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Re-shifting Of a Single String Packer-less Electric Submersible Pump Gas Lift Hybrid to Fit the Up-to-date Environment

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Abstract. Electrical Submersible Pump (ESP) gas lift hybrid advantages as discussed in the previous SPE papers number 128974 and number 176291 MS are now entering the end phase. Unfortunately, the information of the ESP gas lift hybrid limitation was limited; meanwhile the data is critical. Moreover, after time goes on, well properties and operation condition was changing then the ESP hybrid is no longer relevant. Re-shifting was then conducted to fit the current condition.
The methods are developed based on the statistic of ESP gas lift hybrid failure and its causes. Some criteria are defined as a screening process to select which well needs to use ESP gas lift hybrid configuration. The criteria include water cut, gas injection rate when the gas lift mode is running, and oil cut off.
From 2019 to 2020, about 43 ESP well service jobs implemented the criteria to decide the usage between ESP gas lift hybrid and ESP. The number of ESP gas lift hybrid is decreasing; the cost of well services is also cut by the unnecessary side pocket mandrel and gas lift valve. The average run life of ESP in the field is about 3.1 years; meanwhile, the new method is still running and counting for the run life because it has less failure probabilities. Slickline job for gas lift valve maintenance is also not necessary for the ESP configuration.

Keyword(s): Shifting, ESP gas lift hybrid, Electric submersible pump, Hybrid

1 Introduction

Artificial lift conversion project from the gas lift to electric submersible pump (ESP) in R field has been carried out since 2008 and is projected to become the major artificial lift. The conversion project is carried out because of the declining trend of gas supply for gas lift. During the transition, the field faces a problem with ESP downtime when the ESP is shut down because of a downhole problem that requires rig deployment. ESP gas lift hybrid is then proposed as the new configuration to minimize oil loss potentials by running the gas lift until the rig is available. With this configuration, the gas lift can deliver about 35% of liquid compared to normal ESP production (Prakoso, 2010).

Currently, ESP has become the major artificial lift as planned in the conversion project in 2008 with 149 carbonate wells from the total of 196 producing wells. Meanwhile, 47 sandstone wells are still using gas lift because the sandy, gassy, and low liquid rate is below 200 BLPD (barrel liquid per day). In 2019, production engineers evaluated the fact that the condition was changing and demanding that it was still relevant to use the ESP gas lift hybrid in the field. From 2019 to 2020 there were about 43 related ESP rig job that needed to decide and install the suit configuration, whether using ESP gas lift hybrid or the normal ESP. Figure 1 explains the design of a gas lift valve for a packerless system. The side pocket mandrel is designed to be as deep as possible to avoid the gas injecting through the pump intake (Prakoso, 2010).

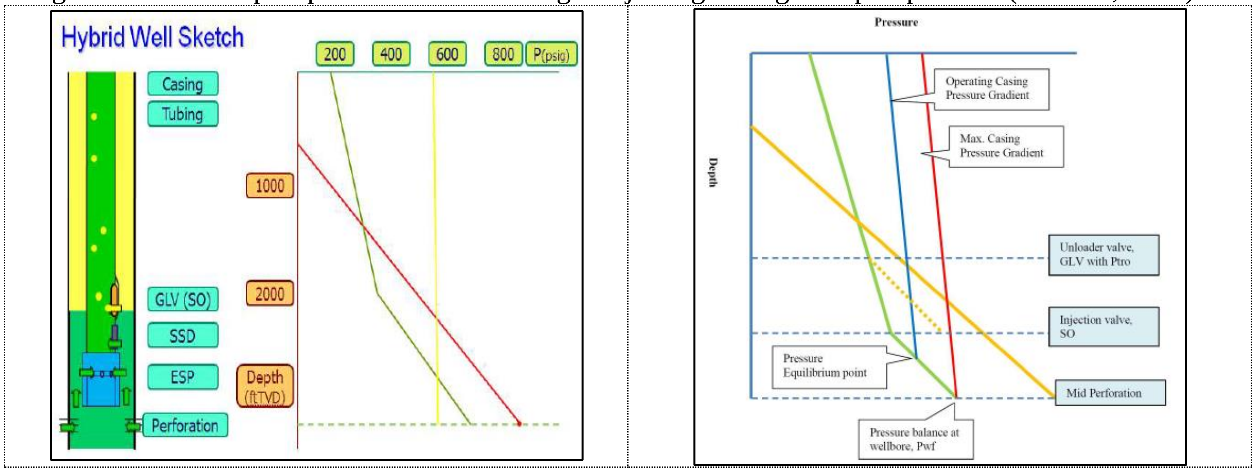

Figure 1. Left: An early ESP gas lift hybrid subsurface design configuration in the R field (Prakoso, 2010). GLV (Gas Lift Valve), SO (Screen Orifice), SSD (Side Sliding Door), ESP (Electric Submersible Pump), TVD (True Vertical Depth), and P (Pressure). Right: Re-design of single string ESP gas lift hybrid using two gas lift valves to provide deeper injection point, increase drawdown and liquid production (Rohman et al., 2015). GLV (Gas Lift Valve), Ptro (Pressure Test Rack Opening). SO (Screen Orifice), Pwf (Flowing Bottom Hole Pressure).

In 2015, an evaluation of a single injection ESP gas lift hybrid identified about 300 ft TVD (True Vertical Depth) opportunity to deeper point of injection and increased the drawdown. Figure 2 explains the new design by adding the unloader valve with a regular gas lift valve to provide liquid unloading before operating at a true injection point using a screen orifice. The system must be carefully calculated to ensure balanced and stable gas lift operation. The end of the tubing connected to the ESP string must be below the equilibrium point to prevent gas injecting through pump intake (Rohman et al., 2015). The re-design improvement also utilizes venturi orifice as the injection point to reduce the pressure drop at the injection point and provide the same injection rate with the same injection pressure at the surface choke which was discussed in the success story of venturi orifice application in the R field for gas lift wells (Rilian et al., 2012). The new design improves the liquid production during ESP downhole problem by 53% to 60% which is better than the early design with only about 35% of liquid production.

2. Problem Statement

This paper will explain the ESP gas lift hybrid limitations that are not present in the previous two papers. Limitations information will help other engineers to avoid the same problem. This paper also describes the best time to use either ESP gas lift hybrid or ESP configuration.

3. Methodology

The researchers constructed the following sequence to answer the stated problem above as follows:

1. Analysis of the additional cost for ESP gas lift hybrid compared to ESP configuration.
2. Analysis of the ESP gas lift hybrid problem including gas lift valve or side pocket mandrel leak, gas lift valve plugging, increasing water cut, probability gas injected through pump intake, and sand problem.
3. Construction of the workflow to decide using either ESP gas lift hybrid or ESP configuration.

4. This study evaluates the ESP gas lift hybrid system since its first implementation in 2008 until 2020 in R field.

4. Limitations Analysis

The limitations analysis consist of gas lift valve and side pocket mandrel leakage, gas lift valve plugging, sand problem, increasing water cut, and gas injection through pump intake probability.

4.1. Gas Lift Valve and Side Pocket Mandrel Leakage

This is one of the limitations of the hybrid system in the R field. From 2019 to 2021, there were nine gas lift valves and side pocket mandrel leakages. The side pocket mandrels were designed with a series of holes to provide access for the gas from annulus entering the tubing trough gas lift valve. Unfortunately, this access was also the weak point of this system compared to the ESP or gas lift methods as described in figure 2. The leaking possibility comes from the unfit gas lift valve setting and erosion during production and debris blockage.

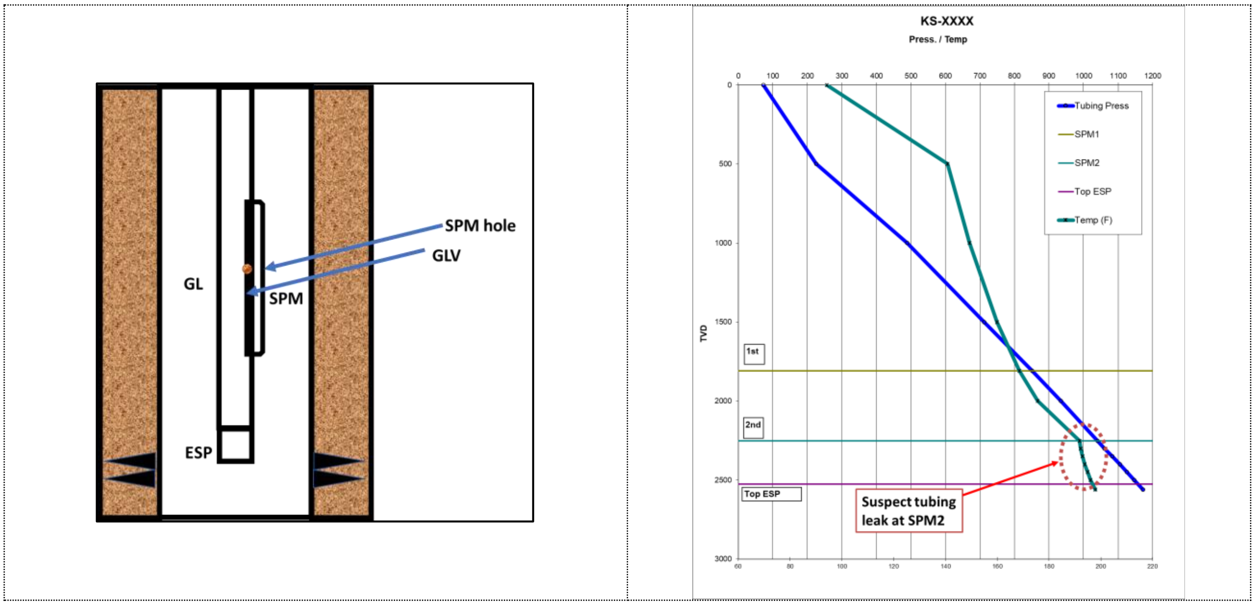

Figure 2. Left: Diagram of ESP gas lift hybrid with SPM hole and gas lift valve (GLV) position that has potential leak during production. GL (Gas Lift), ESP (Electric Submersible Pump), GLV (Gas Lift Valve), and SPM (Side Pocked Mandrel). Right: Pressure and temperature profile for hybrid system indicate side pocket mandrel leak at the injection point. SPM1 (1st side pocket mandrel), SPM2 (2nd side pocket mandrel), ESP (Electric Submersible Pump), Temp (Temperature), TVD (True Vertical Depth), Press (Pressure).

This possibility is lower inside ESP configuration because the upper section is only a tubing string. The problem can be identified using slickline operation by running pressure and temperature survey using electronic memory gauge and it results in the pressure and temperature gradient profile. The first step to solve the problem is typically replacing the gas lift valve with the new one. If the problem still exists, the last suspect is the side pocket mandrel leak that can be solved with only rig job.

Figure 2 right, shows the pressure and temperature profile in leaking conditions. The temperature decreases as the depth increases, indicating liquid circulation and cooling effect. In onshore operation, rig jobs cost relatively low and require a little effort, but in offshore operation, this condition will cause a high-cost consequence.

4.2 Gas Lift Valve Plugging

Typically, for an ESP with a run life of more than 3 years, the gas lift section of the hybrid system is idle, and then while running ESP mode the gas lift valve can experience plugging. When plugging occurs and the ESP section experiences a problem, the gas lift section cannot be operated. Typically, this requires the gas lift valve replacement using slickline, but in some wells gas lift valve cannot be retrieved due to paraffin and scale problems.

4.3 Sand Problem

Another issue found in hybrid and ESP configuration is sand problem. This problem commonly occurs in the hydraulic fractured sandstone formation. The sand is entering the impeller and lead to the pump stuck. For the case the impact is the lower run life of about 2 year compared to the normal run life of 3 year. Then there are need a mitigation to prevent the sand entering the pump.

4.4 Increasing Water Cut

During the initial installation in 2008, the average water cut was about 80% with the best average of efficiency rate of 1750 BLPD (Barrel Liquid Per Day). The hybrid system still delivered oil above the economic limit. With the increasing water cut trend, and had reached an average of 97% most of the wells would deliver oil production less than the economic limit in the hybrid mode. Table 1 is an example design of KS-XXXX re-installation after side pocket mandrel leak when the water cut was 91% and liquid rate target was 302 BLPD (Barrel Liquid Per Day) or 27.2 BOPD (Barrel Oil Per Day), meanwhile from simulation if the water cut increasing to 97% then the production will be 9 BOPD.

Table 1. ESP gas lift hybrid comparison between 91% and 97% water cut.

Critical data	*91% ESP gas lift hybrid*	*97% ESP gas lift hybrid*
Production rate target	302 BLPD	302 BLPD
Water cut	91%	97%
Oil rate	27.2 BOPD	9 BOPD
Static gradient (initial)	0.36 psi/ft	0.36 psi/ft
Target gradient above injection point	0.2 psi/ft	0.2 psi/ft
Gas injection rate requirement	300 MSCFD	Above 300 MSFCD

In addition as an example of the case the differences of hybrid mode with low and high water cut shown in the figure 3. The hybrid mode during average water cut of 94% the oil production is about 54 BOPD, meanwhile when the water cut was 97% the oil production is below 10 BOPD. Moreover, the gas injection demand is automatically increasing with the water cut increase. This condition is contrary with the condition of gas shortage in the field.

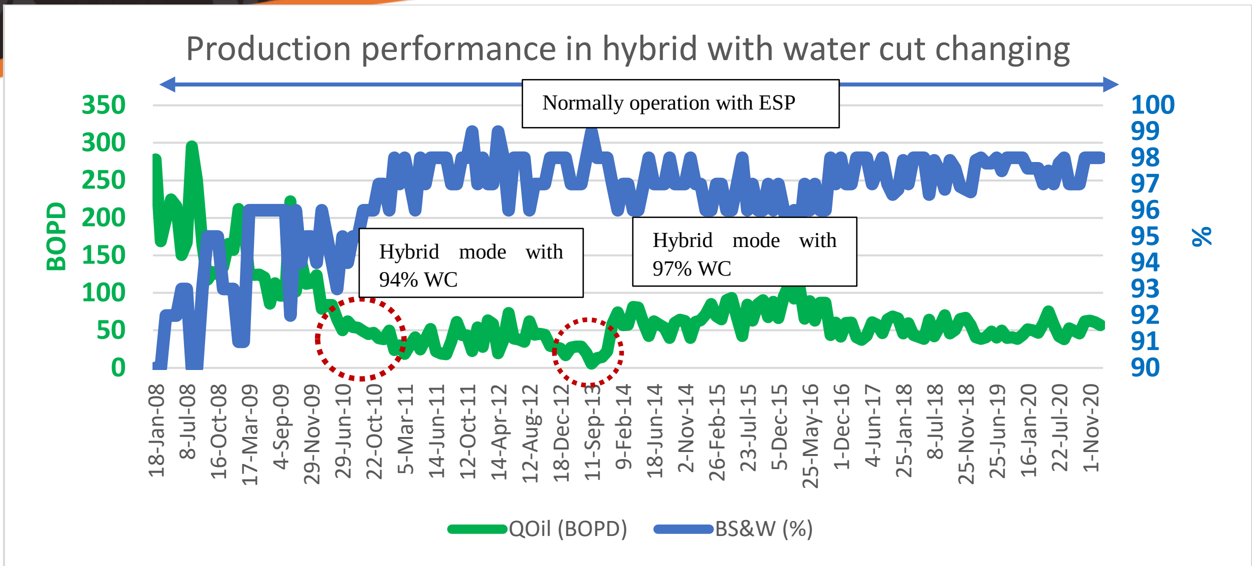

Figure 3. Oil production in hybrid mode comparison for 94% BSW and 97%

4.5 Gas Injection through Pump Intake Probability

If the ESP section in the hybrid system setting is improper, specifically if it is above equilibrium point, then the gas injection will be done through the pump intake, and the gas lift system will not work. To avoid the probability then the pump must be installed below the equilibrium point. Figure 8 explains the red arrow that indicates the equilibrium point depth.

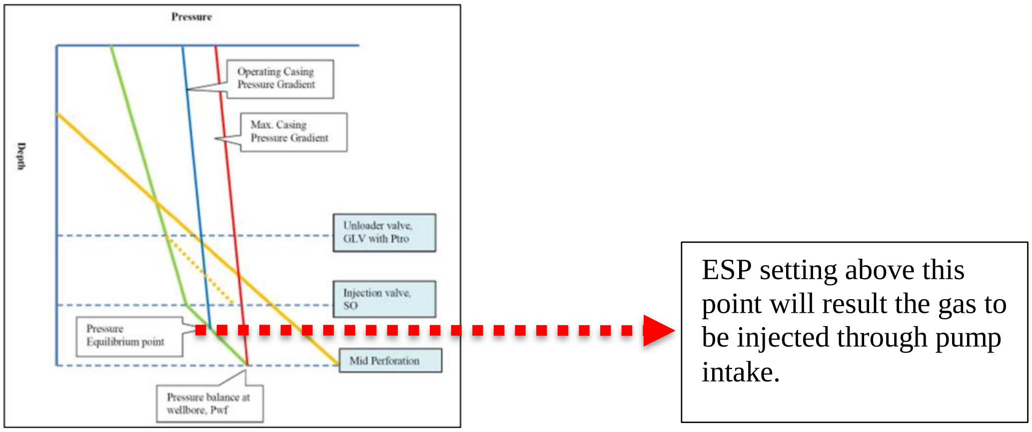

Figure 4. Improper ESP section depth setting in hybrid mode causes gas to be injected through pump intake.

4.6 ESP Gas Lift Hybrid and ESP Equipment Cost Comparison

The ESP gas lift hybrid population from 2008 to 2020 with the massive installation in the 2009 and then it gradually increased until the peak in 2018. The cost for additional side pocket mandrel and gas lift valve compared to ESP for each well was about USD 3,000. After the redesigned hybrid system to deepen the injection point in 2015, needed to use two side-pocket mandrel completed with gas lift with the cost of USD 6,000 difference.

4.7 ESP Gas Lift Hybrid and ESP Run Life

The ESP gas lift hybrid run life in the R field with an average value of 1,141 days which equals to 3.1 years. To date, the researchers have been trying to find ESP run life comparisons from other fields and publications which are not many. They aim to determine whether 3.1 years can be categorized as low, good, or excellent.

5. The ESP shifting

According to the limitation analysis of ESP hybrid, then the team develop the system to conduct selection design whether stay in hybrid or will shifting to normal ESP base on the well properties. The flow diagram was shown in figure 5.

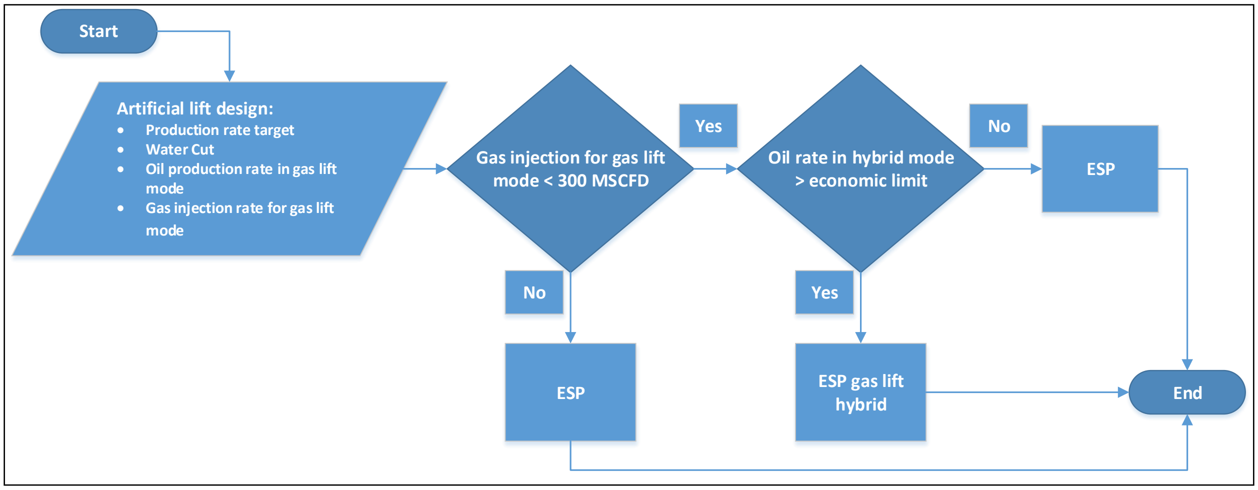

Figure 5. Workflow to conduct decision making to select between ESP gas lift hybrid and ESP

Finally the shifting design as shown in figure 6, was implemented to overcome the limitation. Gas lift valve-SPM leaking and plugging was eliminated by remove the gas lift hybrid configuration. In addition the water cut issue in hybrid mode was no longer exist in normal ESP, because the capability to deliver liquid as high as the well productivity. Meanwhile, the probability of gas injected through intake was also eliminated without gas lift injection. Moreover, the sand problem was mitigated by sand screen installation for 7” and 5-1/2” casing.

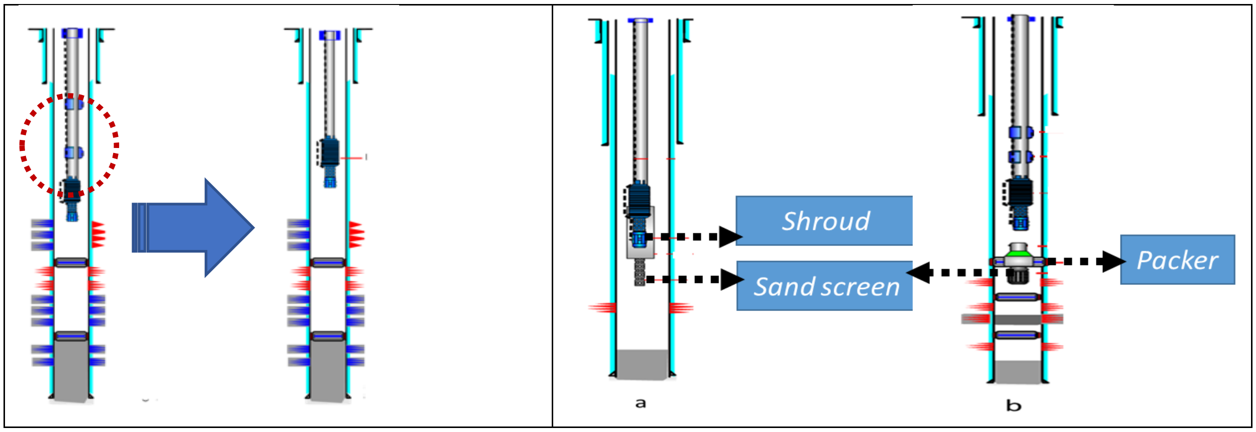

Figure 6. Shifting design from hybrid to normal ESP with mitigation for sand problem.

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5.3 Advantages and disadvantages between hybrid and normal ESP

Table 2. ESP gas lift hybrid and normal ESP advantages-disadvantages summary

System	Advantages	Disadvantages
ESP hybrid	1. During ESP problem and waiting on Rig entry, the well can producing in gas lift mode.	1. Risk of GLV-SPM leaking and plugging. 2. In current water cut (98% and above), gas lift mode is producing oil below economics limits (10 BOPD). 3. Risk of gas passing through pump intake during gas lift mode.
Normal ESP	1. No Risk of GLV-SPM leaking and plugging. 2. Able to deliver oil production above economics limits (10 BOPD) in current water cut (98% and above) by selecting the ESP size and well productivity. 3. No risk of gas passing through pump intake during gas lift mode.	1. During ESP problem and waiting on Rig entry, the well will be shut in.

6. Conclusions

The conclusions from the hybrid system evaluation are, ESP gas lift hybrid has some limitations. In the R field, those include side-pocket mandrel, gas lift valve leak, high water cut, high gas injection, and the possibility of gas injecting through ESP intake. The limitations identification can provide better decision making to select the two options, ESP gas lift hybrid and ESP. Development of the workflow in well services artificial lift selection is useful in the R field during 2019 to 2020 that included 43 jobs. Average run life was 3.1 years and it experienced an upward trend.

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