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Optimum operation of an ejector-assisted combined flash-binary geothermal cycle using R245fa-isopentane mixture-based secondary working fluids

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ABSTRACT

Combined flash binary geothermal cycle (CFBGC) is a traditional geothermal energy conversion technology. However, in a CFBGC, substantial exergy destruction occurs during the steam flashing. To address this issue, in the present study, the steam flashing device of the conventional CFBGC is replaced by an ejector. The ejector enhances steam cycle power output by ensuring a higher steam flow rate through the high-pressure steam turbine stage. The modified cycle is designated as the ejector assisted combined flash binary geothermal cycle (EACFBGC). To take advantage of temperature glide, various compositions of R245fa-isopentane mixture are considered as secondary working fluid. Optimum operating parameters corresponding to the maximum second law efficiencies of the proposed and conventional cycles are explored by applying an iterative method. Both considered cycles yield the highest second law efficiencies with the 0.7 mol fraction of isopentane in the working fluid mixture. For geo-fluid available at 170 °C, the second law efficiency of the optimized EACFBGC is about 8.08% higher than that of the optimized conventional CFBGC. The corresponding levelized cost of electricity (LCOE) is also 5.7% lower. In a word, the proposed EACFBGC can be considered as the upgraded CFBGC with higher energy conversion efficiency and a lower LCOE.

1. Introduction

Secondary energy generation from renewable resources is to be substantially increased for a sustainable energy transition. Geothermal-based secondary energy production is one of the preferred renewable technologies, mostly due to its reliable power supply at a larger capacity.

For geothermal water available below 200 °C, integration of the single flash steam cycle with an organic Rankine cycle (ORC) is a convenient way of producing electricity. The integrated cycle is usually termed as the combined flash-binary geothermal cycle (CFBGC). Shokati et al. [1] demonstrated the operation of the CFBGC for a geo-fluid temperature of 175 °C. R141b, NH_3, R113 and n-heptane had been considered secondary working fluids of the CFBGC. It was reported that the CFBGC with all considered secondary working fluids yielded higher energy and exergy efficiencies compared to those of the double flash geothermal steam cycle. Zeyghami [2] analyzed the performance of the CFBGC for thirty different secondary working fluids. It was revealed that the choice of optimum binary fluid was greatly influenced by the temperature of the geo-fluid. Aali et al. [3] proposed a novel CFBGC recovering heat from the high-temperature and low-temperature geothermal wells simultaneously. The best performance was achieved using R141b as the secondary working fluid. Najjar and Qatramez [4] considered n-butane, isobutane, R123 and R11 as the working fluid of the secondary cycle of a CFBGC. The CFBGC with R11 yielded the highest overall efficiency. Mokarram and Mosaffa [5] integrated a self superheating single flash geothermal steam cycle with the regenerative ORCs. Zhao and Wang [6] reported that operating parameters corresponding to the best exergoeconomic performance of a CFBGC were slightly different from those yielding the best thermodynamic performance. Tomarov et al. [7] revealed that output power of the Mutnovsk single flash geothermal power plant could be enhanced by 5 MW by integrating an ORC with it.

The secondary power cycle of a CFBGC is usually an ORC driven by the low-grade heat of the liquid geo-fluid stream exiting the vapour separator. An efficient secondary power cycle would enhance the overall energy conversion efficiency of a CFBGC. Many recent studies indicated that low-temperature power cycles operating with working fluid

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