Electric Drive Simulation for Drilling Machine Spinner

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Abstract. The present work discloses the scheme of the automated control system that allows automated leaving the vibration mode by the drilling machine with the indirect vibration measuring method. In addition, the system allows entering the constant power method by the engine. This paper presents a system simulation and reveals that the machine spinner electric drive engine facilitates operating the working branch of mechanical characteristics in the mode of maintaining the set speed to the maximum torque (power specified), followed by moving into the constant power mode that facilitates moving the machine off the vibration zone by means of a small decrease of the drilling string rotation frequency. The article proves that the most radical automation approach suggests using the asynchronous engine drive vector control system in a manner that provides the best regulation accuracy possible.

1. Introduction
If a random process is made more complicated by vibrations that emerge in a system, it is the drilling process automation that may become quite a challenge. Automated electric drive systems would be necessary to allow controlling the drilling mode parameters in the most efficient way. Only then it will be possible to maintain the optimal drilling mode in full accordance with the performance criterion approved [1,2].

The main direction for improving the electric drive systems of the drilling machine main mechanisms is to use the automated semiconductor alternate current electric drives with a wide range of rotation frequencies, high dynamic characteristics [3,4]. Usage of such drives facilitates performance improvement and reduces bore works cost, also reducing power spending, and improving the working conditions for the service personnel [1].

The present work aims to obtain the mode of the drilling machine leaving automatically the vibration mode.

2. Equipment and devices used in studies
The most applicable machines in the Russian Federation are drilling ones of SBSH type with the main parameters:
- drilling diameter: 243 - 269 mm;
- depth of drilling: 32000 mm;
- weight: 70 000 kg;
angle of inclination of the well to the vertical: 0; 15; 30 deg.;
travel speed: 0.8 km / h;
dimensions:
  - with a raised mast: 9200 x 5450 x 15450 mm;
  - with the lowered mast: 15000 x 5450 x 6500 mm.
Machine drive: Electric or Diesel Cummins QSK19;
the upper limit of the rotational speed of the drilling rig, rpm: 120-150;
capacity at rock strength f=16 to 18, m/hr: 13.5;
feed force upper limit, kN: 350 – 400;
drill bit rated torque, Nm: 6000 – 6500;
maximum torque of the rotator, Nm: 7000 - 21000.

SBSH-250 self-propelled crawler mounted drilling machines are designed for roller bit drilling of vertical and inclined blast holes and are used in mining mineral resources as well as in building canals and hydro technical facilities.

This drill rig ranks as the best among those available commercially. The specifications and performance indices of the drill rig are comparable with those equipment manufactured by leading companies outside the CIS. From the moment of production of the first machine to today engineering specifications for the prototype system for the automatic control of auxiliary operations for the SBSH had been improved and adjusted, thus allowing considerable time savings.

The existing drilling units are capable of drilling in major operating modes, and the spinner mechanisms in the machines like SBSH-250MNA-32 (SBSH-250MN), produced by national manufacturers, are equipped with direct current electric drives with the system that comprises a thyristor rectifier and an engine (TP-D) [5,6].

To maintain the necessary characteristics sustainable, the negative feedback by anchor speed and the inner current loop are engaged. Automated frequency drives of the TPH-AD systems with non-contact asynchronous drives (AD) and the systems of scalar and vector control look more promising [7].

Let us consider the alternating current electric drive of the EKT-2 (AT04) type with scalar control system for the feedback by speed, the inner loop, the 4A280S6 drive (Fig.1), 75 kW of power and with the additional loop introduced.

Figure 1 shows the AD structure comprising an aperiodic link $K/(T_p+1)$, the multiplier $M_2$ of the magnetic flux on current $\{\Psi_0|j\}$, coefficient $C_m\{C_{in}\Psi_0|j = M\}$, the integrating link $(1/J_p)$; PC and PT are the regulators of the speed and the current; the element with the coefficient $K_n$, which pre-enables the system to create initial magnetic flux (under $\omega = 0$) to prevent noticeable dynamic torques in the drilling string on inputting the speed $\omega$; $K_n$ and $K_d$ are the feedback links by speed and current.

The situation, when a drilling machine begins operating in vibration mode, is undesirable, imposing limitations on performance of works. The time needed to leave the vibration mode depends on the operator’s experience, and in a number of cases the drilling process has to be interrupted [8,9].

Disclosing the vibration mode and leaving the vibration zone automatically without using a direct vibration measurement sensor (the indirect method) required an additional loop (DK) to be introduced into the scheme. The additional loop links are F – the filter; NE – nonlinear element; M – multiplier; $P_{zad}$ – the power specified. Exceeding the specified power $P_{zad}$ at the output of the nonlinear element results in a signal to reduce the speed [10-12].

For the purpose of simulation, the DK is composed by means of typical software visual library blocks, and so is the electric drive, too. As for the hardware, the DK may be implemented on a circuit board with two chips of the 525th and 553rd series.

Simulation of electric drive dynamics with the Simulink system of the MatLab software package allowed comparing the reaction to abrupt load change and the linear change of the speed specified at launch, with the limitation imposed on the maximum power and voltage values of the TPH. 4A280S6
asynchronous engine model was implemented in accordance with Gorev-Park equation, with the machine’s magnetic system saturation in transition modes taken into account [13-15].

Figure 2 shows the process of the drive acceleration with an additional loop during launch within 0.5 second entering the constant power mode.

The acceleration increases power consumed by the engine, including the extra consumption resulting from the machine vibration [16]. In this case, there is a signal at the comparison device US output, the signal passes through the nonlinear element NE and the filter to cause the voltage task signal decrease, and so does the AM speed in accordance with the power $P_{\text{zad}}$ set [17-19].

![Electric drive automated control system structure diagram](image)

**Figure 1.** Electric drive automated control system structure diagram

This causes the machine to leave the fluctuation zone, lowering the vibrations amplitude and providing better performance, and better strength of drilling heads.

Figure 2 (downwards):
By Ordinate Axis – engine rotation speed, $\omega$, rad/sec.;
1 – asynchronous engine current ($I_{\text{max}} = 300$ A);
2 – setting the speed and the actual electric engine speed (1:1 scale);
3 – frequency convertor voltage ($U_{\text{max}} = 230$ V);
4 – flux level (main magnetic flux engagement) (1.2 Wb);
5 – engine torque value (peak value of 1400 Nm).

![Transition process on AD 4A280S6 entering the constant power operation mode](image)

**Figure 2.** Transition process on AD 4A280S6 entering the constant power operation mode
Figure 3 represents the electric drive model scheme implemented by means of Simulink software library blocks.

Figure 3 depicts:
- ZI – intensity setter;
- SAP – automated regulation system, implemented in accordance with the figure 1 with an additional loop DK within the SAP subsystem;
- PH – amplifying and converting device;
- AM – asynchronous engine, load with the idle run torque \( M_o \) specified.

3. Results and discussion
System simulation revealed that the machine spinner electric drive engine facilitates operating the working branch of mechanical characteristics in the mode of maintaining the set speed to the maximum torque (power specified), followed by moving into the constant power mode that facilitates moving the machine off the vibration zone by means of small decrease of the drilling string rotation frequency.

4. Conclusion
The performed research allows one to conclude the following:
1. The spinner asynchronous electric engine with scalar control structure, feedback by the speed \( \omega \) and additional loop provides necessary drilling machine operating modes including the operation approaching the vibration zone.
2. The most radical automation approach suggests using the asynchronous engine drive vector control system in a manner that provides the best regulation accuracy possible [20].

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