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Project of:

REGASIFICATION SELECTION FOR LNG TERMINAL IN SUDAN

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الاية:

بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

(وَيَسْأَلُونَكَ عَنِ الرُّوحِ ۖ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّنَ الْعِلْمِ إِلَّا قَلِيلاً)

صدق اللهُ العظيم

الإسراء (85)

الاهداء :

ما الزمانُ وما المكانُ وما القديمُ وما الجديدُ سنكون يوماً ما نريدُ لا الرحلةُ ابتدأت ولا الدربُ انتهى وما توفيقينا إلا بالله رب العالمين بمناسبه تخرجنا من "كلية هندسة وتكنلوجيا النفط" نهدي بحثنا هذا الي اسرتنا واساتذتنا والي كل من وقف معنا وشاركنا فرحة نجاحنا وتخرجنا

الشكر والتقدير :

قال رسول الله (صلى الله عليه وسلم): " مَنْ صَنَعَ إِلَيْكُمْ مَعْرُوفًا فَكَافِئُوهُ ، فَإِنْ لَمْ تَجِدُوا مَا تُكَافِئُونَهُ فَادْعُوا لَهُ حَتَّى تَرَوْا أَنَّكُمْ قَدْ كَافَأْتُمُوهُ "

وفاءا وتقديرا واعترافًا منا بالجميل نتقدم بجزيل الشكر والعرفان الي استاذنا الفاضل الباش مهندس عمار مجذوب صاحب الفضل في توجيهنا ومساعدتنا في مجال البحث العلمي، وتجميع المادة البحثية، فجزاه الله عنا كل خير.

ABSTRACT

The main objective of this research is to select the appropriate regasification technology for Sudan liquefied natural gas (LNG) terminal at Port Sudan, with a low Operating cost to suit the site climate conditions.

Computer simulation software was used to design and simulate this technology to realize the optimum conditions which can regasify 3 MMTPA of LNG where this quantity per year is the energy demand of Sudan. Aspen HYSYS 11 was used for the simulation to design and determine the vaporizer specifications and to determine the capital cost and operation cost.

Standard selection criteria were used to select the most suitable regasification technology. In this regard using seawater was found to be the best for both selected options: Direct LNG vaporization using seawater or Indirect LNG vaporization using propane as intermediate between LNG and seawater. The comparison between the two options was implemented by regasification cost. The best option with a regasification cost 0.146 €/MMBTU was found to be the open rack vaporizer (ORV).

المستخلص:

الهدف الرئيسي من هذا البحث هو اختيار المبادل الحراري المناسب لتغويز الغاز الطبيعي المسال في ميناء بورتسودان , بتكلفة تشغيل منخفضة لتلائم الظروف المناخية للموقع.

تم استخدام برنامج محاكاة حاسوبي لتصميم ومحاكاة التقنية لتحقيق ظروف مثالية لاعادة تغويز 3 مليون طن في السنة من الغاز الطبيعي المسال حيث تمثل كمية الطلب في السودان.تم استخدام برنامج المحاكاة اسبين هايسيس الاصدار 11 لتصميم وتحديد مواصفات المبادل الحراري ولتقليل تكلفة رأس المال وتكلفة التشغيل.

تم استخدام معايير قياسية لاختيار انسب تكنلوجيا لاعادة تحويل الغاز الطبيعي المسال الى غاز طبيعي ووجد ان استخدام مياه البحر هو الافضل لكلا الخيارين المحددين: التبخير المباشر للغاز الطبيعي المسال بأستخدام مياه البحر أو التبخير غير المباشر للغاز الطبيعي المسال باستخدام البروبان كوسيط بين الغازى الطبيعي المسال ومياه البحر. تمت المقارنة بين الخيارين من خلال تكلفة تغويز الغاز الطبيعي المسال و وجد أن التبخير المباشر باستخدام مياه البحرهو افضل خيار بتكلفة تشغيل 0.146 سنت لكل مليون وحدة حرارية بريطانية.

TABLE OF CONTENTS

List of Figure:

List of Tables:

List of Abbreviations:

LNG	**Liquefied Natural Gas.**
NG	**Natural Gas.**
NGL	**Natural Gas Liquids**
LPG	**Liquefied Petroleum Gas**
MMTPA	**Million Tonne per Annum.**
BOG	**Boil- Off Gas.**
ORV	**Open Rack Vaporizer,**
SCV	**Submerged Combustion Vaporizer.**
AAV	**Ambient Air Vaporizer.**
IFV	**Intermediate Fluid Vaporizer.**
SW	**Seawater.**
FG	**Fuel Gas**
GW	**Glycol-Water.**
HW	**Hot Water.**
STV	**Shell and Tube Vaporizer.**
HTF	**Heat Transfer Fluid.**
LP	**Low Pressure Pump.**
HP	**High Pressure Pump.**
ROI	**Return of Investment**
CAPEX	**Capital Expenditure**
OPEX	**Operational Expenditure**
MMBTU	**Million British Thermal Units**

CHAPTER ONE

INTRODUCTION

1-1 GENERAL CONCEPT:

1-1-1 NATURAL GAS:

Natural gas is one of the world's most important sources of energy. Today, approximately 30% of the world's energy needs are met with this gas. Most of it is supplied in gaseous form by pipeline. However, over the past two decades, Liquefied Petroleum Gas (LPG), Natural Gas Liquids (NGL) and Liquefied Natural Gas (LNG) have become much more important in the world's energy market. Natural gas and LNG in particular are expected to play an essential role in the world's transition to cleaner sources of energy. (Albetra energy ,1995).

Natural gas is one of the cleanest, safest, and most useful forms of energy in our day-to-day lives. It is a hydrocarbon, which means it is made up of compounds of hydrogen and carbon. The simplest hydrocarbon is methane; it contains one carbon atom and four hydrogen atoms. Natural gas can be found by itself or in association with oil. It is both colourless and odourless and is in fact a mixture of hydrocarbons. It is mainly methane; the other hydrocarbons include ethane, propane, and butane. Water, oil, sulphur, carbon dioxide, nitrogen, and other impurities may be mixed with the gas when it comes out of the ground. These impurities are removed before the natural gas is delivered to our homes and businesses. The fact that natural gas is combustible and burns more cleanly than some other energy sources helps reinforce its position as one of the most highly used energy sources typical properties of raw natural gas are outlined in figure 1.1

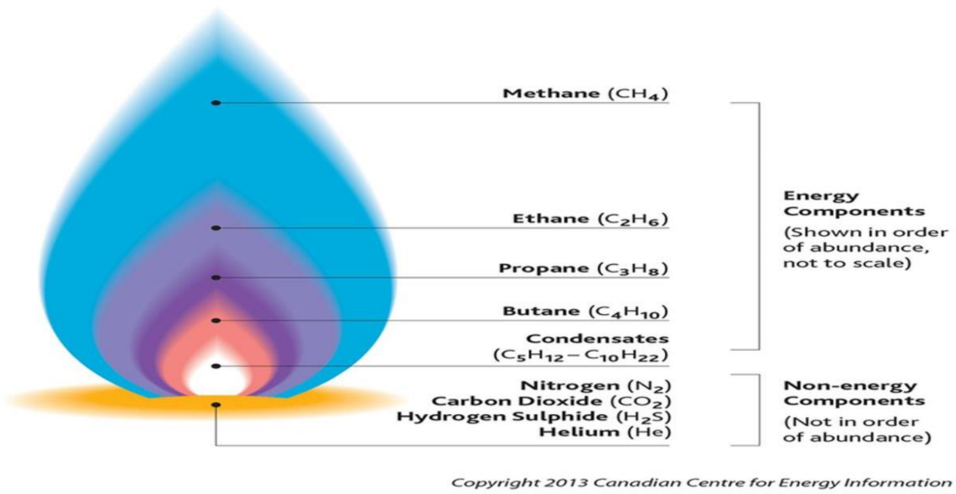

FIGURE 1-1 COMPONENT OF RAW NATURAL GAS

1-1-2 LIQUEFIED NATURAL GAS:

When natural gas is cooled to approximately –162 C or –259 F at atmospheric pressure, the condensed liquid is LNG.

LNG, or liquefied natural gas, is a clear, odourless, noncorrosive, nontoxic liquid that is formed when natural gas is cooled to around -260 F. This shrinks the volume by about 600 times, making the resource easier to store and transport through marine shipments. The more condensed form of LNG allows transport using cargo ships or trucks.

Typically about 10 to 20% of gas delivered into an LNG supply chain is consumed in the process and transportation facilities, comparable with long-distance high-pressure gas pipelines. LNG is not stored under pressure and is not explosive or flammable in its liquid state, and it cannot be released rapidly enough to cause overpressures associated with explosions.

LNG has been safely handled for several decades, with LNG vessels having made more than 100,000 voyages without major accidents or safety problems.

An LNG production plant is designed to meet the production target with specifications that meet the contractual agreement while satisfying the emission and environmental regulations. The LNG liquefaction plant is a complex process, and for this reason, it is important to understand the design limitations and the process interaction among the different units for plant operation.
The focus of this project is to discuss the process parameters and typical pitfalls that operators may encounter in a day-to-day operation.

1-2 Problem Statement:

1-2-1 Worldwide Consumption and Needs of Natural Gas:

The demand of world primary energy is expected to grow by 1.6% per annum during the period 2010–2030. In order to meet this requirement, energy production will need to be increased by 39%. Natural gas (NG) is a natural resource that in recent years has seen a large increase in demand globally.
While the share of oil in energy is forecast to dramatically decrease by 2030, NG is predicted to reach 25.9% of the world's energy usage. LNG demand may reach up to 500 MTBA by 2030. The major use for LNG today is power generation resulting from the growing power demand. Given the large scale of LNG projects, it is tempting for governments to adopt regulations from other countries. (Ford, Barden, 2013).

1-2-2 SUDAN ENERGY CONSUMPTION AND PLANS FOR NEW SOURCE:

As the main source of energy, oil plays a major role in the Sudanese economy, where power plants and most industrial sector depend completely on the refinery fuel product.

Now oil production in Sudan is declining because of natural declines at maturing fields, and suffers severe financial crisis after the secession of its Southern part after a constitutional referendum .Sudan has set ambitious goals to increase production from new fields and to increase recovery rates at existing fields, but production continues to fall short of Sudan's goals because the demand of energy increased daily, another in 2012 a snapshot of the North Sudan macro-markets indicates the industrial production is negatively growing .

The need for a regasification project plays big issue in solving fuel shortage and its only possible solution will be through finding new energy sources, another it can replace diesel and heavy fuel due to more expensive and less environmentally friendly alternative to natural gas. In addition, natural gas will be source of fuel in new power station and other industrial Sector specifically Cement factories.

The Sudan LNG Regasification Project will enable the shortfall in Sudan gas supplies to be covered through importing LNG. This will ensure that natural gas can continue to be used as the main fuel for power generation in the region and prevent potential degradation in air quality, another allows sustainability of energy and able to export excess fuel that produce by the refinery to introduce hard currency to the country.

1-2-3 LNG TERMINAL:

An LNG terminal is a facility or structure for re-gasifying the LNG shipped by LNG tankers or ships from the production zones .It can comprise special tanks, ships or even building structures. Port infrastructures and pipelines are also a part of LNG terminals.

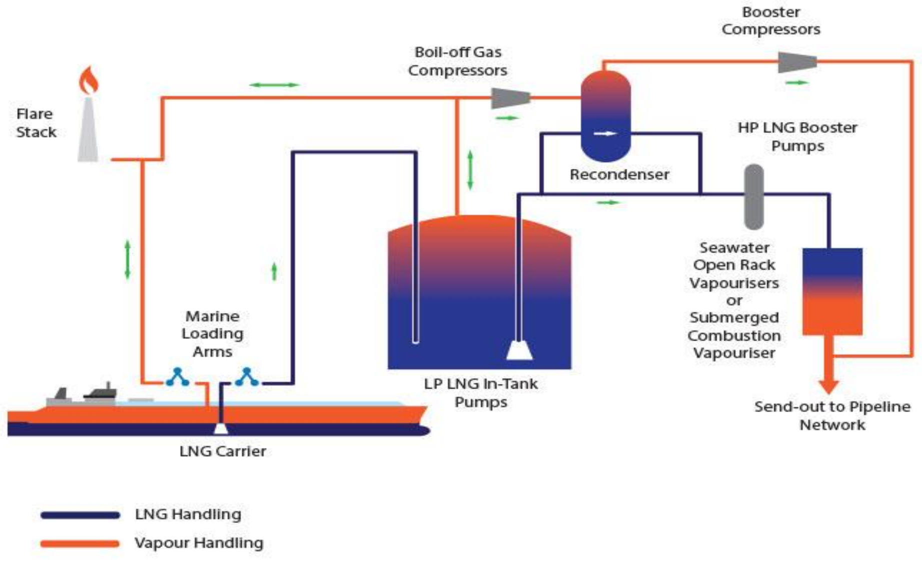

FIGURE 1- 2 LNG TERMINAL

A conventional terminal has four functions:

1. Berthing of LNG tankers and unloading or reloading of cargoes,
2. Storage of LNG in cryogenic tanks (-160°C),
3. Regasification of LNG,
4. Send-out of this gas into the transmission grid.

1-2-3-1 Berthing and Unloading:

On arrival at the terminal, LNG tankers (length 200 to 350 m) are moored to the unloading berth. Articulated arms are connected to the LNG carrier to unload its cargo and transfer LNG to the terminal storage tanks.
The LNG flows through pipes specially designed to withstand very low temperatures (-160°C). This operation takes at least 12 hours. A volume of boil-off gas is sent back from the terminal storage to the LNG tanker in order to maintain the pressure inside its cargo tanks.

1-2-3-2 Storage:

LNG is stored in cryogenic tanks (designed for low temperatures) capable of withstanding temperatures of -160°C to maintain the gas in liquid form. The outer walls of the storage tanks are made of pre-stressed reinforced concrete. They are insulated to limit evaporation.
Despite the high-quality insulation, a small amount of heat still penetrates the LNG tanks. This causes slight evaporation of the product. The resulting boil-off gas is captured and fed back into the LNG flow using compressor and re-condensing systems. This process prevents the occurrence of venting natural gas from the terminal under normal operating conditions. (Han Lee, Kim, 2005).

During maintenance periods, boil off gas can no longer be recovered and is burnt off by the flare stack. It is preferable to burn the methane than to release it into the atmosphere (reduced impact on the greenhouse effect).

1-2-3-3 Re-gasification:

The LNG is then extracted from the tanks, pressurized and re-gasified using heat exchangers. Each tank is equipped with submerged pumps that transfer the LNG to high-pressure pumps. The pressurized LNG (at around 80 times atmospheric pressure) is then turned back into a gaseous state in vaporizers. (Han Lee, Kim, 2005).

1-2-3-4 METERING AND SEND-OUT:

Once returned to its gaseous state, the natural gas treated in a number of ways, including metering and odorizing, before it is fed into the transmission network. (Han Lee, Kim, 2005)

1-3 OBJECTIVES:

In the LNG terminal project, the regasification process is considered heart of the overall terminal process. The vaporizer selection is project specific and is typically selected on the basis of different criteria. The vaporizer must carefully the designed, as it has a major impact on operation costs.

The main objective of this research is to select the appropriate regasification technology, which has a low operating cost to suit Port Sudan site conditions according to the criteria described in the research.

1-4 LNG REGASIFICATION SYSTEM:

Regasification process is considered one of the most important and heart of the LNG terminal unit, and consumes more than half of the total operation cost. In that LNG import countries always interested to make process advanced and economical by doing more studies. Regasification process is a process of converting a liquefied natural gas (LNG) at −162 °C (−260 °F) temperature back to natural gas, where the temperature must be the temperature of send out gas (above 0 °C).

There are three main categories based on the source of the heat used to vaporize the LNG:

1. Seawater (SW) heating.
2. Fuel gas (FG) heating.
3. Ambient air heating.

1-4-1 Seawater (SW) heating:

LNG receiving terminals are generally located close to the open sea for ease of access to LNG carriers. Seawater is generally available in large quantities at low cost as compared to other sources of heat, and is the preferred heat source. The opposition is mainly from the environmental sensitive regions for the concerns on the negative impacts on marine life due to the cold seawater discharge and the residual chemical contents. (Netherlands, 2012).

1-4-1-1 Open Rack Vaporizer (ORV):

An ORV is a vaporizer in which LNG flows inside a tube and is heated up by seawater, which is fed through the shell (refer to Figure (1-3)). The LNG flows in from an inlet nozzle near the bottom, passes through an inlet manifold and is recovered in an outlet manifold placed in the upper zone. To avoid the ice formation in the lower part of the heat transfer tubes, innovative tube structures are proposed, as the Kobe Steel (Super ORV) one composed a duplex-pipe structure to suppress icing on the outer surface, thus significantly improving the vaporizing performance.

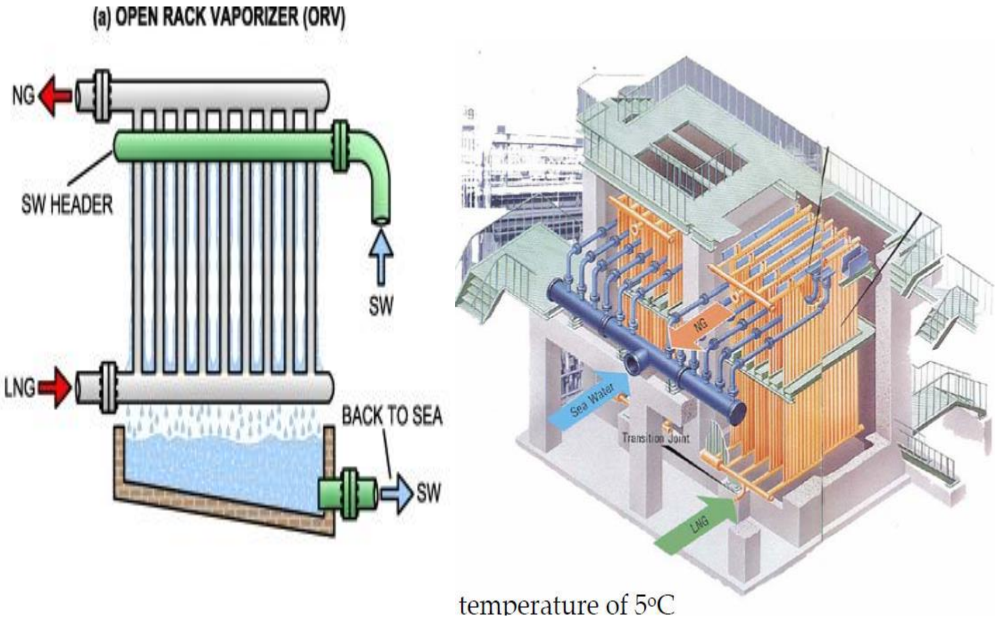

FIGURE 1-3 OPEN RACK VAPORIZER (ORV)

1-4-1-2 INTERMEDIATE FLUID VAPORIZERS (IFV):

An intermediate heat transfer fluid is used in intermediate fluid vaporizers (IFV) to re-vaporize LNG. This technology can be configured to operate in either closed-loop, open-loop or in combination systems. The most common intermediate fluid vaporizers use propane, refrigerant or a water/glycol mixture. Propane and other refrigerants are costly and have high operational handing risks, but have low flash points that are ideal for heat transfer. The water/glycol mixtures are cost-effective, and the associated operational risks are relatively low. They have a high flash point, but require a larger heat transfer area, which results in a larger system than the propane or refrigerant systems.

The open-loop IFV technology requires seawater intake (Figure 1-4). Environmental issues therefore arise and include entrainment of marine in the intake resulting in injury or mortality, as well as low temperature discharge of seawater into the surrounding seawater. Intermediate fluid vaporizers that use propane or refrigerant as the intermediate fluid add a potentially hazardous material to the facility operations. An IFV system that makes use of water/glycol mixtures is a safer way to operate.

The intermediate air is heated by a combustion system and associated combustion emissions, and the carbon footprint can be reduced by the use of waste heat recovery**.**

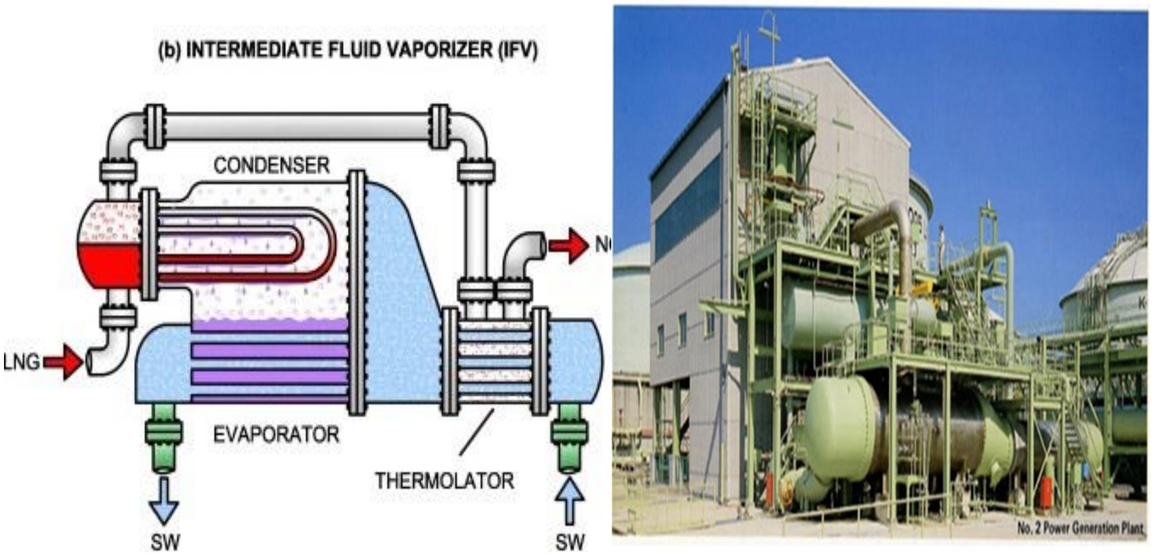

FIGURE 1-4 INTERMEDIATE FLUID VAPORIZER

1-4-2 FUEL GAS (FG) HEATING:

LNG vaporization using fuel gas for heating typically consumes approximately 1.5 % of the vaporized LNG as fuel, which reduces the plant output and the revenue of the terminal. Because of the high price of LNG, SCVs are sometimes used during winter months to supplement ORV, when seawater temperature cannot meet the regasification requirement. They can also be used to provide the flexibility in meeting peaking demands during cold seasons. The SCV burners can be designed to burn low pressure boil-off gas as well as let-down send out gas. (Mak, Fluor, 2013)

1-4-2-1 SUBMERGED COMBUSTION VAPORIZERS (SCV):

Seawater is not used in submerged combustion vaporizers (SCV) for LNG vaporization. Rather, heating of the LNG occurs by it flowing through tube bundles that are submerged in a water bath and heated by natural gas combustion. The hot exhaust gases emitted by the submerged combustion burner bubble through the water to directly heat the water bath then pass to an exhaust stack (Figure 1-5).

Due to the high heat capacity of the water, it is possible to manage rapid load fluctuations and sudden start-ups and shutdowns to maintain a stable operation. Therefore, the SCVs can provide great flexibility and a quick response to varying demand requirements. The huge reserve heat bank of SCVs ensures that surges can be mitigated with heat from the water bath alone even if the combustion processes should suffer a temporary failure. SCVs under normal operation represent a significant operating cost in fuel by consuming from 1.5–2.0 percent of the ship's LNG cargo to supply the burner. In addition, the bathwater becomes acidic due to the acidic combustion products, which are absorbed during the heating process. It is therefore necessary to provide chemical water treatment to the water bath. The associated excess combustion water must be neutralized prior to discharge. Finally, the submerged combustion vaporizer produces a large quantity of emissions to the atmosphere in the form of flue gas. This may be reduced using emission treatment systems, but will add significantly to the operating costs of SCVs.

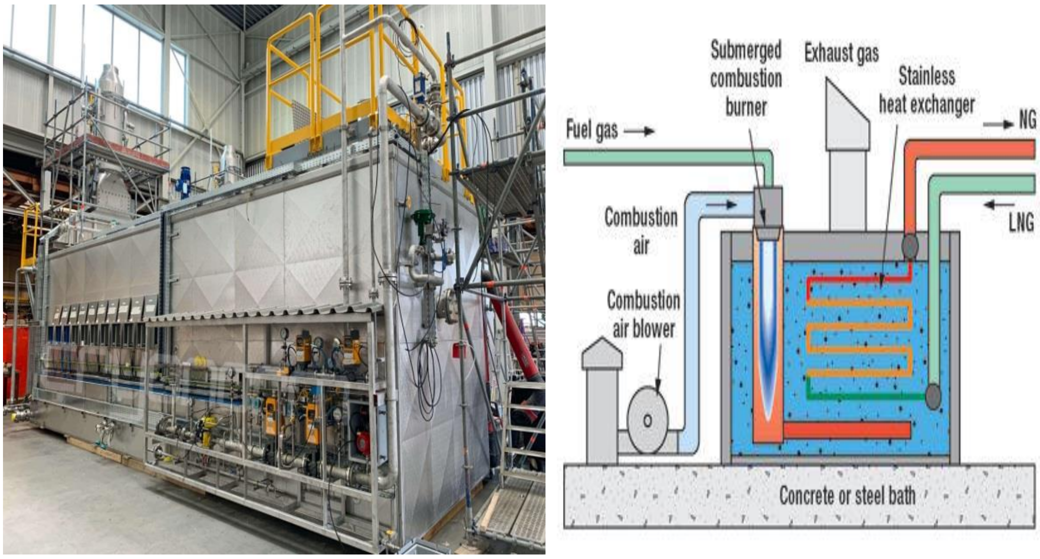

FIGURE 1-5 SUBMERGED COMBUSTION VAPORIZERS (SCV)

1-4-3 AMBIENT AIR VAPORIZER (AVV):

The heat energy source to re-gasify LNG in ambient air vaporization (AAV) technology comes from the ambient air. LNG is distributed through a series of surface heat exchangers. The air cools as it travels down and exits the bottom of the vaporizer. The air flow is controlled on the outside of the exchanger either through natural buoyancy (convection) of the cooled, dense air or by the installation of forced-draft ambient air fans.

AAV technology is most suitable for areas with warmer ambient temperatures. Where cooler climates occur, a supplemental heat system would be needed during colder weather conditions to maintain effective use. Water vapour in the air condenses and freezes, forming frost relatively easily in these systems because the LNG is vaporized directly with air (direct heat system). The frost is a poor conductor, and its build-up reduces performance and the heat transfer coefficient. A significant amount of space is required for the ambient air vaporization system to prevent ambient air recirculation, as well as to maintain vaporization capacity. Fog can be generated under certain geographical location factors including areas with high dew points. Cooling the ambient air can then generate a large fog bank. Though a fog bank is essentially benign, the siting issues need to be taken into consideration. An AAV operates by extracting the heat directly from the surrounding air to heat the LNG by natural convection. This type of technology is cost competitive as it operates on a standalone basis without the need for seawater, burning of fuels or intermediate fluids. However, as the heat capacity of air is significantly less than seawater and no additional heat is added, the number of vaporizer units required to heat LNG is larger when compared to ORVs and SCVs requiring a much larger plot space.

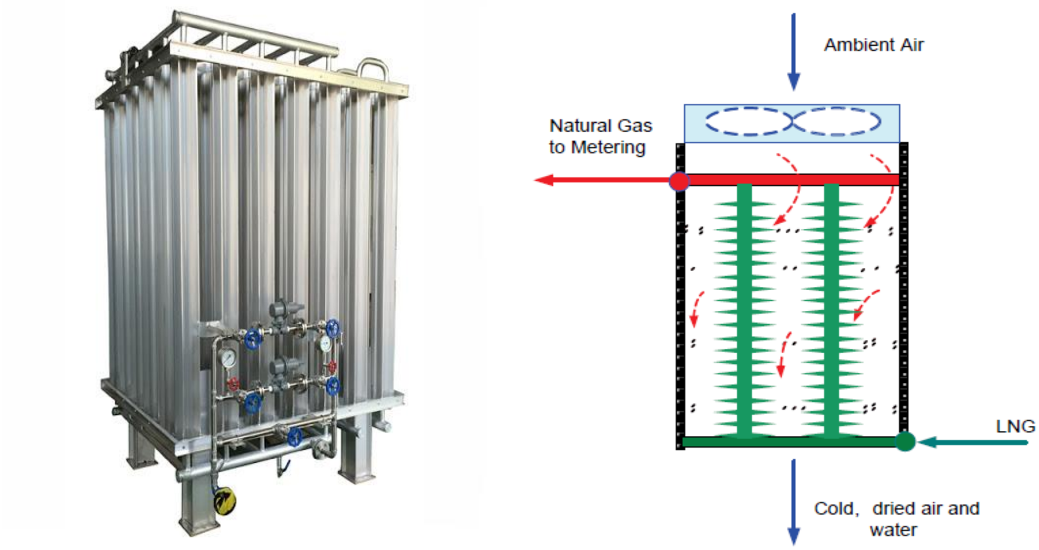

FIGURE 1-6 AMBIENT AIR VAPORIZER

Important factors that should be considered in the LNG vaporizer selection process are:

1- Plant site location.
2- Capital and the operating cost.
3- Climatic conditions. Temperature range.
4- Availability and reliability of the heat source.
5- Throughput capacities and customer demand fluctuation.
6- Emission permit limits.
7- Regulatory restrictions with respect to the use of seawater.
8- Vaporizer capacity and operating parameters.
9- Safety in design.
10- Operating flexibility and reliability

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERALL DESCRIPTION FOR SUDAN LNG TERMINAL:

The SUDAN LNG Terminal has two main functions:

• Unload LNG from LNG carriers into LNG storage tanks

• Pump and vaporize the LNG from the LNG storage tanks to the grid

The project of SUDAN LNG Terminal will be constructed with the capacity equal 3 MMTPA.

2.1.1 LNG UNLOADING SYSTEM:

The LNG terminal unloading system is designed to safely unload a LNG carrier in the LNG storage tanks. Some of them are used for liquid transfer and other used for gas transfer. In case of failure on the gas transfer arm, one of the liquid arms can then be used as gas return arm and unloading can be performed at reduced rate without flaring. The LNG is discharged from the LNG carrier by its cargo pumps.

The quantity of gas required to maintain the pressure in the LNG carrier's storage tanks is returned to the ship through a gas. During unloading, the operating pressure of the LNG storage tanks shall be greater than the operating pressure of the LNG carrier to allow gas to flow naturally from the LNG storage tanks to the ship. When the unloading operation is completed, prior to disconnecting the LNG carrier, the arms are emptied and purged using service nitrogen supplied at the top of the arm. LNG is pushed back to the ship on one side and to the jetty LNG drain drum. From the drain drum, it is then pushed to the LNG storage tanks via the unloading line by means of pressurized nitrogen. During jetty stand-by periods (between unloading), a small LNG recirculation flow maintains the unloading lines cold. The recirculation is obtained by routing part of the LNG from the LP pump discharge header to the recirculation line up to the jetty head and back to the unloading line and the LP header. A control valve adjusts the recirculation flow. The nominal circulation flow rate shall be such that the temperature increase of the LNG circulated backward to the jetty head via the unloading line shall not exceed 5°C. This temperature increase shall be limited to prevent a high flash phenomenon when "warm" LNG is pushed to the tank at the beginning of ship unloading. During unloading, recirculation is interrupted. The flow is then re-established after each unloading operation.

The LNG lines and the gas line routed between the jetty head and the shore are equipped with emergency block valves upstream and downstream jetty trestle.

2.1.2 LNG STORAGE SYSTEM:

LNG is stored in one LNG storage tank, having a working capacity of 160,000 m³. The tanks are full containment type with an inner shell of 9% Ni alloy and a full concrete outer shell (including roof). To avoid any risk of uncontrolled spillage, all instrumentation and piping connections to the tank shall be routed through the tank roof.

Each tank is equipped with two filling lines, one sending LNG to the top of the inner tank and one to the bottom. The filling mode depends on the respective qualities of the stored LNG and of the unloaded one. Filling point shall be selected in order to prevent LNG stratification, which could cause rollover phenomenon. The operator adjusts the ratio of LNG flow sent to the top and to the bottom of the tank by modifying the opening of the top and bottom filling valves.

One block valve, installed on the main filling collector, allows isolating the tank LNG filling lines in case of emergency. Tank is equipped with suitable devices for a safe monitoring of the level, temperature and density of the LNG stock and of the pressure of the vapour phase.

A gas line connected to the common BOG header permits to collect the boil off gas and the gas displaced by the piston effect during unloading phases. The operating load of the BOG compressors withdrawing gas from the common BOG header controls tank absolute pressure.

Between two unloading operations, the tanks should be operated at rather low pressure in order to provide a safe “buffer capacity” in case of issue on the pressure control system. During unloading operations, the tank pressure shall be increased to “quench” flash of unloaded LNG and to allow natural flow of vapour from the tanks to the ship.

If the compressors ever fail to maintain the tanks’ pressure or if the atmospheric pressure varies very quickly, safety devices protect LNG storage tanks against overpressure or vacuum conditions.

The flare handles the first overpressure protection of the storage tanks. When the tank pressure reaches a high pressure, pressure control valves relieve gas to flare. Each tank is equipped with pressure safety valves set at design pressure and providing the ultimate overpressure protection level. The tail pipe of each PSV is routed to atmosphere at a safe location above tank roof.

In case of low pressure (due to sudden atmospheric pressure increase, negative piston effect…), vacuum breaker gas taken on send-out line is injected in the BOG header. If the gas injection is not sufficient to maintain the pressure at an acceptable level, air is introduced in the tanks through the vacuum safety valves installed on each tank.

2.1.3 LNG / NG SEND OUT:

2.1.3.1 LOW PRESSURE PUMPS:

LNG to the send-out is withdrawn from the LNG storage tanks by the LP submerged motor pumps installed in the wells.

Four identical pumps running at constant speed are installed in each tank pumps. The flow rate of the pumps is fixed by:

- The send-out flow rate demand.
- The BOG flow rate that is re-condensed.

The start and stop of the LP pumps is under the control of the operator who shall take care of having enough pumps in operation considering the total flowrate demand.

A hand control valve is mounted on each pump discharge line. The valves allow the operator to share equally the flowrate between the LP pumps in operation and in case of emergency to close the LP pump discharge line.

In order to protect the pumps against low flow conditions, a minimum flow control valve returning LNG to the tank is installed on the discharge line of each pump. The minimum flow line can also be used for LNG mixing in the tank in order to prevent LNG stratification.

One block valve mounted on each tank discharge header allows the isolation of the set of pumps of a tank from the common export header. It allows emergency isolation of the tank’s outlet line and maintenance operations on the pump discharge lines.

2.1.3.2 HIGH PRESSURE PUMPS:

The HP send out pumps are fed with LNG coming from the LNG LP header and supply vaporizers at flow and pressure required for send-out to export pipeline. HP send out pumps are of vertical barrel mounted type.

The HP pumps are operating at constant speed. The flow control valves installed on the feeding line of each vaporizer fix the flow rate of the pumps. The start/stop of the pumps is under the control of the operator who shall take care having enough pumps in operation to fulfil the terminal total send out flow rate demand. A hand control valve is mounted on each pump discharge line. These valves allow the operator to share equally the flow rate between the running pumps. The pump barrel is permanently vented to the BOG re-condenser via a dedicated vent line. In order to protect the pumps against low flow conditions, a minimum flow control valve is installed on the discharge line of each pump.

The minimum flow control valve is also used for pump start-up. The pump shall be started on its kickback line with the discharge valve closed. When the flow is established, the discharge valve shall be gradually opened to the send-out header.
HP pumps shall be used in recycling mode with no send-out only for short periods in order to avoid any excess of vapour generation.

2.1.4 VAPORIZERS:

The type of vaporizers installed is Shell and Tube Vaporizer (STV) using propane as heat transfer fluid in a closed loop to vaporize the LNG. Propane is in turn heated by seawater.
An inlet flow control valve controls the flow rate to each ORV. The set point of this flow rate controller is either specified by the operator who shall take care of the send out demand or directly by the send out flow controller. A high limitation control is provided for cases where the gas outlet temperature is too low. In such cases the LNG flowrate is decreased (flow limitation). Two block valves, one mounted on the inlet LNG line and the other one on the outlet NG line allow the isolation of each vaporizer in case of emergency or maintenance requirements.
Each equipment is protected against over pressure by a pressure safety valve routed to the flare. During the day the LNG send-out rate may vary and along the year, the ambient air temperature changes. So the natural gas send-out temperature will vary in a limited extent.

2.1.5 BOIL OF GAS (BOG) RECOVERY SYSTEM:

2.1.5.1 BOG COMPRESSORS:

The tank pressure naturally tends to increase due to the BOG generated by heat leaks and due to the piston effect during tank filling.
The role of the BOG compressors is to control the pressure in the LNG storage tanks by withdrawing excess gas, and to allow the recovery of this gas by increasing its pressure up to the value required to allow condensation by direct contact with subcooled LNG in the BOG re-condenser. The start and stop of the BOG compressors is under the control of the operator. The capacity (0, 25%, 50%, 75% or 100%) of the BOG compressors is normally under control of the LNG storage tank’s pressure controller. Nevertheless, a high limitation control is provided for cases where the BOG re-condenser is saturated. In such cases, the compressed BOG flow is limited by the re-condenser's capacity control. If the BOG flowrate is higher than the compressor's capacity (or re-condensing capacity), the pressure in the tanks and in the BOG header increases. Beyond a pre-set value, a pressure control valve routes the excess gas to the flare.

The capacity of 1 BOG compressors is enough to handle boil-off generated during "no-unloading" periods. Therefore, the two BOG compressors are simultaneously required only during unloading operations. As the BOG compressors are not strictly necessary in terms of send out availability, no full spare is provided. It is assumed that standard maintenance is performed on the stand-by compressor between two unloading periods. For long time maintenance, unloading rate is reduced or excess BOG is flared.

A de-super-heater is installed on BOG compressor's common inlet line to limit the suction temperature by injecting LNG in the gas stream under temperature control. Downstream this LNG injection point, a suction separator is provided to prevent liquid carrying-over to compressors.

2.1.5.2 BOG RE-CONDENSER:

The purpose of the BOG re-condenser is to condense the BOG by direct contact with subcooled LNG coming from the LNG storage tanks. The LNG required condensing the BOG flows through the packing of the BOG re-condenser whereas the remaining flow bypasses the vessels.

The liquid required for BOG condensation and the boil off gas stream enter the BOG re-condenser at the top of the vessel. The gas and the liquid flow (co-current) through a packing of stainless steel rings. The liquid outlet of the BOG re-condenser and the bypass flow are then mixed and LNG flow is routed to the HP pumps. In case of emergency or for inspection, the BOG re-condenser can be isolated.

2.1.6 FUEL GAS SYSTEM:

Fuel gas is supplied to the flare pilots. It is taken from natural gas send out header.

In order to meet fuel gas requirements at the point of delivery, natural gas is depressurized by pressure let down valves and warmed up by ambient air heater.

2.1.7 FLARE SYSTEM:

The flare system is composed of the following:

• A low pressure flare network collecting vapour from the BOG header in case of an abnormal pressure increase.

• A high pressure flares network collecting vapour from STV's pressure safety valve.

• Elevated Flare.

• A flare KO Drum installed at low point upstream the Elevated Flare. The KO drum is equipped with an electrical heater provided to evaporate liquid that may be carried-over by the relief flow. All pressure safety valves and thermal safety valves on the LNG Terminal are collected to the BOG header except:

• The vaporizer's safety valves which are routed to the high pressure flare network.

• The LNG storage tank is PSV, which release gas directly to the atmosphere at safe locations above the tank roof. To avoid air ingress in the pressure flare networks, the flare header is continuously swept with a low flow of nitrogen.

2-2 SAFETY:

The LNG industry has an excellent safety record. This strong safety record is a result of several factors. First, the industry has technically and operationally evolved to ensure safe and secure operations. Technical and operational advances include everything from the engineering that underlies LNG facilities to operational procedures to technical competency of personnel. Second, the physical and chemical properties of LNG are such that risks and hazards are well understood and incorporated into technology and operations. Third the standards, codes, and regulations that apply to the LNG industry further ensure safety.

Safety in the LNG industry is ensured by four elements that provide multiple layers of protection both for the safety of LNG industry workers and the safety of communities that surround LNG facilities:

Primary Containment is the first and most important requirement for containing the LNG product. This first layer of protection involves the use of appropriate materials for LNG facilities as well as proper engineering design of storage tanks onshore and on LNG ships and elsewhere.

Secondary containment ensures that if leaks or spills occur at the onshore LNG facility, the LNG can be fully contained and isolated from the public. (Mak, Fluor, 2013)

Safeguard systems offers a third layer of protection. The goal is to minimize the frequency and size of LNG releases both onshore and offshore and prevent harm from potential associated hazards, such as fire. For this level of safety protection, LNG operations use technologies such as high level alarms and multiple back-up safety systems, which include Emergency Shutdown (ESD) systems. ESD systems can identify problems and shut off operations in the event certain specified fault conditions or equipment failures occur, and which are designed to prevent or limit significantly the amount of LNG and LNG vapour that could be released. Fire and gas detection and firefighting systems all combine to limit effects if there is a release. The LNG facility or ship operator then takes action by establishing necessary operating procedures, training, emergency response systems, and regular maintenance to protect people, property, and the environment from any release**.**

Finally, LNG facility designs are required by regulation to maintain **separation distances** to separate land-based facilities from communities and other public areas. Safety zones are also required around LNG ships.

CHAPTER THREE

RESEARCH METHODOLOGY

3-1 RESEARCH METHODOLOGY STEPS:

• **Step 1: LNG vaporizer selection based on ranking score.**

The vaporizer selection is project specific and is typically selected based on-site conditions, environmental compliance, and energy efficiency. In this study, we will consider selection based on site condition only.

• **Step 2: Simulation of selected LNG vaporizer.**

The simulation made a comparison between the two best vaporizer based on selected criteria like quantity required for heating, regasification cost, etc.

3-1-1 LNG VAPORIZER SELECTION BY COMPARISON OF VAPORIZER OPTIONS:

The optimum choice of an LNG vaporization system is determined by the terminal's site selection, the environmental conditions, regulatory limitations and operability considerations. It has to comply with the LNG industry's requirements for minimizing life cycle costs. The selection should be based on an economic analysis in maximizing the net present value while meeting the local emissions and effluent requirements.

TABLE 3- 1 LNG VAPORIZATION OPTION QUALITATIVE COMPARISON

OPTIONS	1	2	3	4	5	6
HEATING MEDIUM	Seawater (SW)	Propane (C3)/ Seawater (SW)	Glycol-Water(GW) /Air	Glycol-Water(GW) /Seawater	Hot Water (HW) Fuel Gas (FG)/ Waste Heat(WH)	Air
Feature	Direct LNG vaporization using sea water	Indirect LNG vaporization by condensing propane which is heated by seawater	Indirect LNG vaporization by glycol which is heated by air fin exchanger	Indirect LNG vaporization by glycol which is heated by seawater	Indirect LNG vaporization by hot water which is heated by waste heat and SCV	Direct LNG vaporization using air

Major Application	70% base load plants use ORV	Cold climate application and avoid freezing of seawater	For warm climate application. IFV makes up 5 % of base load plants	Similar to Option 3 except seawater is used as the source of heating	For energy conservation with use of waste heat. SCV is used in 25% of base load plants	For warm climate application, peak shavers and where real estate is not a constraint
Operation & Maintenance	Seawater pumps and filtration system Maintenance of vaporizers and cleaning of exchangers	Similar to Option 1 with addition of a glycol loop and propane system	Similar to Option 2 with a glycol loop and use of air as the source of heat	More Complex, requiring coordination with power plant	More complex control. Need to balance waste heat and fuel gas to SCVs. Require coordination with power plant operation	Cyclic operation, requiring adjustment of the defrosting cycle according to ambient changes
UTILITIES Required	Seawater and electrical power	Seawater and electrical power	Electrical power only	Seawater and electrical power	Fuel gas and electrical power	Electrical power only
Chemicals	Chlorination for seawater treatment	Similar to Option 1 but lower chlorination	None	Similar to option 1 but lower chlorination	Neutralization required for pH control and NOx reduction by SCR	None
Emission & Effluents	Impacts on marine life from cold seawater and residual chloride content	Impacts on marine life from cold seawater and residual chloride content	No significant impact on environment except dense fog	Impacts on marine life from cold seawater and residual chloride content	Flue gas (NOx, CO2) emissions and acid water condensate discharge	No significant impact on environment except dense fog

Safety	Leakage of HC from ORV to atmosphere at ground level	Leakage of HC to atmosphere at ground level. Operating a propane liquid system is additional safety hazard	Leakage of HC to glycol system which can be vented to safe location via surge vessel	Leakage of HC to glycol system which can be vented to safe location via surge vessel	Leakage of HC to water system which can be vented to safe location via the SCV stack and surge vessel	Leakage of HC from AAV to atmosphere at ground level
Plot Plan	Medium Size	Medium Size	Large Size	Medium Size	Small Size	Large Size

The six options considered in this study are:

1- Option 1 uses ORV as in existing regasification terminals

2- Option 2 uses propane as the intermediate fluid with seawater as the heat source.

3- Option 3 uses glycol water as the intermediate fluid with air as the heat source.

4- Option 4 uses glycol water as the intermediate fluid with seawater as the heat source.

5- Option 5 uses SCV using fuel gas and waste heat from cogeneration plant.

6- Option 6 uses ambient air vaporizer (AAV).

All these technologies used only in the location where the temperature above 18 ^oC, while the other options related to countries where the temperature below 18 ^oC will be rejected in this study. (Mak, Fluor, 2013).

3-1-2 PROCESS SIMULATION OF LNG VAPORIZER USING ASPEN HYSYS:

3-1-2-1 ABOUT ASPEN HYSYS:

Aspen Hysys is a process simulation environment designed to serve many processing industries especially Oil, Gas and Refining. With Aspen Hysys, one can create rigorous steady state and dynamic state models for plant design, performance monitoring, troubleshooting, operational improvement, business planning, and asset management. Through completely interactive Aspen Hysys interface, one can easily manipulate process variables and unit operation topology, as well as fully customize simulation using its customization and extensibility capabilities. The process simulation capabilities of Aspen Hysys enable engineers to predict the behaviour of a process using basic engineering relationships such as mass and energy balance, phase and chemical equilibrium, and reaction kinetics. With reliable thermodynamic data, realistic operating conditions and the rigorous Aspen Hysys equipment models, they can simulate actual plant behaviour.

3-1-2-2 STEADY STATE SIMULATION:

The steady state simulations have been used extensively for the design, analysis and optimization of chemical processes. They also provide data for process flow diagrams in terms of material and energy balances. Steady-state models use equations defining the relationships between elements of the modeled system and attempt to find a state in which the system is in equilibrium. These models are therefore independent of the time. Such models are used at the early stages of a study for conceptual design, feasibility studies, detailed engineering and at the initializing steps for dynamic simulations which are used for evaluating the transient behavior of the system.

In this methodology, the steady state model of the process is used mainly for the optimization and to evaluate the vaporizer performance. The following steps are used in developing a steady state simulation model. In general, other software packages also follow similar approach for building the plant model.

1. Selecting the unit set.
2. Defining Simulation basis.
3. Defining the feed streams.
4. Installing and defining the unit operations.
5. Installing the downstream unit operations.

3-1-3 ASPEN SHELL & TUBE EXCHANGER DESIGN AND RATING:

Aspen Shell & Tube Exchanger enables optimum design, rating or simulation of shell and tube, double pipe, or multi-tube hairpin exchangers. The engineering tools allows for improved overall process optimization through better collaboration across engineering disciplines.

Aspen Shell & Tube Exchanger addresses a wide range of application needs, serving both the engineering contractor and the equipment fabricator, with the ability to share models from conceptual design to operational troubleshooting. It facilitates the full range of practical process applications, including reflux condensers, kettle reboilers, thermosiphon reboilers, falling film evaporators, and multi-shell, multi-pass feed-effluent trains. This flexibility allows the process streams to be single phase, boiling or condensing vapors, single component or any mixture with or without non-condensable gases in any condition (including superheated vapor, saturated vapor, or subcooled liquid). (Aspen Technology, 2011)

3-1-3-1 DEFINING THE SIMULATION BASIS:

Defining a simulation basis, include selecting the components and the thermodynamic fluid package. HYSYS uses the concept of the fluid package to contain all necessary information for performing flash and physical property calculations. This approach defines all information (property package, components, interaction parameters, reactions, tabular data, hypothetical components, etc.) inside a single entity. The selection of a suitable thermodynamic package is fundamental to process modeling for accurate predictions. Selection of an inappropriate model will result in convergence problems and erroneous results. Effects of pressure and temperature can drastically alter the accuracy of a simulation giving missing parameters or parameters fitted for different conditions. The selection is based on the nature of process, compositions, pressure, temperature ranges, phase systems involved and availability of data.

One of the main assets of HYSYS is its strong thermodynamic foundation. The built-in property packages in HYSYS provide accurate thermodynamic, physical and transport property predictions for hydrocarbon, non-hydrocarbon, petrochemical and chemical fluids. If a library component cannot be found within the database, a comprehensive selection of estimation methods is available for creating fully defined hypothetical components. For the above process, Methane, Ethane, Propane, n-Butane, n-Pentane, Nitrogen, Glycol, Water and Air are added from the pure component library and the Peng-Robinson equation of state model is used in defining the simulation.

Once the components and the thermodynamic package are selected, the feed streams are defined by specifying the process conditions and the composition. In order to define a stream in HYSYS its required to specify two process variables (Temperature, vapor fraction etc.), flow rate and composition. The other conditions of the stream are estimated by HYSYS. The information in table is used to define input data for simulation.

3-1-3-2 VAPORIZING PROCESS DESCRIPTION:

3-1-3-2-1 USING OPEN RACK VAPORIZER:

As shown in figure 3.1 the LNG extracted from the storage tanks by means of the pumps is pressurized initially to approximately to about 85 bar and temperature about -149 °C and then is sent to the vaporizers.

The LNG is fed to heat exchanger (enter in the tube) and heated by seawater (enter in the shell) sprinkle through tubes. LNG at temperature -149.7°C and mass flow rate 3 MMTPA was entered to the ORV and transfer heat with seawater (25 °C) to reach a temperature 7°C.

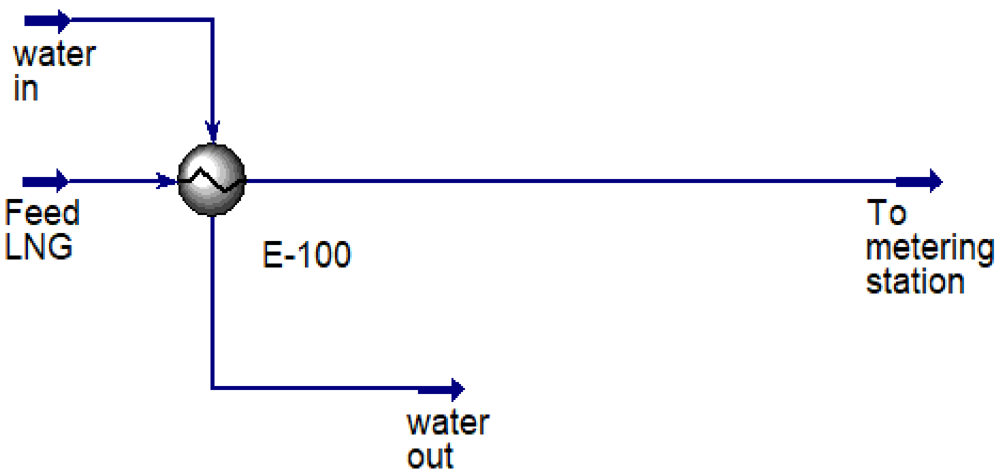

FIGURE 3-1 PROCESS FLOW DIAGRAM OF OPEN RACK VAPORIZER

TABLE 3- 2 FEED STREAM SPECIFICATIONS

Variables	LNG Feed Stream		Water Feed Stream	
Temperature	-149.7 ^{O}C		25 ^{O}C	
Pressure	85.99 bar		7 bar	
Flow rate	3 MMTPA		45.86 MMTPA	
Feed Composition (mol %)	Methane	86.79	Water	1
	Ethane	8.13		
	Propane	3.67		
	n-Butane	1.09		
	n-Pentane	0.1		
	Nitrogen	0.22		

3-1-3-2-2 USING INTERMEDIATE FLUID VAPORIZER (USING PROPANE):

As shown in figure 3.2 LNG is fed to shell & tube heat exchanger where it is heated by intermediate fluid vaporizer using propane (LNG inter in tube side and propane in Shell side).

LNG at temperature -149.7°C and mass flow rate 3 MMTPA was entered to the first heat exchanger (in the tube) and heated by gaseous propane (in the shell) to temperature -80°C. And then entered to the second heat exchanger (in the tube) and heated by seawater (in the shell) to temperature 7°C.

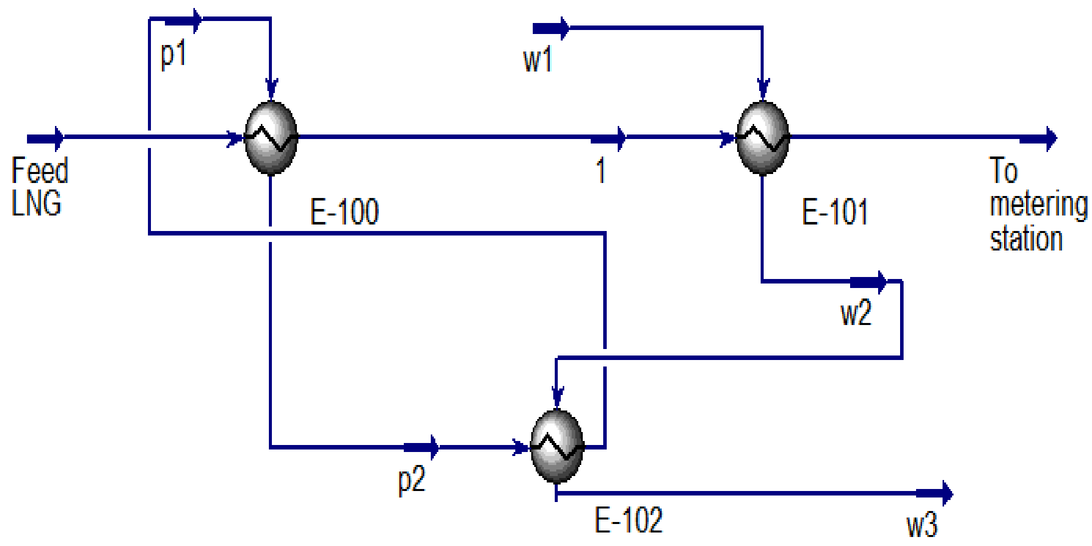

FIGURE 3-2 PROCESS FLOW DIAGRAM OF PROPANE IFV

TABLE 3- 3 FEED STREAM SPECIFICATIONS

Variables	LNG Feed Stream		Propane Feed Stream		Water Feed Stream	
Temperature	-149.7 ^{O}C		-14.12 ^{O}C		25 ^{O}C	
Pressure	85.99 bar		3 bar		7 bar	
Flow rate	3 MMTPA		1.759 MMTPA		29.75MMTPA	
Feed Composition (mol %)	Methane	86.79	Propane	1	Water	1
	Ethane	8.13				
	Propane	3.67				
	n-Butane	1.09				
	n-Pentane	0.1				
	Nitrogen	0.22				

3-1-3-3 SELECTING THE UNIT SET:

HYSYS has the default unit sets like the SI, Field units. However, the unit set used in the simulation can be customized. Either you can modify the units of a particular property or can create a new unit. For the above problem, the SI units are used.

3-1-3-4 INSTALLING AND DEFINING UNIT OPERATIONS

The used unit operation is Heat Exchanger. For each unit operation, it is required to specify certain parameters to satisfy the number of degrees of freedom.. The number of active specifications must equal the number of unknown variables to solve the problem. The following section describes the modeling procedure of the heat exchanger, which is used later in the case study. The detailed modeling procedure of each section in the unit is described in Aspen HYSYS® operations guide.

3-1-3-4-1 HEAT EXCHANGER:

Heat exchangers can be modeled in Aspen HYSYS using either a shell and tube or a cooler/heater configuration. There are different rating models available for example The End Point model. The End point model uses the standard heat exchanger duty equation defined in terms of overall heat transfer coefficient, area available for heat exchange, and the log mean temperature difference. This model treats the heat curves for both heat exchanger sides as linear. In addition to defining the inlet stream of the shell side (i.e. Propane), the pressure drop across both the sides of the exchanger and the tube side exit temperature are specified in order to solve the heat exchanger.

3-1-3-5 THE HYSYS SPREADSHEET:

With complete access to all process variables, the Spreadsheet is a very powerful tool in the HYSYS environment. The power of the Spreadsheet can be fully realized by the addition of formulas, functions, logical operators, and basic programming statements.

The Spreadsheet's ability to import and export variables means that seamless transfer of data between the Simulation Environment and the Spreadsheet is a simple matter. Any changes in the Simulation Environment are immediately reflected in the Spreadsheet, and vice-versa.

3-1-3-5-1 COST ESTIMATION:

The primary criterion for design selection is usually economic performance. The economic evaluation usually entails analysing the capital and operating cost of the process to determine the return on investment (ROI).

The economic analysis of the product or process can also be used to optimize the design (in case of heat recovery vs using more fuel to generate heat). If the two are close in economic, then select the safest design.

TABLE 3- 4 TABLE OF CALCULATION

Total LNG amount (MMTPA)	3.000	
Total LNG amount (MMBTU/Y)	140,062,165.80	
	ORV	IFV (Propane)
Capex($)	2,685,800	3,861,280
Opex ($/Y)	35,544.00	28,544.00
Operation cost ($/Y)	142,347.4	204,647.84
Other operation cost ($)	26,858	38,612.8
Total cost ($/Y)	204,749.40	271,804.64
Total cost (€/MMBTU)	0.146	.0194

The input calculation in spreadsheet:

1. Conversion from MMTPA to MMBTU/Y:

MT = 46.6873886 MMBTU/Y

2. Conversion from $ to €

$ = 100 €

3. Cost estimation:

Regasification Cost = Opex / Total LNG amount (MMBTU/Y)

Operation cost = Capex*(1+interest rate)/20

Interest rate = 6%

CHAPTER FOUR

RESULTS AND DISCUSSION

4-1 VAPORIZER TECHNOLOGIES SELECTION BASED ON SCORE:

4.1.1 RANKINGS OF VAPORIZERS FOR WARM AMBIENT LOCATIONS:

Sudan is considered as warm ambient locations, where site ambient temperature stays above 18°C, the ambient air vaporizers or the air heated intermediate fluid type vaporizer units can provide the full LNG vaporization duty without trim heating. In addition, there is potential revenue to be gained by collecting and marketing the water condensate from the air.

The six options in Table 3.1 are ranked for their performance in terms of environmental impacts, system operability and maintenance requirement. The ranking system is based on a score of 1 to 6, with 1 being the most desirable and six the least desirable. These scores are summed and the one with the lowest score is considered the most desirable option. The ranking for selection of Sudan LNG vaporizer Technology is shown in table 4-1.

TABLE 4- 1 RESULT OF TECHNOLOGIES SELECTION BASED ON SCORE

Option	Vaporizer / Heat Transfer Fluid	Environmental	Operability	Maintainability	Total	Rank
1	ORV (SW)	2	2	1	5	**1st**
2	IFV (C3/SW)	3	1	3	7	2nd
3	IFV (GW/Air)	4	3	4	10	4th
4	IFV (GW/SW)	5	4	5	14	5th
5	SCV (HW (FG) /WH)	6	6	6	18	6th
6	AAV (Air)	1	5	2	8	3rd

For Sudan LNG Project in Port Sudan, the total score for open rack is the top most desirable (option 1) followed by intermediate using propane options (option 2). Option 5 uses fuel gas for heating in the SCV generating emissions and hence the least desirable. The use of air (Option 6) is in third place.

For operability and maintainability, seawater heating (option 1) is simple to operate and maintain. The final selection depends on other factors, such as plot space requirement, capital and operating costs. As well as this project is considered one of the national project which help to solve the economic crisis, so the government of Sudan always attempt to break Obstacles by Providing and permitting all the requirements of project example land for terminal, that make part of factor in vaporizer selection criteria more easy.

4-2 SIMULATION RESULT:

4-2-1 OPEN RACK VAPORIZER:

TABLE 4- 2 PROCESS DATA FOR E-100 IN FIGURE 3-1

Process Data	Hot Stream (Shell Side)	Cold Stream (Tube Side)
Fluid name	Seawater	LNG
Mass flow rate (MMTPA)	45.86	3
Temperature In/ Out [^{O}C]	25 / 10	-149.7 / 7
Operating pressure (absolute bar)	7	85.99

Total cost = 0.146 (€/MMBTU)

4-2-2 INTERMEDIATE FLUID VAPORIZER:

TABLE 4- 3 PROCESS DATA FOR E-100 IN FIGURE 3-2

Process Data	Hot Stream (Shell Side)	Cold Stream (Tube Side)
Fluid name	Propane	LNG
Mass flow rate (MMTPA)	1.759	3
Temperature In/ Out [^{O}C]	-14.12 / -14.12	-149.7 / -80
Operating pressure (absolute bar)	3	85.99

TABLE 4- 4 PROCESS DATA FOR E-101 IN FIGURE 3-2

Process Data	Hot Stream (Shell Side)	Cold Stream (Tube Side)
Fluid name	Seawater	LNG
Mass flow rate (MMTPA)	29.75	3
Temperature In/ Out [^{O}C]	25 / 15	-80 / 7
Operating pressure (absolute bar)	7	85.99

TABLE 4- 5 PROCESS DATA FOR E-102 IN FIGURE 3-2

Process Data	Hot Stream (Shell Side)	Cold Stream (Tube Side)
Fluid name	Seawater	Propane
Mass flow rate (MMTPA)	25.75	3
Temperature In/ Out [^{O}C]	15 / 9.587	-14.12 / -14.12
Operating pressure (absolute bar)	7	3

Total cost = 0.194(€/MMTPA)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5-1 CONCLUSION:

The following are the conclusions drawn from this research work:

1. According to standard criteria used to select an optimal regasification technology, the use of seawater (ORV) heating is considered the most desirable, where the open rack vaporizer is the best choice between the other technologies.

2. The technology was simulated by Aspen HYSYS 11 simulation. It found to be that the optimum LNG heating basis on criteria studied in methodology.

REFERENCES:

-Alberta Energy. 1995. About Natural Gas. [ONLINE] Available at: http://www.energy.alberta.ca/naturalgas/723.asp. [Accessed 02 September 15].

- Anon. 2015. Encana. [ONLINE] Available at https://www.encana.com/natural-gas/natural-gas-101/benefits.html[Accessed 10 January 14].

- Aspen Technology, Inc., 2011. Aspen HYSYS Unit Operations Guide. V7.3 ed. USA: Burlington.

- Durr, C., (2005). LNG IMPORT TERMINALS RECENT DEVELOPMENTS, United Kingdom: M. W. Kellogg Ltd.

- John Mak, Fluor, (2013). LNG Vaporizer Selection Based on Site Ambient Conditions. In Gas Processors Association Europe. Edinburgh, 29 September13. Edinburgh: GPA Membership. 14.

- JungHan Lee, Hochung Kim,, (2005). Design and Construction of LNG Regasification Vessel. In Gastech. Bilbao, Spain, 14 Marchr13. South Korean: Daewoo Shipbuilding & Marine Engineering Co. Ltd.. 3.

- Kim, H., 1999. Fans and Pumps. Canda: Business and Goverment Energy Mangement Devistion

- Michael Ford, Justine L. Barden, 2013. Energy Information Administration. International Energy Outlook 2013, 5, 53

- Naturalgas. 2014. NG. [ONLINE] Available at: http://www. http://naturalgas.org/ [Accessed 20 September 15].

- Shaw Consultants International, I., 2012. CURACAO CNG-LNG TERMINAL FEASIBILITY STUDY, Netherlands: World of Solutions.