MODERN EDUCATION AND DEVELOPMENT
ISSN 3060-4567

CONTROL AND MANAGEMENT OF THE REACTIVE POWER OF AN ASYNCHRONOUS MOTOR THROUGH THE MODELING ALGORITHM OF CURRENT CONVERTERS

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Abstract: *In this article, models and mathematical expressions are presented for studying the processes, quantities and parameters in the electrical and magnetic conversion elements and structures of three-phase electromagnetic current converters used in control and management systems of asynchronous-motor reactive power.*

Keywords: *asynchronous motor, reactive power, converter, model, algorithm, control, element.*

Introduction

Scientific research is being carried out to improve the elements and devices of systems for monitoring and controlling the reactive power of asynchronous motors. In these studies, the main task is to provide the appropriate signals for the control and management of the reactive power of asynchronous motors. For this purpose, the modeling of various current converters and their signal-conversion processes based on optimal algorithms plays an important role in monitoring the reactive power, planning the generated and consumed reactive energy, saving it, and controlling the sources of reactive power.

The process of converting the stator currents of an asynchronous motor into an output signal in the form of a secondary normalized voltage, and the modeling and investigation of the devices and converters participating in this process, are carried out based on models and algorithms [1, 4, 5, 8].

ISSN 3060-4567

1. Modeling of Conversion Processes

- When the asynchronous motor is connected to the power source, the model of the process converting the network voltage U_1 into the magnetic motive force F_0 is developed (Figure 1).

Figure 1. Model of the process of converting the primary voltage U_1 into the magnetic motive force F_0.

- A model of the process of converting the stator current I_1 of the asynchronous motor into the leakage magnetic motive force $F\sigma$ is developed (Figure 2).

Figure 2. Model of the process of converting the stator current I_1 into the leakage

magnetic motive force $F\sigma$.

- The analytical relationship between the magnetic motive forces F_0 and $F\sigma$ of the magnetic conversion element and the primary electric circuit quantities I_1 and U_1 is formulated as:

$$F_0 = KU_1F_0 \times U_1 \qquad (1)$$

$$F\sigma = KI_1F\sigma \times I_1 \qquad (2)$$

where KU_1F_0 and $KI_1F\sigma$ are the inter-circuit coupling coefficients of converting electrical quantities into magnetic quantities.

- A model of the mutual relationship between the main magnetic motive force F_0 of the asynchronous motor and the main magnetic flux Φ_0 is developed (Figure 3).

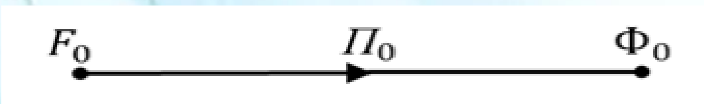

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Figure 3. Model of the process of converting the main magnetic motive force F_0 into the main magnetic flux $Ф_0$.

➢ A model of the mutual relationship between the leakage magnetic motive force Fσ and the leakage magnetic flux Фσ of the asynchronous motor is developed (Figure 4).

Figure 4. Model of the process of converting the leakage magnetic motive force Fσ into the leakage magnetic flux Фσ.

➢ A model of the process of converting the magnetic flux $Ф_1$, which passes through the measuring element, into the secondary output voltage Uoutput is developed (Figure 5).

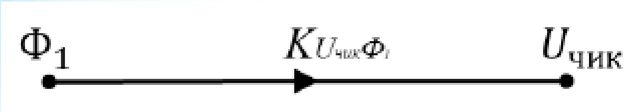

Figure 5. Model of the process of converting the main magnetic flux $Ф_1$ into the output voltage Uoutput.

Here Φ_1 is the main magnetic flux generating the electromotive force (EMF) in the measuring coil, and $\Phi_1 = \Phi_0 - \Phi\sigma$.

The analytical expression of the process of converting the main magnetic flux $Ф_1$ into the secondary output voltage Uoutput is written as:

$$Uoutput = K\Phi_1 Uoutput \times \Phi_1 \qquad (3)$$

where $KФ_1$Uoutput is the inter-circuit coupling coefficient of converting the main magnetic flux $Ф_1$ into the secondary output voltage Uoutput.

2. Modeling the Process of Converting Electrical Quantities

When the asynchronous motor is connected to an electrical network with voltage U_1, the process of changing the stator current I_1, the magnetic motive forces F_0 and Fσ, the magnetic fluxes $Ф_0$ and Фσ, and the secondary output voltage Uoutput is represented as a graphical model (Figure 6).

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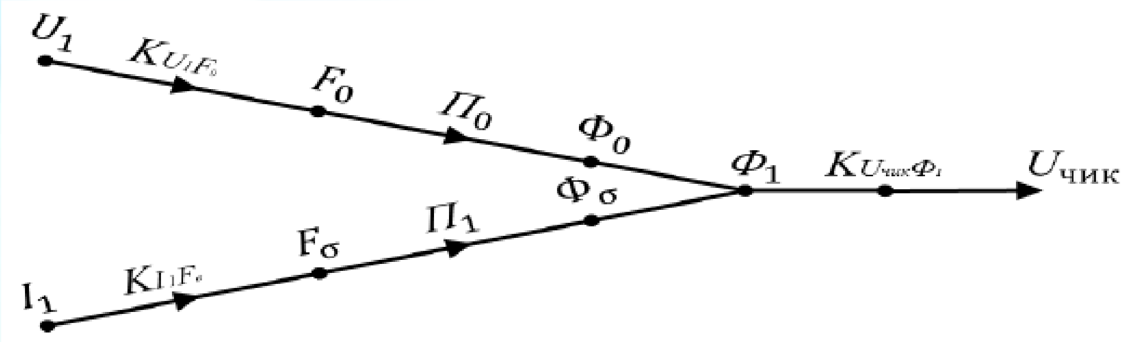

Figure 6. Model of the process of converting U_1 voltage, I_1 stator current, F_0 and $F\sigma$ magnetic motive forces, Φ_0 and $\Phi\sigma$ magnetic fluxes into the secondary output voltage Uoutput.

In asynchronous motors, the control and monitoring signal is generated based on an additional winding placed between the main winding and the slot wedge of the stator. The algorithm for modeling the conversion process of the measured magnetic flux into the output voltage Uoutput is expressed as:

$$Uoutput = P_0 \times KU_1F_0 \times F_0 + P\sigma \times KI_1F\sigma \times F\sigma \qquad (4)$$

where P_0 and $P\sigma$ are the magnetic and electrical parameters of the asynchronous motor.

In expression (4), the component $\boldsymbol{Uoutput_0 = K_0 \times U_1}$ **(5)** represents the part of the output voltage dependent on the network voltage U_1, and it remains constant during operation. The other component $\boldsymbol{Uoutput\sigma = K\sigma \times I_1}$ **(6)** depends on the stator current I_1, and its value changes proportionally with current variations.

Therefore, according to analytical expression (6), by changing the inter-circuit coupling coefficients and parameters that affect the variable component, the relationship between the stator current of the asynchronous motor and the output voltage can be studied. The results are shown in Figure 7.

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3. Energy and Signal Conversion Model

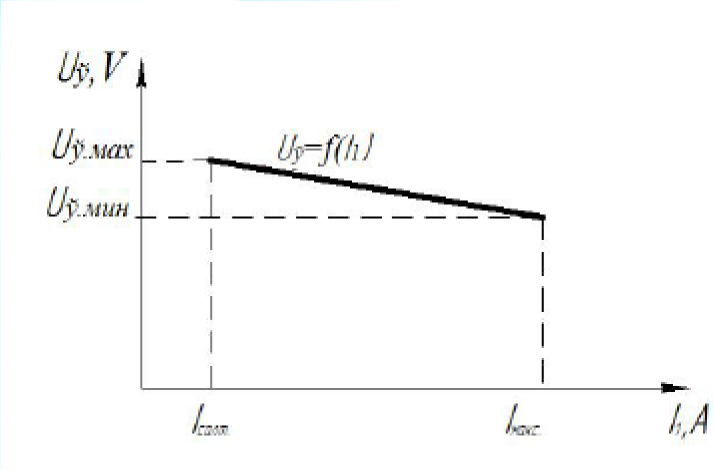

Figure 7. Graph of the Dependence of Output Voltage on the Stator Current of the Asynchronous Motor.

A chain model of the process of converting relationships between the asynchronous motor stator current I_1 and converter output voltage component Uoutput σ into energy and secondary quantities is shown in Figure 8.

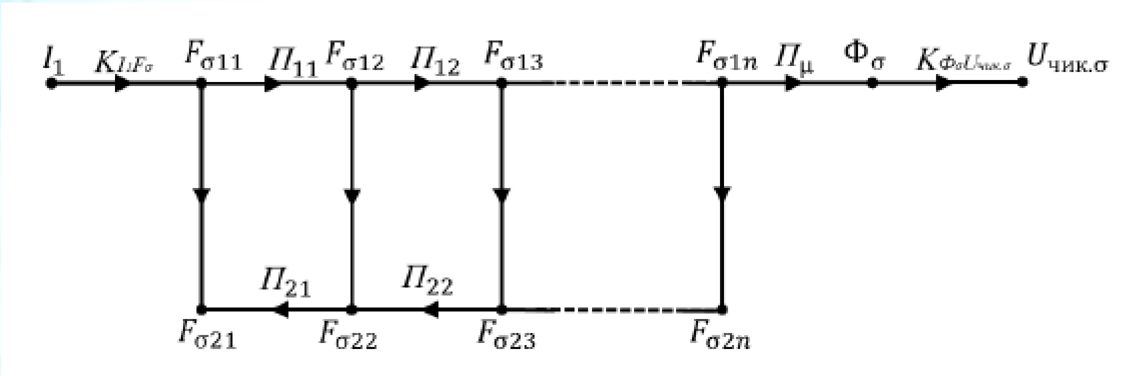

Figure 8. Model of the process of energy and signal conversion between the stator current I_1 and the converter output voltage Uoutput σ.

The analytical form of the chain model of the process of conversion of energy and signal relationships between the stator current I_1 and the converter output voltage Uoutput σ is expressed as:

$$Uoutput\ \sigma\ =\ W\sigma\ (F\sigma_{11}, F\sigma_{1n})\ \times\ K\sigma\ \times\ I_1 \qquad (7)$$

where $W\sigma\ (F\sigma_{11}, F\sigma_{1n})$ represents the transmission coefficient of the signal conversion part of the converter between the first (1,1) and nth (1,n) nodes of the distributed-parameter energy-and-signal-conversion model describing the relationships between the stator currents of the asynchronous motor and the converter output voltage.

Conclusion

A graphical model and its construction algorithm were developed, enabling the study of the distribution of magnetic quantities and parameters formed in the magnetic parts of the measuring-coil current converter used for control and management of the reactive power of an asynchronous motor. Based on this model, the method of normalizing output-signal values (5 V) in voltage form through studying the parameters of the conversion section has been improved.

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