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ScienceDirect

Energy Procedia 142 (2017) 55–62

Energy Procedia

www.elsevier.com/locate/procedia

The 9th International Conference on Applied Energy – ICAE2017

Analysis of A Solar Assisted Combined Cooling, Heating and Power (SCCHP) System

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Abstract

This paper analyzes a solar assisted combined cooling, heating and power (SCCHP) system which supplies electricity, cooling and heat, with internal energy recovery and thermochemical upgrading. The proposed system consists of a chemically recuperated gas turbine cycle, an exhaust heat-driven absorption chiller and a heat exchanger, in which the reformer upgrades the absorbed turbine exhaust heat and solar heat into produced syngas chemical exergy. The system performance is analyzed and compared with a regular CCHP system without solar assistance, and a parameter sensitivity analysis is conducted to investigate the influence of the steam addition ratio. The system exhibits enhanced specific power generation and efficiency, and it saves depletable fossil fuel and commensurately reduces CO_2 emissions. The system exergy efficiency reaches 37%; a fossil fuel saving of 30.4% is attainable with a solar thermal share of 26%; and the reduction of fossil fuel use and improved system performance result in a commensurate 33% reduction of CO_2 emission as compared with the conventional CCHP system with the same technology but without solar assistance.

Keywords: Distributed energy system; CCHP, exergy efficiency, solar heat; fossil fuel saving, CO2 emission

1. Introduction

Distributed energy systems (DES) are typically composed of a number of modular and small scale technologies and situated close to the end users [1,2]. As compared with the conventional centralized power network, they have more 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 [3,4], 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 energy saving.

10.1016/j.egypro.2017.12.010

The researches related to distributed energy systems mainly focus on system design, operation strategy and performance evaluation [5,6]. The CCHP system configuration is mainly determined by the available energy resources, and operation strategy mainly determined by the variation of customers' energy demands. The Four-node system has been proposed by the authors' research group as the basic structure of DES [7]. The four nodes are the energy generation/conversion, the dispatch/utilization section, the storage/transportation section that shifts the energy generated during low-demand periods to peak-demand periods consumption, thus helping to reduce the quantity difference between energy production and utilization; and the recovery/regeneration section which is proposed to recover and upgrade the system internal low grade energy and to use "free" energy from the environment, and to thus reduce the imbalance in energy quality between the production and utilization sides. Based on this concept, the authors have proposed a solar assisted combined cooling, heating and power (SCCHP) system, in which a thermochemical transformer serves as the energy recovery/regeneration section [7]. It uses heat to drive an endothermic chemical reaction and upgrades the absorbed thermal energy into chemical energy of the produced syngas, which can be further used for power generation or transportation.

In this paper, the proposed SCCHP is analyzed and compared with a conventional CCHP system without solar assistance, and a parameter sensitivity analysis is conducted to identify the influence of the solar input share. The following analysis shows that the same rates of electricity, heat and cooling outputs as those generated by their separated production are attained by the proposed novel system with about 30% less fuel input.

2. System configuration description

As shown in Fig. 1, the SCCHP system consists of a chemically recuperated gas turbine (CRGT, [8]) for power generation, an absorption chiller, and a heat exchanger for cooling and heating production, respectively. From high temperature to low temperature, the turbine exhaust heat is recovered by a reformer for the methane-steam reforming, economizer for water preheating, and followed by the absorption chiller and heat exchanger. Solar heat is used to evaporate water, at a relatively low temperature, for generating reforming needed steam.

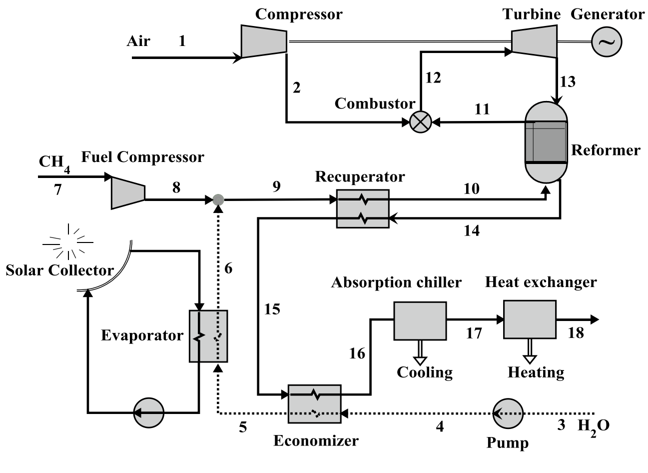

Fig. 1 Schematic diagram of the SCCHP system with solar heat integration

The natural gas reforming process takes heat from both the turbine exhaust gas and solar heat, and adds the absorbed heat to the reforming products heating value, thereby increasing the power generation and efficiency beyond that with direct fossil fuel combustion alone.

3. Main assumptions and performance criteria for the simulation

3.1 Main simulation assumptions

The cycles are simulated using the ASPEN PLUS process simulation software [11]. The RK-Soave thermodynamic model was selected for the thermal property calculations. The most relevant assumptions are summarized in Table 1.