Analysis of the Investment Economic Benefit on Renqiu Buried Hill Reservoir Lift Methods Conversion

Yan Gao
The First Oil Production Plant
Petrochina Huabei Oilfield Company, Renqiu, China
cy1_gy@petrochina.com.cn

Yongxiang Yang
Oil Production Engineering Research Institute
Petrochina Huabei Oilfield Company, Renqiu, China
cyy_yangyx@petrochina.com.cn

Yongning Yang
Hebei Huabei Petroleum Rongsheng Machinery
Manufacture Ltd., Renqiu, China
yyn92@aliyun.com

Xuexia Wei
Administrative Affairs Center
Petrochina Huabei Oilfield Company, Renqiu, China
swb_wxx@petrochina.com.cn

Anqi Yang
The First Oil Production Plant
Petrochina Huabei Oilfield Company, Renqiu, China
cy1_yaq@petrochina.com.cn

Shian Lu
The First Oil Production Plant
Petrochina Huabei Oilfield Company, Renqiu, China
cy1_lsan@petrochina.com.cn

Lei Chen
Exploitation and Development Research Institute
Petrochina Huabei Oilfield Company, Renqiu, China
yjy_chenlei@petrochina.com.cn

Aiqin Liu
Oil Production Engineering Research Institute
Petrochina Huabei Oilfield Company, Renqiu, China
cyy_liuaiq@petrochina.com.cn

Baohui Zhang
Oil Production Engineering Research Institute
Petrochina Huabei Oilfield Company, Renqiu, China
cyy_zangbh@petrochina.com.cn

Jing Wang
Exploitation and Development Research Institute
Petrochina Huabei Oilfield Company, Renqiu, China
yjy_wjing1@petrochina.com.cn

Abstract—Renqiu buried hill reservoir of electric submersible pump well in order to reduce the sewage invalid recycling and saving energy, using the electric submersible pump(ESP) well convert into pumping unit well to produce. The scheme design lifting process adjustment and optimization of 13 wells. Through the analysis of economic benefit, 13 ESP wells convert into the pumping unit wells will obtain the production economic benefit of 5.5809 million Yuan. The investment recovery period is 24 months. The field application results are obvious, reaching the purpose of energy saving.

Keywords-Renqiu buried hill reservoir; electric submersible pump; pumping unit well; lift methods; economic benefit analysis.

I. INTRODUCTION

Renqiu buried hill reservoir began to implement the control of injection and depressurizing production from 1991 [1, 2, 3]. Due to reservoir formation pressure drop, the well PFL reducing, lifting height and discharge requirements. We began to apply a large number of ESP production, ESP plays an important role in the buried hill reservoir exploitation. Control of water injection and depressurizing production ended in 1999. With the gradual realization of all the sewage reinjection, the reservoir pressure gradually recover, the well PFL rising, pumping unit has been to meet some wells production needs. This paper studies the production status of ESP well, ESP wells were directly converted to the pumping unit wells or treated after converting the pumping unit wells, which reduce the amount of sewage invalid cycle, to achieve energy saving purpose.

II. THE PROCESS CHARACTERISTICS AND LIMITATIONS OF ESP

The characteristics of the ESP is a "large displacement, high lift, rodless lifting" [4, 5]. In order to meet the Renqiu buried hill reservoir deep well pumping "large displacement, high lift" production demand, ESP technology is mainly applied in the following three kinds of oil well:

i) The high water cut wells at Renqiu buried hill reservoir need "large displacement, high lift" of ESP. Renqiu buried hill reservoir in middle and later periods of

the development, water cut is high, the PFL is deep. Due to depressurizing production, tubing pump cannot meet the need of production. Using large displacement, high lift ESP, there are 28 Wells, accounting for more than 85% of the well.

ii) Rod tube eccentric wear seriously deviated wells. Use the small displacement ESP for rodless oil production. There are 4 small displacement ESP wells now.

iii) Surface environment is poor, near the city production of oil Wells. ESP has the characteristics of small occupation area, low noise, which can solve the production problem of special production environment requirements.

Under certain conditions, mechanical oil production equipment has the limitations of its economy and operation, etc. Select the mode of mechanical production wells, the main standard to measure is the minimum investment for maximum economic benefit. Along with the progress of reservoir development, affected by the reservoir energy, production situation and other factors changing, the ESP lifting method, system of work adaptability and economic benefits have also changed.

Buried hill reservoir formation pressure has been restored and part of the ESP production need to adjust the lifting way optimization. ESP production statistics from 1994 to 2012, 19 years production situation can be seen that as the Renqiu buried hill reservoir from 1999 began to recover water injection, injection of water increases, formation energy gradually restored, working fluid level began to rise from 2007, the average single well working fluid level rise from 1007 m to 693 m, water cut from 81.9% to 95.8%, the single well oil production from 30.4 t/d reduce to 7.4 t/d.

ESP oil production is high energy consumption. According to 32 ESP wells production power consumption statistics, the average single well power 53×10^4 kW·h, average tons of fluid power 7.9 kW·h, tons of liquid hundred meters power 1.021 kW·h. And 175 pumping unit wells production power consumption statistics, the average single well power consumed 7.9×10^4 kW·h, average tons of fluid power 2.8 kW·h, tons of liquid hundred meters power 0.53 kW·h. By comparison, ESP in single well power consumption is 6.7 times that of the pumping unit well, tons of liquid hundred meters consumes nearly 2 times (Table 1).

TABLE I.   MECHANICAL PRODUCTION WELLS IN RENQIU BURIED HILL RESERVOIR SINGLE WELL AVERAGE POWER CONSUMPTION STATISTICS

Lift methods	ESP	Pumping unit
Statistics the number of wells	32	175
The average pump deep (m)	1191.7	1116.4
Fluid (t/d)	186.0	77.3
Oil (t/d)	8.19	3.65
Theory of displacement (m³/d)	147.41	91.87
Pump efficiency (%)	127.80	84.14
Working fluid level (m)	775.6	523.4
Power consumed ($\times 10^4$ kW·h)	53.01	7.90
Tons of fluid power consumption (kW·h)	7.917	2.800
Tons of liquid hundred meters power consumption (kW·h)	1.021	0.530

III.   FEASIBILITY ANALYSIS OF ESP CONVERTING INTO PUMPING UNIT

In the existing conventional "three pumping (pumping unit, pump, sucker rod)" conditions, the ESP well whether can convert into pumping unit well to meet production are mainly three factors: i) After ESP well convert into pumping unit well, the production output whether can remain basically unchanged; ii) Pumping unit production of lifting process (including the pumping unit, rod, pump, etc.) whether can meet the needs of the oil well production; iii) The surface environment whether to allow fix pumping unit production.

Therefore, in order to "ensure the well oil production basically remain unchanged, the existing three pumping equipment maximum allowable conditions, surface conditions permit", searching for Renqiu buried hills of ESP wells, 13 wells can convert into pumping unit production. Therefore, in order to "ensure the well oil production basically remain unchanged, the existing three pumping equipment maximum allowable conditions, surface conditions permit", searching for Renqiu buried hills of ESP wells, 13 wells can convert into pumping unit to produce. Among them, RX472, RG6, C3P2, RP4, R217, RP7, 6 wells can directly convert into pumping unit to produce, through optimizing design, keep oil production unchanged; R316 RJ7, R340, R380, RX1-3, RX331, R323, 7 Wells working fluid level is high, producing fluid volume is high, the existing tubing pump capacity is small, cannot satisfy the need, through the analysis of the reservoir potential, to implement water plugging measures, reduce the amount of liquid producing after pumping unit production [6, 7, 8, 9, 10].

TABLE II.   OIL WELL SUCKER ROD PUMP LIFTING PROCESS PARAMETERS

The well proration requirements		Three pumping equipment and operating parameters			
The highest fluid (m³/d)	The maximum depth of PFL (m)	Pump diameter (mm)	The maximum pump deep(m)	Theoretical displacement ^{a} (m³/d)	The expected fluid ^{b} (t/d)
150	850	83	950	186.8	149.5
106	1150	70	1300	132.9	106.3
65	1450	56	1600	85.0	68.0
40	1900	44	2050	52.5	42.0
30	2100	38	2350	39.2	31.3

a. Stroke 4.8 m, Speed 5 times/min; b. Limestone well pump efficiency 80 %.

IV.   THE ADJUSTMENT OPTIMIZATION SCHEME OF LIFTING PROCESS FOR ESP WELL

In view of the actual problems of high energy consumption of ESP wells, we adjusted the lifting process of 13 ESP wells to optimization combined with the factors such as "the well behavior after converting to pumping unit well, the risk of treating, the surface condition", based on "the oil well status, formation potential and geological research".

According to the production situation and the formation of wells, we formulate different schemes. After

converting 13 ESP wells to pumping unit wells, the fluid production per day will reduce 1049 t. Less of water production per day is 1049 t, and that is 38.29×10^4 m^3 per year.

Scheme A: Six ESP wells convert to pumping unit wells directly. After converting, the fluid production per day will reduce 41t. The oil production per day will increase 0.1t. Less of water production per day is 41 t.

Scheme B: Seven ESP wells turn to pumping unit wells after treating. Through reservoir potential research and treating risk evaluation, we turn seven ESP wells with high water production to pumping unit wells after WSO. Under the condition of the ideal treating prediction, the oil production per day is unchanged after WSO. After treating the fluid production per day and the producing fluid level (PFL) can meet the production conditions (the pump diameter is 70mm. Working system of the pumping unit is 4.8 m, 5 times/min. The water production is 100 m^3/d). After treating and converting to pumping unit wells, the daily fluid production of the seven ESP wells is expected to reduce 1008t, 1008t of the water reduction, 144t of the average single well water production, and decrease water cut 3.8%.

After calculating the theoretical load of the 13 wells, we could choose 3 pumping units of 10-type, 1 pumping unit of 12-type, 9 pumping units of 14-type. Considering the treating and deepening in the future, we determine to select 13 pumping units of 14-type. Though there are 3 old pumping units, which can't meet the need, we need 13 new pumping units. The original transformer, Christmas tree etc. all need to be replaced.

V. INVESTMENT AND ECONOMIC BENEFIT ANALYSIS

Investment of implementation of converting ESP to pumping unit mainly has two aspects. First is surface equipment investment, including the new beam pumping unit, replace the transformer, Christmas tree and so on. The second is the cost of pump operating, treating and the new rod, new pump.

The benefit mainly has two aspects. First is electricity charge that is saved. The second, as reducing invalid circulation of water, the disposal cost of produced fluid is saved after WSO, including produced fluid gathering process and sewage recycle, etc.

A. Front End Investment

Analyzing all the production preparations for converting to pumping unit, front end investment projected is 11.474 million Yuan.

Among them, the investment in pumping unit, pump and sucker rod is 7.674 million Yuan (Table 3).

The treating cost before converting to pumping unit is expected to 3.8 million Yuan (Table 4).

B. Economic Benefit Analysis

The benefit of ESP converting to pumping unit is mainly manifested on saving electricity charge because of power consumption reduction significantly and cutting down the cost of sewage recycle when the wells reduce the water output. The recycling of old ESP equipment and saving operation cost of the 13 converting wells are not included.

TABLE III. INVESTMENT IN PUMPING UNIT, PUMP AND SUCKER ROD

No.	Equipment	Format and Type	Unit	Quantity	Unit price ($\times 10^4$ Yuan)	Total price ($\times 10^4$ Yuan)
1	pumping unit	CYJW14-5-73F	case	13	38.0	494.0
2	sucker rod	Φ19mm	m	3438	0.0039	13.4
3	sucker rod	Φ22mm	m	5532	0.0043	23.8
4	sucker rod	Φ25mm	m	5980	0.0050	29.9
5	pump	Φ83mm×7.7m	case	1	1.2	1.2
6	pump	Φ70mm×7.7m	case	10	1.0	10.0
7	pump	Φ56mm×7.7m	case	1	0.8	0.8
8	pump	Φ44mm×7.7m	case	1	0.6	0.6
9	well head	KYS25/65	case	13	3.5	45.5
10	transformer	50kVA	case	13	2.5	32.5
11	pumping unit fixing		case	13	3.0	39.0
12	putting on pump		well	13	5.9	76.7
	Total					767.4

TABLE IV. TREATING COST BUDGET FOR ESP WELLS

No.	Well ID	Treating	Cost($\times 10^4$ Yuan)
1	R316	WSO, cement squeezing pointfree to 3050m; according to the water absorbing capacity after WSO, determine to reshoot and acid treatment	75
2	RJ7	WSO; according to the water absorbing capacity after WSO, determine to acid treat	50
3	R340	WSO, cement squeezing pointfree to 3114m; according to the water absorbing capacity after WSO, determine the next treating	50
4	R380	according to the effect of the well R340 treating scheme, if it is feasible, cement squeezing pointfree to 3155m; if it is unfeasible, WSO	50
5	RX1-3	Organic WSO	50
6	RX331	Organic WSO	50
7	R323	Organic WSO	55
	Total		380

13 wells plans to turn ESP production to pumping unit. Before converting, the measured power consumption is 688.1×10^4 kW·h. After converting, when the power consumption of the pumping unit well is 0.53 kW·h/t/hundred meters, estimated power consumption per year is 188.2×10^4 kW·h. Power saving rate predicted is 72%. Power saving per year is expected to 499.93×10^4 kW·h (Table 5). When the electricity calculated at 0.81 Yuan/kW·h, we can save 4.0494 million Yuan per year.

After 13 ESP wells converting, there is expected to reduce fluid 1049 t/d, water 1049 t/d, water production 38.3×10^4 m^3 per year. As the liquid disposal cost is 1.5 Yuan/t. The sewage recycle cost 2.5 Yuan/t, it is expected

No.	Well ID	The measured power consumption of ESP well (kW·h)	Power consumption per year (×10⁴ kW·h)	Predictive power consumption per year of pumping unit (×10⁴ kW·h)	Power saving (×10⁴ kW·h)
1	RX472	31842	38.21	11.1	27.07
2	RP4	49369	59.24	2.5	56.75
3	RP7	42714	51.26	6.5	44.76
4	RG6	46399	55.68	17.2	38.46
5	R217	28266	33.92	10.2	23.71
6	C3P2	43399	52.08	13.8	38.26
7	RJ7	41817	50.18	17.7	32.45
8	R323	57833	69.40	19.3	50.13
9	R340	50035	60.04	17.3	42.70
10	R380	46278	55.53	19.3	36.27
11	R316	34566	41.48	17.7	23.75
12	RX1-3	42714	51.26	17.7	33.53
13	RX331	58186	69.82	17.7	52.10
	Total		688.10	188.2	499.93

to cut down produced fluid disposal cost about 1.5315 million Yuan per year. Among them, the annual produced fluid disposal saves 0.5743 million Yuan. The water reinjection cost 0.9572 million Yuan per year.

C. The Payback Period of Investment

Economic benefits of 13 ESP wells converting to pumping unit (million Yuan)

= saved electricity charge +saved liquid disposal cost

= 4.0494 + 1.5315

= 5.5809

Investment in Disposable equipment and treating (million Yuan)

= 11.474 million Yuan.

Payback period of investment is about 24 months.

VI. FIELD IMPLEMENTATION

Until February 2014, six ESP wells have been converted to pumping unit wells directly. Before converting, the liquid production is 547 t/d, oil 33 t/d, water cut 93.9%, PFL 784 m. After converting, the oil production is stable. In October 2014, the liquid production is 433 t/d, oil 28 t/d, water cut 93.5%, PFL l451 m.

Until March 2014, 5 ESP wells have been converted to pumping unit wells after WSO. Before converting, the liquid production is 1040 t/d, oil 20 t/d, water cut 98.1%, PFL 574 m. After converting, the oil production is stable. In October 2014, the liquid production is 380t/d, oil 12 t/d, water cut 96.8%, PFL 613m.

The reduction of accumulated water production is $27.6×10^4$ t per year. When the water production is reduced, the oil production is also decreased.

In Field implementation, contrasting the electricity consumption of 11 wells after converting to pumping unit with that of ESP wells, the scheme reduce $402.2×10^4$ kW·h, saving electricity charge 3.2578 million Yuan and produced fluid disposal 1.1040 million Yuan. The effect of energy conservation and power consumption reducing is obvious.

VII. CONCLUSIONS

In this paper, according to the technological characteristics and limitations of ESP oil production, Analysis the feasibility of ESP well convert into pumping unit well. Put forward optimization scheme of 13 wells and the analysis of economic benefits. 11 wells on-site implementation, achieve the desired energy saving effect, energy saving effect is obvious.

REFERENCES

[1] Xuechen Zhang, et al, "Depressurization recovery test of Wumishan oil reservoir," Exploitation and Development, vol. 25(3), pp. 80–82, 1998.

[2] Jianguo Yuan, et al. "Practice and knowledge of later period comprehensive adjustment of Wuminshan high water cut reservoir, Renqiu oilfield," Journal of Xi'an Petroleum Institute, vol. 11(4), pp. 25–28, 1996.

[3] Renda Liu, et al, "Basic measures and effect of stabilizing oil production from Wumishan-formation reservoir in Renqiu county by controlling water injection during late high water-cut stage," Oil & Gas Recovery Technology, vol. 1(1), pp. 29–35, 1994.

[4] Baiping He, Xiaoping Wang, et al, Esp Production Technology Ttranslation Collections, Petroleum Industry Press: Beijing, 1993.

[5] Wenxing Wei, Chun Lan. Lifting method optimization during the high-water cut period in Tuha oilfield, Tuha Oil & Gas, vol. 9(2): pp. 151–155, 2004.

[6] Shugui Fu, et al, "Preliminary investigation to efficiency of pumping system in Wumishan reservoirs of Renqiu oilfield," Oil Drilling & Production Technology, vol. 20(4) pp. 94–97, 1998.

[7] Xuechen Zhang, "Practice and understanding for water plugging of Renqiu buried hill reservoir in high water cut period," Oil & Gas Recovery Technology, vol. 4(2), pp. 36–41, 1997.

[8] Xinya Wu, et al, "Research and application of TC-938 blocking agent in limestone reservoir," Oil Drilling & Production Technology, vol. 20(3) pp. 81–84, 1998.

[9] Yuguang Geng, et al, "Stimulation technologies and applying effects in Renqiu buried hill reservoir," Oil Drilling & Production Technology, vol. 22(6) pp. 45–50, 2000.

[10] Zhaocai Pan, et al, "Water plugging and tapping potential integrated technology for fracture-vug carbonates oil wells at high water-cut stage," Oil Drilling & Production Technology, vol. 35(5) pp. 92–96, 2013.