Cascaded Transcritical/Supercritical CO\textsubscript{2} Cycles and Organic Rankine Cycles to Recover Low-Temperature Waste Heat and LNG Cold Energy Simultaneously

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Abstract: Low-temperature waste heat is abundant in the process industries, and large amounts of Liquefied Natural Gas (LNG) cold energy are discarded without being recovered properly in LNG terminals. Power generation is an effective way to utilize low-temperature waste heat and LNG cold energy simultaneously. Organic Rankine Cycles (ORCs) and CO<sub>2</sub> power cycles are promising technologies to convert low-temperature waste heat and LNG cold energy into electricity. If waste heat and LNG cold energy are utilized simultaneously in one system, the performance may outperform separate systems utilizing low-temperature waste heat and LNG cold energy, respectively. Low-temperature waste heat acts as the heat source and LNG regasification acts as the heat sink in the combined system. Due to the large temperature difference between the heat source and the heat sink, cascaded power cycle configurations are proposed in this paper. Cascaded power cycles can improve the energy efficiency of the system considerably. The cycle operating at a higher temperature to recover waste heat is called top cycle and the cycle operating at a lower temperature to utilize LNG cold energy is called bottom cycle in this study. The top cycle condensation heat is used as the heat source in the bottom cycle. The top cycle can be an ORC, transcritical CO<sub>2</sub> cycle or supercritical CO<sub>2</sub> cycle, while the bottom cycle only can be an ORC due to the low-temperature range of the bottom cycle. However, the thermodynamic path of the tCO<sub>2</sub> cycle and sCO<sub>2</sub> cycle are different from that of an ORC. The tCO<sub>2</sub> cycle and the sCO<sub>2</sub> cycle perform better than an ORC for sensible waste heat recovery due to a better temperature match with the waste heat source. Different combinations of the tCO<sub>2</sub> cycle, sCO<sub>2</sub> cycle and ORC are compared to screen the best configurations of the cascaded power cycles. The influence of the working fluid and the operating conditions are also investigated in this study. Each configuration is modeled and optimized in Aspen HYSYS. The results show that cascaded tCO<sub>2</sub>/ORC performs better compared with cascaded ORC/ORC and cascaded sCO<sub>2</sub>/ORC for the case study.

Keywords: LNG cold energy, low-temperature waste heat, organic Rankine cycle, supercritical CO\textsubscript{2} cycle, transcritical CO\textsubscript{2} cycle

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