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THE OPTIMUM DECISION OF OIL AND GAS PRODUCTION SPREADSHEET MODELLING

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A R T I C L E I N F O

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Optimal Production, Mature Wells, Choke Valve Opening, Spreadsheet Modeling

Kata Kunci:
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Abstract. *The optimum revenue of an oil and gas industry is subject to the production volume deliverability and relatively volatile product market price which depends on demand and supply level. Naturally, mature production wells will be dominantly producing water instead of oil and gas, meanwhile, the central processing facilities are having their limited capacity to handle it. This study intends to gain the optimum oil and gas production in mature fields by deciding the opening of well choke valves and considering process facilities limitations as constraints. The model is developed using a simplex LP-based spreadsheet. Three wellhead facilities with a total of forty-seven active producing wells gas, oil, and water data are taken as input parameters. The developed model is validated using the last ten days' actual production data to identify the error margin consistency, a total of 1,410 data combinations were used. It results in an average error margin of 4.57%-gas and 0.9%-oil.*

Abstrak. Pendapatan optimal dari industri minyak dan gas tergantung pada kemampuan pengiriman volum produksi dan harga pasar produk yang relatif fluktuatif yang tergantung pada tingkat permintaan dan penawaran. Secara alami, sumur produksi yang sudah berumur akan secara dominan menghasilkan air daripada minyak dan gas, sementara itu, fasilitas pemrosesan pusat memiliki kapasitas terbatas untuk menanganinya. Penelitian ini bertujuan untuk mendapatkan produksi minyak dan gas yang optimal di lapangan yang sudah berumur dengan memberikan acuan pembukaan katup sumur dan dengan mempertimbangkan keterbatasan fasilitas proses sebagai kendala. Model ini dikembangkan menggunakan lembar kerja berbasis LP simpleks. Tiga fasilitas sumur dengan total empat puluh tujuh sumur produksi gas, minyak, dan air aktif, diambil sebagai parameter input. Model yang dikembangkan divalidasi menggunakan data produksi aktual sepuluh hari terakhir untuk mengidentifikasi konsistensi margin kesalahan, total 1.410 kombinasi data digunakan.

PENDAHULUAN

Most major oil and gas industries planned to produce for 20 to 30 years or more (Lei et al., 2022). In general, currently, several oil and gas production facilities are facing the problem of production decreasing, especially in mature production wells (Bakker et al., 2021). These wells have passed their peak of production and are heading toward the end of their economic value (Essien, 2016; Jha et al., n.d.). Optimum decisions in oil and gas production mean that production operators must make or have strategic decisions including considering factors such as fluctuations in world oil prices (Popoola et al., 2015), and limited processing capacity, which will directly affect the decision-making process, especially for production facilities with marginal profits.

The production facilities to be modeled in this study have been built equipped with three wellhead production facilities which consist of two wellhead platforms and one subsea production well, and a centralized processing facility. By design, there is a total of thirty maximum well slots in each wellhead platform, not all well slots are drilled and connected to its processing facility. The central facility is processing the fluids which are oil, gas, and produced water.

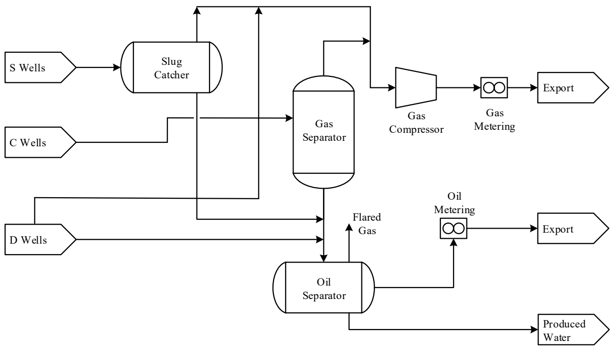

Figure 1. Simplified Process Flow Diagram

Refer to Figure 1, C, and S wells are 4-8 km distance apart from the central processing facilities, connected through a subsea pipeline configuration. Pressure drops occurred during multiphase fluids transportation. To reduce the slugging effect due to low gas mixtures in multiphase flow, the amount of gas flow from C and D wells is limited to certain minimum values. Fluids produced by C wells will be separated based on their density and combined with D and S wells on the gas phase side. A similar connection to the oil and produced water phase side. Several minimum numbers of S wells should be produced according to the Gas Sales Agreement (GSA). In D, the artificial wells (retrofitted gas lift) are expected to be operated by at least four wells out of five.

Current active wells consist of 21 at C, 19 at D, and 7 at S wells, which produce oil, gas, and water in certain amounts and fractions. Each production well is controlled by an individual choke valve. Due to the significant decrease in the well's pressure compared to the initial operating conditions, currently, the choke valve is only to be operated either fully open (100%) or fully close (0%), not functioning to regulate the pressure.

KAJIAN PUSTAKA

In 1947, George Dantzig developed an efficient method, the simplex algorithm (Ronn, 1987). In 1952, George Dantzig developed the first linear programming solver, the "Dantzig-Wolfe Decomposition," which was implemented on the first computer, the UNIVAC I. This solver allowed more complex problems to be resolved and acted as the foundation for future advancements in linear programming.

Linear programming (LP) is one of the solving tools in optimization cases. Linear programming (LP) is a mathematical optimization technique used to find the best possible solution to a problem subject to linear constraints. The basic mathematical formulation of a linear programming problem involves three main components: objective function, constraints, and decision variables. The development of the simplex LP-based method is facilitated by imposing two requirements on the constraints of the problem, all non-negative constraints, and variables (Taha, 2007). LP consists of 3 (three) basic components, which are decision variables, objectives, and constraints. A mathematical programming formulation has been developed to optimize the production and the model is tested on a real field (Lei et al., 2022). The objective function of linear programming represents the quantity that needs to be maximized, minimized, or set at a certain value. It is typically denoted by Z and written in the general form $Z = c_1x_1 + c_2x_2 + \cdots + c_nx_n$, where $c_1, c_2, \ldots, c_n$are the coefficients of decision variables $x_1, x_2, \ldots, x_n$. Whilst constraints represent the limitation of the decision variables. The restrictions are expressed as a set of linear inequalities or equations that are denoted by $A_x \leq b$ or $A_x = b$.

METODE PENELITIAN

3.1 Operating Conditions and Parameters

A numerical approach is used to include the consideration of production or process parameter losses in several parts of the operating equipment or segments such as choke valve, pipeline, gas separator, and slug catcher, including their quantified efficiency of separation approach among gas and liquid phase. For example, 99% gas efficiency means that by volume, 99%-volume gas will flow to the gas piping system, and there is 1%-volume will be carried over to the liquid side. Vice versa to oil and water phase flow efficiency.

Table 1. Maximum and minimum limitations of process parameters

Constraints			Unit
C wells minimum flow	>=	9	MMscfd
Flared Gas	>=	0.27	MMscfd
Produced water	<=	3000	BWPD
Compressor suction flow	>=	40	MMscfd
D wells minimum flow	>=	11	MMscfd
Number of S wells open	>=	6	
Number of gas lift wells open	>=	5	

The flow of flared gas needs to be maintained at a certain volumetric flow rate (0.27 MMscfd) to ensure the quality of the combustion system and to maintain the operating pressure of process equipment. In addition, on the produced water side, according to the facility limitation of the water handling system, a total amount of 3,000 BWPD shall be limited as the maximum number. In the gas compression system, there is a minimum volumetric flow to be maintained according to the compressor capacity, which is 40 MMscfd. This is to ensure that the compressor will be operating under its optimum operating zone. To provide facility electricity and power, an amount of 6.2 MMscfd fuel gas shall be allocated and taken from the discharge of the compression system.

Table 2. The efficiency of the pipeline system, pressure vessel, and separation process

	Loss	Efficiency			Price (USD)
		Gas	Oil	Water	
Choke Valve	0.5%				
C Wells Pipeline	0.2%				
S Wells Pipeline	0.2%				
Gas Separator	0.1%				
Slug Catcher	0.1%				
Compressor Suction		99.0%	0.5%	0.5%	
Condensate Separator		1.0%	99.5%	99.5%	
Gas Price					12,000
Oil Price					80
Fuel Gas Usage	6.2 MMscfd				

3.2 Mathematical Numerical Model

Optimization is a form of decision-making based on one or more objective factors under certain conditions and limitations. In this section, process parameters, decision variables, constraints conditions, and correlated objective functions will be expressed in a mathematical model as a linear programming equation.

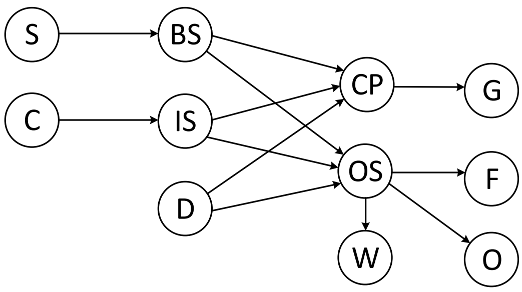

Figure 2. Simplified node modeling according to the process flow diagram

Annotation: S: S Wells, C: C Wells, BS: Slug Catcher, IS: Inlet Separator, D: D Wells, CP: Compressor, OS: Oil Separator, W: Water, G: Gas, F: Flare, O: Oil.

		C Wells		D Wells		S Wells	
Gas	MMscfd	$\sum_{j=1}^{11} a_{1j}X_{1j}$	(1)	$\sum_{j=12}^{30} a_{1j}X_{1j}$	(2)	$\sum_{j=31}^{37} a_{1j}X_{1j}$	(3)
Oil	BOPD	$\sum_{j=1}^{11} b_{1j}X_{1j}$	(4)	$\sum_{j=12}^{30} b_{1j}X_{1j}$	(5)	$\sum_{j=31}^{37} b_{1j}X_{1j}$	(6)
Produced Water	BWPD	$\sum_{j=1}^{11} c_{1j}X_{1j}$	(7)	$\sum_{j=12}^{30} c_{1j}X_{1j}$	(8)	$\sum_{j=31}^{37} c_{1j}X_{1j}$	(9)

Wellhead platform C consists of 21 production wells with gas, oil, and water produced, D consists of 19 producing wells, and S has 7 producing wells respectively. a_{1j}will correlates to the volume of produced gas from well j, oil produced by j well is representing by b_{1j}, and produced water is under c_{1j} variables. The decision variables of produced or not produced well will be decided by the opening of the wells' respective choke valves that will be decided under the variable of X_{1j}. X_{1j} will be under the value of 0 or 1, which means fully closed or opened, a binary decision.

Referring to data from Table 2, which relates to the efficiency number approach of the facility's equipment, in the process of modeling the condition mathematically, Table 2 is expressed as Table 3 as variable inputs of the model.

Table 3. The efficiency of the system is expressed in mathematical variable

	Loss	Efficiency			Price
		Gas	Oil	Water	
Choke Valve	M1				
C Wells Pipeline	M2				
S Wells Pipeline	M3				
Gas Separator	M4				
Slug Catcher	M5				
Compressor Suction		M61	M62	M63	
Condensate Separator		M71	M72	M73	
Gas Price					M8
Oil Price					M9
Fuel Gas Usage	F1				

According to Table 3, prior to presenting the constraints and model objective, the defined model parameters and variables are:

M_1 : A parameter of production losses due to the existed of pressure drop across choke valve from C, D, and S wellhead of producing well number j, linked to choke valve X_{1j}.

M_2 : A parameter that represents the percentage of production losses due to pipeline transportation pressure drop from wellhead C, linked to a_{1j} gas, b_{1j} oil, and c_{1j} produced water losses.

M_3 : A parameter that represents the percentage of production losses due to pipeline transportation pressure drop from wellhead S, linked to a_{1j} gas, b_{1j} oil, and c_{1j} produced water losses.

M_4 : A parameter that represents the percentage of production losses due to inlet gas separator pressure drop and separation efficiencies, linked to a_{1j} gas, b_{1j} oil, and c_{1j} produced water losses at each phase.

M_5 : A parameter that represents the percentage of production losses due to slug catcher pressure drop and separation efficiencies, linked to a_{1j} gas, b_{1j} oil, and c_{1j} produced water losses at each phase.

M_{61} : A parameter that represents the percentage of amount gases transported to the compression system, linked to a_{1j}.

M_{62} : A parameter that represents the percentage of amount liquid (oil) carried over to the compression system due to equipment separation efficiencies, linked to b_{1j}.

M_{63} : A parameter that represents the percentage of amount liquid (produced water) carried over to the compression system due to equipment separation efficiencies, linked to c_{1j}.

M_{71} : A parameter that represents the percentage of amount gas carried over to the condensate separator due to compressor suction scrubber separation efficiencies, linked to a_{1j}.

M_{72} : A parameter that represents the percentage of amount liquid (oil) collected into the condensate separation system, linked to b_{1j}.

M_{73} : A parameter that represents the percentage of amount liquid (produced water) accumulated into the condensate separation system, linked to c_{1j}.

M_8 : Produced gas commodity price in USD, linked to a_{1j}.

M_9 : Produced oil commodity price in USD, linked to b_{1j}.

F_1 : The minimum volume of fuel gas required to be used as facilities electrification source, linked to a_{1j}.

Z : The total amount of oil and gas daily gross revenue is in USD.

There are basically four types of constraints, capacity, demand (minimum well to be produced), and equipment efficiency losses constraints (Duffuaa et al., n.d.). According to the operating condition and to minimize the effects of pipeline slugging phenomena, there will be a minimum volumetric flow of C and D wells to be maintained which is presented in equations 10 and 14. The flow of flared gas needs to be maintained at a certain volumetric flow rate (0.27 MMscfd) to ensure the quality of the combustion system and to maintain the operating pressure of process equipment, it represents in equation 11. In addition, on the produced water side, according to the facility limitation of the water handling system, a total amount of 3,000 BWPD shall be limited as the maximum number (Equation 12). In the gas compression system, there is a minimum volumetric flow to be maintained according to the compressor capacity, which is 40 MMscfd. This is to ensure that the compressor will be operating under its optimum operating zone (Equation 13). A gas sales agreement is obligated to open at least several S wells which are represented by equation 15 and due to depletion of reservoir pressure, an artificial lifting method must be applied to get oil produced, modeled on equation 16 as a constraint. The mathematical models of the constraints formed from the process operation approach are represented by the following equations:

C wells minimum flow
$$\sum_{j=1}^{11} a_{1j}X_{1j} \geq 9 \tag{10}$$

Flared gas minimum flow
$$(1-M_1)M_{71}\left((1-M_2)(1-M_4)\sum_{j=1}^{11} a_{1j}X_{1j} + (1-M_3)(1-M_5)\sum_{j=31}^{37} a_{1j}X_{1j}\right) \geq 0.27 \tag{11}$$

Produced water maximum flow
$$(1-M_1)M_{73}\left(\sum_{j=12}^{30} b_{1j}X_{1j} + (1-M_2)(1-M_4)\sum_{j=1}^{11} b_{1j}X_{1j} + (1-M_3)(1-M_5)\sum_{j=31}^{37} b_{1j}X_{1j}\right) \leq 3000 \tag{12}$$

Compressor minimum suction flow
$$(1-M_1)M_{61}\left(\sum_{j=12}^{30} a_{1j}X_{1j} + (1-M_2)(1-M_4)\sum_{j=1}^{11} a_{1j}X_{1j} + (1-M_3)(1-M_5)\sum_{j=31}^{37} a_{1j}X_{1j}\right) \geq 40 \tag{13}$$

D wells minimum flow
$$\sum_{j=12}^{30} a_{1j}X_{1j} \geq 13 \tag{14}$$

S wells minimum number to be operated
$$\sum_{j=31}^{37} X_{1j} \geq 7 \tag{15}$$

Minimum number of retrofitted gas lift wells to be operated
$$X_{112} + \sum_{j=20}^{23} X_{1j} \geq 5 \tag{16}$$

$$X_{ij} \begin{cases} X_{ij}=1, \text{ if choke valve is assigned to open} \\ X_{ij}=0, \text{ if choke valve is NOT assigned to open (close)} \end{cases}$$

Binary, for i=1 and j=1,2,3,...,47

The objective of the modeling is to find the maximum value of oil and gas production that will be monetized according to the market prices. By considering the various limitations and approaches to assuming the efficiencies of the pipeline system, pressure vessel, and separation process, the objective can be approached by maximizing the following mathematical model shown in equation 17.

$$\begin{aligned} &M_8\left\{\left[(1-M_1)M_{61}\left(\sum_{j=12}^{30} a_{1j}X_{1j} + (1-M_2)(1-M_4)\sum_{j=1}^{11} a_{1j}X_{1j} + (1-M_3)(1-M_5)\sum_{j=31}^{37} a_{1j}X_{1j}\right)\right] - F_1\right\} \\ &+M_9\left\{(1-M_1)\left[(M_{62}+M_{72})\left(\sum_{j=12}^{30} b_{1j}X_{1j} + (1-M_2)(1-M_4)\sum_{j=1}^{11} b_{1j}X_{1j} + (1-M_3)(1-M_5)\sum_{j=31}^{37} b_{1j}X_{1j}\right)\right]\right\} \end{aligned} \tag{17}$$

3.3 Computation Spreadsheet Model

Computational studies and optimization analysis are performed using SOLVER add-in of Microsoft Excel. All process data, parameters, constraints, decision variables, and objectives to be achieved that have been mathematically formulated are then proceeded using the simplex linear programming method. Table 1 and Table 2. The simplified network of oil and gas production has its characteristics (Salih & Rubiani, 2020).

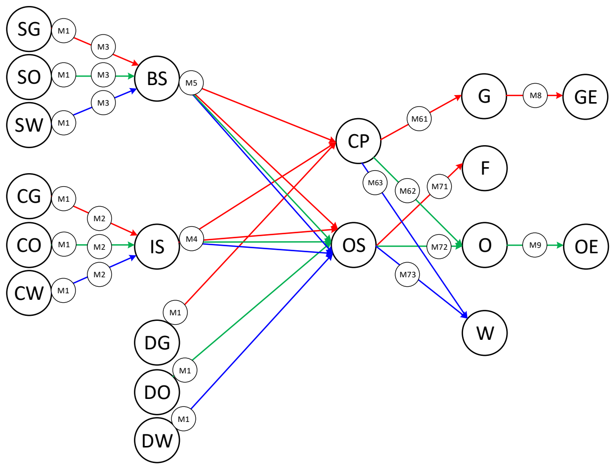

Figure 3. Detailed node modeling incorporating process constraints

Annotation: S: S Wells (SG: Gas, SO: Oil, and SW: Water), C: C Wells (CG: Gas, CO: Oil, and CW: Water), BS: Slug Catcher, IS: Inlet Separator, D: D Wells (DG: Gas, DO: Oil, and DW: Water), CP: Compressor, OS: Oil Separator, W: Water, G: Gas, F: Flare, O: Oil, GE; Gas Export, OE: Oil Export.

RESULT AND DISCUSSION

4.1 Data Requirements

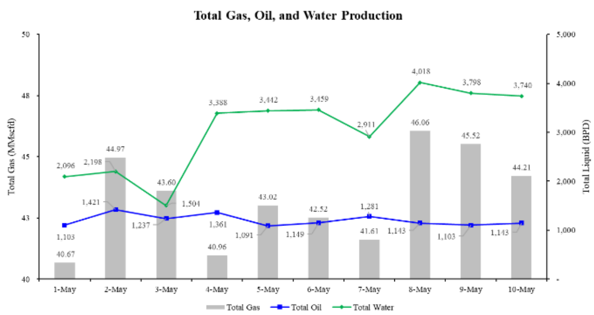

Figure 4. Total of C, D, and S wells production volume trends

Figure 4 shows the information on the total production volume (gas, oil, and water) for the period of 10 (ten) days. This data is required to analyze the deviation of the linear programming model that has been developed according to the actual conditions.

4.2 Result

Process modeling holds a crucial role in oil and gas operations in identifying inefficiencies, bottlenecking, addressing operational hazards, mitigating the risks, and improvements needed. The developed process modeling can be used to be an operational guide in maximizing the production according to the constraints and allows process engineers or operators to analyze based on different scenarios prior to implementation in the real world. By optimizing the processes, production efficiency could be increased, and optimizing operational costs.

C Wells

Well Number	Well Deliverability Gas (MMscfd)	Oil (BOPD)	Water (BWPD)	Choke Opening (%)
C-01	0.41	7.29	15.77	100%
C-02	-	-	-	0%
C-03	1.27	61.87	122.58	100%
C-04	-	13.31	65.30	100%
C-05	1.16	8.02	17.19	100%
C-06	-	-	-	0%
C-07	-	-	-	0%
C-08	-	-	-	0%
C-09	1.28	36.09	138.27	100%
C-10	-	42.25	40.10	100%
C-11	-	0.01	256.62	100%
C-12	1.06	7.51	51.55	100%
C-13	-	-	-	0%
C-14	0.51	10.42	31.93	100%
C-15	-	-	-	0%
C-16	-	-	-	0%
C-17	1.95	83.15	90.51	100%
C-18	-	-	-	0%
C-19	1.42	37.20	155.69	100%
C-20	-	-	-	0%
C-21	-	-	-	0%

D Wells

Well Number	Well Deliverability Gas (MMscfd)	Oil (BOPD)	Water (BWPD)	Choke Opening (%)	Field Ver
D-01GL	-	63.16	63.01	100%	Open
D-02	2.56	28.42	20.23	100%	Open
D-03	0.16	6.73	16.04	100%	Open
D-04	1.48	35.35	8.02	100%	Open
D-05	-	-	-	0%	Closed
D-06	0.36	7.78	9.17	100%	Open
D-07	0.69	25.31	75.61	100%	Open
D-08	-	-	-	0%	Closed
D-09GL	-	-	-	100%	Closed
D-10GL	0.09	67.58	89.36	100%	Open
D-11GL	0.15	87.22	66.50	100%	Open
D-12GL	-	98.68	83.63	100%	Open
D-13	-	-	-	0%	Closed
D-14	-	-	-	0%	Closed
D-15	0.51	32.24	48.12	100%	
D-16	7.01	0.03	61.26	100%	Open
D-17	-	106.58	132.89	100%	Open
D-18	0.77	261.83	26.41	100%	
D-19	0.13	3.68	56.36	100%	

S Wells

Well Number	Well Deliverability Gas (MMscfd)	Oil (BOPD)	Water (BWPD)	Choke Opening (%)	Field Ver
S-01	2.14	1.61	289.04	100%	Open
S-02	1.32	1.58	3.30	100%	Open
S-03	3.46	1.66	3.30	100%	Open
S-04	4.88	1.71	3.30	100%	Open
S-05	-	1.55	741.84	0%	
S-06	4.07	1.68	801.19	100%	Open
S-07	3.66	1.66	156.06	100%	Open

Figure 5. Implementation of model decision result compared to field verification

This spreadsheet of optimum decisions has been shared with operations and used as a day-to-day production guideline. Prior to having the spreadsheet model, operators commonly used their feeling other than the technical model, more wells are opened more production will come.

A field verification has been done based on developed models to get a better understanding of process performance and characteristics. Figure 5 provides optimization results either to open or close the production wells by operating their choke valves in C, D, and S wellheads. A 100% value indicates the well will be fully opened and produced, and vice versa 0% indicates under recommendation not to be produced. Post-implementation of process modeling onsite provides that the actual choke valve opening is near to its optimization decision. The oil and gas production has profiles and deviations as per plots in Figures 6 and 7.

In general, the result of the optimization simulation recommendations using linear programming is close to actual conditions in facilities. There are some differences that are generally due to well-operating conditions that cannot be modeled in this simulation. Some examples are under-management decisions such as well shut-ins due to sand erosional issues that potentially bring the facilities to catastrophic conditions or sub-surface plugging during well work activities.

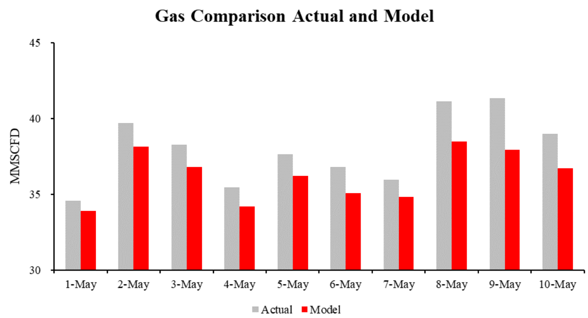

Figure 6. Gas volume flow comparison actual and model

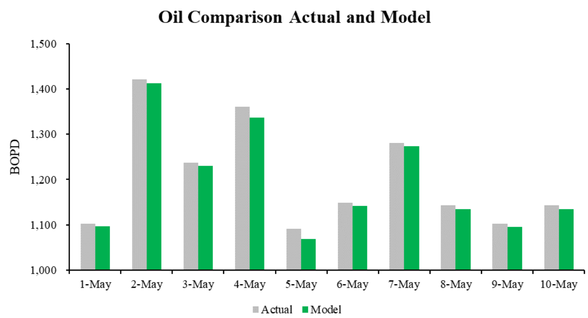

Figure 7. Oil volume flow comparison actual and model

The validating process of the optimization model against actual conditions is carried out, one of which involves more variations in data. Production data is taken in the last 10 days for 47 (forty-seven) wells. Each data per date is optimized and compared with actual production data collected from the field.

It results in an average error margin of 4.57%-gas and 0.9%-oil. This optimization model could be used as an operator decision reference in opening the well's choke valve to get the optimum production rate, a minor adjustment might need considering the dynamic process parameter condition.

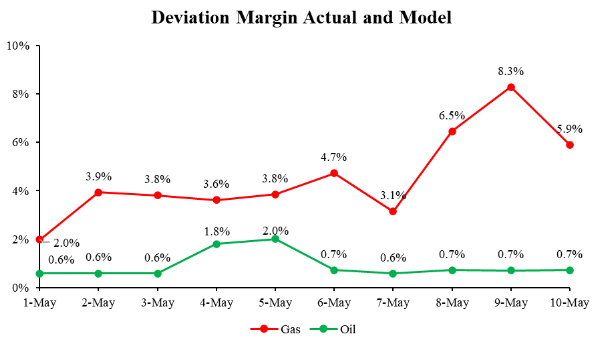

Figure 8. Deviation margin of gas and oil volume flow actual and model

CONCLUSION

The problem in optimizing the production of marginal oil and gas wells is solved with a numerical and simplification approach to the processing system. The result shows a recommendation to open the production wells which have higher oil and/or gas flow and to close wells with higher produced water volume. The optimization model result is close to the actual field condition and correlates with the objective function of maximizing production revenues by considering the minimum and maximum limits. Process modeling assists in efficient resource management, including the allocation of manpower, equipment, and materials. By understanding how different resources interact with each other and affect the overall process, companies can make informed decisions to achieve optimal results.

In this study case, there are still many assumptions and simplifications of the process facilities phenomena carried out. The heat and material balance constraints are represented in simple assumptions, meanwhile, in the real case, it would be a unique process phenomenon and requires complex calculations. Future studies might consider increasing the complexity of the process systems and replacing the efficiency number approaches with function correlation of process parameters. In summary, it is valuable to have a model that helps the industry operate more sustainably and profitably.

REFERENCES

Alas, R., Übius, U., Lorents, P., & Matsak, E. (2017). Corporate Social Responsibility In European And Asian Countries. *Jurnal Manajemen Bisnis Dan Inovasi (JMBI) UNSRAT Vol. 4 No. 1*

Bakker, S. J., Kleiven, A., Fleten, S. E., & Tomasgard, A. (2021). Mature offshore oil field development: Solving a real options problem using stochastic dual dynamic integer programming. Computers and Operations Research, 136. https://doi.org/10.1016/j.cor.2021.105480

Duffuaa, S. O., Al-Zayer, J. A., Al-Marhoun, M. A., & Al-Saleh, M. A. (n.d.). A Linear Programming Model to Evaluate Gas Availability for Vital Industries in Saudi Arabia.

Essien, G. (2016). Development and Validation of Linear Programming Models for Gasoline and Fuel Oil Blending. http://www.ijser.org

Jha, V., Jha, V. N., Karn, S. K., & Kumar, K. (n.d.). Review on the Role of Mathematical Modeling in Energy Sectors. www.ijesi.org

Lei, G., Stanko, M., & Silva, T. L. (2022). Formulations for automatic optimization of decommissioning timing in offshore oil and gas field development planning. Computers and Chemical Engineering, 165. https://doi.org/10.1016/j.compchemeng.2022.107910

Mojambo, G. A., Tulung, J. E., & Saerang, R. T. (2020). The Influence of Top Management Team (TMT) Characteristics Toward Indonesian Banks Financial Performance During the Digital Era (2014-2018). *JMBI UNSRAT (Jurnal Ilmiah Manajemen Bisnis dan Inovasi Universitas Sam Ratulangi).*, *7*(1).

Popoola, L. T., Susu, A. A., Lateef, A. A., & Grema, A. S. (2015). Application of Linear Programming in Profit Optimization of Crude Oil Distillation Column of Port Harcourt Refinery, Nigeria.

Ronn, E. I. (1987). A New Linear Programming Approach to Bond Portfolio Management. The Journal of Financial and Quantitative Analysis, 22(4), 439. https://doi.org/10.2307/2330794

Salih, Y., & Rubiani, H. (2020). Application of Linear Programming in Oil Production Distribution Networks: Literature Review. International Journal of Research in Community Service, 1(3), 1–6.

Taha, H. A. (2007). Operations Research: An Introduction Eighth Edition.