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Research Paper

Optimization next to environmental analysis of harvesting waste heat from a biomass-driven externally-fired gas turbine cycle for sub-zero cooling and production of hydrogen, freshwater, and hot water

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Abstract

This research attempts to present a polygeneration system with five various products to recover waste heat of an externally-fired gas turbine cycle driven by biomass fuel. First, the waste heat of the gas turbine cycle is utilized in a supercritical Brayton cycle for more power generation. Then, it is employed as a heat source in an organic Rankine cycle and a hot water unit. The power generated in the organic Rankine cycle is used to produce freshwater in a reverse osmosis desalination system. Finally, liquefied natural gas acts as a heat sink for the supercritical Brayton cycle and organic Rankine cycle. The subsystem based on the liquefied natural gas is responsible for the production of cooling and required electricity of an electrolysis unit for hydrogen production. The tri-objective optimization of the designed system, using four supercritical gases in the supercritical Brayton cycle, reveals that the system has the best performance by using nitrogen. The system exergy efficiency is improved by 7.8% points due to the integration of the subsystems with the gas turbine cycle. The proposed system can generate electricity, heating, and cooling relatively equivalent to 8126 kW, 2023 kW, and 1305 kW, respectively. The rates of hydrogen and freshwater production are equal to 14.28 $\mathrm{kg\,h^{-1}}$ and 45.81 $\mathrm{kg\,s^{-1}}$, correspondingly. In the context of environmental analysis, sustainability index and exergoenvironmental index were calculated as 2.365 and 0.6354.