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ESP Application for Oil Production in Naturally Fractured Granitic Basement Reservoir

Khai Phuc Nguyen *, Khuong An Pham Nguyen, Huyen Thanh Thi Luong, Minh Ha Tran

Cuu Long Joint Operating Company, Ho Chi Minh City, Vietnam

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ABSTRACT

In fields with increasing water cut and depleting reservoir energy, Electric Submersible Pump (ESP) installation is a sustainable production option. It helps to extend life of the wells by lower abandonment pressure and therefore increases the recovery factor. In addition, the gas lift saving from ESP conversion wells could be utilized to optimize others wells' productivity thus boosting the total field production. Over the last 9 years, Cuu Long JOC has been conducted 5 ESP campaigns in fractured granitic basement reservoirs which bringing full of surprises. The selected field for ESP pilot was brought on production initially in 2008 with over 75,000 bopd. However, water breakthrough occurred after 8 months quickly reduced the total field production to 5,000 bopd in 2013. At the time of ESP conversion, gas lift have already optimized and it is not sufficient to maintain the rate as most of wells flowed with 95% water cut. With ESP application, the wells were able to reach 12,000 blpd and reduce the water cut not only for itself but also for adjacent wells. Despite the pump average run life is not meet the expectation, ESP application shows better efficiency in term of oil production compared to gas lift under the same reservoir conditions. This paper summarizes a process of ESP application in high temperature environment including candidate selection, ESP design and actual production performance. The learning and experience developed from 11 ESPs installation provide an insight about the potential of ESP use for oil production in fractured basement reservoir.

1. Introduction

For many years, gas lift has been a standard method of artificial lift in Vietnam Oil and Gas industry. However, in order to increase the production and sustain the field target rates, revisiting the artificial lift selection proves to be the most cost-effective solution. An ESP pilot project was initially conducted in 2013 for Field A fracture basement reservoir, where most of the wells were produced with >95% water cut. Results from changing artificial lift strategy are highly encouraging with 194 Kbbls incremental oil production after first year implemented. By the

*Corresponding author
E - mail: nguyen.p.khai@cljoc.com.vn
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end of 2022, Cuu Long Joint Operating Company has been installed 11 ESPs in this field and planning for other implementation in the near future.

2. ESP candidates' selection

2.1. Reservoir screening

Table 1 presents the criteria which define a potential reservoir to apply ESP (Romer et al., 2012). Amongst 7 reservoirs in block 15-1, Field A fractured basement is the most suitable candidate where all completion/ operating conditions "fit" with ideal or feasible criteria. Moreover, the platform where ESPs will be implemented has reliable high voltage electric power and available facilities to perform the interventions (conversion or replacement) at lower cost with Work over Pulling unit (platform crane, deck space, living quarters).

2.2. Reservoir overview

The Cuu Long basin is one of the most prolific hydrocarbon basins of Southern Shelf Vietnam (Areshev et al., 1992; Cuong & Warren, 2009; Nguyen, 2019). It has many oil producing fields including the Field A with oil discoveries in fractured basement rock. This type of excellent reservoir is resulting from a series of tectonic events such as basin-rifting before Early Oligocene, and inversion from late Oligocene to Early Miocene, etc. The tops of these basement structures are usually at 2,500 to 3,500 mTVDss with about 500÷1,500 m oil column thickness.

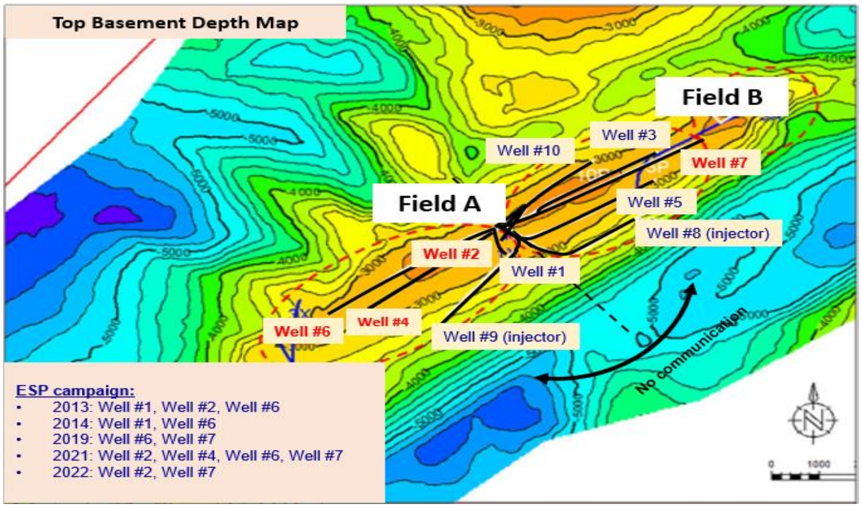

Figure 1. Dashline show north and south compartments of fractured granitic basement reservoir in Field A – ESP Wells Location.

Table 1. Offshore ESP screening criteria (Michael et al., 2012). BFPD = Barrels per Feet per Day.

Recommended Operating Conditions	Ideal	Feasible	Needs Further Evaluation	Economic Challenge	Field A
Casing Outer Diameter (in.)	≥ 9÷5/8	≥ 9÷5/8	≥ 7	≥ 7	9÷5/8
Bottom hole Temperature (oF)	< 250	250÷350	350÷400	> 400	302
Productivity Index (BFPD/psi)	≥ 6	3÷6	1÷3	< 1	20÷100
Measured Pump Set Depth (ft)	< 10,000	10,000÷14,000	14,000÷17,000	> 17,000	< 9,186
Potential (BFPD)	5,000÷40,000	2,500÷5,000	1,000÷2,500	< 1,000	8,000÷16,000
Gas Volume Fraction as Set Depth (%)	< 20	20÷40	40÷70	> 70	30.5

Field A composes of 2 main compartments which are north and south (Figure 1). Each behaves separately as a small, typically fractured basement reservoir which has strong interference between the producers. All wells are able to flow naturally at the beginning but water breakthrough after 8 months ceases the natural flow hence gas lift is used to maintain the liquid rate afterwards. Wells' productivity index ranges from 40÷200 bbl/d/psi, indicating the flow contribution from a number of large fault-type fractures with substantial connected pore volume. The crude is black oil with an API gravity of ± 36.5, low gas oil ratio of 171 scf/stb and very low hydrogen sulphide content in associated gas. The initial reservoir pressure is 4,400 psia at 2,800 mTVDss and temperature is 150^{0}C. In addition, reservoir has strong aquifer support/ injector available which can help to maintain reservoir pressure during ESP production. At the time of ESP conversion (2013), reservoir pressure was stable around 2,500 psia which is far above saturation pressure (1085 psia).

2.3. Well by well screening

Aside from reservoir feasibility, a complete screening of all Field A's oil wells for ESP conversion was performed with the following criteria:

- Well with high production index;
- Well with higher incremental oil compared to gas lift production (Estimated Ultimate Recovery using Water oil ratio/ Decline curve analysis method);
- Well has less interference with existing nearby ESP well.

Table 2. 2022 Screening result – 4 potential candidates are Wells #2, #7, #4, and #3 in north and south compartments (Cuu Long Joint Operating Company, 2022).

2022 Campaign Screening		south area			
		Well #1	Well #2	Well#4	Well #6
Gas lift (current well status)	PI (bbl/d/psi)	20	40	30	2021 ESP is running
	Liquid rate (blpd)	2,300	4,300	5,000	
	WTC (%)	98%	98%	85%	
ESP forecast	Liquid rate(blpd)	10,000	11,000	10,000	
	Cum oil incremental (kbbls) 6 months	38	122	102	
Remark		- Well is currently shut in due to lack of lifted gas - Interfere with Well #2	- Well is currently shut in due to lack of lifted gas - Interfere with Well #1	- Interfere with Well #6	
Economic evaluation		Uneconomic	Feasible	Feasible	
Ranking		-	1	3	

2022 Campaign Screening		north area			
		Well #3	Well #5	Well #7	Well #10
Gas lift (current well status)	PI (bbl/d/psi)	20	20	30	10
	Liquid rate (blpd)	6,000	5,000	2,500	5,000
	WTC (%)	88%	99%	80%	99%
ESP forecast	Liquid rate(blpd)	10,000	10,000	11,0000	7,000
	Cum oil incremental (kbbls) 6 months	74	35	114	27
Remark		- Interfere with Well #7	- Well is currently shut in due to lack of lifted gas	- Interfere with Well #3	- Well is currently shut in due to lack of lifted gas
Economic evaluation		Feasible	Uneconomic	Feasible	Uneconomic
Ranking		4	-	2	-

Table 2 illustrates the screening result of 2022 campaign. Eight oil wells and their key attributes are presented, along with the evaluation and final ranking.

The ranking result shows that Wells #2 and #7 are the best candidates for 2022 campaign as they have higher oil gain compared with other wells. Well #4 is also feasible however with Well #6 2021 ESP is running, reservoir will be depleted rapidly and high drawdown applied during ESP could lead to high water production in both Wells #6 and #4 as these wells have strong interference. Similarly for Well #3 which interfere with Well #7, this well is considered as the last candidate for ESP conversion.

3. ESP design

The ESP provider uses ESP simulation software to develop a design which the pump is able to operate well across a wide range of operating conditions and cover uncertainties of input reservoir information. It is necessary as the well performance changes over time, especially when oil reserves are depleted and production

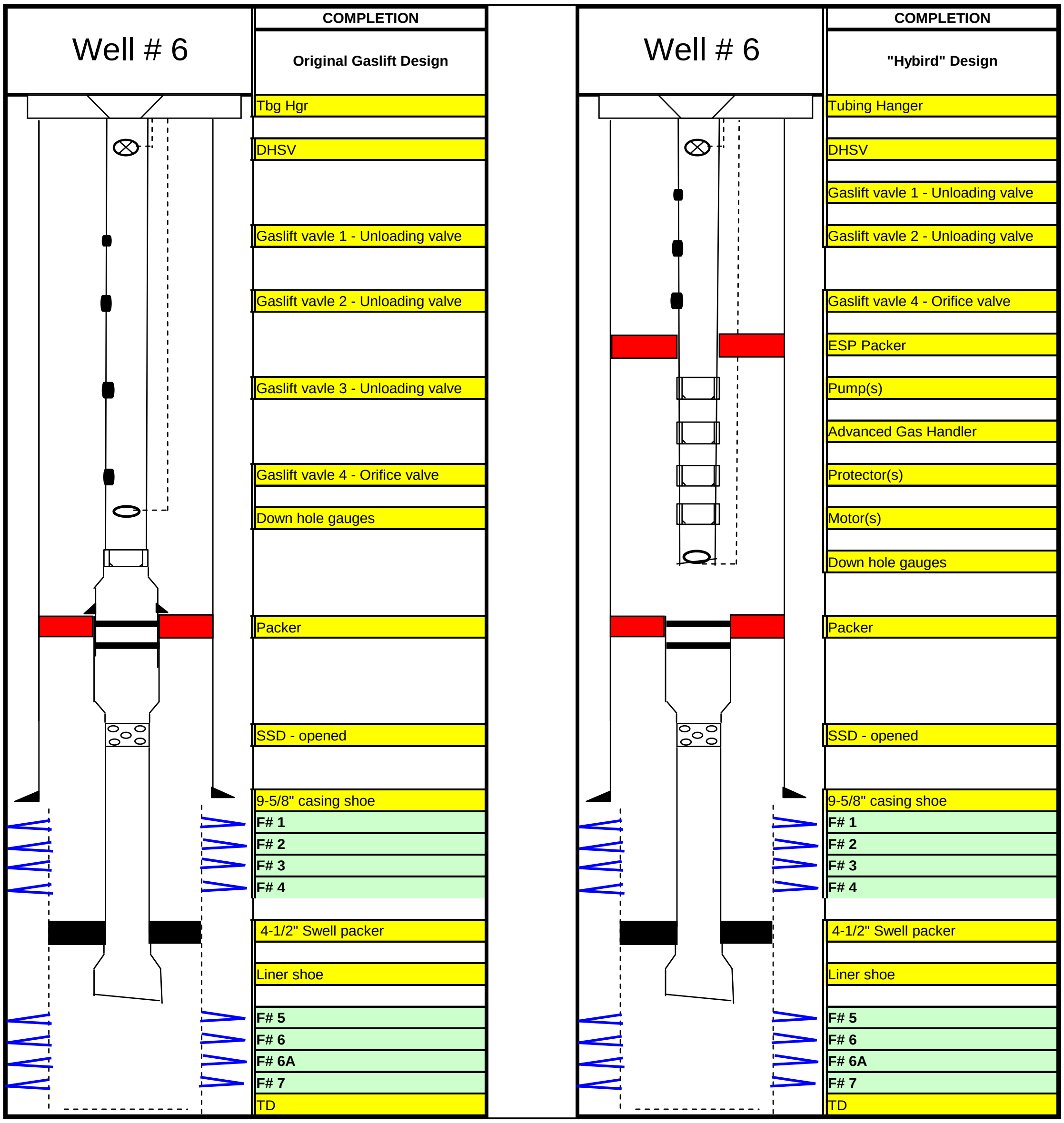

Figure 2. Completion design of a Gas-lift system (left) and a Hybrid (ESP + Gaslift) system (right) (Tuan et al., 2016).

strategies are updated. Figure 2 is the well-sketch of the previous gas-lift completion and the new hybrid ESP-Gas lift. The upper completion string with gas lift equipment was pulled out and replaced with the combined ESP-Gas lift equipment. This design keeps the well producing continuously after the ESP failed.

4. ESP result

Table 3 summarizes the initial production's incremental percentages of 5 campaigns. It is obvious that in highly fractured reservoir, producing by ESP is more advantageous than gas lift. It is important to note that greater production could be ensured in the beginning of pump's installation, but long term production must requires a good production strategy such as water injection, intervention planning (ESP replacement).

- Cumulative oil production with ESPs after 4 campaigns is around 1.4 MMstb (Figure 3);
- Higher liquid production achievable with ESPs (average liquid increase ~ 150%);
- ESP application has, in some cases, led to higher PI with lower water cut due to the contribution of lower PI fractures (WTC reduce from 2÷10% - Figure 4);
- Gas lift can be used on other wells, currently shut-in or sub-optimized due to limited compression capacity;
- Higher drawdown make lower WTC in adjacent wells (Figure 5);
- Improve performance for specific well (remove scale in Well #6, bring Well #2 back to production after longtime SI, stabilize Well #7's production).

All of the wells are successful to increase liquid rate and reduce water cut, except Well #6 in recent campaign where water cut remains the same. It is also observed that water cut reduction decreases after each time installation made the oil incremental percentage of Well #6 in 2021 is no longer attractive despite better run life compared with other wells installed in the same year.

Apart from the benefit that ESPs brings to production, the run life of ESPs remains a challenge for future ESPs project. A good example for this case is Well #6 which 2019 ESP stopped after 2 months despite the design had already upgraded all equipment suggested in DIFA (Dismantle, Inspection and Failure). On the other hand, the other ESP in Well #7 worked properly for 1 year with the same design. It is suspected high temperature in Well #6 shortens the pump's run life. Therefore, it is decided to use Permanent Magnet Motor (PMM) – a new technology to reduce the power requirement hence expected to improve the run life (Schlumberger, 2014.). This ESP is currently running more than 6 months.

Table 3. Initial Production Increments of 2013 – 2022 ESP campaigns.
((*) Including positive effect from nearby well; (**) ESP still running.)

Campaign	Well	BLPD	BOPD	BSW	Run life (days)
2013	Well #1	162%	150%	-3%	50
	Well #2	38%	50%	-2%	330
	Well #6	43%	214% (*)	-15%	43
2014	Well #1	214%	300%	-5%	82
	Well #6	76%	158% (*)	-5%	730
2019	Well #6	79%	150% (*)	-2%	76
	Well #7	175%	391%	-7%	360
2021	Well #2	228%	283%	-2%	68
	Well #4	117%	116%	-5%	30
	Well #6 (**)	106%	30%	0%	240
	Well #7	225%	336%	-5%	132
2022	Well #2 (**)	167%	234%	-2%	37
	Well #7 (**)	340%	409%	-2%	46

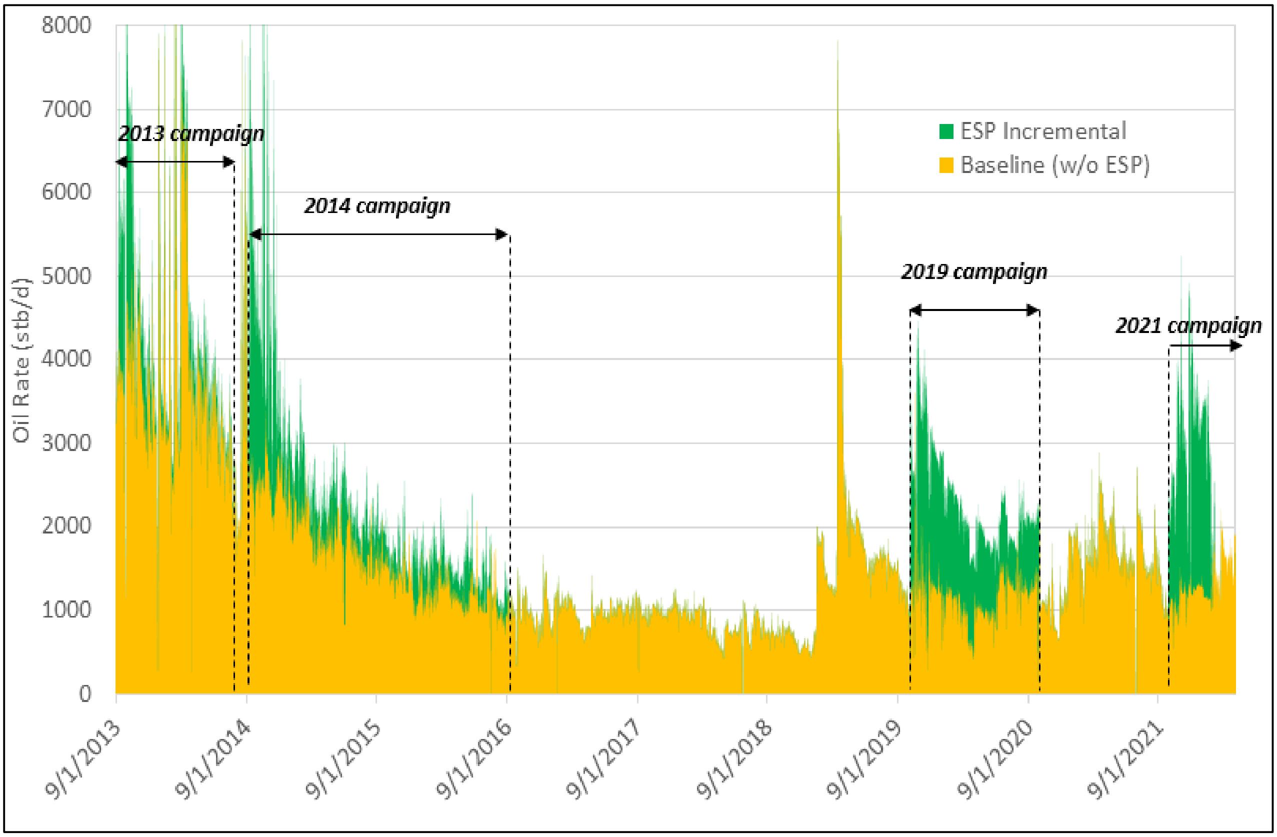

Figure 3. 2013-2021 ESP Incremental Oil (Cuu Long Joint Operating Company, 2021).

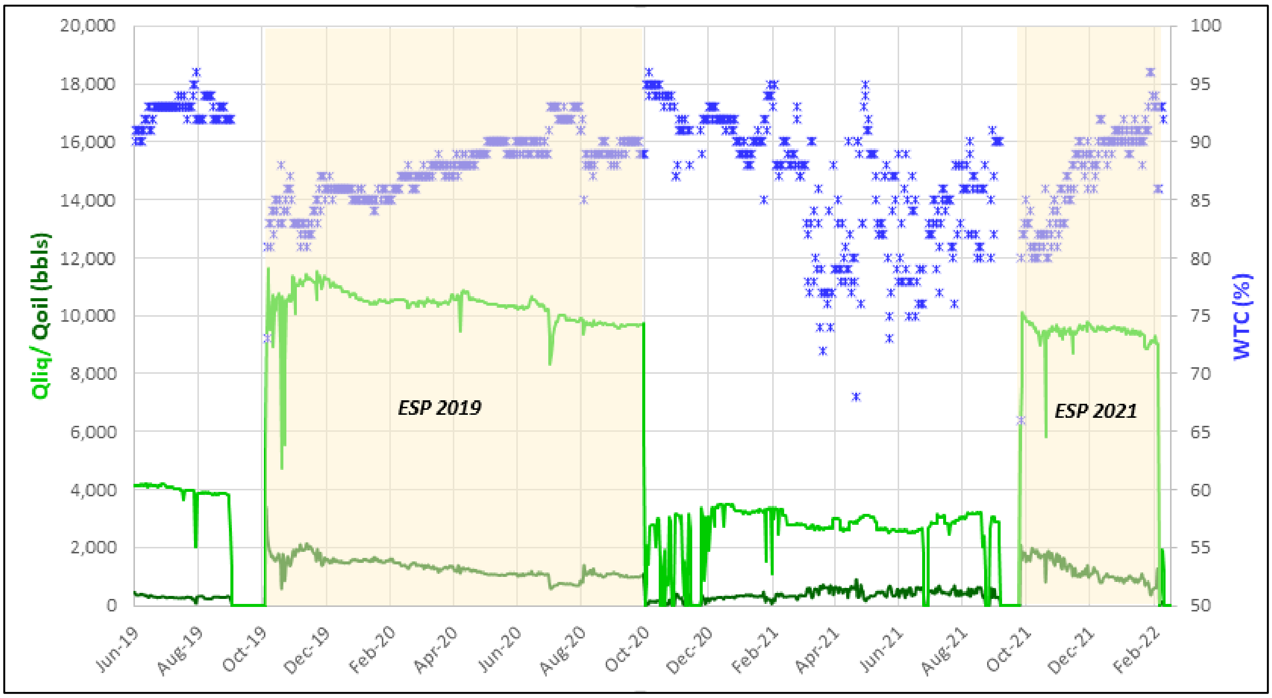

Figure 4. Well #7 in 2019 - 2021 campaign – example of a typical ESP well performance in fractured basement reservoir. ESP efficiently increases oil production by creating high drawdown accompany water cut reduction.

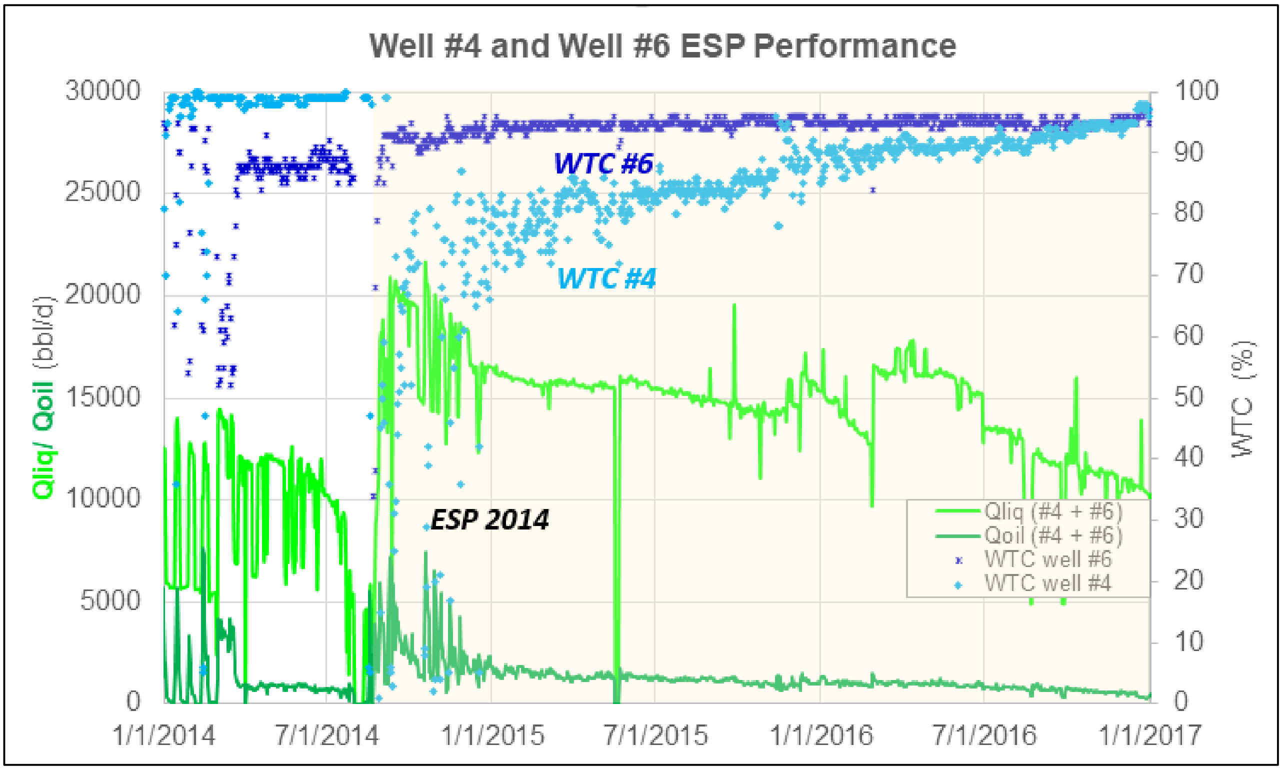

Figure 5. Wells #4 and #6 in 2014 campaign - an upside benefit of ESP application in fractured basement reservoir where there is strong inference among wells through fracture system. Water cut in Well #4 (gas lift well) reduced when Well #6 produced at high rate during ESP.

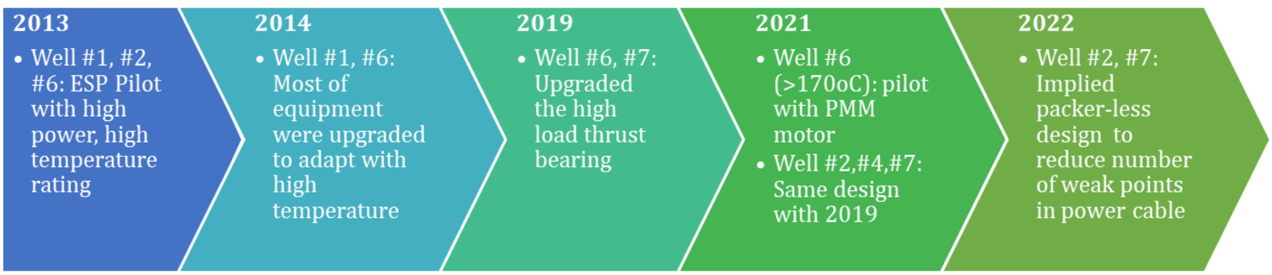

Figure 6. 2013 – 2022 main modification for ESPs' design.

In order to meet the expected run life, equipment selection for future ESPs is improving continuously based on comprehensive investigation and detail failure tracking records. Major modifications of ESP design in each campaign are describes in Figure 6 as an example.

5. Conclusion

In general, ESP is proved to be an effective production improvement approach in naturally fractured basement reservoir, especially when water cut is high and gas lift cannot maintain production rate. Currently, Cuu Long JOC is considering to extend the ESP's application in other basement reservoirs. However, it is apparent that run life improvements need to be made progressively in order to ensure the project's economic.

Contributions of author

Khai Phuc Nguyen - conceptualization, writing, reviewing and editing. Khuong An Pham Nguyen - data curation, Writing - original draft preparation. Huyen Thanh Thi Luong - conceptualization, supervision, reviewing and editing. Minh Ha Tran - conceptualization, supervision, reviewing and editing.

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