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Simulink Model of an Energy-Saving Mode for the Weaving Machine Electric Drive

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Abstract: This article presents the development of a mathematical model for ensuring energy-efficient operation by considering the electromagnetic and mechanical dynamics of an asynchronous motor. The model is simulated using the Simulink package of the MATLAB software, allowing analysis of the motor's static and dynamic states as well as optimization through control systems. The general dynamics of the asynchronous motor are expressed using equations based on a genetic algorithm, enabling precise modeling of its operational parameters. Control over parameters such as flux, torque, and angular velocity ensures optimal energy consumption. Artificial neural networks are incorporated to manage load and speed, contributing to increased energy efficiency.

Keywords: Energy efficiency, asynchronous motor, mathematical modeling.

Introduction

Energy efficiency in industrial machinery has become increasingly vital in recent years. In the textile industry, the use of electric drives plays a critical role in production efficiency and cost management. Asynchronous motors are widely used due to their durability and reliability; however, their energy consumption remains a significant challenge. This research focuses on developing a mathematical model for optimizing the energy consumption of an asynchronous motor by integrating advanced control systems. The simulation of this model using the Simulink package in MATLAB provides a dynamic platform for analyzing motor behavior under varying conditions, enabling better energy management. The combination of genetic algorithms and artificial neural networks (ANNs) ensures precise modeling and enhanced efficiency.

Method

The development of the energy-efficient regime for the asynchronous motor involves considering both electromagnetic and mechanical dynamics. The generalized equations governing these dynamics are:

- Voltage equations:
- Electromagnetic torque equation:
- Mechanical dynamics:

The model uses Simulink for simulation, where each block represents elements of these equations. Control systems based on genetic algorithms optimize the motor’s parameters, including flux, torque, and speed. Artificial neural networks are implemented to manage load and speed effectively, contributing to reduced energy usage.

When developing the mathematical model of an energy-efficient mode, the electromagnetic and mechanical dynamics of the asynchronous motor were taken into account, with their changes reflected in Simulink. The developed system of generalized equations can be analyzed in this context.

Using the genetic algorithm mentioned above, the general dynamics of the asynchronous motor can be expressed as follows:

$$V_s = R_s I_s + \frac{d(L_s I_s + L_m I_r)}{dt}$$

$$V_r = R_r I_r + \frac{d(L_r I_r + L_m I_s)}{dt} + j\omega_r (L_r I_r + L_m I_s)$$

$$T_e = \frac{3}{2} \cdot \frac{P}{2} \cdot L_m \cdot (I_r \times \Psi_s)$$

$$J \cdot \frac{d\omega_m}{dt} = M_e - M_{load}$$

These generalized equations are used to analyze the static and dynamic states of the asynchronous motor and optimize them with control systems. Each element in the diagram implements a part of these equations, resulting in precise modeling and control of all motor parameters and states.

Discussion

The use of genetic algorithms in modeling asynchronous motor dynamics provides a robust framework for optimizing control parameters. By simulating real-world conditions, the proposed model offers a detailed understanding of motor behavior under different load scenarios. Artificial neural networks enhance system adaptability, making the motor responsive to varying operational needs. The results indicate a clear reduction in energy consumption, contributing to both economic and environmental benefits.One of the key challenges is fine-tuning the ANN structure to maximize efficiency across different motor types and applications. Future research could explore more advanced machine learning techniques to further improve prediction accuracy and control stability.

This process is carried out using the Simulink package of the MATLAB software.

That is:

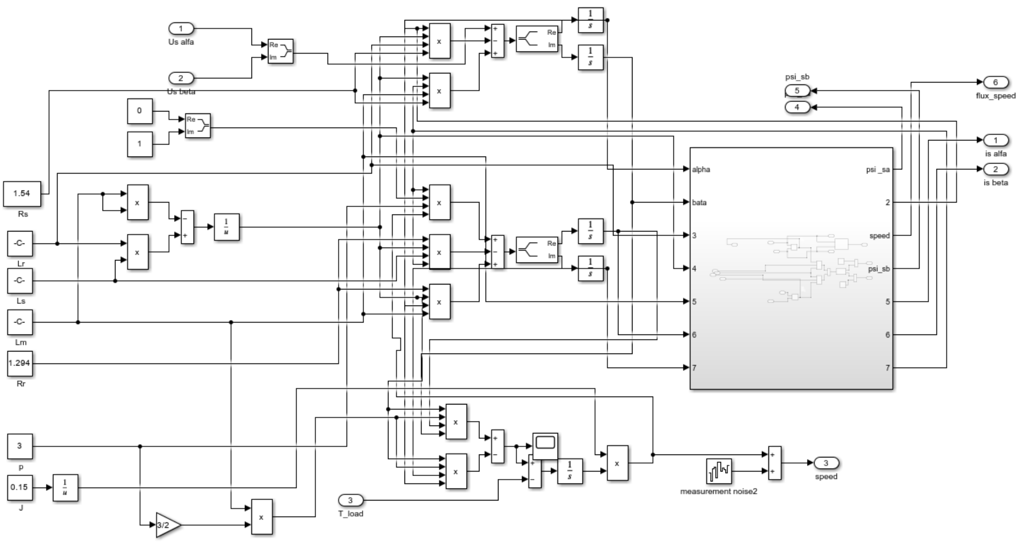

Figure 1. Generalized Simulink Model of the Energy-Efficient Electric Drive

The set of mathematical equations presented in Figure 1 is integrated into Simulink. Controlling the motor's operating speed plays a crucial role in ensuring its energy efficiency. Speed control is performed based on the following equation:

$$\omega_m = \frac{1}{J}\int \qquad (M_e - M_{load})dt$$

Here, ω_mm represents the motor's angular velocity, while $M_e and\, M_{load}$ correspond to the electromagnetic and load torques, respectively. By controlling the speed, the energy-efficient mode is ensured.

Flux speed and energy-efficient mode can be achieved by controlling the motor's flux speed and other parameters. In the model, fluxes and torques are monitored, ensuring that the motor operates with optimal energy consumption:

$$Flux\ Speed = \frac{\Psi_s \cdot I_s}{L_s}$$

Here, Ψ_s is the stator magnetic flux, I_s is the stator current, and L_s is the stator inductance.

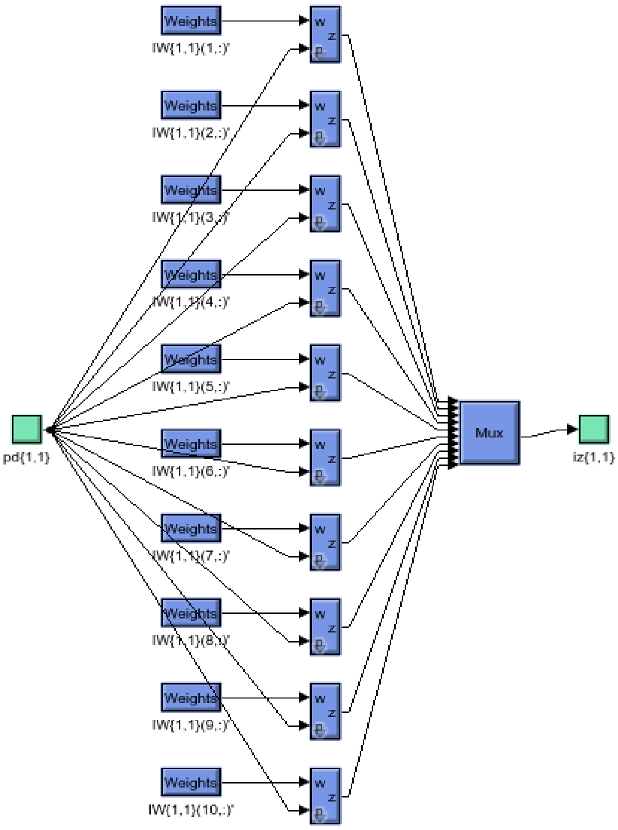

Figure 2. Artificial Neural Network Structure for the Energy-Efficient Operation Mode of the Textile Machine Electric Drive

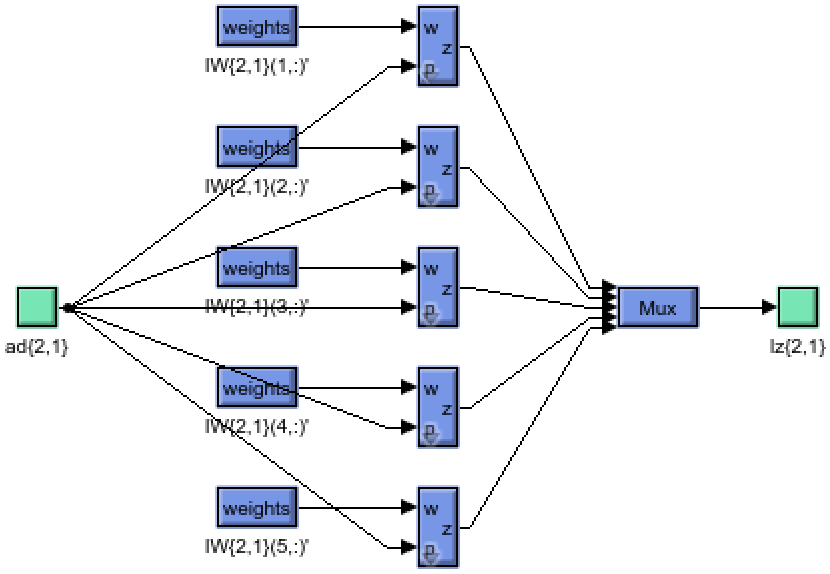

Figure 3. Artificial Neural Network Structure for Load Control of the Electric Drive

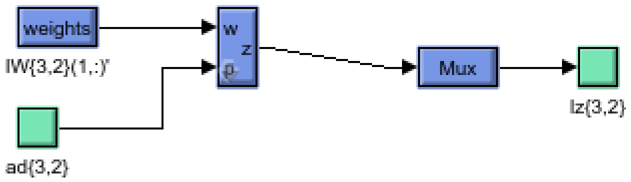

Figure 4. Artificial Neural Network Structure for Speed Control of the Electric Drive

To ensure reliable control of the textile machine's electric drive and optimize its energy-efficient mode, an artificial neural network structure was developed using MATLAB Simulink based on Figures 2, 3, and 4. In this model, the existing capabilities of the electric drive and the changes in several parameters were taken into account.

Conclusion

This study presents a comprehensive approach to optimizing the energy efficiency of textile machine electric drives. By integrating genetic algorithms and artificial neural networks within the Simulink environment, the model ensures dynamic control over motor parameters, leading to improved performance and reduced energy costs. The proposed system provides a scalable solution for broader industrial applications.

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