCHP systems [11–13].

Currently the design and optimization of distributed energy systems is mainly based on mathematical tools to integrate different types of energy resources and energy conversion technologies, with single or mixed targets with weighted combination of energy efficiency, annual energy consumption, annual cost, or CO_2 emission [14–16], usually resulting to a linear combination of available DES technologies and resources. The renewable energy resources, such as solar heat, are usually integrated at the low temperature end for complementary heat production with low energy conversion efficiency [17,18]. Increasing the share of renewable energy input in the energy system, on one hand brings more environmental benefits such as saving depletable fossil fuel and reducing pollutant emissions, but on the other hand lowers the system overall energy efficiency because renewable energy is generally associated with transience and low energy flux. Somma et al. [19] proposed an analysis that matches the quality levels of supply and demand by their exergy, by satisfying, if possible, low quality (exergy) thermal demands with low exergy sources such as solar thermal or waste heat, and electricity demands with high exergy sources, but it is still by direct use of solar thermal or power-generation waste heat. Different from the above mentioned method, solar heat can be upgraded to chemical energy of solar thermochemical fuels through some solar thermochemical processes and solar energy can thus be stored in the form of fuel for continuous use [20–22].

In this paper, the authors proposed and analyzed a solar assisted

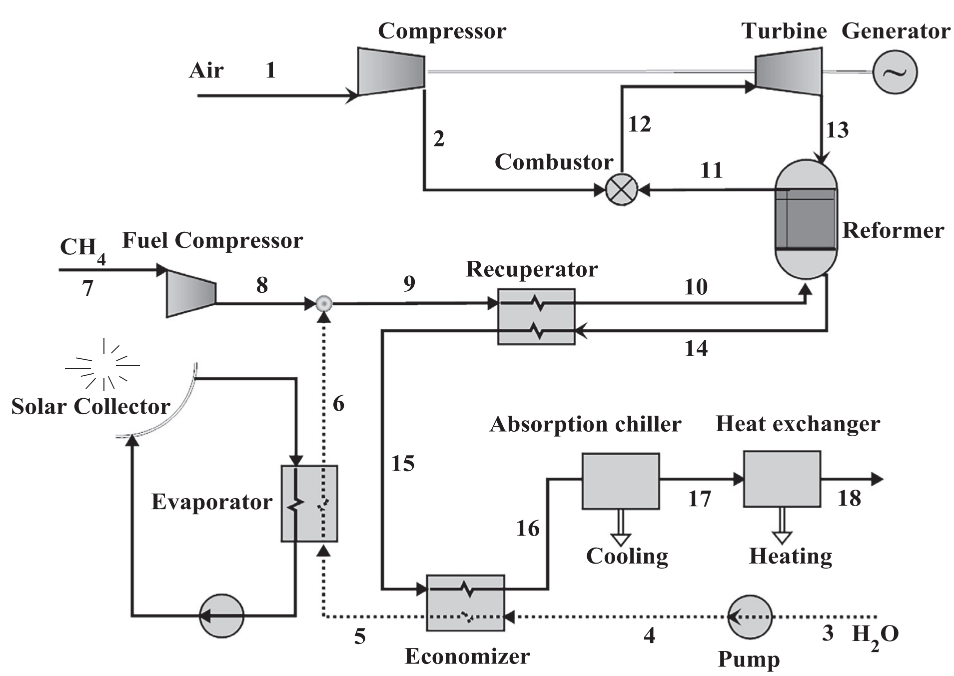

Fig. 1. Schematic diagram of the SCCHP system with solar heat integration.

Download English Version:

https://daneshyari.com/en/article/6680288

Download Persian Version:

https://daneshyari.com/article/6680288

Daneshyari.com