RESEARCH OF A THREE-PHASE INDUCTION MACHINE WITH A SQUIRREL-CAGE ROTOR IN MATLAB.

Niyazova Nasiba Ashurkulovna
Yuldashev Surojiddin Khasanovich
Tashkent Institute of Textile and Light Industry

Abstract: *The article presents a study of a three-phase induction motor with a squirrel-cage rotor through modeling in MATLAB. It discusses the design features and operating principles of the motor, emphasizing its widespread use in industry, transportation, and household applications due to its simple design, high reliability, and cost-effectiveness. Key characteristics are described, including the dependence of electromagnetic torque on slip, the impact of load on current and rotational speed, and methods for determining efficiency and power factor, which are essential for optimizing electric drive performance. A model was developed in MATLAB using the PowerSystemBlockset library, incorporating a three-phase voltage source, blocks for measuring voltage, current, active and reactive power, electromagnetic torque, and rotational speed, as well as an asynchronous machine block. The model's setup parameters are detailed, including the selection of rotor type, parameters of the stator and rotor equivalent circuits, magnetic circuit characteristics, moment of inertia, viscous friction coefficient, number of pole pairs, and initial simulation conditions. The simulation results are presented, illustrating the time dependencies of the motor's state variables during operation. Particular attention is given to the analysis of electromagnetic and mechanical characteristics, enabling a deeper understanding of energy conversion processes and the optimization of operating modes for induction motors. The study contributes to improving the efficiency of electric drive systems and enhancing the understanding of their operation.*

Keywords: *three-phase induction motor, squirrel-cage rotor, MATLAB, modeling, electromagnetic torque, slip, efficiency, power factor,*

PowerSystemBlockset, electric drive, energy efficiency, parameter setup, time dependencies, mechanical characteristics, electromagnetic characteristics.

Introduction. Three-phase induction motors with squirrel-cage rotors are among the most widely used types of electric motors in modern electric drive systems. Their popularity stems from their simple design, high reliability, durability, and relatively low cost, making them a preferred choice for industrial, transportation, and household applications. The operating principle of these motors is based on the creation of a rotating magnetic field in the stator, which induces currents in the short-circuited rotor bars, causing rotation due to electromagnetic interaction. Key characteristics, such as the dependence of torque on slip, the effect of load on current and rotational speed, as well as efficiency and power factor, play a critical role in optimizing electric drive performance.

Studying the processes occurring in induction motors requires the use of modern simulation tools, such as MATLAB, which enables the creation of accurate models for analyzing electromagnetic and mechanical characteristics. This work presents the development of a model of a three-phase induction motor using the PowerSystemBlockset library, along with an analysis of its behavior under various operating conditions. The study aims to provide a deeper understanding of energy conversion processes, optimize operational parameters, and enhance the efficiency of electric drive systems.

Three-phase induction machines with a squirrel-cage rotor occupy one of the leading positions in modern electric drives. Owing to their simple design, high reliability, and relatively low cost, they have become widely used in industry, transportation, and household applications.

The stator of the machine contains a winding connected to a three-phase supply, which creates a rotating magnetic field. In the rotor bars, short-circuited by end rings, currents are induced that interact with the stator field and produce an electromagnetic torque. The rotor rotates at a frequency slightly lower than the synchronous speed, which is characterized by slip.

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The study of three-phase induction machines includes the analysis of mechanical and energy characteristics: the dependence of electromagnetic torque on slip, the influence of load on current and rotational speed, and the determination of efficiency and power factor. This information is essential for the proper selection and efficient operation of the electric motor in various industrial processes.

The squirrel-cage induction machine is a universal and the most widely used type of electric motor. Its study makes it possible to gain a deeper understanding of electromagnetic energy conversion processes, optimize operating modes, and improve the efficiency of electric drive systems.

Building a model in MATLAB for the study of an induction machine.

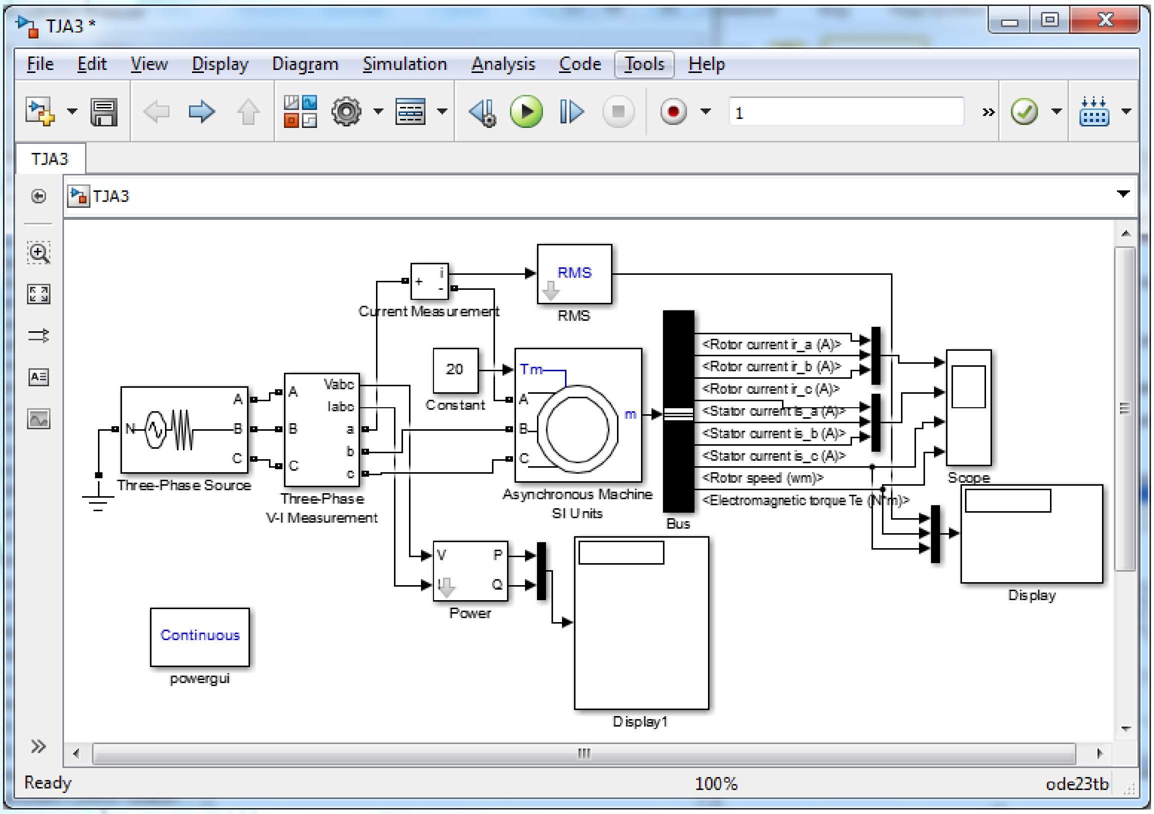


Figure 1. Model for the study of an induction machine

It contains:

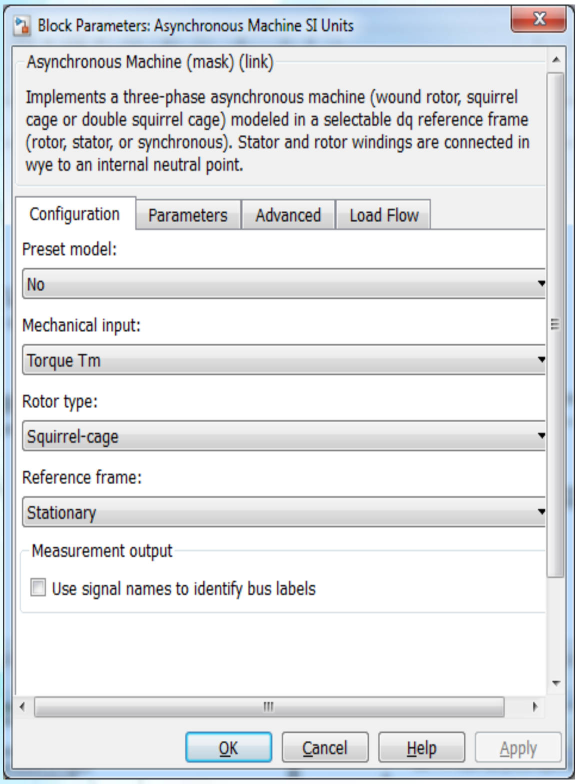
- an AC three-phase voltage source (**Source**) from the library *PowerSystemBlockset / Extras / Electrical Sources*;
- a three-phase voltage and current measurement block (**Three-Phase V-I Measurement**) from the library *PowerSystemBlockset / Extras / Measurement*;

- the studied three-phase induction machine (**Asynchronous Machine**) from the library *PowerSystemBlockset / Machines*;
- an active and reactive power measurement block (**P & Qx**) from the library *PowerSystemBlockset / Extras / Measurement*;
- a **Display** block for the numerical representation of measured powers and a **Scope** block for observing rotor and stator currents, as well as the speed and torque of the induction machine from the main library *Simulink / Sinks*;
- a **Moment** block for applying mechanical torque to the machine shaft from the main library *Simulink / Sources*;
- a **Machines Measurement** block from the library *PowerSystemBlockset / Machines*;
- a **Display1** block for the numerical representation of the measured electromagnetic torque (Nm) and speed (rad/s) of the machine from the main library *Simulink / Sinks*;
- a **Mux** block, combining three signals into a single vector, from the main library *Simulink / Signal & Systems*.

In the fields of the window, the following parameters are set sequentially:

- **Rotor type (Rotor Type)** – in the drop-down menu of this field, either a squirrel-cage or a wound rotor can be selected;
- **Reference frame** for analysis;
- **Power**, rated line voltage, and frequency;
- **Stator equivalent circuit parameters**;
- **Rotor equivalent circuit parameters**;
- **Magnetization branch parameters**;
- **Moment of inertia**, viscous friction coefficient, and number of pole pairs;

- **Initial conditions for simulation** – slip, rotor position, stator currents, and their initial phases.



The parameter setup window of the induction machine is shown in Figure 2.

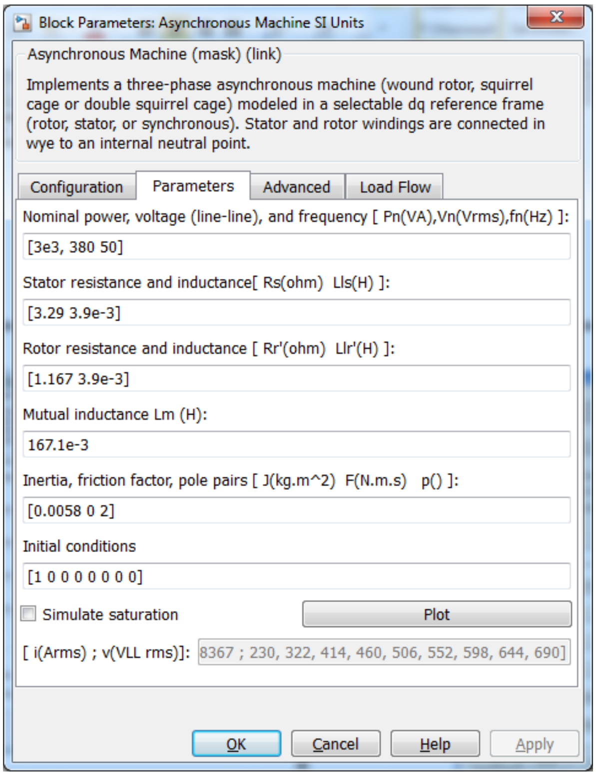


Figure 2.Induction machine parameter setup window

The parameter setup window of the universal machine measurement block is shown in Fig. 3. In the drop-down menu of the **Machine type** field, the type of machine is selected. Checkboxes are used to choose the variables to be measured.

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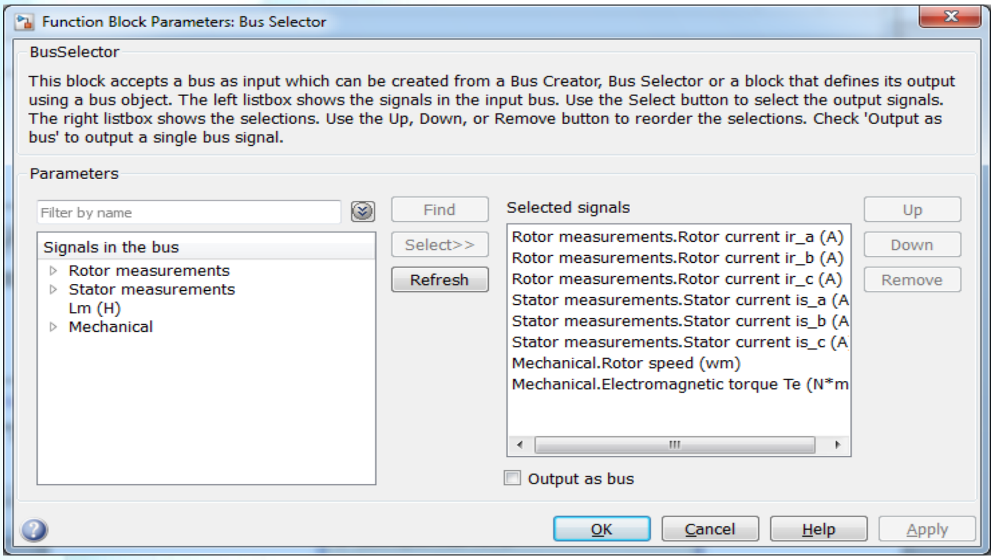

Figure 3. Parameter setup window of the measurement block

The parameter setup window of the power supply is shown in Figure 4. The fields of the window specify:

- **Phase voltage amplitude** of the source (V);
- **Initial phase** in degrees;
- **Frequency** (Hz);
- **Internal resistance** (Ω) and **source inductance** (H).

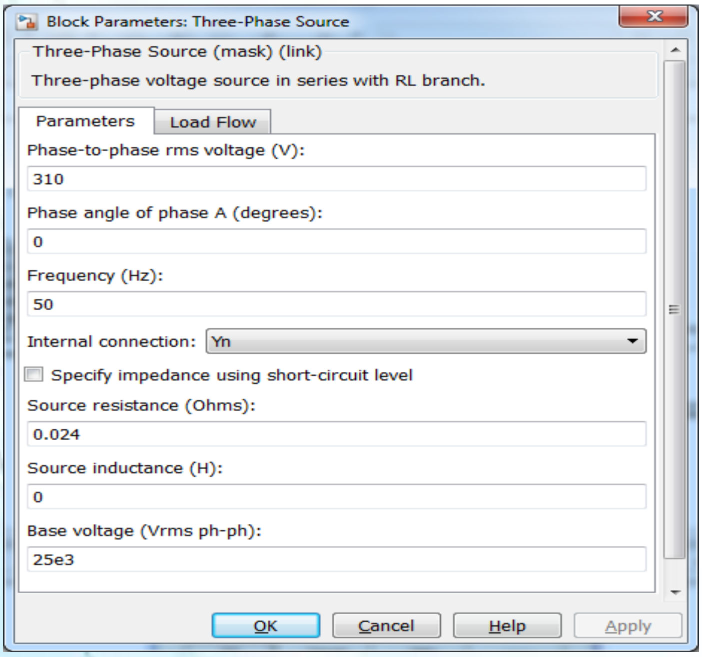

Figure 4. Parameter setup window of the three-phase power supply

The voltage and frequency of the source must correspond to the parameters of the induction machine.

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The parameter setup window of the active and reactive power measurement block is shown in figure 5. Here, only one parameter is set — the frequency, which must be equal to the frequency of the power supply.

The display parameter setup window is shown in Figure 6. In the fields of this window, the format for presenting numerical results is specified, and in the **Decimation** field, the number of calculation steps after which the values are displayed on the display is set. Setting the **Sample time** field to -1 synchronizes the block operation with the simulation step.

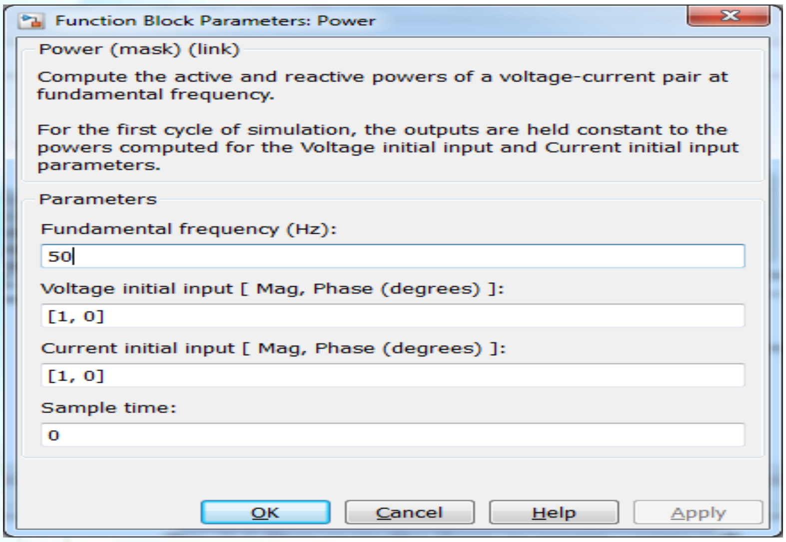

Figure 5. Parameter setup window of the power measurement block

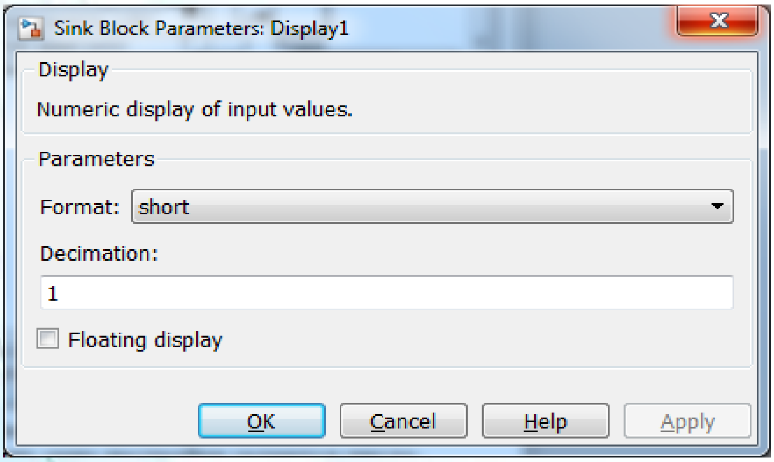

Figure 6. Display parameter setup window

The parameter setup window of the **Mux** block, which combines two signals into a single vector, is shown in figure 7. In the fields of the window, the number of inputs and the block appearance are specified.

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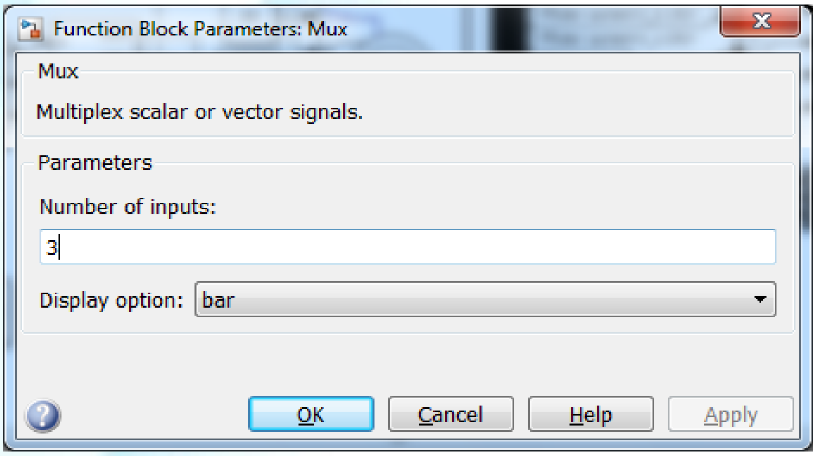
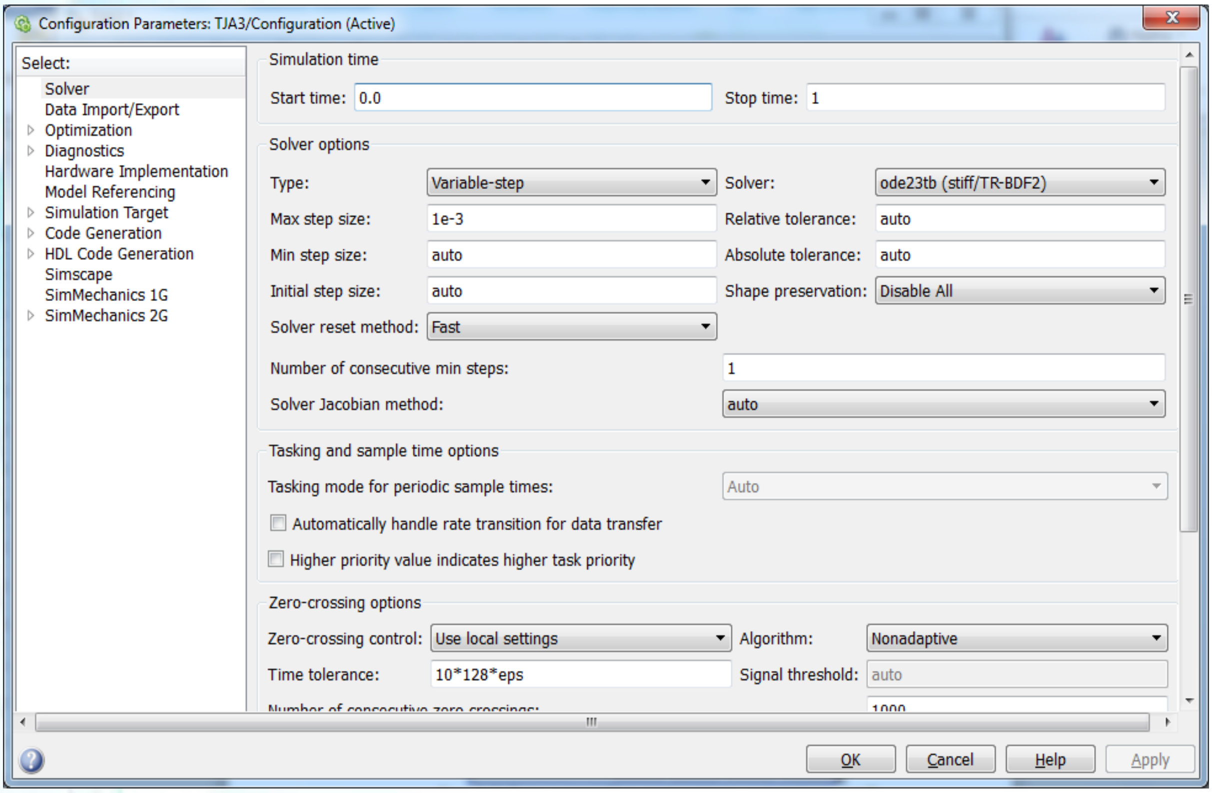


Figure 7. Parameter setup window of the Mux block



The simulation parameter setup window is shown in Figure 8.

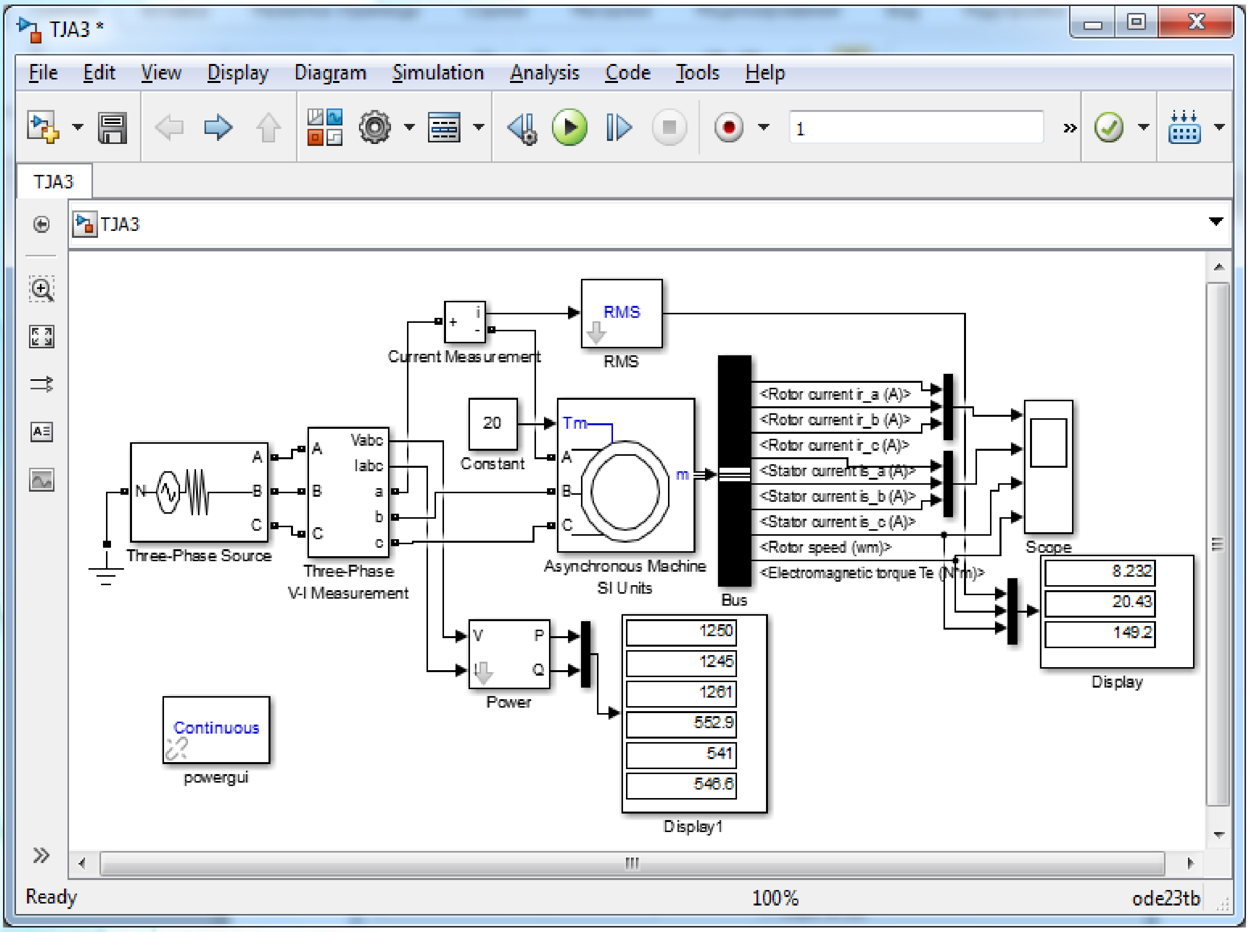


Figure 9. The model for the study of an induction machine after starting the simulation process

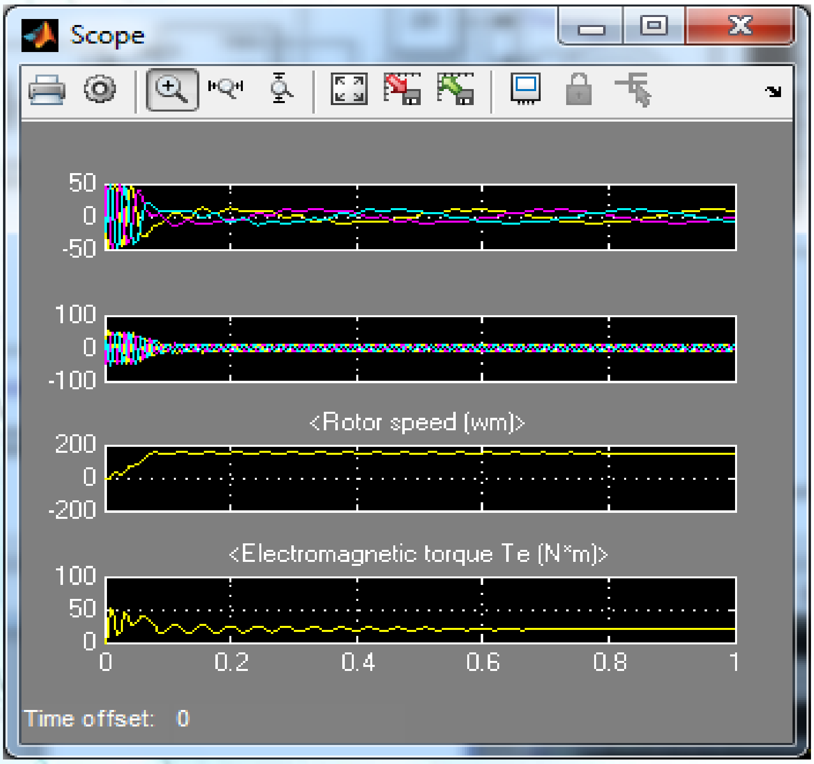


Figure 9. Time dependencies of the machine‘s state variables during operation in motoring mode

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Conclusion. The conducted study of a three-phase induction motor with a squirrel-cage rotor through MATLAB modeling has enabled a comprehensive analysis of its electromagnetic and mechanical characteristics. The developed model, utilizing the PowerSystemBlockset library, accurately reproduced the motor's operational processes, including the dependencies of electromagnetic torque, current, and rotational speed on load and slip. The simulation results confirmed the potential for optimizing operational parameters, such as efficiency and power factor, which are crucial for enhancing the energy efficiency of electric drive systems.

The study highlights the importance of using modern simulation tools like MATLAB/Simulink for analyzing complex electromechanical systems. The obtained data contribute to a better understanding of energy conversion processes in induction motors and can be applied to the design and tuning of electric drives in various industrial applications. Future research could focus on exploring dynamic operating conditions, implementing control methods, and developing energy-saving algorithms for induction machines.

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