International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Optimization Simulation of Condensate Stabilizer Unit on X Field Gas Well Case Study

Boy Candra Valentino[1], Rini Setiati[1], Dwi Atty Mardiana[1], Pri Agung Rahkmanto[1], Muh. Taufiq Fathaddin[1], Suryo Prakoso[1], Dina Asmaul Chusniyah[1,2]
[1]Petroleum Engineering, Faculty of Earth and Technology Energy, Universitas Trisakti, Jakarta, Indonesia
[2]Geodynamics, Institute of Geology and Geophysics, Chinese Academy of Science Email address: rinisetiati@trisakti.ac.id

Abstract *- This study examines the stabilization process of condensate from reservoirs. The condensate needs stabilization before further processing to prevent loss of valuable components, safety risks, and environmental pollution. The stabilization aims to separate light hydrocarbon C1-C4 as well to increase medium and heavy C5+, and also to reduce the vapor pressure of the condensate, marked by Reid Vapor Pressure (RVP), which is climate- dependent. This research focuses on Field X in East Java, processing gas and condensate in a Floating Production Storage Offloading (FPSO) using distillation, fractionation, and flash vaporization within the Condensate Stabilizer Unit. The goal is to analyze the influence of temperature on fuel gas, RVP, and optimal condensate volume produced at Field X. Using Aspen HYSYS Ver.12.1 simulation modeling and Peng and Robinson fluid packages method, the study found that temperature significantly affects RVP, fuel gas, and condensate production, with optimal conditions at 173°C, RVP of 8. Psia, fuel gas usage of 0.0681 MMSCFD, and condensate production of 4222 bbl/d. The study provides operational recommendations to optimize reboiler duty temperature, condensate volume, fuel gas, and RVP at FPSO X.*

Keywords *- Condensate Stabilizer Unit, Optimization, Simulation.*

I. INTRODUCTION

The condensate produced from reservoirs contains a significant amount of light components that will vaporize at low pressure and high temperature, resulting in the loss of valuable components, posing safety risks, and polluting the environment. These conditions are not ideal for condensate storage and transportation, so condensate stabilization is necessary before further processing. The primary goal of the condensate stabilization process is to reduce the vapor pressure of the liquid condensate to prevent vapor phase production when the liquid is transferred to storage tanks, and to separate very light hydrocarbon gases, especially methane and ethane, from heavier hydrocarbon components (C3+) [1]

Stabilized condensate typically has vapor pressure specifications. These specifications are usually identified by Reid Vapor Pressure (RVP) or True Vapor Pressure (TVP). The higher the RVP, the faster the condensate or oil will vaporize into the air. In various references, RVP specifications are influenced by climate [2], as temperature increases will enhance the volatility of condensate gas components. RVP specifications are typically set by local emission authorities or buyers to limit hydrocarbon emissions during storage and transportation. Typical RVP specifications range from 4 to 8 psia.

Field X is a gas field in East Java that has been in production since 2017. The gas produced by Field X is 70 MMSCFD, and the condensate is 4200 BOPD. The condensate separation process is carried out in a Floating Production Storage Offloading (FPSO) unit using distillation methods in separators, and condensate purification is achieved through a reboiler unit and pre-heater (exchanger) assisted reheating process. The Reid Vapor Pressure (RVP) used by Field X is 4.6 psia, still within the current buyer's requirement range, which is <8.2 psia. However, the stabilization process to achieve an RVP of 4.6 psia requires a temperature of 212°C and a fuel gas consumption of 0.122 MMSCFD [3] stated that the reboiler temperature is the most influential parameter in controlling product properties, along with fuel optimization up to 40% without any changes in vapor conditions to meet the required RVP. [4] also mentions that all of this is done in the condensate stabilization process. This process is mainly performed to reduce the Reid Vapor Pressure (RVP) of the condensate. Thus, the amount of medium and heavy components in the condensate increases. Based on these conditions, research to determine the optimum temperature, fuel, and RVP of condensate at Field X needs to be conducted.

Literature study from other research stated that the condensate from natural gas reservoirs needs to be processed to meet safety and environmental standards before storage. Steps such as removing salt, water, and dissolved gases are included in the condensate stabilization process to reduce its Reid Vapor Pressure (RVP), which increases the content of heavy and medium components and prevents evaporation during atmospheric storage. According to research [5], lighter hydrocarbon components such as methane, ethane, and propane, along with acidic components, need to be removed from the liquid hydrocarbon to make it commercially viable.

The pre-separation unit consists of three parts: a three-phase separator, a dehydration unit, and a condensate stabilization unit, as described [6]. Stabilization can be achieved through fractionation or flash vaporization, with fractionation using a column and flash vaporization using a separator at different pressures. However, flash vaporization technology is considered outdated and rarely used in modern plants, as mentioned [3].

[3] conducted simulation studies to evaluate the performance of condensate stabilization using Aspen Hysys, focusing on a stabilizer column without reflux, also measured the RVP of the final product based on four parameters: feed rate, temperature,

pressure, and reboiler temperature, finding that the reboiler temperature had a more significant influence on the RVP. [7] researched column stabilization using simulations with temperature, pressure, and RVP parameters. [8] conducted simulations on reboiler duty and condensate flow. [9] optimized condensate stabilization to reduce operating costs and energy consumption. In additional research, the effects of vapor temperature and pressure on product quality were reviewed, with the optimal vapor temperature being discovered. [10] proposed four alternative options for stabilizing processes, including an integrated heat method that reduces the size of the stabilizer column. [11] conducted simulation studies on the Sannan condensate stabilization unit in Egypt, investigating important variables such as outlet process temperature, stabilizer feed drum pressure, feed tray location, and reflux ratio, finding optimal operational conditions that increased unit condensate productivity by 26.25%. [12] determined several sequential distillations that could replace conventional distillation columns in condensate stabilization units, showing that certain sequences resulted in higher recovery in terms of efficiency and annual costs compared to conventional distillation configurations. [13] mentioned that condensate recovery could reach 12% with good plant operation performance.

For oil, gas, and petrochemical applications, the Peng-Robinson Equation of State (EOS) is commonly recommended, as stated by [14]. The PR Fluid package in Hysys is highly enhanced, with the widest temperature and pressure range and special treatment for key components, making it a good standard for hydrocarbons. [15] also used the PR EOS in their research to find the dew point pressure. [16] applied binary interaction coefficients C7+ using the PR EOS. [17] mentioned the validation of simulations by comparing stabilized crude oil compositions taken from the plant with simulation results from Aspen Hysys. Validation was done in two ways:
(1) validation against pressure and temperature parameters, and (2) validation against the % mole liquid condensate plant.

II. METHODS

In research methodology, the research steps are discussed further within detail as follows: first is the research design, based on a case study that investigates the effect of temperature on the volume of condensate produced, RVP gained and fuel gas used, holistically using secondary data sources from Field X gas field in East Java. This is followed by identifying the types and sources of proper data input during the observation period of August - September 2023. The research tools and materials used include Aspen Hysys Ver 12.1, 2021 software.

The research process consists of five (5) steps: (1) data collection, the required data include: Pressure, temperature from well, separators, condensate stabilizer unit, volume of produced condensate, gas composition, Process Flow Diagram (PFD), Operation Procedure Manual (OPM) from the Stabilizer unit and from the overall FPSO process of Field X. Next is (2) model creation, by data input from HP MP LP Separator, condensate stabilization unit and run the model using simulation software as shown in Figure 1. (3) Model validation, validating with Pressure temperature and volume of condensate data from the plant. (4) Simulation, this step can be conducted if the validation process between simulation and plant data is appropriate, where simulation process uses temperature parameters ranging from 125-300°C, the max design Stabilizer column as per OPM is 232°C also to search for RVP <8,2 Psia as per buyer specification and the lowest fuel usage / observing the most optimal,

(5) analysis, analysis will be conducted on: gas composition exiting the condensate stabilizer unit, analysis of validation results of pressure temperature, and analysis of simulation results.

In the following Figure 1, the simulation model is created to model the actual plant process at the site. The model creation begins by creating a new case, then selecting gas composition in the sub-sheet that matches the laboratory data. The molecular composition sequence must match the data in the laboratory (from C1 to C30+), after the sequence is matched, input the values of gas composition. Then, select the calculation formula using the Peng- Robinson fluid packages method.

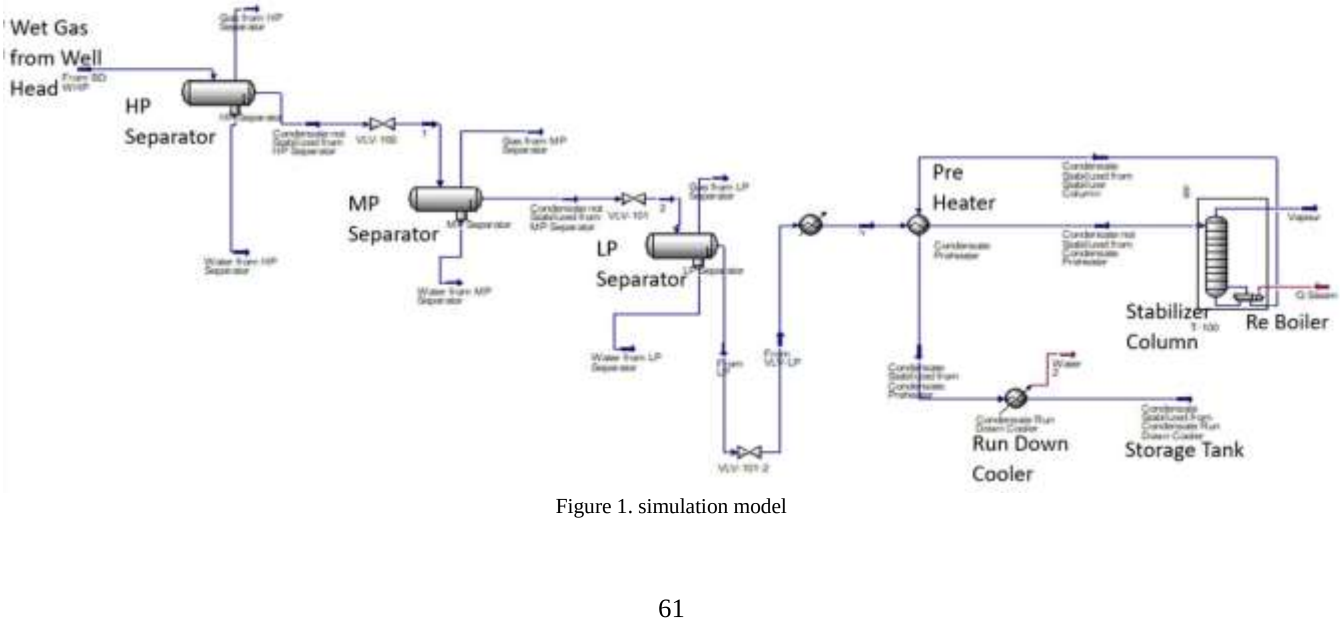

Figure 1. simulation model

III. RESULTS AND DISCUSSION

This study was conducted using software simulation where the model matched the actual plant. From the validation results that have been carried out on the research where the feed gas composition is entered into the initial feed stream composition, then after going through the mechanical phase with specific gravity separation in the separator, a comparison of the liquid composition from the laboratory results is carried out, and the comparison results between the % mole of condensate are obtained as shown in figure 2

In figure 2 it can be seen that most of the light fractions C1-C4 (Methane, ethane, propane butane) also Nitrogen, carbon dioxide hydrogen sulfide. have experienced evaporation, while the medium hydrocarbon fraction C5-C25 (Pentane - pentacosanes) has increased, then the comparison between the simulation results and actual process data between the condensate mole fractions does not have a significant difference. The exact value of the difference is shown in table 1.

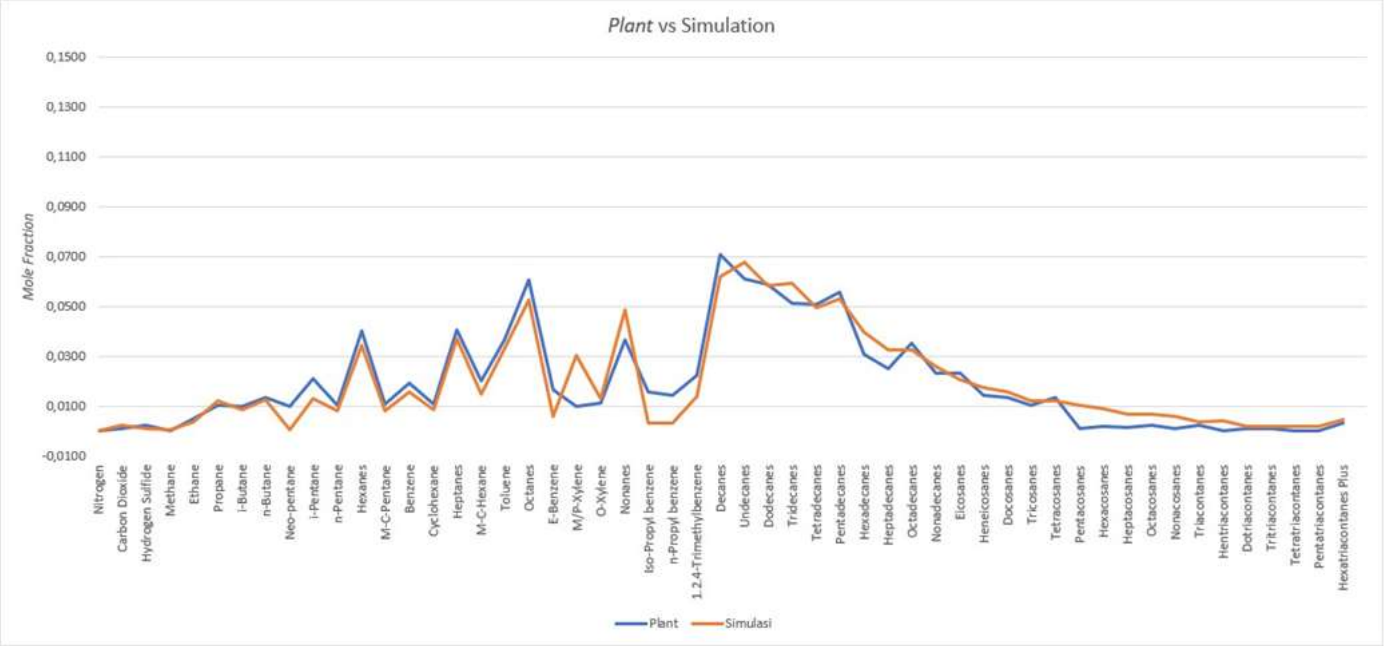

Figure 2. Plant vs simulation data graph comparison

TABLE 1. Plant vs Simulation data difference

Component	Plant Data	Simulation Data	Difference
Nitrogen	0,0000	0,0000	0,0000
Carbon Dioxide	0,0011	0,0023	0,0012
Hydrogen Sulfide	0,0021	0,0011	-0,0010
Methane	0,0002	0,0006	0,0004
Ethane	0,0048	0,0037	-0,0011
Propane	0,0105	0,0122	0,0017
i-Butane	0,0100	0,0084	-0,0016
n-Butane	0,0133	0,0126	-0,0007
Neo-pentane	0,0099	0,0005	-0,0094
i-Pentane	0,0211	0,0132	-0,0079
n-Pentane	0,0103	0,0082	-0,0021
Hexanes	0,0400	0,0345	-0,0055
M-C-Pentane	0,0109	0,0080	-0,0029
Benzene	0,0190	0,0155	-0,0035
Cyclohexane	0,0107	0,0087	-0,0020
Heptanes	0,0405	0,0370	-0,0035
M-C-Hexane	0,0202	0,0147	-0,0055
Toluene	0,0365	0,0332	-0,0033
Octanes	0,0605	0,0525	-0,0080
E-Benzene	0,0167	0,0057	-0,0110
M/P-Xylene	0,0100	0,0305	0,0205
O-Xylene	0,0111	0,0130	0,0019
Nonanes	0,0367	0,0483	0,0116
Iso-Propyl benzene	0,0157	0,0031	-0,0126
n-Propyl benzene	0,0145	0,0031	-0,0114
1.2.4-Trimethylbenzene	0,0222	0,0140	-0,0082

Decanes	0,0706	0,0619	-0,0087
Undecanes	0,0609	0,0677	0,0068
Dodecanes	0,0588	0,0582	-0,0006
Tridecanes	0,0511	0,0591	0,0080
Tetradecanes	0,0507	0,0494	-0,0013
Pentadecanes	0,0555	0,0531	-0,0024
Hexadecanes	0,0308	0,0395	0,0087
Heptadecanes	0,0250	0,0327	0,0077
Octadecanes	0,0351	0,0327	-0,0024
Nonadecanes	0,0232	0,0258	0,0026
Eicosanes	0,0233	0,0206	-0,0027
Heneicosanes	0,0144	0,0172	0,0028
Docosanes	0,0133	0,0155	0,0022
Tricosanes	0,0101	0,0121	0,0020
Tetracosanes	0,0134	0,0121	-0,0013
Pentacosanes	0,0011	0,0103	0,0092
Hexacosanes	0,0020	0,0088	0,0068
Heptacosanes	0,0012	0,0069	0,0057
Octacosanes	0,0023	0,0069	0,0046
Nonacosanes	0,0011	0,0059	0,0048
Triacontanes	0,0021	0,0036	0,0015
Hentriacontanes	0,0001	0,0039	0,0038
Dotriacontanes	0,0009	0,0017	0,0008
Tritriacontanes	0,0008	0,0017	0,0009
Tetratriacontanes	0,0002	0,0018	0,0016
Pentatriacontanes	0,0002	0,0018	0,0016
Hexatriacontanes Plus	0,0033	0,0044	0,0011
Total	1,00	1,00	

From the composition result obtain indicates that the simulation is valid. During the study the comparison between: temperature and the RVP shown in figure 3, and the optimization case study: temperature. fuel gas and condensate produced in figure 4, temperature, RVP and fuel gas used in figure 5.

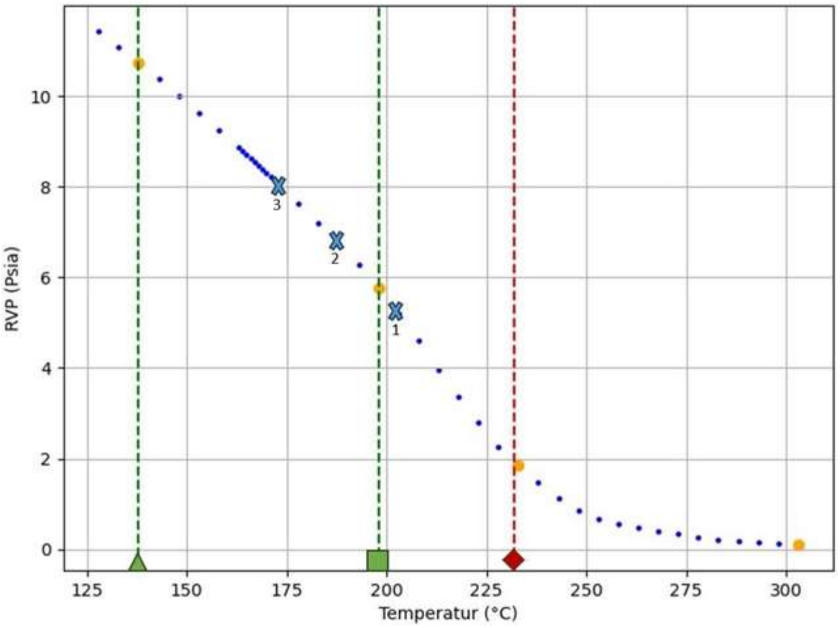

Figure 3. Temperature vs RVP

▲ = Parameter limit temperature 138°C
🟩 = Parameter limit temperature 198°C
◆ = Plant max design parameter temperature 232°C

X1 = Plant base case temperature 212°C
X2 = Plant trial case temperature 193°C
X3 = Simulation optimize case at temperature 172°C

From the temperature indications observe that at a temperature of 138°C, the RVP value is 10.7 Psia. while at a temperature of

198°C, the RVP value is 5.8 Psia, and at a temperature of 232°C, the RVP value is 1.9 Psia. For the plant base case at a temperature of 212°C, the RVP value is 4.1 Psia, while for the plant trial case at a temperature of 193°C, the RVP value is 6.3 Psia. In the simulation optimized case at a temperature of 173°C, the RVP value is 8 Psia. Finally, at a temperature of 300°C, the RVP value is 0.12 Psia

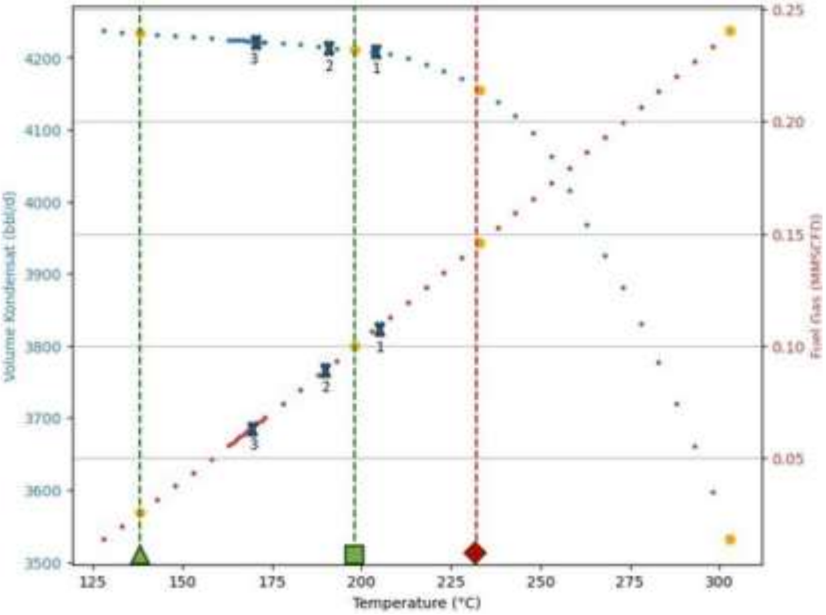

Figure 4. Temperature, fuel gas and condensate produced

Based on the figure 4, there are two curves depicting the relationship between temperature and two different variables: condensate volume and fuel gas consumption. The blue curve represents the condensate volume in barrels per day (bbl/day), while the red curve represents the consumption of fuel gas energy in Million Standard Cubic Feet per Day (MMSCFD).

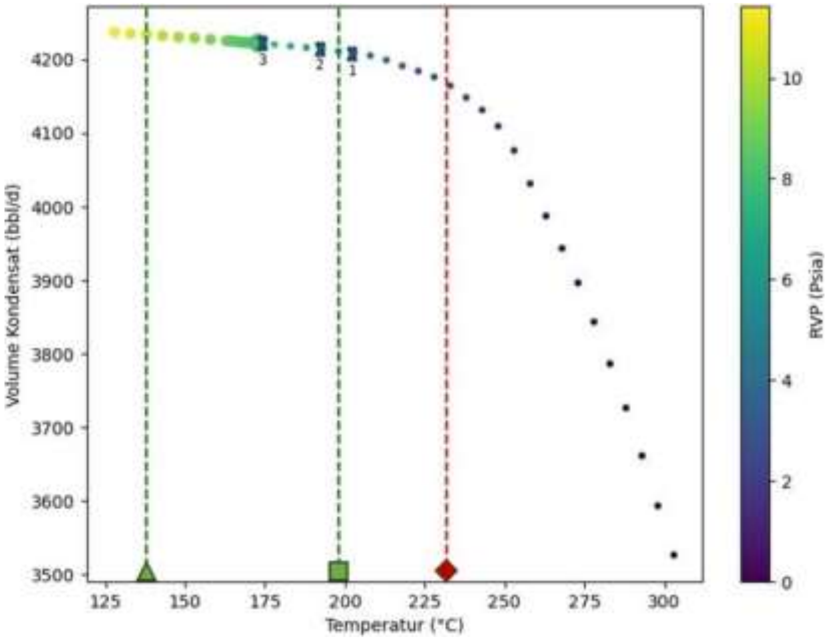

Figure 5. Temperature, RVP and condensate produced

From the figure, the condensate volume stabilizes at around 4200 bbl before the temperature reaches 200°C, and then begins to decrease. On the other hand, the consumption of steam energy continues to increase with the temperature. This indicates that to optimize condensate volume, operations should be run at a temperature around 138°C, which is the point where the condensate volume reaches its maximum value based on the available data. For example, at a temperature of 138°C, the produced volume is 4234 bbl with a fuel gas consumption of 0.0258 MMSCFD, then at 148°C, it produces 4230 bbl with a fuel gas consumption of

0.0376 MMSCFD, and so on. The condensate volume remains relatively constant and maximum from 138°C to 198°C, as well as fuel gas usage. When the temperature exceeds 198°C or the second green line, the condensate volume starts to decrease, albeit not significantly but consistently, until it reaches the temperature of 232°C represented by the red line. At this point, there is a sharper decline in the produced condensate volume, eventually resulting in a volume of 3571 bbl at a very high temperature of 300°C.

From figure 5, it is observed that the first point (1) indicates the RVP limit of 4.08 Psia intersecting with a temperature of 212°C, resulting in a condensate volume of 4201 bbls. Then, at the second point (2), the RVP limit is 6.3 Psia with a temperature of 193°C, producing a condensate volume of 4213 bbls. At the third point (3), the RVP limit is 8 Psia, with a temperature of 173°C, resulting in a condensate volume of 4222 bbls. From the optimization graphs, summarize into table 2.

TABLE 2.

Parameter	Plant Base case	Plant Trial case	Optimized case	Diff
Temperature °C	212°C	193°C	173°C	-23°C
condensate bbl/day	4201	4213	4222	+9 bbl
RVP psia	4.08	6.3	8	+1.7
Fuel gas mmscfd	0.1179	0.0934	0.0681	-0.0253

From the optimization table 2, the actual parameters in the field of FPSO X resulting in a condensate volume of 4201 bbls/day at a temperature of 212°C and RVP of 4.08 Psia, while using fuel gas of 0.1179 MMSCFD. After simulation with software, a condensate volume of 4222 bbls/day is obtained at a temperature of 173°C and RVP of 8 Psia, while using fuel gas of 0.0681 MMSCFD.

From this simulation, the plant reduces the temperature, resulting in the Plant Trial Case figures: temperature of 193°C, condensate volume of 4213 bbls, RVP of 6.3 Psia, and fuel gas usage of 0.0934 MMSCFD. Thus, the difference in condensate volume between the optimization simulation and the plant trial is +9 bbls/day, the temperature decreases by 23°C, the RVP is very close to the buyer's requirement of <8.2 Psia at 8, and the fuel gas usage decreases by 0.0253 MMSCFD.

IV. CONCLUSION

From the case study conclude that:

1. Through simulation using the Peng and Robinson method, significant effects of various reboiler temperature parameters on the resulting RVP value, condensate volume, and fuel gas usage were obtained.
2. A conclusion can also be drawn from the simulation results that the reboiler duty temperature greatly influences the reduction of condensate RVP as well as fuel gas usage, and the operational conditions of FPSO at field X are not optimal. This is based on the data that the optimal parameter is at a temperature of 173°C.
3. From the research results, it was found that:
    - In the temperature range of 138-198°C, there is a decrease in RVP by 0.35-0.50 Psia, condensate volume by 1-3 bbls, and fuel gas consumption by 0.0058-0.0065 MMSCFD.
    - In the temperature range of 198-232°C, there is a decrease in RVP by 0.50-0.64 Psia, condensate volume by 3-16 bbls, and fuel gas consumption by 0.0065-0.0066 MMSCFD.
    - In the temperature range of 232-300°C, there is a decrease in RVP by 0.40-0.02 Psia, condensate volume by 16-65 bbls, and fuel gas consumption by 0.0066-0.0070 MMSCFD.

REFERENCES

[1] N. Moghadam and M. Samadi, “Gas Condensate Stabilization Unit: Different Design Approaches,” *Int. J. Chem. Eng. Appl.*, pp. 461–465, 2012, doi: 10.7763/IJCEA.2012.V3.244.

[2] I. Makinde, *Methods of Stabilization of Gas Condensates*. 2018. doi: 10.17605/OSF.IO/7EFW3.

[3] N. Rahmanian, L. S. Bt Jusoh, M. Homayoonfard, K. Nasrifar, and M. Moshfeghian, “Simulation and optimization of a condensate stabilisation process,” *J. Nat. Gas Sci. Eng.*, vol. 32, pp. 453–464, May 2016, doi: 10.1016/j.jngse.2016.04.028.

[4] S. Nooroldin, “Improving a Process Design for the Condensate Stabilization Unit,” *Iran J Chem Chem Eng*, vol. 40, no. 6, 2021.

[5] L. Zhu, H. Liu, Z. Zhang, and Y. Pu, “Simulation analysis of stripping fractionation process of gas condensate treatment and practical application,” *J. Nat. Gas Sci. Eng.*, vol. 34, pp. 216–225, Aug. 2016, doi: 10.1016/j.jngse.2016.04.057.

[6] “Bahmani, M., Shariati, J., & Rouzbahani, A. N. (2017). Simulation and optimization of an industrial gas condensate stabilization unit to modify LPG and NGL production with minimizing CO2 emission to the environment. Chinese Journal of Chemical Engineering, 25(3), 338–346. https://doi.org/https://doi.org/10.1016/j.cjche.2016.07.006”.

[7] “Kazerooni, N. M., Adib, H., Sabet, A., Adhami, M. A., & Adib, M. (2016). Toward an intelligent approach for H2S content and vapor pressure of sour condensate of south pars natural gas processing plant. Journal of Natural Gas Science and Engineering, 28, 365–371. https://doi.org/https://doi.org/10.1016/j.jngse.2015.12.006”.

[8] A. A. Shaikh, A. AlNouss, and T. Al-Ansari, “Optimising the performance of the condensate stabilisation unit in LNG Processes,” in *Computer Aided Chemical Engineering*, vol. 51, Elsevier, 2022, pp. 379–384. doi: 10.1016/B978-0-323-95879-0.50064-3.

[9] N. Tahouni, R. Khoshchehreh, and M. H. Panjeshahi, “Debottlenecking of condensate stabilization unit in a gas refinery,” *Energy*, vol. 77, pp. 742–751, Dec. 2014, doi: 10.1016/j.energy.2014.09.047.

[10] H. Uwitonze, K. S. Hwang, and I. Lee, “Modelling and improving natural gas condensate process with stripping and heat integration,” *Chem. Eng. Process. Process Intensif.*, vol. 118, pp. 71–77, Aug. 2017, doi: 10.1016/j.cep.2017.04.022.

[11] M. M. El-Eishy, G. M. Abdelalim, and T. M. Aboul-Fotouh, “Simulation Study And Optimization Of The Operating Variables Affecting The Performance Of An Existing Condensate Stabilization Unit,” *Pet. Coal*, 2019.

[12] "Khalili-Garakani, A., Kasiri, N., & Ivakpour, J. (2020). Feasibility study on replacement of atmospheric distillation column with new sequences in a natural gas condensate refinery. Computers & Chemical Engineering, 135, 106745. https://doi.org/https://doi.org/10.1016/j.compchemeng.2020.106745".
[13] "Kalugin, Yu. I., Yakovlev, V. V, & Kalugin, A. (2015). Mathematical modeling and optimization of gas- condensate field development. Journal of Natural Gas Science and Engineering, 27, 1195–1204. https://api.semanticscholar.org/CorpusID:96916726".
[14] "Rahmanian, N., Aqar, D. Y., Bin Dainure, M. F., & Mujtaba, I. M. (2018). Process simulation and assessment of crude oil stabilization unit. Asia-Pacific Journal of Chemical Engineering, 13(4). https://doi.org/10.1002/apj.2219".
[15] "Li, C., Peng, Y., Dong, J., & Chen, L. (2015). Prediction of the dew point pressure for gas condensate using a modified Peng–Robinson equation of state and a four-coefficient molar distribution function. Journal of Natural Gas Science and Engineering, 27, 967–978. https://doi.org/https://doi.org/10.1016/j.jngse.2015.09.034".
[16] "Galatro, D., & Marín-Cordero, F. (2014). Considerations for the dew point calculation in rich natural gas. Journal of Natural Gas Science and Engineering, 18, 112–119. https://doi.org/https://doi.org/10.1016/j.jngse.2014.02.002".
[17] "Al-Ali, H. (2021). Process simulation for crude oil stabilization by using Aspen Hysys. Upstream Oil and Gas Technology, 7. https://doi.org/10.1016/j.upstre.2021.100039".
[18] M. Ehsan, U. Ali, F. Sher, H. M. Abubakar, and M. F. U. Basit, "Dynamic and Steady-State Simulation Study for the Stabilization of Natural Gas Condensate and CO2 Removal through Heating and Pressure Reduction," *ChemEngineering*, vol. 7, no. 5, p. 78, Aug. 2023, doi: 10.3390/chemengineering7050078.