Application of the feedback mechanism in systems using a direct current motor

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Abstract. This article focuses on the study and modeling of an electric drive control system using a feedback mechanism. It explores the mathematical models of direct current motor operation under varying load conditions, including the description of patterns of current and angular speed. Special attention is given to algorithm for regulating control voltage and angular speed, as well as their impact on the system's dynamics. The paper presents the results of computer simulations and analyzes transitional processes in various operating modes, including abrupt and gradual load changes. Based on the simulations, conclusions were drawn about the stability and efficiency of the proposed control methods and their adaptability to enhance overall system reliability.

1 Introduction

The direction of creating digital counterparts of physical objects and processes is becoming more and more popular every year. Efficient control of electric drives, especially under changing load conditions, plays an important role in modern technical systems. This is especially important for dynamic systems, where deviations in engine operating parameters can lead to overloads and reduced efficiency [1-3]. Electric drives are used in areas such as industrial equipment, vehicles, energy, and automation. The management of these devices requires the development of stable and adaptive systems that effectively compensate for load fluctuations and external disturbances [4].

Feedback control systems are an important tool for speed and current stabilization in direct current (DC) motors. They provide correction of engine parameters based on deviations from the preset mode, which minimizes transients and improves dynamic performance. For example, the works [5-6] discuss methods such as the use of combined

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feedback and forward coupling, as well as proportional-integral-differential regulators to improve the accuracy and stability of the drive.

Additionally, the introduction of adaptive management models, such as Model Reference Adaptive Control (MRAC), makes it possible to more effectively compensate for load changes. This is confirmed by studies where MRAC has shown superiority over traditional methods due to the rapid achievement of a stable state [7-8]. The modeling of transient modes and load change modes emphasizes the importance of selecting appropriate control parameters to ensure energy efficiency and reliability [7].

2 Materials and methods

A model consisting of a DC motor, a controlled object, a tachometer, and an electronic control device was used as the studied automatic control system.

The motor drives the shaft, which is connected to the controlled object, creating rotation. The tachometer is connected to the shaft and measures the angular velocity of the rotor, generating an output voltage proportional to this speed. This voltage is transmitted to an electronic control device, which compares it with a preset value. If the current angular velocity value differs from the set value, the control device adjusts the control voltage applied to the motor armature. This feedback allows the system to adjust the angular velocity and stabilize it when the mechanical load changes [7-8].

Using the basic formulas of the engine operation, a Python program was written to simulate the behavior of the engine when the external load changes. It shows how the angular velocity of the rotor (ω) and the armature current (i) change when the motor is switched on and when the load on the shaft is sharply increased. The program used includes a cycle in time (t) and graphs $\omega(t)$ and $i(t)$ are constructed. The Matplotlib library for data visualization with two-dimensional and three-dimensional graphics was used to build simulation graphs.

Table 1 shows the required constant values for system modeling.

Table 1. Constants of the feedback system modeling program.

The constant	Numeric value	Description
I	0,5	Moment of inertia of the motor rotor
K1	0,8	The coefficient of proportionality between angular velocity
K2	1,2	The coefficient of proportionality between the armature current and the torque generated by it
K3	0,05	The coefficient of proportionality between angular velocity and braking torque

Figure 1 shows the algorithm for the functioning of a feedback system simulation program.

3 Practical implementation

We will test the scheme of functioning of the feedback system modeling program. The results of the program's operation during the operation of the feedback system are shown in Figure 1.

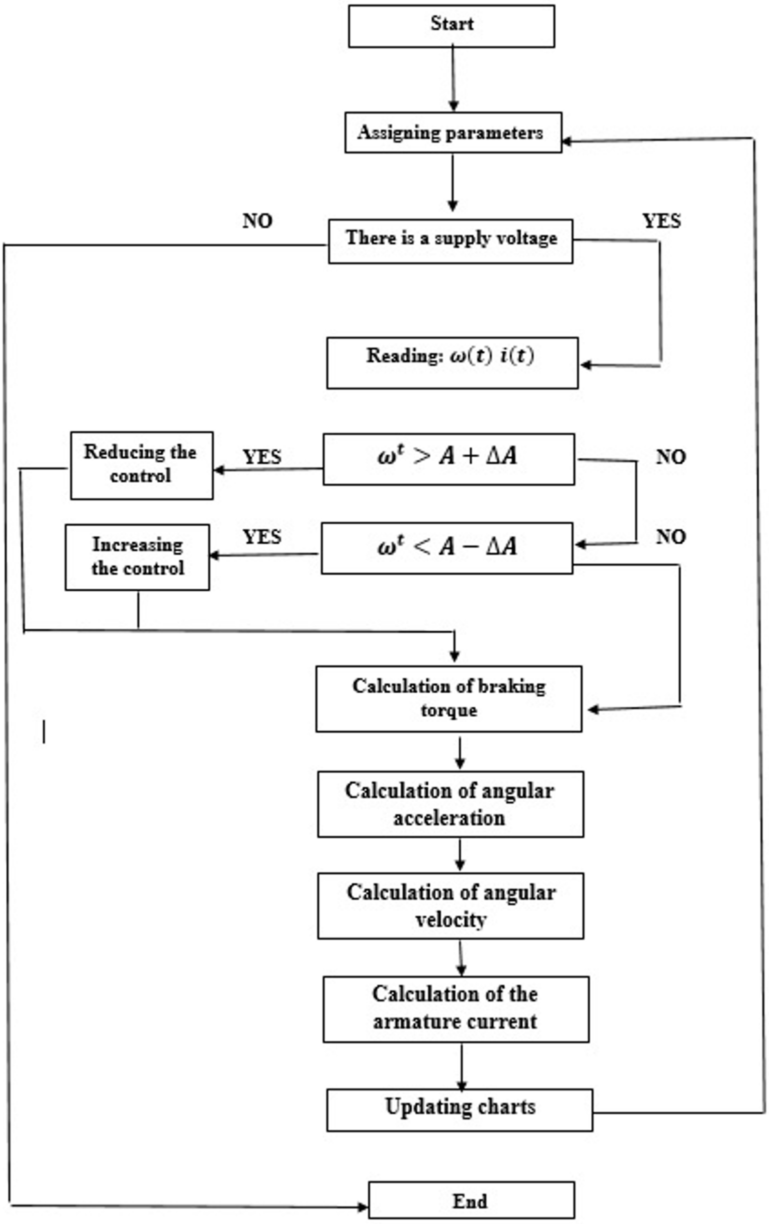

Fig. 1. The algorithm of the feedback system simulation program.

Figure 2 and 3 show the armature current is represented in blue, the angular velocity is represented in green, and the load torque is represented in red. The figure shows that when the system is switched on, the initial angular velocity $\omega = 0 < A - \Delta A$. This leads to an increase in the control voltage u. This causes an increase in the armature current i and the angular velocity ω. When ω reaches the value $A - \Delta A$, the control voltage begins to decrease, which causes a decrease in speed. After several damped oscillations, the system stabilizes, keeping the angular velocity in the range $A - \Delta A \leq \omega \leq A + \Delta A$.

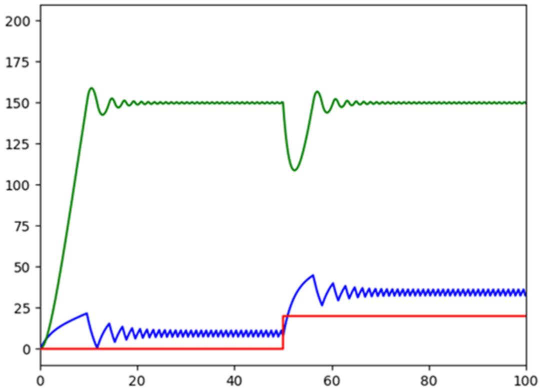

Fig. 2. The results of computer simulation of the feedback system.

As the load on the shaft increases, the angular velocity ω decreases, and the current i and voltage u increase. After that, they undergo damping fluctuations again and stabilize under new conditions. However, when stabilized, the graphs of ω and i have a "jagged" character due to constant small adjustments of the control voltage.

Such a "jagged" graph structure indicates constant small fluctuations in the system parameters around a steady value. This can be a disadvantage, especially in systems where high accuracy and smooth operation are important, for example, in systems with sensitive loads or in mechanisms where speed fluctuations can cause additional vibrations and wear.

If the control voltage u is changed proportionally to the deviation of ω from the set value A, then theoretically the graph can become "smooth". This approach will ensure a smoother voltage change and eliminate small fluctuations, which will increase stability and reduce vibrations. However, this will increase the system's response time to sudden load changes, which should also be taken into account when designing.

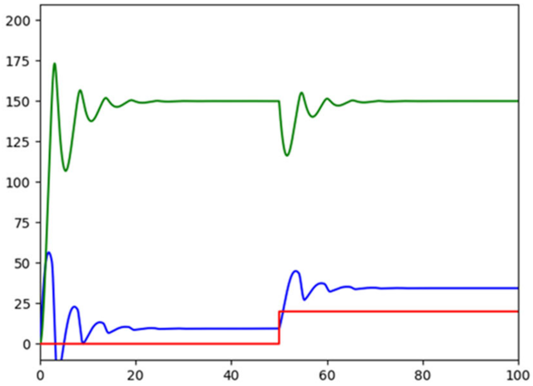

Fig. 3. Results of computer simulation of the operation of a feedback system with proportional change u.

Based on Figure 2, it can be seen that the system behaves in a similar way, in comparison with the fixed control system. However, it can be noted that after start, when the angular velocity ω reaches the set limits $A - \Delta A \leq \omega \leq A + \Delta A$, the armature current i goes into the region of negative values, which reflects the process of active braking of the system. After several attenuating oscillations, the system stabilizes, keeping ω within a set range. When the system is stable and in a state of equilibrium, the graphs of the armature current i and the angular velocity ω become smooth.

The proportional control system demonstrates a smoother and faster stabilization of the angular velocity ω compared to the fixed control system. Due to the dynamic change of the control voltage u, it effectively compensates for deviations that occur when the load changes. This minimizes the amplitude and duration of the oscillations, ensuring stable operation in steady state. However, this scheme requires careful adjustment of the control coefficients. Incorrect parameters can lead to undesirable effects, such as negative values of the armature current i, which may be undesirable in some practical tasks.

4 Conclusion

The article investigates and models an electric drive control system using a feedback mechanism. Mathematical models of the operation of a DC motor under varying load conditions are considered, including a description of the patterns of current change, angular velocity, and load moment. The main attention is paid to the control voltage and angular velocity regulation algorithm, as well as their influence on the dynamics of the system. The simulation showed that feedback control systems significantly increase the stability of the electric drive when the load changes. The proportional control voltage control system provides smoother adaptation and reduces the amplitude of fluctuations, but requires careful adjustment. In the transition mode, significant overloads occur, while a gradual increase in load allows the system to stabilize more smoothly. To ensure reliable and efficient operation, it is recommended to use adaptive control systems with preliminary optimization of parameters.

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