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Enhancement of LNG plant propane cycle through waste heat powered absorption cooling

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In liquefied natural gas (LNG) plants utilizing sea water for process cooling, both the efficiency and production capacity of the propane cycle decrease with increasing sea water temperature. To address this issue, several propane cycle enhancement approaches are investigated in this study, which require minimal modification of the existing plant configuration. These approaches rely on the use of gas turbine waste heat powered water/lithium bromide absorption cooling to either (i) subcool propane after the propane cycle condenser, or (ii) reduce propane cycle condensing pressure through pre-cooling of condenser cooling water. In the second approach, two alternative methods of pre-cooling condenser cooling water are considered, which consist of an open sea water loop, and a closed fresh water loop. In addition for all cases, three candidate absorption chiller configurations are evaluated, namely single-effect, double-effect, and cascaded double- and single-effect chillers. The thermodynamic performance of each propane cycle enhancement scheme, integrated in an actual LNG plant in the Persian Gulf, is evaluated using actual plant operating data. Subcooling propane after the propane cycle condenser is found to improve propane cycle total coefficient of performance (COP_T) and cooling capacity by 13% and 23%, respectively. The necessary cooling load could be provided by either a single-effect, double-effect or cascaded and single- and double-effect absorption refrigeration cycle recovering waste heat from a single gas turbine operated at full load. Reducing propane condensing pressure using a closed fresh water condenser cooling loop is found result in propane cycle COP_T and cooling capacity enhancements of 63% and 22%, respectively, but would require substantially higher capital investment than for propane subcooling, due to higher cooling load and thus higher waste heat requirements. Considering the present trend of short process enhancement payback periods in the natural gas industry, subcooling propane after the propane cycle condenser is recommended as the preferred option to boost propane cycle performance.

1. Introduction

The liquefaction of natural gas (NG) serves to reduce NG volume for economic transportation. Liquefaction is achieved by cooling NG below −160 °C [1], which requires a considerable amount of energy.[1] Enhancing the energy efficiency of the liquefaction process could therefore significantly improve the efficiency of liquefied natural gas (LNG) plants, and reduce both fuel consumption and associated carbon emissions. This is critical to LNG plants located in the Persian Gulf, whose refrigeration capacities are constrained by high yearly ambient temperatures.

Today, the majority of base-load LNG plants employ the propane pre-cooled mixed refrigerant (APCI) cycle [3]. The plant considered in this study is a major LNG facility in the Persian Gulf, whose liquefaction process is based on APCI cycle. In this process, which is illustrated in Fig. 1, the feed gas is passed through a gas sweetening section for removal of H_2S, CO_2, H_2O and Hg. As it passes through the precooler and cold box, its temperature decreases to approximately −30 °C, resulting in condensation of certain components. The remaining gas and condensate are separated in the separator. The condensate is sent to the fractionation unit, where it is separated into propane, butane, pentane, and heavier hydrocarbons. The remaining gas is further cooled in the cryogenic column to below −160 °C and liquefied. Its pressure is then reduced to atmospheric pressure by passing through the LNG expansion valve. Two refrigeration cycles are involved in the overall process shown in Fig. 1, which are the propane cycle and the multi

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[1] Approximately 1,188 kJ are consumed for the liquefaction of 1 kg of NG [2].

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