Simulation of C3MR LNG Refrigeration Process in DWSIM

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Introduction:

Natural gas is viable energy source, but is dependent on existing pipeline infrastructure in order to reach the consumers. Due to the large volume it is not practical or economical to transport gas by vehicles or ships.

Liquefied natural gas (LNG) is condensed natural gas at atmospheric pressure and approximately -162 °C. The process of cooling natural gas to -162°C is highly energy demanding. Here, one of the processes simulated known as C3MR LNG Process is the propane pre-cooled mixed refrigerant process.

Process works based on vapor compression cycle which consists four components; compressor, condenser, expansion valve and evaporator.

LNG Process:

The process of liquefying natural gas is basically the same as described above. In LNG production, different refrigerant fluids are used to cool and condense the natural gas to approximately -162°C. Sea water is used to cool the compressed refrigerant streams which are subsequently expanded to provide cooling to the natural gas. The processes are extremely energy demanding and involve large compressors. So, large saving could be made by just slightly improving operating conditions.

LNG processes may be operated with pure or mixed refrigerants, though mixed refrigerants have the advantages of providing a much closer –fitting cooling curve in heat exchanger with the natural gas. A pure refrigerant gives a large temperature difference in the warm end of the heat exchanger and therefore a low COP. It is necessary to use multiple cascades of pure refrigerant cycles to obtain results to be comparable to those of mixed refrigerants [2].

C3MR LNG Process:

The propane pre-cooled mixed refrigerant (C3MR) process involves a single mixed refrigerant cycle. However, as it's name suggests, the process also consists of a propane pre-cooling cycle. This single component refrigerant eases the duty of the mixed refrigerant by cooling the natural gas and the refrigerant itself before the main cryogenic heat exchanger [2].

Herein, flowsheet propane cycle is used to pre-cool the mixed refrigerant. Propane is compressed to a high enough pressure this is done due to pressure be high enough for propane to be in liquid phase at the temperature achieved by the cooling. The liquid propane stream is let down in pressure and vaporized by heat exchanger with natural gas and mixed refrigerant. The pressure let down and heat exchange is performed in three stages, where the propane vapor is sent back to compression after each stage. The final heat exchanger in the propane cycle must super-heat the propane in order to avoid liquid being fed to the first compressor.

After pre-cooling the mixed refrigerant is partially condensed and is sent to a high pressure –separator prior to entering the main cryogenic heat exchanger. The vapor and liquid MR streams pass through separate circuit in the main cryogenic heat exchanger and are cooled, liquefied and sub-cooled by internal heat exchange along with the natural gas. The liquid refrigerant stream is taken out and expanded at a point other than that for the MR vapor. As the low pressure refrigerant streams flow down the cryogenic heat exchanger it is vaporized and super-heated by the cooling of natural gas (and also MR streams). The super-heated low pressure mixed refrigerant is then recompressed and cooled to complete the cycle [1, 2].

From, the result of this process here we have high pressure natural gas stream of approximately -157°C temperature. From the simulation below results obtained as shown in below figure.

Feed Composition of Natural Gas	
Methane (C1)	89.7%
Ethane (C2)	5.5%
Propane (C3)	1.8%
n-Butane (n-C4)	0.1%
Nitrogen (N2)	2.9%

Mixed refrigerant composition	
Methane (C1)	45.0%
Ethane (C2)	45.0%
Propane (C3)	2.0%
n-Butane (n-C4)	-
Nitrogen (N2)	8.0%

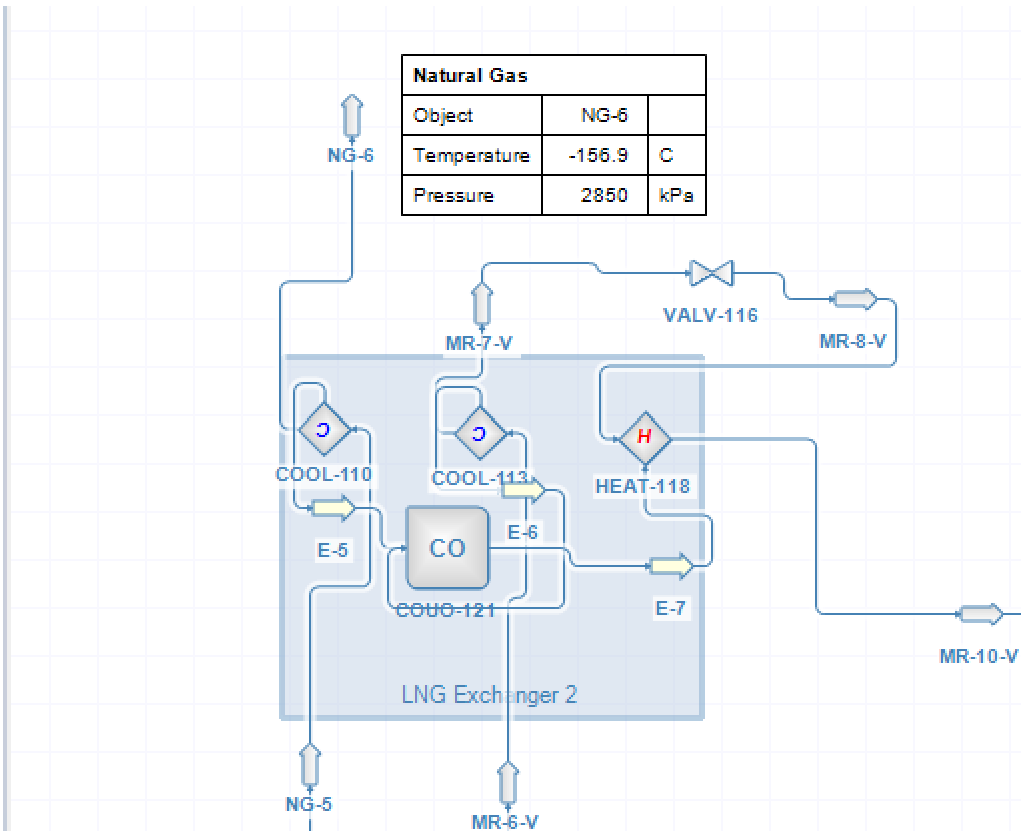

Figure 1: Natural Gas stream (LNG)

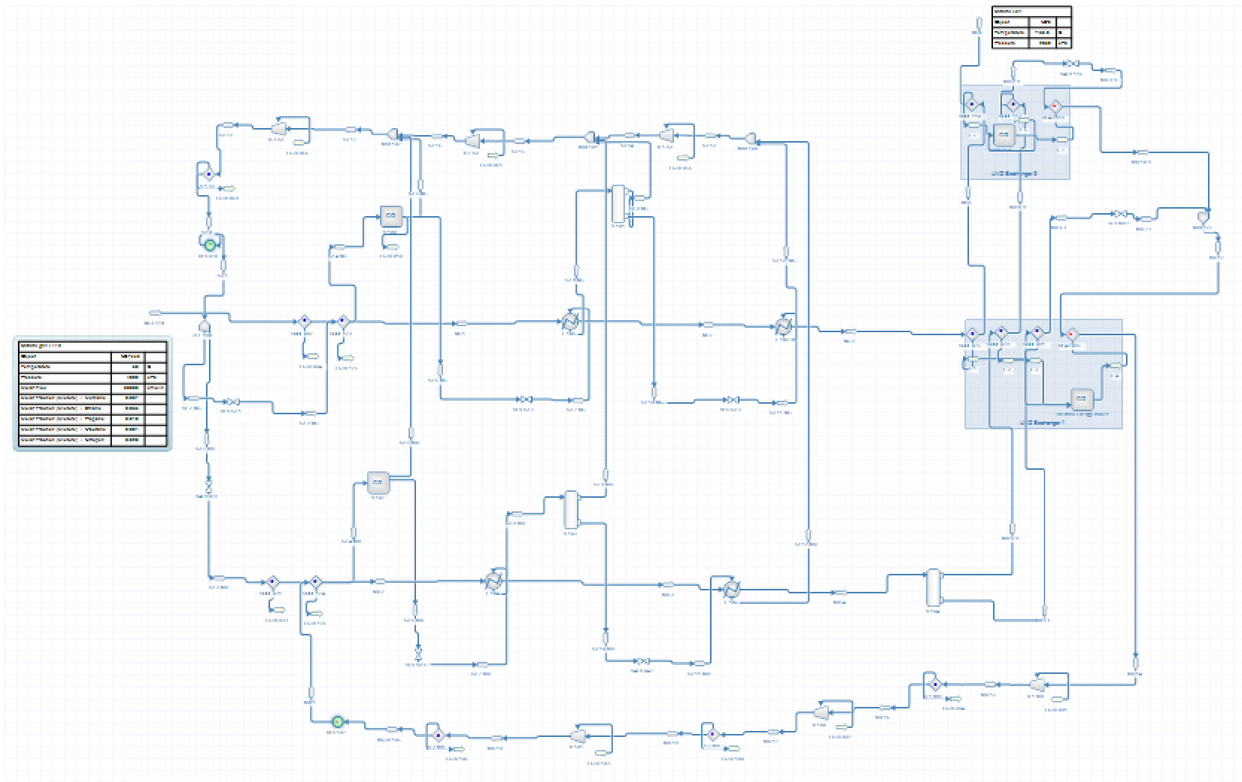

Figure 2: Simulated C3MR Flowsheet

Parameters taken for solving Flowsheet	
Property Package used	Peng-Robinson
Temperature	°C
Pressure	KPa
Molar flow	Kmol/h

References:

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[2] Helgestad, D. E. (2009). Modelling and optimization of the C3MR process for liquefaction of natural gas. *Process Systems Engineering*, *44*.