The Optimization of LNG Dehydration Process

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Abstract—**Natural gas is one of the most important energy in this era. It being delivered to the consumers via pipelines by compressing the gas or liquefying the gas which is known as liquefied natural gas (LNG). Due to the technical and economic reasons, LNG is more favorable process to transport gas. Raw natural gas typically contains water vapour since it is found deep in underground reservoirs at high temperature and pressure. This research is done to simulate a gas dehydration process and to optimize the parameters in absorption dehydration process. The investigate parameters are the type of glycol used, the flow rate of the glycol, number of stages in absorber column, temperature of the reboiler and gas inlet temperature on glycol dehydration unit. The simulator used for this research was Aspen HYSYS. Based on the simulated data, an optimized parameters of dehydration process has been proposed. Results showed that triethylene glycol (TEG) is the most effective type of glycol followed by diethylene glycol (DEG) and ethylene glycol (EG). The higher the number of trays, the lower the amount of water content in the dry gas. The lower water content in the dry gas stream can be achieved by decreasing the temperature of the inlet gas of the absorption column. Results also shown that the higher the temperature of the reboiler the lower the water content of the natural gas stream. The optimum condition of gas dehydration was at 12 number of stages with 200ºC reboiler temperature and 20ºC inlet gas temperature.**

Keywords— natural gas dehydration, glycol, process simulation, Aspen HYSYS, process optimization

I. INTRODUCTION

Natural gas is one of the most important source and is used to generate energy in industrial and transportation. It is the most environmentally and due to this reason it is expected to grow as a primary energy source [1]. Since it yield lesser undesirable by products per unit energy compared to petroleum and coal, it can be categorized as a clean source of energy. The generation of waste heat by a natural gas turbine to supply energy to a steam turbine is 60% efficient in natural gas combined-cycle power plants.

Natural gas is extracted by drilling wells through the geographic layers into the underground. There are two main types of natural gas in industry which are conventional and unconventional gas. Conventional gas exists in large permeable sandstone reservoirs and use traditional well drilling techniques to be extracted. However, unconventional gas is extracted by using horizontal drilling or hydraulic fracturing and can be divided into coal seam gas and shale gas [2].

Natural gas system consists of four segments which are production, gathering and processing, transmission and distribution. Production involves the activity of extracting the raw natural gas by drilling into underground. Then, the natural gas need to be processed to remove the impurities and other hydrocarbons to meet the pipeline quality. Next, the natural gas is transports from the processing plant ot the industrial end user. After that, the natural gas is distributed to the consumers such as residential, commercial and industrial area.

The natural gas is transported to the customers either in the gaseous state via pipelines or in the liquefied state as in special tankers. The usage of pipelines is declining as liquefied natural gas (LNG) operation contribute a high demand. LNG is a liquid form of gas for the purpose of ease and safety of non-pressurized storage or transport as pipeline is not feasible and economical. LNG is an environmentally friendly and attractive for heavy duty vehicles as it reduce space and weight [3].

Liquefied natural gas (LNG) is the liquid form of natural gas when the methane gas is processed into LNG by cooling the gas to -161ºC. Natural gas is converted to LNG to achieve natural gas transport over the sea which is more economically. As the natural gas convert from gaseous state into liquid state, its volume decrease by a factor more than 600 times. The low volume of the LNG facilitates economical transport by sea or road. Before the liquefaction process, certain components such as acid gases, water and heavy hydrocarbons need to be remove because they will cause problem to downstream activity. The natural gas is process in LNG plant to remove impurities which will freeze under low temperatures. High amount of power is needed to produce LNG [4].

The composition of raw natural gas is depend on the depth and underground geology [5]. Even though there are many others compounds in natural gas, methane is the main component of natural gas [6]. Since natural gas is mainly composed of hydrocarbons, water, carbon dioxide, oxygen, nitrogen and other gases, it needs to be processed before converting to LNG. It is found deep underground, so it contains some impurities such as water vapour, carbon dioxide, hydrogen sulphide and others. Hydrocarbons and impurities can cause a serious problem in the oil and gas industry [7]. The presence of water vapour in natural gas can cause problems such as hydrate formation, corrosion and reduction of combustion efficiency [8].

Hydrates are solids that formed from the natural gas hydrocarbons and carbon. Hydrates has the physical appearance of ice-like crystallized solid which produce from the combination of water and hydrocarbon. It restricts the movement of natural gas flowing through the valves and pipes. These can block the pipeline flow and control systems. The effectiveness of the pipelines will reduce due to slugging flow conditions as heat value of natural gas is decrease by the water content [9].

Dehydration process is the removal of water vapour from the wet gas. It prevents plugging of the pipeline by ice formation, formation of liquid slugs, and condensation of water in pipeline and to maximize pipeline efficiency [10]. Therefore, gas is dehydrated to prevent these harmful effects. There are two main methods of dehydration which are adsorption with solid desiccants and absorption with liquid desiccants.

Adsorption dehydration is the process where a solid desiccant is used to remove water vapour from a wet natural gas stream. The solid desiccant can be regenerated to be reuse in the dehydration unit and it also can be used for adsorption-desorption cycles [11]. Adsorption requires two bed system, where the adsorbents filled both beds. The natural gas is flow through one of the column to eliminate the water vapour. Meanwhile, the other column blow the hot dry gas passing through it for regeneration. Later, this gas is cooled and condensation of water occurs. The efficiency of the dehydration by adsorption process be influenced by the type of adsorbent used to eliminate the water vapour. The example of adsorbent is calcium chloride.

Meanwhile, absorption dehydration involves the process of removal of water by a liquid which has a strong ability to attract water. Glycol is the typical type of liquid desiccant used to remove the water vapour [12]. The removal of water from the gas stream by the glycol occurs in an absorption column which is also known as a contractor. The rich glycol must be regenerated where the absorbed water is removed before it can be recycle back into the absorption column. The regeneration is done by distillation of glycol where the water which has been absorb by the glycol will be removed.

Absorption with glycol is chosen to be the best method to remove water vapour from the natural gas. Since, absorption dehydration consume less energy at low and high pressure, it is the more economical method for dehydration [13]. Furthermore, substituting the glycol is cheaper than substituting the adsorption bed. Absorption is the better method because glycol can be changed continuously but changing bed for adsorption need a shutdown of the operation. In addition, this method of dehydration can obtain a low water content [14].

Glycol dehydration process consists of two parts, gas dehydration and glycol regeneration. For gas dehydration part, glycol is used to eliminate water from the gas by flowing countercurrent with the wet gas. It usually involves an inlet scrubber and a contractor. In some cases, the temperature of gas inlet is reduce before entering the absorption column by using an inlet cooler. In regeneration part, the absorbed water is eliminate from the glycol forming lean glycol before it can be recycle back into the absorption column. Regeneration is the important part of dehydration process to maintain a low natural gas dew point which corresponding to a reduction of water content [15].

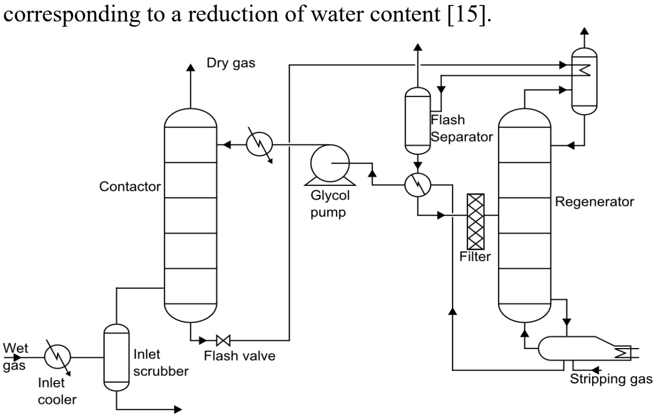

Figure 1 Typical gas dehydration process by absorption with glycol

Based on Figure 1, dehydration process by absorption with glycol consists of several units operation such as the contactor, regenerator, inlet scrubber and heat exchanger. From the figure above, the wet gas will flows through the inlet scubber where the free liquid and liquid droplets in the gas are removed before entering the absorption column. This is to reduce the amount of water that has to be remove in the absorption column which can decrease the amount of glycol to be used to remove the water. Then, the natural gas feed enters the bottom of the absorption tower and flows upwards the column. Meanwhile, the lean glycol will enter from the top of the absorption column and flows downward the column. The wet gas will flows countercurrent with the glycol and leaves as a dry gas at the top of the column. The rich glycol will exit at the bottom of the absorption column and flows through the flash valve and heat exchanger before entering the regenerator tower. In the regenerator tower, water is stripped out from the glycol. The rich glycol is heated and the water vapour flashes out from the glycol. The water vapour exits at the top of the column and the lean glycol is recycle back into the absorption column.

II. METHODOLOGY

A. Adding components in Aspen HYSYS

The groups of chemical components used in the simulation is defined. Since there are two streams in this simulation which are natural gas stream and TEG stream, the components of natural gas and TEG are added. The components for the simulation are nitrogen, carbon dioxide, hydrogen sulphide, methane, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, water and TEG. The composition for these components will be further specified. Figure 2 below shows the components selected during simulation by Aspen HYSYS.

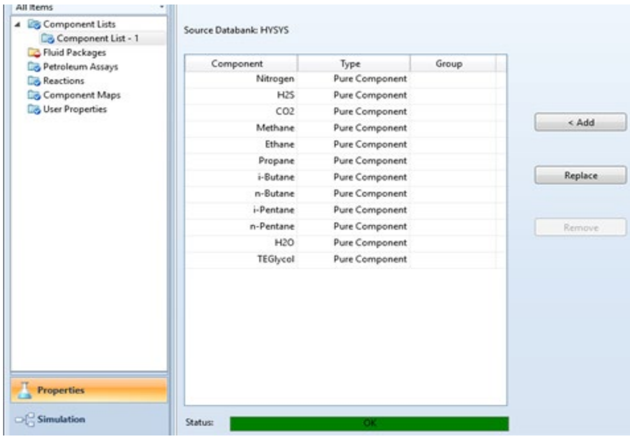
Figure 2 Components of natural gas stream

B. Selecting a fluid package

In HYSYS, it is important to select the right fluid package. The fluid package comprises all the important information about the pure components and physical property calculations. Based on Figure 3, Peng-Robinson is selected for the fluid package which is an ideal model for calculation process. Peng-Robinson equation of stat is suitable in handling system which comprises hydrocarbon and water over a wide range of temperature and pressure. This model is chosen because it has a good phase equilibrium.

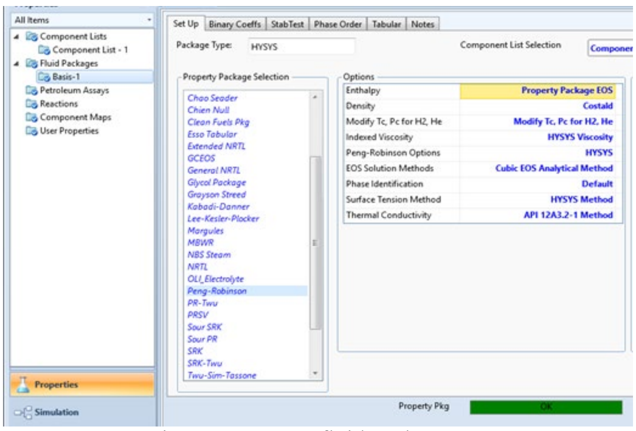
Figure 3 HYSYS fluid package menu

C. Simulation of gas dehydration plant

After selecting the components and the fluid package for the process, the simulation environment can be entered. In this simulation environment, the simulation of the natural gas plant will be carried out where the installation of the unit operation will be made based on the natural gas plant. The material stream is added into the simulation which it is the input and output stream of the unit operations. The properties of the material stream is specify depend on the conditions of the feed into the unit operations. The composition and operating conditions of the natural gas stream feed are shown in Table 1. The unit operations of the simulation are installed as the natural gas plant such as the separator, absorber, heat exchanger and distillation column. The unit operations are connected with each other by material streams. The conditions and the properties of each unit operations are specified. Figure 4 and Figure 5 show the specifications of absorption column and regenerator column respectively. The simulation of the dehydration plant is done and Figure 6 shows the process flow diagram of gas dehydration plant.

Table 1 Natural gas composition and condition

Components	Mole %
Methane	0.8989
Ethane	0.0625
Propane	0.0100
i-Butane	0.0079
n-Butane	0.0040
i-Pentane	0.0035
n-Pentane	0.0030
Water	0.0088
Nitrogen	0.0010
Hydrogen sulfide	0
Carbon dioxide	0.0004
Operating Conditions	
Pressure	6200 kPa
Temperature	35°C
Flow rate	500 kgmole/h

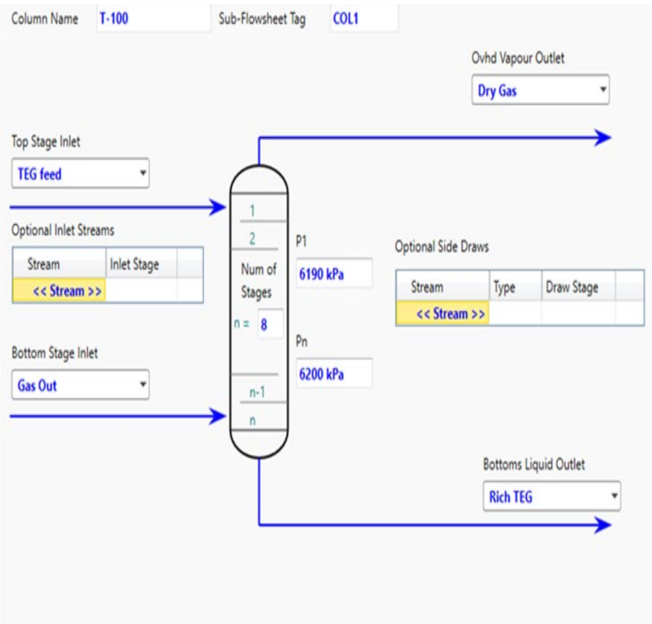

Figure 4 Absorption column design and specifications

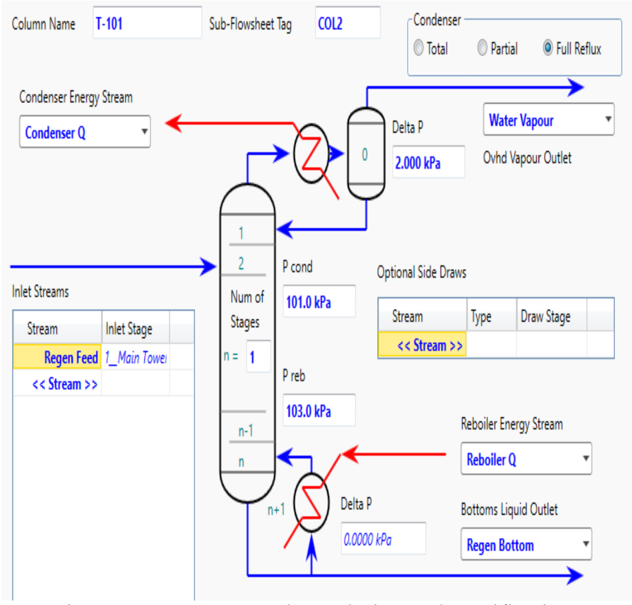

Figure 5 Regenerator column design and specifications

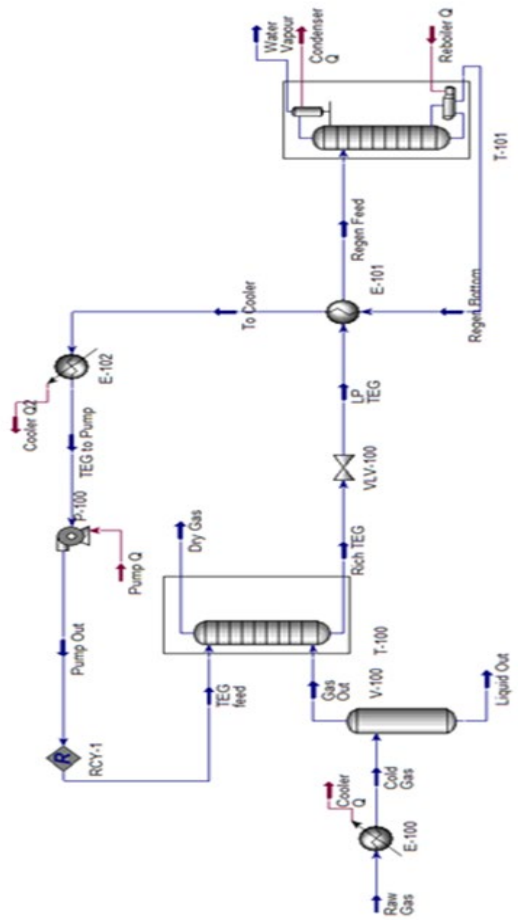

Figure 6 Process flow diagram of gas dehydration plant by using Aspen HYSYS

III. RESULTS AND DISCUSSION

In this thesis, the simulation is done to determine the best type of glycol and the optimum parameters that optimize the dehydration process. It is important to decide the optimum parameter to decrease the content of water in the dry gas to an allowable limit. The optimization process is achieved by examining several operation conditions. The parameters that were investigated are TEG circulation rate, number of stages of the absorber, temperature of the gas inlet of the absorber and temperature of the reboiler of the distillation column.

A. The effect of type of glycol on the water content of a natural gas stream

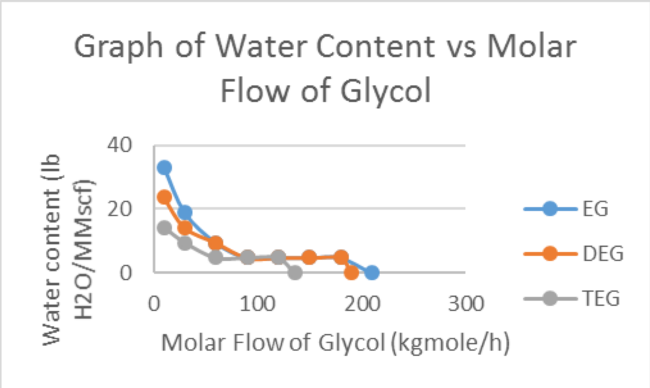

Figure 7 Effect of type of glycol on the water content of natural gas

Based on Figure 7 above, the dehydration efficiency of the different types of glycol are vary. Triethylene glycol (TEG) requires the lowest molar flow rate to achieve the low water content in the dry gas followed by diethylene glycol (DEG) and ethylene glycol (EG). TEG requires 136 kgmole/h which is the lowest compared to EG and DEG with 210 kgmole/h and 190 kgmole/h respectively. This shown that TEG is the best type of glycol to remove water from the gas stream since it only needs small amount of flow rate to obtain low water content of dry gas.

B. The effect of the number of trays on the water content of natural gas stream

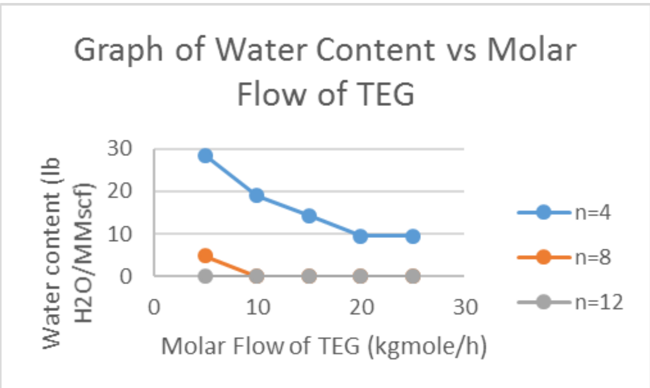

Figure 8 Effect of number of trays on the water content of natural gas stream

Based on the Figure 8, it can be seen that the higher the number of tray, the lower the amount of water content in the dry gas. When there are 4 trays, the minimum amount of water content is still not been achieve even though the molar flow rate of TEG is increased to 25 kgmole/h. For 8 trays absorber, it requires 10 kgmole/h of TEG to achieve the minimum amount of water content. When the trays is increased to 12 trays, it only requires 5 kgmole/h of TEG to achieve the lowest amount of water content. Therefore, more number of trays will use a low amount of TEG to remove the water gas stream.

C. The effect of inlet gas temperature on water content of natural gas stream

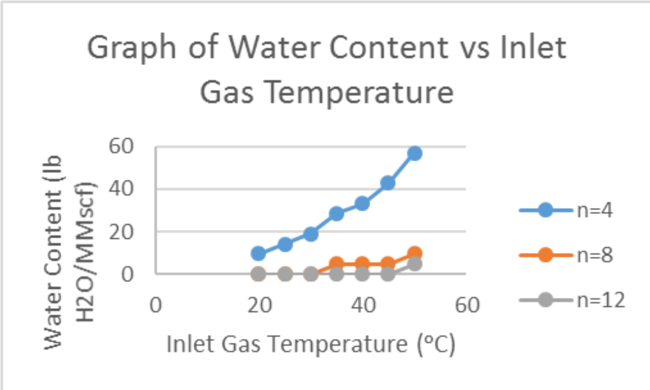

Figure 9 Effect of inlet gas temperature on water content of natural gas stream

From the Figure 9, the lower water content is achieved when decreasing the temperature of the inlet gas. When the contact tray are 12 trays, it has achieved the lowest amount of water content from a range 20ºC to 45ºC. For 8 trays of absorber, it requires a temperate of inlet gas in a range of 20ºC to 30ºC to achieve the lowest amount of water content. However, decreasing the temperature from 50ºC to 20ºC when using 4 trays of absorber will not achieve the lowest water content. From here, it can be seen that despite using high number of stages, decreasing the gas inlet can decrease the content of water in natural gas.

D. The effect of reboiler temperature on water content of natural gas stream

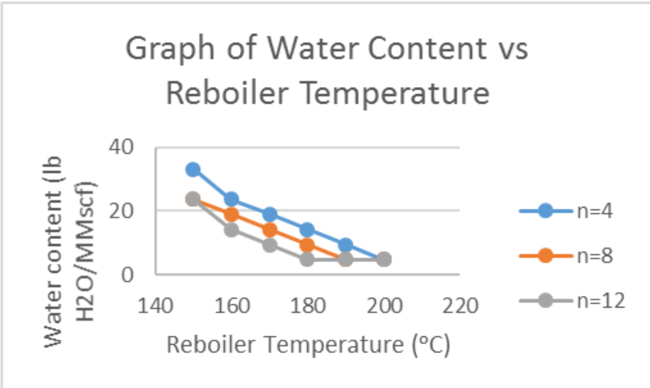

Figure 10 Effect of reboiler temperature on water content of a natural gas stream

From the Figure 10 above, the higher the temperature of the reboiler, the lower the water content of the natural gas stream. When the stages of absorber are 12 stages, the lowest water content can be achieve at 180ºC while 8 stage of absorber need reboiler at temperature 190ºC. For 4 stages of absorber, it requires 200ºC reboiler temperature to achieve the lowest water content which is 5 lb H_2O/MMscf.

IV. CONCLUSION

In conclusion, natural gas is compose of a combination of hydrocarbons and impurities. Since it is located deep in the underground, it contains water vapour which cause the problems such as the hydrate formation and corrosion to the pipeline, equipment and others. Dehydration is the process of minimizing or eliminating water vapour from wet natural gas stream. Dehydration can be categorized into two methods which are absorption with liquid desiccant and adsorption with solid desiccant. Absorption method is more widely use due to the economical reason. Glycol is the common type of liquid desiccant used to eliminate water vapour. Triethylene is the best type of glycol due to low amount of molar flow rate needed to achieve low water content. To achieve low water content, the number of stages of the absorption column need to be increase. Besides that, low water content can be achieve by decreasing the inlet gas temperature and increase the reboiler temperature. The optimum condition of gas dehydration was at 12 number of stages with 200^{o}C reboiler temperature and 20^{o}C inlet gas temperature.

ACKNOWLEDGMENT

Thank you to the Universiti Teknologi MARA (UiTM) for giving me opportunity and providing me equipment to conduct this research. I would like to sincerely thank to my supervisor, Madam Effah Binti Yahya for her non-stop support, patience and time to guide me in completing this research. I also would like to thank to my beloved family and friends for their helpful suggestions, advices and moral support in completing this report. Last but not least, thank you to all people who have giving me hand either directly or indirectly during the completion of this report.

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