Optimization of Oil Well Production Using Binary Programming Method: Case Study Offshore Platform

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Abstract

Indonesia's oil production from year to year has decreased. The decline was because around 90% of the total oil production was produced from fields that were more than 30 years old, so a large investment was needed to contain the decline. The Java Sea Block is one of the oldest major blocks supporting Indonesia's oil and gas production with the production of 32,000 Barel Oil Per Day (BOPD) of oil and 167 Million Metric Standard Cubic Feet Per Day (MMSCFD) of natural gas, which has been operating since 1971. ZU Flowstation is one of the production fields that has been operating since 1984 with a production of 2000 – 2300 BOPD, has 24 artificial lift / Electrical Submersible Pump (ESP) wells with different characteristics. Production results fluctuate every year. This is due to the age of the old wells so they are not able to produce more oil. This study aims to maximize production results on the operating system by adjusting the frequency of the Variable Speed Drive (VSD) automatically. The approach used is the Optimization with Binary Programming method. The results showed an increase in production from 24 wells by 356 BOPD or 3.56%.

Keywords
Binary Programming, Electrical Submersible Pump, Optimization, Variable Speed Drive

1. Introduction
Currently, the growth of petroleum energy consumption in Indonesia is an average of 7% in the last 10 years or it can be said to have decreased. This is evidenced by the depletion of oil reserves from year to year, on the other hand natural gas tends to increase (can be seen in Figure 1). According to the Special Task Force for Upstream Oil and Gas Business Activities, the decline was due to around 90% of the total oil production in Indonesia being produced from fields that are more than 30 years old (Migas, 2021). This has an impact on unstable production results (Ohiorenoya et al., 2016).

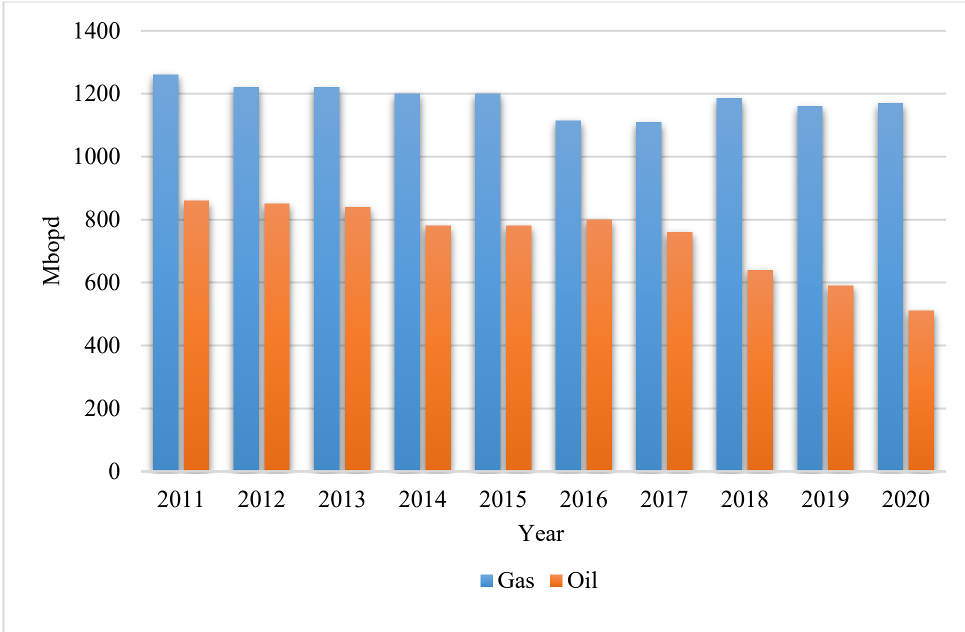

Figure 1. Oil and Gas Production in Indonesia 2011-2020

The Offshore Platform Industry is one of the oil and gas industries in Indonesia which is located in the northern part of the Java Sea. The Java Sea Block is one of Indonesia's oil and gas production blocks since 1971 and is the first offshore rig field operation in Indonesia. Its area of operation stretches from the thousand islands to the northern part of Cirebon. This block covers an area of 8,300 km², there are 11 main stations and 222 oil platforms (Normally Unman Installation) with the production of 32,000 Barel Oil Per Day (BOPD) of oil and 167 Million Metric Standard Cubic Feet Per Day (MMSCFD) of natural gas. One of the main stations of the Java Sea Block is the Zu Flow station which has 11 oil platforms (NUI) with 24 ESP oil wells producing around 3000 BOPD. Production results from the period 2015 to 2020 fluctuated. This is due to the age of the wells which are old and unable to produce more oil. The following data on the oil produced by the Zu Platform can be seen in Figure 2

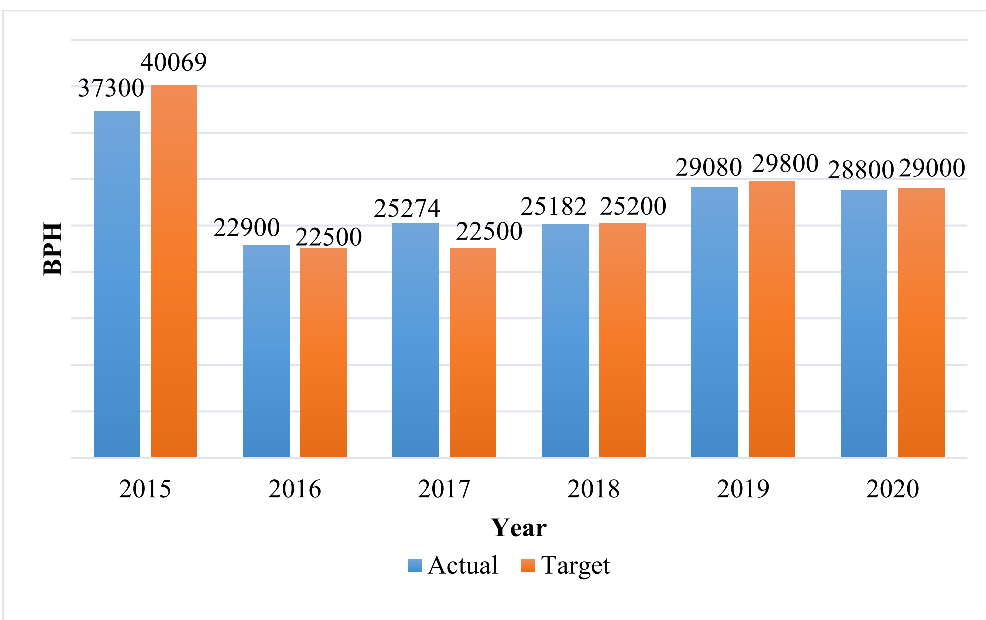

Figure 2. Production and Target Zu Platform 2015-2020

Based on these problems, it is necessary to make improvements. This research will optimize the operating system by adjusting the frequency of the VSD (Variable Speed Drive) automatically (Salunke et al., 2016) (Bakker et al., 2019). Based on previous research, to overcome these problems can use an optimization approach (Alhamaydeh et al., 2017) (Ahmad et al., 2020) (Ghigo et al., 2020). Optimization is a normative approach by identifying the best solution to a problem directed at the maximum point. In the operation process, many benefits arise such as increased factory performance, increased production yields, decreased energy consumption and efficient time (Krishnamoorthy et al., 2019). Optimization can also lead to efficient maintenance costs, effective use of tools, and better staff empowerment. In addition, intangible benefits arise from interactions between plant operators, engineers, and management. This helps to systematically identify goals, constraints, and degrees of freedom in the process, which leads to benefits such as improved design quality, faster problem solving and decision making. The optimization approach that is often used is Binary Programming (Arif H et al., 2018) (Mikolajková et al., 2018) (Jamaluddin et al., 2019) (Kowalik & Rzemieniak, 2021). Binary Programming is an algorithm-based optimization method (Zamani, 2017) (Al-Rekabi et al., 2019). This study aims to maximize production yields with the binary programming method to obtain an analysis of decisions to run production wells that are not Efficient Value (EV) and also obtain the most economical, profitable and optimal operating system decisions.

2. Literature Review

2.1 Optimization

According to Heizer & Barry (2014), Optimization is defined as a process by identifying the best solution of a problem that is directed at the maximum point by using various alternatives in terms of costs, utilization of tools, human resources, time, energy utilization and others.

2.2 Binary Programming

According to Munapo (2016), The Binary Programming model or called integer programming 0-1 is an integer program with the value of the Yi decision variable limited to two values, namely 0 and 1. In determining the constraints on the 0-1 integer programming model problem, several types of constraints can be used, namely Mutually Exclusive Restrictions, Multiple Choice Restrictions, and Precedence or Conditional Relationships. The following is the mathematical formula for Binary Programming.

$$X_{ij} \begin{cases} i = \text{optimization variable} \\ j = \text{frequensy increase frequency} \end{cases}$$

$$X_n \begin{cases} 1 = \text{variable EV} < 100\% \\ 0 = \text{variable EV} > 100\% \end{cases}$$

with :
Xn = Variable to n, n = 1, 2, 3, …

The formula for calculating the percentage of Volumetric Efficiency:

$$EV\ \% = \frac{\text{Q actual}}{\text{Q theoretical}} \quad \text{...(1)}$$

Information:
EV : Volumetric Efficiency (%)
Actual Q : Actual Production Quantity
Theoretical Q : Production amount on the pump curve

Purpose Function :

$$Max\ Z = \sum_{n=1}^{o} i \sum_{n=1}^{p} j \quad X_{ijo} * X_{ijp} \text{.......................................(2)}$$

Constraint Function:

$$\sum X_{ij} \geq 1 \qquad \text{for: i, j ....(3)}$$

$\sum X_{ij} \geq c_{ij}$ for i, j ....(4)
$\sum X_{ij} \geq r_i$ for: i ....(5)
$\sum X_{ij} \geq b_i$ for: i ....(6)

2.3 Lindo LINGO App 18.0

Lindo LINGO is an advanced software for optimizing, analyzing, and solving linear and nonlinear programming problems. Many operations research models can be analyzed using this software. LINGO uses visual modeling to better understand the user and have a significant impact on understanding the problem.

3. Methodology

The purpose of this ESP well production optimization model is to maximize the production of wells that have not met the production targets set by management. The first step is to collect oil well production data from the Zu Flowstation field in the North Java Sea block for the period 2020-2021. Determine the EV (Efficient Value) system. Optimizing with binary programming on oil wells that are operated so that production remains optimal. Get the best model as a result of the repair. This research uses a conceptual framework so that the research carried out is systematic and directed. The following conceptual framework of this research can be seen in Figure 3.

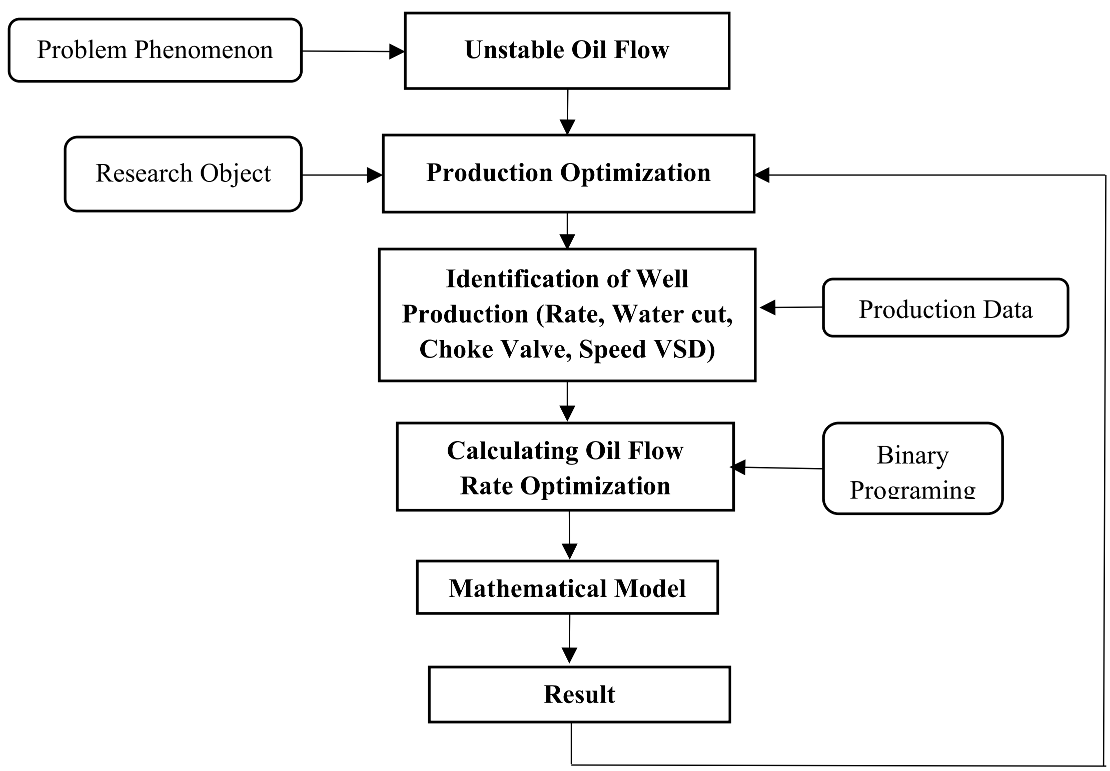

Figure 3. Research Framework

4. Data Collection

The data that has been obtained from data collection will be used in model development and decision analysis, including oil well production data. Through these data, the objective function and limiting function of the binary programming model will be obtained. This research will develop a model for optimization of oil flow production which has different operating conditions (limiting functions) but with different indexes, decision variables and objective functions. the same one. Based on field observations, it is known that in determining the wells to be optimized by adjusting the frequency. So, the decision variable to be determined is a binary integer variable which is expressed in the Xij variable. Where ***i*** represents the well to be optimized, while ***j*** indicates increasing the optimization frequency. The expected value of Xij is 0 or 1 which means:

i= optimization well
j= frequency increase

X_{ij} {

There are 24 Wells.
X_1 = Well 1
X_2 = Well 2
X_3 = Well 3... X_{24} = Well 24

$$X_n \begin{cases} 1=\text{well EV} < 100\% \\ 0=\text{well EV} > 100\% \end{cases}$$

with :
Xn = well ke n, n = 1, 2, 3, …, 24

The formula for calculating the percentage of Volumetric Efficiency:

$$EV\ \% = \frac{Q\ actual}{Q\ theoretical} \quad \text{..(1)}$$

Information:
EV : Volumetric Efficiency (%)
Actual Q : Actual Oil Production Quantity
Theoretical Q : Total Oil Production on the Pump Curve

Purpose Function :

$$Max\ Z = \sum_{n=1}^{14}{}_{i} \sum_{n=1}^{7}{}_{j}\ X_{ij14} * X_{ij7} \quad \text{.......................................(2)}$$

Constraint Function:

$\sum X_{ij} \geq 1$ for: i, j ....(3)
$\sum X_{ij} \geq c_{ij}$ for i, j ....(4)
$\sum X_{ij} \geq r_i$ for: i ....(5)
$\sum X_{ij} \geq b_i$ for: i ....(6)

5. Results and Discussion

Optimization is carried out by referring to the ESP Well production data in 2020. Production is produced in barrels of oil per month. The data were analyzed from January to December. The following data on oil well production can be seen in Table 1

Table 1. Zulu P/F Crude Oil Production Data 2020

Month	Average Oil Production (Barrel Oil per Monthly) 2020												Avg
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec	
Actual	2589	2571	2585	2559	2543	2519	2591	2618	2530	2595	2562	2528	2567
Target	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600

Based on the data in Table 1, the ESP Well optimization is carried out using the Binary Programming method. Following are the calculations and the Binary Programming program:

Calculating the percentage of Volumetric Efficiency:

$$EV\ \% = \frac{Q\ actual}{Q\ theoretical} \quad \text{..(1)}$$

Table 2. Volumetric Efficiency Percentage Data

No	Well	Freq (Hz)	Q actual (BFPD)		Q theoretical (BFPD)	EV (%)
1	ZUA-1	50	1188		858	138.46
2	ZUA-2ST	55	312		944	33.05
3	ZUA-3ST	42	168		721	24.00
4	ZUA-4	55	714		944	75.16
5	ZUA-5	55	186		944	19.70
6	ZUA-6ST	52	1008		892	113.00
7	ZUA-9	60	903		1030	87.67
8	ZUA-10	55	204		944	21.61
9	ZUA-12ST	52	321		892	35.98
10	ZUD-1	Natural Flow	18		0	0.00%
11	ZUD-2	52	118		892	13.22
12	ZUD-4	50	528		858	61.54
13	ZUD-5	55	1374		944	145.55
14	ZUD-6	55	90		944	09.53
15	ZUD-8	60	1414		1030	137.28
16	ZUD-9	52	318		892	35.61
17	ZUD-10	60	594		1030	57.66
18	ZUD-11	50	294		858	37.06
19	ZUG-1	50	660		858	76.92
20	ZUG-3	50	420		858	48.95
21	ZUG-4	60	264		1030	25.63
22	ZUG-5	55	72		944	07.62
23	ZUG-8	60	2298		1030	223.11
24	ZUG-10	60	1507		1030	146.31
Average			623.875		890.291	65.61

Table 2 is a data recapitulation of Volumetric Efficiency. Based on the analysis, it was found that 17 ESP wells will be optimized because the EV value is below 100%, while the frequency is 60 Hz, there are 3 wells. So the total wells to be optimized are 14 wells, which can be seen in Table 3

Table 3. Wells to be Optimized

No	Volumetric Efficiency		
	Well	Value	Reduced Cost
1	ZUA-2ST	33	0
2	ZUA-3ST	24	0
3	ZUA-4	75	0
4	ZUA-5	20	0
5	ZUA-10	22	0
6	ZUA-12	36	0
7	ZUD-2	13	0
8	ZUD-4	62	0
9	ZUD-6	10	0
10	ZUD-9	36	0
11	ZUD-11	37	0
12	ZUG-1	77	0
13	ZUG-3	49	0
14	ZUG-5	8	0

Based on binary numbers, 0 = Optimization is not carried out and 1 = Wells to be optimized. The following can be seen in Table 4.

Table 4. Binary Programming Numbers

No	Well	Frequency						
		42 Hz	45 Hz	50 Hz	52 Hz	55 Hz	57 Hz	60 Hz
1	ZUA-1	0	0	1	0	0	0	0
2	ZUA-2ST	1	1	1	1	1	1	1
3	ZUA-3ST	1	1	1	1	1	1	1
4	ZUA-4	1	1	1	1	1	1	1
5	ZUA-5	1	1	1	1	1	1	1
6	ZUA-6ST	0	0	0	1	0	0	0
7	ZUA-9	0	0	0	0	0	0	1
8	ZUA-10	1	1	1	1	1	1	1
9	ZUA-12ST	1	1	1	1	1	1	1
10	ZUD-1	0	0	0	0	0	0	0
11	ZUD-2	1	1	1	1	1	1	1
12	ZUD-4	1	0	1	1	1	1	1
13	ZUD-5	0	0	0	0	1	0	0
14	ZUD-6	1	1	1	1	1	1	1
15	ZUD-8	0	0	0	0	0	0	1
16	ZUD-9	1	1	1	1	1	1	1
17	ZUD-10	0	0	0	0	0	0	1
18	ZUD-11	1	1	1	1	1	1	1
19	ZUG-1	1	1	1	1	1	1	1
20	ZUG-3	1	1	1	1	1	1	1
21	ZUG-4	0	0	0	0	0	0	1
22	ZUG-5	1	1	1	1	1	1	1
23	ZUG-8	0	0	0	0	0	0	1
24	ZUG-10	0	0	0	0	0	0	1
Total		14	13	15	15	15	14	20

5.1 Model Verification

The verification stage in this study uses the LINGO 18.0 algorithm software. The existing mathematical model is modeled with the LINGO 18.0 programming language by setting the data set first so that all data that has been entered can be read by the LINGO 18.0 software during the run-data process.

After all the data is inputted in the LINGO 18.0 software, the output is as shown in Figure 4 and the optimization model obtained is Global Optimum with the Linear Programming class model. While the results of the Solve Run Program Lingo 18.0 are summarized in Table 5, Table6 and Table 7.

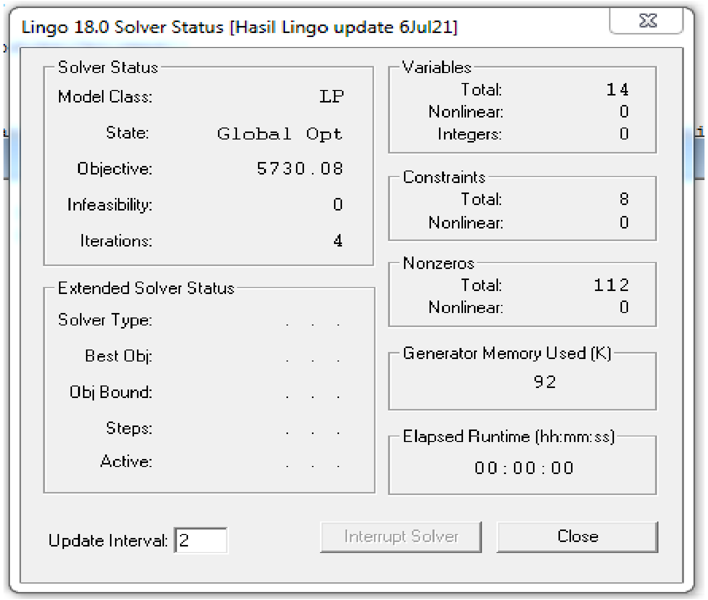

Figure 4. Lindo LINGO 18.0 display

Tabel 5. Well Optimization Results

No	Well	Optimization Result						
		42 Hz	45 Hz	50 Hz	52 Hz	55 Hz	57 Hz	60 Hz
1	ZUA-2ST	22	23	26	27	29	30	31
2	ZUA-3ST	30	32	36	37	39	41	43
3	ZUA-4	10	10	11	12	13	13	1
4	ZUA-5	36	39	43	45	47	49	52
5	ZUA-10	33	35	39	41	43	44	47
6	ZUA-12	20	21	24	25	26	27	29
7	ZUD-2	55	59	66	69	73	75	79
8	ZUD-4	12	12	14	14	15	16	17
9	ZUD-6	72	77	86	89	94	98	103
10	ZUD-9	20	21	24	25	26	27	29
11	ZUD-11	19	21	23	24	26	26	18
12	ZUG-1	9	10	11	12	12	13	13
13	ZUG-3	15	16	18	18	19	20	21
14	ZUG-5	90	97	107	112	118	122	129

Based on Table 7, the optimization results show that there is an average increase per month compared to production results in 2020. The following comparison of results before and after optimization in January – June 2021 can be seen in Table 8.

Table 6. Comparison of Production in 2020 – 2021

	Months												
Production	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec	FYA
Prod monthly 2021 (BOPD)	2659	2671	2640	2649	2643	2619	-	-	-	-	-	-	1323
Prod monthly 2020 (BOPD)	2589	2571	2485	2159	2243	2219	2391	2618	2430	2395	2362	2328	2399
Base Prod Target (BOPD)	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600

5.2 Practical Implications

Most of the oil and gas industry has developed into a large industry. Every production process needs to be improved continuously to run optimally. This case study has provided great results and impact for the Offshore Platform industry to achieve a competitive industry. This case study will guide similar industries to achieve a competitive advantage. In addition to obtaining the optimal model, the implications of this case study are determining the combination of optimization wells, overcoming fluctuating annual production, energy efficiency and increasing production capacity.

6. Conclusion

The results of research conducted on optimization of production in oil wells resulted in several conclusions, among others, based on the developed binary programming model, it can determine the combination of optimization wells to obtain the most optimal production benefits from each well with predetermined limits. Parameter changes in oil wells greatly affect the amount of oil production on the combination of wells, because the decisions are most optimal and influenced by changes in these parameters. The results showed an increase in production from 24 wells by 356 BOPD or 3.56%. Further research, the optimization system can be developed into the software with a good user interface, so that it can facilitate the decision-makers when there are changes in the parameters of the production process.

Acknowledgments

This article was created with financial support from Universitas Mercu Buana Jakarta, Indonesia, to motivate students and lecturers to have innovative research. Thank you to my friends for the Masters Of Industrial Engineering Class 26 and Zu Platform team, who have provided input and suggestions in completing this article.

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