The dynamic improvement methods of energy efficiency and reliability of oil production submersible electric motors

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Abstract. In the organization of production and operation of submersible electric motors (ESP), as the most essential element of electric submersible plants (ESP) in the oil industry, it is necessary to consider specific operating conditions. The submersible electric motors (SEM) as most essential element of electrosubmersible installations (EI) in oil branch accounting of operation specific conditions is necessary in the process production and operation. They are determined by the conditions under which the EPU is operated. They are defined by the EPU operation conditions. For a complete picture the current state of the SED fleet in oil production, the results of its statistical analysis are given. For a comprehensive idea of the SEM park current state the results of statistical analysis are given in oil production. Currently, assessed the performance of submersible equipment produced by major manufacturers. Currently the operational characteristics assessment of the submersible equipment released by the main producers is given. It is stated that standard equipment can not fully ensure efficient operation with the help of serial EIs, therefore new technologies and corresponding equipment are required to be developed. It is noted that the standard equipment could not provide fully effective operation by means of serial ESP therefore new technologies development and the corresponding equipment are required.

1. Introduction

The total volume of oil produced in many regions of Russia by means of electric submersible units (EI), driven by a submersible electric motor (SEM), is more than 80%. The application of this method is economically justified both for new deposits and for those that are under intensive exploitation for a long time. When choosing the method of operation of wells, many factors, such as viscosity, the content of mechanical impurities, the gas factor, the economic feasibility of the equipment used, must be taken into account. Based on the classification and comparative analysis of statistics on the park of the main SEM in domestic oil production, it can be argued that more than 20% of the wells from the entire fund in Russia are idle, since standard equipment has no opportunity to operate effectively using serial EPUs of both domestic and expensive foreign Production. Therefore, the development of new technologies and corresponding equipment is required. The main goal of the work is to study the modern SED fleet in the oil industry of Russia with the development of specific proposals for increasing the energy efficiency and reliability of the entire technological process of oil production, the key element of which is the energy industry. The study is based on the current scientific approaches to the use of EPU in oil production. The theoretical basis for studying the issues of the work presented was the work of domestic and foreign specialists. The study of questions of theory and methodology in the EPU of oil extraction was devoted to the studies of such authors as A.N. Kitabov, V.Ya. Charonov, T.A. Atakishev, RV Babayev, A.A. Baryudin, V.P. Tokarev, S.S. Shubin. From the point of view of the analysis of the condition of the submerged electrical equipment park, it is worth
noting the large and painstaking work to collect data on the operation of the SEM, which was carried out at JSC "Samaraneftegaz" by V.P. Sotnikov.

2. Formulation of the problem

Proceeding from the foregoing, there is a need to create and study EPUs for operation in complicated conditions with high efficiency in the basic modes, with a wide range of feed rates and the possibility of adjusting the head of the facility, which ensures the synchronization of the parameters of the system "formation-well-facility". Reduction of the mass-dimensions parameters of the underground part of the installation will significantly increase the possibility of unobstructed passage of curved sections of wells with complex geometry and small casing dimensions. Most of the regions of oil production in Russia are remote areas with sharply continental climatic conditions. Remoteness of oil fields from equipment manufacturers entails an increase in the costs of delivering and storing a large range of bulky EPUs, which once again [1, 2], emphasizes the need and relevance of reducing weight and size characteristics. It is also necessary to minimize losses in submersible motor line supplying from the surface, to ensure automatic adaptation to changing operating conditions and optimization of an operating mode of a pumping unit. For this, an effective system for monitoring the parameters of the EI is required, which allows reducing the intervals between repair intervals. It should be noted that an important aspect in the selection and introduction into production of the equipment is a minimization of the cost price of SEM.

3. Theory. Technical analysis of ESP structures

For a more complete and effective presentation of the current state of SED used in domestic oil production at present, it is necessary to analyze the operating data of their fleet. The diagram in figure 1 clearly shows the distribution of the main producers of the SEM market, used in Russia.

![Figure 1. The main producers of the SEM market in Russia.](image)

The FED of Borets is a three-phase short-circuited oil-filled bipolar manual winding motor. The rotation speed of the asynchronous bipolar motor at full load is 3000 rpm at a power frequency of 50 Hz and 3600 rpm at a power frequency of 60 Hz. The engines are filled with a high level of cleaning dielectric oil, which provides lubrication of bearings and thermal conductivity. The engine is able to withstand extreme temperatures both on the surface and in the well, which, as a rule, are a reason of damage to the EI and can even cause premature failure of a pump.

“Almaz” company produces oil-filled SEM for EI of SEM-Y series with a power from 22 to 360 kW and parametric submersible three-phase oil-filled series RPPED-YA (Russian parametric SED designed by Professor NV Yalovega). The main differences between the RPPED-Y and the conventional ones are smaller dimensions, stable operation over a wide range of supply voltages, regulation of a rotor speed in a wide range by changing a supply voltage, increased power, large starting torque, stable operation with significant changes in the supply voltage. The engines are available in sizes 117 and 103 mm, in heat-resistant and conventional designs. Sectional engines are present in the nomenclature series. Power of the engines is from 28 to 340 kW.

Novomet CJSC produces three-phase, short-circuited, oil-filled SEM versions of various modifications (for operation in complicated operating conditions, with installed immersion control units of the plant parameters, etc.). SEMs are available in one-, two- and three-sectional layouts and are in the form of a design version according to the method of mounting 1М3631, designed for
continuous operation of S1 GOST R 52776-2007 from AC mains with a frequency of 50 Hz. The engine consists of a stator, a rotor, a head, and a base. The stator is made of a tube into which the magnet core is pressed. The magnet core is made of sheets of electrical steel with heat-resistant coating. The stator winding is single-layered, stretched, reeled, made of heat-resistant winding wire with insulation from polyimide-fluoroplastic films. The phases of the winding are connected as a star. The rotor is squirrel-cage, sectional. Advantages of SEM: reliability of construction, application of high-temperature materials, long operating time, provision of technical requirements of customers, continuous improvement of production processes.

OJSC Alnas produces certified complete submersible pumping units for oil production, reservoir pressure maintenance, various ground equipment, including control systems. The certificate for this equipment is issued by BureauVeritasQuality. OJSC "Alnas" confirms its compliance with the requirements of ISO 9001: 2000. The manufacturing technology determines a high quality and reliability of the SEM. The stator is executed with the closed groove increasing the purity of the internal cavity of the engine, it allows successfully use grooving insulation in the form of a tube. Winding wire of the stator insulation company "DuPont". In the SED rotor, the original bearings are used, which have a mechanical fixation from the rotation and thus retain the possibility of easy movement along the axis of the shaft. Using special electrotechnical materials makes it possible to operate SED at a formation fluid temperature of up to 120 °C, and in superthermally resistant version - up to 160 °C.

Woodgroup PSN produces SED and multistage centrifugal pumps. The main advantages: high resistance to abrasive wear, shaft material is made of nitronic 50, which significantly increases the corrosion resistance of the unit, a number of innovative measures aimed at reducing the failure of the EPO. Weatherford Company, whose representative offices operate in all major oil and gas regions of the world, produces highly efficient electric motors and multi-stage centrifugal pumps, which use modern speed controllers for a drive. The main advantage is the minimum requirements for an installation on the surface, especially in low-temperature conditions. The percentage of EPL failures is significantly reduced, as a result of the use of innovative materials and structures.

The company Reda (Schlumberger) produces an innovative quick-connect design of SED, hydroprotection and sensors of the REDA Maximus system. Main advantages: there is no need for responsible assembly operations, that can be affected by weather conditions; Execution of installation operations, such as adjustment of shafting, oil filling of electric motors and hydraulic protection in controlled conditions of the company's production and service centers; There is no need to install a current lead isolation on an outfall; components of the Maximus system are ready for installation to a well; Reliable installation in an extremely low ambient temperature; Reduction of the work time for a facility installation; Increased period of operation of the facility; Optimum performance.

BakerHughes (a division of Centrilift) produces EPU for operation in complicated conditions. Advantages of these designs are: modularity; Possibility of replacing individual units of the installation without disturbing the alignment of the shafts; A significant reduction in repair work; Ecological compatibility, in sum of absence of leaks in oil-filled EI units, low noise level and absence of system vibration; Work in high-temperature conditions; Effective monitoring systems; The possibility of exploitation in conditions of high sand content, etc.

4. The discussion of the results
Typical principles of innovative changes in modern EIs and, above all, submersible electric motors (SEM) are: a use of a valve drive, an increase in the rotational speed of 3000-6000 rpm and nominal voltage, schematic and parametric changes in structures, etc. They are strategically aimed at increasing their Energy efficiency and energy saving, increase in between-repair intervals. Each of the selected strategies of innovation changes in the EI and in particular, SEM has its advantages and disadvantages. However, when choosing a method for operating a well, it is necessary to individually consider each of the proposed methods based on local conditions for obtaining the maximum economic effect. One of the most promising areas of energy saving and energy efficiency improvement for oil and gas producing enterprises is the increase in between-repair periods (MCI) of the EPU [1] and, first of all, for SEM is a minimization a number of emergency failures and violations. Reliability and efficiency
of operation of SEM [2, 3] depend to a large extent on the organization of maintenance and repair (MRO), which are implemented in the oil industry by two main approaches:

• by the operation time of the EPU (or its individual components) with reference to a known standard group (for example, SEM 63-117) with terms and composition of work established for it [2];
• according to the current technical condition, which is determined by the comparison of the continuous monitoring data (which is currently being introduced in the industry) and technical diagnostics with an established boundary data of the diagnostic parameters [3 ± 5].

In the first case, MRO includes routine maintenance and preventive maintenance of the equipment in accordance with regulatory deadlines, which are established on a basis of guidance documents and operational experience for a particular type of SED and its life cycle phase. At the same time, a condition of a SEM is checking according to the preventive principle when performing maintenance, current and major repairs.

This approach has a number of significant drawbacks, primarily related to technically unjustified costs. Thus, for the formation of a volume and composition of preventive maintenance and repair works [2] for individual SEMs and their groups, works for MRO and SED, and their components with different time schedules, are often combined for organizational and technical reasons. A number of objects are included in the MRO total works and deadlines are assigned. This leads to underutilization of electrical installation resources and, in addition, to a downtime due to unnecessary long running and lifting operations [2].

At the same time, here are quite typical a shortage of oil, a significant reduction in MCI and, as a result, an increasing losses. It can be stated that MRO on the operating time as a whole is determined by the type of SEM and does not take into account the individual features of the operation of SEM in the conditions of specific wells. In addition, even with high-quality maintenance, with careful disassembly, detailed analysis and replacement of worn out components and parts, if necessary, it is not possible to avoid violations of their compatibility (which increases the possibility of new defects and violations) and ensure the absence of sudden failures in MCI. Efficiency of EPU operation can be improved by generally organizing MRO with the definition of time, composition and schedule for the current state of SEM. In other words, taking into account a rational use of internal reserves of durability of its individual elements and in general of the whole EPU, as a technical resource. It should be noted that in this organization of maintenance and repair, as in the previous case, underutilization of electrical installations takes place, since when performing repair of a specific element of EPU, it is expedient to expand the composition of work for efficient components that have significant wear.

At the same time, it is necessary to provide a full-scale determination of an actual technical condition of the SEM by an available composition of diagnostic parameters (DP), sufficient in content, quality and reliability of information [4-6]. Further, based on comparison of the DP with their boundary permissible values, takes a decision on the possibility of further operation of the installation and the required volume of maintenance.

The exception of this approach is an elimination of the consequences of sudden failures. In these situations, the analysis of a pre-emergency condition of the SEM is especially important. Since it allows obtaining necessary information on dynamics of defect development with the purpose of their operative diagnosis, localization, prediction and, as a result, reduction of emergency damage [3-6].

5. Conclusions

Based on the analysis of operation data for the SAM fleet of OJSC Samaraneftegaz, it has been established that the planned repairs and preventive maintenance of the equipment in accordance with the scheduled terms have technically unjustified costs. They are caused by the fact that a number of objects are included in the overall composition of MROs earlier than previously assigned terms. This leads to underutilization of electrical installation resources and shortage of oil. Organizing maintenance for the current state check of SEM, taking into account the rational use of their internal reserves of durability, in a number of cases, the resources of the submersible equipment are also insufficiently use. To increase efficiency, a full-scale determination of an actual technical condition of the SEM is necessary on the basis of detailed diagnostics.

The foregoing can be generalized by the following conclusions.
1. Analysis of serial EPU produced by domestic and foreign manufacturers shows that in complex conditions of modern oil production they do not fully meet the high demands of modern efficient operation. It is necessary to develop new technologies and related equipment.

2. It is necessary to widely introduce EPU for operation in complicated conditions with high efficiency in modes with a wide range of feed rates and possibility of regulating the head of the installation with the provision of parameters synchronization of the "formation-well-installation" system.

3. Reduction of mass-dimensions parameters of an underground part of EPO will significantly increase a possibility of unimpeded passage of curved sections of wells with complex geometry and small casing dimensions.

4. In the organization of operation and management of SEM life cycle parameters of the petroleum industry, the integrated organization of MRO is appropriate, using jointly both the operating data and the current status as the main provisions.

The high energy intensity of the oil production sector, the need to reduce energy costs and increase the efficiency of the oil industry, as well as the short service life of the SEM require system accounting and processing of operational data for specific submersible electrical equipment based on information technologies.

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