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Study The Effect of The Main Variables on The Objectives of The Natural Gas Dehydration Plant by ASPEN-HYSYS v8.8

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Abstract

In the NGD process, TEG dehydration is commonly employed to prevent corrosion and blockage of equipment, valves, and piping systems. TEG is frequently lost in the system during this procedure owing to vaporization and carryover. Therefore, it is necessary to study the affection of variables of the dehydration process the process was simulated with ASPEN-HYSYSV8.8 and the thermodynamic model was glycol-package; the process was validated by comparing the Plant results with the simulation results and demonstrating good acceptance. ASPEN-HYSYS conducted a sensitivity study to investigate the impact of variables on the main objectives. , as this study showed that not all of these variables have a strong effect, some of them have a weak effect, for example (wet gas pressure and same case of solvent pressure) and the rest of the variables have a strong effect on this process, so it must be taken into consideration by the station operators where this The changes were targeted because they are subject to change within the plant, and the highest value and the smallest value were taken according to the factory's parameters. As these variables are taken into account and the requisite improvements are made, the natural gas drying process will improve, and the dry gas requirements needed will improve, resulting in increased benefit.

Keywords: Natural gas; Dehydration process; Tri-ethylene glycol; ASPEN-HYSYS v8.8

1. Introduction

Natural gas is major sources of energy and it is becoming increasingly relevant as an alternative fossil energy. Before using natural gas by end users, it must be processed in many stages to reduce major problems [1]; Water, other toxins, sand, and other impurities are removed from natural gas. Liquids can reduce the system's volumetric ability and interfere with the operation of pressure regulators and filters; additionally, concentrated liquids accumulated in pipelines, causing an increase in operating pressures and the risk of equipment damage due to liquid carryover, As a result, it is important to prevent liquid water and hydrocarbons from condensing [2]. The presence of moisture in natural gas can lead to issues like hydrate formation or freezing, which can lead to pipe plugging, corrosion, and a decrease in combustion efficiency [3].

As a result, the gas needs to be dried. Dehydrating natural gas can be done in a variety of ways, including: Using a solvent to absorb [4], Cooling [5], Adsorption [6], Membrane separation [7], and Separation at ultrasonic speed [8]. The absorption with tri-ethylene glycol in the gas dehydration procedure is one of these processes. TEG has strong absorption properties as well as low volatility, making its application more economically and environmentally viable [9].

There are two stages to the procedure: The water is drained from the gas in the first phase in a staged tower (absorption column), and the solvent is regenerated in the second column (distillation tower). After that, the solvent is returned to the first column to extract more water from the feed gas. TEG is normally lost in the system as a result of vaporization or carryover in this phase and the economic matters and another common concern, such as an insufficient TEG circulation rate or high methane content in rich TEG [10], energy obligation intake, and dry gas water concentration [11]. To achieve the permissible water concentration in the gas, minimize the use of energy, and minimize the depletion of TEG, it is important to investigate the effects of multi-variables on the dehydration process. Furthermore, objective functions in most chemical engineering optimization problems are incompatible.

In the dehydration mechanism, for example, minimizing water content and minimizing heat duty are at odds. When the former is minimized in the otherworld, the above is usually maximized. As a result, all objective functions can be viewed at the same time. There are many studies on how to study and improve the gas dehydration process, Ranjbar [12] investigated the use of a relative sensitivity function (RSF) to optimize a domestic TEG dehydration device. RSF resulted in a decrease in the water content of dehydrated gas, TEG circulation capacity, and re-boiler duty. Rahimpour [13] investigated the Sarkhun gas processing facility's dew point adjustment unit, The multiple separator and filters were simulated using the steady-state simulation program HYSYS, and the optimum separation temperature was calculated as a result. Kamin [11] optimized the glycol dehydration device using response surface methodology (RSM) to generate gas with an adequate water content while consuming the least amount of energy and losing the least amount of glycol. Jacob [14] used the HYSYS simulator to optimize the effects of different glycol flow speeds, absorber levels, re-boiler temperature (180 C, 190 C, and 200 C), and stripping gas rate on the water content of the gas, He discovered that increasing the re-boiler temperature above 200 C caused glycol to thermally decompose, and that adding stripping gas had a greater effect than raising the re-boiler temperature.

The research proposal has two main goals. The first is to use the ASPEN HYSYS v8.8 software application to model the natural gas dehydration process for the Basra plant to use it as a case study. Figure 1 depicts the process flow diagram of the Basra plant and displays all of the operating conditions of temperature, pressure, and mass flow for each channel. After that, an inspection of the method was carried out by comparing the actual plant findings as shown in Figure 1 with simulation results data to ensure that the simulation is accurate. The second goal is performing a sensitivity analysis to determine the degree of the effect of the variables (Twgt, Pwgp, Mwgf, TTEG, MTEG, and Trgt) on the objective functions (Wout, Qhd, Ls, and Mdry).

2. Process description and Simulation

The glycol process is the most efficient and widely used process in the gas industry [15], Triethylene glycol liquid desiccant is used as a solvent in this procedure to extract water vapor from natural gas. Furthermore, glycol solvent has a strong attraction to water vapor [16], NGD is a renewable energy source. Gas dehydration and TEG regeneration are the two main aspects of the dehydration method. The feed wet gas is dehydrated by an absorption tower in the dehydration section, and water is separated from the solvent in the regeneration section; after regeneration, lean TEG is recycled directly to the contactor tower (Absorption).

A dehydration device usually includes the following components: contactor, flash tank, exchangers, scrubber, and distillation [10], to investigate the effects of a TEG process field, you must first simulate a base case (Figure 1). The glycol kit model was used in an Aspen HYSYS simulation V8.8. The model is better for gas dehydration process simulation because it offers correct water quality, dew point temperature, and activity coefficient calculations. As previously said, the Basra gas dehydration plant is used as a case study (see Figure 1) and is simulated with Aspen HYSYS V8.8. To extract water vapor from the feed wet gas source, TEG is used as an aqueous solvent. The first step in simulation is to incorporate two streams, the wet gas stream and the TEG solvent stream, as well as operating conditions and compositions that are identical to the data in this case study (see Figure 1). The simulation setting is reached after completing the above. Furthermore, the simulation environment can take into account the main simulation area, which deals with the process plant and displays the process plant's PFD. It's important to use an inlet gas scrubber to clear any unwanted impurities including liquids and solids. The absorption tower for tri-ethylene glycol is a vital part of the process plant that requires certain requirements, such as stream temperature, pressure, and flow rate as mention in Figure (1) and Table (1).

The absorption takes place on the contactor or absorber column, which are vessel trays. The wet natural gas reaches the bottom of the tower and the lean TEG glycol enters the top of the shaft. The upflowed wet gas comes into contact with the lean glycol solvent as it runs down into the trays. The wet gas's water vapor is absorbed by the lean glycol solution, which then escapes from the bottom of the tower as rich glycol. As a dry gas commodity, the gas escapes the top of the column. Furthermore, the rich TEG glycol must be regenerate, which can be accomplished by building a distillation tower, with specifications that must simulate the distillation column seen in Figure (1) and a total of 6 trays. The Rich glycol flows down to the Re-boiler in the distillation tower, where it comes into contact with hot gases (mostly water vapor and glycol) coming up from the re-boiler. The Rich glycol is heated to 200 C in the re-boiler to expel sufficiently water vapor.

The simulation of the natural gas dehydration process was successful, and Figure (2) depicts the simulation process flow diagram for the Basra gas dehydration plant. Several process units are used in the gas dehydration process, as seen in Figure (2). The specifications for building these heat exchangers are seen in Figure (1) and Table (2), where the rich glycol passes through these heat exchangers to be heated in two steps. The first exchanger E-100 heats the Rich glycol to about 72 degrees Celsius, after which it reaches the Flash tank, where it is disposed of the water vapor as well as some hydrocarbons. The installation requirements for the flash tank separator are shown in Figure (1). After that, the Rich solvent is transferred to the E-101 second heat exchanger. It reaches a temperature of about 154 degrees Celsius there. In order to prevent any technical issues, it is important to add a flash separator for rich TEG solvent.

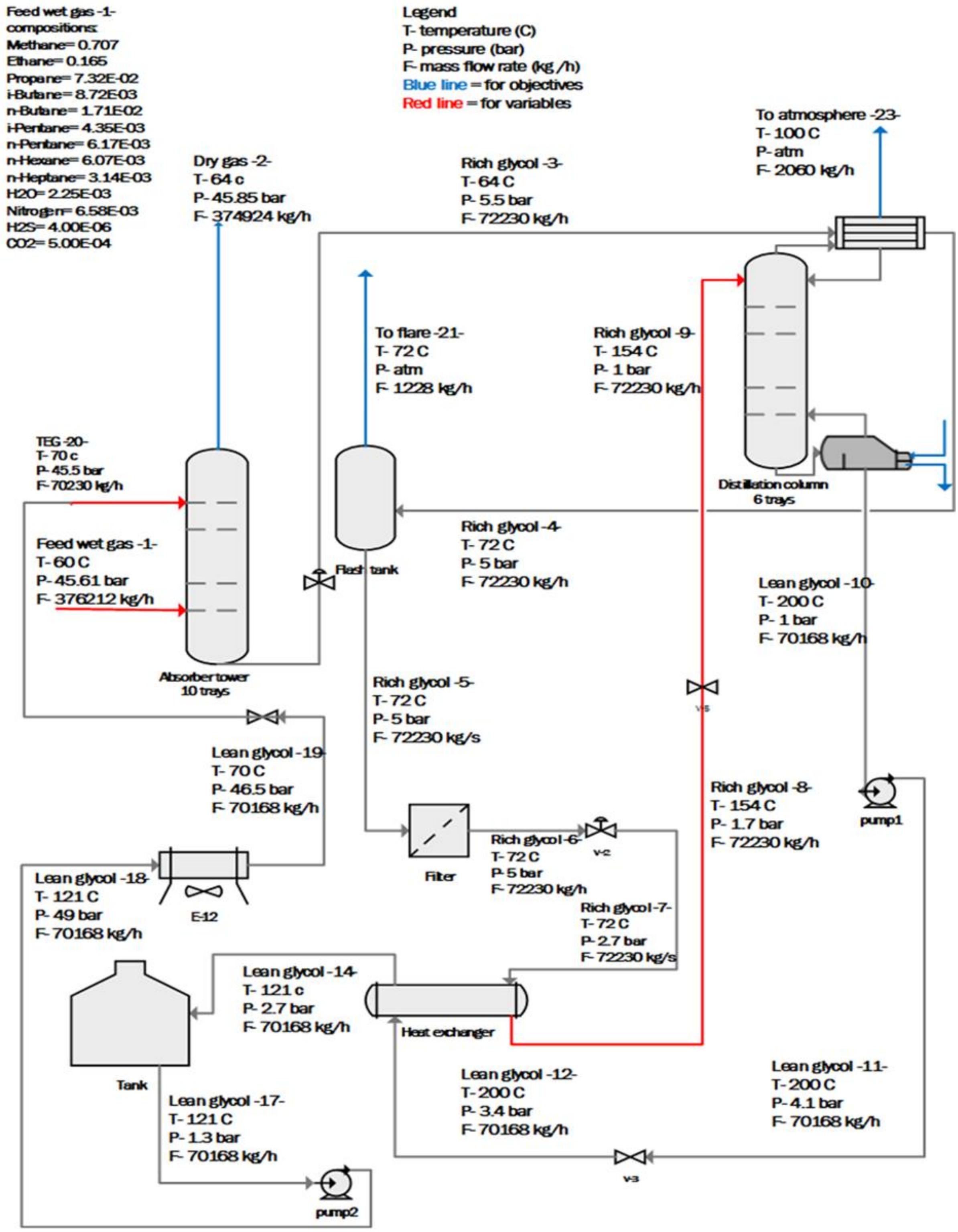

Fig. (1): PFD of Basra dehydration plant

Table (1) Design dimensions of absorber

Height	9396 mm
inner diameter ID	3800 mm
Operation temp. OT	64 c
Operation press. OP	45.61 bar
Number of trays.	10

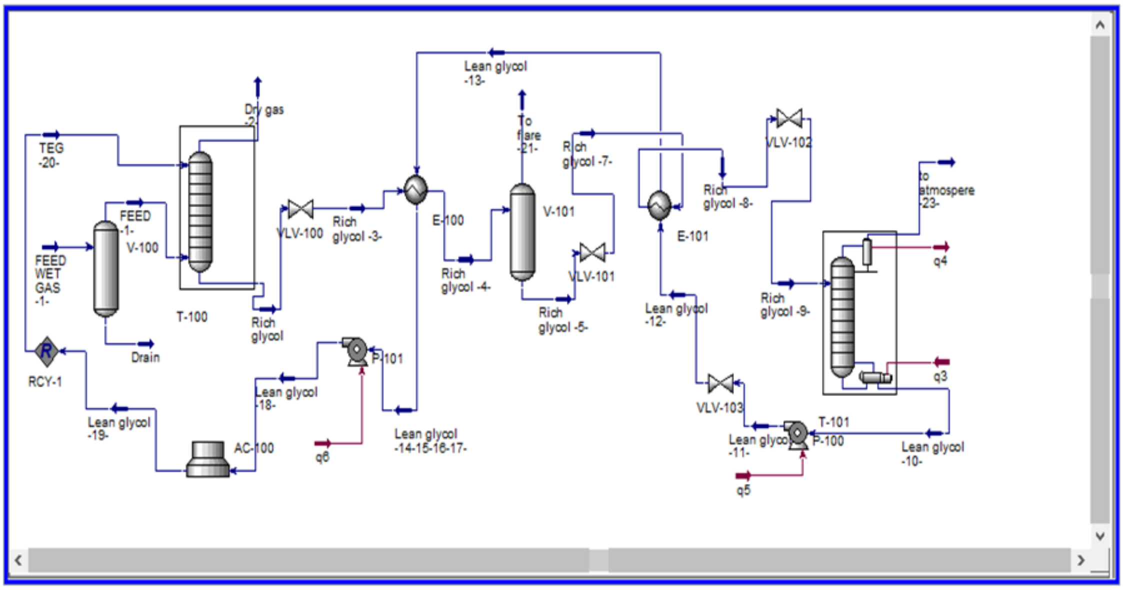

Fig. (2): Process flow diagram of NGD

Table (2) Heat exchanger information

	Shell	Tube
Operation temp. OT (outlet)	121 c	154 c
Operation press. OP	2.7 bar	2.7 bar
Operation temp. OT (inlet)	200 c	72 c

The plant simulation was completed, and the simulation resulted in a high-water removal rate, which will be addressed in the outcome and discussion section. The distillation column's tri-ethylene glycol is cooled and recycled back into the TEG inlet stream. A logical recycling operator tool must be placed between the two streams to accomplish this. The recycling of tri-ethylene glycol has an issue in that small quantities of TEG solvent are lost in the gas flow from the contactor, separator, and regenerator during the phase. Table (3) displays the simulation results for each stream.

3. Process Validation

Since the model must mimic the behavior of the real process facility, the consistency of the process simulation model is critical. Through comparing the forecasts from the simulation process plant data with standard design data details (actual data) and evaluating the deviations, the process validation can be carried out [17], The simulated natural gas dehydration method is depicted in Figure (2). The natural gas dehydration process is built on a simplified process flow diagram of the Basra refinery factory. Aspen HYSYS' simulation model was specially engineered to precisely describe any unit of equipment and process line in the process plant. The previse section shows the fluid property package, towers, heat exchangers, generators, separators, and other device operations in detail. The method simulation's operating conditions of streams and compositions of commodity dry gas were compared to industrial data and their relative error; where, calculated by Equation (1).

Error% = abs (true value – approximate value)/ abs (true value) ……….. (1) [18].

Where, the true value is the data from the factory, and the estimated value is the data from the simulator. The relation of actual data and simulation data for stream operating conditions and dry gas composition is seen in Table (3). With an average absolute error of less than 1.0 percent, the simulation data and standard actual data (plant data) were found to be in fair agreement. The temperature of stream no.3 has a maximum absolute error of 3.0 percent, while the methane component has a minimum absolute error of 0.07 percent.

Table (3) Operation and composition data comparison

	plant results	simulator result	Error%
Methane (ppm)	760000	710000	0.0007
Ethane (ppm)	186000	164000	0.001
H2O (ppm)	277	323	0.002
Stream No.2			
Pressure (bar)	44.85	44.85	0
Temperature C	64	63.3	0.011
Flow rate (kg/hr)	374924	375018.85	0.00025
Stream No.3			
Pressure (bar)	5.5	5.5	0
Temperature C	64	62	0.032
Flow rate (kg/hr)	72230	72078.85	0.0021
Stream No.20			
Pressure (bar)	45.5	46.5	0.022
Temperature C	70	70	0
Flow rate (kg/hr)	70168	70897.7	0.01
Stream No.4			
Pressure (bar)	5	5	0
Temperature C	72	72	0
Flow rate (kg/hr)	72230	72078.8	0.002
Stream No.5			
Pressure (bar)	5	5	0
Temperature C	72	72	0
Flow rate (kg/hr)	70942	71763.76	0.011
Stream No.21			
Pressure (bar)	1.013	1.013	0
Temperature C	72	72	0
Stream No.9			
Pressure (bar)	1	1.013	0.013
Temperature C	154	153.4	0.004
Flow rate (kg/hr)	70900	71763.76	0.012
Stream No.10			
Pressure (bar)	1	1.013	0.013
Temperature C	200	199.96	0.0002
Flow rate (kg/hr)	70168	70889.34	0.0103

4. Sensitivity analysis of NGD process

The gas dehydration process model was subjected to a sensitivity analysis to observe the effects of a few key variables, with the aim of identifying these variables as decision variables in the subsequent optimization research on process results. The variables are wet feed gas temperature (T_{wgt} , oC), wet feed gas pressure (P_{wgp} , bar), wet feed gas mass flow rate (m_{wgf} , kg/s), inlet TEG temperature (T_{TEG} , oC), inlet TEG mass flow rate (M_{TEG} , kg/s), and rich glycol temperature (T_{rgt} , oC). To notice the results of contrast on certain measured quantities indicate the process efficiency, the value for each of these variables differed in a predetermined case while others were kept constant. The water content of dried gas ppm, re-boiler heat duty kJ/s, TEG loses, and dry gas flow rate kg/s are the objective functions.

The effect of the wet gas flow rate: According to the sensitivity analysis of the input feed wet gas mass flow (Figure 3Ab). wherein an equation (2) was used, the empirical equation (2) proposed by [2] is as follows:

$$T_{dew.eq} = 18.228 * \ln (0.001685 * W_{out} * P_g^{0.81462}) \text{———————} (2)$$

Because the dew point is directly proportional to the water content, when the water content drops, so does the dew point [6]. Furthermore, as shown in (Figure 3Ac), when all process plant parameters are fixed and the mass flow rate of wet gas is increased, the tri-ethylene glycol TEG losses are reduced. This is because the solvent flow rate is constant when the sensitivity of this variable is investigated, As a result, when the solvent percentage is divided by the quantity rate kg/s, increasing the wet gas mass flow rate resulted in a drop in water content in the dry gas stream (Figure 3Aa), which led to a reasonably linear fall in dry gas dew point temperature of gas exiting the tower, this value steadily reduces as the gas flow rate increases, with the exception that heat duty consumption rises as the feed wet gas mass flow rate rises, as shown in (Figure 3Ad). The fundamental reason for this is that a larger feed wet gas mass flow rate puts more strain on the process plant system, resulting in higher heat duty consumption. It's only logical that when the wet gas flow rate rises, the dry gas flow rate rises as well, as seen in (Figure 3Ae).

Effect of TEG mass flow rate: Within the rate, the optimal value for the quantity of TEG solvent is (0.017 - 0.042 m3 TEG per kg of water) [14]. The feed wet gas in the Basra

Company’s gas treatment plant comprises 0.23 kg/s of water after simulation, hence the ideal quantity for this plant is between (10 - 20 kg/s TEG). The number of absorption tower trays affects the TEG solvent flow rate. As a result, the absorber tower requires (6) trays to run at 0.025 m3 TEG/kg water [19], As previously stated, these values are in terms of pure TEG solvent (100 percent mass fraction). When using the ASPEN HYSYS software to investigate the influence of the TEG solvent flow rate on the water content, the findings revealed that raising the TEG solvent flow rate from 10 to 1000 kg/s increased the water content, as shown in Figure 4Ba. However, this result was not pure owing to the return TEG solvent from the distillation tower (0.918 mass fraction TEG and 0.082 mass fraction water). Because this TEG is pure (100 percent TEG) and this purity is difficult to get, raising the pure TEG mass flow rate from 10 to 100 kg/s reduces the water content percentage until it gets close to zero, as shown in (Figure 3Bb). TEG glycol solvent circulation levels that are too high can create a slew of issues. If this is the case, the device is over circulating the TEG, and lean TEG glycol cannot have enough heat exchangers to be properly cooled, and the resulting dry lean glycol will not be removing water at the appropriate rate. A rapid rate of circulation does not provide enough time for the hydrocarbons in a phase separator to settle, which can result in hydrocarbon deposition, glycol loss, foaming, and even pollution. Increased glycol circulation levels can also result in an increase in the re-heat boiler's demand. Over circulation also adds to increased air pollution since emissions are proportional to the rate of circulation. Under circulating the TEG solvent gives inadequate quantities of TEG for the amount of water to be extracted in the absorber and resulting in Wet Gas Marketing. In view of the above, leans TEG glycol flow rate must be targeting and study the affection of variables on it, where this can be achieved by testing the moisture of the treated gas dew point temperature [20]. As shown in Figure 4Bc, increased solvent flow results in larger TEG losses. This is due to the fact that an excess of the solvent causes an increase in evaporation and the possibility of a carryover. In addition, (Figure 3Bd) depicts the affection, in which the increase in energy amounts begins gradually as the TEG solvent rate increases, and it also demonstrates that the flow rate has a substantial influence on heat duty consumption. Due to the solvent's propensity to absorb not only water but also hydrocarbons [21], raising the TEG solvent flow rate results in a drop in the dry gas flow rate (Figure 3Be), and hence the increase results in a drop in output.

Effect of Feed wet gas temperature: As illustrated in Figures (3Ca) and (3Cb), raising the temperature of the feed wet gas input led in a rise in the water content of the exit dry gas product, resulting in an increase in dew point temperature. Lower feed wet gas temperature, on the other hand, minimizes TEG losses, as illustrated in Figure (3Cc). As shown in Figure (3Cd), the Re-boiler heat duty is inversely related to the temperature of the incoming wet gas, with rising wet gas temperature resulting in lower heat duty consumption. As a result, temperature has a significant impact on the operation of dehydration plants. As the temperature of the incoming wet gas rises, the flow rate of the resultant dry gas rises, as shown in Figure (3Ce). The reason for this is that when the temperature rises, the absorption tower's solvent work efficiency falls. As a result, despite their great quantity, the dry gas standards are inadequate and have excessive water content%.

Effect of solvent temperature: The impact of TEG temperature on the water content in dry gas is shown in Figure (3Da). The water content rose from 0.00018 to 0.00072 for the solvent temperature range of 40 c to 200 c. The temperature of the incoming TEG influences the partial pressure of the water when the lean solvent enters the absorption at the top stage. As a result, a high-temperature TEG causes the dried gas to have higher water content (Hernandez-Valencia, 1992). As well as the similar case affection for dew point as shown in Figure (3Db). The temperature of the solvent appears to have just a little impact on TEG losses. However, as previously shown in Figure (3Dc), solvent losses are only modestly sensitive to variations in lean glycol temperature during the operation. Increasing the TEG temperature reduces the re-boiler heat duty, as seen in Figure (3Dd). The impact of the TEG solvent temperature on the dry gas flow rate is seen in Figure (3De); as the temperature rises, the dry gas flow rate rises. The reason for this is that, as previously stated, increasing the temperature of the solvent reduces the absorption tower's effectiveness, resulting in a large volume of gas with high water content.

Effect of wet gas pressure: Pressure has a minor impact on the dehydration process. Increases in pressure reduce the amount of water in the dry gas stream, as shown in Figure (3Ea), slightly lowering the dew point temperature of water (Figure 3Eb), while raising the wet gas pressure increases TEG losses (Figure 3Ed) and reducing the heat duty consumption (Figure 3Ec), When the pressure rises over 100 bar, the plant's performance suffers, necessitating the installation of a compressor, chiller, and separator drum, resulting in greater capital and operating costs. When shown in Figure 4Ee, as the pressure of the wet gas rises, the dry gas flow rate rises as well, and as can be seen from the curve line, the effect is strong and evident from 30 to 45 bar, and at 46 bar and above, the impact begins to stabilize and the increase is minor. The effect of Rich solvent temperature: As illustrated in section 2, the temperature of the Rich solvent is regulated by the functioning of the Lean glycol/Rich glycol heat exchanger (E-101) (Figure 2). Because it has a huge influence on the distillation tower, especially the boiler of the distillation tower, as shown in Figure (4), rising rich glycol temperature leads to a considerable drop of re-boiler heat responsibilities.

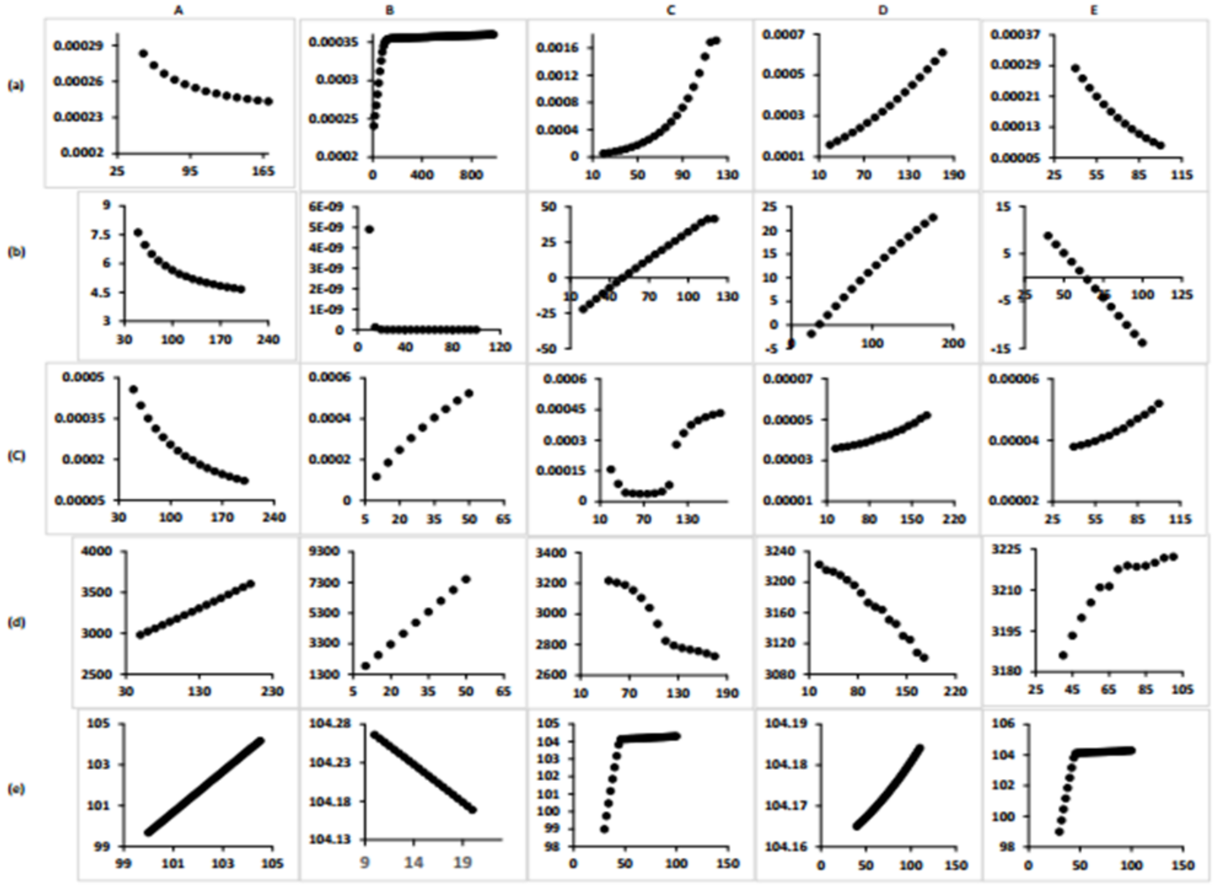

Fig. (3): Sensitivity of water content, dew point, TEG losses, heat duty, and dry gas flow rate (shown on the y-axis a, b, c, d, and e respectively) to decision variables (shown on the x-axis): (A) wet gas flow rate (M_{wgf}); (B) TEG flow rate (MTEG); (C-E)T_{wgt}, T_{TEG}, and P_{wgp}, respectively.

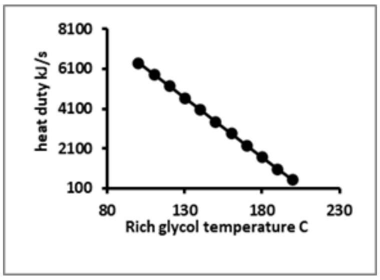

Fig. (4): The affection of Rich tri-ethylene glycol temperature on the Re-boiler heat duty kJ/s

The rise in feed temperature, as seen in Figure (5), Increased lean solvent purity and, as a result, decreased water content in dry gas generation are the results of high tri-ethylene glycol concentration. TEG losses, on the other hand, are reduced by solvent purity.

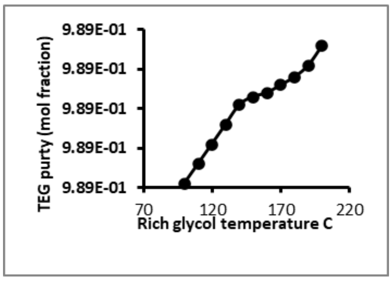

Fig. (5): The affection of Rich tri-ethylene glycol on the TEG purity

5. Conclusions

The natural gas dehydration process at the Basra plant was used as a case study in this study, and it was modeled using the Aspen HYSYS V8.8 computer program. The Aspen HYSYS simulator model was successfully verified using design information from a TEG dehydration process; the process was then sensitivity analyzed for four sets of objectives and six primary factors, including water content in dry gas, re-boiler heat duty, TEG solvent losses, and dried gas flow. Wet gas temperature, wet gas mass flow rate, wet gas pressure, TEG temperature, TEG mass flow, and Rich glycol temperature are among the variables.

A sensitivity analysis of these variables was conducted on the main objectives, as this study showed that not all of these variables have a strong effect, some of them have a weak effect, for example (wet gas pressure and solvent pressure) and the rest of the variables have a strong effect on this process, so it must be taken into consideration by the station operators where this The changes were targeted because they are subject to change within the plant, and the highest value and the smallest value were taken according to the factory's parameters.

Nomenclature

NGD = natural gas dehydration.

T_{wgt} = wet gas temperature C.

M_{wgf} = wet gas flow rate kg/s.

P_{wgp} = wet gas pressure bar.

T_{TEG} = TEG temperature C.

M_{TEG} = TEG mass flow rate kg/s.

T_{rgt} = rich glycol temperature C.

W_{out} = water content (kilograms of water per million standard cubic meters).

T_{dew}; is dew point in C.

P_g = pressure (MPa).

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