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Thermodynamic analysis of a gas turbine inlet air cooling and recovering system in gas turbine and CO_2 combined cycle using cold energy from LNG terminal

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ABSTRACT

Research on the CO_2 cycle has been conducted in various fields, such as nuclear power plants, centralized solar power plants, coal-fired power plants, waste heat recovery, combined cycle, and LNG cold energy recovery. In contrast to the steam Rankine cycle, the CO_2 cycle is able to utilize the sub-zero temperature heat sink using LNG cold energy. In this study, a novel configuration is proposed that the gas turbine-carbon dioxide combined cycle power plant (GT-CO_2 CCPP) with a gas turbine inlet air cooling (TIAC) and heat recovering (HR) system when using LNG cold energy. The TIAC and HR system cools the gas turbine inlet air using condensate CO_2 to enhance the power output while air energy is simultaneously recovered to the CO_2 bottoming cycle for additional power output and higher efficiency. To determine the capacity of this type of plant, the most commonly implemented LNG terminal is investigated, and the 62 MW medium-size gas turbine is selected for a simulation case study. The thermal performance potential of the proposed configuration is analyzed and compared to a conventional GT-steam CCPP, a GT- CO_2 CCPP without the TIAC and HR system. The results show that the relative power output is enhanced by 14.9% and that the efficiency is improved by 2.1% (1.4%p) compared to the GT- CO_2 CCPP without it. Meanwhile, this system enables higher power output and efficiency by 25.4% and 11.5% (6.8%p), respectively, compared to the conventional GT-steam CCPP, and the effect is increased according to the ambient temperature.

1. Introduction

Worldwide concern over carbon dioxide (CO_2) emissions has grown continuously since the COP 21 Paris Agreement. The natural gas-fired combined cycle power plant enables higher efficiency and less pollutant emission than coal-fired or oil-fired power plants [1-3]. Thus, the demand for liquefied natural gas (LNG) is expected to be increased continuously [4,5], thereby the level of unused cold energy from LNG terminals is also projected to increase. To recover the LNG cold energy, the *trans*-critical CO_2 (tCO_2) cycle has been investigated [6], with results showing advantages in the recovery of both high-temperature gas turbine exhaust energy and low-temperature LNG cold energy. Therefore, research on the tCO_2 cycle for efficiency improvements in relation to LNG cold energy continues to attract attention.

Improving the energy conversion efficiency in the power generation industry overall is crucial, and the supercritical CO_2 cycle (sCO_2) has been proposed as an alternative thermal cycle for efficiency improvements. Research on the fourth-generation nuclear CO_2 cycle is representative in this application. This cycle can improve both the safety of nuclear reactors and the efficiency of the nuclear CO_2 cycle [7-9]. Research on the CO_2 cycle has been conducted in other fields as well, such as centralized solar power plants [10-12], coal-fired power plants [13-15], waste heat recovery [16-19], the combined cycle power plant (CCPP) [20-22], and LNG cold energy utilization [6,23-30].

The sCO_2 power cycle has drawn attention since Dostal et al. [7] suggested this sCO_2 power cycle for nuclear reactors instead of the saturated steam cycle with the increased efficiency. Xia et al. [10] analyzed the performance of a solar power tCO_2 cycle for desalination. Mecheri and Moullec [13] suggested supercritical CO_2 Brayton cycles apply to coal-fired power plants, finding that this approach offers higher efficiency than the steam cycle even though using existing materials. Na et al. [16] optimized the mass split ratio of the sCO_2 power cycle based on a fixed total heat exchanger inventory and was able to maximize the

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