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Energy Consumption Analysis and Optimization of Electric Submersible Pump System

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Abstract

Electric submersible pumps account for a considerable proportion in the development of the Bohai Oilfield. Improving the system efficiency of the electric submersible pump wells, ensuring that the units operate in the high-efficiency zone, is essential. Analysis shows that the efficiency of the electric submersible pump system depends on the wear and tear of each component of the submersible pump equipment, the setting of operational parameters, and more importantly, the production status and daily management level of the oil well. Therefore, improving the structural performance of the submersible pump product, optimizing the parameters setting of the oil well, strengthening daily management, establishing a scientific management system, and improving the production management process and system can effectively improve the production efficiency and economic benefits of the oil well, and further achieve the goal of energy saving and emission reduction. In addition, it is necessary to actively promote the concept and technology of energy saving and emission reduction, encourage oilfield enterprises to explore effective measures to reduce the energy consumption of the electric submersible pump system by strengthening the scientific management system, and achieve a green, low-carbon, and high-quality development of oilfield production to achieve the unity of economic benefits, social benefits, and environmental benefits. This article applies the above measures in the P oilfield to achieve energy optimization of submersible electric pump systems, reducing the daily power consumption of single well submersible electric pump systems by 371 kWh per day, increasing the submersible electric pump's lifespan by 200 days, generating considerable project benefits.

Keywords

Offshore Oil Fields, Electric Submersible Pumps, System Energy Consumption, System Efficiency, Energy Conservation and Consumption Reduction

1. Introduction

After the oil field is put into development, the underground conditions are in motion and change, which are reflected by the changes in production well's oil, gas, water production and pressure. Understanding the movement and distribution of oil, gas, and water in the reservoir, as well as the relationship between changes in production capacity and water injection intensity and pressure, is important for maintaining stable production of oil wells using submersible electric pumps. Through comprehensive analysis of various changes in a large number of submersible electric pump wells, accurate data and basis will be provided for the mass use of submersible electric pumps in oil fields.

Submersible electric pumps account for a considerable proportion in the development of the Bohai oil field. As the overall water content of the oil field rises, energy-saving and consumption-reducing of submersible electric pump wells are not only suitable for current production needs but also adaptable to the production needs of the subsequent development stage of the oil field. Especially when the oil field enters the high water content period and the ultra-high water content period, improving the system efficiency of the submersible electric pump well to ensure the operation of the unit in the high-efficiency zone becomes more important. Analysis shows that the system efficiency depends on the component losses and operating parameter settings of the submersible electric pump equipment, as well as the condition and management level of the oil well. Therefore, measures such as improving the performance of submersible electric pump products, optimizing oil well parameter settings, and strengthening daily management are taken to improve the system efficiency of submersible electric pump wells, and thus achieve the goal of energy-saving and consumption-reducing.

2. Main Technical Content

2.1. Working Principle and System Efficiency of Submersible Electric Pump

The submersible electric pump is powered by electricity. The grid voltage is first changed by a step-down transformer, input to the frequency converter, and then transformed into the required power frequency. After that, it is input to the boosting transformer to increase the voltage to the required voltage of the electric motor. The electrical energy is transmitted to the submersible electric motor through the submersible cable. The submersible electric motor converts the electrical energy into mechanical energy and drives the submersible pump to rotate at high speed. Each stage of impeller and guide shell in the submersible pump gradually increases the pressure of the well fluid until it reaches the lifting head required by the submersible pump at the outlet of the submersible pump. The well fluid is lifted to the surface through the tubing and then transmitted to the surface gathering system through the surface pipeline. The purpose of applying submersible electric pumps for oil production is to transfer electrical energy from the surface to the downhole liquid, thus lifting the liquid to the wellhead. When the entire oil production system is in operation, it is a process of continuous energy transfer and transformation. Each transfer and transformation of energy will have certain losses. After deducting various losses of the system from the energy input from the surface, the effective energy given to the fluid by the system is called the system efficiency of the mechanical oil production system. Detailed calculation and analysis of the system efficiency of the submersible electric pump well is carried out in order to further improve its system efficiency [1].

2.2. Optimal Selection for Electric Submersible Pumps

In the selection of electric submersible pump units, if the rated power of the submersible motor is not reasonably selected, it may lead to the phenomenon of "big horse pulling the small car" and "small horse pulling the big car". Excessive power of the motor can cause additional loss of energy consumption. In addition, unreasonable selection of the displacement of the electric submersible pump can cause a mismatch in the formation liquid production, causing the electric submersible pump system to operate outside the optimal operating range, and reducing the efficiency of the unit system, causing unnecessary energy loss. Therefore, it is necessary to optimize the pump selection. In addition, the higher the single stage head of the impeller in a multi-stage centrifugal pump, the greater the wear of the impeller during operation. Therefore, when selecting an electric submersible pump, comprehensive consideration should also be taken to avoid excessive wear of the multi-stage centrifugal pump causing production well failures [2].

2.3. Optimization of Unit and Frequency Converter Adaptation

By adjusting the frequency, the working characteristic curve of the electric submersible pump will change, and the head of the electric submersible pump will change with the change of frequency. Therefore, it is necessary to ensure that the variable frequency regulation electric submersible pump operates within an efficient range. If the frequency is too high, it will lead to a significant increase in the speed of the motor and pump, causing excessive wear and tear during long-term operation of the unit, reducing the safe operating cycle of the unit. In the case of high frequency, the frequency converter and motor run under the condition of high current and high voltage for a long time, which will reduce the service life of the frequency converter and electric submersible pump unit. In addition, high current and voltage will impose strict requirements on the voltage withstand level of the cable, furthermore, it increases the supporting cost of the entire unit [3].

2.4. Frequency and Tubing Choke Optimization of Electric Submersible Pump System

To achieve the goal of increasing and reducing production through the coordination of frequency and tubing choke.

2.5. Optimization of Abnormal Conditions of Electric Submersible Pump

Timely handling of problems such as emulsification, evacuation, and gas lock in oil well fluids can directly reduce energy consumption while improving production and oil well lifespan.

3. Project Implementation and Benefits

The project is currently being targeted in the oil wells of P oilfield, including the selection of electric submersible pumps and the adaptation of frequency converters to indirectly reduce energy consumption while improving the lifespan of the oil wells. Therefore, the progress in recent years can be seen from the pump failure rate. The annual failure rate of electric submersible pump unit is shown in Figure 1.

The improvement in daily management is more intuitive and significant. One is to achieve the goal of increasing and reducing production through the coordination of frequency and tubing choke. When increasing production, priority should be given to the tubing choke. If the pressure difference between oil pressure and return pressure is greater than 20 psi, the tubing choke can be expanded. Then, by increasing frequency, priority should be given to reducing frequency and then reducing the tubing choke. To achieve the goal of increasing and reducing production while reducing energy consumption, and to achieve the goal of energy conservation and production increase. The second is the analysis and handling of abnormal well problems, which can quantify the benefits to a certain extent. Taking the emulsification of oil wells underground as an example, a total of 33 oil wells were affected by emulsification throughout the year. Oil well emulsification mainly exists in the form of W/O. During the process of lifting the well fluid to the ground through an electric submersible pump unit, centrifugal force is generated due to the high-speed rotation of the unit when passing through the pump, which drives the well fluid to move upwards.

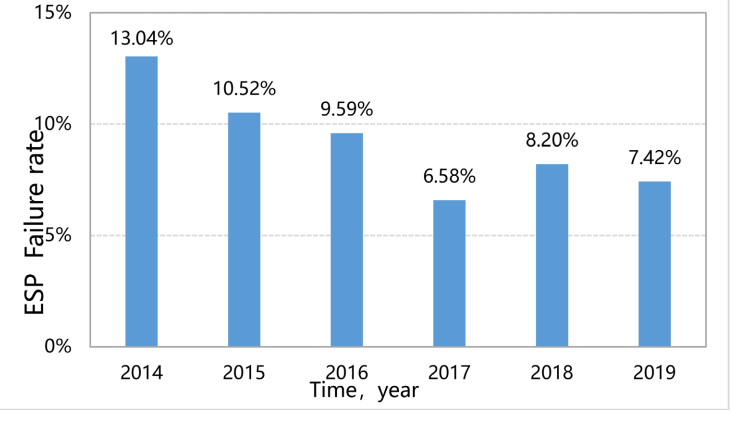

Figure 1. Annual failure rate of electric submersible pump unit.

The high-speed rotation stirs the well fluid, resulting in emulsification of the well fluid. This increases the frictional resistance and motor power of the well fluid during the lifting process [4] [5].

Taking Well E35ST1 as an example, at the same time as the emulsification of the well fluid occurs, the current of the electric submersible pump unit significantly increases, the work done increases, and the current fluctuates frequently and significantly. The operating state of the unit is unstable. Due to the obvious decrease in liquid production capacity observed during on-site wellhead sampling, it further confirms the possibility of emulsification of the well fluid in the pump. Inject a 20 gallon/day dose of demulsifier underground, and inject it to the bottom of the well after about 20 hours of calculation. After effectiveness, the current returns to the pre emulsification value, and the inlet and outlet pressures of the electric submersible pump return to the pre emulsification condition and operate stably. From this, it can be seen that the emulsification of well fluid during the lifting process will cause a significant increase and significant fluctuation in the motor current; The inlet pressure of the electric submersible pump increases and the liquid production decreases; The increase in outlet pressure of the electric submersible pump overcomes frictional resistance and increases work done; Stable rise of motor winding, etc. Once emulsification occurs, the oil well production decreases, the energy consumption of the electric submersible pump unit increases, and the stability decreases. After adding demulsifiers for downhole demulsification, the relevant parameters return to normal and the liquid production rate returns to normal.

The daily oil production loss of a single well ranged from 3 to 50 cubic meters, with a total cumulative loss of approximately 438 cubic meters. If left untreated, allowing oil well emulsification to affect production will result in a loss of approximately 160,000 cubic meters of crude oil throughout the year. A total of 33 oil wells were affected by emulsification throughout the year, with power increases ranging from 2 kW to 35 kW, with a total cumulative increase of approximately 510 kW. If left untreated, allowing oil well emulsification to affect energy consumption would result in a waste of 12,240 kilowatt hours of electricity per day and an annual consumption of approximately 4.46 million kilowatt hours.

4. Conclusion and Understanding

By applying the above measures in the P oilfield, the energy consumption of the electric submersible pump system can be optimized, reducing the power consumption of a single well electric submersible pump system by 371 kWh/day, comprehensively improving the service life of the electric submersible pump by 200 days, and generating considerable project profits.

Optimizing the selection and selection of electric submersible pumps, frequency converter adaptation, and the coordination and adjustment of oil well frequency tubing chokes can effectively reduce energy consumption, power loss, and improve the lifespan of oil wells. The analysis and handling of abnormal well problems can significantly reduce the energy consumption of the electric submersible pump system and improve production. Therefore, it is meaningful to continue promoting energy consumption optimization of electric submersible pumps in oilfield work.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Wang, D.J. and Lu, X.Y. (2014) Calculation and Analysis of the Efficiency of Electric Submersible Pump Wells. *Petroleum and Petrochemical Energy Conservation*, **4**, 4-7. (In Chinese) https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKgchrJ08w1e7M8Tu7YZds8_MBYFMH59sTpOjN0P_sfv610WtKAp_lZ604eIqCZ4pkTcro4fGAcRB&uniplatform=NZKPT&src=copy

[2] Xu, D.F. (2017) Design and Operation Management of Multiphase Fluid Electric Submersible Pump. *Equipment Management and Maintenance*, **411**, 66-68. (In Chinese) https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7iAEhECQAQ9aTiC5BjCgn0RlPFaKWbCB5_UnE3MiVs04v-IqAzQlCBPEnl4mEZYnMu&uniplatform=NZKPT

[3] Duan, Y.C., Yu, J.F., Cao, Y.F., *et al.* (2019) Energy Consumption Analysis of Electric Submersible Pump Wells in Offshore Oilfields. *Petrochemical Technology*, **26**, 287. (In Chinese) https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7iLik5jEcCI09uHa3oBxtWoMXwGI6aY4y3zp2u1s2UYH3hFXzjV4eYpOGhPVkTB5tk&uniplatform=NZKPT

[4] Xiao, Z.H. (2008) Research on the Demulsification Mechanism and Influencing Factors of Crude Oil Emulsion. *Journal of Petroleum and Natural Gas*, **106**, 165-168+178. (In Chinese) https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKgchrJ08w1e7VSL-HJEdEx3x9ccUi4t8AjLtzr6t3IaOhVAIHtq8iS6D7BsqwkymqiMUVEm50uUN&uniplatform=NZKPT

[5] Wang, M.H. (2022) Research on Crude Oil Demulsification Technology Treatment. *Shandong Chemical Industry*, **51**, 113-114+117. (In Chinese) https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C44YLTlOAiTRKibYlV5Vjs7iJTKGjg9uTdeTsOI_ra5_XfVL_CgafzYW7XzHbO1-lVEYAUbHdkeAe3QYLsgZ6Iev&uniplatform=NZKPT