Improved Lifting Efficiency of a Moderate Oil Well through Sensitivity Analysis of Electrical Submersible Pump: A Simulation Approach

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Abstract: Proper selection of artificial lift method and its operation is challenging in current era for petroleum industry. Electric submersible pump (ESP) is known as an effective method for optimization of production that requires simulation approach before installation in well for operation. The optimization process consists of selecting the appropriate operational frequency for the ESP system and selection of compactible pump model, number of stages and tubing size. The simulation approach has been utilized for a well located in lower Indus basin, Pakistan to install electrical submersible pump. Prosper software was used to design well deliverability model to analyze well with electrical submersible pump for optimization of production with various sensitivity analysis. Initially simulation is carried out with natural flow, later it was tested with ESP to increase its production. Sensitivity analysis was also carried out with different parameters such as water cut, pump frequency, well head pressure. The simulation model shows that the well has the lowest reservoir pressure of 1140 psi, with solution gas oil ratio 215 SCF/STB. The production rate enhances with increases in reservoir pressure or decrease of water cut. The simulation study has shown that centrilift T100-4 inch is best selection of ESP for this well, similarly operating frequency of 60 Hz has given the best result as well started to flow with 2174 STB/day. It was recommended to use centrilift T100-4 inch with 60 HZ frequency for optimum production of Oil.

Keywords: Artificial Lift Method, Electrical Submersible Pump, Production optimization, Hydrocarbons

1. INTRODUCTION

Primary hydrocarbon recovery is the initial phase to recover the hydrocarbons from the reservoir. The hydrocarbons are driven towards the production well during primary recovery because of the reservoir's intrinsic pressure and energy, which allows the fluid to flow to the surface [1]. With passage of time and production the pressure starts to decline due to fluid flow resistance and restrictions or blockages in the completion and tubing. Therefore, it does not contain bottomhole energy to move the liquid or hydrocarbon from the zone of production to the surface. Reduction in production capacities is owing to steady drop in pressure and increase in water-cut [2]. mostly oil reservoirs are of the volumetric type where the solution gas expansion is dominant as drive mechanism when inflow pressure declines owing to fluid production resultantly oil well is not capable to produce at required rates, unless natural driving mechanisms (i.e., aquifer and/or gas cap) or other mechanisms of Energy, help to stabilize reservoir energy [3]. In such conditions, production can be increased by increasing the pressure using artificial lift techniques[4]. Approximately 50% of wells worldwide need additional lift systems. Electrical submersible pumps, Gas Lift, Plunger lift system and Hydraulic jet pumping are the widely used artificial lift methods [5]. Each of these has its own characteristics and operational criteria varying with selection of pump [2]. Electrical submersible pump (ESP) technology is the first choice of artificial lift for the operators both offshore and onshore to increase the rate of production in all types of reservoirs [6] [7]. ESP installations become successful for first time in late 1920 when beam pumping was replaced with ESP in Oklahoma Field. The pump has capability to lift volumes of oil up to 1,000 bpd, an amount 2–3 times greater than beam pumping units were able to produce [2].similarly it has capacity to uplift more than 10000 stb /day.

The aim of this research is to optimize production using electrical submersible pump with real time data. Well model is simulated using prosper software. Prosper is designed to calculate the fluid properties (PVT), develop the efficiency of vertical lift performance (VLP) and Inflow performance relationship (IPR) curves by calculating and comparing the models with actual reservoir performance [8] [6], [9]. Key parameters that impact performance of any well are reservoir pressure, tubing size, PVT data, gas oil ratio and water cut [10]. All these important parameters are considered in this simulation-based study. Moreover, Inflow performance analysis & vertical lift performance model is also carried out for better evaluation of well performance with and without ESP. Similarly pump operating frequency models are generated to evaluate the well performance with simulation model [11].Each artificial lift method has distinguished criteria. However, the essential factors for selecting ALF of a well are listed in Table.1[12].

Table.1: Parameters for Selection of Artificial lift methods.

Parameters for consideration of Artificial lift methods	
Production characteristics and history	Well conditions and geometry
Investment and performance of the system	Depth of well and well type (Horizontal or Vertical)
Natural drive mechanism characteristics	Casing and tubing specification
completion Types – Open or cased hole	Production rate at bottom and surface
Reservoir fluid characteristics and specification	characteristics and formation
Reliability and history of the artificial lift in a well	Production characteristics and history
Installation and operation cost	Pump model compactable to well conditions

Table 1 describes the selection parameters for any artificial lift methods. These are the major elements to be considered for better selection of artificial lift method in terms of performance and economics as well[13].each parameter has its own impact on selection and design of artificial lift method for instance depth, well type and fluid characteristics has major impact on artificial lift method.

2. METHODOLOGY

The procedure of this study consisted of many stages i.e., data collection stage, running simulation using prosper, IPR curve creation, ESP design for well [9], [10]. The first stage of data collection is completed by acquisition of data in x field of Lower Indus basin such as reservoir data, well bore data, down hole equipment data & production test data. The second step is to generate IPR curve using that data. In which reservoir performance curve (IPR) is generated.

IPR is tool to analyze capability of reservoir or in other word what reservoir can deliver to the well [8]. Similarly, Data of desired Q (flow rate) and flowing bottom hole pressure (pwf) is then used as input data for designing of ESP and Its calculation. Moreover, the result of the ESP design is then analyzed to determine whether the ESP method is applicable for the well or not. furthermore, sensitivity analysis helps us know whether ESP will Optimize production or not. The required data for simulation is presented in Table.2.

Table. 2: Required Data of Lower Indus basin well for simulation.

Data	**Value**	**Data**	**Value**
Solution Gas oil ratio	215 SCF/STB	Reservoir Pressure	1140 Psi
Oil gravity	47 API	Water cut	40%
Gas gravity	0.832	Total GOR	385 SCF/STB
Water salinity	75000 ppm	Productivity Index	0.5 STB/day/psi

Measured depth	7382 ft	Oil FVF	0.77 RB/STB
Tubing ID	2.9 inch	Formation Permeability	115 md
Tubing OD	3.25 inch	Formation Thickness	35 feet
Casing ID	6.4 inch	Drainage Area	200 acres
Casing OD	7 inches	Dietz Factor	31.6
Formation temperature	185 °F	Well bore Radius	0.54 ft
Heat transfer co-efficient	0.00253 BTU/h.ft^2/F		

3. RESULTS AND DISCUSSION

3.1 Well Modeling and Optimization Sensitivities for Well

Simulation model was carried out with help of process where various sensitivity analysis was carried out. It was noticed that well started to flow with induction of ESP. However, operating frequency has a major impact on production along with number of stages as it is shown in table 3.

3.2 Inflow Performance Relationship (IPR)Generation

PROSPER Simulation software offers many models for generating IPR-such as jones, Darcy etc. However, this model is carried out with Darcy's model. the well is cased hole using 7 inch-casing, calculated parameters through this model are given as; PI is 5.27 STB/day/psi, AOF 6989 STB/day for 40% water cut & Gas Oil Ratio(GOR) input is as 430 SCF/STB. The skin factor was 1.3 as depicted in Figure 1, the IPR model was generated with reservoir pressure 1140 psig.

Figure.1: Production rate vs Pressure for Inflow Performance Curve (IPR).

3.3 Vertical Lift performance Relationship (VLP) Generation

The vertical lift performance of a well is a key parameter to know performance of well. In this study VLP was calculated with different top node pressure such as 300,400,500,600 and 700 Psig. The change in pressure has shown impact on TPR and ultimately affecting well performance as shown in Figure 2.

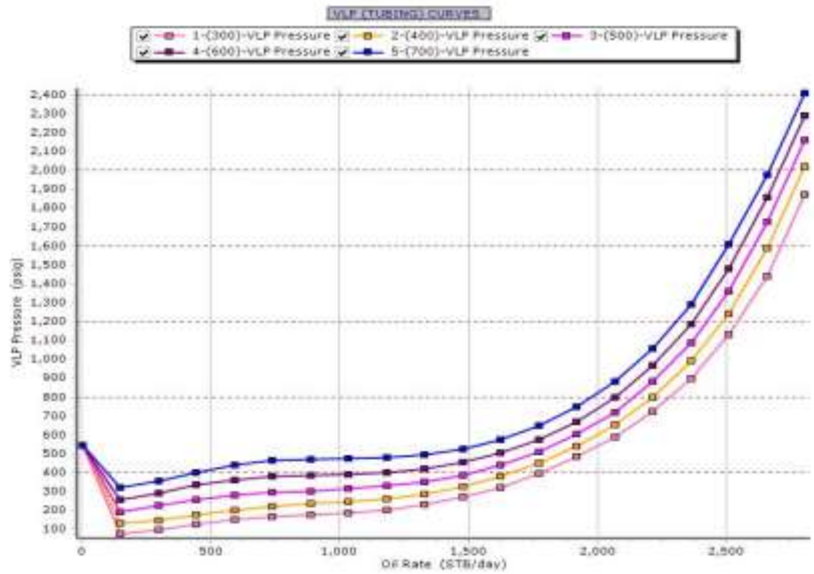

Figure. 2: Production rate vs Pressure for Vertical Lift Performance (VPL).

3.4 Sensitivity Analysis Without Artificial Lift Method

Once VLP & IPR is generated then sensitivity analysis is carried out to know whether well is in flowing condition or not. Sensitivity analysis results are shown below for VLP vs IPR, which depicts that well is not flowing despite having pressure quantification as shown in Figure 3.

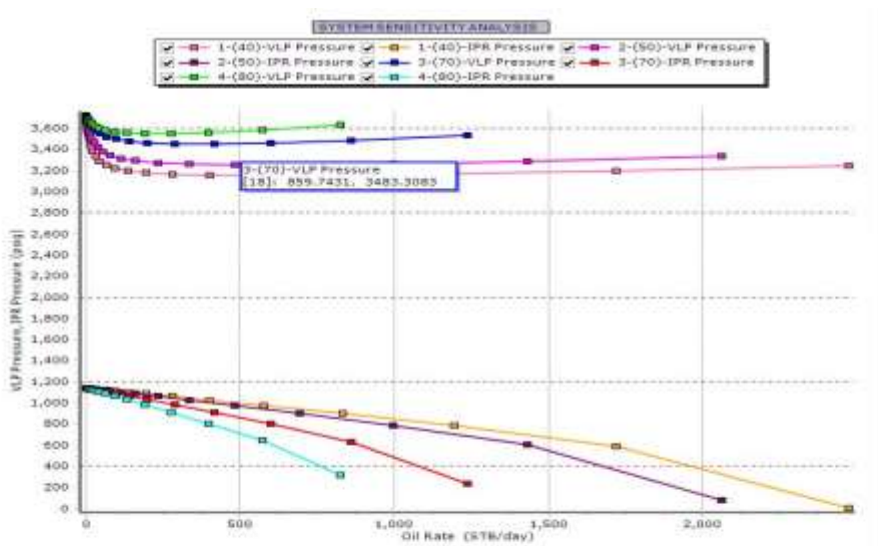

Figure. 3: Sensitivity analysis (VLP vs Oil rate).

Sensitivity or system Analysis of a well is clearly showing that well is not flowing at natural pressure and requires additional energy of artificial mean to be produced at economic level for that electrical submersible pump is introduced and model is carried out to know impact of ESP at given well.

3.5 Induction Of ESP & Well Performance Evaluation Under Different Operation Conditions

As we know, like natural flow well; change in the reservoir and operational parameters and conditions have enormous effect on productivity of well. Consequently, ESP design can be changed under different conditions such as water cut, Declination of pressure and change in ESP stages and frequency during production with pump [3][9].
Electrical submersible pump was selected as artificial lift method in prosper software. Once ESP was introduced the system analysis was carried out at different parameters such as water cut (40% ,50%,60%,70%) & operating frequency of pump (40,50,60,70) Hertz (HZ) provided in Table 3.

The below mentioned data and figure 4 Figure 4 depicts the performance and efficiency of pump at various frequencies as given below for variable liquid head values. The value of operational frequency was 52 Hertz and simulated it to be 57 Hertz for the desired efficiency for optimum recovery of hydrocarbons. However, above 60 Hz pump stopped producing oil rate.

Table.3: Results of variables liquid heads at different operating frequencies.

Variable	Operating Frequency 40 Hz	Operating Frequency 50 Hz	Operating Frequency 60 Hz	Operating Frequency 70 Hz
Liquid rate (STB/Day)	996.6	2572	3624	No flow
Oil rate (STB/Day)	598	1543.65	2174	No flow
Water rate (STB/Day)	398	1029	1449.76	-
Gas rate (MMScf/day)	0.2	0.59431	0.839431	-
Pump efficiency in percentage	45.4	53.8	57.12	-

Above table is depicting the results at various frequency @ 40 % water cut. Similarly at various water cut such as 50, 60,70 well was simulated but the best results are obtained at 40% water cut with 60 Hz of ESP. Blue line shows best efficiency for Electrical submersible pump. In addition, it also gives the best result of 40 % water cut. However operating point is depicting in between 50 and 60 Hz of pump.

3.6 Pump Design

It was designed by using data of well and reservoir.recommended pump is centrilift 4 inch.prosper simulator has recomended the mdoel of pump best fits to this well.however, despite change in frequncy the best operating frequncy is 57% as shown in figure 4 and figure 5.

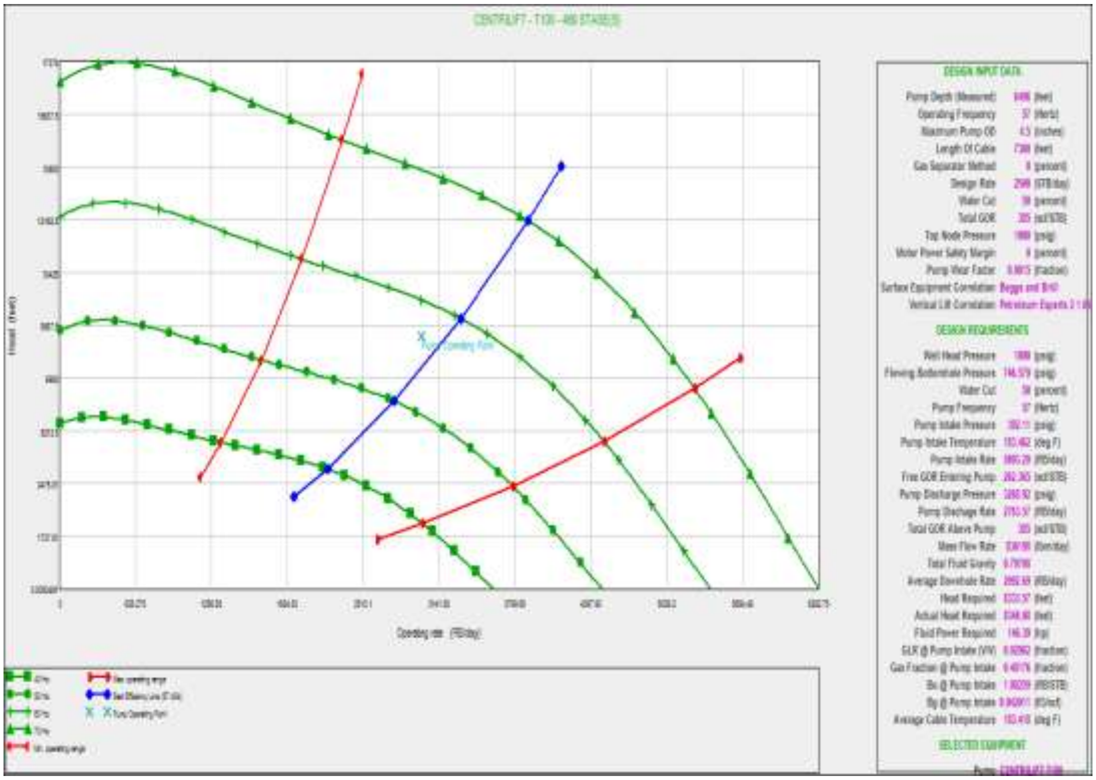

Figure.4: Pump Operating point in terms of frequency

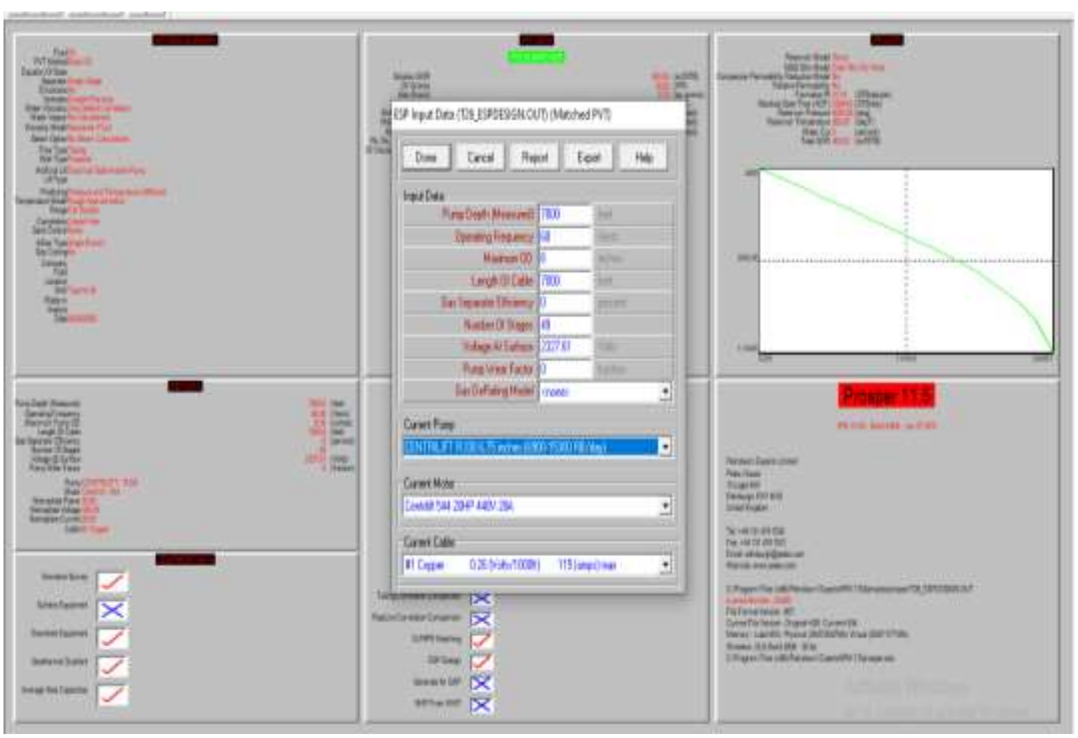

Figure.5:Recommended pump design through simulation for artificial lift equipment.

4. CONCLUSIONS

Through the simulation approach using prosper it was concluded that the induction of ESP well has given production, and considered as useful to increase well productivity, where well is unable to produce naturally. For ESP well, the production rate increases or decreases with change in operating frequency. Similarly, the number of stages has also impacted on ESP performance. Production conditions may change with span of time and production; Therefore, it is noteworthy to re-design the well from timely according to new situations. ESP design is restricted to initial well completion, therefore for future development reservoir management should take all these into account for installation specially tubing ID/OD, Casing ID/OD, and model of pump along with frequency and number of stages. Recommended pump after simulation model is centrilift T100-4 inch having flow rate of 2000/4500 Rb/Day is the best choice for such wells because with installation of artificial lift method well has started flow. Moreover, well has started flow with operating frequency of 40Hz and 50 Hz but the optimum recovery of hydrocarbons and best efficiency is attained with 60HZ.therefore it is recommended that well should be equipped with this ESP model to get optimum recovery of HCs. However, with change in formation and well properties model of pump model and operating frequency can vary.

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DECLARATION OF COMPETING INTEREST

The authors affirm that they have no known financial or interpersonal conflicts that could have influenced their research.

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