Optimal Synthesis of Cascade Refrigeration in Liquefied Natural Gas Cycles by Pinch-Exergy

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ABSTRACT

Iran's vast common natural gas resources and the necessity to extract and export it as Liquefied Natural Gas (LNG) to distances more than 3000 km has opened a lucrative field for researchers to optimize LNG cycles. In this article, heat integration in cryogenic cycles by determining interacycle partition temperature and optimizing refrigeration features like subcooler, presaturator, aftercooler, reboiler, superheater, and economizer is investigated to reduce compressor shaftwork. Better conceptual understanding of design improvement is illustrated on Composite Curve (CC) and Exergetic Grand Composite Curves (EGCC) of Pinch-Exergy analysis diagrams. Further, a program (LNG-Pro) is developed by integrating Visual Basic Application, Refprop (Reference Fluid Thermodynamic and Transport Properties) and Excel MINLP Solver to automate the methodology on an LNG plant with a capacity equal to a South Pars Gas Field phase. Shaftwork is reduced step by step from 1479.36 kJ/kg to 1255.5 kJ/kg and 1158.8 kJ/kg which is 2.46% less than the required energy for liquefaction in LNG industry.

1. Introduction

Natural Gas is an attractive source of clean fossil fuel. It can be used to generate electricity; feedstock for petrochemical and refinery plants. The most economical way of transporting natural gas beyond 3000 KM is to liquefy it. LNG projects are capital intensive and around 10% of feed gas is consumed in liquefaction stage for compressor shaftwork. Liquefying 1 Kg of LNG consumes around 1188 Kj energy [1]. The liquefier is where the greatest cost saving of and LNG plant can arise. In this paper, design of cryogenic refrigeration cycles which are operating under the temperature of 110 K is investigated by a step by step method. Most of industrial refrigerators and liquefiers work with pure refrigerants. Although pure cycles use more energy in comparison to mixed refrigeration cycles, reliability and controllability of pure cycles are higher than mixed refrigerant cycles [2]. High compressor shaftwork consumption and operating cost have motivated some researchers to retrofit pure refrigerant cycles of ethylene plants with mixed refrigerants. [3]

Many researchers have tried to introduce systematic design procedures for refrigeration cascade systems by either pure mathematical method or conceptual methods like pinch and exergy. For instance, Linnholf and Dhole [4] set a qualitative guideline based on pinch technology and Exergy analysis for placing heat pump to minimize shaftwork consumption. The method estimates shaftwork by simple graphical tools, called Exergy Grand Composite Curve (EGCC). As the area between EGCC and utility levels is proportional to the exergy loss, the programs try to minimize this area. In another study, Shelton and Grossmann [5] discretized the entire temperature range of refrigeration to find temperature level of intermediate stage, which is a pure mathematical approach. In this approach, many fixed temperature levels were used and the number of temperature levels and other parameters were determined.Vaidyaraman and Maranas [6] elaborated on generalized network representation of Shelton and Grossmann. They introduced more refrigeration features and refrigerants were selected from a pre-specified list. Their nodal network optimization focused on finding the number and temperatures of intermediate stages and the temperatures at which refrigerant switches occur. Lee and Smith, [7] also combined the super structure network presentation of Shelton and Grossmann, with Linnholf and Dhole approach of Pinch-Exergy analysis by using EGCC graphical method. Aspelund et al. [8] presented a new methodology based on Pinch-Exergy called ExPAnD which was developed in LNG industry. Although ExPAnD is a very interesting and useful method, it could only be applied when a liquid refrigerant is already available. Therefore, it could not be applied for natural gas cooling cycles of mega scale size as such a liquid refrigerant is not available for free. Torrella [9] analysed intermediate refrigeration features in staged vapour compression cycles by using subcooling and de-superheating options. Castillo [10] also introduced a thermodynamic criterion for selecting suitable refrigerant for the pre-cooling stage of a refrigeration cascade. In this article, the attempt is made to combine both methods to find the minimum required shaftwork of a pure refrigerant multi-stage cascade refrigeration cycle.

2-Theoretical principles of refrigeration and LNG systems

LNG industry requires very low temperature that is only viable through cascade refrigeration systems. Many refrigeration features are available which can be mounted over simple refrigeration cycles. These options reduce the required compression shaftwork. To describe these options, a cascade refrigeration system and its P-H diagram are shown in Figure1. The lower cycle absorbs heat at temperature level of 1-4 and rejects condensation heat to the upper cycle at temperature level of 2-3. The upper cycle absorbs rejected heat from the lower cycle by operating at evaporation level of 5-8, which is colder than the level 2-3. Finally, the heat in the upper cycle is rejected at level 6-7 to external heat sinks similar to cooling water and air cooling systems.

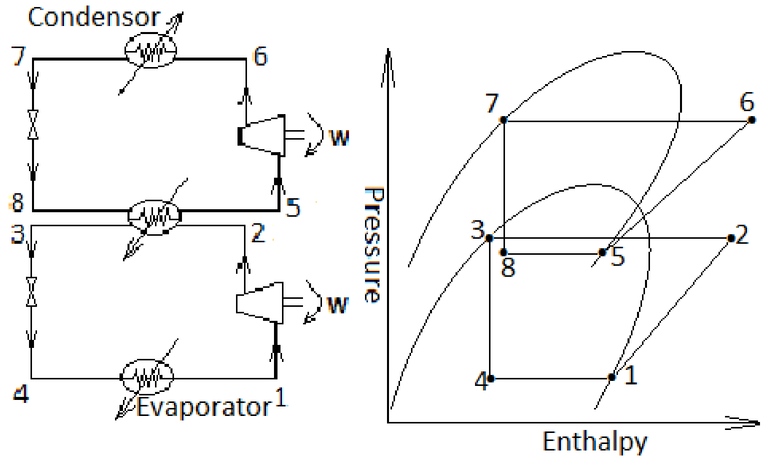

Figure 1. A simple cascade refrigeration system

The reasons for using this kind of cascade refrigeration systems are two-folds. First, there is no single refrigerant in a single cycle to cover all temperature range of refrigeration. Figure 2 below summarises the operating ranges for some commonly used refrigerants.

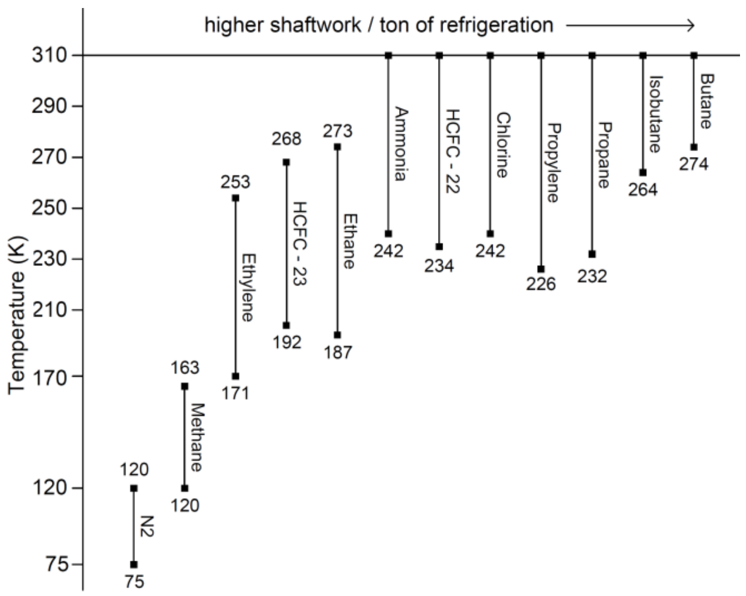

Figure 2. Refrigerant operating range.

Second, in terms of energy consumption, using a single refrigerant for the whole refrigeration demand may consume more shaftwork than using multiple refrigerants.

Refrigeration features in a cycle increase heat integration and complexity of a design. These options which can considerably reduce the compression shaftwork are described in the next section.

2.1 Design Options

For a refrigeration system, it is possible to improve its performance by using the following design options (Figure 3):

- **Economizer**: Figure3 (i). In an economizer, the condensed refrigerant is flashed to an intermediate pressure, where the flash vapor is returned to the suction of the compressor and the remaining liquid is further expanded to a lower temperature. As a result, the amount of vapor flowing through the lower pressure part is reduced, thus saving shaftwork.
- **Aftercooler**: Figure 3 (i). With this option, the superheated refrigerant vapor is cooled down after compression by other available heat sink before further compression. This causes the reduction of required shaftwork and the aftercooling duty. Also, aftercoolers provide the opportunity of heat integration between refrigeration systems and the processes.

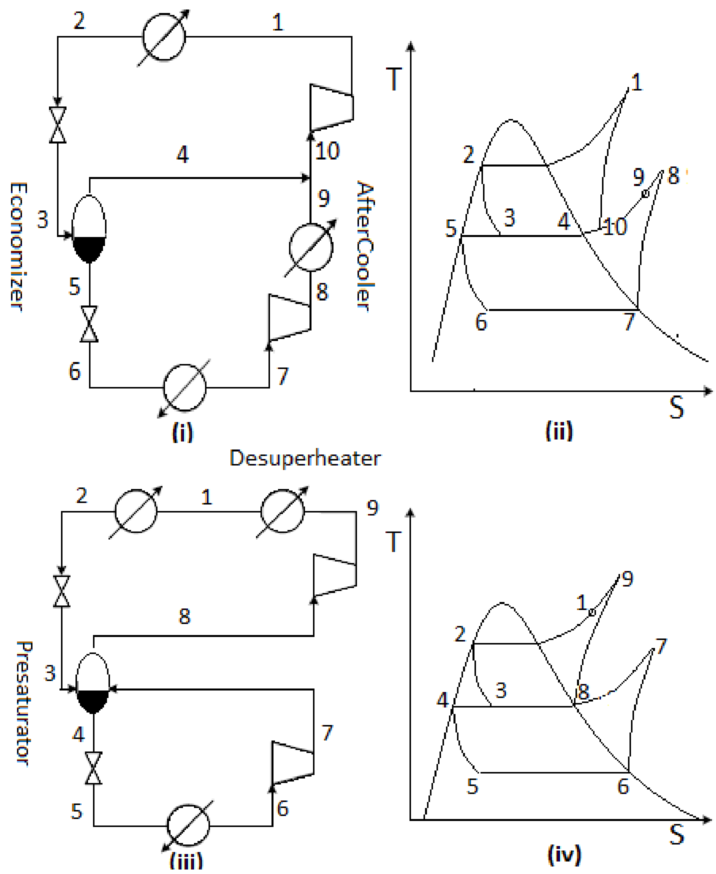

Figure 3. Refrigeration system design options in a cycle

- **Presaturator**: Figure 3 (iii). A presaturator has similar structure as that of an economizer, but the partially compressed refrigerant vapor is presaturated in the flash vessel with the expense of evaporating some part of the refrigerant liquid from the corresponding economizer. This decreases the temperature of the refrigerant vapor entering the next stage of compressor, and saves shaftwork. On the other hand, presaturation may have two drawbacks: (1) it requires a higher refrigerant flow rate which may cause more compression shaftwork and (2) both economizer and presaturator, add an intermediate pressure level, which may cause an increase in capital cost for compressors. Several small compressors can be more expensive than a single large compressor, even though the total shaftwork requirement is reduced.
- **Desuperheater**: Figure 3 (iii). Using a Desuperheater, the final stage superheated refrigerant vapor is precooled after compression by a warmer heat sink before entering the condenser. This adds the possibility of heat integration to processes.

2.2 Liquefied Natural Gas Process description

In natural gas liquefaction process, acid gases and merceptanes are removed from sour natural gas and its pressure is increased to an average value of 90 bar before entering the liquefaction cycle.

Liquefying natural gas needs Cascade refrigeration to reach very low temperatures. A simplified cascade refrigeration cycle for mega scale LNG plant consists of three sub-cycles, each using a different pure refrigerant (Figure 4).

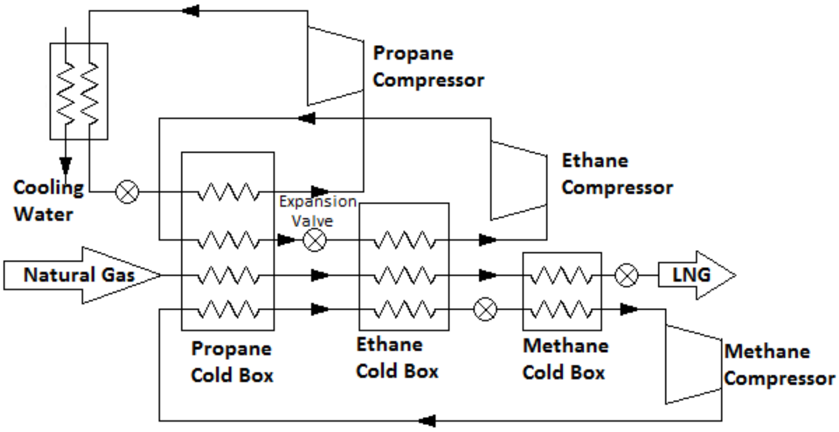

Figure 4. Schematic of cascade refrigeration cycle

Only one stage for each refrigerant cycle is shown for simplicity, but in real industrial cycles 2 or 3 pressure stages are available by using expansion valves and each stage shall have its own Presaturator, economizer, Desuperheater, etc. In the first cycle, propane leaves the compressor at a high temperature and pressure (maximum permissible outlet temperature of compressor shall not exceed 275 ^{0}F [11]) and enters the condenser where the cooling water or air is external heat sink. The condensed propane then enters the expansion valve where its pressure is decreased to the evaporator pressure and the temperature of hot streams decreases to -40^{0}C. As the natural gas and methane are cooling down and ethane of lower cycle is condensing, the liquid refrigerant propane evaporates. Propane leaves the evaporator as superheated vapor and enters the compressor, thus completing the loop. The condensed ethane in the middle cycle expands in the expansion valve and evaporates as methane condenses and natural gas is further cooled and liquefied. In ethane cycle, temperature of hot streams decreases to -100^{0}C. Finally, methane expands and then evaporates as natural gas is liquefied and subcooled to -160^{0}C. As methane enters the compressor to complete the loop, the pressure of LNG is dropped in an expansion valve to the storage pressure. Each of these refrigeration cycles has usually three compression and expansion stages. Consequently, there are three evaporation temperature levels for each refrigerant (Figure 5). Considering the pressure ratios and flow rates in LNG industry, the main compressor type is Centrifugal [12].

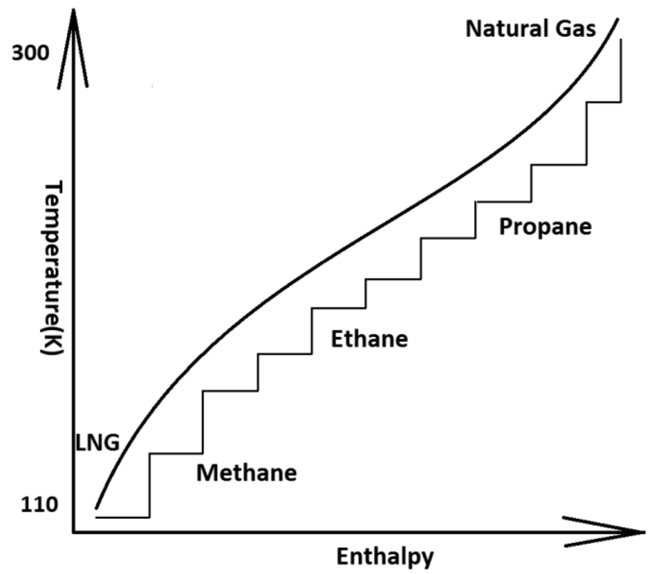

Figure 5. Cooling curve of natural gas and evaporation stages of the refrigerants

Optimal placement of Intra-cycle partition temperature between cycles in the cascade is the most important decision in refrigeration design. Some constraints and industrial practices which have to be abided to achieve a realistic and applicable design are introduced to place the partition temperature.

2.3 Technical heuristics for placing partition temperature and finding the best refrigeration cascade in LNG industry

Some practical guidelines which are used in the design of cascade systems state that:

- Size of LNG plant dictates the complexity of design. LNG plants with capacities less than 1 MTPA (Million Ton per Annual) use only one cycle and the designer should avoid a cascade design. However, this cycle can be a multi-stage mixed refrigerant and all refrigeration features like economizer, Presaturator, reboiler, etc. can be applied. When the LNG plant size increases, it is logical to use two or three cycles in a cascade and the same features used in single cycle can be used [12].
- One of the major equipment in any LNG plant is the compressor and its driver. For ease of operation, maintenance and lower cost, it is a common practice to have 2 or 3 compressors with the same shaftwork, so the designer should adjust the partition temperature to get the same shaftwork in each cycle. [12]

- The lowest temperature of natural gas in a cascade depends on the required composition of the produced LNG. LNG quality is determined by the main market to which it shall be exported. European market requires lower heating value and East Asia requires higher heating value. When the main market for the plant is determined, the specification of the product is known and the lowest required temperature will be found. This temperature shall dictate suction pressure of the lowest cycle compressor.
- LNG plants are the world largest vapor recompression cycle and regarding the pressure ratio and flow rate, centrifugal compressors are the best choice. Compressor manufacturers build compressors which have at most seven stages. As a normal practice, the compression ratio of each stage is around 1.7 [11]. Pressure levels in the cycle are determined by multiplying base pressure to this ratio powered by the number of sections between corresponding pressure levels.
- Each cycle transfers heat load of process stream and compressor's work to the upper cycle. The mixed refrigerant returning from higher cycles should be fully condensed, as the main heat rejection usually occurs during the condensation [15].
- Required shaftwork for the construction of a liquefaction plant is estimated by the experimental trend of LNG industry which is around: Shaftwork (MW) = 42*Liquefaction capacity (MTPA) + 0.77 [12], so if we wish to know the approximate shaftwork of a 3 cycle cascade, we should divide the total shaftwork by 3.
- Three guidelines help us to place partition temperature between each cycle:
  a) Each cycle's shaftwork should be around (if possible) the above estimated load
  b) The superheated mixed refrigerant discharged from the lower cycle to the upper cycle should return in liquid phase. This constraint is the main criterion that determines initial guess for refrigerant composition.
  c) Temperature of discharged vapor stream of each compressor shall not exceed 135^0C [11].

2.4 Pressure level and intra-cycle partition temperature placement by using Grand Composite and Exergetic Grand Composite Curves

Refrigeration cascade design starts from the lower cycle to the upper cycle, as there is no external heat load from any cycle to the lowest cycle. At first step, Figure 6(i), cooling demand curve is drawn in a Grand Composite Curve (GCC). Then an initial partition temperature that divides cooling load between lower and upper cycles is assumed. Next, lower cycle's refrigeration load is met and the heat is rejected to the upper cycle and the GCC is updated, Figure 6(ii). Effect of introducing a pressure level and refrigeration option in second cycle is shown in the grand composite curve (GCC) of Figure 6(iii). At last the accumulated heat load is rejected to the ambient heat sink.

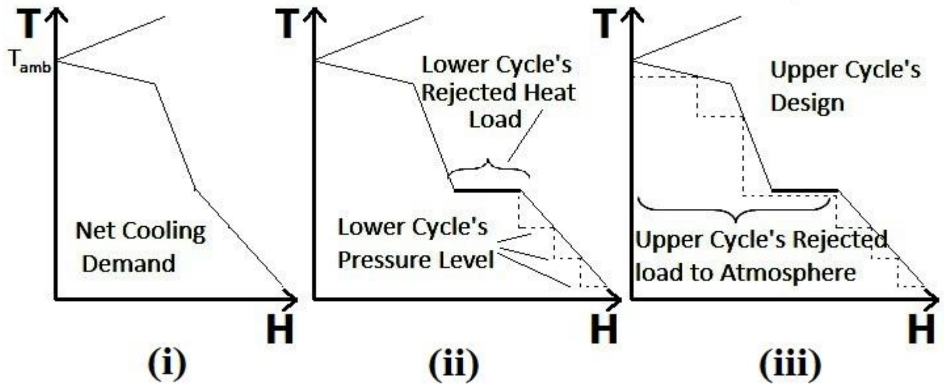

Figure 6. Refrigeration Cascade Design Procedure

If temperature axis of the GCC diagram is turned to Carnot factor, then Exergetic Grand Composite Curve (EGCC) will be obtained [4]. Introducing any new pressure level or refrigeration feature in a cycle results in lower exergy loss and compressor shaftwork, Figure 7.

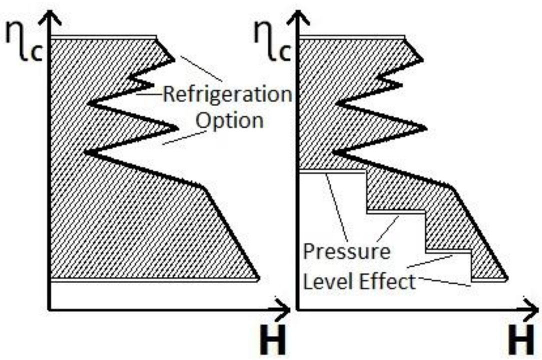

Figure 7. Effect of new refrigeration features and pressure level on shaft work reduction

Figure 7 enables us to evaluate the effect of different design options on the refrigeration system quickly and visually. EGCC diagrams of a cascade helps the designer to estimate the required compression shaftwork. EGCC guides design procedures to find the best compression configuration and partition temperature by minimizing the area encircled between utility line and the EGCC diagram.

3. Design of a methodology for finding an optimal refrigeration synthesis of an LNG Plant

Refrigeration cascade design is divided into three steps. At first, the designer has to find the best placement of partition temperature between cooling cycles. In the second step, the best compression configuration and pressure levels have to be found by GCC and EGCC diagrams. Finally, refrigeration features should be determined by minimizing the total compression shaftwork.

Aforementioned steps are fulfilled by a stepwise procedure drawing on the theoretical principles developed in section 2. The procedure will be applied on a mega scale LNG plant with the capacity of liquefying 25 Million cubic meters per day of natural gas that is equal to the upstream production rate of one standard phase of Iran’s South Pars Gas Field. Design procedure illustrates the ease of use, flexibility and applicability of the method.

Sample description

There is a gas field block with a capacity of around 90 billion cubic meter (BCM) and an LNG plant by a lifecycle of 25 year is to be built on it. This amount of gas equals to an LNG plant with the capacity of 5.4 MTPA. Treated natural gas composition is propane 3%, ethane 5%, methane 90%, Nitrogen 2% on mole basis and its pressure is 90 bar. A set of multi-stream heat exchanger (MSHX) with approach temperature of 5^0C and compressor's with isentropic efficiency of 82% and the ambient temperature of 300 K is available. As the size of the plant is big enough, it can be partitioned into three different cycles [12]. Evaporation rate after each expansion valve is assumed to be 5%,10%,15% for the lowest, middle and the highest cycle for initial guess, and the base pressure is 2.25, 1.15, 1.15 bar, respectively.

LNG-Pro which is a program developed to automate the above-mentioned theoretical and heuristic guidelines integrates Visual Basic Application (VBA), Refprop [13] (Reference Fluid Thermodynamic and Transport Properties) and Excel MINLP Solver. LNG-Pro starts to establish heat-material balance from lower to higher cycles and find the best partition temperature between interacting cycles by drawing GCC and EGCC diagrams. It establishes a rough and primitive cascade cycle by minimizing the encircled area between cooling utility and hot streams.The methodology used by LNG-Pro can be briefly explained as below:

- Modelling a simplified refrigeration cycle based on the following guidelines and constraints
  1) Each cycle's shaftwork in Cascade should be distributed equally based on the available drivers
  2) The superheated mixed refrigerant discharged from lower cycle to the upper cycle should return in liquid phase.
  3) Temperature of discharged vapor stream of each compressor shall not exceed 275^0F
- Finding the best partition temperature and Refrigerant Composition by incorporating Composite and Grand Composite Curves through minimizing the compression shaftwork
- Establishing a refrigeration Super-Structure which includes both Boolean and Non-Linear parameters:

a) Pressure Levels b) Compression Configuration	Boolean parameters
a) Compressor cost formula b) Compression Cost Ratio to Plant Cost c) Annualization factor of Capex d) Electricity Cost	Non-Linear Parameters

- MINLP Solver uses Boolean Mathematics [14] (Mixed Integer Programing) to find the best pressure level and compression configuration and Non-Linear Programing (NLP) [14] to find the most economical (Capex+Opex) configuration by interacting between cycles. Heat material balance is verified by investigating composite diagram and shaftwork is minimized by decreasing the encircled area of EGCC Diagram.

The results of first step are shown in Composite Curve (CC) and Exergetic Grand Composite Curve (EGCC) diagrams of Figure 8 and Figure 9 below. The area between hot and cold curves is directly related to shaftwork consumption and is an indicator of irreversibility and exergy loss of cascade. These curves help us to be assured that heat material balance is met in refrigeration cascade and no heat cross between hot and cold stream has happened in MSHX.

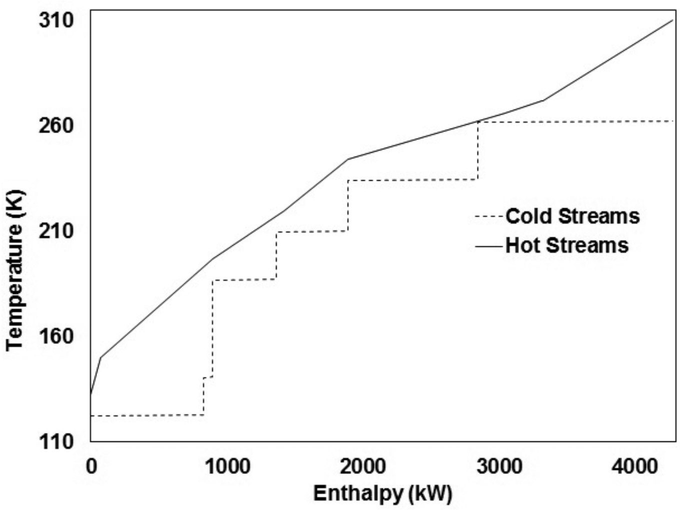

Figure 8. First step Composite Curve

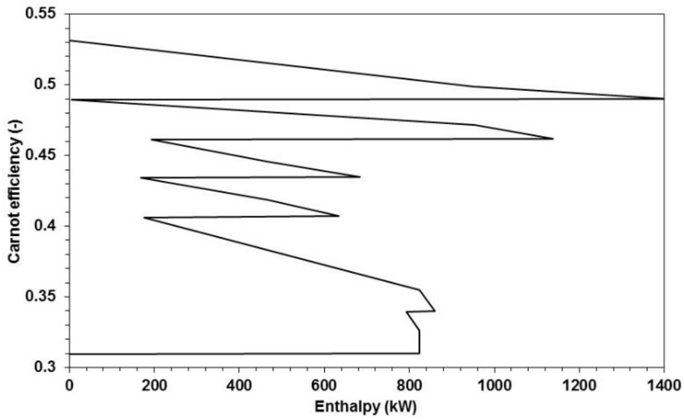

Figure 9. First step Exergetic Grand Composite Curve

These diagrams illustrate pinch point that is the most critical place in our design. By avoiding sharp edges in CC, flexibility and reliability of the design is increased.

A summary of the first step results is presented in Table1.

Table 1. First step results on partition temperature and compressor shaftwork

	Partition temp (K)	Refrigerant Temp range(K)	Shaftwork (MW)
Higher Cycle	233.9	233.9-300	140.6
Middle Cycle	186.9	186.9-233.9	67.4
Lower Cycle	120.2	120.2-186.9	60

Total required shaftwork for a 5.4 MTPA LNG plant in the first step is 268 MW that is 24.53% above the normal industrial consumption rate. LNG cycles normally consume 1188 kJ/kg energy [1] to liquefy natural gas but the priliminary cascade design is consuming 1479.36 kJ/kg energy. All obtained results of this step are transferred to the next step to find the best compression configuration and refrigeration pressure level.

In the second step, pressure levels of multistage cycle and the compressor configuration are considered. Pressure levels of a refrigeration cycle are obtained by multiplying base pressure to each compressor section pressure ratio which is 1.7 [11]. Many different possibilities and configurations can be considered for either a single cycle or different interacting cycles. MINLP model in conjunction with EGCC are used to find the best pressure levels and compression configuration by minimizing annual cost which is related to the required refrigeration shaftwork. EGCC diagrams are used in this stage to reduce calculation time. Many optimizing features of refrigeration system in the superstructure like presaturator, aftercooler, reboiler, superheater and economizer are canceled out to increase the calculation speed in this stage. Refrigerant subcooling is the only refrigeration feature considered in this stage as subcooling poses a major effect and cannot be ignored. Vapor ratio after expansion valve is assumed to be 0.05, 0.1, and 0.15 in lower, middle, and upper cycle which is an assumption resulted from the refrigerant subcooling. In the third stage, after determining compression configuration, this simplifying assumption is omitted and the cascade is rigorously modeled.

There are thousands of refrigeration configurations that can meet an LNG cycle thermodynamically, but we have to constrain these configurations by many industrial limits and also consider operational and economical parameters to select the best multistage cascade cycle for an LNG plant.

In the aforementioned superstructure we have annualized all expenses. Cost of compressors as the main single component of a liquefier is estimated to be [16]:740*(Shaftwork (KW))+612630 US$. Cost of a compressor for such a plant is estimated to be around 12% of the total plant cost, [16]. The electricity cost for compressor driver is assumed to be 0.06 $ per KWH and a 5-year period is considered to annualize the plant capital cost.

If we change the above assumptions, for instance by giving more importance to operating cost (Higher electricity price) or capital cost (compressor price formula or total plant cost ratio), we will obtain different configurations and pressure level which are compatible with those conditions.

Table. 2 summarizes compression configuration and selected pressure levels. Compression configuration means the required number of compression sections between pressure levels. The compression pressure ratio in each section is 1.7. For instance, in higher cycle there are three pressure levels and between first and second pressure level there is only one section. Between second and third pressure level there is again one more compression section, but from third refrigeration pressure level to the highest pressure where all absorbed heat is rejected to either ambient heat sink or higher cycle there are three compression sections. Table 3 shows the estimated capital and operating cost for the second step decision made by this method.

Table 2. Compression Configuration and selected scenarios of the Second Stage

	Pressure Levels (bar)	Compressor Stage Configuration
Higher Cycle	1.15-1.95-3.32-16.33	1-1-3
Middle Cycle	1.15-1.95-3.32-16.33	1-1-3
Lower Cycle	2.25-3.825-6.5-31.9	2-2-2

Table 3. Capital and Operating cost of determined configuration of Second Stage

	Shaftwork (MW)	Capital Cost(M $)	Annual Operating Cost(M $)
Higher Cycle	127.38	1316.6	63.28
Middle Cycle	62.86	651.12	31.23
Lower Cycle	37.2	389.52	19.45

Construction cost for such a plant is anticipated to be 2357.24 million $.

Total required shaftwork for the second step is 227.44 MW (1169.13 kJ/kg) that is 5.68% more than the industrial trend [1]. The stepwise procedure illustrates an improving trend in design. It should be noted that comparison between available industiral shaftwork or its optimized shaftwork and the obtained cascade shaftwork is not the aim of this paper as it depends on each LNG plants size and complexity, environmental condition, equipment specification (like compressor's efficiency and MSHX's approach temperature) and etc., but by comparing the required shaftwork in each step, improving design trend is illustrated.

The composite curve (CC) and Exergetic Grand Composite Curve (EGCC) of selected configuration in Figure 10 and Figure 11, represent the progress on design as the area between the two curves decreases. These results are transferred to the third step.

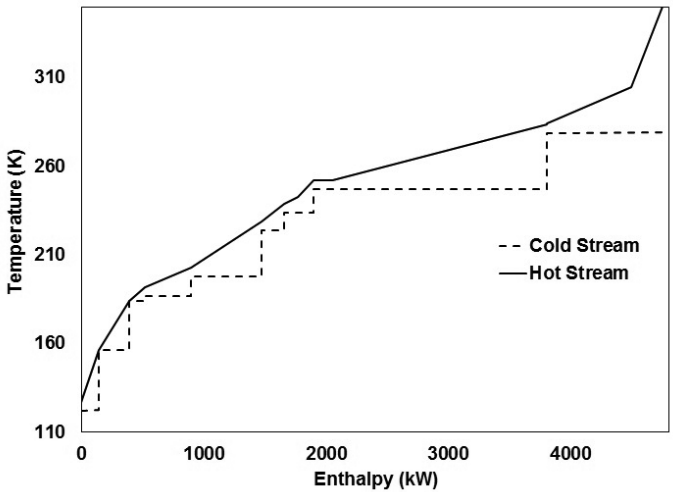

Figure 10. Second step Composite Curve

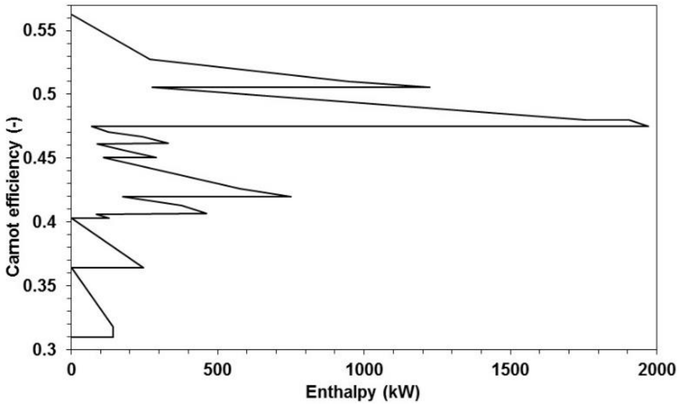

Figure 11. Second step Exergetic Grand Composite Curve

In the third step, optimal refrigeration features in a cycle are found. All design options are modeled in an Excel spreadsheet that is linked to REFPROP to retrieve refrigerant properties. The options in super structure model are disjuncted by Boolean variables and the problem is solved by an MINLP Solver Engine. Applying all aforementioned technics, we find the best refrigeration features of 2.1. The calculated shaftwork for optimized multistage cascade is 209.92 MW (1158.76 kJ/kg) which is well below the available industrial LNG plant cycle. Total required shaftwork is 2.46% less than the industrial trend [1].

The Composite Curve (CC) and Exergetic Grand Composite Curve (EGCC) can clearly show the step by step progress in design procedure Figures 12 & 13.

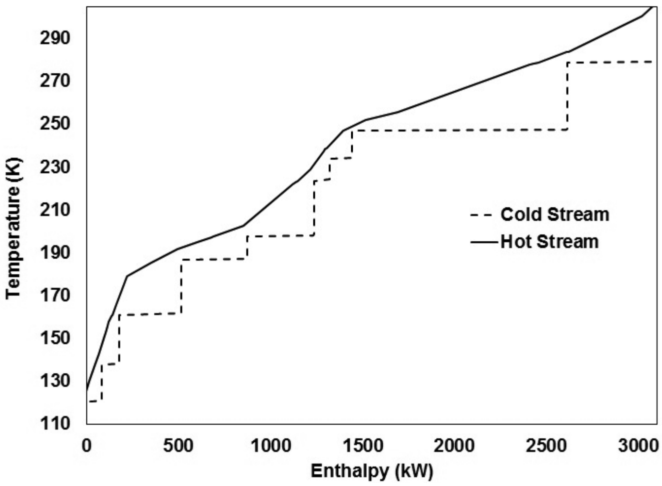

Figure 12. Third step Composite Curve

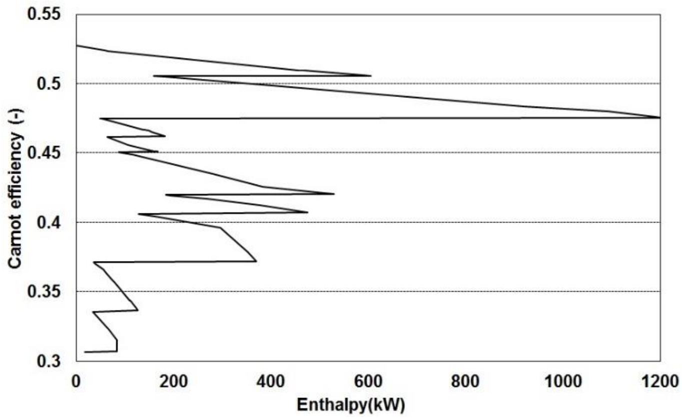

Figure 13. Third step Exergetic Grand Composite Curve

The introduced stepwise procedure shows a gradual compressor shaftwork saving from 268 MW (1479.36 kJ/kg) in the first step to 227.44 MW (1255.47 kJ/kg) in the second step and 209.92 MW (1158.76 kJ/kg) in the third step. The area between EGCC of each step which is an indication of the required shaftwork has gradually reduced.

4. Conclusion

A stepwise design procedure for the complex refrigeration system was introduced in this paper. There are two different approaches in the design of these systems: First is to use a large mixed integer non-linear mathematical superstructure which is a very time-consuming and complicated procedure. This design procedure is a black box and the designer is not able to use his engineering concepts and experiences properly. The second is using Pinch-Exergy method, which is more conceptual. Effect of added new pressure levels and refrigeration feature into the basic cycle can be easily seen in the Composite Curve, but this method can only be used as a guidance to speed up the design procedure. The introduced stepwise procedure combines these methods and uses heuristic guidelines which are applied in LNG industry. Important parameters such as partition temperature and base pressure are determined in the first step. In the second step, a super structure determines the best configuration for compressors by minimizing the OPEX and CAPEX of the plant. This step is performed by an MINLP solver. The third step deals with all refrigeration features like subcooler, economizer, presaturator, etc. which are mounted on the top of previously determined configuration. Design approach is applied on a sample LNG cycle and the required compressor shaftwork of each design stage is gradually reduced. Energy consumption to liquefy 1 Kg of natural gas in the first, second and third step are 1479.36, 1255.47, 1158.76 kJ/kg, respectively. The first and second steps are conceptual steps which determine the major decisions in a refrigeration cycle and use simplifying assumptions to speed-up the calculation, but in the third step a detailed simulation is performed and the heat-material balance and compression configuration of the cascade is calculated.

This stepwise procedure was automated by a program (LNG-Pro) and applied on a mega scale LNG plant with the capacity equal to a standard South Pars Gas Field phase. The resulted refrigeration cascade system consumes

209.92 MW of power for a 5.4 MTPA production capacity of LNG which is 2.46% less than the normal LNG plant energy consumption. Cost of this plant is considerably minimized to be around 2357.24 million US $.

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طراحی ساختار بهینه سیستم‌های آبشار سرمایشی ال ان جی با مبرد خالص و به کار گیری ریاضیات گسسته غیر خطی

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چکیده

اقتصادی ترین روش انتقال گاز طبیعی در فواصل طولانی استفاده از مایع سازی گاز می‌باشد. مایع سازی گاز طبیعی با استفاده از سیستمهای سرمایش تراکمی نیاز به هزینه‌های بالای عملیاتی و سرمایه ای دارد. به علت نبود راه حل‌های سیستماتیک برای طراحی سیستمهای سرمایش چند طبقه ای و سرمایشی، روشهای طراحی کنونی بسیار زمان بر و همراه با آزمایش و خطا می‌باشند. در این مقاله با معرفی روش ریاضیات غیرخطی گسسته اقدام به انتخاب بهترین ساختار چیدمان سیکل سرمایشی می‌نماییم به طوری که هزینه سرمایه ای و عملیاتی کارخانه کمینه گردد و در این راه از تکنولوژی پینچ بهره گرفته می‌شود. در این راهکار یک ابرساختار پیچیده سرمایشی تشکیل شده و پارامترهای اصلی یک سیستم (دمای جدایش بین سیکلی، چیدمان کمپرسورها، گزینه‌های بهبود سیکل سرمایشی و نرخ دبی جریان‌ها) انتخاب و بهینه می‌گردد. روش طراحی معرفی شده زمان محاسبات را کاهش داده و تعداد گزینه‌های مورد بررسی برای اصلاح سیکل را که می‌توان روی ابرساختار به کار گرفت را افزایش می‌دهد. بر اساس همین روش برنامۀ LNG-Pro با یکپارچه سازی برنامه‌های VBA و MINLP Solver و RefProp توسعه داده که موجب اتوماسیون الگوریتم به کار گرفته شده می‌شود. نمودارهای مفهومی تکنولوژی پینچ نشانگر بهینه سازی مرحله به مرحله این روش و کاهش تدریجی کار کمپرسورها در آبشار سرمایشی می‌باشد. سیکل طراحی شده به وسیله این روش کار کمپرسورهای یک سیکل LNG را از kJ/kg ۱۲۵۵ به kJ/kg ۱۱۴۱,۹ کاهش می‌دهد.