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A comparative analysis of novel combined flash-binary cycles for Sabalan geothermal wells: Thermodynamic and exergoeconomic viewpoints

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ABSTRACT

Sabalan geothermal field is one of the most important geothermal fields in Iran. In this study, four novel configurations namely Single Flash-ORC (SF-ORC), Double Flash 1-ORC (DF1-ORC), Double Flash 2-ORC (DF2-ORC) and Triple Flash-ORC (TF-ORC) are proposed to produce power from two wells of the field. The configurations are assessed by thermodynamic and exergoeconomic viewpoints. The exergy and SPECO based exergoeconomic equations are developed for the components of the proposed cycles and thermodynamic as well as exergoeconomic performance parameters are calculated for the components and the cycles. A comprehensive parametric study is also carried out for the proposed configurations considering various working fluids in the ORCs. Moreover, an optimization is performed to maximize the produced power from the wells. The results depicted that the DF1-ORC produces 4.03%, 1.32% and 1.2% more power than the SF-ORC, DF2-ORC and TF-ORC, respectively, in the optimum condition. It can be concluded from the exergoeconomic analysis that the SF-ORC with R123 working fluid has the best exergoeconomic performance with the power specific cost of 3.62 $/GJ. The thermodynamic and exergoeconomic performance of the DF1-ORC is compared with previous similar studies which shows the superiority of the proposed cycle.

1. Introduction

The high use of fossil fuels has led to environmental issues such as greenhouse gas emission and climate changes in the recent years, therefore, renewable energies (biomass, solar, wind, and geothermal energy) are proposed as alternative scenarios to replace fossil fuels [1–3]. The geothermal energy is stable, reliable, and unlimited [4]. According to the International Energy Agency (IEA) report, it is expected that the geothermal energy produces about 3.5% of the world's total production power by 2050 [5].

The geothermal energy coming from beneath of earth has different temperatures (50–350 °C) which can be used for different purposes based on the thermodynamic properties e.g. temperature, pressure, etc. Moderate (i.e. 90–150 °C) and low-temperature resources (i.e. <90 °C) are used in direct consumptions e.g. heating and cooling systems or industrial units, while, high-temperature resources (i.e. >150 °C) are suitable for power generation in plants [6]. According to the thermodynamic conditions of the wellheads, single-flash, double-flash, binary, combined flash-binary, or integrated cycles can be employed for power generation in Geothermal Power Plants (GPPs). Some studies have been published in this regard in recent years. Harvey and Wallace [7] investigated single, double, and triple-flash and combined steam turbine-binary for geothermal plants. Also, separated brine as well as non-condensable gases for more power generation are proposed. Performance of the binary cycles for the geothermal temperature of 180 °C, and another configures such as single-flash, double-flash and flash-binary combined cycle for geothermal temperature of 230 °C, are investigated by Yari [8], who reported that the ORC with IHE has the best thermal efficiency of 7.65% in binary cycles while a maximum efficiency of 11.81% is obtained for flash-binary combined cycle using R123 as a working fluid in the flash based configurations. For medium temperature geothermal, the performance of combined flash-binary is analyzed by Zeyghami [9], who reported for the binary cycle that R-152a, Butane, and Cis-butane have the best performance for geofluid temperatures of 150, 200

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