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Investigation of the torque electric drive of the enclosing structure at low temperatures

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Abstract. The article deals with the study of a torque electric drive at low negative air temperatures used as part of the enclosing structure of a ventilated underground building. The increasing of the efficiency of the torque electric drive of the enclosing structure is analyzed, a simulation model of the torque electric drive is developed and a model of the control system of the enclosing structure in the language of MATLAB&Simulink is designed. A software model in the form of Arduino software package was developed to study the drive operation of the ventilated underground of building enclosure structure in the permafrost zone.

1. Introduction

Currently, various electric drive systems are used in many areas of engineering, including the construction industry. This article presents a study of the torque electric drive at low negative air temperatures used as part of the enclosing structure of the ventilated underground of the building. A distinctive feature of these electric drives is the high-quality torque characteristics and low speed, as well as the absence of a transfer device, which provides high transmission stiffness and high frequency of its vibrations. However, the torque electric drive, along with the advantages, has disadvantages, which are expressed by a relatively large mass and power consumption.

The research has shown that when operating asynchronous torque electric drives of industrial equipment at low ambient temperatures, there is a significant change in the parameters of the engine that provides mechanical energy transfer to the executive mechanism. It is known that as a result of reducing the ambient temperature, the active resistance of the rotor winding of an asynchronous engine changes, which has a significant impact on the mechanical characteristics of the electric drive. Along with this, in modern asynchronous torque electric drives with a frequency converter, the effect of current displacement in the rotor rods of an asynchronous engine is manifested, which leads to a change in its active resistance [1-4].

The purpose of this work is to study the torque electric drive at low negative air temperatures.

2. Methods and materials

The object of research is a torque electric drive with a direct current (DC) engine (figure 1).

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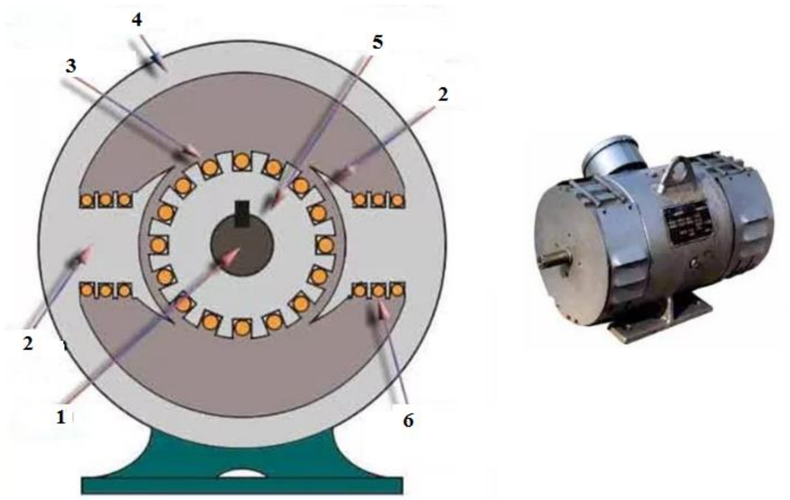

Figure 1. Design of a torque electric drive with a direct current engine: 1-shaft; 2-poles; 3-anchore windings; 4-stator; 5-core; 6-excitation winding.

3. Results

A mathematical model of a torque electric drive with counter-EMF (electromotive force) is written as a system of differential equations.

$$\begin{cases} J\dfrac{d^2\gamma}{dt^2} = 2\text{M} - 2\text{M}_{\text{тр}}; \\ 2\text{M} = 2i(u)Blr = iK_i; \\ u = L\dfrac{di}{dt} + iR + \text{K}_e\dfrac{d\gamma}{dt}, \end{cases} \tag{1}$$

where γ is the angle; J is the moment of inertia of the mirror with the magnets; M is the torque produced by engine; $M_{тр}$ is the friction moment; B is magnetic induction; i is the current flowing in coils of the engine; u is the voltage on the windings of the engine (control); R, L is resistance and inductance of the coil; l is the total length of the coil turns; r is the distance between the engine axes and the axis of mirror rotation; K_i is the coefficient of proportionality between the current in the engine windings and torque; $K_в$ is the EMF coefficient.

From the system of equations (1) let's move to the equation "input-output" of the considered electric drive. For this purpose, we take into account that for the described engine the moment of friction is negligible, i.e. $M_{тр} \approx 0$, from the third equation of the system (1), we obtain an expression for the current i

$$u = \frac{1}{R}u - \frac{L}{R}\frac{di}{dt} + \frac{\text{K}_e}{R}\frac{d\gamma}{dt}. \tag{2}$$

Substituting this expression into the first equation of the system (1), we get

$$J\frac{d^2\gamma}{dt^2} = \frac{\text{K}_i}{R}u - \frac{\text{K}_i L}{R}\frac{di}{dt} + \frac{\text{K}_i\text{K}_e}{R}\frac{d\gamma}{dt}. \tag{3}$$

Since 2M = iK_i, the first equation of the system (1) can be represented as

$$i\text{K}_i = J\frac{d^2\gamma}{dt^2}. \tag{4}$$

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Differentiating the left and right parts of equality (4) in time, we get an expression for the current derivative di/dt

$$\frac{di}{dt} = \frac{J}{К_i}\frac{d^3\gamma}{dt^3}. \tag{5}$$

Substituting expression (5) in expression (3), we get the desired differential equation "input-output" of the electric drive

$$T_k\frac{J}{К_u\,К_e}\frac{d^3\gamma}{dt^3} + \frac{J}{К_u\,К_e}\frac{d^2\gamma}{dt^2} + \frac{d\gamma}{dt} = \frac{1}{К_e}u. \tag{6}$$

where $К_u = К_i/R$ is the coefficient of proportionality between the control voltage on the engine windings and the moment M in the steady-state mode;

$T_к$ is the time constant of stator coils, defined by the expression $T_к = L/R$.

In addition, a significant change in the design characteristics of the gear elements and the properties of the lubricant at low temperatures leads to a significant increase in the static moment of resistance of the mechanical load of the electric drive [5-6].

The block diagram of the torque electric drive is shown in figure 2.

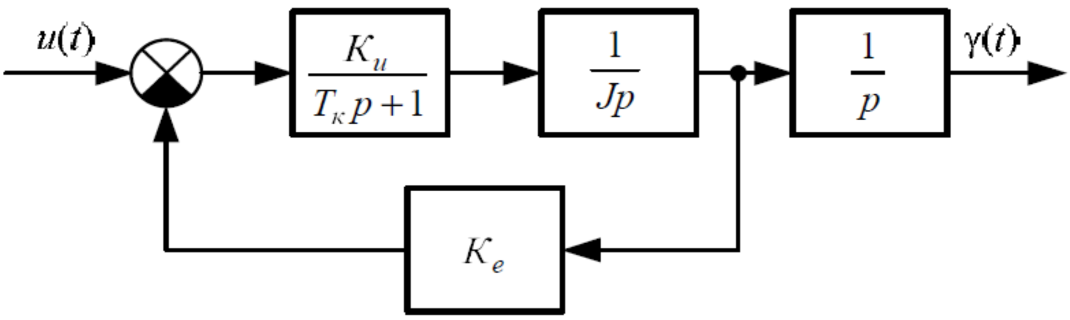

Figure 2. Block diagram of a torque electric drive.

The system works as follows: when the outside air temperature decreases and the atmospheric pressure increases, unidirectional valves forcibly open the inlet openings, and air from the atmosphere flows through the inlet channels into the airtight elastic hollow elements until the pressure equalizes outside and inside the hollow elements. In this case, there is a stepwise stretching of airtight elements due to possible changes in atmospheric pressure, which continues until they are filled with cold air to the maximum. When the ambient air temperature rises above +1°C, the temperature sensor sends a signal to the input device that converts the signal from analog to digital, then to the EPROM block. The EPROM block performs calculation transactions in accordance with the algorithm, namely, compares the received digital signals from the input device with the EPROM pre-programmed optimal temperature environment. If the optimal ambient air temperature does not match, the EPROM block signals the electric drive to close the adjustable louvres to prevent heated streams through the enclosing module [7].

The MATLAB mathematical modeling system was used to analyze the obtained model of a torque electric drive. The purpose of the simulation was to verify the identity of the received analog and digital models of the torque electric drive.

The block diagram of the experiment with an analog and discrete drive model created in the MATLAB&Simulink package is shown in figure 3.

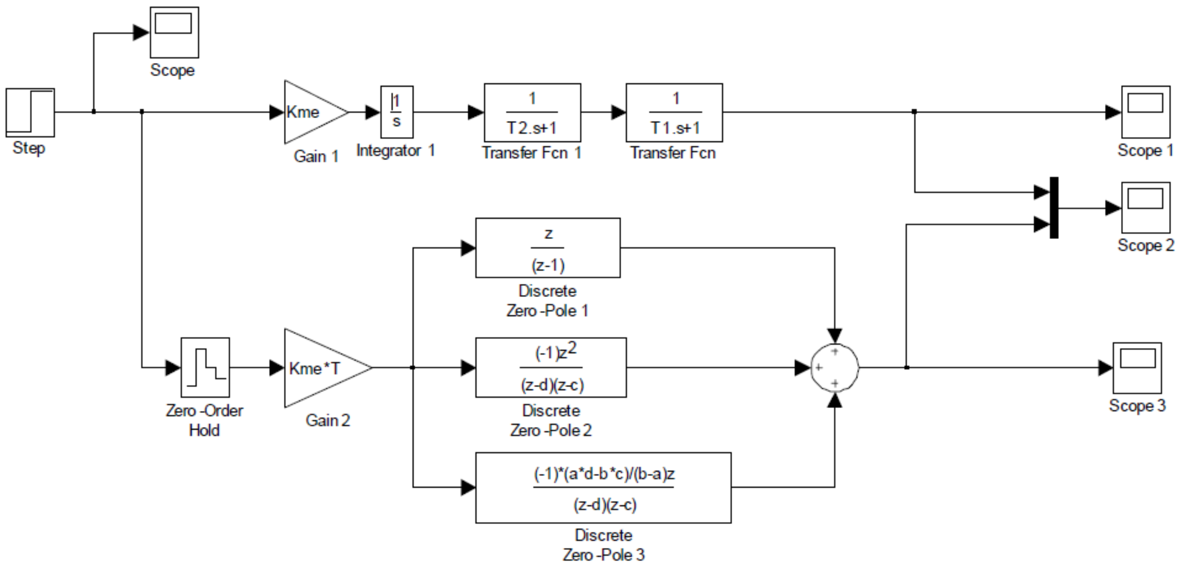

Figure 3. Block diagram with analog and discrete electric drive model.

The reaction of torque electric drive models to a power surge is shown in figure 4. From the coincidence of the graphs, one can conclude that the analog and digital models of the torque electric drive are identical.

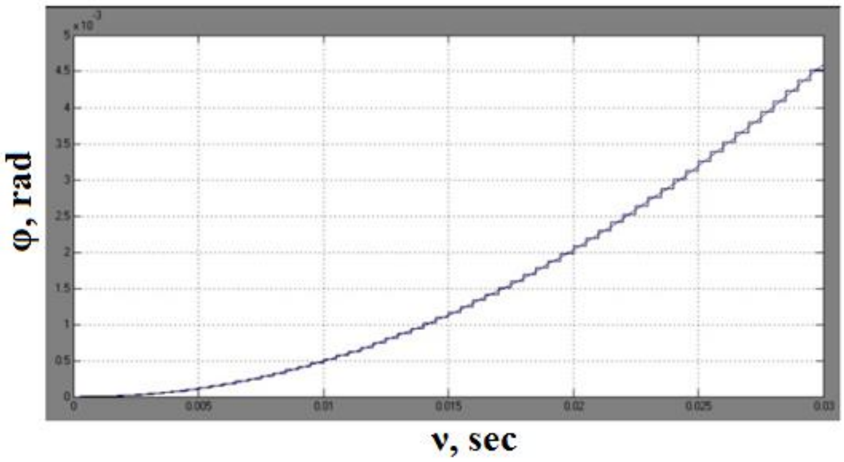

Figure 4. Electric drive response to power surge.

4. Conclusion

The efficiency increasing of the torque electric drive of the enclosing structure is analyzed, the simulation model of the torque electric drive is developed, and a model of the control system of the enclosing structure in the language of MATLAB&Simulink is designed. The research results are presented in the software package Arduino and expressed in the form of software research model of drive operation of the ventilated underground of building enclosing structure in the permafrost zone [8].

References

[1] Smirnov A O, Bukreev V G and Zubrekov A E 2016. Ensuring the sustainability of work of an asynchronous electric drive at low ambient temperatures *Izvestia VUZ. Electromechanics* **4** 41-8
[2] Kopylov I P 2001 Mathematical modeling of electric machines *Vysshaya Shkola* p 274

[3] Bukreev V G, Khokhryakov B G and Smirnov AO 2013 Improving the performance of an asynchronous electric drive with a wave reducer at low ambient temperatures *Izvestiya VUZ. Electromechanics* **4** p 27-31
[4] Smirnov A O, Langraf S V, Kazakov V S and Bekishev R F 2011 Investigation of the dynamic modes of operation of a frequency-controlled asynchronous electric drive at low temperatures *Izvestiya TPU* **4** 107-10
[5] Karakulov A S and Langraf S V 2006 Development of a control system for an electric drive of stop valves by the method of separation of mathematical models of control objects *Izvestiya VUZ. Electromechanics* **3** 54-6
[6] Schreiner R T 2000 Mathematical modeling of AC electric drives with semiconductor frequency converters *URO RAN* p 654
[7] Klimov A S et al. 2018 The enclosing structure of the ventilated underground *Russian Federation FIPS Patent* No. 181936
[8] Klimov A S and Stepanyan A S 2020 A program model for research the drive of the enclosing structure of a ventilated underground building in the permafrost zone *Russian Federation FIPS Certificate of state registration of a computer program* No. 2020611559