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Proposal and thermoeconomic assessment of an efficient booster-assisted CCHP system based on solar-geothermal energy

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ABSTRACT

An efficient solar-geothermal based system is proposed to produce desired cooling, heating, and power. The system consists of the organic Rankine and ejector refrigeration cycles. A booster is also employed to increase the cooling capacity. To better realize the system performance, energy, exergy and thermoeconomic analyses are investigated for three working fluids including R423A, R1234ze and R134yf. Two single-objective function optimization studies are conducted with the fluid that exhibits the lowest exergy destruction rate. In the first one, a thermodynamic objective is optimized, while the second deals with a thermoeconomic function. A third optimization task weights these two objectives simultaneously, approaching a multi-objective study. At the base case conditions, the results showed that the system with R423A working fluid has the lowest total exergy destruction rate equal to 405.3 kW. The outcomes for this working fluid show that the levelized cost of cooling, heating and electricity obtained from multi-objective optimization is less by 91.17% and 73.22% compared to the cases when the cycle is optimized from energy efficiency and cost viewpoints, respectively. Moreover, energy efficiency is 13.53%-points higher than the base case conditions. The energy and exergy efficiencies are determined as 44.02% and 7.389%, respectively, under multi-objective optimal design conditions.

1. Introduction

Increasing energy demands of various sectors are one of the biggest challenges of the modern era. Since more than 80% of today's energy needs are met by fossil energy resources [1], the increased demand led to several environmental concerns and the depletion of these resources. About 35% of the world's total energy consumption is used to satisfy electricity demand, space heating, domestic hot water, and space cooling [2]. Because of flexible strategies and high utilization efficiency, distributed energy systems have recently received a lot of attention. Combined Cooling, Heating, and Power (CCHP) systems, unlike typical centralized energy plants, have high reliability and can be installed near end-users. Cascade utilization of source energy increases a CCHP system's energy efficiency to about 70–90% [3].

Renewable energy-based CCHP systems are suggested to reduce environmental pollution and fossil fuel consumption. Recently, the capital costs of renewables are decreased dramatically because of distributed generation development and liberalization policies, which makes the renewable-based systems competitive with the conventional energy systems [4]. However, efficient and sustainable development must be pursued in this framework. Many efforts have been made in recent years to achieve this goal. Three novel geothermal-based Organic Rankine Cycles (ORCs) are proposed to enhance the efficiency and for the waste heat recovery purposes by Aliahmadi et al. [5]. The proposed systems are modeled based on a basic ORC system (concept 1), an ORC system with an internal heat exchanger (concept 2), and a regenerative ORC system (concept 3). Zare and Rostamnejad Takleh [6] suggested two CCHP systems based on geothermal energy in which a Rankine cycle is integrated with an ejector-assisted transcritical CO_2 cycle. In a study by Saini et al. [7], the performance of a solar-based CCHP system was evaluated in three different configurations. They assessed these

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