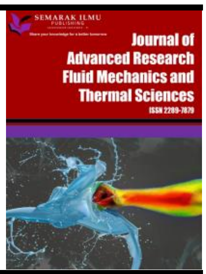
SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879



Optimization of Upstream Natural Gas Compression Processes based on Sensitivity Analysis of Gas Throughput

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ARTICLE INFO

Article history:
Received 26 April 2024
Received in revised form 13 September 2024
Accepted 21 September 2024
Available online 10 October 2024

Keywords:
Compressor; optimization; natural gas processing; net profit; sensitivity analysis

ABSTRACT

As the global population increases, there is a corresponding increase in the energy demand. Most of the energy consumption still comes from the use of fossil fuels. Natural gas, a fossil fuel in gaseous form, serves as a primary component in the shift towards renewable energy, making its use imperative for society. At present, transportation and high energy consumption pose significant challenges to natural gas production. Non-optimal design and operating variables lead to irreversible processes, thereby generating energy waste so that process evaluation is needed as the first stage in optimizing the process. Sensitivity analysis can be used in optimization which leads to evaluation activities that involve achieving optimal results under certain conditions. This research seeks to evaluate the effect of changes in natural gas pressure and flow rate on operational units, especially on compressors, to obtain a comparative analysis of which variables have great significance in the natural gas compression process. This evaluation study was simulated using Aspen Plus V.12 on the compressors. From the study that has been conducted, the largest net profit in the sensitivity analysis of the flow rate and pressure variables is found in the +80% change in flow rate and pressure from the Base Case, which is USD 1069.2 per hour. Then, to observe the significance of flow rate and pressure variables on net profit, it is found that changes in flow rate have a more significant effect on net profit than changes in pressure. This research can be useful as a guide to conduct a simple economic analysis by making changes to several parameters that have a significant impact and can be done as an optimization of the natural gas compression process.

1. Introduction

As the global population increases, there is a corresponding increase in the energy demand. According to The World Counts, global energy consumption has more than tripled since 2000 and is projected to continue growing. By 2040, it is estimated that global energy consumption will reach 740 billion terajoules. Most of the energy consumption, 83%, still comes from the use of fossil fuels,

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https://doi.org/10.37934/arfmts.122.1.8093

as per The World Counts. Oil is the primary source of energy, followed by coal and natural gas. Thus, fossil fuels have a considerable impact on global energy availability.

The global demand for natural gas is projected to rise by 140 billion cubic meters (bcm) between 2021 and 2025 [1]. Methane, which comes from oil, is the principal component of natural gas. The Ministry of Energy and Mineral Resources of the Republic of Indonesia reports that the availability of oil reserves, notably in Indonesia, is only 9.5 years. According to the BP Statistic Review 2021, Indonesia's oil reserves constitute just 0.1% of the world's reserves. Indonesia's oil reserves have decreased from 7.4 billion barrels in 2012 to 3.9 billion barrels in 2021 [2]. Indonesia's total production of natural gas in 2021 reached about 6,668 MMSCFD. In 2012, gas production in Indonesia reached approximately 8,698 MMSCFD. However, current production has decreased partly due to gas depletion at several Indonesian gas fields [2]. It is worth noting that Indonesia is an oil-exporting country, which suggests it possesses sufficient oil reserves to cater to both domestic and foreign demand. According to SKK Migas, Indonesia boasts at least 4,500 active oil wells, producing roughly 2,500 barrels of oil daily.

Natural gas, a fossil fuel in gaseous form, possesses unique properties [3]. As of now, natural gas serves as a primary component in the shift towards renewable energy, making its use imperative for society [4]. At present, transportation and high energy consumption pose significant challenges to natural gas production. Non-optimal design and operating variables lead to irreversible processes, thereby generating energy waste so that process evaluation is needed as the first stage in optimizing the process [5]. Sensitivity analysis can be used in optimization which leads to evaluation activities that involve achieving optimal results under certain conditions. When designing, many technological and managerial determinations must be made at different stages. The goal of all these determinations is to minimize the workload or maximize the desired revenue [6].

Many researchers have conducted studies related to process optimization using various methods. For example, Mohammad *et al.,* [7] optimized the Heat Exchanger Network (HEN) at the oil refinery by using cross-pinch exchanger analysis in the olefin unit which will affect the possibility of reducing the load from the atmospheric furnace. In addition, Anugraha *et al.,* [8] developed a preliminary study in the optimization process for mini-oil refineries in rural areas and then made an economic analysis for variables of furnace temperature. Mak *et al.,* [9] conducted a study on dynamic optimal gas flow (DOGF), aiming at minimizing gas compression costs based on pressure and time constraints. However, this research is only applicable to dynamic conditions, which are more complex than static conditions. Chebouba *et al.,* [10] researched optimizing natural gas pipeline transportation using the Ant Colony Optimization (ACO) algorithm, which employs local and global iteration methods to find the optimal value.

Austbø and Gundersen [11] devised an optimization formula for the liquefaction process of liquefied natural gas (LNG). This study aims to optimize the heat exchanger network process by minimizing investment and operating costs through variable temperature differences. The sequential quadratic programming algorithm (NLPQLP) method, using the Aspen HYSYS was employed. That method uses a mathematical algorithm which needs more sophisticated than the simulation-based common algorithm. Additionally, Alabdulkarem *et al.,* [12] conducted an optimization simulation on a C3-MR unit that was pre-cooled using propane-mixed refrigerant. This was performed using the Genetic Algorithm (GA) from the optimization toolbox of Matlab whose purpose is to obtain the minimum power consumption by using variables on pinch temperature and type of heat exchanger used.

In natural gas network optimization, there are many simulations on heat exchanger networks and refrigerants but there are not many studies on compression networks related to simple power optimization in compressors that are related to power generation. Two main elements play a role in developing a sustainable power generation system, which are renewable energy and energy efficiency [13]. Therefore, further research is needed to minimize the power consumption of the natural gas compressor network to maximize energy saving for the process. In addition, this research also tried to get the maximum net profit in the compressor network. This research seeks to evaluate the effect of changes in natural gas pressure and flow rate on operational units, especially on compressors, to obtain a comparative analysis of which variables have great significance in the natural gas compression process.

2. Methodology
2.1 Process Description

The oil and gas industry can be segmented into three parts: upstream, midstream, and downstream, based on market demands. Upstream refers to oil and gas exploration and development [4]. Essentially, upstream natural gas production involves various processes like separation, compression, dehydration, and liquefaction, depending on the gas composition and the presence or absence of certain impurities such as acid gas, inert gas, and so on. Gas wells typically comprise three fluid phases: gas, oil, and water [14]. This study specifically concentrates on the natural gas compression process. Figure 1 illustrates the process flow diagram of the base case scheme for natural gas compression.

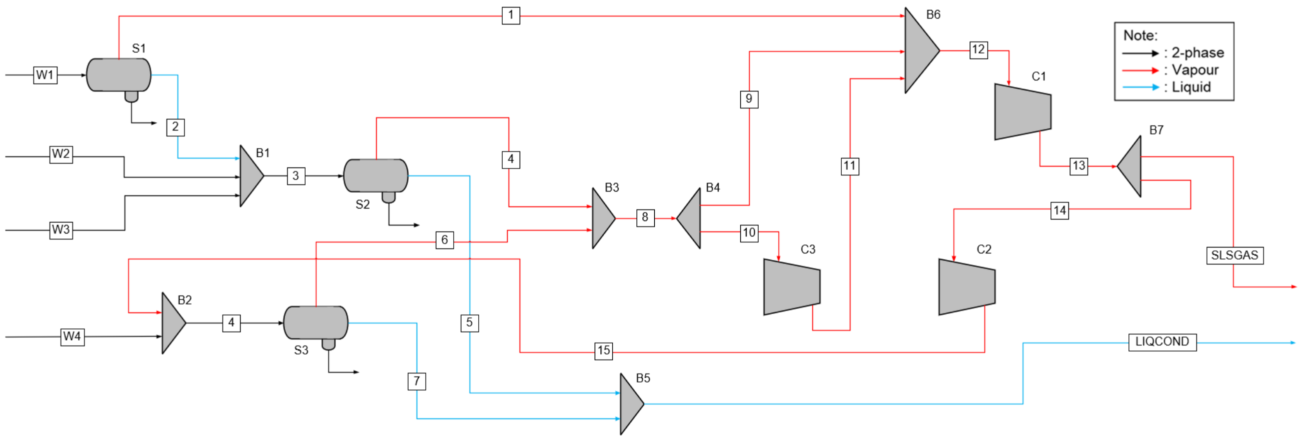


Fig. 1. Process Flow Diagram (PFD) of natural gas compression process in base case

In the PFD, where the W element represents the gas well, the C element stands for the compressor, the S stands for a three-phase separator and the B element is the mixer-splitter points. The product is divided into two, namely product gas which has a vapor phase (SLSGAS), and liquid condensate (LIQCOND). The base case used in this natural gas network is based on existing industrial processes at one of the gas plants in Indonesia. The properties contained in the gas well are temperature, pressure, flow rate, and gas composition. The gas composition is obtained from several gas wells in Indonesia. The gas well properties are shown in Table 1.

Table 1
The gas well properties in the base case option

Stream	W1	W2	W3	W4
Temperature (°C)	19.8	67.6	25.2	60.9
Pressure (bar)	10.07	5.45	5.45	10.34
Flow Rate (kg/h)	34099	1574	5093	45267
Density (kg/m^3)	12.6	6.46	5.13	10.55
Volume Flow Rate (m^3/h)	2705.5	243.81	992.20	4291.54
Gas	2705.44	243.8	992.19	4291.44
Liquid	0.059	0.009	0.003	0.100
Component (%mole)	Ardjuna [15]	Senoro [16]	Badak [17]	Nilam [17]
Methane	65.7	86.87	82.8	77.55
Ethane	8.5	4.14	3.87	7.18
Propane	14.5	2.07	3.70	4.18
i-Butane	0	0.48	0.99	0.87
n-Butane	5.1	0.73	1.03	1.00
i-Pentane	0	0.42	0.52	0.38
n-Pentane	0.8	0.34	0.29	0.23
Hexane+	0	2.22	2.38	2.07
N2	1.3	0.87	0	0
H2S	0	0.06	0	0
CO2	4.1	1.8	4.42	6.54

Then, the operating unit in the form of a compressor has operating conditions in Base Case that contain the design pressure and flowrate capacity of each compressor shown in Table 2 below.

Table 2
Operating conditions of each compressor in Base Case

Compressor	P Suction Design (kPa)	P Discharge Design (kPa)	Maximum Flowrate (m^3/h)
C1	1620	6858	1029108
C2	3765	7474	23543
C3	1000	1586	18835

The detailed properties of the stream in this Base Case including gas composition, temperature, pressure, and flow rate of selected nodes in the network system are shown in Table 3 below.

Table 3
Detailed properties of selected nodes in the Base Case network

Stream	10	11	12	13	14	15	SLSGAS	LIQCOND
Temperature (°C)	419.11	504.54	372.11	581.36	581.36	588.91	648.98	36.37
Pressure (bar)	5.45	15.86	5.45	68.58	68.58	74.74	68.58	5.45
Flow Rate (kg/h)	34455	34455	171886	171886	85943	85943	85930	103.6
Composition (%mole)								
Methane	69.45	69.45	67.48	67.48	67.48	67.48	67.48	2.08
Ethane	6.70	6.70	6.94	6.94	6.94	6.94	6.94	0.59
Propane	6.83	6.83	8.54	8.54	8.54	8.54	8.54	1.64
i-Butane	0.74	0.74	0.59	0.59	0.59	0.59	0.59	1.06
n-Butane	3.01	3.01	4.13	4.13	4.13	4.13	4.13	1.88
i-Pentane	0.47	0.47	0.38	0.38	0.38	0.38	0.38	2.35
n-Pentane	1.11	1.11	1.53	1.53	1.53	1.53	1.53	2.67
Hexane+	6.10	6.10	4.93	4.93	4.93	4.93	4.93	87.49
N2	0.29	0.29	0.46	0.46	0.46	0.46	0.46	0
H2S	0	0	0	0	0	0	0	0
CO2	5.30	5.30	5.01	5.01	5.01	5.01	5.01	0.25

Each compressor's efficiency varies depending on the specifications used. This efficiency parameter indicates the compressor's performance. The efficiency based on the isentropic process can be used to estimate the performance of each compressor. Thus, the efficiency based on the isentropic process can be used to estimate the performance of each compressor, which affects the energy requirements necessary to increase the natural gas pressure to meet the desired specifications. Yan *et al.,* [18] provide a correlation in Eq. (1) for predicting the isentropic efficiency of each compressor.

$$\eta_{is} = 0.874 - 0.0135 \frac{P_{disc}}{P_{suc}} \quad (1)$$

where η_{is} is the isentropic efficiency of the compressor, then P_{disc} is the design output pressure of the compressor, and P_{suc} is the design inlet pressure of the compressor.

2.2 Sales Calculation

In this natural gas network, there exists an equation that is the basis for calculating the net profit obtained from each option that has been given. The formulation of all sales is described in Eq. (2) and Eq. (3) below.

$$R_{total} = R_g + R_l \quad (2)$$

$$R_{total} = \left(F_g^c \times E_g\right) + (F_l^c \times E_l) \quad (3)$$

The total net profit is determined by adding the sales revenue from liquid condensate products and the net profit of net gas products. To determine the net profit of vapor products in the natural gas network, the calculation involves multiplying the converted net gas flow rate in MMBtu units by the price index of natural gas that was adjusted to the market price. Similarly, the sales for liquid condensate products are determined by multiplying the flow rate of liquid conversion in barrel units by the market price of condensate represented by the price of crude oil. The market prices of natural gas and crude oil are provided in Table 4.

Table 4
Commodity market price of products on the natural gas network in 2022

Commodity	Unit price (USD)	References
Natural Gas	11.17/MMBtu	Ministry of Energy and Mineral Resources Republic of Indonesia [19]
Crude Oil (Liquid Condensate)	97.03/Barrel	Ministry of Energy and Mineral Resources Republic of Indonesia [19]

The unit in the flow rate used is a volume unit (m^3) so a conversion is needed to be able to calculate sales based on the market unit price of each commodity. Therefore, every cubic meter is converted to 0.0354 MMBtu of gas which is equal to 6.2898 barrels of oil and to harmonize units, 1 barrel of oil is equivalent to 5.6 MMBtu of natural gas.

Then, the net flow rate of natural gas is shown in Eq. (4) below.

$$F_g = F_n - F_f \quad (4)$$

Net gas production is obtained from the total gas production in the network minus the gas used as compressor fuel in m^3/h. Inside the gas turbine, a combustion process occurs that typically utilizes particular fuels and involves sufficient combustion, such as natural gas and diesel fuel [20].

In calculating fuel requirements for all compressors, it can use the formula in Eq. (5) below.

$$F_f\left(\frac{m^3}{h}\right) = \frac{pwr_{total}\ (kW)\times 0.001\frac{MJ/s}{kW}\times 3600\frac{s}{h}}{LHV\ \left(\frac{MJ}{m^3}\right)} \quad (5)$$

As already known, the calculation of gas fuel for compressors is influenced by the total power requirements that have units of m^3/h from the three compressors with kW units and Lower Heating Value with units of MJ/m^3. The fuel compressor's element also includes converting power that represents one kilowatt equal to 0.001 MJ/s and converting time that must be changed to an hour.

3. Result and Discussion

This evaluation study was simulated using Aspen Plus V.12 on the compressors. The first thing to do is to determine the fluid package to be used. The Peng-Robinson equation of state is preferred for real gas processing because of its better precious, surpassing the commonly used UNIFAC method for vapor-liquid equilibrium (VLE) applications that rely on predictive modeling through activity coefficients [21]. The latter requires inter-component coefficient data that are not always available for each component in the feed gas [22].

The operating unit modules used include 'Compr' as a compressor, 'Flash3' as a representation of the three-phase separator, a mixing point represented by the 'Mixer' module, and 'FSplit' to represent the splitter unit. The operating unit module will then be designed following the Block Flow Diagram in the base case. Then, data input is carried out on the feed gas well which is accompanied by the addition of options from sensitivity analysis on the flow rate and pressure in the gas well which are described in Table 5 and Table 6.

Table 5
Operating condition sensitivity options

Options	Condition change compared to Base Case
Base Case	-
Option 1 (+20%)	+20% flowrate and pressure
Option 2 (+40%)	+40% flowrate and pressure
Option 3 (+60%)	+60% flowrate and pressure
Option 4 (+80%)	+80% flowrate and pressure
Option 5 (-20%)	-20% flowrate and pressure
Option 6 (-40%)	-40% flowrate and pressure
Option 7 (-60%)	-60% flowrate and pressure
Option 8 (-80%)	-80% flowrate and pressure

Table 6
Gas well operating conditions for each option

Options	W1		W2		W3		W4	
	Flowrate (kg/h)	Pressure (bar)	Flowrate (kg/h)	Pressure (bar)	Flowrate (kg/h)	Pressure (bar)	Flowrate (kg/h)	Pressure (bar)
Base Case	34099	10.07	1574	5.45	5093	5.45	45267	10.34
+20%	40919	12.08	1889	6.54	6112	6.54	54320	12.41
+40%	47739	14.098	2204	7.63	7131	7.63	63374	14.476
+60%	54559	16.112	2518	8.72	8149	8.72	72427	16.544
+80%	61379	18.126	2833	9.81	9168	9.81	81480	18.612
-20%	27279	8.06	1259	4.36	4075	4.36	36213	8.27
-40%	20460	6.042	944	3.27	3056	3.27	27160	6.204
-60%	13640	4.028	630	2.18	2037	2.18	18107	4.136
-80%	6820	2.014	315	1.09	1019	1.09	9053	2.068

Next is to enter data on each operating unit. For the compressor, input data from the specifications of each compressor in Table 2. In addition to these specifications, input data in the form of isentropic efficiency based on Eq. (1) so that the isentropic efficiency data obtained for C1 is 81.69%, C2 compressor is 84.72%, and at C3 is 85.26%. This efficiency data will affect the power requirements of each compressor. When operating under isentropic conditions, incoming and outgoing design pressures should be compared. Compressors that follow the polytropic process should compare actual operational conditions of incoming and outgoing flows [23].

In the other unit, the splitter, the initial value is determined for specification. Since all streams will be split into two streams, then have two splitters, B4 and B7. The value used in the B4 split fraction is 0.25 to stream 10, which accommodates the maximum flow rate to C3, and the B7 splitter uses a split fraction of 0.5. Additionally, in natural gas processing, a separation process in a three-phase separator module acts to split the gas or vapor phase from the liquid phase. However, gravity separation is incapable of fully separating the two phases, resulting in some liquid being carried away with the separated vapor and some vapor being carried away with the separated liquid, a phenomenon known as carryover [24].

In this scenario, a 5% mole fraction of the liquid phase will be entrained into the output vapor. Because the separator used in this natural gas network does not add heat or is adiabatic, the duty is set to zero and the design pressure adjusts to the flow in the previous stream if it is at the mixing point, the pressure will follow the smallest pressure of each stream mixed and if the feed gas flow to be separated, the pressure used is the pressure of the gas well.

In this process simulation, the Base Case results obtained are the flowrate of the two products, namely Gross Sales Gas (SLSGAS) of 85943 kg/h or equal to 3299.3 m^3/h and Liquid Condensate (LIQCOND) products of 90.34 kg/h which is equivalent to 0.142 m^3/h. In addition, other simulation results were obtained, including the power requirements of the three compressors, the flow rate passing through the three compressors, and an analysis of the calculation of compressor fuel requirements in the Base Case scenario presented in Table 7.

Table 7
Simulation results and compressor calculations in the Base Case scenario

Compressor	Suction Pressure Simulation (kPa)	Suction Pressure Design (kPa)	Power (kW)	Flowrate Compressor (m^3/h)	Fuel Consumption (m^3/h)
C1	545	1620	32920	61719	2019
C2	6858	3765	641	3299	39
C3	545	1000	2676	13396	164
Total			36238		2222

In the compressor fuel calculation, the LHV parameter of 58.69 MJ/m^3 was used. This value is based on simulation results in Aspen Plus. Since the LHV parameter is to express the properties of the gas product, the determination of the LHV as defined is obtained from the gas product node (SLSGAS) at standard conditions.

The LHV of the product gas is obtained from simulation results using Aspen Plus V.12, which is 38.8 MJ/m^3. To validate LHV, data from Tarabet *et al.,* [25] was used and found to be 39 MJ/m^3. Using data from Guo *et al.,* [26] the LHV was found to be 33.77 MJ/m^3 as opposed to our calculated LHV, which is 33.88 MJ/m^3.

Lower Heating Value (LHV) is an energy content parameter measured in energy units per mass or volume that is used when gaseous phase water is produced as a part of the combustion reaction [27]. The difference with Higher Heating Value (HHV) is that the HHV parameter is the total heat of combustion measured through a calorimeter bomb per unit mass or volume. As for LHV, it does not take into consideration the heat of vaporization of water, so in the calculation of compressor fuel, the LHV parameter is used along with the lack of water component in the composition of natural gas feed [28]. In addition, the LHV value has a lower value than the HHV.

Therefore, if the gas has a high heating value, it will affect the incomplete combustion process which will cause soot and will cause serious problems in the compressor. Then, a sensitivity analysis is carried out based on the variables in Table 5 and Table 6. The results include total compressor power, gross gas sales product, net gas sales, liquid condensate, and net profit in an hour, which are presented in Table 8 below.

Table 8
Sensitivity analysis of flowrate and pressure variable at Gas Well

Variable options	Total power compressor (kW)	Gross Gas Production (m^3/h)	Net Gas Production (m^3/h)	Liquid Condensate (m^3/h)	Net Profit (USD/h)
Base Case	36238	3299.3	1076.5	0.142	512.4
+20%	37597	3692.2	1386.1	0.173	653.6
+40%	38551	4056.5	1691.8	0.204	793.6
+60%	39192	4397.0	1993.1	0.236	932.2
+80%	39581	4717.4	2289.6	0.269	1069.2
-20%	34333	2870.4	764.5	0.112	370.6
-40%	31642	2393.9	453.0	0.082	229.4
-60%	27707	1849.0	149.5	0.054	91.8
-80%	21310	1185.3	-121.8	0.026	-32.4

Then, plotting is done for each variable's total compressor power, and profit per hour to be analyzed to get the optimal point shown in Figure 2.

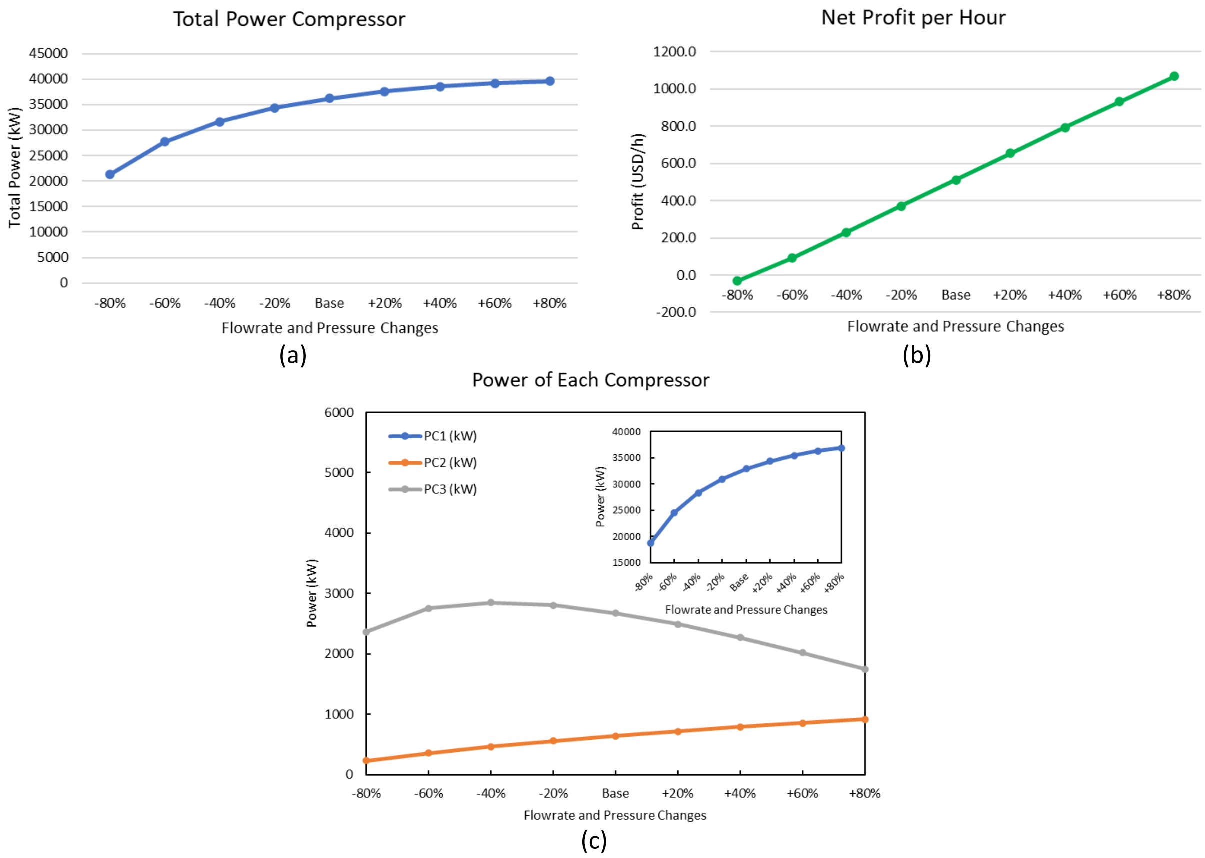


Fig. 2. Sensitivity analysis plot based on pressure and flow rate changes resulting in (a) Net profit per hour, (b) Total power compressor, and (c) Power of each compressor

In Figure 2, for the power graph of each compressor, it is found that the power requirements on the C1 and C2 compressors increase along with the increase in changes in the variables but on the C3 compressor, the power increases up to a change of -40% and then decreases. This happens to the C3 compressor because of the maximum flowrate limit that enters the C3 compressor so that it affects the B4 splitter unit which adjusts the split fraction must be the same so that the maximum flowrate limit on C3 is met for all variable changes.

Then, in the total compressor power, a profile is obtained that continues to increase for rising variable changes and then flatten. Then, for the highest net profit results, there is a +80% change with a net profit of USD 1069.2 per hour, however, the -80% change cannot be used as an option for evaluating changes in flowrate and pressure variables because the net profit obtained is minus so that it is facing a loss or deficit, but it needs to be observed for next analysis. Further sensitivity analysis will be conducted by setting one of the variables (pressure or flow rate) at +80%, and the other variables are made variable as in Table 6 and comparing each scenario. The results of changing the independent variables are presented in Table 9 and Table 10 below.

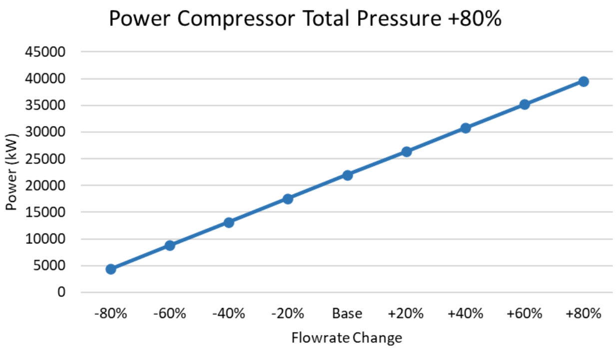
Table 9
Sensitivity analysis based on variable pressure at +80% in Gas Well

Variable Pressure	Variable Flowrate	Total power compressor (kW)	Gross Gas Production (m^3/h)	Net Gas Production (m^3/h)	Liquid Condensate (m^3/h)	Net Profit (USD/h)
+80%	Base Case	21989	2620.8	1272.0	0.149	594.0
	+20%	26387	3144.9	1526.4	0.179	712.8
	+40%	30785	3669.1	1780.8	0.209	831.6
	+60%	35183	4193.2	2035.2	0.239	950.4
	+80%	39581	4717.4	2289.6	0.269	1069.2
	-20%	17591	2096.6	1017.6	0.119	475.2
	-40%	13194	1572.5	763.2	0.090	356.4
	-60%	8796	1048.3	508.8	0.060	237.6
	-80%	4398	524.2	254.4	0.030	118.8

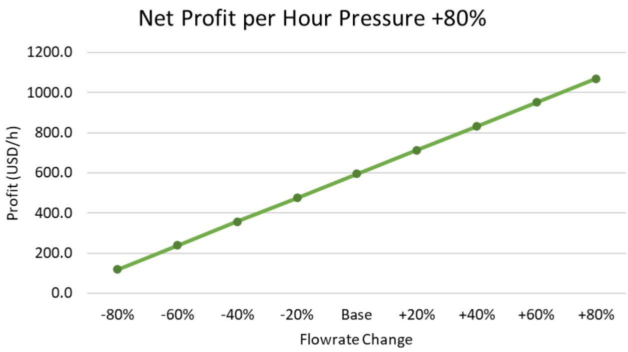
Table 10
Sensitivity analysis based on variable flowrate at +80% in Gas Well

Variable Pressure	Variable Flowrate	Total power compressor (kW)	Gross Gas Production (m^3/h)	Net Gas Production (m^3/h)	Liquid Condensate (m^3/h)	Net Profit (USD/h)
Base Case	+80%	65228	5938.7	1937.8	0.256	922.3
+20%		56395	5538.3	2079.1	0.259	980.4
+40%		49566	5215.5	2175.2	0.263	1020.3
+60%		44091	4946.7	2242.2	0.266	1048.7
+80%		39581	4717.4	2289.6	0.269	1069.2
-20%		77249	6458.5	1720.2	0.252	833.9
-40%		94945	7181.6	1357.9	0.247	687.8
-60%		124683	8320.5	672.7	0.241	413.2
-80%		191793	10667.8	-1096.4	0.232	-291.9

After that, graphical plotting of simulation results from each fixed variable pressure at +80% and flow rate at +80% in the form of power each compressor, total compressor power and net profit per hour is shown in Figure 3 and Figure 4 below.



(a)



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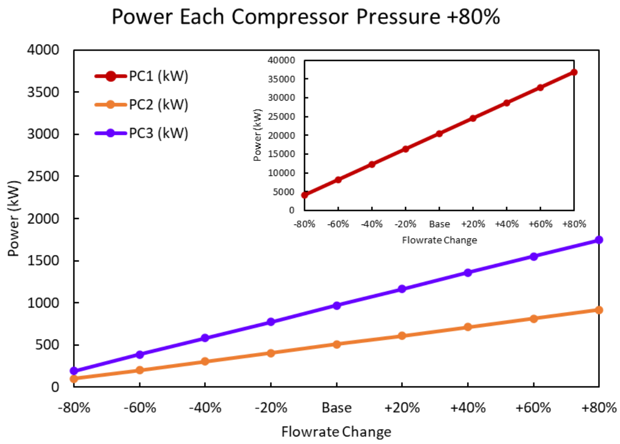
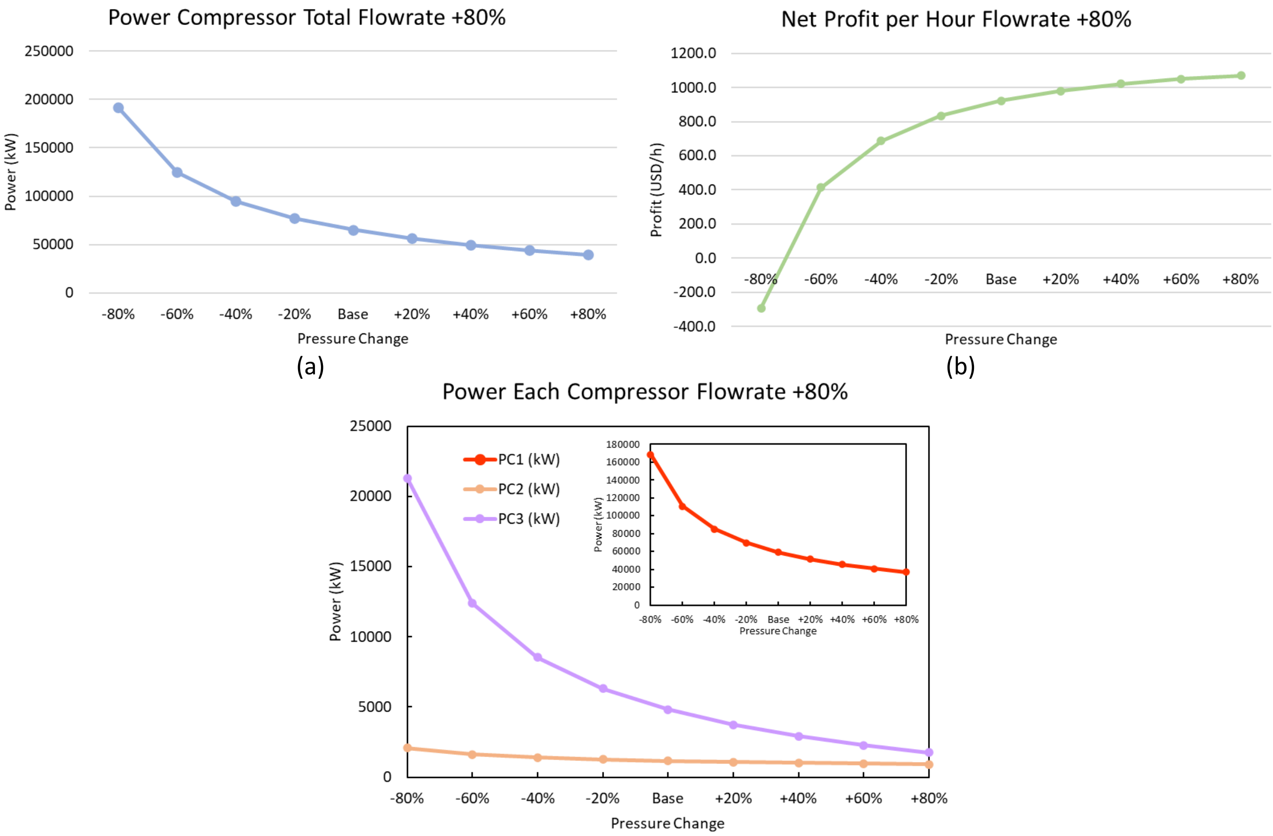


(c)

Fig. 3. Sensitivity analysis plot based on fixed variable pressure at +80% resulting in (a) Net Profit per hour, (b) Power compressor total, and (c) Power each compressor



(c)

Fig. 4. Sensitivity analysis plot based on fixed variable flow rate at +80% resulting in (a) Net Profit per hour, (b) Power compressor total, and (c) Power each compressor

Based on Figure 3 above for a fixed variable at +80% pressure, it is found that all aspects of the power requirements of each compressor and in total will be directly proportional and linear to changes in flow rate increase. The same thing is obtained in the element of net profit per hour. If the flow rate at the gas well is decreased with a fixed gas well pressure, the net profit per hour will also decrease. Then for Figure 4, which contains a fixed variable at a flowrate of +80%, it is found that the power demand on the compressor will decrease along with the increase in changes in pressure exponentially, and in the analysis of net profit per hour, it is found that the increasing pressure change will result in an increasing net profit even though the profile is flattened. If the pressure change is increased by more than 80%, the net profit obtained will likely be in a stagnant condition so that the maximum value for net profit per hour is obtained.

As an additional note, the variable flow rate change of +80% and pressure change at -80% obtained minus in net profit per hour so this pair of variables is considered extremely disadvantageous. In addition, the incoming flow rate was observed for each pair of pressure and flow rate variables based on the simulation results shown in Table 11.

Table 11
The simulation results of the flow rate inlet in the compressor are compared with the maximum flow rate

Variable Pressure	Variable Flowrate	Inlet Flowrate C1 (m^3/h)	Inlet Flowrate C2 (m^3/h)	Inlet Flowrate C3 (m^3/h)
+80%	-80%	6294	582	1368
+80%	-60%	12588	1165	2737
+80%	-40%	18882	1747	4105
+80%	-20%	25175	2330	5473
+80%	Base	31469	2912	6841
+80%	+20%	37763	3494	8210
+80%	+40%	44057	4077	9578
+80%	+60%	50351	4659	10946
+80%	+80%	56645	5242	12314
-80%	+80%	1044690	11853	226056
-60%	+80%	415988	9245	90105
-40%	+80%	242941	7981	52666
-20%	+80%	165899	7176	35988
Base	+80%	123439	6599	26791
+20%	+80%	96953	6154	21052
+40%	+80%	79044	5795	17171
+60%	+80%	66223	5496	14391
Maximum Flowrate		102908	23543	18835

Based on the simulation results in Table 11, it is found that at all fixed pressure variables +80% the flow rate entering each compressor is still below the maximum flow rate so that all pressure variables at +80% flow rate changes can be executed. However, different results are found at a fixed flow rate of +80% where only the pressure variables at +40%, +60%, and +80% satisfy the maximum flow rate on each compressor.

4. Conclusion

From the study that has been conducted, the largest net profit in the sensitivity analysis of the flow rate and pressure variables is found in the +80% change in flow rate and pressure from the Base Case, which is USD 1069.2 per hour. Then, to observe the significance of flow rate and pressure variables on net profit, it is found that changes in flow rate have a more significant effect on net profit than changes in pressure. In pressure changes, several variables state the net profit reaches a minus value or has losses so that if techno-economy analysis is carried out, the usage of pressure change variables can be reduced. This research can be useful as a guide to conduct a simple economic analysis by making changes to several parameters that have a significant impact and can be done as an optimization of the natural gas compression process, but the current analysis still requires further development based on different process flow diagrams of natural gas processing.

Acknowledgment
This work was supported by KEMENDIKBUDRISTEK under the Hibah Penelitian Tesis Magister (PTM) number: 112/E5/PG.02.00.PL/2023 and DRPM Institut Teknologi Sepuluh Nopember number: 2009/PKS/ITS/2023.

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