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A COMPARATIVE STUDY BETWEEN PIPESIM SIMULATION MODEL AND SOFTWARE APPROACH FOR ESP DESIGN

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Abstract: This study considers the design of an electric submersible pumping (ESP) system, an analysis of the production system that is used to determine the potential of any well and a discussion of a case study of an oil well in Sarir oilfield for ESP design throughout the various parameters. Artificial well lifting will become increasingly important in the coming years. A large portion of the world's fields are entering their late life production; Sarir field is a mature field, with increasing water production and decreasing reservoir pressure. The operator company has used electrical submersible pumps (ESPs) to assist struggling wells in order to increase production and extend the life of the field. The main objective of this study is determining how to design the most ideal ESP systems that can extend the life of the systems, given that the installation cost of ESP is very high. So, the majority of this work was done by hand calculations and run in production software approach and Pipesim simulation model, which involved manipulating both modeling the subjected wells and a series of simple detailed calculations to find the most efficient and optimum ESP equipment. The procedure path is titled: designing the ESP pump, motor, cable, and determining surface voltage. According to the study's findings, the design of ESP varies depending on various parameters from well to well. However, the obtained results exhibit of manual calculation and software approach are close to results of Pipesim simulation model. Based on this research, it is possible to conclude that the REDA D800N pump is the best submersible pump for Well C-349H-65, with a pump efficiency of approximately 62 %; from the designing this well can return to produce at desired flow rate 580 STB/Day.

Keywords: Sarir oilfield, ESP design, software, Pipesim, model, production rate

Introduction

Oil is the most important source of energy on the planet. Crude oil can be extracted either naturally or artificially. Because the natural energy in their reservoirs is insufficient, the vast majority of the world's oil wells require some kind of artificial lifting mechanism to bring their liquid to the surface. Electrical Submerged Pumps are a type of artificial lift that has been used for decades (ESP) [1]. Because of the presence of mature reservoirs and high deep wells, as well as the availability of produced gas, the artificial lift methods that are widely used in Libya are SRP, gas lift, and ESP, which is the cornerstone of this work [2]. In terms of early history, ESP was invented and developed in the late 1910s by a Russian named Armais Arutunoff. Arutunoff conducted his initial experiments in the Baku oilfields near the Caspian Sea and later founded the Russian Electrical Dynamo of Arutunoff (REDA). The first submersible pumping unit was installed in an oil well in 1928 [3, 4], and the concept has proven itself throughout the oil-producing world since then. It is currently regarded as an efficient and cost-effective method of lifting large volumes of fluids from great depths under a variety of well conditions. Since their inception, ESP units have excelled at lifting much higher liquid rates than most other types of artificial lift and have found their best application in high-rate onshore and offshore applications. High gas production, rapidly changing liquid production rates, viscous crudes, and other conditions that were once extremely detrimental to ESP operations are now easily handled by modern units. Submersible pumping installations are thought to produce approximately 10% of the world's oil supply today [5].

Problem Statement

Petroleum production rates sometimes declining with time in several wells, this attributed to different factors; one of them is the choice of the suitable ESP for well characteristics, fluid behavior and reservoir properties. This study shows the design of an ESP artificial lift system and production optimization of a well in Sarir field. Concerning this well, reservoir issues such as pressure depletion and high water cut can result in sand formation and subsequent sand production. By having and understanding a little bit of well history, it is necessary for production engineer to design the most ideal ESP systems that can overcome the production problem and can extend life of the systems as installation cost of ESP are very expensive.

Objectives of Study

The purpose of this research is to estimate the appropriate design of submersible electric pump (ESP) components for oil well. This design will be completed by both running it through production software and hand calculations to determine the most efficient and optimal ESP components. We will compare the efficiency and number of stages of different types of pumps in the same operation condition by using different types of components such as the pump. Based on the results, we can determine the appropriate ESP components such as pump, motor, and cable from running different types of components from different manufacturers.

Scope and Limitations of Study

The scope of this study is limited to the use of a manual method and Pipesim software to optimize production by designing an ESP for artificial lift. There are other softwares that can be used to design an ESP system, but Pipesim is used for this project due to its availability. The research is being carried out in the Sarir fields, and an appropriate ESP will be implemented to increase the well's production potential.

Importance of Study

The significance of this study in the petroleum industry is that it demonstrates the importance of designing ESP for wells as well as the use of artificial lift in maximizing oil production.

Location of Study

1. Overview of Sarir Field

The Sarir or, more specifically, the Sarir "C" field is the largest oil field in Libya, located on the western edge of the Calanscio sand sea in the southern portion of the Sirte basin. It is found on the southern edge of the Upper Cretaceous-Tertiary Sirte basin, which contains all of Libya's major oil fields and is the most prolific oil-producing basin in North Africa. The Sarir "C" field, part of a complex of three fields, is 56 kilometers long and 40 kilometers wide, covering approximately 378 kilometers2. To its north is the Sarir "L" accumulation, which covers roughly the same area as the Sarir North pool. The ultimate recovery from the "C" field is estimated to be 3.8 billion barrels of oil, and the ultimate recovery from the "L" field is estimated to be 1.2 billion barrels of oil, ranking them as the

51st and 201st largest fields in the Carmalt and St.compilation John's 1986 (Lewis and Sanford).

Figure 1 a map showing the location of Sarir oilfield.

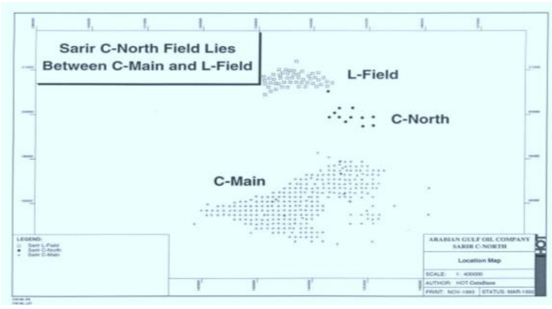

Fig. 1: Sarir C-North is lying between C-Main and L-Field [6]

As a result of this depletion, some form of artificial lift was required in 1980 in order to lift oil from the producing interval to the surface and onto stations. The first candidate well for an ESP installation was C002-65, which was depleted to 3200 psi in 1983, and was followed by two wells, C-117-65 and C-073-65, in 1984.

Approximately 400 wells are currently producing by ESP, and this method has proven to be very successful. Sarir entire output is derived from electrical submersible pumped wells. Many tools can be run in the hole to monitor pump efficiency, temperature, motor vibration, current leakage, and other parameters.

The field production infrastructure consists of a large network of gathering pipes that connect each wellhead to the gathering center (GC) that receives the crude oil. Each group of wellheads is linked to a gathering point determined by the distribution of wells over a specific area. Each gathering center (GC1, GC2, GC3, GC4, GC5, and GC6) is linked to the GC main via a trunk line (Figures 2 & 3).

Methodology

This study's main methodology is concerned with the design of an ESP system using basic hand calculations and Pipesim simulation software. This chapter provides brief information about the fields used in this study.

1. Electrical Pump Design

An ESP installation, like other artificial lift methods, is complicated and varies greatly depending on well conditions and the type of fluids to be pumped. Good quality data covering these conditions is required to ensure proper installation design. The procedure for sizing submersible pumps and designing an entire ESP system is given below:

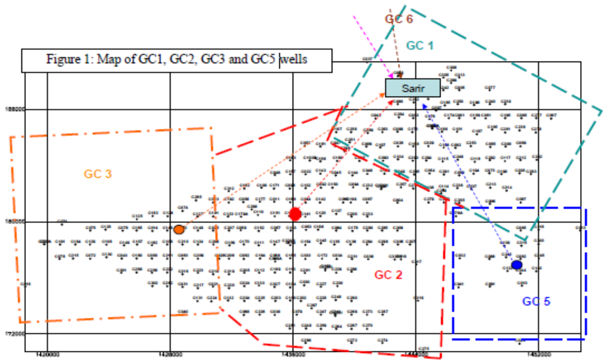

Fig. 2: Map showing the location of Map of GC-1, GC-2, GC-3 and GC-5 [7]

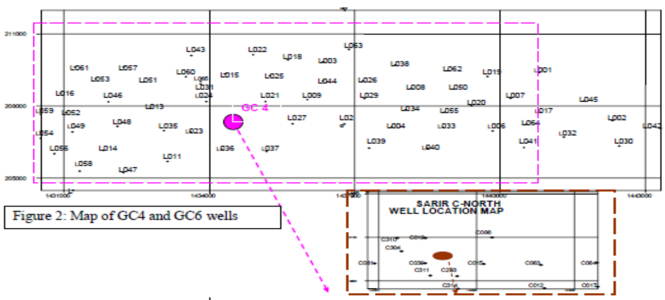

Fig. 3: Map showing the location of GC-4 and GC-6 [7]

1.1. Data Requirements

The proper design of an ESP installation necessitates knowledge of a wide range of data. The most important of these is consistent data on the well's productivity, which allows the desired fluid rate from the well to be calculated [5]. Necessary input data can be grouped as given here.

1. Well physical data
2. Well performance data
3. Fluid properties
4. Surface power supply parameters
5. Unusual operating conditions

2. PIPESIM

PIPESIM is a petroleum engineer and facilities design, operation, and optimization software modeling tool. PIPESIM is a tool for production engineers that cover a wide range of applications in the oil and gas industry. The software allows for the creation of well models that take into account all variables, such as well configuration, fluid characteristics (PVT), multiphase VLP correlations, and various IPR models.

2.1. Basic Theory of PIPESIM

Fluid properties as a function of pressure and temperature must be predicted in order to accurately predict pressure and temperature changes from the reservoir, along the wellbore, and through the flow line tubular. The Black Oil PVT model is used in the vast majority of applications. The Black Oil model in PIPESIM can be used for a variety of purposes. In black oil fluid modeling, correlation models are used to simulate the key PVT fluid properties of the oil/gas/water system.

These empirical correlations, in contrast to the more rigorous multi-component compositional model methods, treat the oil/gas system as a simple two-component system. In relation to stock tank conditions, the hydrocarbon is simply treated as a liquid component (if present) and a gas component. For most applications, a minimum of production data, oil gravity, gas gravity, solution gas/oil ratio, and, if water is present in the system, the water cut are all that is required [8, 9].

PIPESIM is used throughout this work for all calculations regarding setting up of a reliable model and building on it a productive ESP lift system [10].

2.2. Building a Model

When modeling a new well in PIPESIM, the first step is to choose a method and fill out a system summary, as shown in Figure 4.

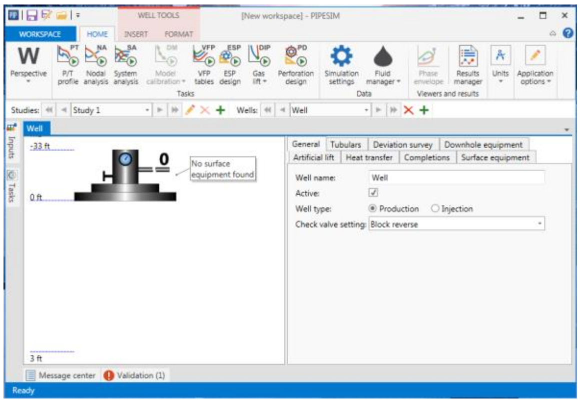

Fig. 4: Layout of Pipesim system summary

Start with entering general data, followed by tubular data, deviation survey, down whole equipment, heat transfer, completions, and surface equipment data. Following the entry of the basic data for the well model. Second, the artificial lift method can be chosen based on the design requirements. Then, at the bottom hole, a well model is built and a Nodal Analysis is performed (At this stage, it is assumed that there is no pump in the well) [10].

2.3. Pump Selection/Design In selecting and designing the ESP, with the aim to determine the following:

- The number of stages required
- The pump HP required.
- Generate a Pump Performance Plot showing the potential operating flow rate range for desired frequency.

Figure 5 depicts the requirements of input data for ESP design.

3.1 Programing Using Visual Basic Language

Visual Basic (VB) is a high level and one of the most commonly used programming languages developed by Microsoft used for developing computer programs. It is evolved from the earlier DOS version called BASIC. BASIC means Beginners' All-purpose Symbolic Instruction Code. The code looks a lot like English Language. Over time the community of programmers developed third party components. VB is a third-generation event-driven programming language and integrated development environment (IDE) for its Component Object Model (COM) programming model first released in 1991. VB was derived from BASIC, a user-friendly programming language designed for beginners, and it is a programming environment in which a programmer uses a Graphical User Interface (GUI) to choose and modify preselected sections of code written in the BASIC programming language. Like other languages, VB is not case sensitive.

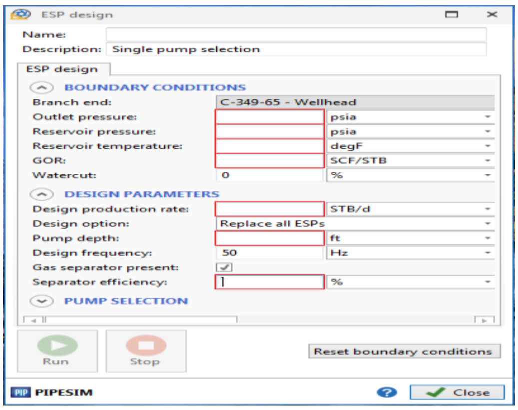

Fig. 5: Input data needs for ESP design

3.1.1. Visual Studio 2017 Enterprise

Visual Basic 2017 is the latest version of Visual Basic launched by Microsoft in 2017. Visual Basic 2017 is bundled together with other Microsoft Programming languages C#, C++, F#, JavaScript, Python and other development tools in an integrated development environment called Visual Studio Enterprise 2017 Release Candidate. Microsoft has added many new features in Visual Studio 2017 particularly those features for building mobile applications and gaming as well as web and cloud-based applications.

3.1.2. Visual Studio Enterprise 2017 Start Page

The Visual Studio Enterprise 2017 Start Page as shown in Figure 6.

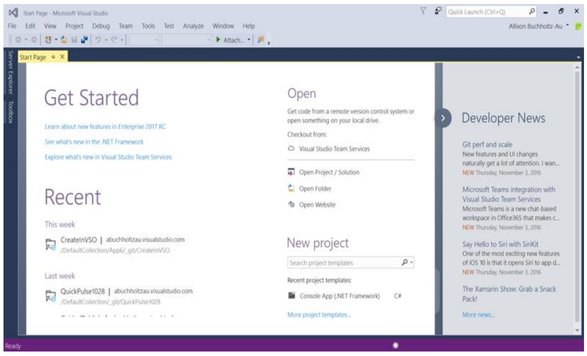

Fig. 6: Visual Studio Community 2017 Start Page

Now click on New Project under Start to launch the New Project window, as shown in Figure 7.

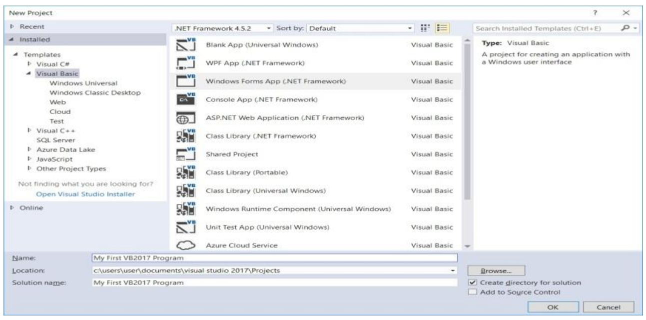

Fig. 7: New Project Window

Results and Discussion

If the data is reliable, the design of an ESP system is usually not too difficult. Before beginning the design procedure, it must be determined that sufficient well data is available.

1. ESP Design for Productive Well of Sarir field

1.1. Input Data and Information

General Information

Location C-NOTRTH GC-6

Field & Lease Sarir-65

Well Name C-349H-65

API Well Reg. # 37.7

Well and electric submersible pumping system data are presented in the Table 1.

Table 1: Required data of Well C-349H-65 for reservoir, fluid and desired conditions and mechanical data

Reservoir Data		Fluid Data		Desired Conditions	
Static Reservoir pressure SBHP	2520 psi	Current Production rate	180 BFPD	Desired Production rate	580 BFPD
Bubble Point Pressure	520.3 psig	Water Cut	0 %	Frequency	50 Hz
Productivity Index	0.5 STB/D/psi	Oil Gravity	37.7 API	Wellhead Pressure	350 psig
Gas Oil Ratio	112 SCF/STB	Specific Gravity of Water	1.14	Pump Setting Depth	6577 ft
Bottom hole temperature	230°F	Specific Gravity of Gas	0.85		
Perforation Intervals MD	9183-10817 ft	Specific Gravity of Oil	0.8363		
Perforation Depth	9175ft	Wellhead Pressure	350 psig		
oil volume formation factor (B_o)	1.140 bbl./STB				
water volume formation factor (B_w)	1.040bbl/STB				
Datum Depth	8756 ft				

Mechanical Data (Casing Data)				
OD Size (inch)	ID Size (inch)	Weight 1bm/ft	Roughness	Length, ft
13.375	12.515	61	0.00065	3185
9.625	8.835	40	0.00065	**8042**
3.5	2.992	9.3	0.00065	6473.6

2. ESP Design by Hand Calculations

However, these calculations include the following:

1. Calculating Producing Pressure and Pump Intake Pressure
2. Gas, Oil, and Water Calculations
3. TDH calculations
4. Calculate minimum pump depth
5. The Selection of ESP Pump
6. The Selection of ESP Motor
7. The Cable Selection
8. The transformer selection

The results of hand calculations are presented in Table 2.

3. Building a Base Model for Well C-349H-65

The physical model is the first step in modeling any well. Building the physical model, as depicted in Figure 8, entails introducing all of the well items from the source to the sink. The reservoir, completion, tubing, and well head are the only items modeled in this case.

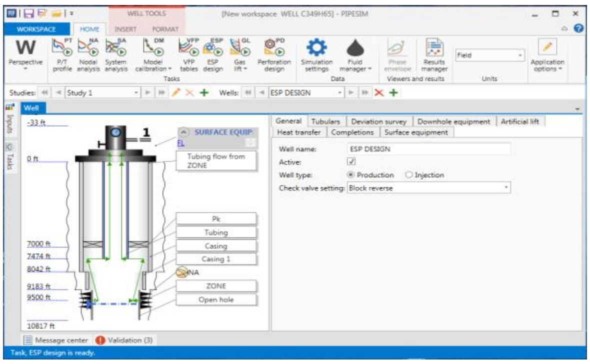

Fig. 8: Physical Model for C-349H-65

Pipesim generates a production profile for the hypothetical well based on the input parameters. Because the well is weak producing oil, it must be considered uneconomical. (Figure 9)

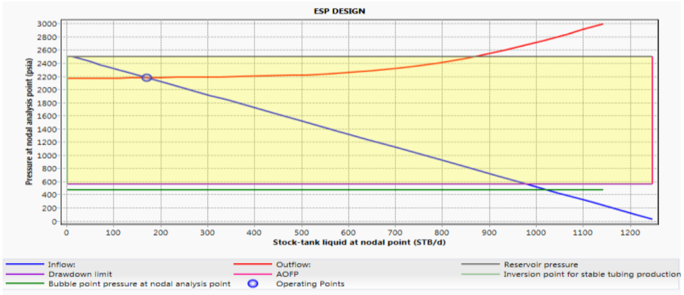

Fig. 9: Well C-349H-65 with no artificial lift (weak intersection between IPR and VLP "situation today")

A full workover is required to implement gas lift or ESP in the well. ESPs are built into the tubing, and the well lacks side pockets that would allow wireline installation of gas lift valves. PIPESIM simulations, on the other hand, use the current well completion. The model includes the inner and outer diameters of casings, tubings, and liners. The inner diameter of restrictions such as the downhole safety valve is also taken into account. The inside roughness of the tubing and casing is 0.00065 inch.

3.1.1. Modeling the Well C-349H-65 with ESP

Selections of equipment start with pump section, a list of pumps matching the design criteria is used for choosing the most suitable pump and number of stages is calculated for a given frequency. Pump list includes the maximum and minimum recommended rates of the pumps. While selecting the pump unit it was desired to find the closest rate at peak efficiency to the theoretical rate. An equipment data base is available in the programs' features. Once the design of the production system completed appropriate equipment can be chosen from that data base. The pump design data were entered into the Pipesim database using the ESP design conditions, and the Select Pump button was clicked, which filtered the pump database for all the pumps that met the design criteria (Figures 10 & 11). The model uses these coefficients to calculate pump curves (Figure 12), allowing one to simulate for any condition.

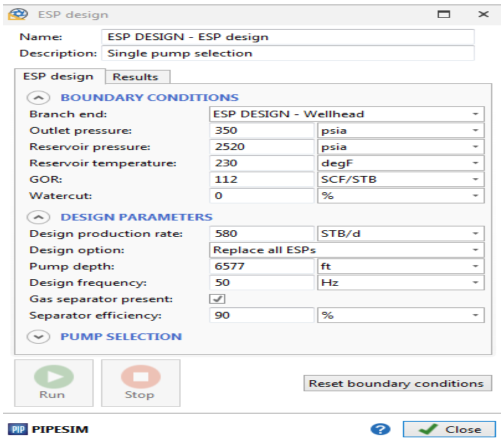

Fig. 10: ESP Design input layout

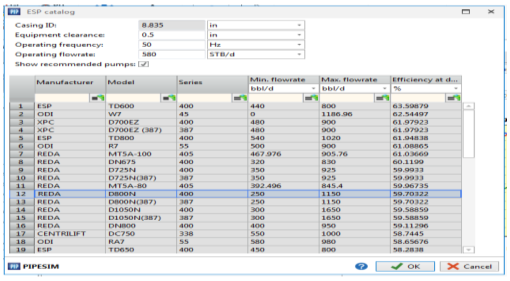

Fig. 11: ESP input pump selection layout

3.1.2. ESP Design Using Pipesim Model

Following are ESP design parameters obtained using Pipesim simulation.

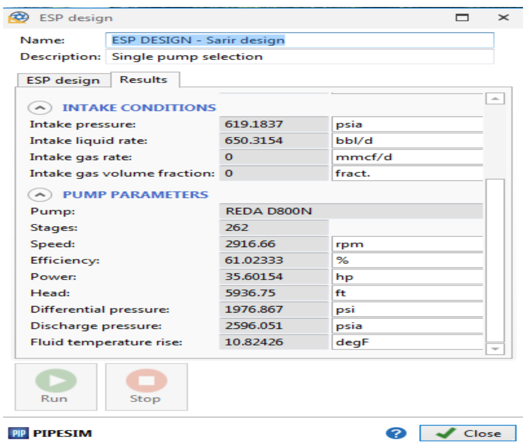

Fig. 12: Well C-349H-65 ESP design parameters obtained using software simulation

4. ESP Design Using Software approach

Characteristic features and properties of ESP design can be determined by using software program as mentioned previously, and the results are illustrated in Figures 13 through 15.

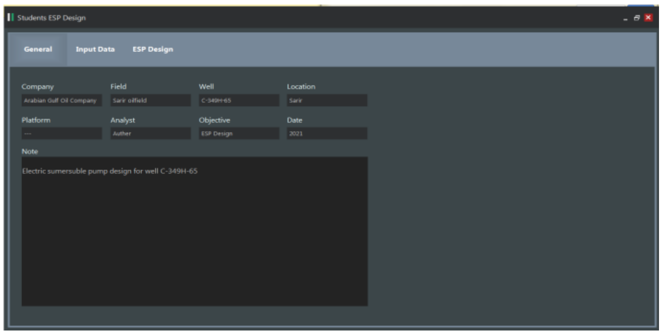

Fig. 13: The first step of software program for calculations

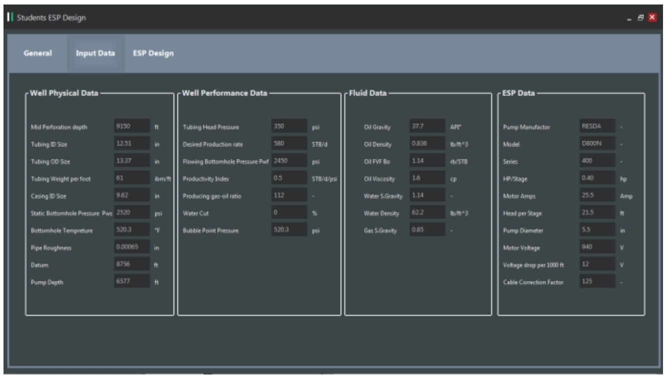

Fig. 14: The second step of software program for calculations

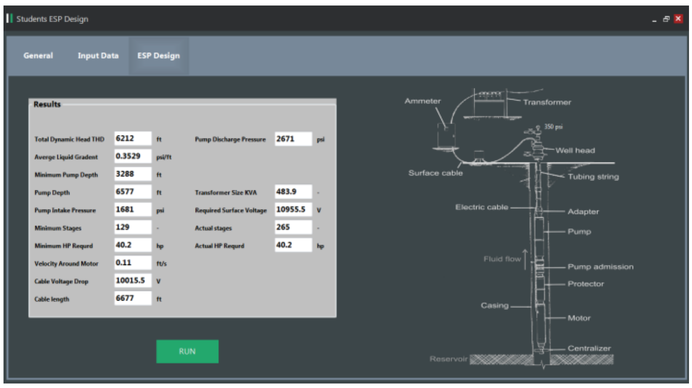

Fig. 15: The third step of software program for calculations

At throughput of production rate, from chart in Figure 16 we can get the pumping head per stage, horse power an ESP efficiency (Table 2).

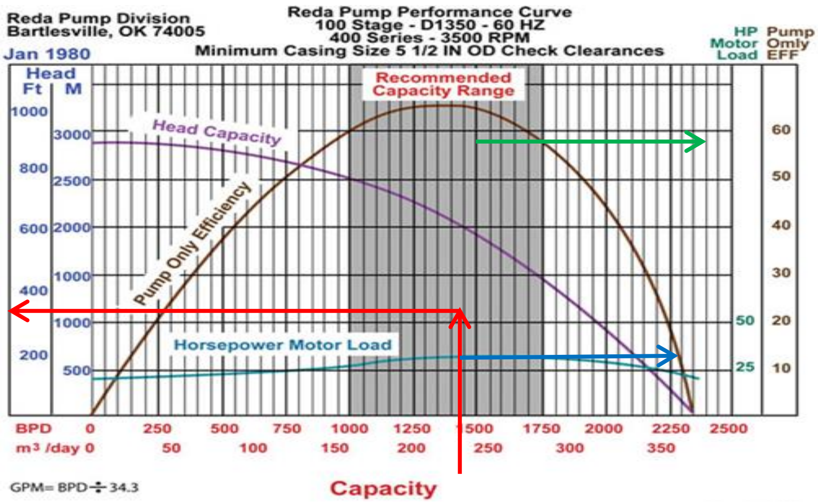

Fig. 16: Estimation parameters of ESP design

Table 2: ESP design results for well C-349-H-65

Parameters	Hand calculations	Pipesim model	Software approach
Pump Type	D800N	D800N	D800N
Series	400	400	400
No. Stages	269	262	265
Efficiency %	62	61.02	63.0
Horse Power	52	35.60	40.2
PIP (psi)	420	619	568
TDH (ft)	6450	5936	6212
Design Frequency, Hz	50	50	50

The ESP system horse power is the pump horse power plus the gas separator horse power. Since gas separator is installed, the system horse power is the pump's which the sum of horse power of each stage. This submersible pump needs 269 numbers of stages. The power required is about 52 hp.

We notice a high number of required stages (269 stages) in the proposed design, so we need to put down two pumps (Tandem Pumps) of the same design, i.e. D800N, to cover the number of required stages, a high operating point, and to maintain the pump's longest run life.

Because the series of down-hole motors are available different in power rating, therefore the chosen motor should be with next available power rating higher horsepower than the calculated horse power which was considered in selecting the motor. The motor horse power required a form hand calculation is 57 HP and as a result the chosen motor power rating is 62.5 (Table 3).

Table 3: The proposed motor parameters, selected cable characteristics and desired surface power data for well C-349-65

Motor Parameters		Cable Characteristics		Desired Surface power	
Manufacturer	REDA	Manufacturer	REDA	Surface Voltage ,Volts	1090
Series	562	Type	Redahot	Transformer, KVA	68
Type	S	Size	2 Cu	Frequency, Hz	50
Name Plate Power, HP	62.5	Shape	Round		
Name Plate Voltage, Volts	1000	Conductor Type	Solid		
Name Plate Current, Amps	36	Maximum Conductor Temperature, °F	300		
Design Frequency, Hz	50	Voltage Drop	90		
Length	7.1 ft	Frequency, Hz	50		
Weight	534 Ibm				
Fluid Velocity, ft/sec	0.2				
Well Fluid Temperature, °F	230				

Figure 17 depicts a comparison between some ESP design parameters for the investigated oil well. It is obviously from this comparison between hand calculations, Pipesim model and software approach that there is no much difference between them, except the pressure intake pump (PIP). Accordingly, the sofware approch can be applied for ESP to achieve the requiements of production rates.

5. Production Performance (Well C-349H-65)

The wells produce significantly more than in the ESP case and in the base case (no artificial lift). The total liquid rate of the well is well within the pump's operating range, between the minimum and best efficiency line. This means that there is still plenty of room for more fluid. Figure 18 depicts the production point, which is the point at which the VLP and IPR curves intersect.

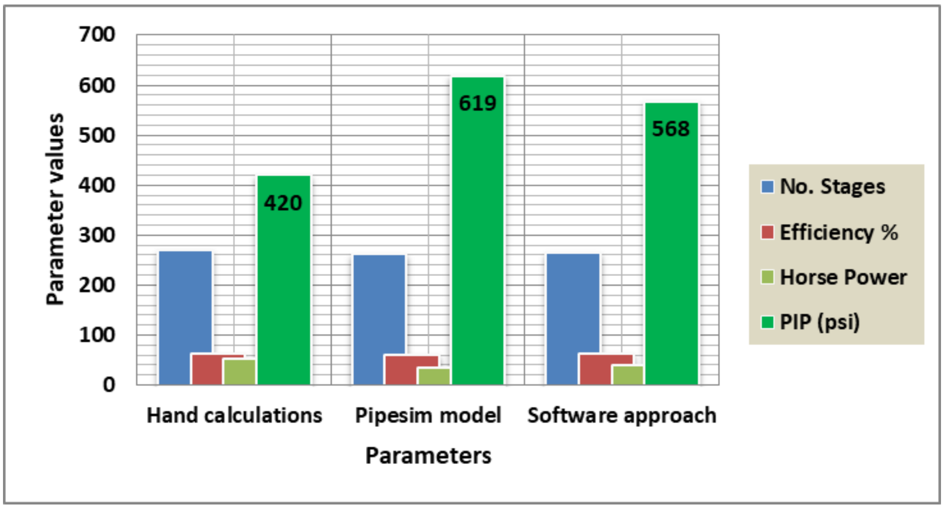

Fig. 17: A comparative bar chart for ESP design

The intersection of IPR and VLP in Figure represents the operating point of 580 STB/day achieved by ESP installation.

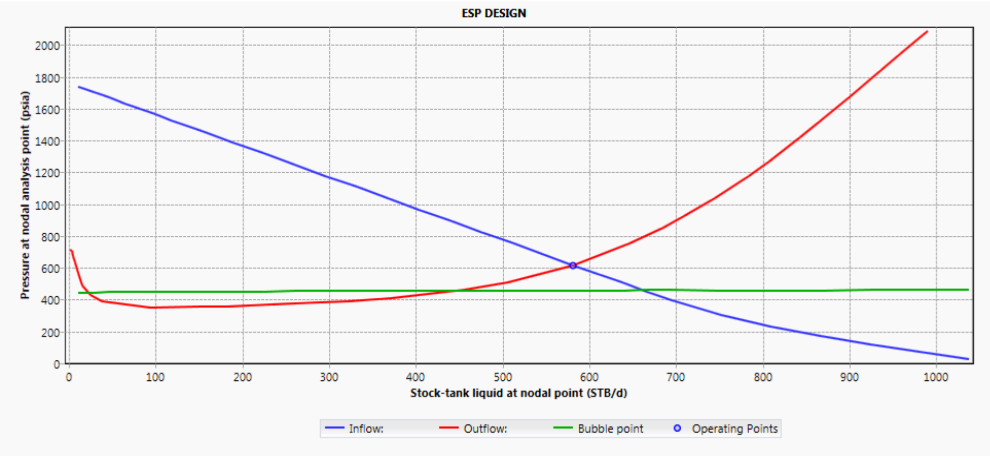

Fig. 18: Effect of ESP design on inflow and outflow curves (intersection of IPR and VLP)

Figure 18 shows that, designing ESP have improved VLP curve and it also made improvement in the well performance and it made liquid production rate to increase to 580 STB/day. Furthermore, designing an ESP can also be applied when the well cannot flow and the reservoir pressure is low. Regarding well C-349H, before in Figure 9, it was shown that when the reservoir pressure decreased, there was Weak (not desired) flow inside the well, but as it is shown Figure 18 after setting an ESP inside the well, the designed ESP provided enough pressure for the well to start to flow.

Figure 19 shows three different operating frequencies for the designed ESP in order to see how the well production performance will respond to those frequencies.

It is shown in Figure 19, when the operating frequency for the designed ESP increased from 30 to 40 to 50 and to 60 Hertz, the well performance has also increased, and it will facilitate the achievement of the production rate. On the other hand, when the operating frequency was reduced to 40 Hertz, a lesser performance was observed in well C-349H-65.

From all the figures shown above, it is observed that the intersection of inflow and outflow satisfy the condition when oil is produced. The intersection of each intake curve with the IPR plotted above is to show a comparison of flow rates provided or not provided by ESP methods.

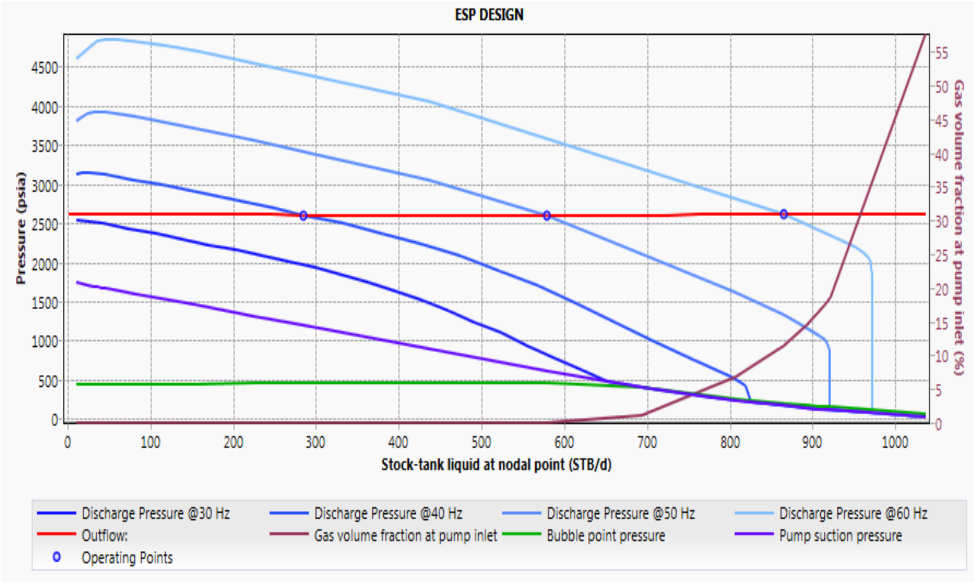

Fig. 19: Effect of changing ESP operating frequency Performance Plot

Figure 20 present the effect of ESP on oil production performance for well C 349H-65. There is a sharp increase in the liquid production as the ESP installed with efficiency of 62 %. Thereafter the liquid production starts to stabilize and reaches a maximum rate of approximately 580 BFPD. Currently the well is stabilized at production rate of 680 BFPD with 0 % water-cut and 110 GOR (SCF/STB).

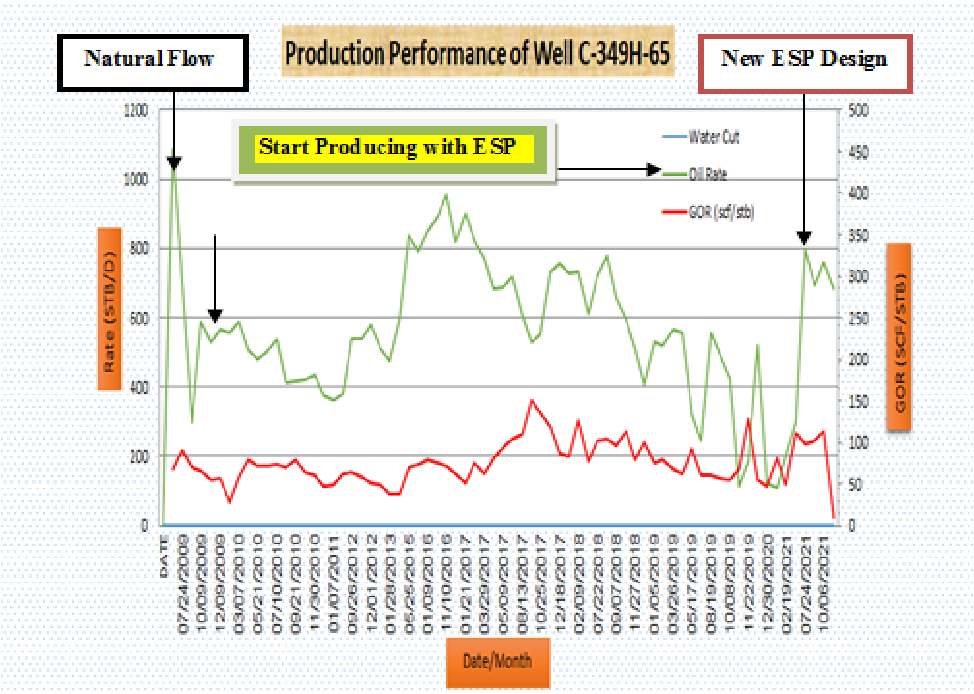

Fig. 20: Production performance of Well C-349H-65

Figure 21 illustrates the production history of well with cumulative oil production in April 2021 was estimated at 1.174 MM bbls and without water produced through the life yet, as when the first ESP applications were started. It doesn't notice any rise of the water cut was. The new ESP design was installed after the well stop to produce (No flow) on June 2021. The design has been developed to overcome the production engineering challenges which have been encountered following the commencement production from the stage oil field .Using ESP Method as kind of artificial lift will contribute in increasing the cumulative of oil to achieve the production to economical rate as show in Figure 21.

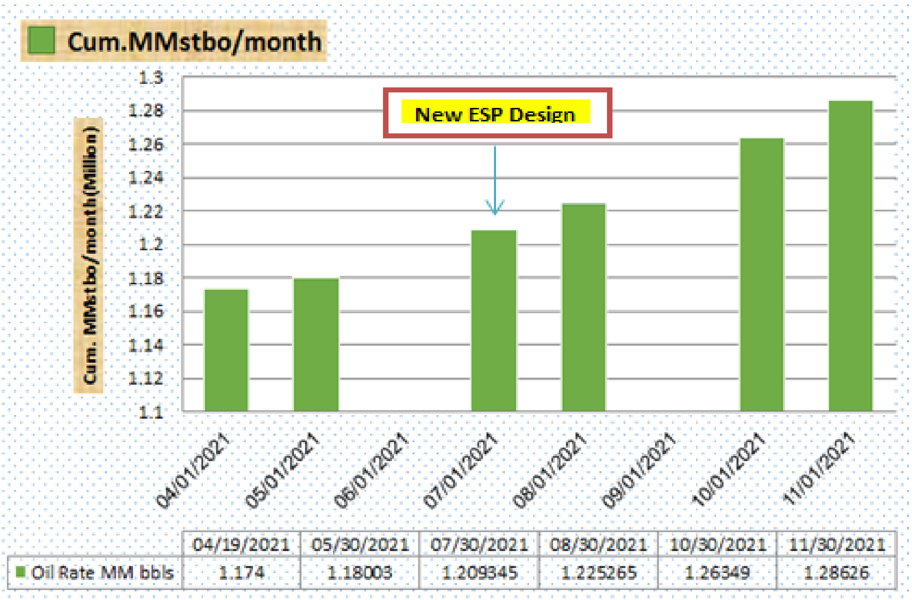

Fig. 21: Cumulative oil production of Well C-349H-65

However, the incremental in oil production has been even as of the date 30/11/2021 that has been 106.230 Mbbls , and so on the price of Crude oil as average price recently 60 Dollars ($) (106.230 *60=6373800 (6.37 MM $) that is economically beneficial and the cumulative of oil production increased which is 1.28626 MMbbls. The pump continues to produce until today.

To summarize, Table 4 provides detailed information for each base case scenario:

Table 4: Economic base case condition

Scenario	Minimum Economic Production Rate Produced	Maximum Economic Production Rate Produced
Without ESP	110 (oil production)	289 (oil production)
With ESP	280 stb/d at 2520 psia at 40 Hz with 0 %WC	860 stb/d at 2520 psia at 60 Hz with 0 %WC

Looking at the review of each base case scenario, it can be concluded that has giving higher volume of oil production, ESP is considered as more economical. However, ESP is an effective method to lift large volume of oil.

Conclusion

To produce to its full potential and have a successful run life, an ESP well must have optimal production conditions, which means that ESP down-hole and surface equipment must be properly designated and operated. After developing detailed simple calculations, the best design was implemented using Pipesim model and software approach.

The production issue was analyzed and designed an electrical submersible pump (ESP) system that addresses the well data and issues. Furthermore, ESP is the best artificial lift method for wells with high water cut and pressure depletion. Installing ESP allows for more oil to be recovered in less time, improving field economics. Because there are numerous ESP system designs on the market today, we must design the most optimum and ideal ESP systems as stated in the study objective from the start. ESP is, once again, a dynamic displacement, multistage centrifugal turbine pump connected by a short shaft to a downhole electrical motor powered by a cable that extends to the surface. As in the production engineer discipline, it is necessary to design the best ESP system possible in order to extend the life of ESP components, which are a costly investment for the company. Based on this research, it is possible to conclude that the REDA D800N pump is the best submersible pump for Well C-349H-65, with a pump efficiency of approximately 62 %; from the designing this well can return to produce at desired flow rate 580 STB/Day.

Recommendations

The findings of this study are pertinent to the objectives. If we broaden the scope of this work to include more parameters, we will be able to study a lot more theories while also gaining more knowledge in the artificial lift discipline.

Here, I'd like to make a few recommendations to future work for this research:

- Because variable speed drive (VSD) technology was not used during the design procedure for ESP applications, the study could be improved by including that option in ESP systems.
- Future research on this topic may include progressive cavity pumps, as that artificial lift method is available to use in those fields.
- Conduct a cost-benefit analysis for each ESP component. We can then select the most efficient and economical option.
- ESP design and installation in extreme conditions, such as a gassy well.

References

[1] Matthew, A., "Artificial Lift Systems" Artificial Lift Methods and Surface Operations PGE 482 Lecture Note, 2013.

[2] Clegg, J. D., Bucaram, S. M. and Hein, N. M., Jr.: "Recommendations and Comparisons for Selecting Artificial-Lift Methods." JPT, December 1993, 1128–67.

[3 Brown, K.E., "The Technology of Artificial Lift Methods", Vol. 2b, Penn Well Publishing Company, Tulsa, Oklahoma, 1980.

[4] Brown, K.E., "The Technology of Artificial Lift Methods", Vol. 4, Penn Well Publishing Company, Tulsa, Oklahoma, 1984.

[5] Gabor Takacs, "Electrical submersible pump manual: design, operations, and maintenance", published by Elsevier Inc., 2018.

[6] Arabian Gulf Oil Company: Sarir Field Data base and History File.

[7] AGOCO, Sarir 3D Seismic Interpretation Areas 1 and 3 Final Report (Preliminary Draft) - Reply to Geo Quest Comments from Sarir Reservoir Engineering Group, 1998.

[8] Guo B and et al, " Petroleum Production Engineering, A Computer-Assisted Approach Publisher: Elsevier Science & Technology Books, 2007.

[9] Schlumberger, (2017). Pipesim. https://www.software.slb.com/products/pipesim.

[10] Schlumberger, (2017). PIPESIM user Manual.