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RESEARCH OF THREE-PHASES CURRENT'S TRANSDUCERS OF FILTER-COMPENSATION DEVICES FOR CONTROL REACTIVE POWER'S CONSUMPTION OF ASYNCHRONOUS MOTOR

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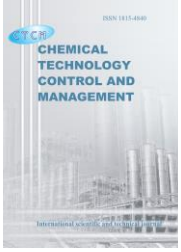

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RESEARCH OF THREE-PHASES CURRENT'S TRANSDUCERS OF FILTER-COMPENSATION DEVICES FOR CONTROL REACTIVE POWER'S CONSUMPTION OF ASYNCHRONOUS MOTOR

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Abstract: *In the article given materials of developing of three-phase electromagnetic current transducers of reactive power, using with asynchronous motor, methods connecting of two sensing element, series, parallel and differential and loops suitable for each phase, dynamic characteristics of output signals of three-phase electromagnetic current transducers asynchronous motor.*

On the basis of modern calculation and design complexes are of great importance in the research variable sizes of three-phase current electromagnetic transducers of filter-compensation devices of reactive power of asynchronous motors. Presented mathematical model of research of electrical, electromagnetic and magnetic elements of electromagnetic current transducers in the control and management system of the filter-compensation devices of the reactive power of asynchronous motor, as well as research of their processes and quantities.

Researched interactions of quantities with different characteristics, affecting tof asynchronous motors three-phases electromagnetic current transducers, studying the dynamic characteristics of the voltage signals coming out of the loops of the sensitive element, characterizing the output signals and studying differential equations representing tooth processes were created. The determination of the dynamic characteristics of the three-phase electromagnetic current transducers of the asynchronous motor was carried out on the basis of the results determined practically through theoretical calculations and modern technologies.

Keywords: *three phase current transducers, filter-compensation device, sensing element, magnet parameter, asynchronous motor, dynamic characteristics.*

Аннотация: *Мақолада асинхрон мотор уч фазали электрмагнит ток ўзгарткичларининг графлар назариясига асосан ишлаб чиқилган математик моделлари ёрдамида, иккита сезгир элемент ҳалқасига, ҳар бир фаза учун мос уланиш усулларига кўра кетма-кет, параллел ва дифференциал ҳамда битта ҳалақага эга бўлган электрмагнит ток ўзгарткичларининг чиқиш сигналларини вақтга боғлиқлик динамик тавсифларини тадқиқ этиш натижалари келтирилган.*

Асинхрон мотор реактив қувватининг фильтр-компенсация қурилмалари учун уч фазали ток электрмагнит ўзгарткичларининг мураккаб ва ўзгарувчан катталикларни тадқиқ этишда замонавий ҳисоблаш ва лойиҳалаш мажмуаларидан фойдаланиш муҳим аҳамиятга эга. Асинхрон мотор реактив қувватининг фильтр-компенсация қурилмалари назорат ва бошқариш тизимидаги электрмагнит ток ўзгарткичларининг электр, элетрмагнит ва магнит ўзгартириш элементлари ҳамда улардаги жараёнлар ва катталикларни тадқиқ этишнинг математик ифодалари келтирилган.

Асинхрон мотор уч фазали электрмагнит ток ўзгарткичга таъсир кўрсатувчи турли хусусиятга эга бўлган катталикларнинг ўзаро таъсирини инобатга олган ҳолда, сезгир элемент ҳалқаларидан чиқувчи кучланиш сигналларининг динамик тавсифларини ўрганиш, чиқиш сигналларини тавсифловчи ва ўтиш жараёнларини ифодаловчи дифференциал тенгламалар тузилган. Асинхрон мотор уч фазали электрмагнит ток *ўзгарткичларининг динамик тавсифларини аниқлаш, назарий ҳисоб-китоблар ва замонавий технологиялар орқали амалий аниқланган натижалар асосида олиб борилган.*

Таянч сўзлар: *уч фазали ток ўзгарткич, фильтр-компенсация қурилмаси, сезгир элемент, магнит параметри, асинхрон мотор ва динамик тавсиф.*

Аннотация: *В работе приведены разультаты исследования асинхронных двигателей с трехфазным электромагнитным преобразователем трехфазного тока, отличающиеся по способам соединения каждой фазы контурами чувствительного элемента: последовательный, параллельный и дифференциальный и один петля. Исследованы выходные сигналы динамических характеристик трехфазного тока электромагнитного преобразователя и асинхронного двигателя.*

Использованные современные расчетно-конструкторских комплексов имеют большое значение при исследовании сложных и переменных типоразмеров электромагнитных преобразователей трехфазного тока для фильтро-компенсационных устройств реактивной мощности асинхронного двигателя. Приведены математические выражения для исследования электрических, электромагнитных и магнитных элементов электромагнитных преобразователей тока в системе контроля и управления фильтро-компенсационными устройствами реактивной мощности асинхронного двигателя.

На основе учета взаимодействия величин с различными характеристиками, воздействующих на асинхронный двигатель трехфазного электромагнитного преобразователя тока, изучения динамических характеристик сигналов напряжения, выходящих из контуров чувствительного элемента, характеристика выходных сигналов и изучения дифференциальных уравнений, были созданы процессы. Определение динамических характеристик трехфазных электромагнитных преобразователей тока асинхронного двигателя проведено на основе результатов, определенных с помощью теоретических расчетов и современных технологий.

Ключевые слова: *трехфазный преобразователь тока, фильтро-компенсационное устройство, чувствительный элемент, параметр магнита, асинхронный двигатель и динамическая характеристика.*

Introduction

A number of inconveniences and shortcomings in analysis of complex magnetic circuits consisting of several circuits, which causes difficulties in determining results, taking into account characteristics of magnetic system of transformers that convert the stator current into voltage in control and management systems of the reactive power of asynchronous motors. Currently, there are several types of calculation systems, through which it is possible to determine results, taking into account properties and characteristics of magnetic quantities and factors affecting them. Making calculations taking into account such a large number of factors complicates e process of determining results. Therefore, it is desirable to improve the calculation methods and mathematical models of magnetic, electric and electromagnetic circuits, as well as increase speed, accuracy and simplification of calculation results.

The analysis and calculation of the conversion circuits for three-phase asynchronous motor stator current to output voltage conversion is based on graph theory. Analyzing and calculating the circuits for converting asynchronous motor stator current to output voltage through graph theory makes it possible to clearly understood of processes involved. Three-phase current electromagnetic transducers for filter-compensation devices of asynchronous motor reactive power are characterized by a number of parameters and quantities, including electrical, electromagnetic, magnetic, mechanical, thermal and technical-economic indicators.

In three-phase asynchronous motor electromagnetic current transducerss, it is important to take into account the structure of certain parts of transducers in process of changing stator current to the output voltage. Modeling is mainly carried out with the help of models developed by graph theory, based on the defining parameters and indicators of the electromagnetic current transducers.

Materials and Methods

The model of electromagnetic current transducers is based on relationships behind the input and output quantities, that is, the model of the process of changing the stator current to the output voltage depends on the number of element sections, geometric dimensions and research their formed depending on characteristics quantities. The output signals are formed based on distribution of quantities in which number of rows, columns and nodes defining change sections is determined (Figure 1 and Figure 3) [1].

Three-phase stator currents by combining models of each part of induction motor stator current to output voltage conversion process, models of three and six output voltage conversion processes and differential structures suitable for each phase according to the number is constructed as follows:

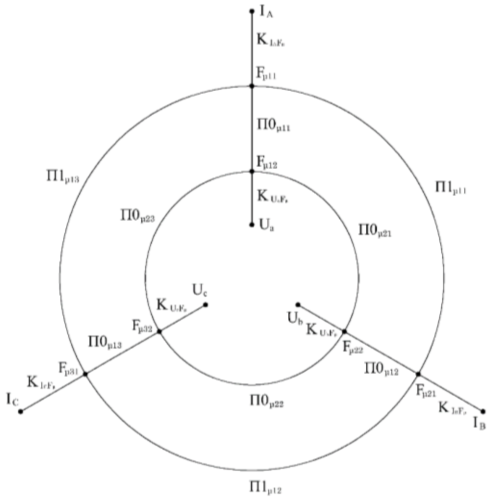

Figure 1. ***A graph model for organizing the components of output voltage of a three-phase asynchronous motor electromagnetic current transducer with one sensing element.***

It is suitable for each phase of a three-phase asynchronous motor with one sensing element loop, and the output voltages generated in sensing elements are generated by magnetomotive forces (m.m.f.) (Figure 2). The process of interconnection of electric and magnetic quantities in the electromagnetic field is determined based on Kirchhoff's and Ohm's laws, depending on the geometric dimensions of the electromagnetic system [2]. The interrelationships of the magnetomotive forces, stator current and output voltage in the stator and in the air gap for each phase are expressed according to the graph model as follows (1):

$$\begin{cases} \dfrac{F_{\mu 11}-F_{\mu 12}}{\Pi 0_{\mu 11}}+\dfrac{F_{\mu 11}-F_{\mu 21}}{\Pi 1_{\mu 11}}+\dfrac{F_{\mu 11}-F_{\mu 31}}{\Pi 1_{\mu 13}}=K_{I_A F_\mu} I_A; \\ \dfrac{F_{\mu 21}-F_{\mu 22}}{\Pi 0_{\mu 12}}+\dfrac{F_{\mu 21}-F_{\mu 31}}{\Pi 1_{\mu 12}}+\dfrac{F_{\mu 21}-F_{\mu 11}}{\Pi 1_{\mu 11}}=K_{I_B F_\mu} I_B; \\ \dfrac{F_{\mu 31}-F_{\mu 32}}{\Pi 0_{\mu 13}}+\dfrac{F_{\mu 31}-F_{\mu 11}}{\Pi 1_{\mu 13}}+\dfrac{F_{\mu 31}-F_{\mu 21}}{\Pi 1_{\mu 12}}=K_{I_C F_\mu} I_C; \\ \dfrac{F_{\mu 12}-F_{\mu 11}}{\Pi 0_{\mu 11}}+\dfrac{F_{\mu 12}-F_{\mu 22}}{\Pi 0_{\mu 21}}+\dfrac{F_{\mu 12}-F_{\mu 32}}{\Pi 0_{\mu 23}}=K_{U_a F_\mu} U_a; \\ \dfrac{F_{\mu 22}-F_{\mu 21}}{\Pi 0_{\mu 12}}+\dfrac{F_{\mu 22}-F_{\mu 32}}{\Pi 0_{\mu 22}}+\dfrac{F_{\mu 22}-F_{\mu 21}}{\Pi 0_{\mu 21}}=K_{U_b F_\mu} U_b; \\ \dfrac{F_{\mu 32}-F_{\mu 31}}{\Pi 0_{\mu 13}}+\dfrac{F_{\mu 32}-F_{\mu 12}}{\Pi 0_{\mu 23}}+\dfrac{F_{\mu 32}-F_{\mu 22}}{\Pi 0_{\mu 22}}=K_{U_c F_\mu} U_c; \end{cases} \quad (1)$$

On the bases of graph model, analytical models for the research of m.m.f. are formated as follows [3]:

$$F_{\mu.i,j}=K_{I_i F_\mu} I_i \quad (2)$$

$$U_{\mu.i,j}=K_{U_{i.out} F_\mu} F_{\mu.i,j} \quad (3)$$

$$\Pi_{\mu.i,j}=\omega L_{\mu.i,j}=X_{\mu.i,j} \quad (4)$$

$$\Pi 1_{\mu.i,j}=\frac{l1_{\mu.i,j}}{\mu 1_{\mu.i,j} S1_{\mu.i,j}} \quad (5)$$

$$\Pi 0_{\mu.i,j} = \frac{l0_{\mu.i,j}}{\mu 0_{\mu.i,j} S0_{\mu.i,j}} \; ; \quad (6)$$

where $\Pi 1_{i,j}$ – magnetic parameters of stator core, $\Pi 0_{i,j}$ – resistances of the magnetic parameters of air gap.

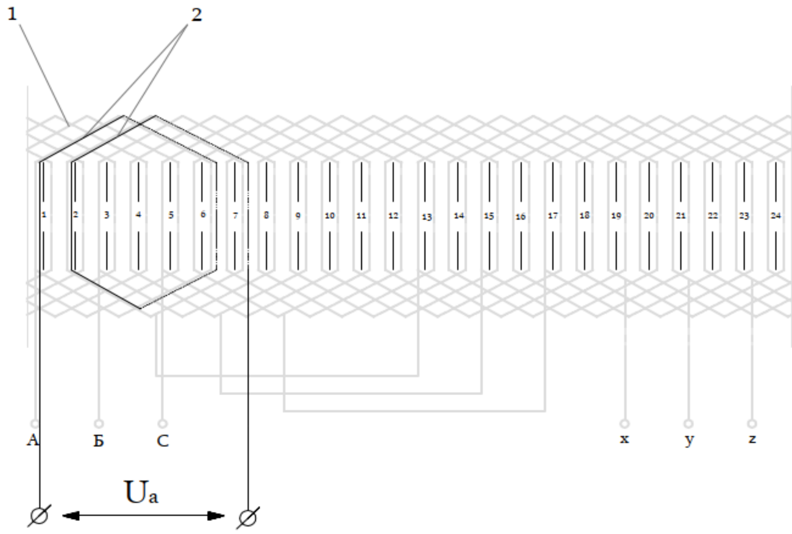

Figure 2. ***Three-phase electromagnetic current transducers of asynchronous motor (on phase A) with one sensing element loop arranged in accordance with stator grooves.***
1 - windings of the stator, 2 - the winding of the sensing element.

Determining the dependence of output voltage on e stator current is expressed as follows based on the above system of equations (7):

$$A_{i,j} \cdot F_{\mu.i,j} = \begin{bmatrix} I_i \\ U_{i.out} \end{bmatrix} \quad (7)$$

where $F_{\mu.i,j}$ – m.m.f and $A_{i,j}$ – magnetic parameters.

Modeling of the processes of changing magnitude of stator current I_1 to the magnitude of output voltage U_{out} in an asynchronous motor by electromagnetic current transducers with one sensing elements presented below [4, 5].

The dynamic characteristic of output voltages, using mathematical equations, determined by graph model of three-phase electromagnetic current transducers with one sensing element loop of asynchronous motor is given below (8) [6, 7]:

$$\begin{cases} U_a = K_{U_a F_\mu} W\,(F_{\mu s}, F_{\mu x}) K_{I_A F_\mu} \left(I_{A.d} \sin \omega t + I_{A.n} e^{-\frac{t}{T}} \right) \\ U_b = K_{U_b F_\mu} W\,(F_{\mu s}, F_{\mu x}) K_{I_B F_\mu} \left(I_{B.d} \sin(\omega t + 120^0) + I_{B.n} e^{-\frac{t}{T}} \right) \\ U_{c.} = K_{U_c F_\mu} W\,(F_{\mu s}, F_{\mu x}) K_{I_C F_\mu} \left(I_{C.d} \sin(\omega t - 120^0) + I_{C.n} e^{-\frac{t}{T}} \right) \end{cases} \quad (8)$$

where $I_{A.d}$, $I_{B.d}$, $I_{C.d}$, $I_{A.n}$, $I_{B.n}$, $I_{C.n}$ – the periodic and non-periodic values of each phase current of the stators windings.

Determining of the dynamic characteristic of output voltages using mathematical equations defined by the graph model of electromagnetic current transducers with two sensing element loops of asynchronous motor is given below (9) [8, 9]:

$$\begin{cases} U'_a = K_{U'_aF_\mu} W(F'_{\mu s}, F'_{\mu x}) K_{I_AF_\mu} \left(I_{A.d} \sin \omega t + I_{A.n} e^{-\frac{t}{T}} \right) \\ U''_a = K_{U''_aF_\mu} W(F''_{\mu s}, F''_{\mu x}) K_{I_AF_\mu} \left(I_{A.d} \sin(\omega t - 180^0) + I_{A.n} e^{-\frac{t}{T}} \right) \\ U'_b = K_{U'_bF_\mu} W(F'_{\mu s}, F'_{\mu x}) K_{I_BF_\mu} \left(I_{B.d} \sin(\omega t + 120^0) + I_{B.n} e^{-\frac{t}{T}} \right) \\ U''_b = K_{U''_bF_\mu} W(F''_{\mu s}, F''_{\mu x}) K_{I_BF_\mu} \left(I_{B.d} \sin(\omega t - 60^0) + I_{B.n} e^{-\frac{t}{T}} \right) \\ U'_c = K_{U'_cF_\mu} W(F'_{\mu s}, F'_{\mu x}) K_{I_CF_\mu} \left(I_{C.d} \sin(\omega t - 120^0) + I_{C.n} e^{-\frac{t}{T}} \right) \\ U''_c = K_{U''_cF_\mu} W(F''_{\mu s}, F''_{\mu x}) K_{I_CF_\mu} \left(I_{C.d} \sin(\omega t - 300^0) + I_{C.n} e^{-\frac{t}{T}} \right) \end{cases} \quad (9)$$

where $I_{A.d}$, $I_{B.d}$, $I_{C.d}$, $I_{A.n}$, $I_{B.n}$, $I_{C.n}$ – the periodic and non-periodic values of each phase current of the stator.

The stator windings current I_1 of asynchronous motor, the m.m.f. F_μ in the stator, the m.m.f. $F_{\mu x}$ in the air gap, and the model of the variation of the output voltage of the flywheel in the electromagnetic field are constructed in the following form based on the theory of graphs [10].

$$U_{out} = K_{U_{out}F_\mu} \Pi_\mu K_{I_1F_\mu} I_1 \quad (10)$$

Analytical expression of plane voltage coming out of the loop of one sensitive element placed in the order with the stator windings of an asynchronous motor and representing the stator current is as follows (10) [11]:

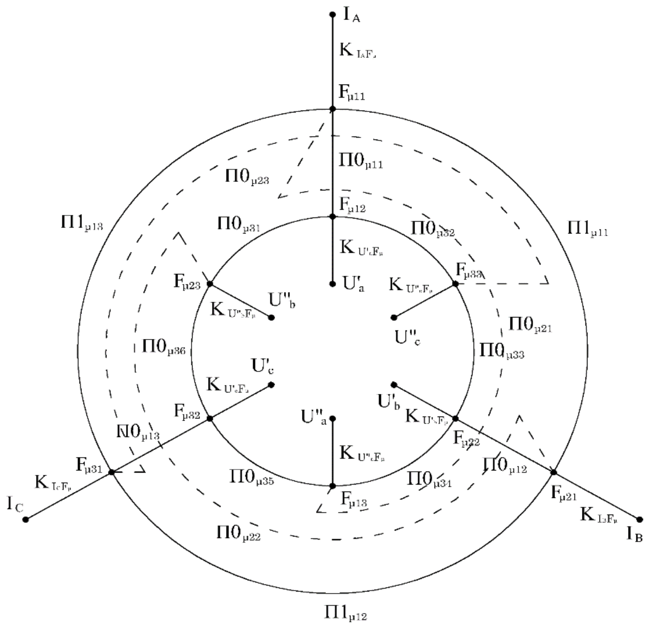

Figure 3. ***A graph model for organizing the components of the output voltages of a three-phase asynchronous motor electromagnetic current transducers with two sensing element loops.***

The relationship between the output voltages representing the stator current in the three-phase asynchronous motor electromagnetic current transducers with two sensing element loops suitable for each phase, and the m.m.f. the stator and in the air gap, is expressed based on the graphical model as a follows (11) [12]:

$$\begin{cases} \frac{F_{\mu11}-F_{\mu21}}{\Pi1_{\mu11}}+\frac{F_{\mu11}-F_{\mu31}}{\Pi1_{\mu13}}+\frac{F_{\mu11}-F_{\mu12}}{\Pi0_{\mu11}}+\frac{F_{\mu11}-F_{\mu13}}{\Pi0_{\mu21}}=K_{I_AF_\mu}I_A; \\ \frac{F_{\mu21}-F_{\mu11}}{\Pi1_{\mu11}}+\frac{F_{\mu21}-F_{\mu31}}{\Pi1_{\mu12}}+\frac{F_{\mu21}-F_{\mu22}}{\Pi0_{\mu12}}+\frac{F_{\mu21}-F_{\mu23}}{\Pi0_{\mu22}}=K_{I_BF_\mu}I_B; \\ \frac{F_{\mu31}-F_{\mu21}}{\Pi1_{\mu12}}+\frac{F_{\mu31}-F_{\mu11}}{\Pi1_{\mu13}}+\frac{F_{\mu31}-F_{\mu32}}{\Pi0_{\mu13}}+\frac{F_{\mu31}-F_{\mu33}}{\Pi0_{\mu23}}=K_{I_CF_\mu}I_C; \\ \frac{F_{\mu12}-F_{\mu11}}{\Pi0_{\mu11}}+\frac{F_{\mu12}-F_{\mu23}}{\Pi0_{\mu31}}+\frac{F_{\mu12}-F_{\mu33}}{\Pi0_{\mu32}}=K_{U'_aF_\mu}U'_a; \\ \frac{F_{\mu22}-F_{\mu21}}{\Pi0_{\mu12}}+\frac{F_{\mu22}-F_{\mu33}}{\Pi0_{\mu33}}+\frac{F_{\mu22}-F_{\mu13}}{\Pi0_{\mu34}}=K_{U'_bF_\mu}U'_b; \\ \frac{F_{\mu32}-F_{\mu31}}{\Pi0_{\mu13}}+\frac{F_{\mu32}-F_{\mu13}}{\Pi0_{\mu35}}+\frac{F_{\mu32}-F_{\mu23}}{\Pi0_{\mu36}}=K_{U'_cF_\mu}U'_c; \\ \frac{F_{\mu13}-F_{\mu11}}{\Pi0_{\mu21}}+\frac{F_{\mu13}-F_{\mu22}}{\Pi0_{\mu34}}+\frac{F_{\mu13}-F_{\mu32}}{\Pi0_{\mu35}}=K_{U''_aF_\mu}U''_a; \\ \frac{F_{\mu23}-F_{\mu21}}{\Pi0_{\mu22}}+\frac{F_{\mu23}-F_{\mu32}}{\Pi0_{\mu36}}+\frac{F_{\mu23}-F_{\mu12}}{\Pi0_{\mu31}}=K_{U''_bF_\mu}U''_b; \\ \frac{F_{\mu33}-F_{\mu31}}{\Pi0_{\mu23}}+\frac{F_{\mu33}-F_{\mu12}}{\Pi0_{\mu32}}+\frac{F_{\mu33}-F_{\mu22}}{\Pi0_{\mu33}}=K_{U''_cF_\mu}U''_c; \end{cases} \quad (11)$$

Based on graph model, analytical equations for research of m.m.f. formatted as follows:

$$F_{\mu.i,j}=K_{I_iF_\mu}I_i \quad (12)$$

$$U'_{\mu.i,j}=K_{U'_{i.out}F_\mu}F_{\mu.i,j} \quad (13)$$

$$U''_{\mu.i,j}=K_{U''_{i.out}F_\mu}F_{\mu.i,j} \quad (14)$$

$$\Pi_{\mu.i,j}=\omega L_{\mu.i,j}=X_{\mu.i,j} \quad (15)$$

$$\Pi0_{\mu.i,j}=\frac{l0_{\mu.i,j}}{\mu0_{\mu.i,j}S0_{\mu.i,j}} \quad (16)$$

where $\Pi1_{i,j}$ – resistances of the magnetic parameters of the stator core, $\Pi0_{i,j}$ – resistances of the magnetic parameters of the air gap.

Determining the dependence of the output voltage on the stator current is expressed as follows based on the above system of equations (17):

$$A_{i,j}\cdot F_{\mu.i,j}=\begin{bmatrix} I_i \\ U'_{i.out} \\ U''_{i.out} \end{bmatrix} \quad (17)$$

where $F_{\mu.i,j}$ – m.m.f. and $A_{i,j}$ – magnetic parameters.

Modeling of process of change of stator current I_1 to output voltage U'_{out} and U''_{out} in electromagnetic current transducers of asynchronous motor with two sensing element loops suitable for each phase [14].

The analytical expression of voltages coming out of first and second loops of sensitive element placed in the order corresponding to the stator windings of asynchronous motor and representing the stator current is as follows (18):

$$U'_{out}=K_{U'_{out}F_\mu}\Pi'_\mu K_{I_1F_\mu}I_1 \quad (18)$$

$$U''_{out} = K_{U''_{out}F_{\mu}} \Pi''_{\mu} K_{I_1 F_{\mu}} I_1 \quad (19)$$

where $K_{U'outF\mu}$ – $F'_{\mu x}$ and $K_{U''outF\mu}$ – $F''_{\mu x}$ is the inter-chain coupling coefficients of the conversion of the magnetomotive force in the air gap into the output voltage U'_{out} and U''_{out}, Π'_{μ} – U'_{out} and Π''_{μ} – U''_{out} is the magnetic parameters related to the output voltages.

An asynchronous motor three-phase electromagnetic current transducer determines the output signals according to the series, parallel and differential connection of two sensing elements (Figure 4, Figure 5 and Figure 6). In this case, based on the above formulas, the amount of voltage in the circuits of each sensing element is determined [15, 16].

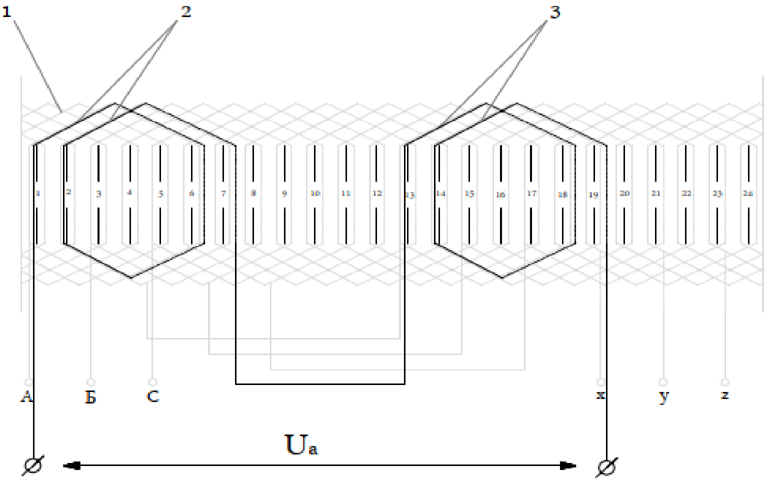

Figure 4. ***An asynchronous motor is a three-phase electromagnetic current transducers (for phase A) with two sensing element loops connected in series, which are placed between the poles of the stator grooves.***
1 - windings of the stator, 2 - the first loop of the sensing element, 3 - the second loop of the sensing element.

$$U_a = U'_a + U''_a \quad (20)$$

The output signal of the electromagnetic current transducers, which has two sensitive element loops suitable for each phase, corresponding to the stator winding loops, placed between the poles and connected in series with each other, is determined as follows (for phase A) (20).

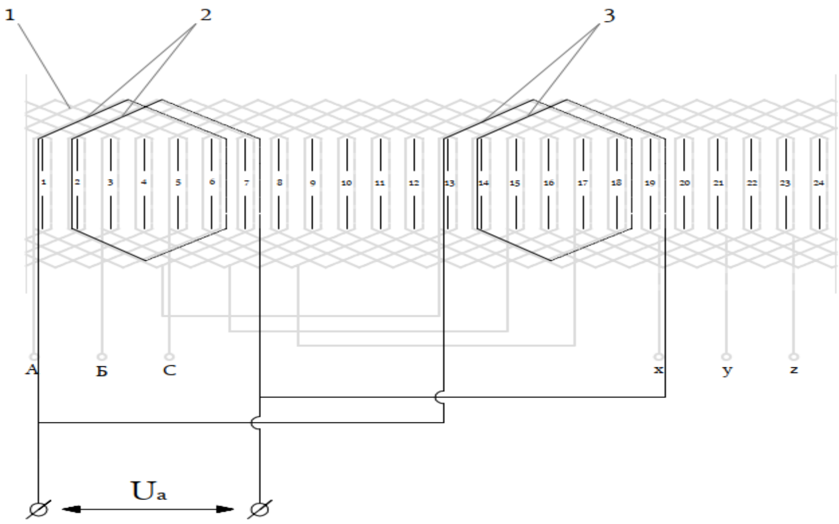

Figure 5. ***An asynchronous motor is three-phase electromagnetic current transducers (for phase A) with two sensing element loops connected in parallel, which are placed between the poles of the stator grooves.***
1 - windings of the stator, 2 - the first loop of the sensing element, 3 - the second loop of the sensing element.

$$U_{out} = \frac{U'_a U''_a}{U'_a + U''_a} \qquad (21)$$

The output signal of an electromagnetic current transducer with two sensing element loops, corresponding to the stator winding loops, placed between the poles and connected in parallel is determined as follows (for phase A) (21).

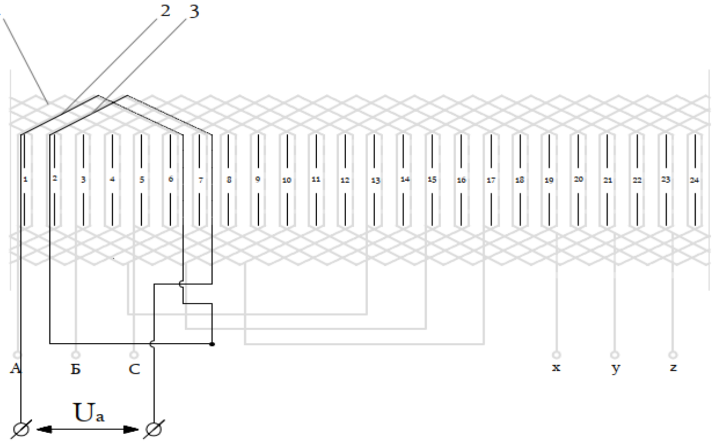

Figure 6. ***Three-phase electromagnetic current transducers (for phase A) with differential connection of two sensing element loops, suitable for asynchronous motor stator windings.***
1 - windings of the stator, 2 - the first loop of the sensing element, 3 - the second loop of the sensing element.

The output signal of an electromagnetic current transducer with two sensing element loops, corresponding to the grooves located on the stator winding loops, placed oppositely and differentially connected to each other, is determined as follows (for phase A) (22) [17].

$$U_{out} = \frac{4.44 w_{se} f I_A \mu \mu_0 \sum S_{se}}{\delta} \qquad (22)$$

where f is the mains frequency, I_A is the stator current, S_{se} is the surface of the sensing element loop, w_{se} is the number of sensing element windings, δ is the air gap, μ is the magnetic permeability, μ_0 is the magnetic constant.

Results

The dynamic characteristic of the electromagnetic current transducers formed by the series connection of two sensitive element loops suitable for each phase is determined practically by the CassyLAB device, according to Figure 8, the time of reaching the stability of the output voltage is the time of reaching the stability of the stator current we can see that it is almost equal and that the influence of higher harmonics on the output signal of the electromagnetic current transducers during the start of the asynchronous motor is less than that of the single-phase current transducers.

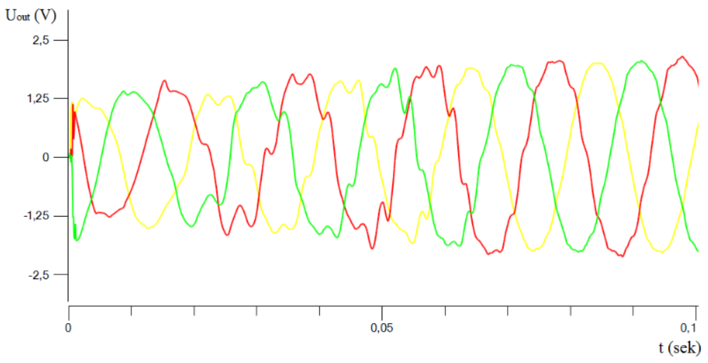

Figure 7. ***Dynamic characteristic of the output voltage of an electromagnetic current transducer with one sensitive element loop suitable for each phase.***

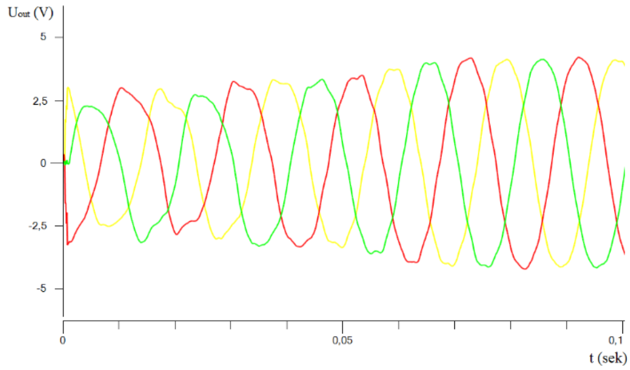

Figure 8. ***Dynamic characteristic of output voltage of electromagnetic current transducers with two sensitive element loops, which are placed between the stator poles and connected in series, suitable for each phase.***

In practice, dynamic characteristic of e output signals of an electromagnetic current transducers with two sensitive element loops, suitable for each phase, placed on the inter-pole heads of the stator and connected in parallel. According to Figure 9, the output voltage is equal to the output voltage of an electromagnetic current transducer with a single loop, and the output of high harmonics we can see the effect on the signal.

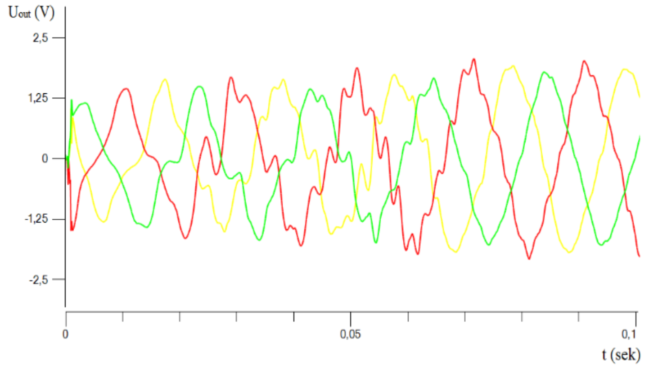

Figure 9. ***Dynamic characteristic of output voltage of electromagnetic current transducers with two sensitive element loops placed between the stator poles and connected in parallel for each phase.***

The determined dynamic characteristic of e output signals of electromagnetic current transducers with loops of two sensitive elements placed in the slots where the stator windings are located and differentially connected. According to Figure 10, the value of output voltages is equal to signals of current transducers with loops connected in series, to output signals of the upper harmonics. We can see that the effect is small and settling time of the signal is equal to settling time of stators current.

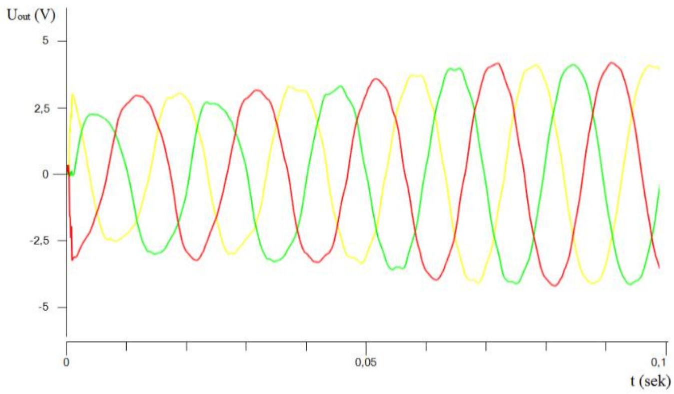

Figure 10. ***Dynamic characteristic of the output voltage of a differentially connected electromagnetic current transducers with two sensitive element as loops suitable for each phase.***

Conclusion

Based on the results of research, determined possibles of clearly see processes in the magnetic circuit due to highly formalized mathematical models of three-phase current transducers of asynchronous motor with one or two sensing element loops, based on the graph theory, which converts the stator current output voltage. It is important to evaluate electric and magnetic quantities in the change. As a result, based on the mathematical model of synchronous motor three-phase electromagnetic current transducers, it was possible to increase the speed, accuracy and simplification of the calculation results.

Based on the practical results determined by the CassyLAB device, time-dependent voltages $U_{out}=f(t)$ of the three-phase electromagnetic current transducers of an asynchronous motor with one sensitive element loop or two sensitive element loops in series, parallel and differential connection based on the description of the characteristics, may be conclude that, based on theoretical calculations, the time of reaching the stability of the output signals of the three-phase electromagnetic current transducers of the asynchronous motor is compatible with the practically determined results.

According to the dynamic characteristics of the electromagnetic current transducers with one or two sensing element loops, compatible with the stator windings discussed above, suitable for each phase, the stator windings are placed opposite the slots, and the sensing element loops are differentially, it was found that the accuracy of the output voltage signal of connected three-phase electromagnetic current transducers is high.

Based on the results of the research, we can conclude that the time to reach stability of the output voltages of three-phase electromagnetic current transducers of asynchronous motor with one or two sensitive elements is almost equal to the time of stator currents to reach stability, and the output voltage signals represent the reactive power, the asynchronous motor is reactive it is effective to use three-phase currents as electromagnetic current transducers for the control and management of power filter-compensation devices.

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