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Design and optimization of electrical submersible pumps (ESP) using PROSPER software for a well E-52

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Analysis
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Optimization
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ABSTRACT

The decline in reservoir energy over time requires the use of artificial lift methods to maintain economic production rates in oil wells. This paper presents a comprehensive study on designing and optimizing Electrical Submersible Pump (ESP) systems using PROSPER software for under-saturated oil reservoir with weak water influx, experience a decline in reservoir energy over time, negatively affecting the economic production rates of oil wells. To address this challenge, artificial lift methods such as Electrical Submersible Pumps (ESPs) are required. By collecting and analyzing reservoir and well data, performing sensitivity analyses, and selecting optimum parameters. This study aims to design and optimize ESP systems to enhance well productivity and maintain economic production rates. Statistical error analysis was conducted to evaluate the reliability and accuracy of the optimization results, providing a quantified margin of error. The results from well E-52 show iimproved Production Efficiency: Significant production rate increase after ESP optimization (593 STB/day). After complete selecting of best ESP model that improve production, the selected TYEP was based on required power is 28.35hp and this value lowest value compared with other models, also gives best pump and motor efficiency with 63% and 83% respectively. Operation oil rate expected about 1500 STB/day by increasing 593 STB/day. Limited Scope: Focus on a single well (E-52); broader validation needed. Cost Considerations: Lack of detailed financial analysis of ESP implementation.

تصميم وتحسين المضخة الغاطسة بأستخدام برنامج بروسبر للبئر *E-52*

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الكلمات المفتاحية:
التحسين
التحليل
برنامج *PROSPER*
تصميم المضخات الغاطسة الكهربائية

الملخص

انخفاض الطاقة في المكمن مع مرور الوقت يتطلب استخدام طرق الرفع الصناعي للحفاظ على معدلات الإنتاج الاقتصادية في آبار النفط. تقدم هذه الورقة دراسة شاملة حول تصميم وتحسين أنظمة المضخات الغاطسة الكهربائية (ESP) باستخدام برنامج PROSPER. من خلال جمع وتحليل بيانات المكمن والبئر، وإجراء تحليلات الحساسية، واختيار المعايير المثلى، تهدف هذه الدراسة إلى تعزيز إنتاجية البئر. تظهر النتائج من البئر E-52 تحسينات كبيرة في معدلات الإنتاج، مما يؤكد كفاءة عملية تحسين المضخة الغاطسة الكهربائية.

1. Introduction

Reservoirs often have insufficient energy to produce fluids to the surface at economic rates throughout their natural life. To address this, artificial lift method is used to increase production by adding energy to the production system. This system includes both surface and subsurface equipment. Subsurface pumps, surface compression equipment to reduce bottom hole flowing pressure [1], can provide additional energy.

In the oil industry, wells begin production immediately after drilling is completed, initially driven by the reservoir's natural energy. Over time, production declines as the reservoir's energy depletes, making it unable to produce fluids at economic rates [2].

Petroleum engineers must solve this by enhancing productivity through artificial lift methods, which reduce bottom hole flowing pressure or increase drawdown. The choice of artificial lift depends on factors like production characteristics (water cut, gas-liquid ratio, liquid production rate, inflow performance), fluid properties (viscosity, formation volume factor), well characteristics (depth, tubular size, completion type, deviation), surface facilities, location, power sources, operational challenges, service availability, and economics [3, 4].

The main objectives of this paper are to design an Electrical Submersible Pump (ESP) system using PROSPER software to

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optimize well productivity, including selecting the optimal pump, motor, and cable.

Understanding reservoir behavior and predicting future performance requires knowledge of the driving mechanisms that control fluid movement. The overall performance of oil reservoirs is significantly influenced by the energy available for moving the oil to the wellbore [5, 6].

Artificial lift, which adds energy to the fluid column in a wellbore to enhance production, is necessary when reservoir drives cannot sustain acceptable rates. Techniques like ESP pump is used [7].

In 2012, Nurliana binti Alias conducted a study on optimizing oil and gas well production using the PROSPER well model in Field X, Peninsular Malaysia. The process involved four phases: building the well model with PVT, IPR, surface, and equipment data; well matching using monthly test data for calibration; analyzing well performance to identify issues restricting flow; and proposing modifications to enhance production [8].

In 2018, Abdul Aali Al Dabaj compared ESP and gas lift in the Buzurgan Oil Field, Iraq. The study found that ESP is more durable and cost-effective, especially as water cut increases. Gas lift was limited by surface injection pressure and gas volume, restricting production rates as water cut rose.. Nodal analysis showed that without artificial lift, production stops at a 30% water cut. ESP, however, could maintain production up to a 50% water cut, increasing production to 3615 STB/day at 0% water cut with a reservoir pressure of 5050 psi [9].

In 2020, Hamzah Amer Abdulameer conducted a study using nodal analysis software to design two wells in the Mishrif formation of the Nasriya oil field (NS-5 well). One well was designed for natural flow, and the other utilized an Electric Submersible Pump (ESP). The study made use of actual reservoir fluid and well data, outlined the steps for well design in detail, and applied optimization sensitivity to evaluate the effects of both individual and combined parameters [10, 11, 12].

In 2020, Tega Odjugo used PROSPER software for nodal analysis to address frictional power losses via artificial lifts in the Barbra 1 well, Niger Delta. The study compared continuous gas lift, intermittent gas lift, and electrical submersible pump (ESP), yielding productions of 1734.93 bbl/day, 451.50 bbl/day, and 2869 bbl/day, respectively. Without artificial lift, production was 1370.99 bbl/day. The study showed that artificial lifts, especially ESP, significantly increase well productivity, making wells like Barbra 1 ideal candidates for artificial lift [13].

In 2020, Miroslav Crnogorac and colleagues developed a fuzzy logic-based optimization approach for selecting an artificial lift method. This model reduces subjectivity in defining priorities compared to conventional multi-decision analysis models. It can be customized for each oil field, improving precision in selecting the optimal lift method. Results are presented using two methods: surface overlap percentages for different exploitation methods and center of mass with standard deviation. The model was validated with the Iranian Salman field, confirming gas lift (GL) as the most appropriate method, matching previous results [14].

The similarities with previous studies include the use of nodal analysis for optimizing well performance with ESP, as demonstrated in Hamzah Amer Abdulameer's study. Additionally, PROSPER software is utilized for designing and analyzing ESPs, similar to the methodologies in studies by Tega Odjugo and Nurliana binti Alias. The focus on enhancing well production through ESPs by evaluating well components for overall performance improvement is another common aspect.However, there are differences as well. My study specifically focuses on the design and analysis of ESPs, unlike Miroslav Crnogorac's broader model for selecting artificial lift methods.

The suggested steps for designing an ESP involve collecting reservoir and well data, using PROSPER to build and analyze the well model, performing well matching with test data, selecting the appropriate pump, motor, and cables, conducting sensitivity analysis to evaluate the impact of various factors on pump performance, and comparing the expected performance with previous studies to ensure effectiveness.

2. METHODOLOGY

The case study involved several steps to achieve the paper objectives:

1. Data Collection:
 - Gathered essential data including PVT, well schematic, production, and pressure tests.
2. Well Performance Analysis:
 - Studied well productivity using production and pressure history data, analyzing parameters like total fluid, water cut, total gas, and pressures.
3. Matching Data in PROSPER:
 - Matched well data with correlations in PROSPER, starting with PVT and progressing through IPR and VLP matching processes.
4. Well Model Building:
 - Constructed a well model in PROSPER with minimal error percentage after completing the matching process.
5. Future Production Prediction:
 - Predicted future production performance by optimizing reservoir parameters and assessing their impact on well productivity using the ESP method.
6. ESP Parameter Optimization:
 - Optimized ESP parameters including pump setting depth, frequency, well head pressure, and pump stages.
7. Pump Selection and Optimization:
 - Selected the best pump type and optimized ESP parameters to enhance well productivity.

Table (1): Reservoir Gir (A): Data summary

Reservoir Gir (A)	Depth	Units
Formation Depth, (D)	6764	Ft
Avg. Net Pay, (h)	100	Ft
Initial Pressure, (P_i)	3002	Psia
Current Pressure, (P)	2576	Psia
Reservoir Temperature, (T_{res})	196	F°

Table (2): Reservoir Rock properties Data summary

Rock Properties		
Avg. Porosity, ($\phi_{avg.}$)	25	%
Initial Water Saturation, (S_{wi})	27	%
Avg. Permeability, ($k_{avg.}$)	13	Md

Table (3): Reservoir Fluid properties Data summary

Fluid Properties		
Saturation Pressure, ($P_{sat.}$)	435	Psia
Gas Oil Ratio, (GOR)	185	SCF/STB
FVF @ Initial Pressure, (B_{oi})	1.169	RB/STB
Oil Viscosity, (μ_o)	1.74	Cp
Oil Gravity, (API)	33	API°

Table (4): Reserves Data summary

Reserves		
Original Oil In Place, (N)	172	MMSTB
Initial Oil Reserves, (N_p)	64	MMSTB
Original Gas In Place, (G)	29	BSCF
Initial Gas Reserves, (G_p)	12	BSCF

3. RESULTS and DISCUSSION

3.1 Input Data for Well E-52

Starting with the input data by insert the PVT data from PVT report and run the models to find the best correlation to work in the model as shown in figure 1. and figure 2.

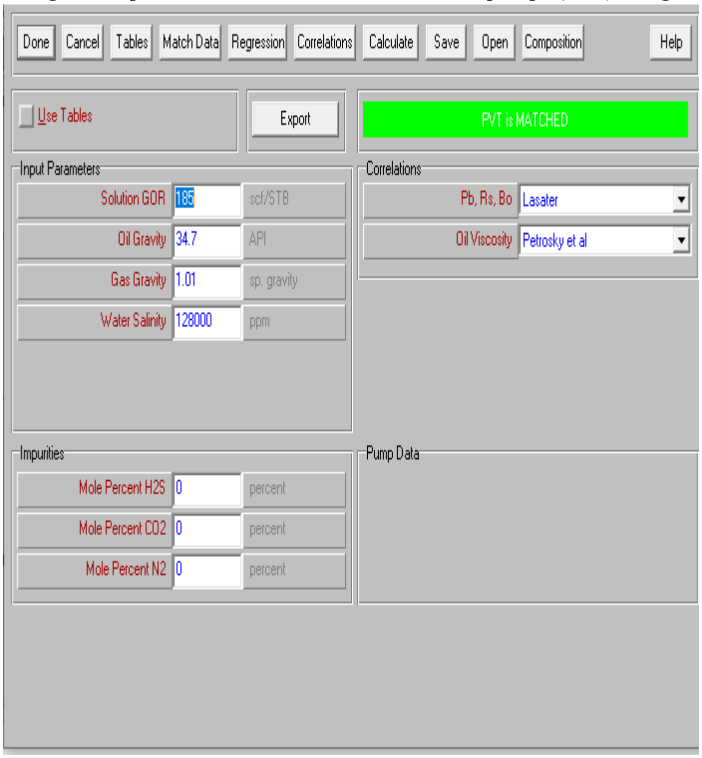

Figure 1. PVT data entered in second window in the software

Figure 3. (IPR) Inflow Performance relation

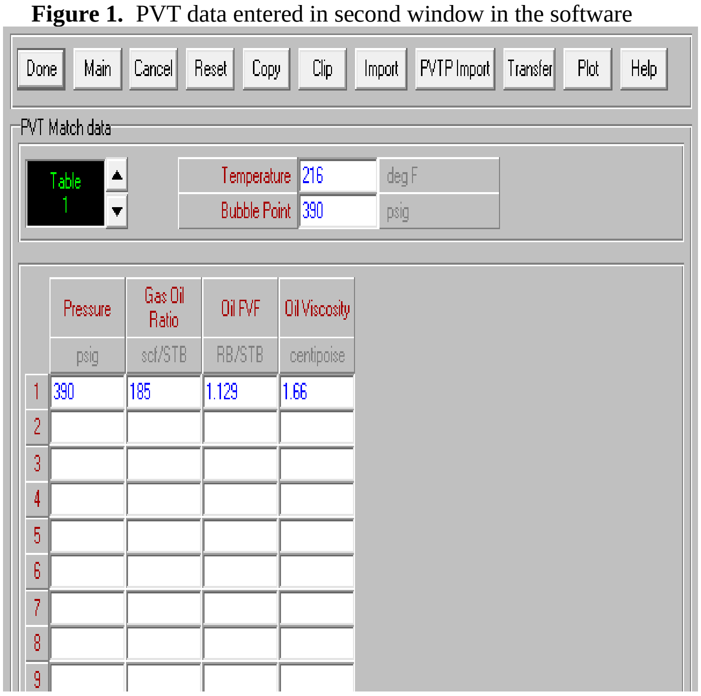

Figure 2. PVT match data

Figures .3 and .4 explain how to create the IPR curve using production test data.

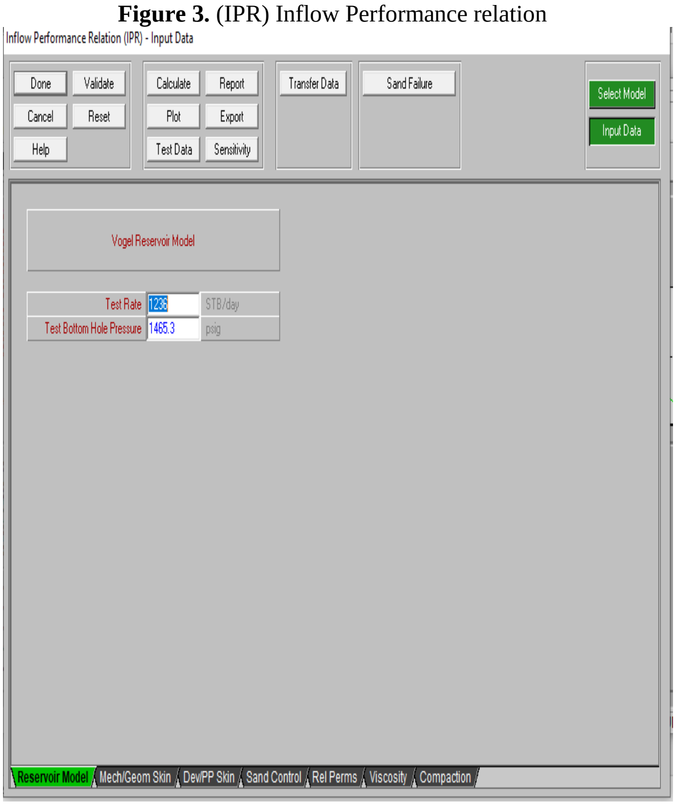

Figure 4. IPR input data

To identify the well schematic, enter the well depth data and temperature survey. Figure .5

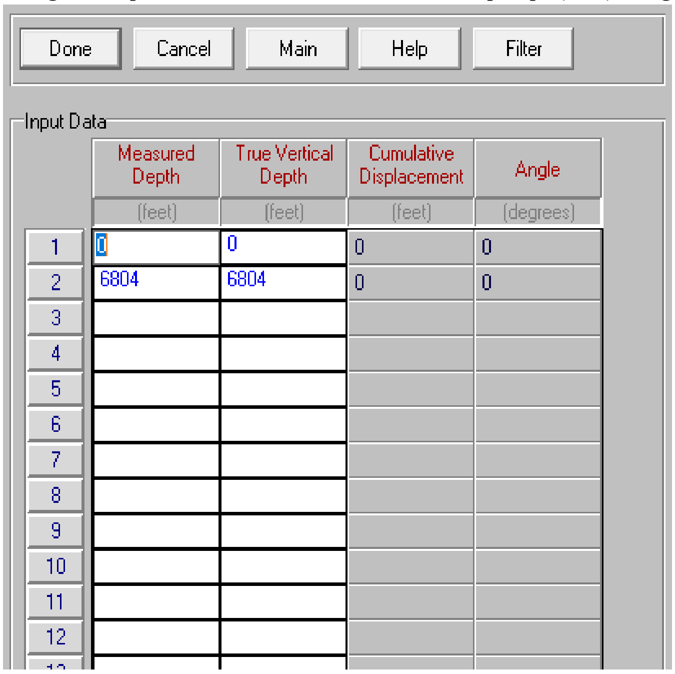

Figure 5. Geothermal gradient data for E-52

The modeling procedure will be described in the next part after the input data for well E-52 has been completed.

3.2 Well Modeling E-52

The well has been modeling as follows after completing the input data to generate the well model:

3.2.1 PVT Modeling

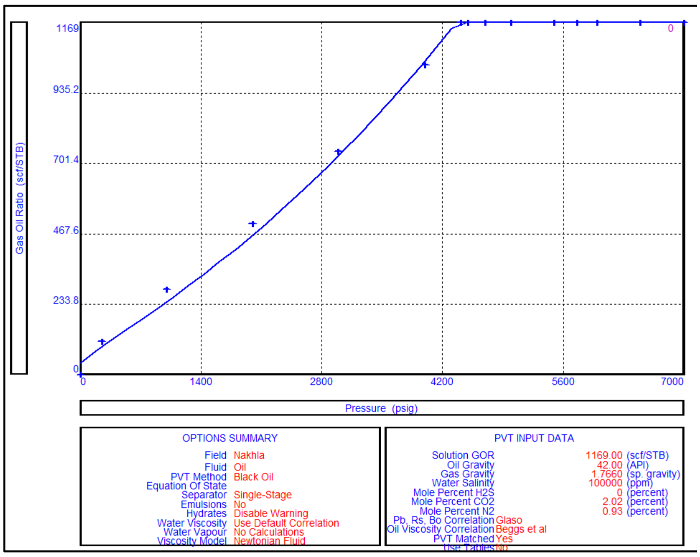

Figure 6. Gas Oil Ratio vs. pressure

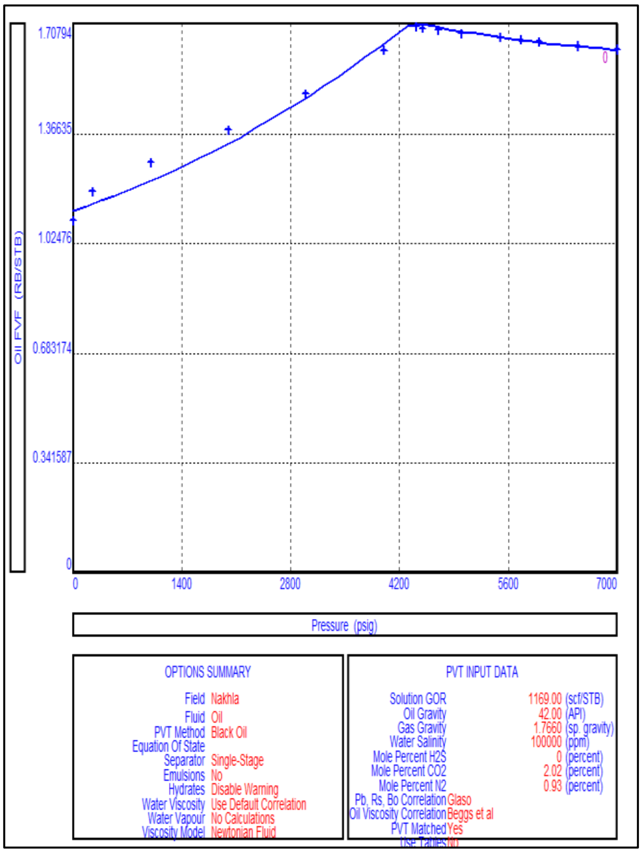

Figure .7 Oil Formation Volume Factor vs. Pressure

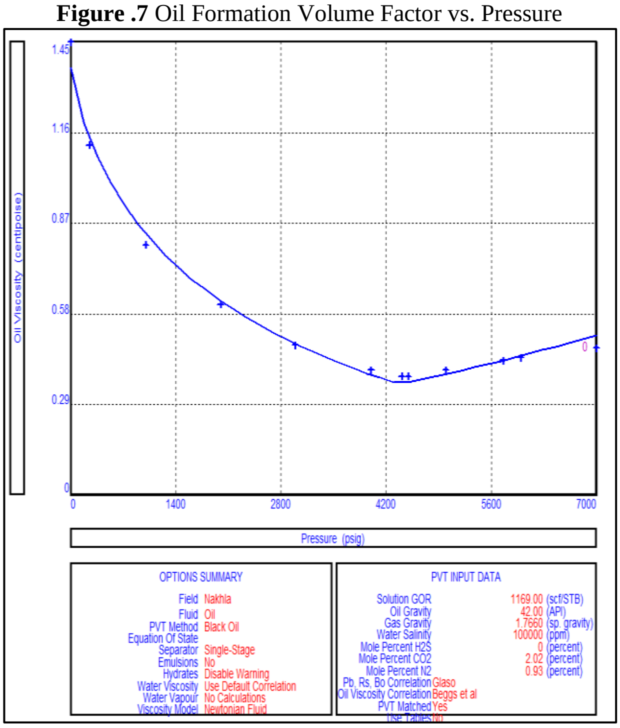

Figure 8. Oil Viscosity vs. Pressure

3.3 ESP Design for Well E- 52

Several steps were applied to run ESP on well E-52 to improve producivity of well using ESP with different types.

First, start with input the required data to design the pump and correlation that matched in pervious steps.

Then, start to select the optimum pump, motor, and cable with different types of pumps with suitable motor and cable the figures below present models of pumps to select the best ESP that will improve well productivity.

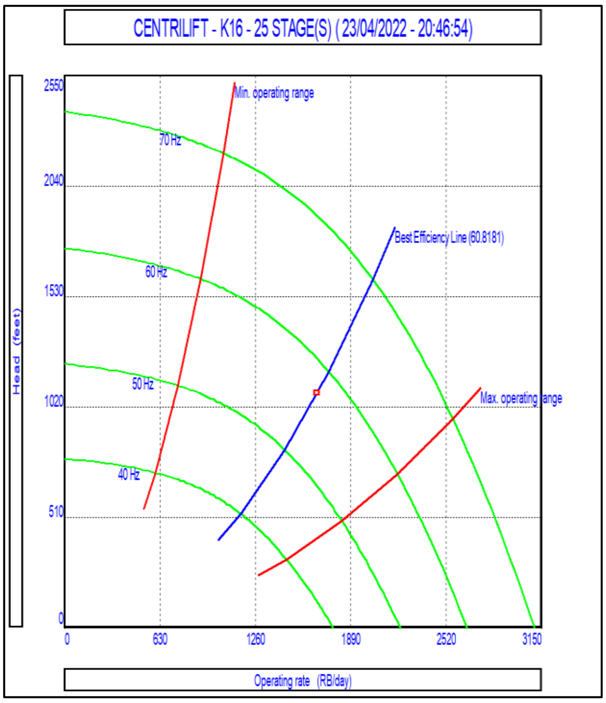

Figure 9. Performance curve of the ESP for E-52 (CENTRLIFT – K16)

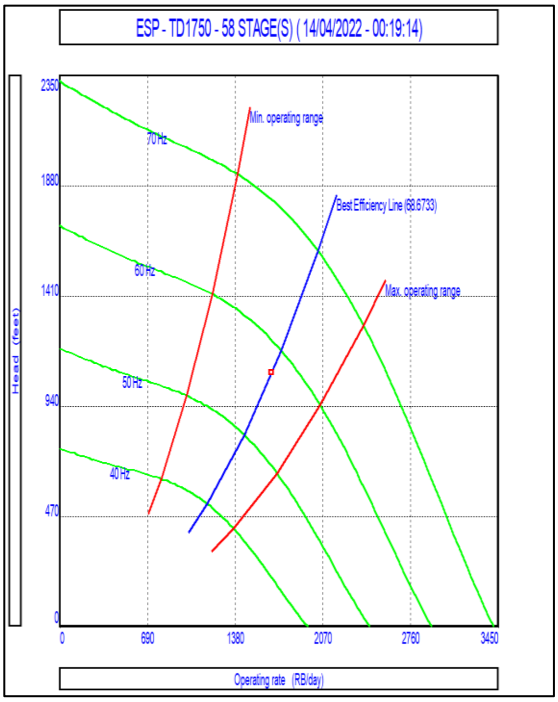

Figure 10. Performance curve of the ESP for E-52 (ESP TD1750)

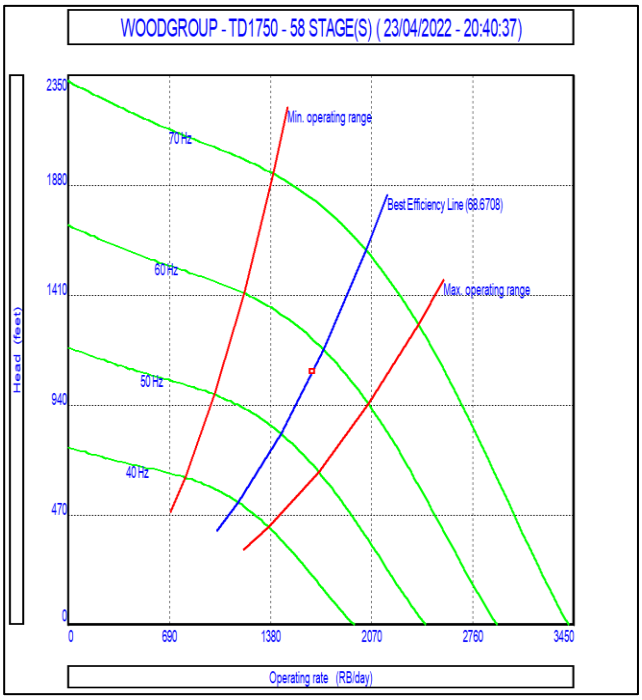

Figure 11. Performance curve of the ESP for E-52 (WOODGROUP TD-1750)

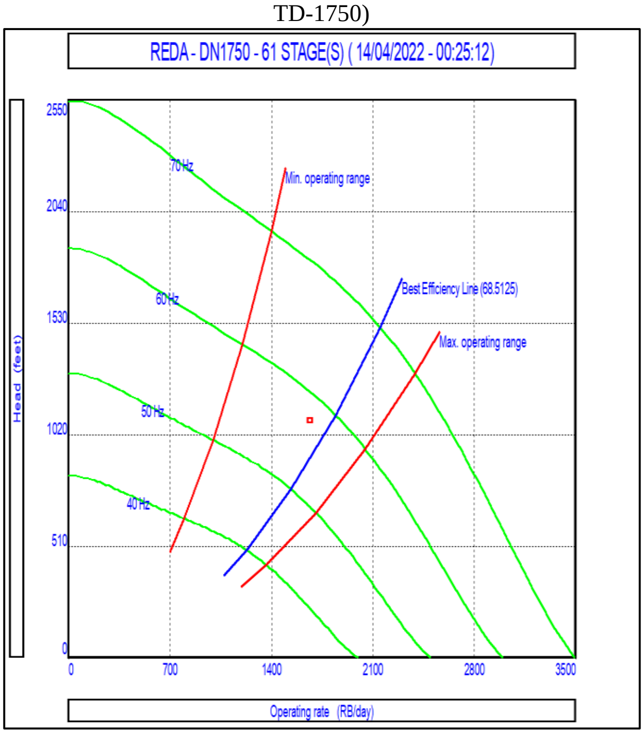

Figure 12. Performance curve of the ESP for E-52 (REDA DN-1750)

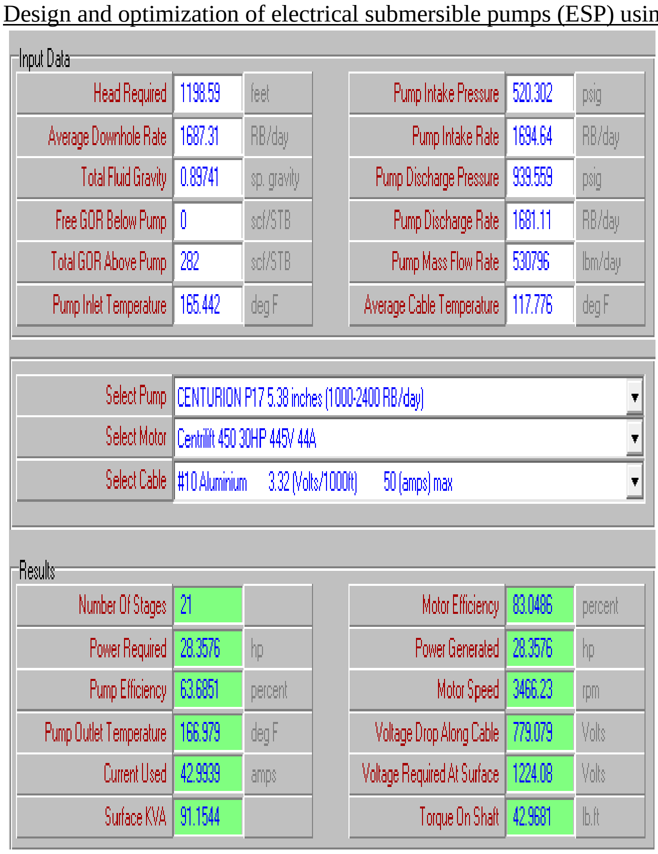

Figure 13. Selecting pump, motor and cable for E-52 (CENTURION – P17)

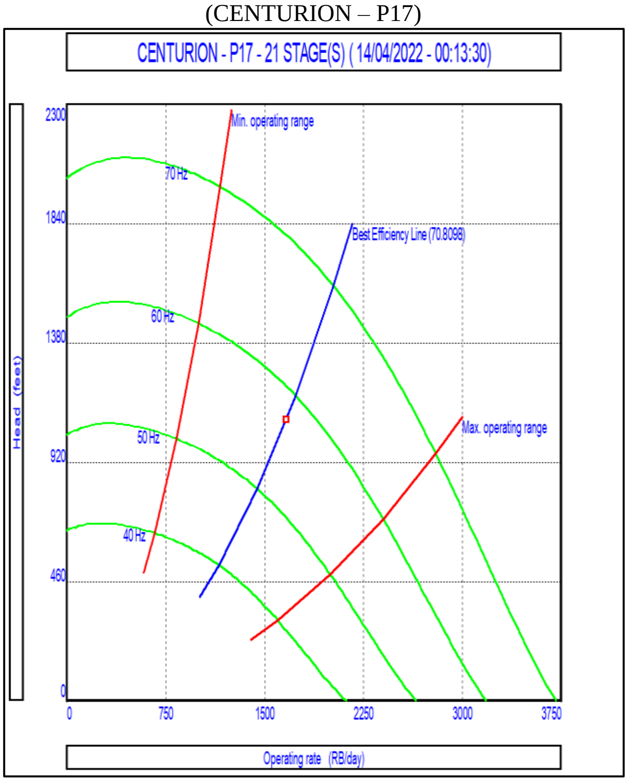

Figure 14. Performance curve of the ESP for E-52 (CENTURION – P17)

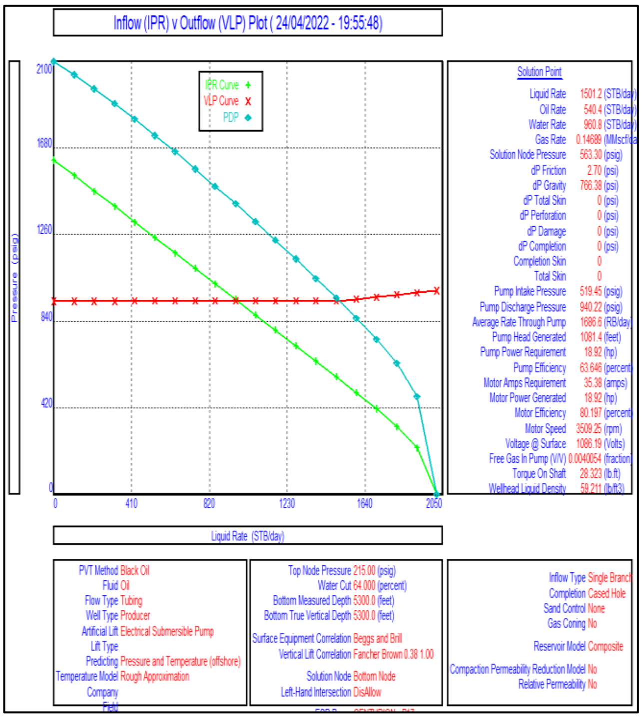

Figure 15. ESP Performance for E-52

After carefully selecting the optimal ESP model to enhance production, the selected ESP TYPE was determined based on a required power of 28.35 horsepower, which was the lowest power requirement among all considered models. This selection not only meets the production needs effectively but also ensures efficiency in energy usage. The ESP model, CENTURION – P17 (4 inches), was selected for its Reliable performance characteristics and suitability for the well's operational requirements.

The ESP system includes a CENTRLIFT 450 motor rated at 30 horsepower, which operates with high efficiency, achieving 83% motor efficiency. This ensures that energy consumption is minimized while maximizing production. The pump itself operates at 63% efficiency, optimizing fluid lifting performance.

For electrical connectivity, an Aluminum 50 A cable type was chosen, ensuring safe and reliable power transmission to the ESP system. This cable type is selected based on its ability to handle the required electrical load with minimal power losses and ensuring operational safety.

As a result of these selections, the expected operational oil rate is predictable to increase by approximately 593 barrels per day, reaching an estimated production rate of 1500 barrels per day. This improvement highlights the effectiveness of the selected ESP configuration in enhancing well productivity and optimizing production operations.

4. CONCLUSION

The following conclusion has been withdrawn from this study;

1. The design fluid rate should fall within the recommended pump range in order to avoid down-thrust and up- thrust problems.
2. The fluid velocity in the annulus surrounding the motor should be high enough to carry away the heat generated by the motor fast enough and, hence, avoid overheating of the motor.
3. The best optimization parameter was reservoir pressure 3400 psi, pump setting depth 5000 ft and operation frequency 60 Hz and number of stages 125.
4. A new design for well E-52 was implemented by selecting the ESP type (CENTURION – P17 4 inches), which improved production. The expected oil rate is about 1500 STB/day, representing an increase of 593 STB/day, or approximately 65.4%.
5. After optimization of ESP system in cased study wells shows that clear effect of production parameters on ESP efficiency.

Advantages:

1. Improved Production Efficiency: Significant production rate increase for well E-52 after ESP optimization (593 STB/day).
2. Comprehensive Methodology: Detailed approach using PROSPER software for data analysis and parameter optimization.

3. Practical Recommendations: Actionable guidelines for ESP selection and avoiding operational issues.
4. Validated Results: Consistent with previous research, reinforcing reliability.

Limitations:

1. Limited Scope: Focus on a single well (E-52); broader validation needed.
2. Cost Considerations: Lack of detailed financial analysis of ESP implementation.
3. Technical Complexity: Requires advanced technical knowledge and familiarity with PROSPER software.
4. Environmental Impact: Environmental considerations not addressed.

Applications:

1. Well Productivity Enhancement: Applicable to other wells with declining production rates.
2. Artificial Lift Method Selection: Useful for selecting and designing ESP systems in various fields.
3. Operational Guidelines: Improves efficiency and existence of ESP systems in different wells.
4. Further Research: Basis for future studies under different conditions and integrating financial/environmental analyses.

5. RECOMMENDATIONS

- ESP is restricted to a certain production range: Electric Submersible Pumps (ESP) are designed to operate within a specific range of production rates. This range is recommended based on factors like well conditions and pump design to avoid issues such as excessive wear and mechanical failures.
- Availability of proper equipment (pump, motor, cable, etc) in stock forces the application of oversized or undersized equipment, which leads to failure of these equipment or inefficient pump performance.
- The cable type and size should be selected according to the well environments, such as well depth, bottom hole temperature (BHT), hydrogen sulfide (H_2S) …etc
- The paper offered practical recommendations for improving the performance of ESPs, allowing engineers to apply the findings in similar scenarios.

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