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Energy analysis and parameter optimization of TEG dehydration utilizing the NSGA-II algorithm

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Abstract: *To ensure compliance with dew point requirements and achieve low energy consumption in the natural gas dehydration process, this study utilizes Aspen HYSYS to simulate the natural gas dehydration process, using a gas field gathering station as an illustrative example. Through an in-depth analysis of operational parameters, we have successfully identified the optimal variables that significantly impact the energy consumption of the dehydration system. The Box-Behnken design (BBD) experimental design approach is employed, and parameter optimization is performed using the non-dominated sorting genetic algorithm (NSGA-II). Our findings indicate that variations in Tri ethylene glycol (TEG) circulation rate, reboiler temperature, and steam stripping rate are highly sensitive to energy consumption. Analysis of the Pareto front reveals that under similar dew point conditions before and after optimization, there is a notable reduction in specific energy consumption by 4.18% compared to the pre-optimization state. Conversely, when specific energy consumption is comparable, optimization results show a decrease in dry gas dew point by 1.92°C after optimization. Furthermore, comparison with optimization results obtained using HYSYS's built-in optimizer demonstrates reductions in both TEG circulation rate and steam stripping rate. In summary, the NSGA-II algorithm demonstrates superiority in reducing energy consumption and optimizing parameters by providing globally optimal solutions. This research presents an efficient solution for optimizing energy consumption in natural gas dehydration while enhancing process efficiency and economic benefits.*

Keywords: *TEG dehydration; Mult-objective optimization; energy consumption; NSGA-II*

1. Introduction

The dehydration process of natural gas plays a pivotal role in the transportation of gas fields[1,2]. By implementing dehydration treatment, the formation and blockage of hydrates during pipeline transportation can be effectively mitigated[3–5]. Moreover, this process inhibits the corrosion rate caused by acidic substances in natural gas on pipelines and equipment while reducing the energy consumption of compressors[6,7]. However, it is worth noting that the dehydration process itself consumes a substantial amount of energy. Currently, the TEG solvent absorption method is widely employed for natural gas dehydration[8,9]. Therefore, optimizing the parameters of the TEG process to minimize energy consumption without compromising dehydration requirements holds significant importance [10,11].

To date, numerous studies have been conducted on the optimization of process parameters for TEG. For instance, Renanto et al.[1] refined the regeneration process of TEG and compared the effects of inert gas stripping, partial condensation, reduced-pressure distillation, and the Drizo process on lean TEG and dew point reduction. Bahadori et al.[9], aiming to minimize the environmental impact of flash gas and regenerated gas, optimized parameters in areas such as waste gas recovery, TEG-rich liquid stripping, and low-pressure stripping of TEG-rich liquid. These efforts resulted in a significant reduction in reboiler energy consumption[12–14]. Current research primarily focuses on process improvement and energy consumption analysis, while neglecting the optimization of parameters within the dehydration process. Therefore, addressing the issue of multi-objective optimization is of utmost urgency. Consequently, this study employs Aspen HYSYS to simulate the natural gas dehydration process flow and selects influential parameters as optimization variables. Furthermore, it utilizes response surface methodology to design experimental schemes and establish multi-objective regression functions[15]. Finally, the NSGA-II algorithm is applied for optimization to effectively balance both dehydration depth and comprehensive energy consumption.

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2. Process simulation and parameters analysis

2.1 TEG process simulation

The process flow of TEG dehydration is illustrated in Fig. 1. Wet natural gas undergoes separation to remove liquid and solid impurities using a separating space located in the bottom of absorber, with the liquid portion being directed to the wastewater treatment system. The untreated as enters the absorber from the bottom, where it comes into contact with lean TEG solution entering from the top, effectively eliminating moisture content from the gas. Subsequently, the dried gas is separated in a dry gas separator before being exported. The TEG-rich liquid exits at the lower part of the absorption tower, passes through a filter, and enters the regeneration tower for heating purposes. It then proceeds to a flash drum for pressure reduction, whereby any separated flash gas is directed back to the raw gas tank. After flashing occurs, resulting in reduced pressure within the drum, TEG-rich liquid flows out from its bottom and enters the rectification column to be heated by hot vapor generated from TEG reboiler and enters into the rich TEG separator to separate the light hydrocarbon dissolved into rich TEG solution. After pass of the rich TEG filter and TEG plate heat exchanger in sequence, the hot rich TEG solution goes into the rectification column and the TEG reboiler. Inside the two equipment, distillation and rectification processes occur, vaporizing moisture through reboiling at its base using a reboiler unit. Lean TEG is introduced from this reboiler unit as it passes through a lean liquid stripping column before entering the TEG buffer tank. Following cooling via heat exchange mechanisms and subsequent pressurization using circulation pumps, it is fed into the top section of the absorption tower to complete one cycle.

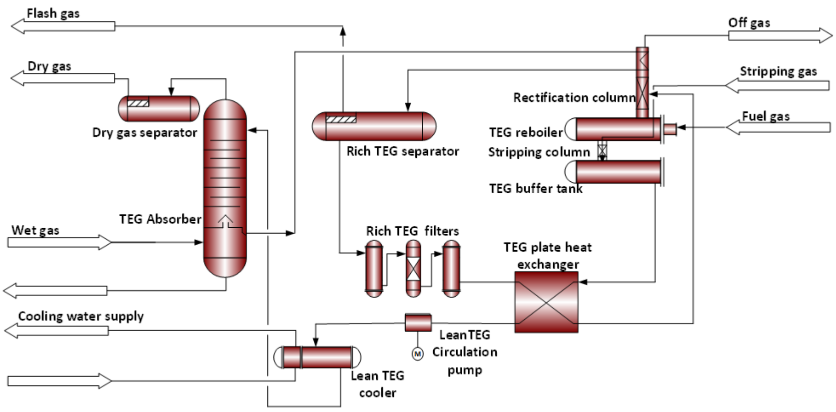

Figure 1: TEG dehydration process flow diagram

In this TEG process, a stripping column is incorporated to further enhance the purification of the lean solution, thereby increasing the concentration of TEG in the process. Lowering the outlet temperature of the reboiler proves advantageous for augmenting dehydration efficiency. Consequently, this process is widely applied in China and is considered a prototypical dehydration process flow.

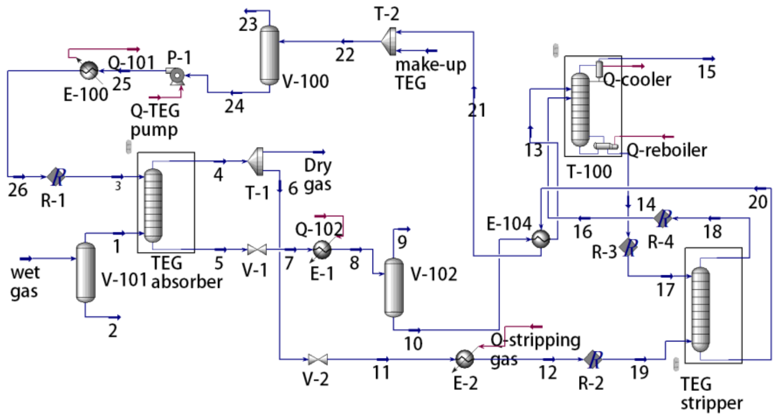

Figure 2: TEG dehydration process simulation process

Due to the exceptional accuracy of Aspen HYSYS software in oil and gas treatment, natural gas condensate recovery, and liquefaction processes, the dehydration process was established on the robust

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platform of HYSYS software. The thermodynamic parameters of the gas-liquid two-phase system were calculated using the Peng-Robinson (PR) equation, as illustrated in Fig. 2.

The established model was utilized to obtain a steady-state solution by randomly selecting a set of operational data, and the corresponding results are presented in Table 1. Comparative analysis reveals that the dew point of the dry gas at the outlet satisfies the design requirements, exhibiting a relative error of merely 0.27% when compared to actual values. The relative errors for both lean TEG temperature entering the absorption tower (2.77%) and reboiler temperature (1.56%) can be attributed to two factors: firstly, the idealized adsorption-regeneration modeling within Hysys; secondly, inherent inaccuracies in field test parameters themselves. Overall, these relatively minor discrepancies affirm the rationality and reliability of our model, enabling its use for further research.

2.2 Energy consumption of the key parameters

Through the analysis of the process flow, it was determined that the primary energy-consuming equipment in the dehydration system includes the lean solution circulation pump (Q-TEG pump), the reboiler located at the bottom of the regeneration tower (Q-reboiler), and the stripping gas heater (Q-stripping gas heater)[5,16]. Building upon previous research on factors influencing the dehydration process and based on the operational parameters presented in Table 1, a quantitative analysis and selection of optimization parameters were conducted. From an energy consumption perspective (Q-TEG pump), it was observed that the energy consumption of the lean solution circulation pump decreases with increasing raw gas temperature and reboiler bottom pressure, while it increases with increasing TEG circulation rate, stripping gas volume, and reboiler temperature. The energy consumption exhibits an initial increase, followed by a decrease, and then another increase as the raw gas pressure rises. Elevated raw gas temperatures reduce the solubility of water vapor in the TEG solution, which subsequently impacts absorption efficiency and energy consumption. Higher raw gas pressures can lead to inadequate gas-liquid contact within the absorption tower, thereby increasing pressure drop across trays and affecting dehydration effectiveness. However, minimal influence on energy consumption of the lean solution circulation pump is observed with varying pressure levels shown as Fig. 3. The dimensionless parameters are considered as independent variables, while the energy consumption of the lean liquid circulating pump is regarded as the dependent variable. Sensitivity analysis results are obtained and are presented in Fig. 4. A higher slope indicates a stronger parameter sensitivity. Thus, it is identified that the TEG circulation amount is the key parameter influencing the energy consumption of the lean liquid circulating pump. For every increase of 1 kmol/h in circulation amount, there is an approximate rise of 950 kJ/h in energy consumption.

Table 1: Comparison between operating data and simulation data

	Flow rate kmol/h	Temp. of wet gas ℃	Pressure of wet gas MPa	Temp. of TEG ℃	Temp. of reboiler ℃	Dew point of dry gas ℃	Water content of dry gas kmol/m^3
Operating data	2560	30.71	5.5	42	182	-10.99	0.0557
Simulation data	2560	30.71	5.5	43.2	184.9	-11.02	0.0541

From the perspective of energy consumption (Q-reboiler), the reboiler's energy consumption decreases with an increase in stripping gas volume and bottom pressure of the regeneration tower, while it increases with an increase in raw gas pressure, TEG circulation rate, and reboiler temperature. As the temperature of the raw gas rises, initially there is a slow decrease in reboiler energy consumption followed by a rapid decrease until it stabilizes as shown in Fig.5. Similarly, after dimensionless treatment of parameters and considering reboiler energy consumption as the dependent variable, Fig. 6 presents the results of sensitivity analysis. The key parameter influencing reboiler energy consumption is its temperature; for every 2°C rise in temperature, there is an approximate increase of 14,900 kJ/h in energy consumption. Fig. 7 presents Influence of operating parameters on energy consumption of stripping gas heater, the wet gas temperature rises, the stripping gas flowrate decreases. This implies that less stripping gas is needed for the dehydration process at higher temperatures, possibly because the gas contains less moisture at elevated temperatures. Increasing the wet gas pressure, however, increases the stripping gas flowrate. Higher pressures may require more stripping gas to maintain dehydration efficiency. Higher TEG circulation flowrate leads to a reduced stripping gas flowrate. Increased TEG enhances dehydration efficiency, thereby reducing the amount of stripping gas required. Similarly, higher pressures in the regeneration tower result in a greater stripping gas flowrate. Increased pressure in the tower may necessitate additional stripping gas to effectively remove water from the TEG. The stripping gas flowrate decreases as reboiler temperatures rise. At higher temperatures, water is removed more efficiently from the TEG, reducing the need for stripping gas.

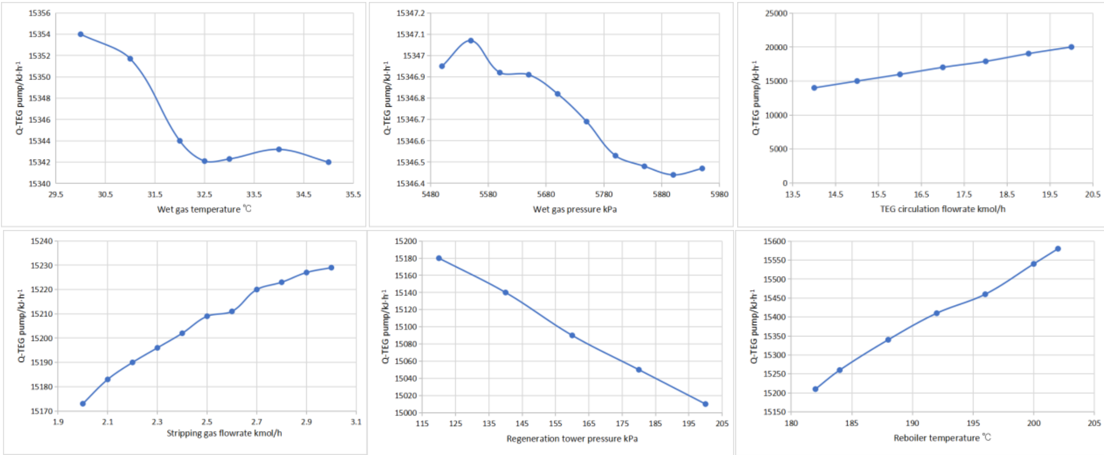

Figure 3: Influence of operating parameters on energy consumption of lean liquid circulating pump

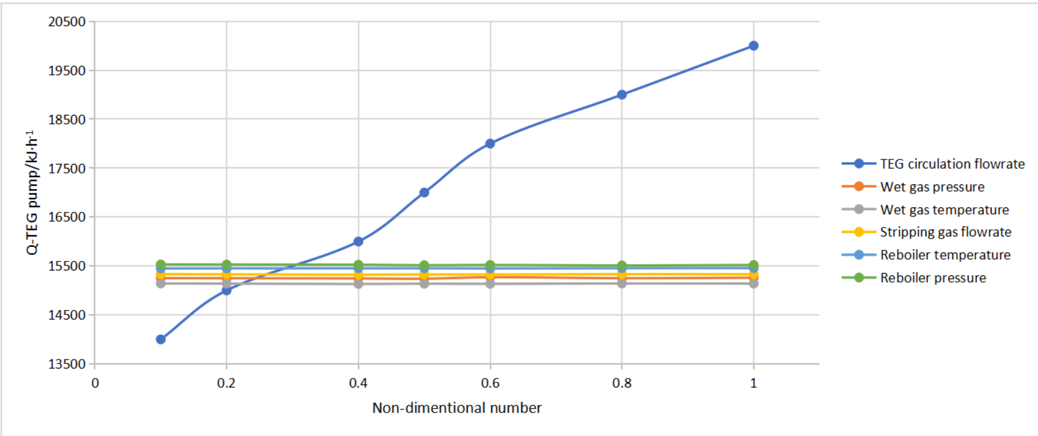

Figure 4: Sensitivity analysis of lean liquid circulation pump energy consumption

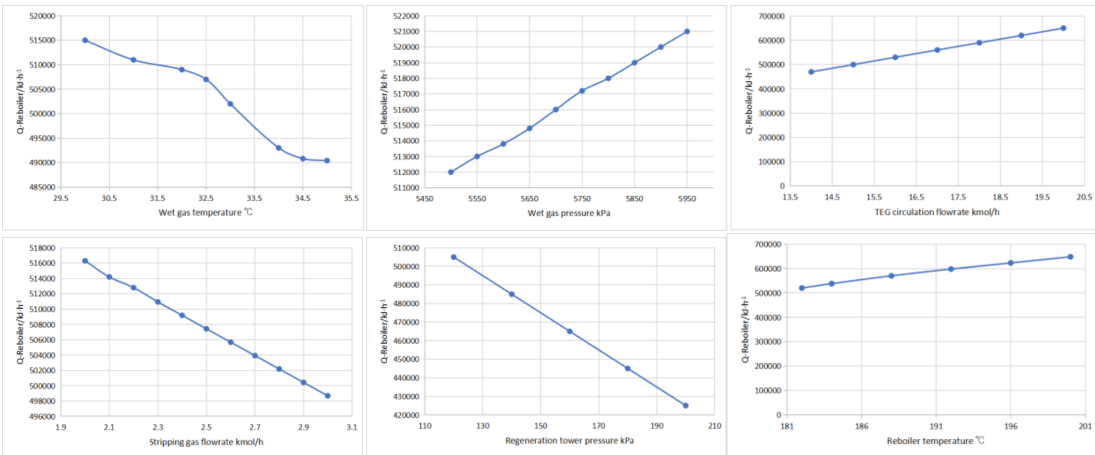

Figure 5: Influence of operating parameters on energy consumption of reboiler

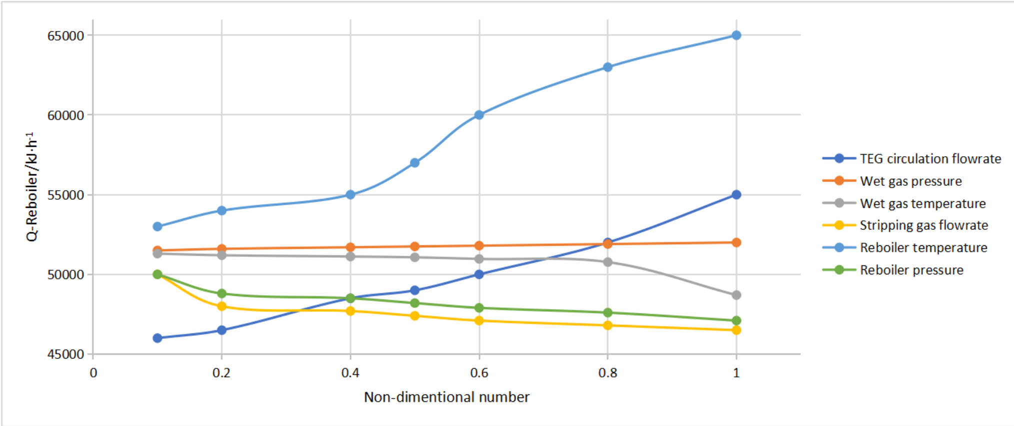

Figure 6: Sensitivity analysis of reboiler energy consumption

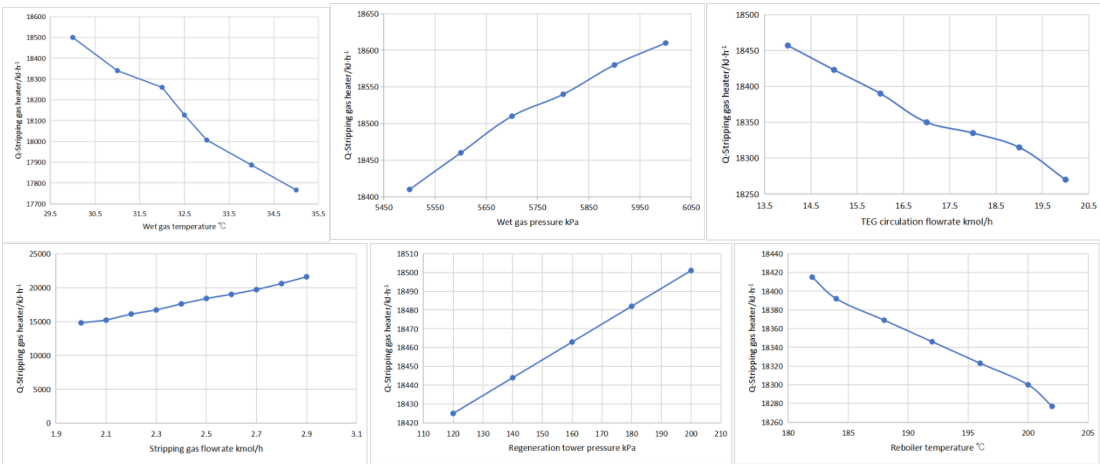

Figure 7: Influence of operating parameters on energy consumption of stripping gas heater

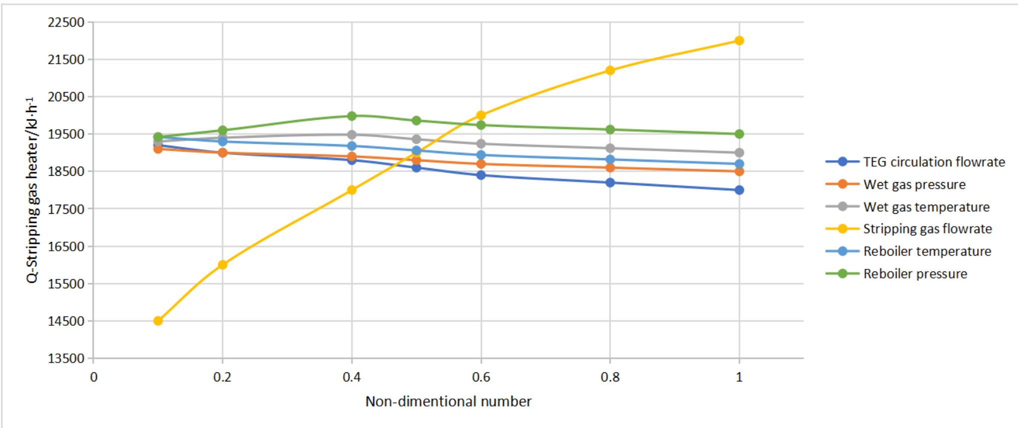

Figure 8: Sensitivity analysis of stripping gas heater energy consumption

From the perspective of energy consumption (Q-stripping gas heater), the energy consumption of the stripping gas heater decreases with an increase in raw gas temperature, TEG circulation rate, and reboiler temperature, while it increases with an increase in raw gas pressure, stripping gas volume, and bottom pressure of the regeneration tower. Similarly, by utilizing dimensionless processed parameters as independent variables and considering the energy consumption of the stripping gas heater as a dependent variable, Figure 8 presents the results of sensitivity analysis. The primary parameter influencing the energy consumption of the stripping gas heater is the volume of the stripping gas. With every increment of 0.1 kmol/h in gas volume, there is an approximate increase in energy consumption by 740 kJ/h.

ISSN 2616-5775 Vol. 7, Issue 10: 147-156, DOI: 10.25236/AJCIS.2024.071020

3. Multi-objective functions

3.1 Evaluation functions

Based on the aforementioned analysis, it is evident that among the energy-consuming equipment, the reboiler exhibits the highest proportion of energy consumption[17,18]. Furthermore, there is a direct correlation between energy consumption and dehydration effectiveness, indicating that deeper levels of dehydration result in increased energy utilization[19,20]. To ensure scientific validity, the normalization of energy consumption for all three devices was performed, and specific energy consumption was introduced as a measurement parameter.

$$W_{eq} = \eta Q_{reb}\left(\frac{T_{reb} + 10 - 313.15}{T_{reb} + 10}\right) + W_{pump} + W_{hot} \quad (1)$$

Using the TEG circulation rate (x1), the reboiler temperature (x2), and the amount of stripping gas (x3) as independent variables, a multi-objective optimization function for the equivalent work (Weq) and the dew point of the exit dry gas (Tdew) was established. A three-factor distribution analysis was conducted using the Design Expert software, as shown in Table 2. An experimental design scheme was constructed using the Box-Behnken Design (BBD) method, and simulation results were obtained through the HYSYS software shown as Table 3.

Table 2: Distribution of factors

Factor level	Parameters		
	x_1 kmol/h	x_2 °C	x_3 kmol/h
-1	14	182	2
0	17	191	2.5
1	20	200	3

Table 3: Comparison between operating data and simulation data

Experimental scheme			Simulation results	
x_1 kmol/h	x_2 °C	x_3 kmol/h	W_{eq} kJ/h	T_{dew} °C
17	182	3	197000	-11.59
17	191	2.5	224747	-14.39
20	191	2	258724	-7.62
14	200	2.5	214642	-26.77
17	200	3	258799	-25.49
17	200	2	257211	-15.86
17	191	2.5	227028	-14.18
17	182	2	197287	-4.77
20	182	2.5	222349	-5.81
14	182	2.5	167482	-11.99
14	191	2	190479	-14.00
17	191	2.5	225562	-14.32
17	191	2.5	226010	-14.32
14	191	3	195060	-23.26
17	191	2.5	227812	-14.08
20	191	3	260251	-14.52
20	200	2.5	293041	-17.19

The experimental data were fitted with multivariate quadratic regression model to derive the regression functions for the equivalent work (Weq) and the dew point of the exit dry gas (Tdew).

$$W_{eq} = 26638.10 - 22999.25x_1 + 323.97x_2 - 40316.48x_3 + 217.88x_1x_2 - 509.13x_1x_3 + 104.19x_2x_3 - 183.25x_1^2 - 2.51x_2^2 + 6184.61x_3^2 \quad (2)$$

$$R^2 =- 43.99 - 2.66x_1 + 0.96x_2 + 10.82x_3 + 0.03x_1x_2 + 0.38x_1x_3 - 0.15x_2x_3 - 0.09x_1^2 - 4.75 \times 10^{-3}x_2^2 + 0.85x_3^2 \quad (3)$$

The regression model was subjected to an analysis of variance, as presented in Table 4. Both parameters exhibited p-values below 0.01, indicating a remarkable level of precision in the fit of the

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regression model. Moreover, all signal-to-noise ratios exceeded 4, implying robust reliability and significance of the model. Additionally, the three correlation coefficients were substantial, signifying a strong concordance between predicted values and actual observations with negligible errors.

Table 4: Results of regression equation variance analysis

Items	Value	
	Equation (2)	Equation (3)
p-value	<0.001	<0.001
SNR (Signal to Noise Rati	1134.096	35.646
R^2	0.999	0.999
R_{adj}^2	0.998	0.998
R_{pre}^2	0.995	0.993

3.2 Optimization strategy

The NSGA-II is an adaptive, elitist, multi-objective genetic algorithm that incorporates a rapid non-dominated sorting mechanism[21–23]. This algorithm ensures the preservation of optimal solutions, thereby enhancing convergence properties and search performance for potential parallel solutions within a relatively short computational time[24,25]. However, it is often observed that when the equivalent work (Weq) reaches its optimum, simultaneous optimization of the dew point of the exit dry gas (Tdew) may not be achieved. This conflict between the two objective functions indicates an infeasibility of obtaining a single definitive solution, necessitating the derivation of a compromise solution known as the Pareto set[26,27]. The Pareto front, formed by this set, represents a surface that embodies trade-off solutions achieved through the utilization of the NSGA-II algorithm to solve equations (2) and (3). This approach facilitates the exploration of diverse non-dominated solutions constituting the Pareto front, which is pivotal in addressing multi-objective optimization problems aiming for optimal balance amidst conflicting objectives.

The algorithmic steps for NSGA-II are as follows: (1) Initialization: Random numbers are generated within the range space of decision variables to form the initial parameter values. (2) Evaluation and Sorting: The objective functions are inputted, and the fitness of each individual in the population is calculated. Subsequently, a fast non-dominated sorting is applied to individuals, followed by computation of their crowding distance. Crossover and mutation operations are then performed to generate the next generation of individuals. (3) Termination Check: The total number of evolutionary generations serves as the limiting condition. If the output results fail to meet the termination criteria, the algorithm returns to step (1). Conversely, if the termination criteria are satisfied, the process proceeds towards outputting the Pareto front. This iterative process continues until a satisfactory set of non-dominated solutions is obtained that effectively represents trade-offs between conflicting objectives. The Pareto front encompasses these optimal solutions wherein no solution can enhance one objective without deteriorating another within context.

The population size is set to 100, and the number of evolutionary generations is set to 10,000. By employing a crossover factor of 0.8, the optimal Pareto front is obtained as depicted in Fig. 9. The red dot A in the figure represents the current operational condition. From the Pareto front, optimized operating points B and C can be derived for this condition along with their corresponding operational parameters and objective function values as presented in Table 5. While maintaining a dew point close to its current value, an equivalent work reduction (Weq) of 8373.19 kJ/h is achieved, resulting in a decrease of 4.18% compared to the pre-optimization state. Additionally, by keeping the dew point (Tdew) near its initial value, it experiences a reduction of 1.92°C which corresponds to a significant decrease of 17.47%. In practical production scenarios, diverse solution sets can be selected based on Fig. 9 to cater to various operating conditions.

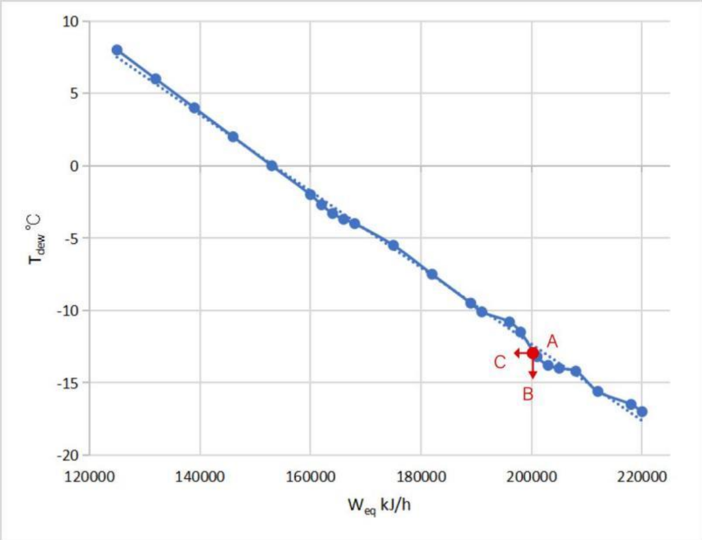

Figure 9: Pareto frontier

3.3 Results comparison

In order to validate the scientific nature of the NSGA-II algorithm, we employed the optimizer of HYSYS software to solve it. The objective function, decision variables, and constraint conditions were established based on the aforementioned criteria. The Box (black box) and Mix (mixed) algorithms were utilized for solving purposes. Table 6 demonstrates the application scope of these two algorithms with a step size of 0.5 for decision variables, while Table 7 presents the optimization results obtained. Following optimization, there was a reduction in both TEG circulation amount and stripping gas usage; however, no optimization was observed in reboiler temperature. Additionally, Weq decreased while Tdew increased; nevertheless, energy consumption did not exhibit as favorable an outcome as that achieved by the NSGA-11 algorithm. To summarize, the NSGA-II algorithm excels in reducing energy consumption and optimizing parameters including three operating parameters—thus indicating that it represents a global optimal solution.

Table 5: Optimal solution before and after optimization

Operating point	W_{eq}	T_{dew}	TEG circulation flowrate kmol/h	Temp. of reboiler ℃	Stripping gas flowrate kmol/h
A	200000	-10.99	17.00	182	2.50
B	191627	-11.04	15.70	181	2.43
C	200510	-12.91	18.50	184	2.62

Table 6: Application scope of optimization algorithm

Method	Unconstrained function	Inequality constraint function	Equal-constraint function	Calculated derivative
Box	✓	✓	×	×
Mix	✓	✓	×	✓

Table 7: Optimization results of HYSYS built-in optimizer

Operating point	W_{eq}	T_{dew}	TEG circulation flowrate kmol/h	Temp. of reboiler ℃	Stripping gas flowrate kmol/h
A	200000	-10.99	17.00	182	2.50
Box	197521	-10.21	15.50	182	2.46

ISSN 2616-5775 Vol. 7, Issue 10: 147-156, DOI: 10.25236/AJCIS.2024.071020

4. Conclusion

Utilizing the Hysys software as a platform, we established a comprehensive model of an on-ground natural gas dehydration system. We conducted a screening of operational parameters that impact the dehydration process and introduced objective functions such as equivalent work (Weq) and dry gas dew point (Tdew). By employing the Box-Behnken Design (BBD) experimental design and implementing the NSGA-II algorithm, we successfully achieved target optimization of process parameters, leading to the following noteworthy conclusions.

(1) The TEG circulation rate, reboiler temperature, and amount of stripping gas are the key parameters that significantly impact the energy consumption of the lean solution circulation pump, reboiler, and stripping gas heater respectively.

(2) The dew point was effectively maintained at the current operating state, resulting in a reduction of Weq by 8373.19 kJ/h, equivalent to a decrease of 4.18%. Simultaneously, Tdew was lowered by 1.92°C while ensuring that the equivalent work (Weq) remained close to its present state, corresponding to a decrease of 17.47%.

(3) When utilizing the built-in optimizer of the Hysys software, both the TEG circulation rate and stripping gas quantity were reduced; however, optimization of the reboiler temperature was not achieved. In contrast, the NSGA-II algorithm exhibits superiority in terms of energy consumption reduction and parameter optimization by attaining the global optimal solution.

References

[1] Renanto R, Affandy S A, Kurniawan A, et al. A novel process synthesis of a dehydrating unit of domestic natural gas using TEG contactor and TEG regenerator[M]//Computer Aided Chemical Engineering. Elsevier, 2022, 49: 235-240.
[2] Gui C, Lei Z. Natural gas dehydration using glycol absorbents[M]//Advances in Natural Gas: Formation, Processing, and Applications. Elsevier, 2024: 79-109.
[3] Haghighatjoo F, Rahimpour M R. Process modeling and simulation of natural gas dehydration by absorption technology[M]//Advances Natural Gas: Formation, Processing, and Applications. Volume 8: Natural Gas Process Modelling and Simulation. Elsevier, 2024: 165-184.
[4] Azhari S N, Hussein N B, Putra Z A. Process modeling and analysis of a natural gas dehydration process using tri-ethylene glycol (TEG) via Symmetry[M]//Chemical Engineering Process Simulation. Elsevier, 2023: 181-200.
[5] Cong W C ,Gang X Y ,Ping L , et al.Enhanced Regeneration of Triethylene Glycol Solution by Rotating Packed Bed for Offshore Natural Gas Dehydration Process: Experimental and Modeling Study[J].Chemical Engineering and Processing - Process Intensification,2021,168:108562.
[6] Isa A M ,Eldemerdash U ,Nasrifar K .Evaluation of potassium formate as a potential modifier of TEG for high performance natural gas dehydration process[J].Chemical Engineering Research and Design,2013,91(9):1731-1738.
[7] Zainab A A ,M. A G ,Reza G V .Simultaneous energy and environment-based optimization and retrofit of TEG dehydration process: An industrial case study[J].Process Safety and Environmental Protection,2021,147:972-984.
[8] Darwish, Naif A. and Nidal Hilal. Sensitivity analysis and faults diagnosis using artificial neural networks in natural gas TEG-dehydration plants[J].Chemical Engineering Journal,2008,137:189-197.
[9] Bahadori A ,Vuthaluru B H .Simple methodology for sizing of absorbers for TEG (triethylene glycol) gas dehydration systems[J].Energy,2009,34(11):1910-1916.
[10] Twu H C ,Tassone V ,Sim D W , et al.Advanced equation of state method for modeling TEG–water for glycol gas dehydration[J].Fluid Phase Equilibria,2005,228-229:213-221.
[11] Ranjbar H ,Ahmadi H ,Sheshdeh K R , et al.Application of relative sensitivity function in parametric optimization of a tri-ethylene glycol dehydration plant[J].Journal of Natural Gas Science and Engineering,2015,25:39-45.
[12] Eldemerdash N U ,Abdrabou M ,Sheltawy E T S , et al.Assessment of chemical enhancement and energy consumption of natural gas dehydration processes[J].Gas Science and Engineering, 2024, 123: 205226.
[13] Eldemerdash U ,Kamarudin K .Assessment of new and improved solvent for pre-elimination of BTEX emissions in glycol dehydration processes[J].Chemical Engineering Research and Design, 2016, 115: 214-220.
[14] Chebbi R ,Qasim M ,Jabbar A N .Optimization of triethylene glycol dehydration of natural

ISSN 2616-5775 Vol. 7, Issue 10: 147-156, DOI: 10.25236/AJCIS.2024.071020

gas[J].Energy Reports,2019,5:723-732.

[15] Salman M ,Zhang L ,Chen J .A computational simulation study for techno-economic comparison of conventional and stripping gas methods for natural gas dehydration[J].Chinese Journal of Chemical Engineering,2020,28:2285-2293.

[16] Li W ,Zhuang Y ,Zhang L , et al.Economic evaluation and environmental assessment of shale gas dehydration process[J].Journal of Cleaner Production,2019,232:487-498.

[17] Petropoulou G E ,Carollo C ,Pappa D G , et al.Sensitivity analysis and process optimization of a natural gas dehydration unit using triethylene glycol[J].Journal of Natural Gas Science and Engineering, 2019,71:102982.

[18] Satyro A M ,Schoeggl F ,Yarranton W H .Temperature change from isenthalpic expansion of aqueous triethylene glycol mixtures for natural gas dehydration[J].Fluid Phase Equilibria, 2011, 305(1):62-67.

[19] Neagu M ,Cursaru L D .Technical and economic evaluations of the triethylene glycol regeneration processes in natural gas dehydration plants[J].Journal of Natural Gas Science and Engineering, 2017,37:327-340.

[20] Dalane K ,Josefsen T N ,Ansaloni L , et al.Thermopervaporation for regeneration of triethylene glycol (TEG):Experimental and model development[J].Journal of Membrane Science, 2019,588:117205.

[21] Tiago P ,Rodrigo B ,Francisco L J A , et al.Triethylene glycol recovery by an energetically intensified thermosyphon-assisted falling film distillation unit: Experimental assessment on a pilot-scale unit and in-silico comparison with a conventional column from natural gas processing[J]. Chemical Engineering and Processing - Process Intensification,2022,176

[22] Jaćimović M B ,Genić B S ,Djordjević R D , et al.Estimation of the number of trays for natural gas triethylene glycol dehydration column[J].Chemical Engineering Research and Design,2010,89(6):561-572.

[23] Erik L. Estimation of tray efficiency in dehydration absorbers[J]. Chemical Engineering and Processing 2003,42:867-878.

[24] Rahimpour R M ,Jokar M S ,Feyzi P , et al.Investigating the performance of dehydration unit with Coldfinger technology in gas processing plant[J].Journal of Natural Gas Science and Engineering, 2013,12:1-12.

[25] Hongji R ,Aijun Y ,Zongxian D , et al.Parameter screening and optimized gaussian process for water dew point prediction of natural gas dehydration unit[J].Process Safety and Environmental Protection,2023,170:259-266.

[26] Wang F ,Zhao J ,Hoang V V .Prediction of variables involved in TEG Dehydration using hybrid models based on boosting algorithms[J].Computers and Chemical Engineering,2024,188:108747.

[27] Sakheta A ,Zahid U .Process simulation of dehydration unit for the comparative analysis of natural gas processing and carbon capture application[J].Chemical Engineering Research and Design, 2018,137:75-88.