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The Current Transducers For Monitoring And Controlling The Reactive Power Of An Asynchronous Motor

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Abstract: This in the article asynchronous motor is reactive power control to do and manage for from the transformer used. The main element of the current transformer is the measuring instrument, i.e. the sensitive element. Depending on the number of asynchronous motor stator blades, the measurement sensitive element is placed between the main winding and the rotor as a two-ring or three-ring. Measurement accuracy, reliability, and sensitivity increase compared to an independent measuring device. The measuring element loops are independent or connected in series . When the measurement loops are connected in series, the amount of output voltage is doubled. This is explained by the main formulas and schemes that ensure the output of the signal in the form of voltage due to the main and stray magnetic currents generated in the asynchronous motor stator coil. To control the signal in the form of voltage, a method of placing the measuring coil in the form of independent, parallel and series connected loops based on the number of asynchronous motor stator phases has been developed. Taking into account the interaction of various external quantities, the accuracy, reliability and errors of the signal received from the measuring instrument are considered. The static and dynamic characteristics of the current transformer used in the control and management of the reactive power of an asynchronous motor are presented. Due to the difficulties arising in the formation of differential equations describing the transition processes in the primary currents in the secondary signal transformation sections of the asynchronous motor stator coil, signal transmission elements, the research is based on the advanced mathematical apparatus - the graph model and its analytical expressions. To control and control the reactive power of an asynchronous motor, a cumulative and distributed parameter model has been developed, which allows to study the distribution of magnetic quantities and parameters generated in the magnetic pieces of the current transformer with controlled output voltage.

Key words: Asynchronous motor. Primary stator current. reactive power, tension a signal in the form of a sensitive element, a graph model,

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1. Introduction

Extensive scientific research is being carried out in the world to improve the elements and devices of control and management while providing consumers with high-quality and uninterrupted electrical energy. In particular, expanding the capabilities of the system for monitoring and controlling reactive power in asynchronous motors, one of the most common consumers of electricity, is one of the urgent tasks. And these opportunities are explained by such indicators as high accuracy, speed, reliability and sensitivity of elements and devices for replacing signals, the quality and continuity of the signals they provide. In developed countries, scientific research on this issue and their application in practice are considered top priorities.

A number of research works are being carried out in the world to improve the elements and devices of the control and management system for the reactive power of an induction motor. In these studies, the main task is to provide appropriate signals to control and control systems for reactive power of asynchronous motors. To achieve this goal, significant importance is given to control, planning of production and consumption of electricity, modeling of processes on different converters and in their composite structures based on rational algorithms. When developing means for controlling the magnitude and parameters of the reactive power of an induction motor, digital technologies are widely used. Also relevant issues are the development and creation of elements and tools that provide the modeling process, and on their basis the development of new structures and the creation of converter installationswhen your works is submitted for the initial review stage.

2. Metods

The reactive power consumed by the controlled and controlled asynchronous motor, when the power supply system was turned on, was used by single-phase, three-phase or sensing elements of a three-phase current converter.

. During the study of the process of consumption of reactive power by an asynchronous motor, an equivalent circuit was drawn up and performance characteristics were obtained based on analytical expressions.

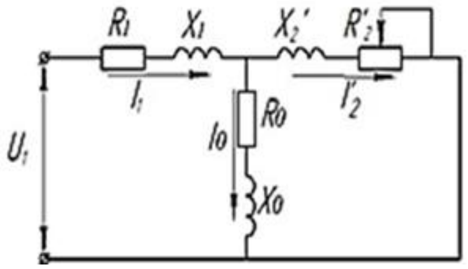

Fig.1. The equivalent circuit of an asynchronous motor.

The equivalent circuit of the operating characteristic of an induction motor made it possible to express the consumed reactive power by the following expression:

$$Q_A = \frac{P\,tg\varphi}{\eta} = \frac{P_{ном}}{\eta_{ном}}\left(\frac{I_0}{I_{ном}\cos\varphi_{ном}} + \beta^2\cdot\left(tg\varphi_{ном} - \frac{I_0}{I_{ном}\cos\varphi_{ном}}\right)\right)$$

where P, $I_{ном}$, I_1 and I_0, $tg\varphi_{ном}$ and $tg\varphi$, $cos\varphi_{ном}$, β and η are, respectively, the operating active power, the rated, operating and no-load current consumed by the motor, rated and operating reactive power, active power, load and efficiency factors.

Based on the analysis, it can be concluded that the consumed reactive power of an induction motor depends on its load in the operating state, which is explained by a change in the magnetic leakage flux in the stator part.

A preliminary analysis of primary current converters of asynchronous motors and a comparative assessment of their capabilities show that for monitoring and controlling the reactive power of an asynchronous motor, the presence of a stator magnetic system, ease of placement of sensitive elements, with high reliability and efficiency, the most promising are converters of signals of primary three-phase stator currents to signals in the form of tension.

When an electric source with voltage U1 is connected to the inputs of the stator coils of an induction motor, current I_1 flows through the coil, while the main and stray magnetic currents are formed on the basis of the magnetic driving force F_1 and $F_{\sigma1}$. The T-shaped circuit for switching on an asynchronous motor with a measuring circuit provides an adjustable output voltage. Based on the equivalent circuit, the electromotive force generated in the measuring coil and shown in fig.1.

Modeling of the control current converter and control of the reactive power of an asynchronous motor", the processes of converting the signal of an electromagnetic converter of three-phase primary currents into secondary output voltages for control systems and control of reactive power of an asynchronous motor, as well as models and algorithms for studying conversion sections, the capabilities of the cloud computing model, converter structures and principles of physical and technical effects of signal conversion.

A graph model (Fig. 2) of the formation of an alternating output voltage in three-phase three-sensitive elemental current converters for monitoring and controlling the reactive power of an asynchronous motor has been developed.

The flow of primary currents through the stator windings of an induction motor creates Fσ-magnetic driving forces and Φσ-magnetic fluxes, and the secondary output voltage is formed as a result of the passage of these magnetic fluxes through sensitive windings.

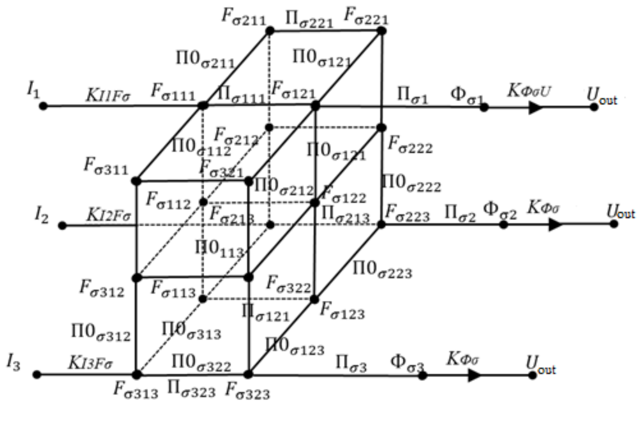

Fig.2. Graph model of an electromagnetic three-phase current-to-voltage converter of an asynchronous motor.

Based on the graph model, an analytical expression for the dependence of magnetic driving forces in the nodes of the stator part on magnetic fluxes has been developed:

$$\begin{cases} \dfrac{F_{\sigma 111}-F_{\sigma 121}}{\Pi_{\sigma 111}}+\dfrac{F_{\sigma 111}-F_{\sigma 211}}{\Pi_{\sigma 211}}+\dfrac{F_{\sigma 111}-F_{\sigma 112}}{\Pi 0_{\sigma 112}}=K_{I_1F_\sigma} I_1/\Pi_{\sigma 1}; \\ \dfrac{F_{\sigma 213}-F_{\sigma 223}}{\Pi_{\sigma 213}}+\dfrac{F_{\sigma 213}-F_{\sigma 212}}{\Pi 0_{\sigma 212}}+\dfrac{F_{\sigma 213}-F_{\sigma 113}}{\Pi 0_{\sigma 113}}=K_{I_2F_\sigma} I_2/\Pi_{\sigma 2}; \\ \dfrac{F_{\sigma 313}-F_{\sigma 323}}{\Pi_{\sigma 323}}+\dfrac{F_{\sigma 313}-F_{\sigma 113}}{\Pi 0_{\sigma 313}}+\dfrac{F_{\sigma 313}-F_{\sigma 312}}{\Pi 0_{\sigma 312}}=K_{I_3F_\sigma} I_3/\Pi_{\sigma 3}. \end{cases}$$

The principle of construction of the developed current-to-voltage converter consists of a stator core 1, stator slots 2, main 3 and additional 4 windings and slot wedges 5. Additional windings are placed in the direction of the leakage magnetic flux in the stator slots. These magnetic fluxes generate signals in the form of voltage at the outputs of the sensing elements. When the current-to-voltage converter is located in the slots of the stator of the asynchronous motor, a perpendicular intersection of magnetic fluxes with the sensing element is ensured

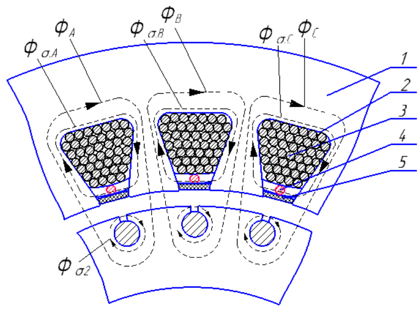

Fig. 3. The location of the measuring winding of the current-to-voltage converter in the stator slots of the asynchronous motor and the type of magnetic fluxes:
1-magnetic stator core, 2-stator slots, 3-main stator winding, 4-measuring winding, 5-slot wedges.

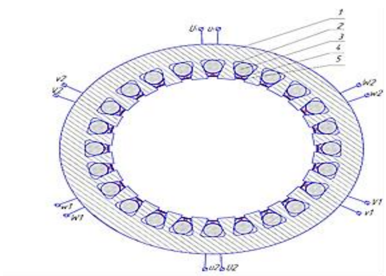

Fig. 4. General view of the stator part of a three-phase asynchronous motor with measuring windings:
U1-U2, V1-V2, W1-W2 - the ends of the three-phase stator windings, u1-u2, v1-v2, w1-w2 - three-phase measuring windings

The layout of the measuring windings as a sensitive element in the stator slots is performed in the same way as the layout of the main stator windings

Connection of measuring winding rings in series with each other. In this converter, the change and regulation of the primary currents flowing in the stator coils of an asynchronous motor is carried out on the basis of magnetic currents. Two independent rings connected in series with the sensing elements of a current converter with adjustable output voltage are shown in fig.5.

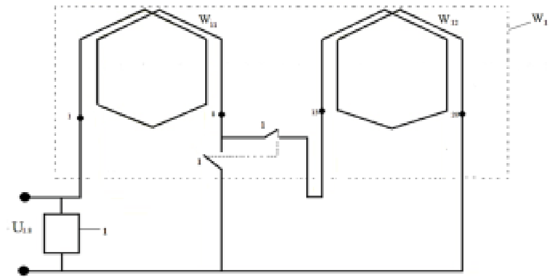

Fig 5. Current converter with adjustable output voltage with two independent rings of measuring windings connected in series

The measuring circuit W_1,, which converts the primary current I_A of one phase of the stator winding of an asynchronous motor into a secondary voltage U_a, consists of two independent rings of measuring windings W_{11} and W_{12}, depending on the position of the variable blocking contacts K_{11} and K_{12} of the controller K_1 directly, separately or in series. When an asynchronous motor is connected to the network, the value of the output voltage U_a of one independent measuring ring of the measuring windings W_{11} is determined as follows:

$$U_{a\Sigma} = U_a = U_{1,8} = \left(4{,}44 \cdot f \cdot W_{c1} \cdot \frac{I_A}{R_\mu}\right) W_{11}$$

f-frequency; W_{c1} - the number of turns of the stator winding of phase A of the induction motor; W_{11}=W_{12}-measuring coils of the transducer.

If the leakage magnetic flux created by the primary current of one phase of the asynchronous motor is insufficient for the operation of the K_1 controller, which receives the output voltage of the converter, that is, the value specified in the regulatory standards for measurements and controls is less than — 5 Volts, then the K_1 controller program, based on which contact K_{12} is connected, and the output voltage value is determined as follows:

$$U_{a\Sigma} = U_{1,8} + U_{14,15},$$

$$U_a = \left(4{,}44 \cdot f \cdot W_{c1} \cdot \frac{I_A}{R_\mu}\right)(W_{11} + W_{12}).$$

If W_{11}=W_{12}, then K=2, that is, the total voltage is twice the voltage of one current transformer coil: $U_{a\Sigma}=2U_a$

The expansion of the measurement limit of the primary current of an induction motor is achieved by controlling the magnetic flux generated by the currents of the stator winding by connecting the rings of the measuring winding separately or in series based on the blocking contacts of the regulator, where the output voltage is determined by the connection of the circuits: motor, the output voltage measuring circuit is twice the output signal of a separate measuring winding ring.

3. Results

Three-phase stator currents of an asynchronous motor in the form of output voltages are used by the sensitive elements of the value converter to supply signals to measurement and control, control and protection systems. Based on this, the design of the primary current-to-voltage converter has a simple and easy manufacturing technology, which makes it possible to supply a continuous signal to the systems for measuring, monitoring and controlling the reactive power of an induction motor. As a result of research, the possibility of obtaining signals in the form of voltages up to 5 V at the output of sensitive elements of a three-phase current converter for reactive power control and monitoring systems has been expanded

When an asynchronous motor is running, the output voltage of the current converter changes in accordance with the change in stator currents.

According to the results of practical and theoretical study of the output signals of the controlled output voltage converter, the values of the asymmetry of the measuring sensitive elements of the reactive power of the asynchronous motor were determined, the mutual adequacy of the assessment of the values of the asymmetry was determined.

The static characteristics of the unbalance values of the reactive power of the asynchronous motor for each phase of the current converter with adjustable output voltage are shown in fig. 6.

The three-phase static characteristic of the stator currents of an induction motor, representing the unbalance values, is investigated as follows.

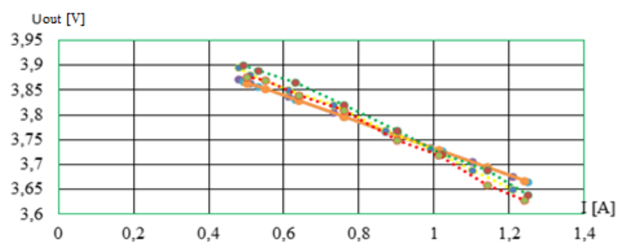

Fig. 6. Practical and theoretical characteristics of all phases of the stator winding of an asynchronous motor through a current converter with adjustable output voltage.

Under the action of magnetic currents arising from the passage of primary currents in the stator windings of a three-phase asynchronous motor, voltages U(out.a) (t), (out.b) (t), (out.c) (t). Dynamic processes in the series connection of the rings of the measuring coils of the current converter with adjustable output voltage are shown in fig. 7.

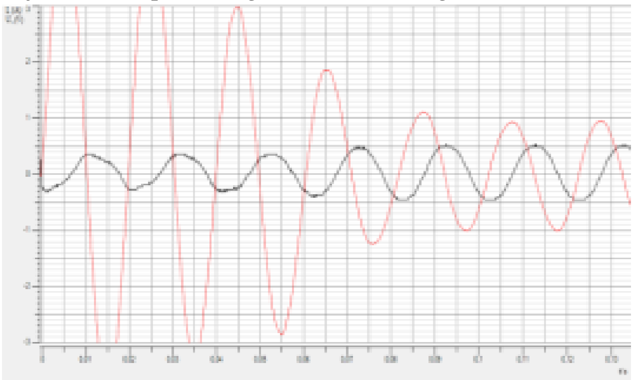

Fig. 7. dynamic characteristics of the primary current of the stator of the asynchronous motor and the current converter (red line - change in the stator current of the asynchronous motor, black line - output voltage of the current converter).

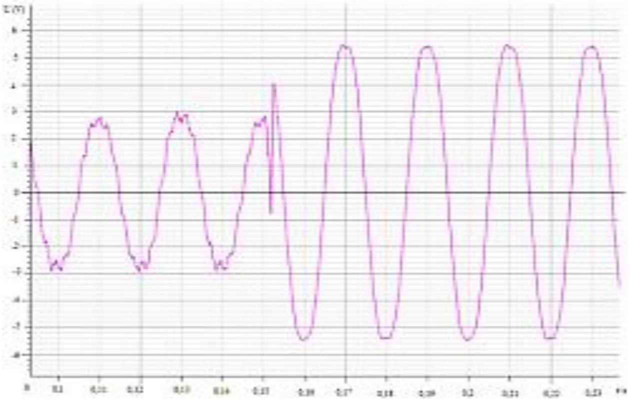

Fig 8. dynamic characteristics of a current converter with adjustable output voltage when measuring rings are connected in series

Based on the fact that the main electrical parameters of the studied asynchronous motor with a power of 250 W reach a steady state in the interval t = 0 – 0.09 s after the motor is started, the output parameters of the current converter with adjustable output voltage are achieved after a time t = 0 – 0.04 s. It is proved that this value fully satisfies the requirements for measuring, control and control devices.

4. Discussion

Analytical expressions for Fast Foure Translation of variable harmonics generated by separate, series and parallel connection of non-sinusoidal currents of the stator windings of an asynchronous motor of a regulated output voltage current converter have been simplified as follows

$$A_1 = \sqrt{(A_1')^2 + (A_1'')^2} = \sqrt{2{,}75^2 + 0{,}06^2} = 2{,}75$$

The coefficient of non-sinusoidality of the periodic variable function of one ring of the measuring winding of the current converter with adjustable output voltage was determined as follows:

$$K = \sqrt{5{,}32^2 + 0.122^2 + 2{,}13^2 + 0.752^2 + 0.213^2} = 9{,}54\%.$$

The harmonics of the function of a periodic variable when the rings of the measuring winding of the current converter with adjustable output voltage are connected in series were calculated as follows:

$$K_3 = \frac{A_3}{A_1} * 100\% = \frac{0{,}146}{2{,}75} * 100\% = 6{,}08\%$$

$$K_5 = \frac{A_5}{A_1} * 100\% = \frac{0{,}033}{2{,}75} * 100\% = 0{,}873\%,$$

$$K_7 = \frac{A_7}{A_1} * 100\% = \frac{0{,}058}{2{,}75} * 100\% = 0{,}507\%$$

$$K_9 = \frac{A_9}{A_1} * 100\% = \frac{0{,}207}{2{,}75} * 100\% = 0{,}93\%,$$

$$K_{11} = \frac{A_{11}}{A_1} * 100\% = \frac{0{,}0063}{2{,}75} * 100\% = 0{,}408\%$$

The coefficient of non-sinusoidality of the output values of the converter was determined as follows.

$$K = \sqrt{6{,}08^2 + 0{,}87^2 + 0{,}507^2 + 0{,}93^2 + 0{,}408^2} = 6{,}24\%$$

$$\varepsilon = \frac{K_{сам} - K_{посл}}{K_{сам}} 100\ \% = \frac{9{,}54 - 6{,}24}{9{,}54} 100\ \% = 34{,}59\ \%,$$

It has been theoretically and practically proved that on the basis of a significant increase in the conversion accuracy with a series connection of the measurement rings of the adjustable output voltage converter, the non-sinusoidality in comparison with an independent measuring winding ring improves by 34.59%.

5. Conclusion

1. A model of lumped and distributed parameters and an algorithm for its construction have been developed, which make it possible to investigate the distribution of magnetic quantities and reactive power parameters of an induction motor in the magnetic elements of current converters with adjustable output voltage; the method of presenting the values of the output signals of the series connections of the measuring coil rings in the form of normalized one-, two- and three-phase output voltages with 5 V, 0.1 A has been improved.

2. It is proved that the output parameters of the current converter reach a controlled output voltage after t=0 – 0.04 s on the basis that the primary electrical parameters of a 250 W induction motor reach a steady state in the interval t = 0 – 0.09 s after engine start, and that this value fully meets the requirements of measurements, accuracy and speed of control devices.

3. Analytical theoretical and practical studies have confirmed the possibility of doubling the output voltage due to the series connection of the rings of the measuring winding of the current converter. The quality indicators of output signals in the form of voltage have been improved: serial connection of the measuring ring of the current converter with adjustable output voltage has improved the sinusoidality of the output values by 34.59% compared to independently connected measuring winding rings.

4. As a result of the analysis of signal conversion processes, it was determined that the basic requirements for converting three-phase primary stator currents into a signal in the form of a controlled secondary voltage, such as accuracy, speed and linearity, are met.

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