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Research Article

Design and Economic Evaluation of the ESP and Gas Lift on the Dead Oil Well

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Abstract

Owing to the increasing water cut and decreasing in reservoir pressure of the well, the oil production of the well has seized and the well has become dead. This research study evaluates the implementation of the artificial lift methods ESP and Gas Lift- economically and technically on the well by using the production performance software (PROSPER) and economical yardsticks (NPV & ROI). The theory, design, production forecast, capital and operating expenditures of the electric submersible pump and gas lift are discussed for the appropriate selection of any of two options. The PROSPER software is used as the simulation tool for the design and production forecasting of the ESP and Gas Lift based. The ESP and Gas Lift methods have been simulated for the design and production forecast by entering the reservoir and completion inputs in the software. Subsequently, the software has been simulated to run on different sensitivities of the variables such as water cut, wellhead pressure setting depth, operating frequency and gas injection rates to check the production rates at different scenarios. Having performed the production performance simulation on the selected artificial lift methods, the methods have been investigated by capital budget-ing. In capital budgeting, the capital and operating expenditures of both lift methods were evaluated by determining their discounted value (NPV) and re-turn on investment (ROI). The prime objective of the research is to accomplish maximum production rates and profitability by selecting the most appropriate artificial lift method for the well; as a consequence it is concluded that the suitable artificial lift method for a well can be selected by applying the simulation and economical schemes.

Keywords: *Artificial lift methods, Inflow Performance Relation, Vertical Lift Performance, Net-present value, Return on investment*

1. Introduction

The petroleum industry encounters a great many challenges in the exploration, drilling, production and management of the hydrocarbons found beneath the surfaces of the earth. Notwithstanding voluminous obstacles, the petroleum engineering is capable of producing the oil and gas from the risky and hazardous conditions. There are several artificial lift methods including some new artificial techniques which are making parallels with the older artificial lift technologies (Electric Submersible Pump, Sucker Rod Pump, and Progressive Cavity Pump) and how they have evolved (Abdel Ben Amara *et al,* 2016).

In this research, two options are evaluated for a pilot well through the PROSPER software and economic yardsticks. The PROSPER is a PROduction and Systems PERformance analysis software. The production of a well can be optimized by critically analyzing the performance of a well with the purpose of the production economics also increases (Petroleum Experts, 2009). The gas lift and electric submersible pump (ESP) are employed to optimize the well production. For the evaluation of the two approaches in the perspective of production rates and economics, the special oil and gas industry software- PROSPER- is used. The energy efficiency, lift time cost, operational costs and capital investment are used to make the decision trees and these graphs helps to evaluate the selection of the artificial lift method for a well (Heinze Lloyd R. *et al,* 1996). The selection process of the artificial lift process is totally based only the expenditure factors like: investment costs, operational costs and revenue costs (Akchay L. Pandit *et al,* 2015). The NPV and ROI methods provide the facility of using feasible and economical method for a well. These economic yardsticks do the calculation and selection of the screened method what the company actually requires for the business (Clegg J.D., 1988).

There are three main factors for the selection of an artificial lift method (James F. Lea, 1999):

i. Production rate

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ii. Downhole flowing pressure
iii. Gas-liquid ratio

Rarely, the selected method does not function fit on the well; hence it increase the services costs, workover costs and drastically reduces the production rates and the net present value of the company (J.F. Lea, *et al,* 1994).

2. Artificial Lift

In the beginning when a well is tapped into the reservoir, it has massive energy to drive the oil to the surface. At this phase, the initial reservoir pressure manages to produce the oil from reservoir to the sand-face and from sand-face to the well completion jewelry and from the completion to the separator. However with the production, the natural reservoir pressure depletes owing to reservoir fluids production and the wellbore pressure increases due to the water loading in the wellbore and increases the overall density of fluid. Successively, the desired production rates cannot be obtained at the surface merely with the natural energy of reservoir. The performance of well can be estimated by the concept of inflow performance relationship (IPR) and vertical lift performance (VLP). The IPRs are used to analysis the performance of a well, diagnosing the problems of a well and solving their problems in an efficient way. The vertical lift performance (VLP) is affected by such factors; tubing size, liquid rate, fluid type, gas-oil ratio, water cut and fluid properties. Currently, it has been reported that about 95% of oil and gas well on run any of the artificial lift method and only 5% well are producing with the natural flow. The following is generalized fig.1 which shows the six artificial lift methods.

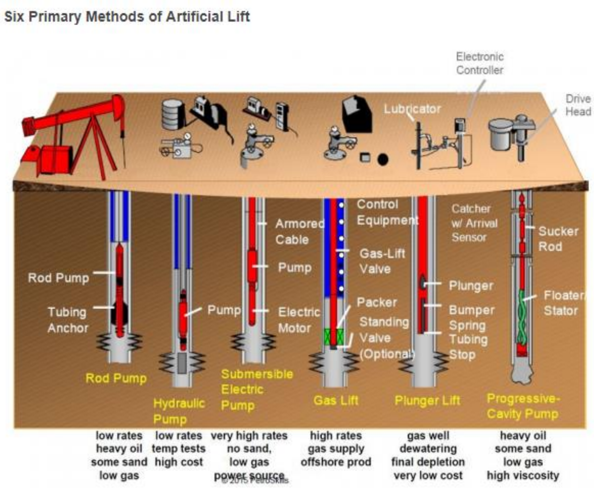

Fig. 1 Schematic of primary six artificial lift methods.

In such conditions, the reservoir needs an artificial means to produce the oil to the desired rates. In offshore applications, ESP and Gas Lift significantly dominate the market of Artificial Lift, with smaller proportion of PCP and Jet Pumps. The artificial lift methods are used to lift the fluid from the wellbore to the surface by using pump pressure at the bottom of the well or injecting the pressurized gas. This method inspects the availability of the resources for the selected methods. For ESP pump requires huge amount of electric while gas lift method does not require any electric power for the injection of the gas (M. A. Naguib, *et al,* 2000).

There are two key choices to increase pressure (Clegg, J.D., 1988):

- A pump is run into well which increase the pressure of the fluid to push it to the surface.
- Gas injection at a certain pressure into the well to decrease the density of fluid and increase the pressure of the fluid to produce the fluid to the surface.

2.1 Electric Submersible Pumps (ESP)

The electric submersible pump system which is configured very simply consists of a centrifugal pump and electric pump unit. They are run down in completion assembly and connected electrically through cables to the surface control system and transformer. The TOPSIS is one the great method of selecting the artificial lift method from the limited information of choices (Alemi M., *et al,* 2010). The production tubing hangs the down hole equipment of the ESP above the perforations of well. Generally the motor of the pump is positioned on the end of the string. The pump, the intake or gas separator and seal section are situated above the motor. The power cable is fastened to the tubing. API RP11S3 provides the guidelines for the proper installation and handling of an ESP system. Several resources are available in the menu which provides empirical means to prolong the life of ESP which includes the numerous formulation, fabrication and operational mechanisms (Baillie, 2002).

2.2 Continuous Gas Lift

In the process of gas lift, the gas is injected into the well through the annulus and then the gas enters into the tubing by the means of gas lift valve which seated in the side pocket. The gas mingles with the reservoir fluid collected in the wellbore and diminishes the bottom hole pressure. Then the column fluid encounters the least impedance in the flow; hence the well produces high flow rates of oil. The gas lift is majorly broken into two sub types in the petroleum industry; the continuous gas lift method and intermittent gas lift method.

For a successful gas lift operation, there are many parameters are taken into considerations. The optimum parameter makes the high production and generates more monetary. There are many parameters in the gas lift but among them the most vital one is injection rate of gas. Therefore, optimum amount of injection gas ought to be to found in order to get improve production rates because the addition injection of gas causes decrease in production owing to more slippage between liquid and gas (Ebrahimi, 2010).

3. Prosper Modeling

The simulated model of the well is prepared on PROSPER software for modeling the natural flowing well, ESP and Gas Lift method. The model of the well is developed by entering the basic well characteristics such as: PVT properties, reservoir properties, downhole equipment detail and production data.

3.1. Base Case Modeling

The base case modeling is developed by enter the basic well characteristics such as: PVT properties, reservoir properties, downhole equipment detail and production data. In this case, no artificial lift method is selected from the System Summary section. Therefore, Black Oil Model is selected with oil and water as the flowing fluids. The PVT properties of the reservoir fluid are given in the Table 1.

Table 1 PVT properties of the reservoir fluid

PVT Properties	Value	Unit
Solution GOR	500	Scf/stb
Oil gravity	38	API
Gas gravity	0.749	
Water salinity	85600	ppm
Mole percent of H_2S	0	%
Mole percent of CO_2	3.5	%
Mole percent of N_2	5.6	%

When the PVT data has been properly matched, one can start making the IPR curve. PROSPER provides many types of reservoir models for generating the IPR. In this case, the reservoir model for the well is Darcy and mechanical/ geometrical skin is entered by hand. Other reservoir and wellbore parameters are given in the Table 2.

Table 2 The reservoir and wellbore properties for IPR data

Properties	Value	Unit
Reservoir pressure	1490	Psi
Reservoir temperature	210	°F
Water cut	35	%
Total GOR	552	scf/stb
Reservoir permeability	95	md
Reservoir thickness	45	ft
Drainage area	20	acre
Dietz shape factor	30.99	
Wellbore radius	0.354	Ft
Skin	2.88	

3.2. Results of the base case

The fig.2 shows the inflow and outflow curves, and the PROSPER shows that the well is not producing the oil because IPR and VLP curves do not intersect each other; hence the well is dead.

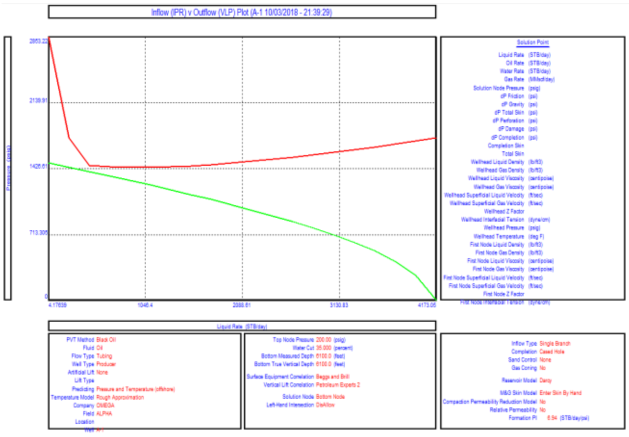

Fig.2 IPR vs. VLP of the well without any artificial support

3.3. ESP Case Modeling

PROSPER helps us to install the ESP on a well as artificial lift method. In this case, ESP is selected from the system summary section as the artificial lift method.

Now for design the ESP, the software provides the selection pump, motor and cable for the well. Thus, it is very simple to select the all three parts from the database of the PROSPER. The pump, motor and cable are selected from the database which shows maximum performance of the ESP as shown in the fig.3

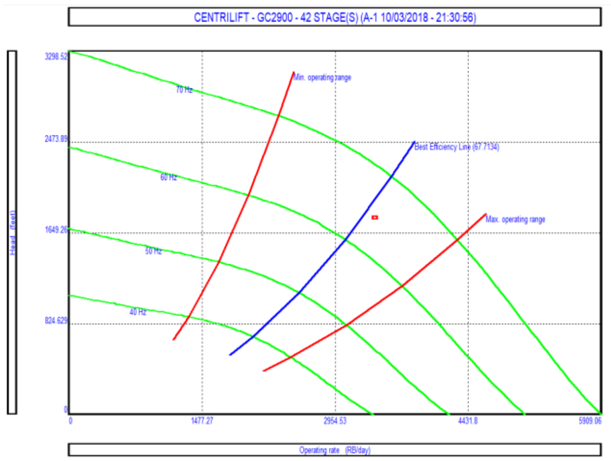

Fig.3 Performance curve of the ESP for the well

3.4. Results of ESP

The PROSPER calculates the ESP system analysis at the pump discharge (outlet of pump). The fig.4 shows that the inflow performance curve is represented by the green curve which shows the bottom of the well. The pump discharge pressure is depicted by the blue curve. And the vertical lift performance curve is shown by the red curve. The red and green intersect each other means the well is flowing and produced some liquid rates.

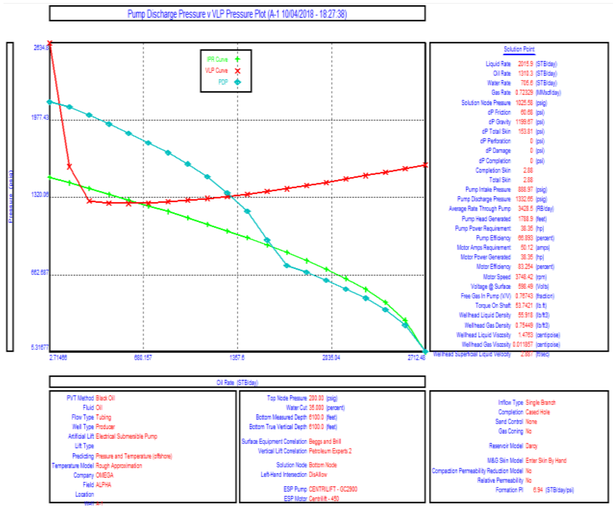

Fig.4 Pump discharge pressure vs. VLP pressure of the well

3.5. Continuous Gas Lift Case Modeling

The Gas Lift artificial lift method is selected from System Summary screen.

For design gas lift, the design section requires maximum liquid rate, maximum gas available, flowing top node pressure, maximum depth of injection, operating injection pressure, kickoff injection pressure, desired dP across valve, water cut, minimum spacing, total GOR and etc.

Now the PROSPER calculates the gas lift performance curve shown in the fig.5.

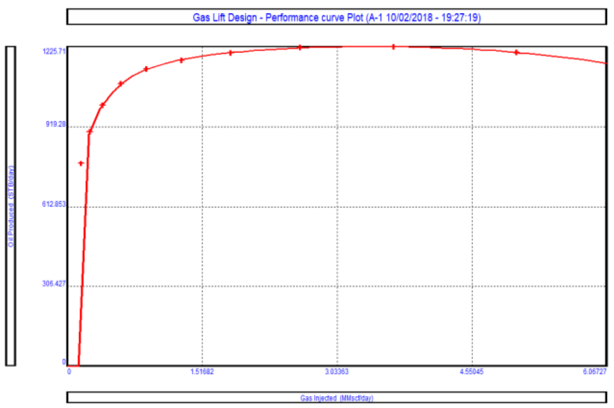

Fig.5 Performance curve of the gas lift for the well

The performance curve shows the relationship between the volumes of gas injection to the oil produced. This graph is used to select the optimum gas injection rates where maximum oil production can be obtained. Looking at the performance plot, it can be calculated that, the well is not producing any oil without gas injection. The plot shows that as the injection volume is increasing the production of oil is also increasing. The maximum oil can be produced form the well by injection 2.44 MMscf/d gas in the well.

3.6. Results of Gas Lift

The results show that the well gets a significant increase in production from gas injection. The system calculation reveals that IPR and VLP intersect each other and the well produces 1011.2 STB/D oil rate, 1555.7 STB/D liquid rate, 544.5 STB/D water rate and 0.55818 MMscf/D gas rate at the 200 Psi top node pressure, and 35% water cut shown in the fig.6.

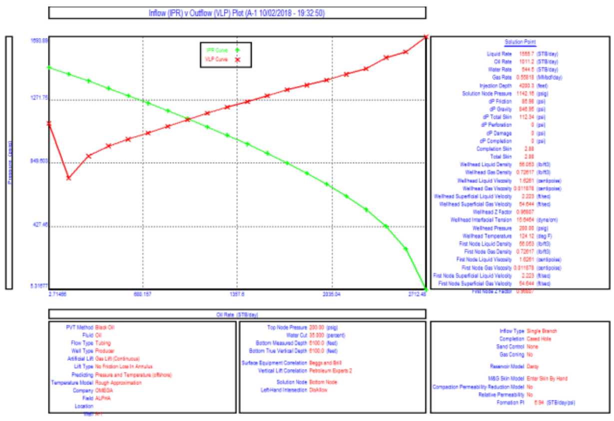

Fig.6 IPR vs. VLP of the well with gas lift

4. Economical Evaluation

Having carried out the simulation work and getting the production profile of both the methods, is the firstly portion of this research. The second portion of the research is the complete economic evaluations of the artificial methods used for the well. In the economic assessment, the capital costs, operating costs, workover costs and income costs are taken into the consideration. Before making a final decision a thorough economic analysis has to be done. As described, it is the profitability of a project that has to be the final decision criteria.

The following Table 3 and 4 are showing the capital expenditure and operating expenditure of ESP and Gas Lift of the well.

Table 3 CapEx of ESP and GAS LIFT

Services	Cost of ESP ($)	Cost of Gas Lift ($)
Artificial Lift Equipments	120,30	165,387
Installation/Workover	42,000	29,000
Surface Equipments	150,800	182,100
Electric Surface Equipments	84,000	96,300
Metering	0	62,000

Table 4 OpEx of ESP & Gas Lift

Services	Cost of ESP ($)	Cost of Gas Lift ($)
Horse Power per Annum	1,051,200	705,600
Running Cost	700,000	700,000
Maintenance cost	833,333	600,000
Water Treatment	550,000	550,000

The following Table 5 is showing volume of oil produced by each method in day and in a year. Then, the income of one year of oil is calculated and finally the profit oil is calculates in dollars by subtracting the CapEx and OpEx from the income of one year of oil.

Table 5 Oil production & profit oil of ESP and GAS LIFT

Method	Stb/day	Stb/year	Income of oil per year ($)	Profit oil per year ($)
ESP	1310.3	479,062.5	39,283,125	35,751,492
GAS LIFT	1011.2	369,088	29,527,040	26,436,653

4.1. Net-present value of ESP and Gas Lift

The NPV is economic yardstick which is used to evaluate the profitability of the project and it can be calculate from discounted value of the both projects ESP and Gas Lift. Following is basic equation (1) of the NPV:

$$\mathrm{NPV} = \mathrm{C_o} + \frac{\mathrm{C_1}}{(1+\mathrm{R})} + \frac{\mathrm{C_2}}{(1+\mathrm{R})^2} + \frac{\mathrm{C_3}}{(1+\mathrm{R})^3} \ldots\ldots \frac{\mathrm{C_n}}{(1+\mathrm{R})^n} \qquad (1)$$

By using the above equation, the net present value of both can be found easily. Hence the net present value of ESP is far greater than the NPV of gas lift which impudently shows that ESP is the better option to be chosen for the well because it will give huge sum income by producing more oil and less expenditure. The NPV of the ESP and GAS LIFT is given in the Table 6.

Table 6 NPV of ESP and Gas Lift

Method	NPV of year ($)
GAS LIFT	20,942,933
ESP	28,969,723

4.2. Return on investment

ROI is also another economic yardstick which determines the profitability of the project by estimating the net profit and total investment of the project. The following is basic equation (2) of ROI:

$$\mathrm{ROI} = \frac{\text{Net Profit Oil}}{\text{Total Investment}} \qquad (2)$$

From the calculation of ROI, it has been found that the ROI of ESP is also greater than that of gas lift; consequently it can surely judge that the performance and profitability of ESP is far better than that of gas lift. The ROI of the ESP and Gas LIFT are given in the Table 7.

Table 7 ROI of ESP and GAS LIFT

Method	Return on investment
GAS LIFT	7.55
ESP	9.12

Conclusion

After the simulation and economical evaluation of the ESP and Gas Lift on the well, the oil production rates discounted values of both lift methods has been obtained. The oil production rate of the ESP is 1310.3 STB/D at 35 % water cut while the oil production rate of the Gas Lift is 1011.5 STB/d at 35 % water. Further, the NPV and ROI of the ESP for year are $28,969,723 and 9.12; while the NPV and ROI of Gas Lift are $20,942,933. In the light of above results, it is concluded that ESP is better than Gas Lift for the well in terms of the production and economics.

Recommendations

The selection of the artificial lift can performed through simulation of the production performance and economics of the method on the well. In addition to above criteria, the following factors should also be considered for final selection:

1) Planning and administrative resources: Gas lift is simple and easy to manage after implementation; while the ESP method is very complex and difficult to plan and implement.
2) The ESP has a very short lift in the well. The common lift expectancy of ESP is 2- 3 years.
3) The Gas Lift method requires full workover on the well; therefore few number of wells or individual well are not economical for gas lift method.

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