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Performance Analysis of DN1750 and DN1800 Electric Submersible Pump for Production Optimization on the Oil Well

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Abstract. Electric Submersible Pump (ESP) is an artificial lift method to lift fluid from the reservoir to the surface with a certain production rate, the ability of the pump to lift a certain fluid to the surface is adjusted to the capacity of the well itself. Along the time, the production of oil wells will experience a decrease in the rate of production which will cause a decrease in pump performance. In several oil wells, well-maintenance activities have been carried out. Therefore, in this research, an analysis of pump performance and optimization of ESP pumps has been carried out using the Nodal Variable Speed Drive analysis method, the aim is to determine the production capacity of the oil well and determine the pump speed according to the desired flow rate through frequency changes. Oil well performance analysis and optimization of the ESP pump were carried out by mathematical calculations with the optimization results obtained that the DN1750 pump was installed at a frequency of 50 Hz, 55 Hz, 60 Hz, 65 Hz, and 70 Hz. Those Hz numbers do not cross the desired flow rate line (q optimum) or are outside the desired fluid flow rate range by the oil well so that it can be interpreted that based on the observation of the optimization process, the condition of the DN1750 pump does not work optimally so that the oil production capacity is not optimal. The DN 1800 pump at a frequency of 55 Hz with a speed of 3300 rpm is in accordance with the production capability of the oil well so that a suitable pump is obtained and is expected to work at optimum conditions. At a frequency of 55 Hz with a speed of 3300 rpm, it succeeded in cutting the desired flow rate line (q optimum) from the observed characteristics of the oil well or was in the range of fluid flow rates desired by the oil well, which was 1936,698 Barrels Per Day (BPD) with a wellbore pressure (PWF) of 629 psi.

Keywords: electric; submersible; pump; oil; well; nodal; speed; drive; pressure

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1. Introduction

A pump is a device that can move liquids, gases or sometimes slurries, by mechanical action, usually converted from electrical energy to hydraulic energy. The pump used in oil wells is an Electric Submersible Pump (ESP) where the pump uses an electric motor that is submerged below the surface of the liquid that drives a multilevel centrifugal pump [1]. The fluid removal method with ESP is widely used because it is very effective and efficient for wells that have a large Productivity Index (PI) in the deep wells and for the inclined wells. Oil wells that are continuously produced can decrease the production rates caused by reduced fluid reserves in the reservoir, a decrease in natural driving pressure from the well, and a decrease in pump performance [2].

If the pump is operated continuously not in optimum condition, the pump may have an operation failure which causes the oil production can stop, one of the production well maintenance activities is

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to maintain a stable production rate and high pump performance, it is necessary to evaluate the pump in order to obtain a pump that is in accordance with the oil well's production capability [3].

In several oil wells, well-maintenance activities have been carried out, such as the oil well in the Bantayan field, which is produced using an ESP pump, it is known that the production of the well can still be increased.

2. Methodology

This research uses the Nodal Variable Speed Drive analysis method to determine the production capability of the oil well and determine the appropriate pump speed at the desired flow rate through frequency changes [4].

2.1 Data of Research

This study uses secondary data which is divided into physical oil well data, oil well production data, and installed pump data. The data is taken from the oil well production test process (Sonolog test) [5]. Sonolog test is used to analyze oil wells by measuring depth and subsurface pressure (Bottom Hole Pressure) as data for the oil well analysis [6].

The measurement results are expected to be used to determine the efficiency of the oil well production [7]. Evaluation of the Electrical Submersible Pump is done by calculating the Inflow Performance Relationship (IPR) using the Vogel method to determine the characteristics of the well as well as the maximum flow rate and the desired production optimization [8].

Optimization of data processing is carried out using nodal analysis to determine the appropriate pump speed at the desired flow rate through frequency changes [9]. If the resulting optimization results cut the desired flow rate line (q optimum) from the observed oil well characteristics that are within the range of fluid flow rates desired by the oil well, then the optimization can be interpreted as pumping according to the well's production capability [10]. If the optimization results of the observed oil well characteristics are outside the desired fluid flow rate range, so need a suitable pump for the oil well production capacity [11].

a. Oil Well Completion Data

Below is the data table about the oil well completion.

Table 1. Oil Well Completion Data

Completion Data	Value
Top Perforation (Ft)	6390
Bottom Perforation (Ft)	7684
OD Casing (Inch)	7
ID Casing (Inch)	6.276
Casing Pressure (Psi)	82.83
OD Tubing (Inch)	2 7/8
ID Casing (Inch)	2.441
Tubing Pressure (Psi)	575.61

b. Oil Well Production Data

Below is the data table about the oil well production.

Table 2. Oil Well Production Data

Data	**Value**
q_{fluid} (BFPD)	1134
q_{oil} (BOPD)	249.48
q_{water} (BWPD)	884.52
SG Oil	0.87

SG Water	1.05
Water Cut (%)	78
Oil Cut (%)	22
Bottom Hole Temperature (°F)	266
Reservoir pressure (Psi)	1610
Well Bottom Flow Pressure / Pwf (Psi)	1126.48
Total of depth (Ft)	7827

*c.	Specification Data of The ESP Pump DN1750*

Below is the specification data table about the ESP pump DN1750.

Table 3. Specification of the ESP Pump DN1750

Data	Value
Constanta Friction ©	120
Frekuensi (Hz)	60
Total stages (stages)	261
Power (Hp)	120
Pump Setting Depth (Ft)	6800

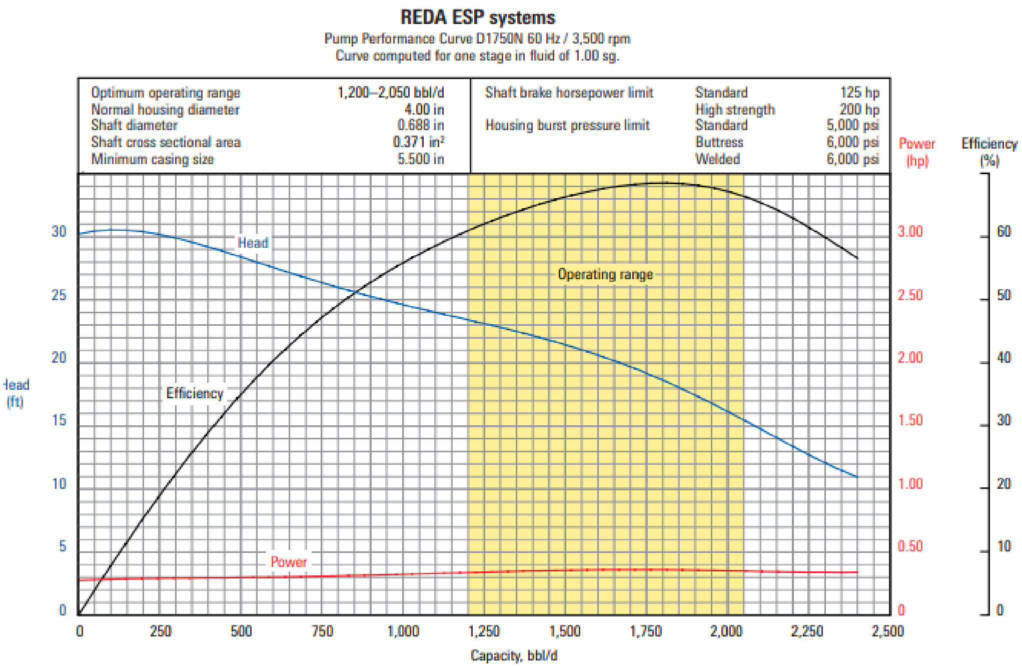

Figure 1. Curve Performance of the ESP Pump DN1750

*d.	Performance of the ESP Pump DN1800*

Below is the curve performance of the ESP pump DN1800.

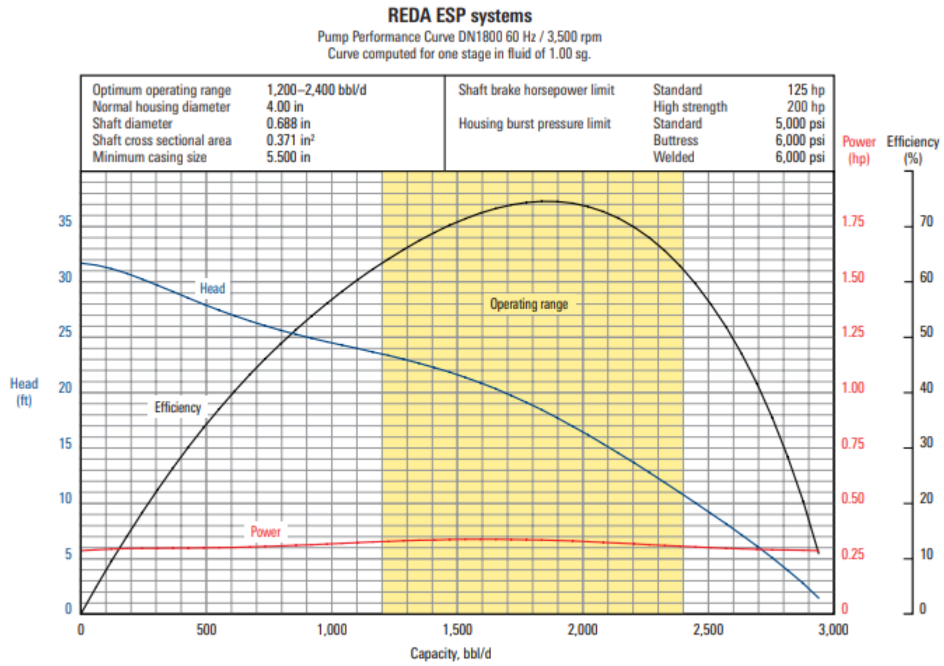

Figure 2. Curve Performance of the ESP Pump DN1800

2.2 Calculation of the Oil Well Production Capability

Before optimizing the pump, it is necessary to know how big the production capability of the oil well is so that the pump design obtained will be in accordance with the production capability of the oil well [12]. The production capability of a well is known from the IPR (Inflow Performance Relationship) curve [13]. The method of calculating the IPR curve in this research uses the Vogel method [14]. From reservoir data and test data for oil well, the steps to calculate the IPR curve are as follows:

a. Calculating the Maximum Production Rate

$$q_{max} = \frac{q}{1 - 0.2\left(\frac{Pwf}{P_s}\right) - 0.8\left(\frac{Pwf}{P_s}\right)^2} = \frac{1134}{1 - 0.2\left(\frac{1126.48}{1610}\right) - 0.8\left(\frac{1126.48}{1610}\right)^2} = 2420.872 \text{ BPD}$$

b. Calculating the Amount of the Production Flow Rate

Assuming that the pressure of Pwf = 200 Psi

$$q = q_{max}\left[1 - 0{,}2\left(\frac{Pwf}{P_s}\right) - 0{,}8\left(\frac{Pwf}{P_s}\right)^2\right] = q_{max}\left[1 - 0.2\left(\frac{2420.872}{1610}\right) - 0.8\left(\frac{2420.872}{1610}\right)^2\right]$$
$$= 2330.840 \text{ BPD}$$

Table 4. Production Rate

Pwf (Psi)	q (BPD)
0	2420.872
100	2383.328
200	2330.840
300	2263.409
400	2181.036
500	2083.719
600	1971.459
700	1844.256

800	1702.110
900	1545.021
1000	1372.989
1100	1186.013
1200	984.095
1300	767.234
1400	535.429
1500	288.682
1610	0

c. Calculating the Desired Production Rate (q Optimum)

The desired production rate is the optimum production rate from an oil well, which is 80% of the maximum Q [15]. The optimum production rate is 1936,698 BPD.

d. Creating an IPR Curve

Plotting the production rate (q) on the horizontal axis against the bottom well pressure (Pwf) on the vertical axis and the desired production rate is 1936,698 BPD with a Pwf price of 629 psi, the following curve will be obtained:

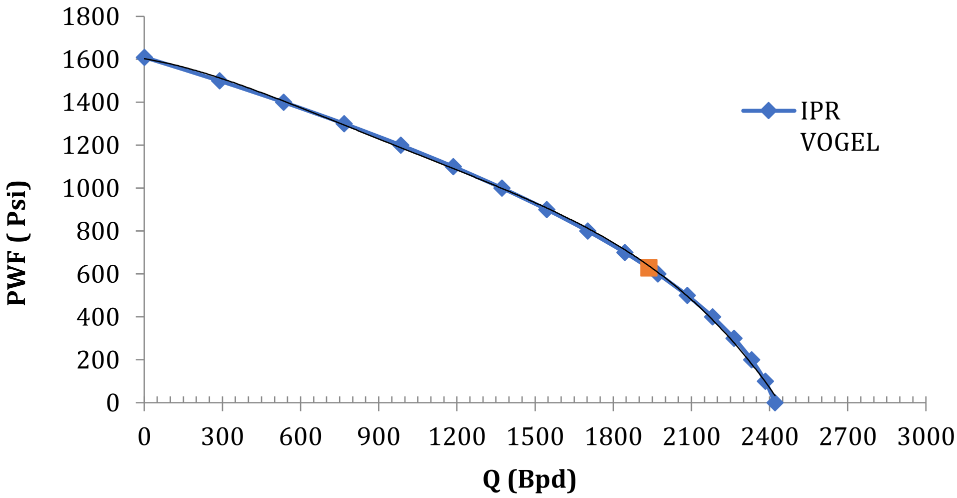

Figure 3. IPR Curve of ESP Pump DN1750

2.3 Use of Nodal System

Nodal is a meeting point between two components, where physically there will be mass balance or pressure balance. This means that the mass of the fluid leaving one component will be equal to the mass of the fluid entering the next interconnected component or the pressure at one end of the component will be equal to the pressure at the other end of the connected component [16].

Nodal system analysis is done by making a pressure-production rate diagram, which is a graph that relates pressure changes and production rates for each component. The procedure for making intake tubing curve (node outflow) for Liquid Only with Nodal at the Bottom of the oil well is as follows:

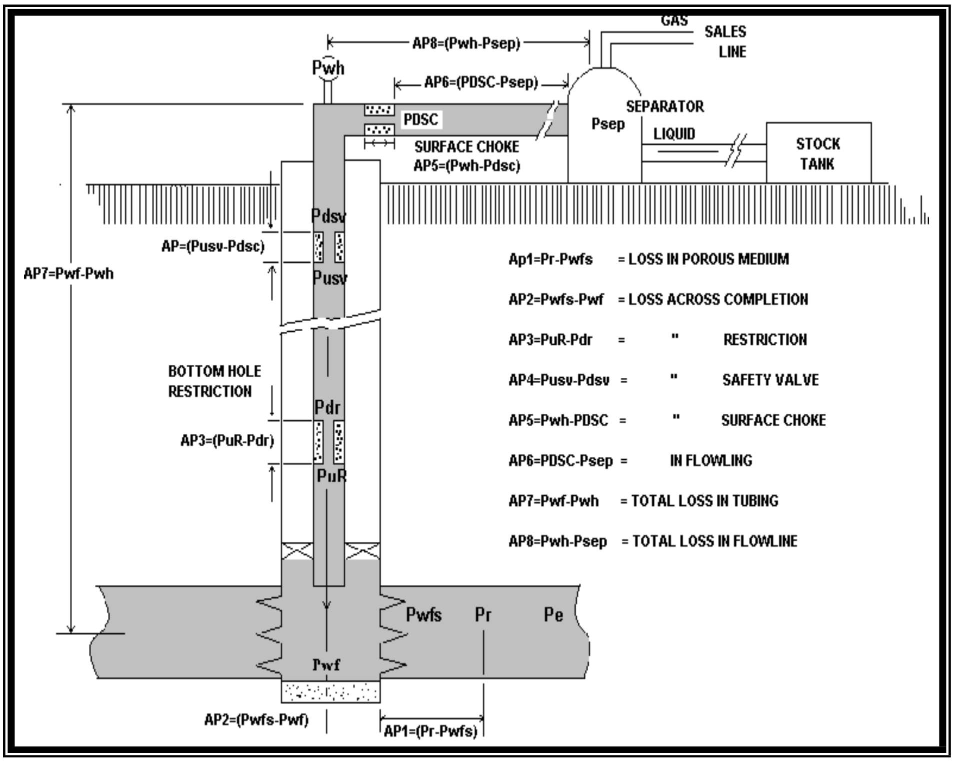

Figure 4. Oil Well Production System

The selected outflow node is at pump pressure. So the Nodal equation used to determine the appropriate pump speed at the desired flow rate through frequency changes is as follows:

Pr – Pwf = Ppump + Tubing Pressure Loss + WHP

a. Determain the Head Friction Loss

Determining Head Friction is using the Hazen-William Friction Loss graph, by reading the Hazen-William Friction Loss graph below, based on the value of the outer diameter of the casing which is 2.441 inches, and the desired production rate of 1936,698 BPD, it can be seen that the value of Head Friction Loss is 35 ft.

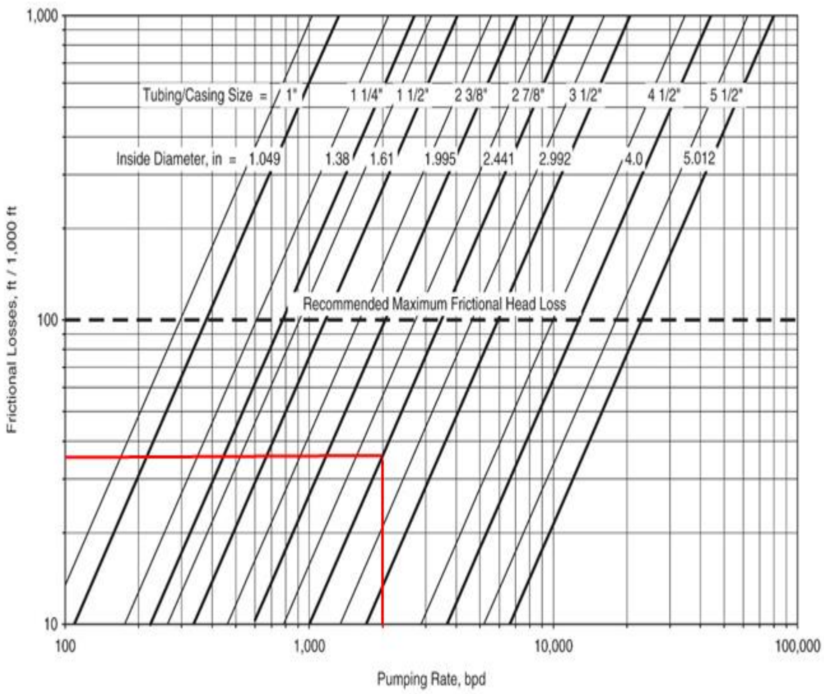

Figure 5. Friction Loss Hazen-William Graph

b. Determine the Tubing Pressure Loss

Tubing Pressure Loss/1000 ft = 0.433 x Head x Sg Oil

Tubing Pressure Loss/1000 ft = 0.433 x 35 x 0.87

Tubing Pressure Loss/1000 ft = 13.185 Psi/1000 ft

Tubing Pressure Loss = 13.185 Psi/1000 ft x Pump Setting Depth

Tubing Pressure Loss = 13.185 Psi x $\frac{6800}{1000}$ = 89.66 Psi

c. Conversion Hz to Rpm

The conversion calculation starts from the frequency of 50 Hz:

50 Hz = 50 Rev/s

50 Hz = 50 Rev X 60 s = 3000 rpm

Table 5. Pump Speed

Frequency (Hz)	Revolution (rpm)
50	3000
55	3300
60	3600
65	3900
70	4200

d. Determine the Pump Pressure

Determine the recommended Pump Head based on the frequency variant. By plotting the recommended production rate range (q) of 1000 BPD on the horizontal axis against the recommended pump head value at 50 Hz on the vertical axis, gets a pump head of 16 ft.

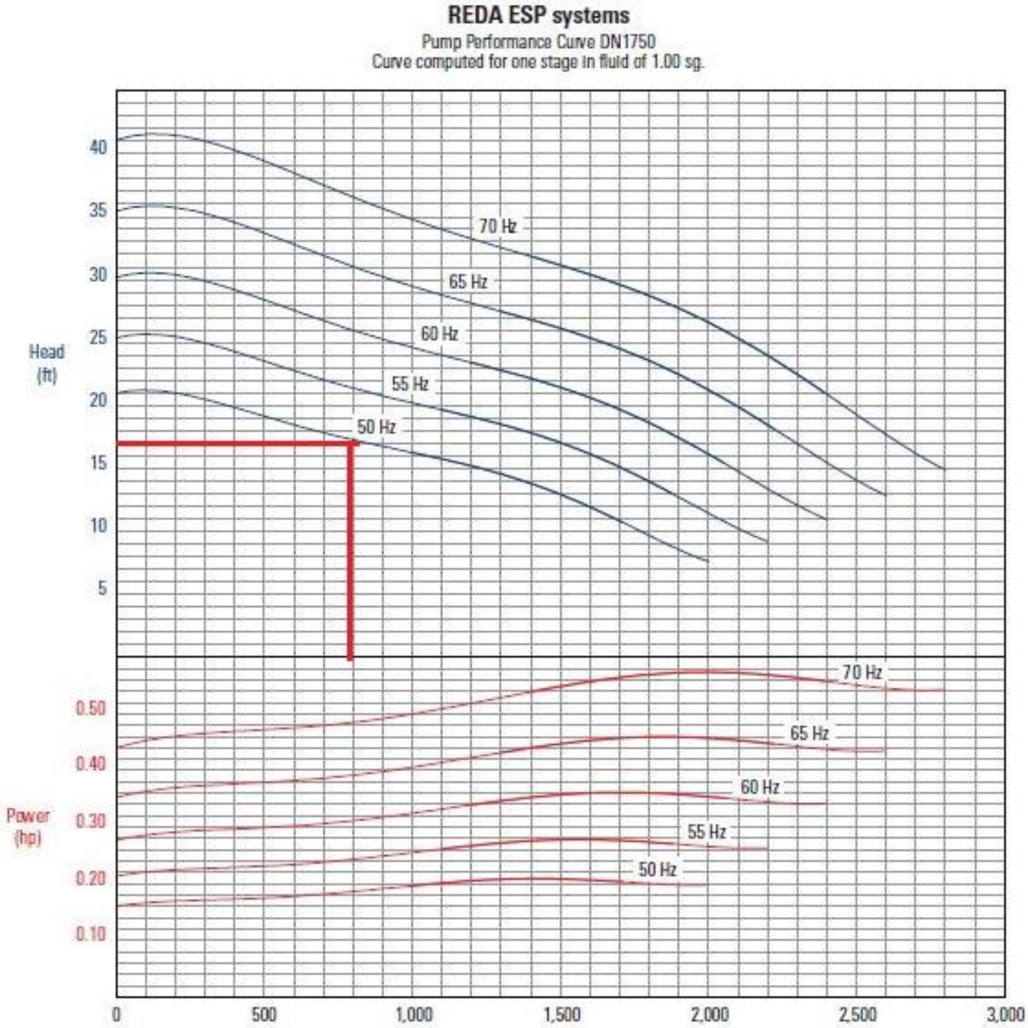

Figure 6. Pump Performance Curve DN1750

3. Results and Discussions

In this section, the author will show the performance analysis of DN1750 and DN1800 ESP pumps. The analysis results will show which pumps are in accordance with the production capabilities of the oil well so that a suitable pump is obtained and works at optimum conditions.

3.1 Data Result of DN1750 ESP Pump

Data below is showing the recommended production rate (Pump Optimum Range) per frequency variant and tabulate it as follows.

a. *Frequency 50 Hz (3000 rpm)*

Table 6. Tabulation of Outflow Node Frequency 50 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (PSI)	Oil Well PWF (Psi)
16	1000	447,862	496,871
15,5	1100	433,866	510,867
15	1200	419,871	524,862
14,5	1300	405,875	538,858
14	1400	391,879	552,854
13	1500	363,888	580,845
12	1600	335,897	608,836
11	1700	307,905	636,828

b. *Frequency 55 Hz (3300 rpm)*

Table 7. Tabulation of Outflow Node Frequency 55 Hz

Head (Ft)	Rate (BPD)	Pump Pressure Psi)	Oil Well PWF (Psi)
19,5	1100	545,832	398,901
19	1200	531,836	412,897
18,5	1300	517,841	426,892
18	1400	503,845	440,888
17	1500	475,853	468,880
16	1600	447,862	496,871
15	1700	419,871	524,862
14	1800	391,879	552,854
13	1900	363,888	580,845

c. *Frequency 60 Hz (3600 rpm)*

Table 8. Tabulation of Outflow Node Frequency 60 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (Psi)	Oil Well PWF (Psi)
23,5	1200	657,797	286,936
23	1300	643,802	300,931
22	1400	615,810	328,923
21	1500	587,819	356,914
20,5	1600	573,823	370,910
19,5	1700	545,832	398,901
18,5	1800	517,841	426,892
17,5	1900	489,849	454,884
16	2000	447,862	496,871
15,5	2050	433,866	510,867

d. *Frequency 65 Hz (3900 rpm)*

Table 9. Tabulation of Outflow Node Frequency 65 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (Psi)	Oil Well PWF (Psi)
27,5	1300	769,763	174,970
27	1400	755,767	188,966
26	1500	727,776	216,957
25	1600	699,785	244,949
24,5	1700	685,789	258,944
23,5	1800	657,797	286,936
22,5	1900	629,806	314,927
21	2000	587,819	356,914
20	2100	559,828	384,905
18	2200	503,845	440,888

e. Frequency 70 Hz (4200 rpm)

Table 10. Tabulation of Outflow Node Frequency 70 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (Psi)	Oil Well PWF (Psi)
32	1400	895,724	49,009
31	1500	867,733	77,000
30,5	1600	853,737	90,996
29,5	1700	825,746	118,987
28,5	1800	797,754	146,979
27,5	1900	769,763	174,970
26,5	2000	741,772	202,961
25	2100	699,785	244,949
24	2200	671,793	272,940
22	2300	615,810	328,923
21	2400	587,819	356,914

The table above shows the results of the tabulation of determining the Node Outflow (PWF) according to pump pressure with flow rate and Head in the optimum range obtained based on the Frequency variant through the NPSH DN 1750 pump graph at a frequency of 50 Hz (3000 rpm), 55 Hz (3300 rpm), 60 Hz (3600 rpm), 65 Hz (3900 rpm) and 70 Hz (4200 rpm).

At a frequency of 50 Hz (3000 rpm) with a Q value of 1500 it produces a PWF value of 580,845 Psi, while at a frequency of 55 Hz (3300 rpm) with the same value (Q) it produces 468,880 Psi. At a frequency of 60 Hz (3600 rpm) the PWF value is 356.914 Psi and at a frequency of 65 Hz (3900 rpm) it produces 216.957 Psi and at a frequency of 70 Hz (4200 rpm) it produces 77,000 Psi. These results indicate that when the rpm used is different and reaches the same rate value, it will produce different PWF values. The higher the number of rpm when the Q value reaches the same number will result in a lower PWF value.

3.2 Performance Result of the ESP pump DN1750

Plot the results of the Node Outflow calculations for different pump pressures according to the flow rate and pump head per variant Frequency on the IPR Vogel inflow curve for oil wells and connect these points and plot the efficiency calculation results at various power according to the optimum flow rate range per frequency, the graph obtained outflow and efficiency graph as follows:

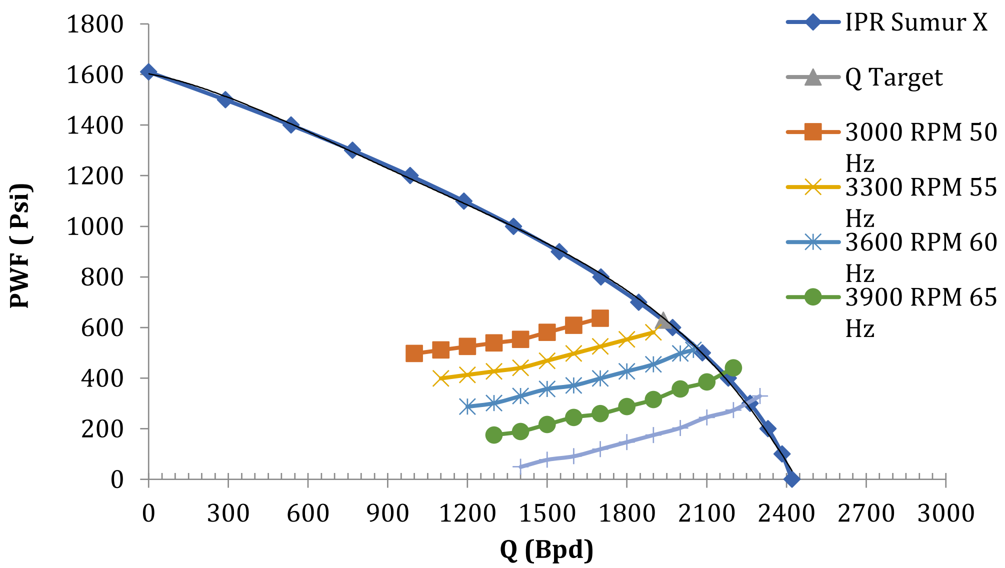

Figure 7. Inflow and Outflow Graph of the Oil Well Pump DN 1750

Based on the results shown in Tables 6 to 10 and Figure 7, it can be seen that the higher the rpm value, the higher the Q value and the lower the PWF value. Figure 7 shows that the greater the rpm value, the PWF value will be closer to the X line, while the resulting Q value is greater as seen from the lowest Q value generated for each rpm value.

3.3 Data Result of DN1800 ESP Pump

Data below is showing the recommended production rate (Pump Optimum Range) per frequency variant and tabulate it as follows.

a. Frequency 50 Hz (3000 rpm)

Table 11. Tabulation of Outflow Node Frequency 50 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (PSI)	Oil Well PWF (Psi)
16,5	1000	461,858	482,875
16	1100	447,862	496,871
15,5	1200	433,866	510,867
14,5	1300	405,875	538,858
14	1400	391,879	552,854
13	1500	363,888	580,845
12	1600	335,897	608,836
11	1700	307,905	636,828
10	1800	279,914	664,819
8,5	1900	237,927	706,806
7,5	2000	209,935	734,798

b. Frequency 55 Hz (3300 rpm)

Table 12. Tabulation of Outflow Node Frequency 55 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (PSI)	Oil Well PWF (Psi)
19,5	1100	545,832	398,901
19	1200	531,836	412,897
18,5	1300	517,841	426,892
18	1400	503,845	440,888

17	1500	475,853	468,880
16	1600	447,862	496,871
15	1700	419,871	524,862
14	1800	391,879	552,854
13	1900	363,888	580,845
11,5	2000	321,901	622,832
10,5	2100	293,909	650,824
9	2200	251,922	692,811

c. *Frequency 60 Hz (3600 rpm)*

Table 13. Tabulation of Outflow Node Frequency 60 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (Psi)	Oil Well PWF (Psi)
23,5	1200	657,797	286,936
23	1300	643,802	300,931
22,5	1400	629,806	314,927
21,5	1500	601,815	342,918
21	1600	587,819	356,914
20	1700	559,828	384,905
19	1800	531,836	412,897
18	1900	503,845	440,888
16,5	2000	461,858	482,875
15	2100	419,871	524,862
13,5	2200	377,884	566,849
12	2300	335,897	608,836
11	2400	307,905	636,828

d. *Frequency 65 Hz (3900 rpm)*

Table 14. Tabulation of Outflow Node Frequency 65 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (Psi)	Oil Well PWF (Psi)
27,5	1300	769,763	174,970
27	1400	755,767	188,966
26	1500	727,776	216,957
25,5	1600	713,780	230,953
24,5	1700	685,789	258,944
23,5	1800	657,797	286,936
23	1900	643,802	300,931
21,5	2000	601,815	342,918
20	2100	559,828	384,905
18,5	2200	517,841	426,892
17,5	2300	489,849	454,884
16	2400	447,862	496,871
14,5	2500	405,875	538,858
12,5	2600	349,892	594,841

e. *Frequency 70 Hz (4200 rpm)*

Table 15. Tabulation of Outflow Node Frequency 70 Hz

Head (Ft)	Rate (BPD)	Pump Pressure (Psi)	X PWF (Psi)
32	1400	895,724	49,009
31,5	1500	881,728	63,005
30,5	1600	853,737	90,996
30	1700	839,741	104,992
29	1800	811,750	132,983
28	1900	783,759	160,974
27	2000	755,767	188,966
25,5	2100	713,780	230,953
24,5	2200	685,789	258,944
23	2300	643,802	300,931
21,5	2400	601,815	342,918
19,5	2500	545,832	398,901
18	2600	503,845	440,888
16,5	2700	461,858	482,875
14,5	2800	405,875	538,858

The table above shows the results of the tabulation of determining the Node Outflow (PWF) according to pump pressure with flow rate and Head in the optimum range obtained based on the Frequency variant through the NPSH DN 1800 pump graph at a frequency of 50 Hz (3000 rpm), 55 Hz (3300 rpm), 60 Hz (3600 rpm), 65 Hz (3900 rpm) and 70 Hz (4200 rpm).

At a frequency of 50 Hz (3000 rpm) with a Q value of 1500 it produces a PWF value of 580,845 Psi, while at a frequency of 55 Hz (3300 rpm) with the same value (Q) it produces 468,880 Psi. At a frequency of 60 Hz (3600 rpm) the PWF value is 342,918 Psi and at a frequency of 65 Hz (3900 rpm) it produces 216.957 Psi and at a frequency of 70 Hz (4200 rpm) it produces 63.005 Psi. These results indicate that when the rpm used is different and reaches the same rate value, it will produce different PWF values. The higher the number of rpm when the Q value reaches the same number will result in a lower PWF value.

3.4 Performance Result of the ESP pump DN1800

Plot the results of the Node Outflow calculations for different pump pressures according to the flow rate and pump head per variant Frequency on the IPR Vogel inflow curve for oil wells and connect these points and plot the efficiency calculation results at various power according to the optimum flow rate range per frequency, the graph obtained outflow and efficiency graph as follows:

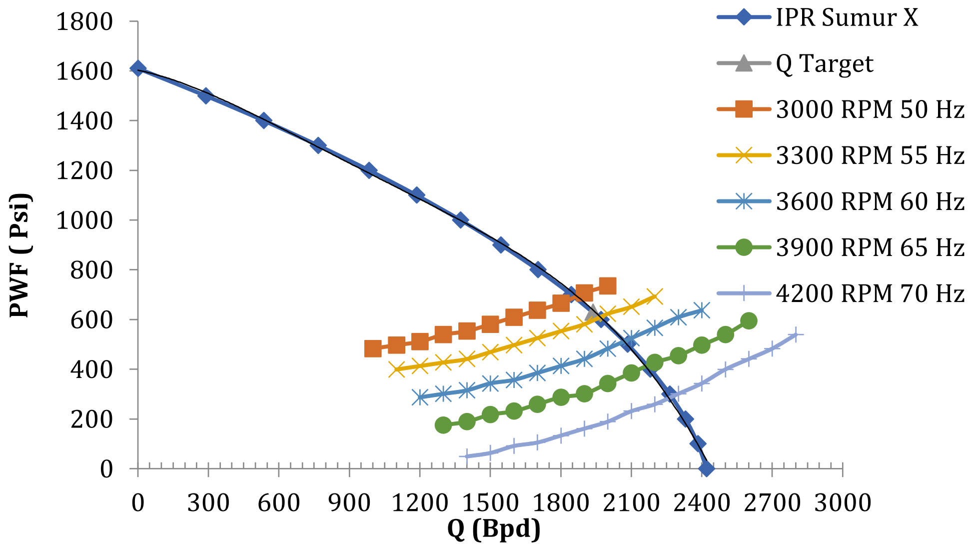

Figure 8. Inflow and Outflow Graph of the Oil Well Pump DN 1800

Based on the results shown in Tables 11 to 15 and Figure 8, it can be seen that the higher the rpm value, the higher the Q value and the lower the PWF value. Figure 8 shows that the larger the rpm value, the PWF value will be closer to the X line, while the resulting Q value is greater as seen from the lowest Q value generated for each rpm value.

The results of this measurement indicate that there is a difference between the PWF value between the ESP pump DN1750 and the ESP pump DN1800. The difference is in the frequency of 60 Hz (3600 rpm) and a frequency of 70 Hz (4200 rpm) where the PWF value of the ESP Pump DN1800 is lower than the ESP DN1750. ESP Pump DN1750 and ESP Pump DN1800 when running at the same frequency and the same speed will produce.

3.5 Analysis

a. ESP Pump DN1750

Based on the figure 8, it can be seen that the DN 1750 Pump Node Outflow line for frequency variation has not crossed the desired flow rate line (q optimum) from the observed characteristics of the oil well or is outside the desired fluid flow rate range by the oil well, which is 1936,698 BPD with PWF is 629 psi. This physically does not occur mass balance or pressure balance. This means that the mass of fluid leaving one component is not the same as the mass of fluid entering the next interconnected component or the pressure at one end of one component is not the same as the pressure at the other end of the connected component.

The DN1750 pump installed at a frequency of 50 Hz with a pump speed of 3000 rpm and a frequency of 55 Hz with a pump speed of 3300 rpm operates below the desired optimum production rate. And the DN1750 pump is installed at a frequency of 60 Hz with a pump speed of 3600 rpm, a frequency of 65 Hz with a pump speed of 3900 rpm, and a frequency of 70 Hz with a pump speed of 4200 rpm operating above the optimum limit of the desired production rate. Therefore, it can be interpreted that based on the observed optimization, the DN 1750 Pump is not in accordance with the production capability of the oil well because it works under conditions that are not optimal. The use of DN1750 will reduce the performance of the well because it works under conditions that are not optimal and can cause a decrease in system performance.

b. ESP Pump DN1800

Based on figure 9, the curve between the DN 1800 pump performance inflow graph vs the Velocity Variation Outflow Graph, it can be seen that the DN 1800 pump outflow Node channel with frequency variation is installed at a frequency of 50 Hz with a pump speed of 3000 rpm operating below the optimum limit of the desired production rate. The DN1800 pump is installed at a frequency of 60 Hz with a pump speed of 3600 rpm, a frequency of 65 Hz with a pump speed of 3900 rpm, and a frequency of 70 Hz with a pump speed of 4200 rpm operating above the optimum limit of the desired production rate.

At a frequency of 55 Hz with a speed of 3300 rpm successfully cut the desired flow rate line (q optimum) from the observed oil well characteristics or is in the range of fluid flow rates desired by the oil well, which is 1936,698 BPD with a PWF of 629 psi. This physically occurs in mass balance or pressure balance. Therefore, it can be interpreted that based on the observed optimization, the DN 1800 Pump at a frequency of 55 Hz with a speed of 3300 rpm is in accordance with the production capacity of the oil well so that a suitable pump is obtained and is expected to work at optimum conditions. The use of DN1800 will improve the performance of the well because it works under conditions that are not optimal and can cause a decrease in system performance.

4. Conclusions

From the results of the research and analysis above, this research concludes as follows:

1. The DN1750 pump installed at a frequency of 50 Hz with a pump speed of 3000 rpm and a frequency of 55 Hz with a pump speed of 3300 rpm operates below the desired optimum production rate. And the DN1750 pump is installed at a frequency of 60 Hz with a pump speed of 3600 rpm, a frequency of 65 Hz with a pump speed of 3900 rpm, and a frequency of 70 Hz with a pump speed of 4200 rpm operating above the optimum limit of the desired production rate. The DN 1750 Pump is not in accordance with the production capability of the oil well because it works under conditions that are not optimal.

2. The DN 1800 Pump at a frequency of 55 Hz with a speed of 3300 rpm is in accordance with the production capacity of the oil well so that a suitable pump is obtained and is expected to work at optimum conditions.

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References

[1] Shahid, S., Dol, S. S., Hasan, A. Q., Kassem, O. M., Gadala, M. S., & Aris, M. S. (2021). A review on electrical submersible pump head losses and methods to analyze two-phase performance curve. *WSEAS Transactions on Fluid Mechanics*, *16*(February), 14–31. https://doi.org/10.37394/232013.2021.16.3.

[2] Zhao, P., Wang, X., Liu, Y., Wu, M., & Yue, W. (2015). The design of oil well production engineering analysis system. *Open Mechanical Engineering Journal*, *9*(1), 437–442. https://doi.org/10.2174/1874155X01509010437.

[3] Zhigarev, D. B., Lekomtsev, A. V., Gorlov, A. E., & Dengaev, A. V. (2021). Experimental studies of the efficiency of high-speed ESPs. *E3S Web of Conferences*, *266*, 1–8. https://doi.org/10.1051/e3sconf/202126601023.

[4] Chatzarakis, G. E. (2009). Nodal analysis optimization based on the use of virtual current sources: A powerful new pedagogical method. *IEEE Transactions on Education*, *52*(1), 144–150. https://doi.org/10.1109/TE.2008.921459.

[5] TARYANA, N. (2014). Sonolog Test Sumur Minyak menggunakan Alat Total Well Management Echometer sebagai Well Analyzer Sumur di Pertamina EP Subang. *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, *2*(2), 152. https://doi.org/10.26760/elkomika.v2i2.152.

[6] Olufemi, A., Adesina, F. A. S., & Olugbenga, F. (2008). Predictive Tool for Bottom-Hole Pressure in Multiphase Flowing Wells. *Petroleum & Coal*, *50*(3), 67–73.

[7] Feriyanto, D., Zakaria, S., Alva, S., Pranoto, H., Sudarma, A. F., & Wong, A. P. J. (2020). Closed-Horizontal Rotating Burner Development for Optimizing Plam Shell Charcoal (PSC) Production. *International Journal of Advanced Technology in Mechanical, Mechatronics and Materials*, *1*(2), 39–44. https://doi.org/10.37869/ijatec.v1i2.23

[8] Shokri, A., Azdarpour, A., & Honarvar, B. (2017). Analysis of infl ow performance relationship and reservoir characteristics using Saphir software. *Bioscience Biotechnology Research Communications*, *10*(1), 143–150. https://doi.org/10.21786/bbrc/10.1/22.

[9] Ahmed, S. A., Ahmed, K. K., Mohammed, L. A., & Zalam, A. G. (2019). *Design project Project Title : Optimization of Oil and Gas Production Using Nodal Analysis Technique Prepared by : Sardam Akram Ahmed 14-00523*. *December*. https://doi.org/10.13140/RG.2.2.29161.03680.

[10] Ubanozie Julian, O., Stanley Toochukwu, E., Nnaemeka Princewill, O., Kevin Chinwuba, I., Anthony Chemazu, I., & Anthony, K. (2019). Mathematical Approach to Determination of Optimum Oil Production Rate in Oil Rim Reservoirs. *Petroleum Science and Engineering*, *3*(2), 60. https://doi.org/10.11648/j.pse.20190302.14.

[11] Fleshman, R. (1999). *Artificial Lift for High-Volume Production Rod pumps bring oil to surface in many fields , but for better flow rates more than*. 49–63.

[12] Julianto, C., Tulloh, H., Priambodo, A., Nugroho, M. R., & Kurniawan, H. (2020). *Production Forecast Studies for Oil Well Performance Prediction and Field De-velopment Scenario Using Decline Curve Analysis in Multilayer Reservoirs: A Case Study of Field Z*. *December*, 133–139. https://doi.org/10.11594/nstp.2020.0520.

[13] Nashawi, I. S., & Mir, M. I. (2016). *Inflow performance relationships for layered solution-gas drive reservoir Inflow performance relationships for layered solution-gas drive reservoir Fuad H . Qasem , Adel Malallah , Ibrahim Sami Nashawi * and Muhammad Irfan Mir*. *January*. https://doi.org/10.1504/IJPE.2016.084116.

[14] Eghbali, S., & Gerami, S. (2013). Modification of vogel's inflow performance relationship (IPR) for dual porosity model. *Petroleum Science and Technology*, *31*(16), 1633–1646. https://doi.org/10.1080/10916466.2010.551232.

[15] Zhang, J., Chen, X., Lv, B., & Feng, Y. (2016). *Oil production rate and Recovery factor evaluation for Beierxi*. *Iceep*, 306–316. https://doi.org/10.2991/iceep-16.2016.53.