ABSTRACT

Liquefied natural gas (LNG) regasification terminals usually reject cold thermal energy to the seawater. It affects the marine life and loses the opportunity to convert the cold energy available with vaporized pumped LNG to power through Organic Rankine cycle (ORC). The delivery pressure of compressed natural gas) CNG may be equal or lower than the regasification pressure of LNG. Additional power can be produced by direct expansion (DE) when regasification pressure is higher. The capital cost of an ORC is largely dependent on the surface area of the heat exchangers that are usually designed with a fixed temperature approach or pinch temperature difference. This work shows that it is possible to increase power production substantially by re-distributing a given total surface area optimally among the heat exchangers that involves no additional cost. Initially, a three-stage cascaded ORC with krypton, ethane, ethane and propane as the working fluids is chosen for analysis. LNG at 6 bar(a), 30 bar(a) and 70 bar(a) are vaporized and the cold energy utilized in ORC to derive power. The analysis shows that the power produced from the third stage constitutes a small fraction of the total power. The thesis shows that the ORC and DE system together produce much higher power than an ORC alone. Compared to 30 bar(a) regasification pressure of LNG, 70 bar(a) pressure has lower total outlet volume flow rate through turbine, pump inlet, hot side of heat exchangers and lower total capital investment in. Further a cascaded three-stage ORC system has been progressively truncated to two-stage and single-stage ones with and without cascading. A variety of the combinations of working fluids (out of ethene, ethane and propane) is evaluated in search of high power production and required surface area of heat exchangers with 70 bar(a) regasification pressure of LNG. Cascaded three-stages delivers maximum power, a two-stage system with first stage cascading is the best option in terms of power produced and number of components to be used in the ORC.

In addition to that, the utilization of LNG cold energy in an air separation unit (ASU) has the potential to reduce the net specific power consumption of the ASU that produces only liquid oxygen. Design, parametric analysis and optimizations of ORC and ASU systems are done with the aid of commercial software, Aspen HYSYS® V8.6. There is always safety concern of pure oxygen coming in contact of natural gas that may lead to fire or explosion hazard. We evaluated a safer air separation unit (ASU) to utilize the LNG cold energy in a separate nitrogen heat exchanger that consumes higher specific power than that of the utilization of LNG cold energy in the main heat exchanger. We go a step further to propose two operational modes for producing a small quantity of liquid nitrogen and store it in a tank. In the second operational mode the stored liquid nitrogen is used to maintain the cold energy of the ASU in case the LNG supply shuts down.

Keywords: LNG Regasification; Cold utilization; Organic Rankine Cycle; Power generation; Cryogenic air separation; Operational flexibility;