Thermoelectric and Solar Photovoltaic Synergy for Optimized Trans-critical CO2 Refrigeration in Hot Climates

Mohammad Tarawneh[1] and Emad Bani Melhem[1]

[1]The Hashemite University Faculty of Engineering

November 04, 2024

Abstract

Traditional trans-critical CO_2 refrigeration cycles are energy-intensive, and their efficiency is influenced by outdoor conditions. This study presents a novel technique to enhance the efficiency of these cycles by integrating a thermoelectric sub-cooler tailored to Jordan's climate. The trans-critical CO_2 refrigeration cycle, with a nominal refrigeration capacity of 14 kW, was modeled using Engineering Equation Solver (EES) software. A key aspect of this study is the incorporation of solar energy through a custom-designed photovoltaic (PV) system to power the refrigeration cycle, contributing to sustainable cooling technology. Key performance indicators, including refrigeration capacity, power consumption, and coefficient of performance (COP), were thoroughly investigated across varying parameters such as gas cooler pressure (8,000–13,000 kPa), evaporation temperature (-15 to 15°C), ambient temperature (28–40°C), current supply (5–15A), and the number of thermoelectric pairs (50–150). Results showed that increasing gas cooling pressure increased refrigeration capacity by approximately 79%. At a gas cooling pressure of 9,000 kPa, the thermoelectric sub-cooler increased refrigeration capacity by 55%. Increasing the evaporation temperature improved the COP by approximately 125% and reduced power consumption by 67%. At an evaporation temperature of -15°C, the thermoelectric sub-cooler improved performance by 7.5%. Lowering the ambient temperature also enhanced COP by 60% and reduced power consumption by 33%. At a 40°C ambient temperature, the sub-cooler improved COP by 7.6%. Experimental validation showed a 6% average deviation between simulation and experimental results for COP. The on-grid PV system designed with PVsyst software successfully met the cycle's energy demands, achieving 45.3% energy savings.

Hosted file

`submission Thermoelectric Paper _Tarawneh _Emad (10) -.docx` available at https://authorea.com/users/851599/articles/1237893-thermoelectric-and-solar-photovoltaic-synergy-for-optimized-trans-critical-co2-refrigeration-in-hot-climates