



Off-design performance analysis of a solar-powered organic Rankine cycle



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ABSTRACT

Performance evaluation of a thermodynamic system under off-design conditions is very important for reliable and cost-effective operation. In this study, an off-design model of an organic Rankine cycle driven by solar energy is established with compound parabolic collector (CPC) to collect the solar radiation and thermal storage unit to achieve the continuous operation of the overall system. The system off-design behavior is examined under the change in environment temperature, as well as thermal oil mass flow rates of vapor generator and CPC. In addition, the off-design performance of the system is analyzed over a whole day and in different months. The results indicate that a decrease in environment temperature, or the increases in thermal oil mass flow rates of vapor generator and CPC could improve the off-design performance. The system obtains the maximum average exergy efficiency in December and the maximum net power output in June or in September. Both the net power output and the average exergy efficiency reach minimum values in August.

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1. Introduction

Utilizing the renewable energy resources is proved to be an alternative way to solve the energy crisis and achieve the sustainable development of human beings due to their potentials in reducing fossil fuel consumption and alleviating environmental problems. Solar energy as a promising clean renewable energy has attracted much attention particularly in recent years due to its zero pollution and broad prospects in applications.

Concentrating Solar Power (CSP) system as an alternative effective way to utilize solar energy is a proven large-scale solar power technology with a variety of collector systems such as the parabolic trough, the solar dish, the solar tower or the Fresnel linear collector. However, most of the currently CSP plants typically include a condensing vapor cycle power block, requiring a minimum power of a few Mwe and high collector temperature and large-area field. Thus, the CSP cost is not yet competitive with conventional alternatives unless subsidized. In recent years, distributed energy systems have drawn much attention due to their small-scale capacity, flexibility and high efficiency. A solar-power organic Rankine cycle system with small-scale capacity compared with steam Rankine cycle has been focused on due to its low working temperature, high energy conversion efficiency and little negative impact on environment.

Since the organic working fluids have significant effect on the environment deterioration, the system operation and efficiency for solar organic Rankine cycle, some studies have been carried out on the selection of proper working fluids. Tchanche et al. [1] compared twenty working fluids from efficiencies, volume flow rate, mass flow rate, pressure ratio, toxicity, flammability, ODP and GWP and found that R134a was the most suitable working fluid for small scale solar applications. Rayegan and Tao [2] developed a procedure to select the working fluids used in solar Rankine cycles and found that eleven working fluids had been recommended in solar ORCs that used low or medium temperature solar collectors. Wang et al. [3] conducted a comparative study of pure and zeotropic mixtures in low-temperature solar Rankine cycle and found that the zeotropic mixtures had the potential for overall system performance improvement.

Except for the selection of working fluid, some researches have devoted to the sensitive analysis of key parameters and performance optimization of the solar-powered ORC. He et al. [4] conducted a simulation of a solar-powered organic Rankine cycle with parabolic trough collector using TRNSYS software. They examined the effects of several key parameters on the performance of the parabolic trough collector field based on the meteorological data of Xi'an city in China. Li et al. [5] presented a low temperature solar Organic Rankine Cycle (ORC) using R123 with compound parabolic concentrators. The influences of the collector tilt angle adjustment, the connection between the heat exchangers and the

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