Control over parameters of ESCP unit to improve efficiency in bringing wells to stable production using a frequency-controlled drive on R. Trebs oil field

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Abstract. The article deals with the results of technological process of bringing an oil well to stable production; the well is equipped with an electric submersible centrifugal pump unit, its drive function is changed by a frequency-controlled drive. The paper presents data obtained while bringing an oil well to stable production: the liquid flow rate, oil flow rate, operating current, submersible electric motor loading, current frequency, water content of the products. The authors describe the process and specific aspects of bringing an oil well to stable production, conditions necessary for the process, variation of operation parameters. Recommendations were developed to ensure optimal operation of oil wells equipped with electric submersible centrifugal pump units considering technological and economic costs.

1. Introduction

Electric submersible centrifugal pump (ESCP) units are the most common pumping units for oil production. They account for almost 80% of all oil produced. Proper functioning of ESCP largely determines the efficiency of oil production and the performance of the entire system. ESCP working conditions are quite complex, they are determined by geological and technical characteristics of the bottom-hole zone, operation of flooding systems to maintain reservoir pressure, as well as properties of reservoir fluid and its variation when entering the well. Under such different conditions occurring in the mining system, ESCP's functioning may become unstable, optimal operation is not observed, which causes additional mechanical losses and energy costs.

2. Results and discussion

During technological process of ESCP start-up and its further bringing to stable operation, there is a significant number of mechanical impurities. Modern ECP units are powerful and productive, their operation implies complicated conditions, such as increased depression pressure drop of the reservoir fluid, the presence of mechanical impurities in the fluid when moving from the oil reservoir to the bottom of the well, as well as heating of the submersible motor and cable section [1].

To reduce the above mentioned negative factors ESCP is equipped with frequency-controlled drive [2]. Thanks to this device, the entire mining system receives several advantages:
- the pump starts smoothly;
- it is possible to change the rotation direction of a submersible electric motor (SEM) shaft without stopping the drive;
- to ensure optimal operation of the SEM and cable electric power line by reducing shaft speed;
- regulation of depression on the oil formation by changing the pumping capacity;
- automatic process of bringing the well to stable production with a gradual increase in the current frequency in the range from 1 second to 3 hours, preventing sudden entry of mechanical impurities into the pump from the well.

Excessive overheating and vibration of the drive and pumping equipment are controlled at lower frequencies of the supplied electric current than in power lines. During bringing ESCP to stable operation a smooth start is required without a rapid increase in frequency, which is a preventive measure to combat sudden entry of mechanical impurities. It is allowed to start ESCP with a frequency of 40 Hz and long-term operation of the SEM with a frequency of 50 Hz when creating additional drive power [3, 4].

This change in frequency leads to a change in basic parameters of ESCP: capacity Q (linear dependence), discharge pressure (pump head) H (quadratic dependence), power consumption N (linear dependence):

\[ Q = Q_{50} \frac{F}{50}, \quad H = H_{50} \left(\frac{F}{50}\right)^2, \quad N = N_{50} \left(\frac{F}{50}\right)^3, \]

where Q is calculated flow; Q_{50} – supply at 50 Hz; F – calculated frequency, N – calculated pressure; N_{50} – pressure at 50 Hz; N_{50} – power at 50 Hz.

Before starting the ESCP, necessary parameters are determined: initial frequency of start-up; the rate of frequency increase; maximum frequency during operation.

For proper technological operation process of bringing the well to stable production, data on the well's previous operation are required (i.e. volume of operating time, identified complications, characteristic failures).

When designing the process, in the calculation it is necessary to select such operating frequency, which ensures the start-up of the ESCP at the required level of the idle well with the creation of a nominal supply and a high head. During the operation process an operating current is registered, the excess of which above nominal current is not allowed. In the electrical system, additional branches are installed to eliminate inefficient shutdowns of ESCP and ensure optimal operation of the unit [5].

With a favorable bringing to stable production using a frequency-controlled converter and to adjust the frequency to the industrial one further increase in frequency continues, considering the efficiency of the ESCP.

The steadiness of the well flow rate and the dynamic level is the criterion for the favorable bringing the well to stable production, as well as the compliance of the pumping unit performance and the actual well flow rate are considered [6, 7].

The use of frequency-controlled converter in ESCP provides:
- stability of ESCP;
- implementation of the highest well flow rate by adjusting ESCP parameters;
- further improvement of mining system performance in the optimization process.

Depending on the frequency adjustment, both downwards and upwards, the ESCP parameters can vary [8, 9].

When increasing the frequency, it is necessary to consider the following factors:
- power reserve factor of SEM
- ESCP shafts safe-load factor;
- optimal ESCP setting depth.

When decreasing the frequency, it is necessary to consider the following factors:
- developed pressure of ESCP;
- permissible lowest frequency of electric current;
- permissible highest frequency of electric current;
- the highest possible voltage for the SEM.
Under such conditions for ESCP it is necessary to receive the highest frequency not exceeding the nominal frequency [10, 11].

When switching to an optimized operation mode of the mining system, it is necessary to take into account:
- the highest current loads affecting electrical equipment, transformer as well equipment, devices and apparatus;
- applied electric cable necessary at work with overloads;
- maximum power that is possible when consumed by a transformer;
- optimal position of ECP relative to the dynamic level for flow stability;
- stability of the ESCP operation mode according to the parameters of the current supply;
- prevent ESCP operation with overload current or close to it.

There are the following stages of ESCP with frequency-controlled converter:
- acceleration – increase in the frequency during ESCP operation;
- drilling run – termination of acceleration at a required frequency rising interval to remove the characteristics;
- stabilization – termination of acceleration at signs of the ESP operation abnormality and return to the initial mode;
- optimal operation – operation at maximum efficiency with the appropriate frequency and fluid withdrawal;
- deviation – reduction of operating frequency, but below the achieved one, due to frequent shutdowns of ESCP, sudden entry of mechanical impurities, instantaneous reduction of operating parameters.

Acceleration dynamics is classified as follows:
- nominal acceleration (stable mode, suction pressure 4 MPa or more, number of suspended particles (NSP) less than 0.5 g/l);
- restrained acceleration (ESCP operation mode below average, suction pressure 4 MPa or more, NSP at a critical level and is equal to 0.5 g/l);
- dynamic acceleration (recovery of the operating frequency after multiple shutdowns ESCP to a complete stop).

3. Experimental

Field tests were carried out on R. Trebs oil field. To assess the impact of frequency control, oil well No. 2026 was selected, it is equipped with the equal pumping units with pumps ESCP5A-200-2600.

Test of ESCP operation was carried out first without using a frequency-controlled converter (option 1), then the test was conducted with the frequency-controlled converter (option 2). The results of the tests are given in figures 1 and 2, which show that current frequency at option 1 is constant and equal to the industrial frequency (50 Hz), at option 2 it changes by increasing from 40 Hz to 50 Hz. As a result of this action, the oil flow rate increased by 75 %, the liquid flow rate decreased by 32 %, the water content of products decreased by 59%, SEM load decreased by 18 %.
4. Conclusion
As a result of the research, we analysed parameters of the ESCP set in oil wells of the oil field named after R. Trebs. In the process of bringing the wells to stable production without using frequency control the dynamic acceleration of ESCP occurs, which causes a significant production of mechanical impurities. This phenomenon contributes to rapid wear of working elements of the pump, causing a decrease in the efficiency of the entire pumping unit.

In oil wells equipped with ESCP with a frequency-controlled converter, acceleration lasts from 48 to 86 hours. As a result, SEM receives a smoothed load, the operation is restrained. A 10 % increase in frequency contributed to a 7 % increase in oil production.
Application of frequency control resulted in bringing the well to stable production, adjusting the well production, increasing average runtime and ensuring reliability of the entire mining system, as well as reducing the probability of pumping equipment failure.

References

[1] Pragale R and Shipp D D 2017 Investigation of Premature ESP Failures and Oil Field Harmonic Analysis IEEE Transactions on Industry Applications 53(3) pp 3175–81

[2] Haberer S, Krasikov A and Lavrinenko A 2014 ESP monitoring and control system implementation in western Siberia brownfield Society of Petroleum Engineers - SPE Russian Oil and Gas Exploration and Production Technical Conf. and Exhibition 2014, RO and G 2014 - Sustaining and Optimising Production: Challenging the Limits with Technology 1 pp 67-74

[3] Kozikhin R A, Daminov A M, Fattakhov I G, Kuleshova L S and Gabbasov A Kh 2018 Identifying the efficiency factors on the basis of evaluation of acidizing of carbonate reservoirs IOP C. Ser.: Earth Env. 194(6) 062013

[4] Macary S, Mohamed I, Rashad R, El-Noby M, Latif M A, Awni I and Khalek M A 2003 Downhole Permanent Monitoring Tackles Problematic Electrical Submersible Pumping Wells SPE Annual Technical Conf. and Exhibition pp 817–24

[5] Khabibullin M Ya, Suleimanov R I, Sidorkin D I and Arslanov I G 2017 Parameters of damping of vibrations of a tubing string in the operation of bottomhole pulse devices Chem Petrol. Eng+ 53(5-6) 378-384

[6] Gamboa J and Prado M 2012 Experimental study of the two-phase performance of an electric-submersible-pump stage SPE Production and Operations 27(4) pp 414–21

[7] Khuzina L B, Mukhametshin V Sh, Tyncherov K T and Shaikhutdinova A F 2018 On the choice of the oscillators’ installation site Int. J. of Civil Engineering and Technology 9(9) 1952–59

[8] Suleimanov R I, Gabdrakhimov M S, Khabibullin M Y, Zaripova L M and Vasilieva E R 2018 The study of hydraulic hammer device in drilling tool assembly in hydraulic rotary drilling Int. J. of Engineering and Technology 7(2) 28-30

[9] Tyncherov K T, Mukhametshin V Sh, Paderin M G, Selivanova M V, Shokurov I V and Almukhametov E M 2018 Thermoacoustic inductor for heavy oil extraction IOP Conf. Ser.: Mat. Sci. 327(4) 042111

[10] Noonan S G, Kendrick M A, Matthews P N, Sebastiao N, Ayling I and Wilson B L 2003 Impact of Transient Flow Conditions on Electric Submersible Pumps in Sinusoidal Well Profiles: A Case Study SPE Annual Technical Conf. and Exhibition pp 775-785

[11] Akhmetov R T and Mukhametshin V V 2018 Estimation of displacement coefficient with due account for hydrophobization of reservoir using geophysical data of wells IOP C. Ser.: Earth Env. 194(6) 062001