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# Highly Effective and Efficient Production Optimization Method Using Combined Artificial Lift Method

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## Abstract

A better production operation, in terms of technical aspect and economy, is the ultimate goal of any production optimization activities, including during artificial lift selection and application. Because there is no '*one-for-all*' artificial lift, its selection must be thoroughly analyzed based on specific well conditions to achieve the most optimum condition. Some artificial lifts require high cost for expenditures and maintenance to overcome their own challenges and limitations which restrict the scope of production operation. An innovative solution is required to optimize the production and overcome these problems, one of which is the combined artificial lift application, where two regular artificial lift methods are applied simultaneously, which is then called as combined system.

Although combined system design is more complex than that of regular system, nodal analysis approach can still be applied in order to achieve the most optimum operating condition of combined system based on the design result of regular systems. Eventually, production operation betterment can be achieved.

In this study, the data were collected from an onshore Field X which are produced using six active wells. This study is proposed to evaluate the performances of combined system, both ESP-GL and SRP-GL, and compare the results to the regular system of ESP, Gas Lift, and SRP. It is then shown that both combined systems have better performances and lead to higher net present value (NPV) compared to each regular system.

Along with technological advancement, combined system is a highly innovative and novel method to proceed the production in a better and highly-optimized operation. Besides its novelty and great potential, it is also considered as a form of energy efficiency because flare gas can be utilized to optimize the production.

## Introduction

Production optimization covers a vast scope related to activities of measuring, analyzing, modelling, and executing plan to improve productivity of a well/field. One of which is optimizing the performance of artificial lift. Artificial lift is commonly applied to proceed the production when a well is either unable to produce naturally or uneconomical to be produced using its own natural energy. There are various artificial lifts to be selected, yet in this study, it is only focused on Electrical Submersible Pump (ESP), Sucker Rod Pump (SRP), and Gas Lift. The selection of focus study is based on the application of the artificial lift by considering its potentials: SRP is the most-widely applied artificial lift in the world which is considered to be simply-operated, ESP has a great potential which can accommodate high flowrate with a vast operating condition, and Gas Lift is essentially the key part of the combined system design to improve the production performance by injecting gas, which in this study, is taken from flare gas in Field X. Each of them has their unique parameters and requirements, operating condition range, limitations, advantages & disadvantages, which need to be thoroughly analyzed before deciding which artificial lift is suitable the most.

Nevertheless, with the increment of lifting height, application of regular system becomes less efficient and less economic. The deeper well, the more cost it will take, which will worsen the total revenue. For instance, ESP would require more pump stages and power requirement to operate at deeper layer due to more total dynamic head is required, SRP can only operate at lower flowrate at deeper layers due to more loading on pump plunger during fluid lifting which lead to lower revenue, and Gas Lift requires higher surface injection, more gas injection rate, and higher investment in equipment to produce at deeper layers. Eventually, the application of regular system is inevitably unsatisfying and needs improvement.

As an alternative solution, combination of two artificial lift methods, which is applied in the same well simultaneously, can be utilized to optimize the production and overcome the problems dealt by regular system. Besides becoming a new method to optimize the production, combined system has many advantages such as the technology requirements have all existed, a better production operation can be easily achieved, and it is a form of energy efficiency by utilizing the flare gas to optimize the production as explained in the later section of this study.

Data were taken from Field X where six active wells are available to produce the fluid in this field. Those wells are B-1, B-4, B-5, B-6, B-10, and B-11, which produce from different reservoir layer. Nevertheless, the reservoir pressure of this field has been depleted compared to its initial pressure, yet based on the recent trend, the reservoir pressure is considerably constant thus the assumption of constant production rate is considerably valid. The focus of this study is to evaluate the performance of combined system, in terms of technical aspect and economy, compared to the regular systems to understand the possibility of combined system application because there have been any fields in Indonesia to apply this system. In economic evaluation, two important economic parameters would be provided, i.e. Net Present Value (NPV) with discount rate of 10%, and Rate of Return (ROR) to support the selection of the best scenario. Considering the application of combined system in two Colombian Fields, i.e. ESP-GL in Balcon field and SRP-GL in Tello field, significant cost savings and increased operating flexibility were obtained[1].

## Data and Method

The methodology of this study is listed below including the required data.

- Obtain/gather and/or calculate data required to design each regular system, i.e. well data, production data, PVT data, reservoir characteristics, and data related to artificial lift method.
- Construct IPR and TPR based on each well's condition to determine well deliverability and determine desired flowrate based on AOFP.
- Design regular system, i.e ESP, SRP and Gas Lift, based on desired flowrate.
- Design the combined system based on design results of each regular systems.
- Conduct economic analysis to evaluate the design of combined system due to its complexity and wider operating range.
- Re-design the combined system for case of smaller pump to produce at the same desired flowrate, and/or for case of increasing flowrate using the same pump if necessary.

The flowchart is presented in Figure 1.

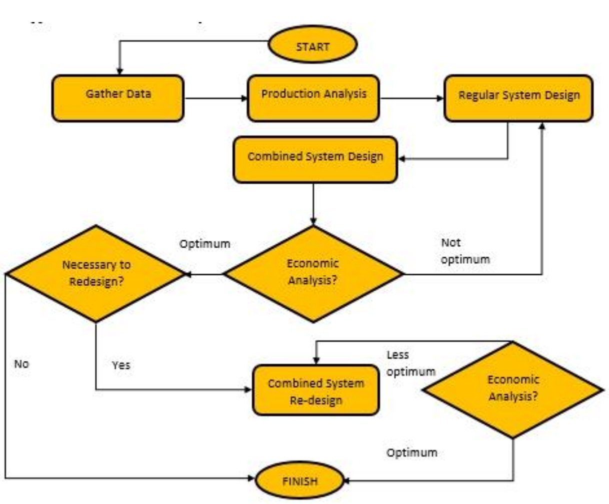


Figure 1: Flowchart

## Result and Discussion

This study was conducted to evaluate the possibility and the performances of combined ESP-GL and combined SRP-GL in Field X with six active wells, i.e. B-1, B-4, B-5, B-6, B-10, and B-11. In this study, there will be presented five design scenarios, i.e. three regular system designs (ESP, SRP, and Gas Lift) and two combined system designs (ESP-GL and SRP-GL).

Firstly, the most optimum condition of both regular systems needs to be determined. Afterwards, it is proceeded to obtain the most optimum condition of combined system design based on the design result of regular systems. Lastly, comparison result from each design needs to be conducted to determine the best scenario in terms of technical aspect and economy.

### 1. Regular ESP Design

The most important parameter to design the ESP is total dynamic head (TDH). TDH is a parameter which describes the ability of ESP to lift any fluid up to a certain height. TDH has three main components: wellhead pressure, total friction loss, and net vertical lift. After obtaining the TDH, a certain pump catalogue is chosen based on the desired flowrate to obtain the design parameter such as head per stage, HP per stage, and efficiency which are required in ESP design. Not only from its availability, but also the voltage and current design are selected based on the available options provided by the manufacturer. The design result of ESP for each well is provided in table 1.

Table 1: Regular ESP design results

| Well | ESP Type | Efficiency, % | Liquid Rate, BFPD | Target Run Life, days |
|---|---|---|---|---|
| **B-1** | QN70 ARC, 98 stages, 172 HP, 2237 V, 50 A | 71 | 5,880 | 483 |
| **B-4** | QN20 ARF, 55 stages, 56 HP, 1270 V, 31 A | 62 | 1,488 | 876 |
| **B-5** | QN10 ARC, 76 stages, 34 HP, 1050 V, 21 A | 57 | 806 | 1,263 |
| **B-6** | RCD1000NX, 104 stages, 35 HP, 950 V, 31 A | 70 | 855 | 745 |
| **B-10** | QN70, 104 stages, 183 HP, 2400 V, 50 A | 71 | 5,827 | 402 |
| **B-11** | QN70 ARF, 98 stages, 172 HP, 2237 V, 50 A | 71 | 5,986 | 799 |

### 2. Regular SRP Design

Loading becomes one of the most important parameters which limits the application of SRP type. In its design, it is very vital to ensure that the PPRL and Peak Torque are still less than the maximum limit of the selected SRP type. Besides, the maximum pump deliverability with volumetric efficiency of 0.80, as a function of maximum pumping speed, stroke length, plunger area, and fluid density, also determines the expected flowrate that can be achieved from a certain operating condition. The Target Run Life of SRP is assumed to be 450 days because no SRP data is available in Field X. The design result of SRP for each well is provided in table 2.

Table 2: Regular SRP design results

| Well | SRP Type | PPRL, lbs | Peak Torque, lbs-in | Liquid Rate, BFPD |
|---|---|---|---|---|
| **B-1** | C-912D-305-168 | 25,746 | 834,176 | 1,775 |
| **B-4** | C-912D-305-168 | 25,004 | 811,451 | 1,698 |
| **B-5** | C-912D-305-168 | 22,864 | 743,583 | 1,719 |
| **B-6** | C-1280D-305-240 | 28,384 | 1,139,922 | 1,797 |
| **B-10** | C-1280D-305-240 | 25,746 | 834,176 | 1,782 |
| **B-11** | C-912D-305-168 | 21,679 | 702,973 | 1,816 |

### 3. Regular Gas Lift Design

Gas injection rate and surface injection pressure become two of the most important parameters in Gas Lift design. In this study, the lift gas was taken from the available flare gas in Field X which was then allocated to all active wells in Field X as mentioned earlier. It is also obtained that the optimum gas injection rate, in which the maximum oil flowrate of 208.17 BOPD could be expected, is about 17.92 MMSCFD or about 2.7 times greater than the available 6.47 MMSCFD of lift gas which will result in oil rate of about 185.15 BOPD.

Surface injection pressure would be determined by the location of operating valve for each well. The deeper injection valve, the higher surface injection pressure. Surface injection pressure will determine compressor horsepower requirement which is assumed, in this study, there is no limitation in compressor size which will then limit the maximum horsepower supply. Thus, any number of horsepower requirement can be provided.

The design result of Gas Lift is provided in table 3 and the calculation of compressor horsepower requirement is mentioned below by using the following equation:

$$BHP = 22\left(\frac{ratio}{stage}\right)(\#\ of\ stage)(MMSCFD)(F) \ldots\ldots (1)$$

$$Total\ BHP = BHP\ x\ (Auxiliary\ Factor) \ldots\ldots (2)$$

$$Actual\ BHP = Total\ BHP\ /\ (Efficiency) \ldots\ldots (3)$$

where ratio/stage is calculated as the ratio of discharge and intake compressor pressure, which will determine the number of stages. The number of stages should be increased until the ratio per stage, r, is less than 4. After obtaining the surface injection pressure for each well, the highest value of injection pressure is taken as the discharge pressure of compressor and the intake pressure is taken as the separator pressure with taking 10 psi of pressure drop. The value of F depends on the compression stage, i.e. for single-stage is 1.00, for two-stage is 1.08, and for three-stage is 1.10. Thus, it is obtained:

| | |
|---|---|
| Discharge pressure | = 786 psig |
| Separator pressure | = 130 psig |
| Intake pressure | = 120 psig |
| No. of stages | = 2 |
| Compressor ratio per stage | = 2.44 |
| Volumetric efficiency | = 0.8 |
| Actual Brake Horse Power | = 1030.71 HP |

In this study, a reciprocating compressor is preferably selected. According to the assumption, thus Field X is able to provide the required compressor horsepower.

Table 3: Regular Gas Lift design results

| Well | No. of GL valves | Gas Injection Rate, MMSCFD | Surface Operating Pressure, psig | Liquid Rate, BFPD |
|---|---|---|---|---|
| **B-1** | 5 | 1.99 | 786 | 2,696 |
| **B-4** | 7 | 1.13 | 489 | 364.3 |
| **B-5** | No design due to gas lift incapability | | | |
| **B-6** | No design due to gas lift incapability | | | |
| **B-10** | 8 | 1.10 | 579 | 789.6 |
| **B-11** | 6 | 2.25 | 689 | 2,872 |

### 4. Combined ESP-GL Design

The expected outcome of combining ESP with Gas Lift operation simultaneously is to enhance the production performance by allowing the existing ESP to produce at higher flowrate due to gas injection which will then result in higher revenue. In this study, all wells are suitable to be applied combined ESP-GL system except well B-5 and B-6 because these wells are not suitable for regular gas lift system, thus application of combined system would not be feasible. The principle of constructing Combined ESP-GL Performance Curve is quite similar with ordinary GLPC, where the sensitivity of injection gas rate is conducted for a series of different number of ESP stages. Then, for a specific number of ESP stage and injection rate, we can obtain the increased flowrate.

As mentioned before that the design of combined system is based on the design results of both components of its regular system. Because of that, the amount of gas injection and number of ESP stages are the same as in the regular system design.

### 5. Combined SRP-GL Design

Having the same outcome as combined ESP-GL system, i.e. enhancing production performance to gain higher revenue, the design of combined SRP-GL system also relies on the amount of gas injection to each well to achieve a better production optimization using the existing SRP type. The well schematic diagram for both combined system, ESP-GL and SRP-GL, would look similar thus it is only attached one sample only as presented in figure 2 until figure 5.

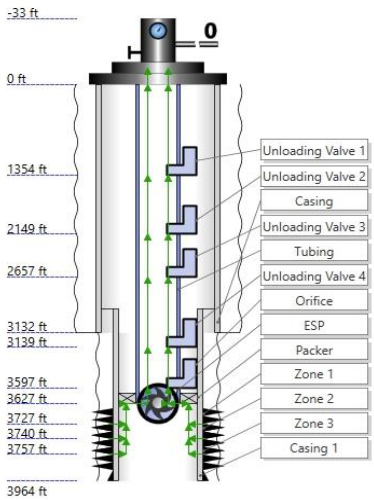


Figure 2: Well schematic diagram of combined system B-1

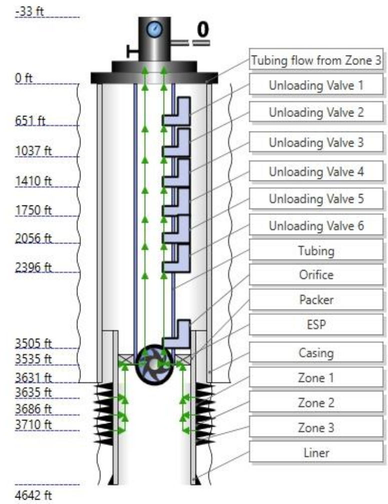


Figure 3: Well schematic diagram of combined system B-4

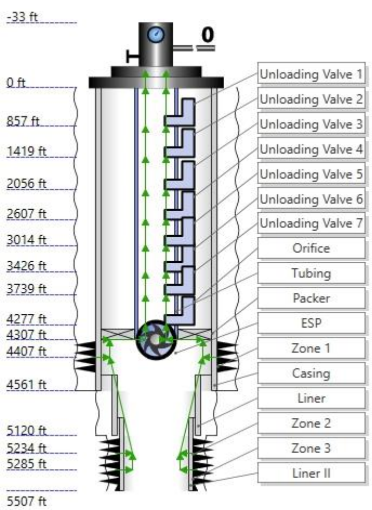


Figure 4: Well schematic diagram of combined system B-10

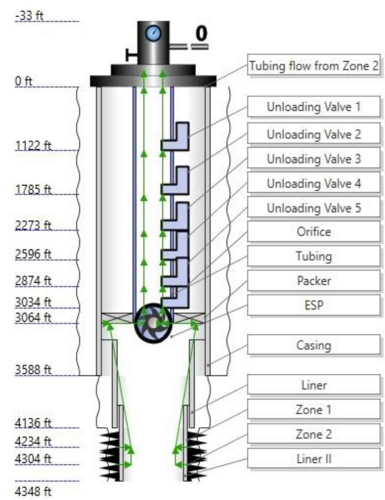


Figure 5: Well schematic diagram of combined system B-11

### 6. Best Scenario Selection

In this section, there are two aspects which will be discussed in detail regarding the evaluation and comparison of all presented scenarios.

### 6.1. Technical Aspect

In this study, technical aspect would cover the area of production performance, especially the ability of producing fluid with the most optimum design from each scenario. The comparison in liquid and oil flowrate for each case is presented in table 4.

Table 4: Liquid and oil flowrate comparison

| Well | Scenario | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Regular ESP | | Regular SRP | | Regular Gas Lift | | Combined ESP-GL | | Combined SRP-GL | |
| | BFPD | BOPD | BFPD | BOPD | BFPD | BOPD | BFPD | BOPD | BFPD | BOPD |
| **B-1** | 5,880 | 117.6 | 1,775 | 35.5 | 2,696 | 53.9 | 7465.7 | 149 | 1,989 | 39.78 |
| **B-4** | 1,488 | 89.28 | 1,698 | 101.88 | 364 | 21.9 | 2,207 | 132 | 1,882 | 112.92 |
| **B-5** | 806 | 80.6 | 1,719 | 171.9 | 0 | 0 | 806 | 80.6 | 1,719 | 171.9 |
| **B-6** | 855 | 171 | 1,797 | 359.4 | 0 | 0 | 855 | 171 | 1,797 | 359.4 |
| **B-10** | 5,827 | 174.81 | 1,782 | 53.46 | 789 | 23.7 | 7,004 | 210 | 2,034 | 61.02 |
| **B-11** | 5,986 | 179.58 | 1,816 | 54.48 | 2,872 | 86.2 | 7,144 | 214 | 1,968 | 59.04 |
| **Total** | **20,842** | **812.87** | **10,587** | **776.62** | **6,721** | **185.7** | **25,482** | **957.78** | **11,389** | **804.06** |

From table 4, Gas Lift has the lowest liquid flowrate potential, only 6.721.9 BFPD, because Field X is not perfectly suitable for Gas Lift operation due to considerably low reservoir pressure. Because the principle of Gas Lift is to lighten fluid density, not provide additional energy/pressure support, thus the primary energy to lift the fluid up to the surface remains the reservoir pressure. This statement is supported by the result of Gas Lift design is only suitable for four active wells, while the other two wells, i.e. B-5 and B-6, cannot be operated by Gas Lift due to insufficient reservoir pressure no matter how much gas is to be injected.

ESP can provide a lot greater production flowrate compared to Gas Lift because ESP provides additional energy support required to lift the fluid at the desired flowrate. In Field X, the production flowrate is limited only up to 6,000 BFPD for each well because of severe sand problem if the production rate exceeds the limit. Regular ESP can produce up to 20,842 BFPD from six active wells.

Meanwhile, the SRP is limited by its maximum pump deliverability as mentioned earlier. Unlike ESP which can provide a greater pressure support at a certain rate, the performance of SRP is limited by its ability to withstand the loading during operation which mainly results in lower flowrate. In this case, regular SRP can only produce at 10,587 BFPD or about a half of the production of ESP.

In this study, it can be concluded that combined ESP-GL and SRP-GL can increase the production up to 25,482 BFPD and 11,389 BFPD respectively by using the existing regular pump designs and 6.47 MMSCFD of gas injection which was taken from the flare gas in Field X which have a great potential to increase the revenue as it will be discussed in the next section.

### 6.2. Economy

Economic evaluation covers the area of project economy to determine the most economically beneficial scenario from all presented scenarios. This aspect would have bigger portion in selecting the best scenario because the company tends to seek the scenario which can generate the highest profit. Consequently, an assumption of ideal operating condition for all scenarios should be held, which means, for instance, there is no difference in safety level between one scenario with another, or in another word, the selection of the best case is not affected by safety.

Here is only discussed two of the most important economic parameters, i.e. Net Present Value (NPV) and Rate of Return (ROR). NPV describes the feasibility of project in which if it has positive value, the project is profitable most likely to be executed. On the contrary, if it is negative, the project is not profitable and will not be executed. However, the project cannot be straightforwardly determined by NPV only. It requires the additional economic parameter, i.e. ROR, which determines the level of discount rate which results in zero value of NPV. If it is still higher than the Minimum Attractive Rate of Return (MARR) which is commonly taken at 20%[9], the project is economically attractive and has very high chance to be executed.

In the economic calculation, the capital expenditure, the expense at the beginning of the project, is only to purchase compressor. However, in Field X, the power for supplying electrical power required to operate the pump, compressor, and other electrical devices, is generated using its own produced gas, thus the electricity and power cost would be zero. Meanwhile for purchasing the pump, the company tends to rent it daily by dividing the total pump string price by Target Run Life (TRL) from the manufacturer.

By assuming ideal condition where the pump will work well until it needs replacing after reaching TRL in a 5-day workover, it can be projected the frequency of pump replacement in a 10-year production period. Both combined systems have successfully expected to generate more profit compare to its regular systems. Thus, the application of both combined systems is economically attractive and feasible. This statement is also supported by the value of ROR which is considerably high and exceeds the MARR. The economic evaluation comparison is presented in Figure 6 and 7 for NPV and ROR comparison respectively.

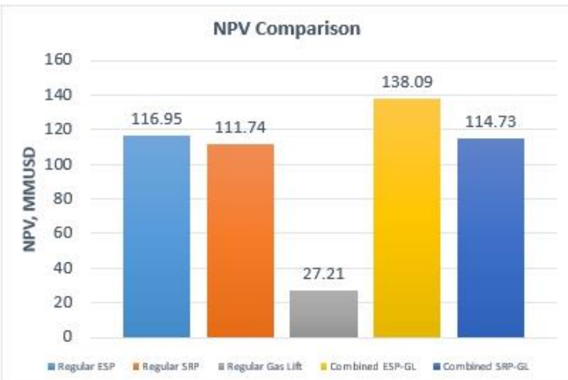


Figure 6: NPV Comparison

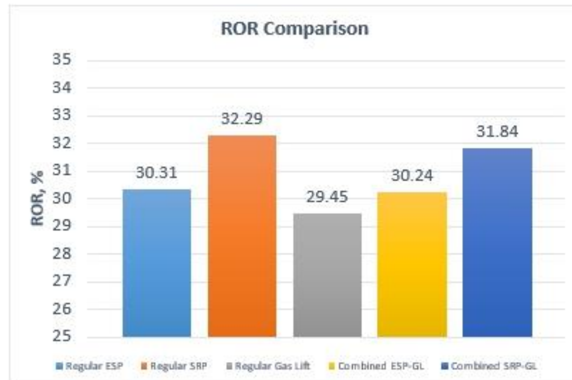


Figure 7: ROR Comparison

After being presented and compared in terms of technical aspect and economy between the regular systems and combined systems, it has been proven that combined system has a great potential to be applied instead of regular systems due to its better production performances and economically more attractive Combined ESP-GL generates higher NPV than both regular ESP and Gas Lift, and combined SRP-GL generates higher NPV than both regular SRP and Gas Lift.

In this study, the best scenario to be applied in Field X is Combined ESP-GL because this scenario can produce at the highest flowrate which leads to highest profit generation in a 10-year production with the expected NPV of about 138.09 MMUSD with a 10% discount rate and ROR of about 30.23%.

## Conclusions

The conclusions of this study are:

1. Both combined systems, ESP-GL and SRP-GL, show better performance compared to each regular system in terms of technical aspect and economy as they are evaluated from production flowrate increment and NPV & ROR.
2. The best scenario to be applied in Field X is combined ESP-GL as this scenario can produce at the highest flowrate which lead to the highest NPV and attractive ROR. However, there would be some requirements to support its application, such as uninterrupted supply gas and electricity.

Combined system studies still have many things to improve and can be further developed in the future. With proper design method and good potential of reservoir, combined system can optimize the production hence increase the revenue.

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