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Electromagnetic converter of reactive power and monitoring of high-voltage induction motors

Azizjan Abubakirov[1], *Naurizbek* Eshmuratov[1*], *Gulayim* Esemuratova[2], and *Muzaffar* Nazarov[2]

[1]Nukus Mining Institute, Nukus, Uzbekistan
[2]Karakalpak State University named after Berdaq, Nukus, Uzbekistan

Abstract. In this paper, the control and monitoring of reactive power in an over-voltage induction motor are elucidated through a comparative analysis of theoretical and practical research findings. These results are based on structural principles, research models, and the static, dynamic, metrological, and technical characteristics of three-phase electromagnetic current converters, evaluated against established criteria. The effectiveness of employing current converters with straightforward design, high sensitivity, speed, and reliability, along with simple switching elements that transform the primary input stator current into a secondary voltage output signal, is emphasized. Utilizing a graph model, the static characteristics of the stator current to secondary voltage converter, essential for regulating and monitoring the reactive power of an asynchronous motor, are delineated, and a research algorithm is developed.

1 Introduction

Today, above-voltage asynchronous motors, which are the main consumers in our Republic, play a decisive role in the electric power and mining industries. Expanding the capabilities of the supervising and monitoring system for reactive power of above-voltage asynchronous motors is one of the urgent tasks, and these capabilities are explained by such indicators as high accuracy, speed, reliability and sensitivity of signal conversion elements and devices, quality and continuity of the signals they transmit.

A number of scientific studies are being carried out around the world to improve the elements and devices of the supervising and monitoring system for reactive power of above-voltage asynchronous motors. In these studies, the main task is to provide appropriate signals to the supervising and monitoring system of reactive power of an above-voltage induction motor. To do this, it is important to manage the reactive power of an above-voltage induction motor, plan, save and conserve reactive energy, as well as model various current converters and their signal conversion processes based on optimal algorithms. Widespread use of digital technologies is required in the development of supervising of the magnitude and parameters of reactive power of an above-voltage asynchronous motor. Also relevant are the development and practical implementation of mathematical apparatuses, physical elements

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[*] Corresponding author: nawrizbekeshmuratov@gmail.com

and tools that implement the modeling process, as well as new designs of devices for primary signal conversion based on them.

The analysis shows that the use of modern technologies in supervising and monitoring systems for reactive power of above-voltage asynchronous motors, obtaining standard exit signals for supervising and monitoring, studying converters that allow estimating reactive power consumption, modeling signal conversion and process algorithmization. The development of optimal current converters based on the technical capabilities of asynchronous motors and their implementation in practice have not been sufficiently studied.

The supervising and monitoring of reactive power of an above-voltage induction motor is explained through a comparative comparison of theoretical and practical research results obtained from structural principles, research models, static, dynamic, metrological and technical descriptions of three-phase electromagnetic current. transformers according to generally accepted criteria.

2 Materials and methods

Currently, there are several types of current converters, which differ from each other in the principles that determine their physical and technical action, design, signal conversion processes and scope of application. The works reflect the classification of these variables and their mutual differences.

Current converters for supervising and monitoring of reactive might of above-voltage motors can be divided into two groups according to the method of connection to the network:

1) contact current converters - based on determining the voltage drop across resistive, inductive and capacitive elements of known resistance.
2) non-contact current transducers - based on the use of magnetic currents generated by the measured current.

Based on the type of magnet and sensitive elements used, non-contact transducers are divided into electrometric, electromechanical, induction, magnetogalvanic, magnetic resonance and magneto-optical.

Despite the unchanged performance of contact switches, external magnetic fields and ferromagnetic masses, the absence of the need for auxiliary might sources, they have a relatively large mass and might consumption, low reliability, are difficult to implement in a wide range, they are used in electroautomatic supervising and monitoring systems. It is practically impossible to use in above-voltage might transmission system circuits and might distribution systems, and they also have large dynamic errors [1].

Table 1. Comparative analysis of the main characteristics of current transformers.

Type	Change limit	Error	Advantages	Flaws
Electromechanical	0–1000 A	5 %	Has a simple structure	There is a rotating working element.
Magnetomodulation	0–30 kA	0.2 – 0.5 %	High operational reliability, easy maintenance	It has large geometric dimensions and weight.
Stable	0–10 kA	0.2 – 0.5 %	Has a simple structure	Possible circuit break
Nuclear magnetic resonance	0–10 kA	0.01 – 0.03 %	Change accuracy is high	Possible circuit break

Current transformer	0–150 kA	0.2 – 0.5 %	The working condition is very reliable, maintenance is simple.	Large volume-weight indicators
Magneto-galvanic	0–200 kA	0.1 – 0.5 %	Accuracy and sensitivity of changes are high	The structure and application process are complex.
Magneto-optical	0–200 kA	0.05 – 0.1 %	Can be used in high voltage networks.	The structure and process of change is complex.
Converter of stator current of an asynchronous motor to voltage	0–3 kA	0.1 – 0.5 %	The reliability of the operating state is high, the accuracy and sensitivity of the change is high, the cooking technology is simple, economical, and the static characteristic is linear.	External temperature has a big influence.

A comparative analysis of the main characteristics of existing types of current converters showed that, despite the fact that contact converters do not require auxiliary sources of electricity, due to their relatively large weight and energy consumption and low operational reliability, they are used to supervising and supervising the reactive might of asynchronous motors, their It is not practical to use it as a current converter in supervising systems. [2].

Single-phase, three-phase or three-phase current converters with sensitive elements are used to connect an induction motor, the reactive might input of which is controlled and controlled, to the might supply system (Figure 1).

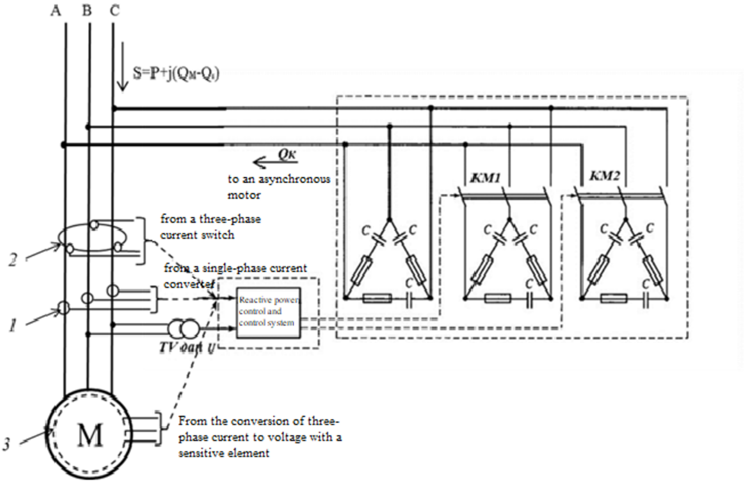

Fig. 1. Diagram of the supervising and monitoring system for reactive might of a above-voltage induction motor: 1 - single-phase current converter, 2 - three-phase current converter, 3 - three-phase current-voltage converter with a sensitive element, TV - voltage transformer, RPMCS - reactive might monitoring and supervising system , KM1, KM2 - magnetic starters.

Current converter - sensors have a number of disadvantages in the supervising and monitoring system of reactive might of an above-voltage asynchronous motor, the ability to capture changes in parasitic magnetic fluxes in the stator part is limited, and the conversion process has a nonlinear static description after the rated current will have.

An analysis of converters used in controlling and monitoring the reactive might of above-voltage asynchronous motors shows that in these processes they have a simple design, high sensitivity, speed and reliability, have simple switching elements, and the primary input stator is efficient. use current converters that convert the current value into an exit signal in the form of a secondary voltage [3].

The sensitive element (measuring coil) of the current transformer, which converts the stator current of an above-voltage asynchronous motor into an exit voltage signal, is placed between the stator coil and the pin (wedge) located on the stator magnet. The core sufficiently satisfies the requirements for management and supervising (Figure 2).

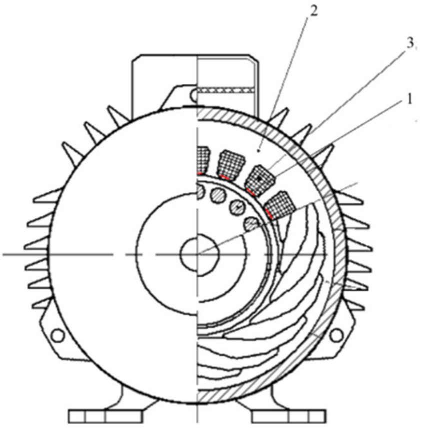

Fig. 2. Placement of the measuring coil in the stator core of an asynchronous motor: 1 – sensitive element, 2 – stator magnetic circuit, 3 – stator winding.

Placing the measuring element between the main stator coil and the dielectric layer (can be wedge, special wood) in the stator housing makes it possible to detect a change in the stray magnetic flux $F_{\sigma 1}$, which determines the desired change in reactive power.

In the analysis of the static characteristics of the converters of the asynchronous motor stator currents to the output signal in the form of voltage, it is necessary to determine the dependence of the terminal output voltages U_{exit} on the asynchronous motor stator currents, the number of windings of the measuring coil - $w_{c'}$, as well as the parameters of the stator system.

The static characteristics of the converter of stator currents into secondary voltages, used in controlling and monitoring the reactive might of an asynchronous motor, are determined by the following analytical expression, formed on the basis of a graph model [4-5]:

$$\begin{cases} U_{exit.\sigma 1} = K_{\Phi_\sigma U_{exit}} P_{\sigma 1} (W(F_{\sigma 111}, F_{\sigma 121}) K_{I_1 F_\sigma} I_1 + W(F_{\sigma 213}, F_{\sigma 121}) K_{I_2 F_\sigma} I_2 + \\ + W(F_{\sigma 313}, F_{\sigma 121}) K_{I_3 F_\sigma} I_3; \\ U_{exit.\sigma 2} = K_{\Phi_\sigma U_{exit}} P_{\sigma 2} (W(F_{\sigma 213}, F_{\sigma 223}) K_{I_2 F_\sigma} I_2 + W(F_{\sigma 111}, F_{223}) K_{I_1 F_\sigma} I_1 + \\ + W(F_{\sigma 313}, F_{\sigma 223}) K_{I_3 F_\sigma} I_3; \\ U_{exit.\sigma 3} = K_{\Phi_\sigma U_{exit}} P_{\sigma 3} (W(F_{\sigma 313}, F_{\sigma 323}) K_{I_3 F_\sigma} I_3 + W(F_{\sigma 111}, F_{\sigma 323}) K_{I_1 F_\sigma} I_1 + \\ + W(F_{\sigma 213}, F_{\sigma 323}) K_{I_2 F_\sigma} I_2; \end{cases} \quad (1)$$

Here $K_{\Phi_\sigma U_{exit}} = w_{\breve{y}}$ – F_σ magnetic fluxes and $U_{exit.\sigma}$ correlation coefficient between exit voltages;

$P_{\sigma i} = \frac{\mu_0 F_i}{\delta_{\mu i}}$ $(i=\overline{1.2})$ — magnetic parameter of the conversion sections generating the exit voltage $U_{exit.}$ of the converter;

μ_0 – magnetic absorption of air gaps in which the feeling element is installed:

$$(\mu_0 = 1{,}25 \cdot 10^{-6}\,H/m).$$

Based on the requirement that the exit voltage must be rated (5 V) at rated values of the currents of the primary stator winding takes values up to $w_c = 1 \div 4$.

F – the cross-sectional surface of the air gaps where the measuring elements are installed;

δ_μ – heights of air gaps where measuring elements are installed (m);

$W(F_{\sigma ijk}, F_{\sigma inn})$ – transfer function of magnetic conversion sections;

$K_{I_1 F_\sigma} = w_1$ – coefficient of inter circuit coupling between currents flowing from the stator windings of an asynchronous motor and the magnetic driving force created in the magnetic core, w_1 – number of turns of the stator winding;

I_1, I_2, I_3 – three-phase currents of the stator windings of an asynchronous motor, (A).

In private $U_{exit.\sigma 1}, U_{exit.\sigma 2}, U_{exit.\sigma 2}$ the exit voltages of the components are correspondingly large I_1, I_2, I_3 and depend on the stator currents of the asynchronous motor:

$$\begin{cases} U_{exit.\sigma 1} = K_{\Phi_\sigma U_{exit}} P_{\sigma 1}(W(F_{\sigma 111}, F_{\sigma 121}) K_{I_1 F_\sigma} I_1; \\ U_{exit.\sigma 2} = K_{\Phi_\sigma U_{exit}} P_{\sigma 2}(W(F_{\sigma 213}, F_{\sigma 223}) K_{I_2 F_\sigma} I_2; \\ U_{exit.\sigma 3} = K_{\Phi_\sigma U_{exit}} P_{\sigma 3}(W(F_{\sigma 313}, F_{\sigma 323}) K_{I_3 F_\sigma} I_3; \end{cases} \tag{2}$$

The research used the calculation of quantities and parameters of electrical and magnetic circuits, the theory of errors, the formation of graphs, signals, digital processing and transmission, design and modeling of electromagnetic converters [6].

3 Results and discussion

Based on the above equations (1 and 2), the relationship between the stator current of an asynchronous motor and the exit voltage component of the converter is shown in Figure 3 in the form of a static characteristic.

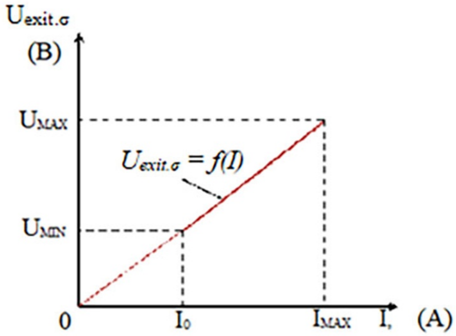

Fig. 3. Static characteristic of the relationship between the stator current of an asynchronous motor and the converter exit voltage component.

Here $U_{exit\sigma}$ – characteristic of the alteration in the exit voltage component based on the current converter model.

The alteration in exit voltage for different values of the number of windings of the stator current measurement circuit in an above-voltage asynchronous motor is shown in Figure 4.

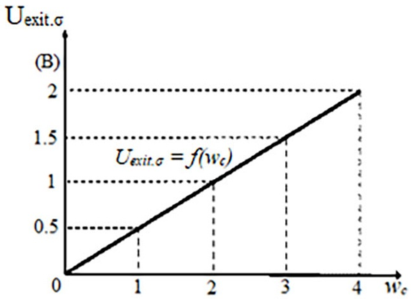

Fig. 4. Changes in exit voltage at values from 1 to 4 of the number of coils of the primary current converter of an above-voltage asynchronous motor.

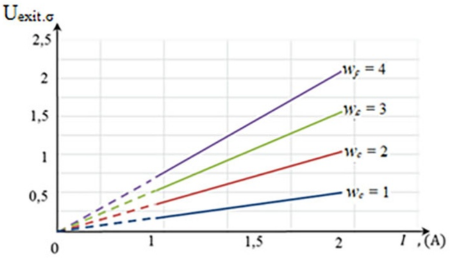

Fig. 5. Characteristics of the dependence of the exit voltage on the currents of the primary stator coil for values of the number of coils from 1 to 4, the measuring circuit of the converter in the state of an above-voltage asynchronous motor from the no-load state to the rated load state.

Based on the static descriptions presented in Figures 3, 4 and 5, the metrological indicators of the converter of stator currents of an above-voltage asynchronous motor into secondary voltage were studied: linearity of the exit characteristic, conversion accuracy, susceptivity of the converting element [7-8].

An algorithm has been developed for studying the static characteristics of a three-phase current converter for monitoring and controlling the reactive might of an asynchronous motor (Figure 6).

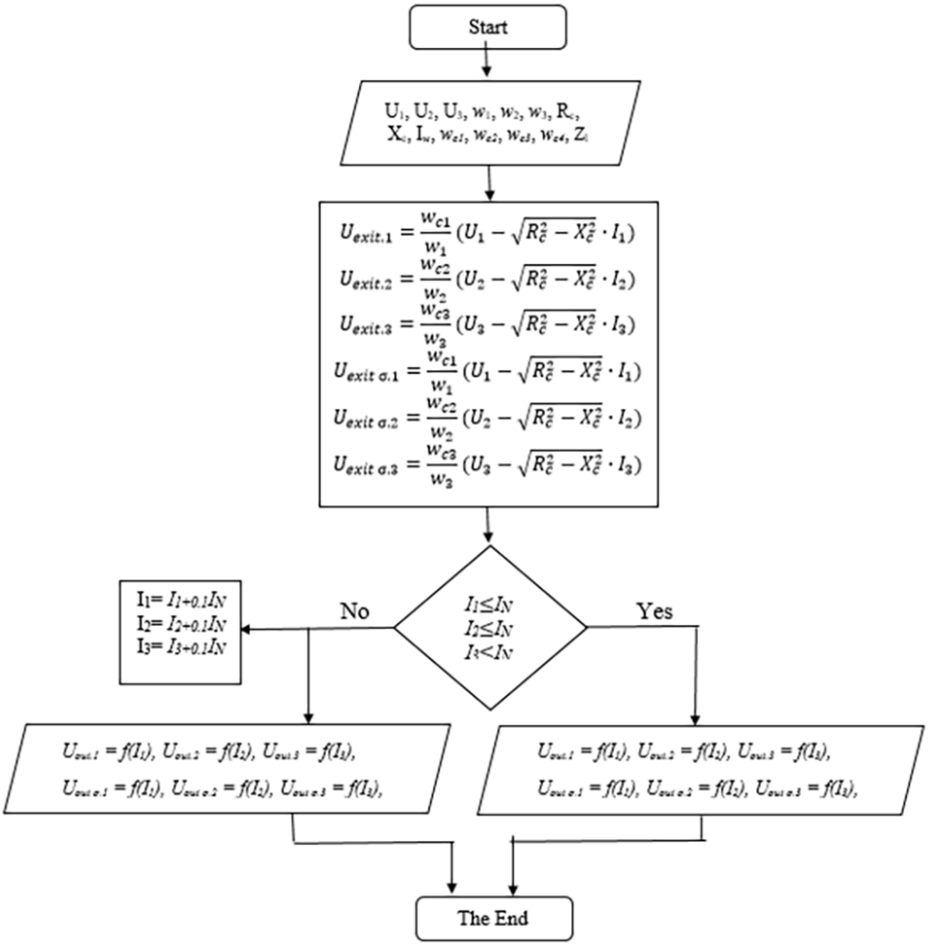

Fig. 6. Algorithm for studying the static characteristics of a three-phase current converter.

4 Conclusion

The following conclusions can be drawn from the above experiments and research:

- The special characteristics of reactive might sources of above-voltage induction motors controlling and monitoring current converters, as a result of the analysis, supervising and monitoring of current converters, are an important element that accurately, continuously and quickly meet the reactive might needs. The induction motor allows the evaluation and generation of an exit signal to supervising a source of static reactive might.
- As a result of the analysis of the signal conversion processes occurring in the stator current converters of asynchronous motors and the design basis of the converting elements, it has been established that the three-phase currents of the primary coil of the stator can be converted into a signal in the form of a secondary voltage and that this satisfies the basic requirements, such as accuracy, speed and linearity.
- An analytical expression has been developed to study the characteristics of a three-phase current converter for controlling and monitoring the reactive might of a above-voltage asynchronous motor, the number of coils is located in the stator

wedges between the main stator coils and the number of coils 1 - 4 ensures that the exit voltage corresponds to the standard value for the monitoring and supervising system.

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