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Control station based on synchronous motors

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Abstract. The oil and gas industry is one of the leading branches of Russia, the basis of the economy. Therefore, it is obvious that increasing the technical and economic characteristics of equipment in the field of oil production is a priority for the scientific community. And there are several solutions aimed at solving this problem: use of intelligent control systems for electric drive; replacement of asynchronous motors with synchronous ones. With the integrated use of these points, it is possible to reduce energy consumption, as well as increase the percentage of extracted resource. Numerical values are individual for each particular variant, but savings of 25-35% are achieved.

1. Introduction

The introduction of intelligent energy-resource-efficient control stations for oil pumping machines is the key to solving the existing problem - optimization of oil production.

According to the Energy Strategy of Russia for the period until 2030: "The strategic goal of the state energy policy is the creation of a sustainable national innovation system in the energy sector to provide the Russian fuel and energy complex with highly effective domestic technologies and equipment, scientific, technical and innovative solutions in the amounts necessary to maintain energy security of the country".

The development and use of a new type of energy-saving technologies in the electric power industry in Russia can be achieved only due to several conditions:

- the achievements of international science should be taken into account;
- technologies must satisfy modern trends, and correspond to forecasts in this area.

A large share in the cost of oil is the cost of electricity and maintenance of the energy complex. They reach up to 25-35% of the cost of oil.

The key tasks in the oil and gas industry are to increase the efficiency of the use of technological power equipment and to develop measures and technical means to increase the energy efficiency of the use of equipment.

At the moment, the international market offers a large selection in the field of electric drive control for rocking machines. In Russia, various solutions are also presented in the field of intelligent control systems. They are distinguished by control algorithms, data processing options, interfaces and others. It is important to note that for optimized asynchronous motors, the optimization will not reach the specified savings, due to the lack of wide possibilities for regulation, which does not allow to fully realize the advantages of systems of intelligent control systems. Also for rocking machines characterized by an uneven load regime, which reduces the useful power of induction motors.

Synchronous electric drives with permanent magnets on the rotor provide more economical consumption of energy resources, including, through the organization of feedback to the electric drives



of other machines. An engine of this type is a system included in an adjustable electric drive, and is used not only for energy conversion, but also for changing the parameters of the rocking machine.

"Forecast of scientific and technological development of Russia's fuel and energy industry for the period until 2035" indicates the need, in the medium term, to optimize the cost price of heavy and viscous oil production in areas with developed infrastructure without foreign technologies. Consequently, the development and production of domestic electronics to reduce production costs with the help of "rocking machines" can be a priority.

2. Theoretical position

We should briefly dwell on the principle of synchronous machines.

The main property of synchronous machines is the field of the rotating part of the motionless relative rotor itself and performs a rotational motion together with it. The intrinsic excitation region is used in magnetic and electric machines, and the field penetrating the rotor in synchronous-reactive ones.

In the development of electric drives, the classification of synchronous machines is associated not only with the physical, design features of the machine itself, but rather with the characteristics of use, control algorithms and the construction of control stations.

A synchronous motor with permanent magnets is an electric machine with alternating current. The stator of the engine is structurally similar to the static part of induction motors containing a three-phase type of winding.

There are magnets on the moving part, depending on the position, there are only 2 types of synchronous machines: motors with magnets located on the rotor itself, in the English literature called a surface motor with permanent magnets, and motors with magnets located directly in the steel structure of the rotor. The synchronous motor is usually designed for a small power, which does not exceed hundreds of kW (7.5 - 60 kW), and is most often used in servo drives in combination with frequency converters.

2.1. Management methods

The direction of developing principles for controlling synchronous machines is determined by the improvement of the hardware component of the electric drive: the characteristics of the electric motor, the type of the converter, the presence of various sensors, and the parameters of the controllers [1].

The fundamental factors for the realization of the control station of the electric drive are the use (non-use) of the magnetic state sensors, speed and rotational angle of the rotor. For this reason, the methods are classified into a view using a rotor position sensor and a non-sensorless view, called "sensorless control".

In the standard drive on the basis of synchronous motors, a position sensor is placed on the motor shaft [2]. Types of sensors: Hall sensor, encoder, resolver, reductosin, etc. The control system is quite simple in this case, but the machine becomes less constructive, which reduces the reliability of the system.

Significant advances in the field of relevant intelligent management systems, especially the improvement of situation observers, led to the creation of electric drives that do not use rotor position sensors. In such systems, the position sensor is not available, and the necessary information for implementing the control algorithm comes from the status observer. A special role is played by such systems in those electric drive systems where the installation of a sensor is simply impossible. The advantages of systems that do not use these sensors are reliability, cheapness, and compactness.

Most control methods that do not use the rotor position sensor, described both in domestic and foreign literature, are based on mathematical models of electromagnetic processes occurring in AC motors. In such methods, the calculation of the velocity estimate is combined with the calculation of the module and the direction of the electromotive force of the moving part of the engine [3].

The most common control systems for synchronous motors are the method of direct control of torque and vector [4]. The direct control method works better for monitoring and eliminating

interference, and the vector method loses response speed to changing characteristics and requires the use of more energy-consuming pulse width modulation. But it is worth noting that the vector control system also has its advantages in static modes: lower power costs and a lower ripple ratio. Consequently, this method is preferred in drives with stable load and control. Since this paper analyzes the drive for rocking machines, a choice will be made to the direction of the vector system as a method for controlling the synchronous machine, since more energy efficient modes of operation are achieved due to low levels of harmonics, in contrast to the direct control method [5].

2.2. Management system model

The model of a synchronous machine is usually considered in a rotating coordinate system (d, q), while combining the axis d along the axis of the rotor. In this case the system will look like:

$$\begin{aligned}u_d &= R_s i_d + \frac{d\psi_d}{dt} - \psi_q \omega \\u_q &= R_s i_q + \frac{d\psi_q}{dt} - \psi_d \omega \\ \psi_d &= L_d i_d + \psi_f \\ \psi_q &= L_q i_q \\ M &= \frac{3}{2} p (\psi_d i_q - \psi_q i_d) \\ J \frac{d\omega_m}{dt} &= M - M_H - \beta \omega_m\end{aligned}$$

When working with an uncontrolled drive of a rocking machine, the characteristics of changing the location of the suspension point of the rod column can be determined through the geometrical dimensions of the machine elements, but it is assumed that the speed of rotation of the rocking arm will not change for a length of time equal to the period of rocking motion of the rocking machine. From this point of view, a large number of authors and in sufficient detail has investigated the kinematic system of the machine. In these studies, it was assumed that the law of the change in the location of the rocking crank (given that the rotational speed is a constant) was set, and based on this, the characteristics of the displacement of the remaining elements of the machine were determined. And based on what the dynamic forces in the links of the pumping unit were determined, and, accordingly, the electric power parameters of the drive of the machine.

When using a converter that is compatible with the swing drive, it is possible to optimize the characteristics of the suspension point. This optimization is achieved due to the fact that the frequency of rotation of the rocking engine changes, and as a result the maximum values of dynamic forces in the links of the whole machine decrease. At the same time, it is necessary to determine the law of displacement of the suspension point, as a set of laws for converting the engine speed and the movement characteristics of the rocking crank.

Thus, in the process of further development of the kinematic model of the machine, it is necessary to solve the following tasks:

1. to determine the parameters for moving the suspension point with certain rules for cranking the machine when the instantaneous value of the engine speed of the pumping unit is inconstant (let us call the direct movement);
2. determine the characteristics of the cranking motion of the rocking machine under the given laws of displacement of the suspension point (let us call the return motion).

Calculation of the characteristics of the crank motion of the machine for certain laws of displacement of the suspension point (this calculation is necessary to determine the values of the return motion)

Suppose that the law of displacement of the suspension point is given, in this case it is necessary to determine the parameters of the crank motion of the machine-the angle of rotation, the angular velocity and the angular acceleration (determine the equations of motion of the rocker crank), that is:

$$\phi_{kp} = f(S_A)$$

$$\omega_{kp} = f(S_A, v_A)$$

$$\varepsilon_{kp} = f(S_A, v_A, \alpha_A)$$

When we find the characteristics of the crank motion of the machine, we assume in the sequel that the positive direction of the displacement characteristics of the suspension point is directed downward (in the direction of acceleration of gravity). In addition, as the zero angle of the rotational motion of the rocking crank (origin), take the angle of the crank, at which the suspension point is located at the bottom dead center. In this case, the moment is considered when the crank of the rocking machine rotates clockwise.

2.3. Control station

A system simulating a pumping station control station based on high-performance synchronous motors with permanent magnets.

The model of the control station under consideration includes the following interrelated elements:

- model of a synchronous motor with permanent magnets, which describes the mechanical and electrical processes in the drive of the machine;
- block that simulates a system based on vector control, and describes the changes in the drive;
- models of kinematic problems;
- converter of values from a standard algorithm to a rotating one;
- model characterizing the "column-pump installation - liquid level";
- dynamic model of the machine, which describes the dynamic processes in the links of the installation, provided that the value of the speed of the engine shaft of the pumping unit is not constant;
- controller, necessary for implementation of sensorless control method.

3. Conclusion

The article demonstrates the relevance of this subject, based on a comparison of electric drive systems with synchronous and asynchronous motors, from an economic and practical point of view, taking into account the features of the use of electrical machines in the oil industry.

Possible areas of application of data and management methods are considered, with an overview of the solutions and advantages and disadvantages of each system. The components of the system model are included, including a synchronous motor model (rotating coordinate system) and a rocking machine (solutions of the direct and inverse kinematics problem), in the form of mathematical equations, based on which the management system is constructed.

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