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Optimum Design Of Electric Sumerssible Pump (Esp) By Using Software Program

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Abstract

The petroleum engineers are concerned to find a solution for maximizing production rates and deceasing costs through optimum design of artificial lift particularly electrical submersible pump (ESP) techniques. In this time, we approach to raise the productivity by decreasing the pressure at the bottom of the well by using one of the artificial lift methods. The selection of the most suitable type of artificial lift required is influenced by several factors, such as producing characteristic (water cut, gas–liquid ratio, liquid production rate, inflow performance), fluid properties (viscosity, formation volume factor), hole characteristic (depth, size of tubular, completion type, deviation), surface facilities, location, available power sources, operation problem, service availability and relative economics. This study has been conducted on two well are namely Well L-075-65 at Sarir oilfield in Sirte Basin of Arabian Gulf Oil Company (AGOCO) and N-55 at Nafora oilfield in Oasis area in the south. The main goal of the study is to achieve production optimization of electrical submersible pump by using software program of Visual Basic (VB). Desired conclusion will be reached after determining the optimum pump stages and horsepower requirement for a possible production rate by the hand calculations that compared with software results. The study will let us to suggest optimum submersible pump running conditions for the wells to continue production in a more economical and enhanced oil production approach. The obtained results revealed that the software program can be used successfully in ESP design, this is due to the similarity between its results and the calculation ones, as well as the actual results in the oilfield.

Keywords: *Artificial lift, optimum design, ESP, software program, oil, production.*

1. Introduction

Oil is considered to be the primary source of energy in the world due to its high energy density, easy transportability, and relative abundance. It is a vital factor in every country's economy. Almost all items that we buy, use, and consume are products of oil. The Energy Information Administration (EIA) stated that the world consumption of crude oil daily is 85.64 million barrels, which is equivalent to 2 liters of oil per day per person [1].

Petroleum production engineering is that part of petroleum engineering that attempts to maximize oil and gas production in a cost-effective manner. To achieve this objective, production engineers need to have a thorough understanding of the petroleum production systems with which they work. To perform their job correctly, production engineers should have solid background and sound knowledge about the properties of fluids they produce and working principles of all the major components of producing wells and surface facilities [2].

The role of a production engineer is to maximize oil and gas production in a cost-effective manner. Familiarization and understanding of oil and gas production systems are essential to the engineers.

To design and analyze ESP performance, three major points have to be understood:

1. The well's productivity;

2. The fluid ratios of the produced fluid; and

3. The mechanism of each stage of the pump.

Bearden stated that ESP is the most competent and consistent method of artificial lift when moderate to high volume of oil needs to be lifted from the well . He also estimated the lifting capacity of ESPs to be as low as 150 barrels per day and as high as 150,000 barrels per day [3].

Pumping equipment is capable of producing as high as 60,000 bbl/d and as low as 200 bbl/d. The oil cut may also vary within very wide limits, from negligible amounts to 100%. The pump performs at highest efficiency when pumping liquid only; it can handle free gas with the liquid but high volumes of free gas causes inefficient operation and gas lock problems. The first submersible pumping unit was installed in an oil well in1928 and since that time the concept has proven itself throughout the oil producing world [4,5].

Analysis requires pressure gradient correlation in order to reach a solution so it is necessary to use a vertical multiphase flow correlation method in the computer program. Hagedorn and Brown vertical multiphase flow correlation [6] has been used to determine the pressure and pressure losses at required depth. However, it was observed that Hagedorn and Brown correlation failed to give accurate output at bubble flow. Griffith Correlation was constructed at bubble flow to obtain accurate results [7].

2. Objectives Of Study

The main aim of this work is to satisfy the following:

1. Develop a new ESP installation design software meets for selecting the proper and most efficient downhole equipment for longer well's run life. The software was given a name: "New ESP Design®".
2. Develop a new software capable of determining the operating parameters of the ESP. So, the Visual Basic 2017 enterprise version will be used.
3. Apply the newly developed software to design one well selected from Sarir oil field.
4. Use all of ESP's equations and applied them manually to design the same well selected from Sarir Field.
5. Compare the results obtained by the new developed software to those obtained by the manually design.

3. Materials And Methods

3.1. Location Of Study

This study has been carried out on the well No. L-075-65 at Sarir oilfield in Sirte Basin and well No. N-55 at Nafora oilfield at Oasis area in the south. Figure 1 shows the location of oilfields.

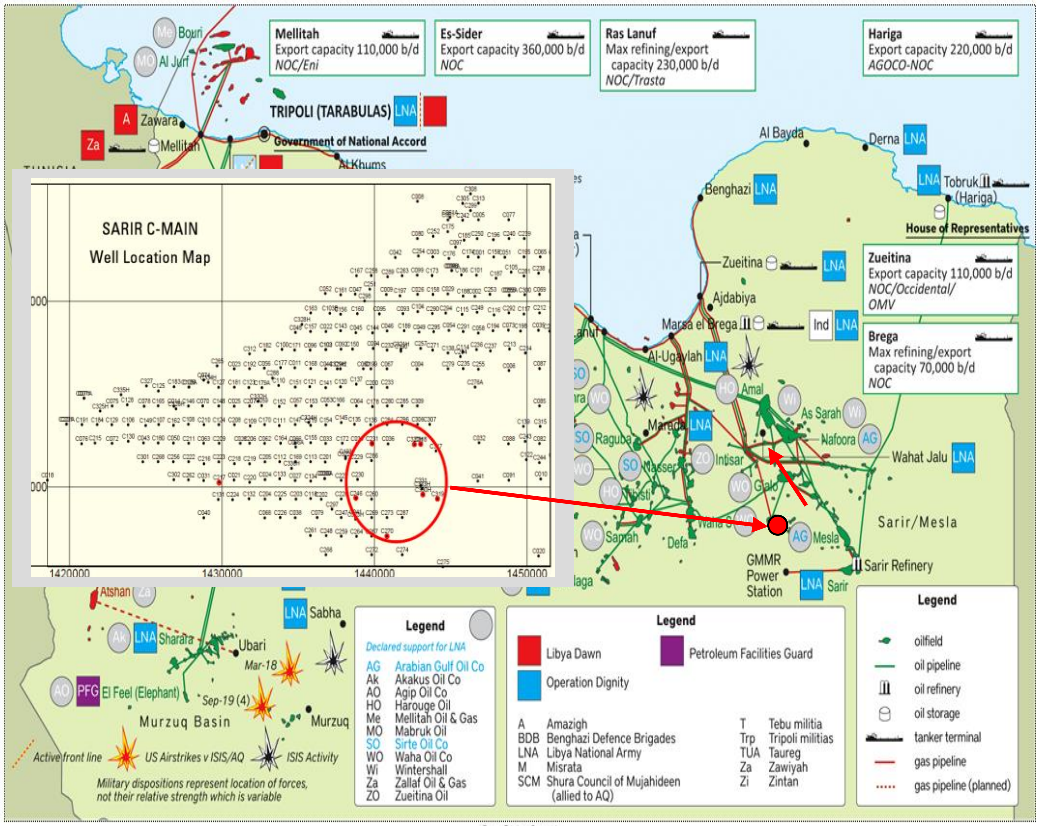

Fig. 1 A map showing Sarir oilfield and well locations [8]

3.2. Programing Using Visual Basic Language

- A programming language is a formal language, which comprises a set of instructions that produce various kinds of output. Programming languages are used in computer programming to implement algorithms. Thousands of different programming languages have been created, and more are being created every year.
- 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.

- Now, there are many versions of VB available in the market, the latest being Visual Basic 2017 enterprise that is bundled with other programming languages such as C#.
- Microsoft intended VB to be relatively easy to learn and use. Since VB is easy to learn and fast to write code with, it's sometimes used to prototype an application that will later be written in a more difficult but efficient language. VB is also widely used to write working programs. Microsoft says that there are at least 3 million developers using Visual Basic.

    - Visual Basic Language Features

- Programmers can create both simple and complex GUI applications.
- Programming in VB is a combination of visually arranging components or controls on a form, specifying attributes and actions for those components, and writing additional lines of code for more functionality.
- Since VB defines default attributes and actions for the components, a programmer can develop a simple program without writing much code.
- Visual Basic is user friendly and interactive. Users can code, test and debug with ease, given that Visual Basic offers ready-made controls and MDSN (Microsoft Developer Network) assistance for technical issues.
- Visual basic is a powerful front-end tool. It is able to achieve simple and complex business requisites effectively and efficiently.

    - 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.

3.2.3. Visual Studio Enterprise 2017 Start Page

The Visual Studio Enterprise 2017 Start Page as shown in Figure 2.

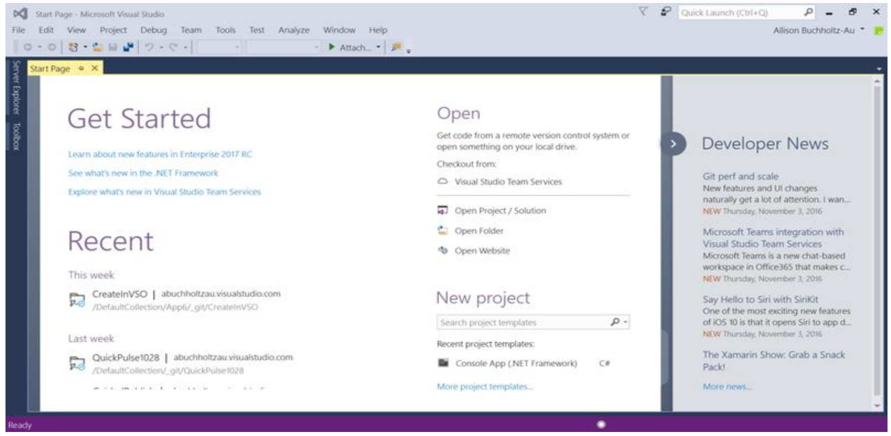

Fig. 2 Visual Studio Community 2017 Start Page

Now click on New Project under Start to launch the New Project window, as shown in Figure 3.

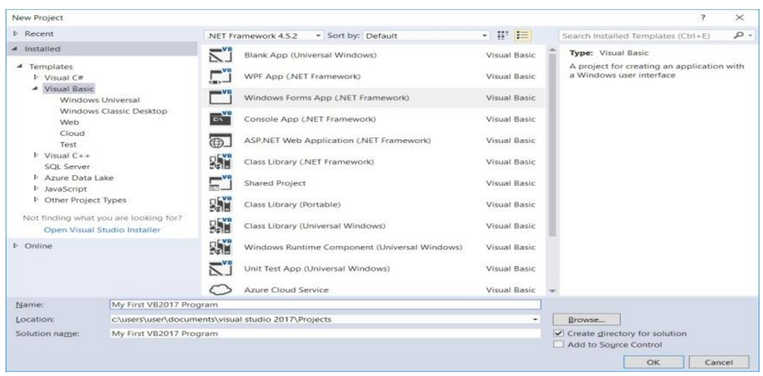

Fig. 3 New Project Window

3.2.4. Visual Basic Enterprise 2017 Integrated Development Environment

Upon clicking Windows Form Application, the Visual Basic Enterprise 2017 Integrated Development Environment appears, as shown in Figure 4. You can see that the name of the project you entered earlier appears on the top right corner of the IDE.

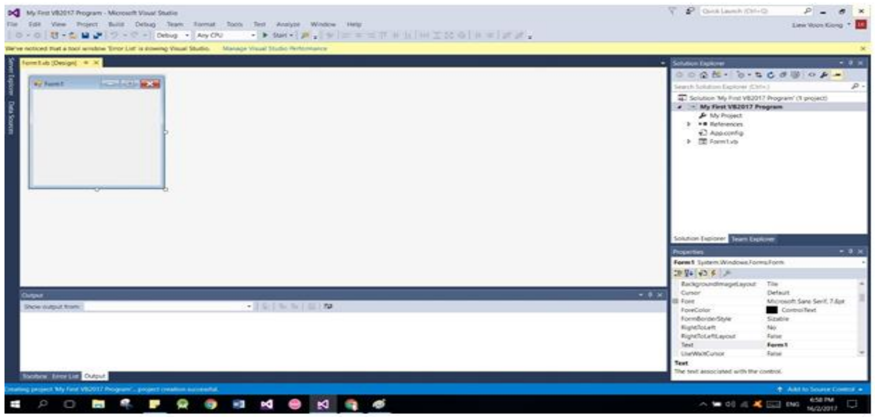

Fig. 4 Visual Basic 2017 IDE

Now, we shall proceed to show you how to create your first program in Visual Basic 2017. First, change the text of the form to My First VB 2017 Program in the properties window, it will appear as the title of the program. Next, insert a button and change its text to Show Message. The design interface is shown in Figure 5.

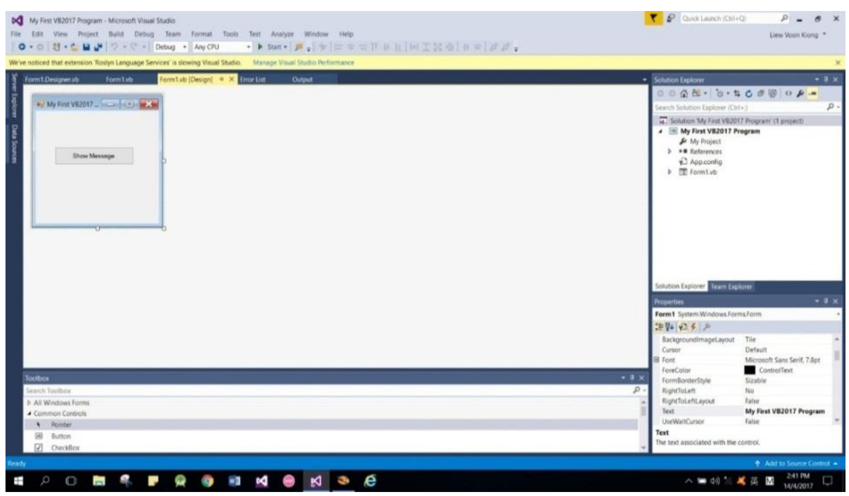

Fig. 5 The Design Interface

Click on the Show Message button to bring up the code window and enter the following statement between Private Sub and End Sub procedure, as shown in Figure 6.

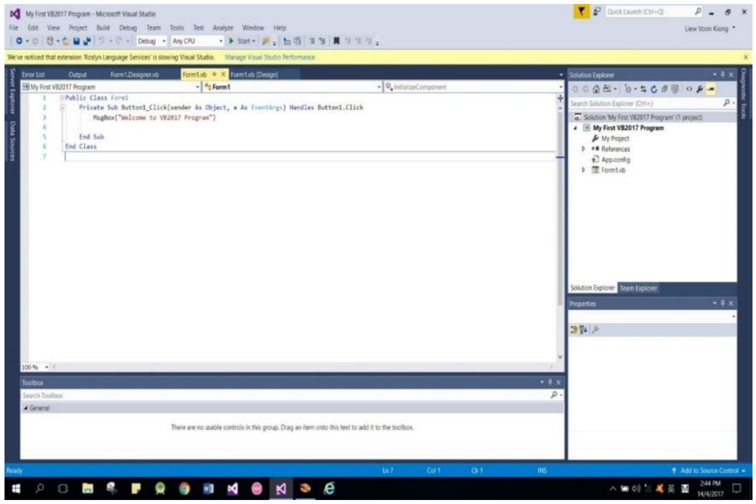

Fig. 6 Visual Basic 2017 Code Window

3.2.5. Programming visual studio 2017

3.2.5.1. 2017 Enterprise

The Visual Studio interactive development environment (IDE) is a creative launching pad that you can use to view and edit nearly any kind of code, and then debug, build, and publish apps for Android, iOS, Windows, the web, and the cloud. There are versions available for Mac and Windows.

3.2.5.2. Programming the " ESP Design®" Software

The Visual Basic Programming Language was used from many Visual Basic versions available from Microsoft.

The "Visual Studio 2017 enterprise“ was used to develop the target software in this project.

4. Results And Discussion

The wells L-075-65 and N-55 in Sarir and Nafora oilfields were selected for the application of the new software. Well data of Sarir field presented in Table 1 which obtained from Arabian Gulf oil Company, (AGOCO)[9].

Table 1 The data of well L-075-65

ARABIAN GULF OIL COMPANY — DATA REQUIRED FOR ESP DESIGN					
FIELD: SARIR			WELL NO.: L-075		
WELL DATA					
Casing Size	9 5/8	in.	Tubing Size	3 1/2	in.
Top of Perforation	8918	ft.	Datum Depth	8400	ft.
WELL INFLOW DATA					
Productivity Index (PI)	5.0	b/d/psi			
Static Bottomhole Pressure (SBHP)	2825	psi	Flowing Bottomhole Pressure (FBHP)	2545	psi
Static Fluid Level (SFL)	-	ft.	Dynamic Fluid Level (DFL)	1217	ft.
PRODUCTION DATA					
Oil Production	1100	BOPD	Water Cut	21	%.
Water Production	300	BWPD	Production GOR	90	scf/stb
Wellhead Pressure	220	psi	BH Temperature	210	°F
FLUID PROPERTIES DATA					
Bubblepoint Pressure (P_b)	600	psi	Oil FVF (B_o)	1.14	rb/stb
			Water FVF(B_w)	1.04	rb/stb
Oil Gradient	0.32	psi/ft	Water Gradient	0.48	psi/ft
POSSIBLE PROBLEMS					
Sand Production		Paraffin Buildup		Corrosion	
Emulsion		Gassy Well		High Temperature	

4.1. Esp Design For Productive Well In Oil Fields

4.1.1. Sarir Oilfield

4.1.1.1 Hand Calculations

The characteristic features of ESP design can be determined according to the following steps:

1- Allowable oil $= 1100\ STB/D\ x\ F.V.F\ 1.14 \quad = 1254\ BOPD$

$$\text{Allowable water} = 300\ STB/day\ x\ F.V.F.\ 1.040 = 312\ BWPD$$

$$Pump\ intake = 1566\ bbl/day$$

2- Flowing bottomhole pressure = $p_{wf} = p_s - \frac{Total\ fluid}{PI}$

$$= 2825 - \frac{1400}{5.0} = 2545\ psi$$

$$Pwf\ =\ 2545\ psi$$

3- Water gradient $= \frac{300}{1400}\ x\ 0.480 \quad = \ 0.11 \frac{psi}{ft}$

Oil gradient $= \ 1100/1400\ x\ 0.320\ =\ 0.26\ psi/ft$

Average flowing liquid gradient $(\boldsymbol{AGL}) \quad = \ 0.37\ psi/ft$

4- Minimum pump depth

$= D_{datum} - \left[\frac{p_{wf} - Saturation\ pressure}{Grad_L}\right] = 8400 - \left[\frac{(2545-600}{0.37}\right] = 3144\ ft$

5- Producing liquid level (L_D)

$L_D = D_{datum} - \left[\frac{p_{wf}}{Grad_L}\right] = 8400 - \left[\frac{2545}{0.37}\right] = 1522\ ft\ from\ surface$

6- Frictional head loss estimated from the Figure 7, as 21.5.

T_f = minimum pump depth x $\left[\frac{Tubing\ friction}{1000}\right] = \frac{21.5}{1000} \times 4440 = 95.5\ ft$

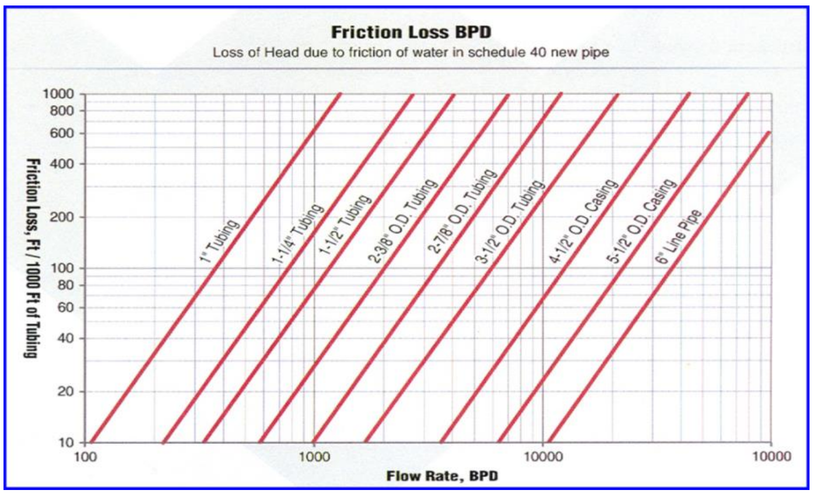

Fig. 7 Estimation of frictional head loss

7- Well head pressure

Well head pressure = 220 psi @260 ft

8- *Total dynamic* head , *TDH*

$$TDH = L_D + T_f + W_{hd} = 1522 + 95.5 + 220 = 1837.5\ ft$$

Actual Pump Performance Curve – Pump GN1600, 102 stages

9- Required pumping head (h) = 2100 ft (from Figure 8).

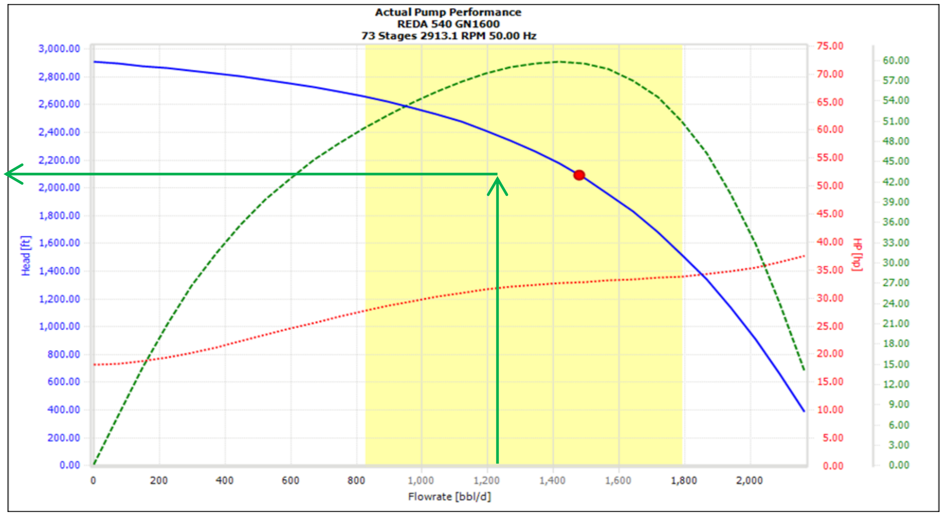

Fig. 8 Determination parameters of ESP design for well No. L-075-65

10- Required number of stages =

$$\text{No. of Stages} = \frac{\text{TDH}}{\text{Head/stage}} = \frac{2133}{21} = 102 \text{ stages}$$

11- Required power(hp) = from chart gives the power of 0.34 hp.

12- Required power for 102 stage (HP) =

$$HP\ (required\ by\ one\ stage)\ X\ No.\ of\ stages\ 0.34\ x\ 102 = 35\ hp$$

13- Efficiency of the selected pump from chart, $E_p \cong 61\%$

14- Velocity around motor = at throughput 1566 bbl/day, from Figure 9 which gives the velocity around motor of 1.40 ft/sec

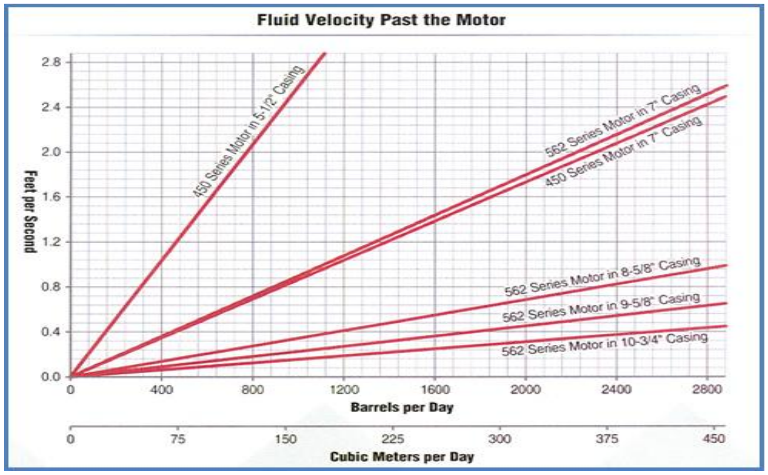

Fig. 9 Velocity around motor

4.1.1.2. ESP Design® Software User Interface

Characteristic features and properties of ESP design can be determined by using software program as following steps:

1. The first step of program is represent the general status as in Figure 10.

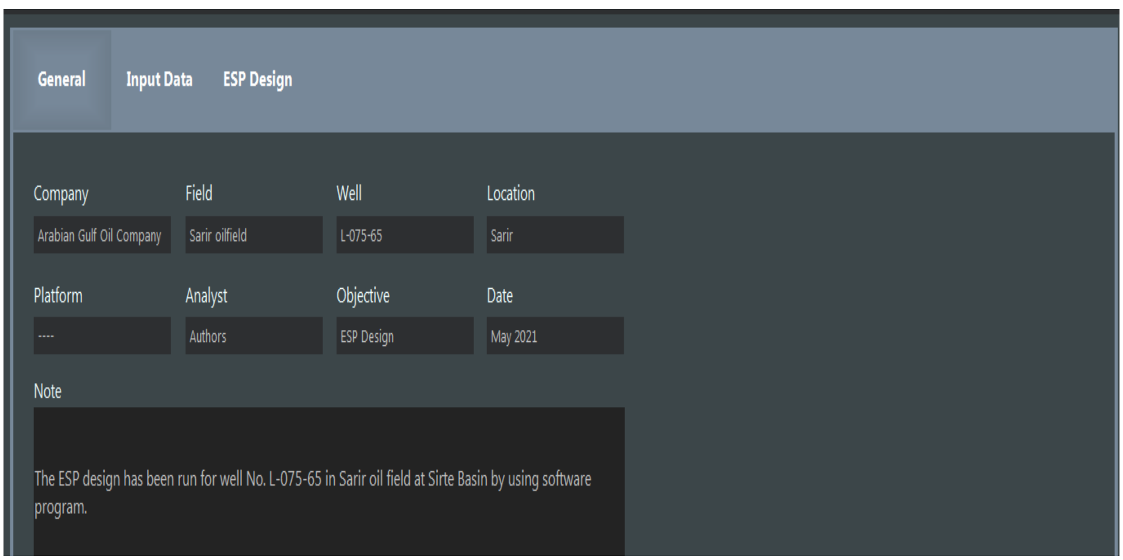

Fig. 10 The first step of program for Sarir oilfield

2. The data of the investigated well will input in the second step as shown in Figure 11.

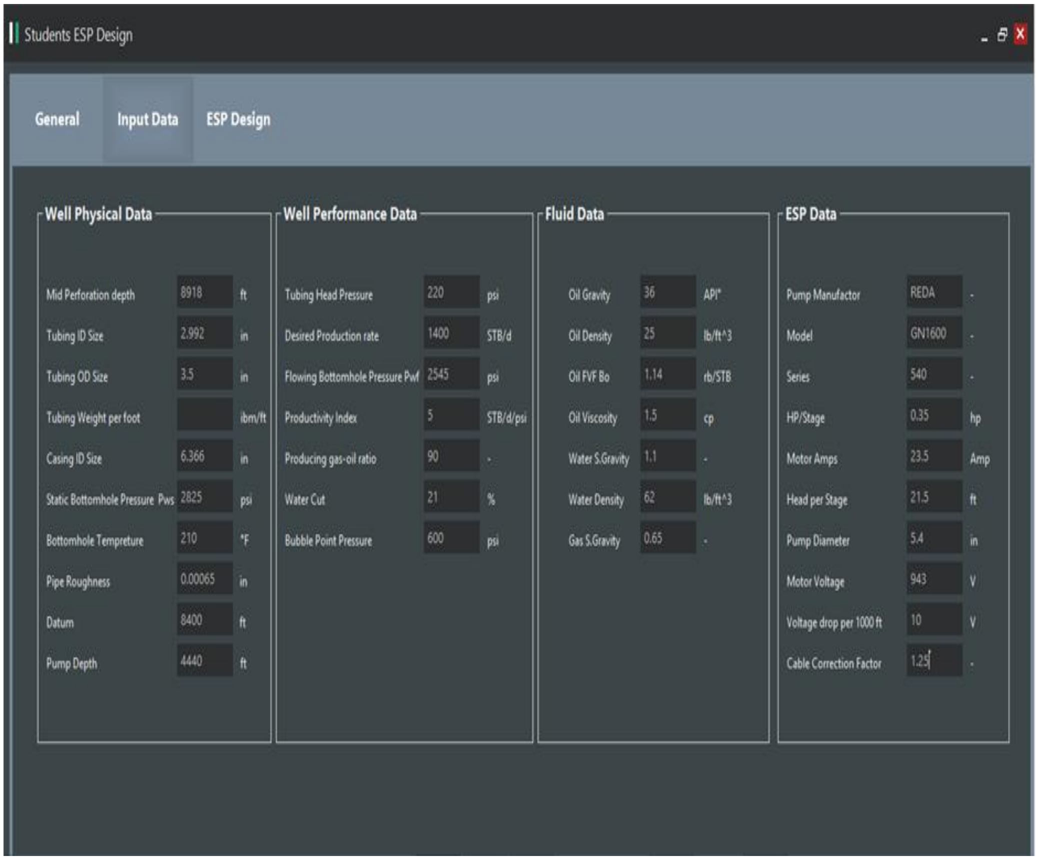

Fig. 11 The second step of program for Sarir oilfield

3. In the third step after program running, the ESP design will perform as shown in Figure 12.

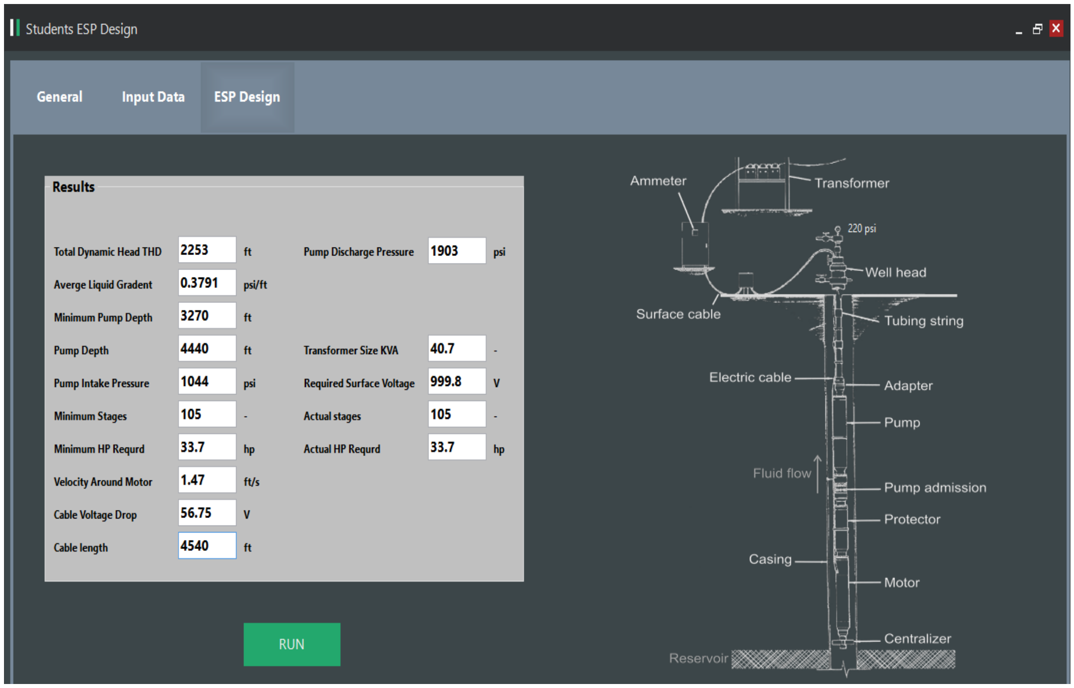

Fig. 12 The third step of program for Sarir oilfield

4.1.2. Nafora Oilfield

4.1.2.1. Hand Calculations

The characteristic features of ESP design of well No. N-55 can be determined according to the following steps as the previous ones for Sarir oilfield as following:

1- Allowable oil $= 1550\ STB/D\ x\ F.V.F\ 1.20 \quad = 1860\ BOPD$

$$\text{Allowable water} = 250\ STB/day\ x\ F.V.F.\ 1.10 = 275\ BWPD$$

$$Pump\ intake = 2135\ bbl/day$$

2- Flowing bottomhole pressure $= p_{wf} = p_s - \frac{Total\ fluid}{PI}$

$$= 2540 - \frac{1800}{6.0} = 2240\ psi$$

$$Pwf = 2240\ psi$$

3- Water gradient $= \frac{250}{1800} x\ 0.460 \quad = 0.063\ \frac{psi}{ft}$

$$\text{Oil gradient} = 1550/1800\ x\ 0.320 = 0.276\ psi/ft$$

Average flowing liquid gradient $(\boldsymbol{AGL}) \quad = 0.338\ psi/ft$

4- Minimum pump depth

$$= D_{datum} - \left[\frac{p_{wf} - Saturation\ pressure}{Grad_L}\right] = 8540 - \left[\frac{(2240-500}{0.388}\right] = 3961.05\ ft$$

5- Producing liquid level (L_D)

$$L_D = D_{datum} - \left[\frac{p_{wf}}{Grad_L}\right] = 8400 - \left[\frac{2545}{0.338}\right] = 1840.73\ ft\ from\ surface$$

6- Frictional head loss estimated from the Figure 7, as 14.6.

$Total\ loss\ T_f$ = minimum pump depth x $\left[\frac{Tubing\ friction}{1000}\right] = \frac{14.6}{1000} \times 4390 = 64.09\ ft$

7- Well head pressure

Well head pressure = 310 psi @370 ft

8- *Total dynamic* head , *TDH*

$TDH = L_D + T_f + W_{hd} = 1840.73 + 64.09 + 310 = 2214.82\ ft$

Actual Pump Performance Curve – Pump GN1600, 102 stages

9- Required pumping head (h) = 1700 ft (from Figure 8).

10- Required number of stages =

$$\text{No. of Stages} = \frac{\text{TDH}}{\text{Head/stage}} = \frac{2134.82}{17.0} = 125 \text{ stages}$$

11- Required power(hp) = from chart gives the power of 0.36 hp.

12- Required power for 125 stage (HP) =

$$HP\ (required\ by\ one\ stage)\ X\ No.\ of\ stages\ 0.36\ x\ 125 = 45\ hp$$

13- Efficiency of the selected pump from chart, $E_p \cong 65\%$

14- Velocity around motor = at throughput 2135 bbl/day, from Figure 9 which gives the velocity around motor of 1.92 ft/sec

4.1.2.2. ESP Design® Software User Interface

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 program for Nafora oilfield

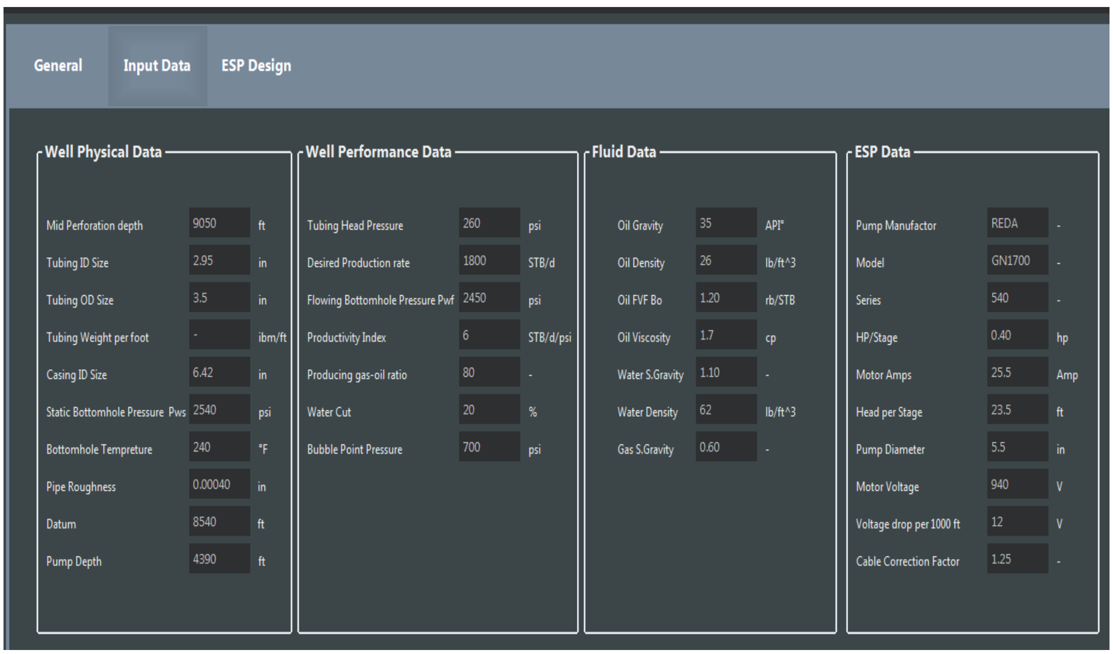

Fig. 14 The second step of program for Nafora oilfield

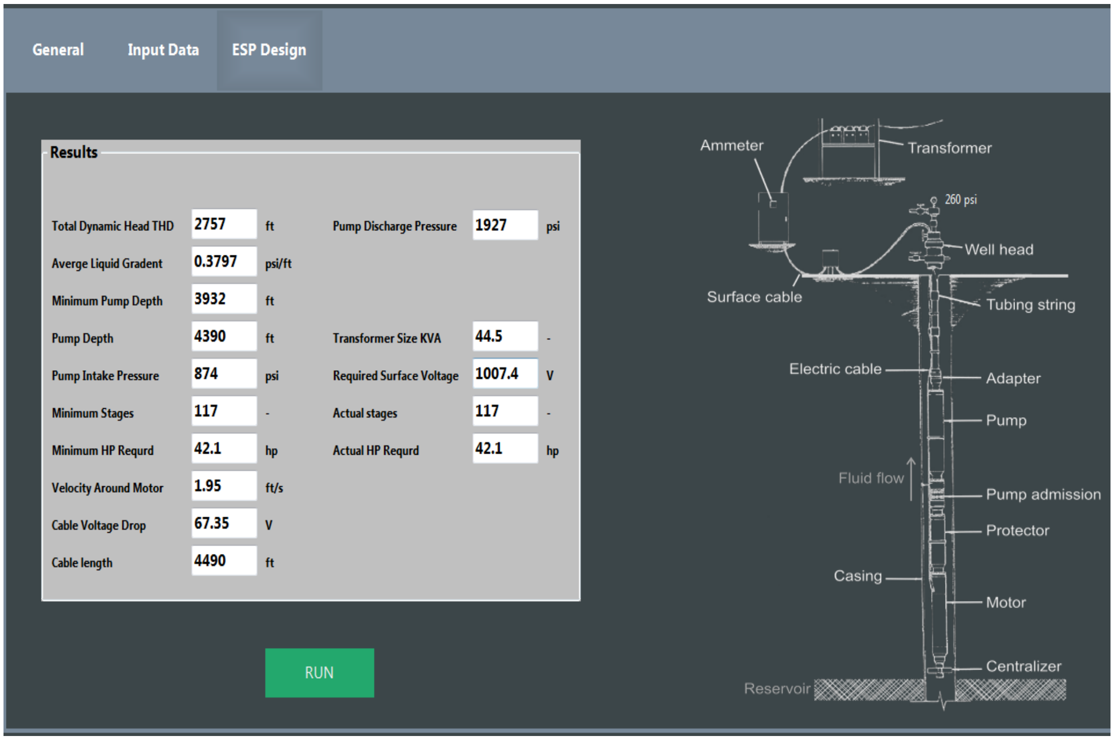

Fig. 15 The third step of program for Nafora oilfield

Tables 2 & 3 give the results of calculated design data and the data obtained by software program for of both Sarir and Nafora oilfields.

Table 2 Calculated design data and software data for Sarir oilfield

Parameters	Calculated results	Software program results
Average liquid gradient, psi/ft	0.37	0.3791
Minimum pump depth, ft	3144	3270
Total dynamic head, ft	2133	2253
Required pumping head, ft	2100	2150
Required number of stages	102	105
Minimum horse power required hp	35	33.7
Velocity around motor	1.40	1.47
Efficiency of the selected pump %	61%	69%

Table 3 Calculated design data and software data for Nafora oilfield

Parameters	Calculated results	Software program results
Average liquid gradient, psi/ft	0.388	0.379
Minimum pump depth, ft	3961.05	3932
Total dynamic head, ft	2134.82	2757
Required pumping head, ft	1700	1694
Required number of stages	125	117
Minimum horse power required hp	45	42.1
Velocity around motor	1.92	1.95
Efficiency of the selected pump %	63%	66%

On the other hand, the calculated results for different parameters of ESP design for wells L-075-65 and N-55 have been compared with the software program results that depicted in Figure 16 & 17.

The calculated results exhibit more or less a similarity with that results of software program except some deviation in some parameters such as number of stages was 102 stages of hand calculations, while 105 stages in software calculations for Sarir field, and 125 and 117 of Nafora oilfield respectively.

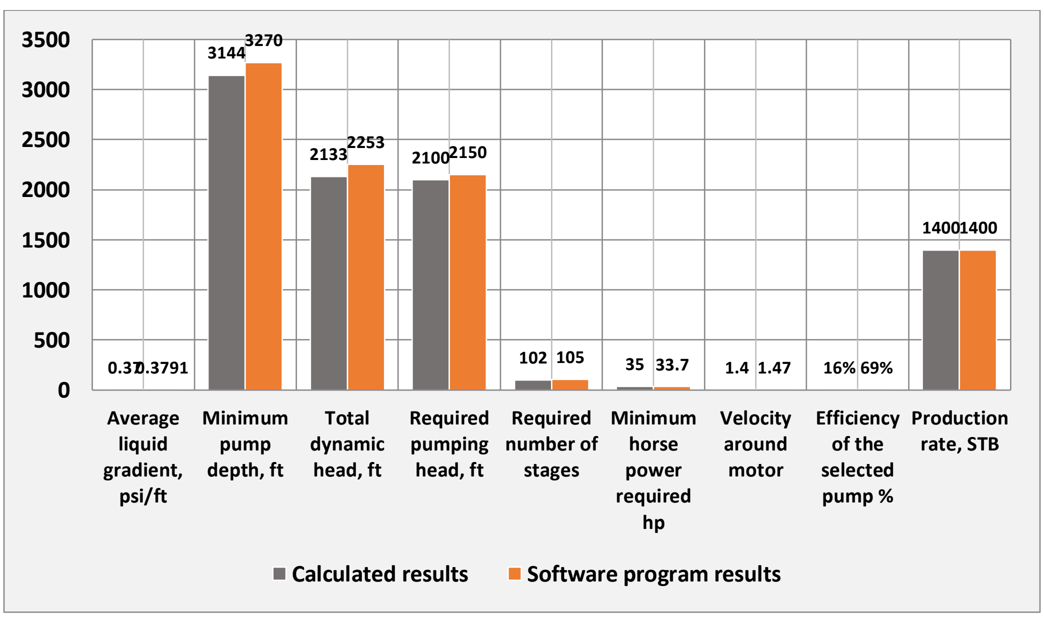

Fig. 16 Comparison between software results and calculated results for Sarir oilfield

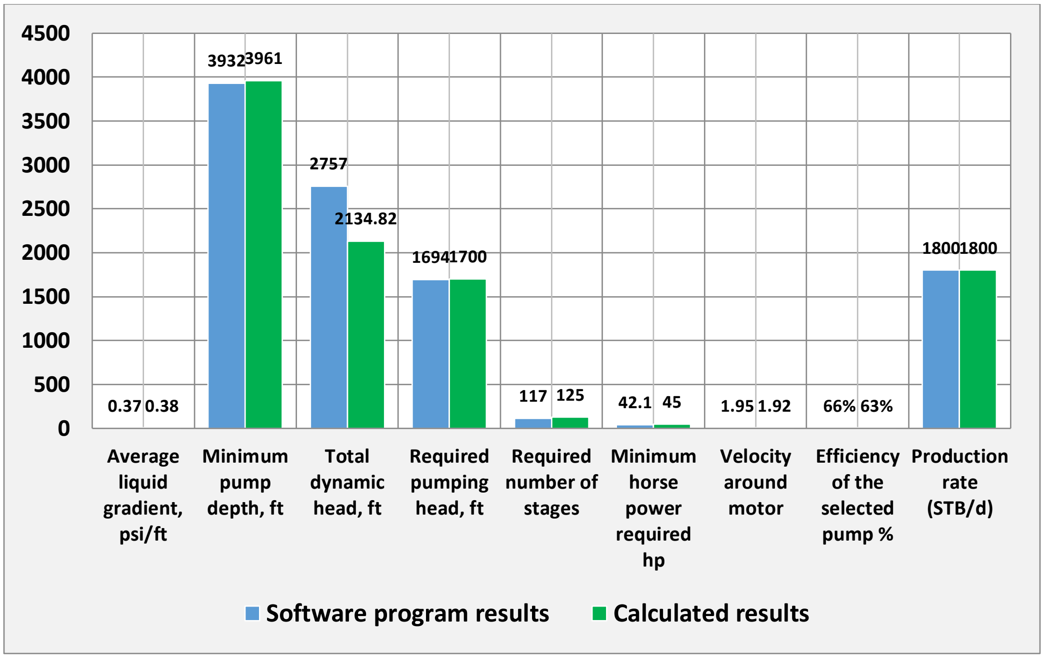

Fig. 17 Comparison between software results and calculated results for Nafora oilfield

5. Conclusion

In the light of the previous study it could be concluded the following:

1. The ESP Design software has been developed as a response to the industry need of being able to design ESP equipment for any oil well.
2. Visual Studio 2017 Enterprise version as a visual basic programming language was used to develop an ESP software which given the name " ESP Design ® ".
3. The lift by ESP is attractive and more useful due to economic consideration and the high production rate.
4. Modifying software is a fact of life. Users will demand more features and easier ways to use software.
5. There is no much differences between the results of hand and software calculations.

6. The work will be extended as an ambitious to continue with the programming by adding more features in order to make this software complete and competitor.

6. Recommendations

1. Modifying software is a fact of life. Users will demand more features and easier ways to use software.
2. The fluid velocity around the ESP's motor is very important for motor cooling system.
3. Running and pulling of the ESP equipment should be handled carefully to avoid damaging the cable during trip.
4. It is recommended to use ESP more than any other system to increase the production rates.

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