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Research of The Dynamic Characteristics of Current Transducers For Monitoring And Controlling The Reactive Power of Asynchronous Motors

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Abstract. *This article presents a model and research results, developed on the basis of Matlab, that the dynamic characteristics of the output values of a current transducer located on the stator slots at the time of starting asynchronous motors. For control systems and regulation of reactive power of an induction motor, the role is important in research that the dynamic characteristics of the three-phase alternating current of the stator to voltage, these characteristics reflects change and the dependence in time, value of the stator current, parameters of measuring elements, external influences, parameters of an asynchronous motor and other influences that output signals in the form of voltage. The study of the dynamic properties of the signal received from the measuring medium, taking into account the interaction of various characteristic quantities in connection with the difficulties arising in the formation of differential equations of the transducer describing the transition processes in the primary and secondary sections of signal conversion, signal transmission elements, studies are carried out on the basis of a large-scale simulation model and its analytical expressions.*

Keywords: dynamic characteristics, current transducer, asynchronous motor, measuring elements, circuit

1. INTRODUCTION

The use from the research model developed on the basis of Matlab in the study of the dynamic characteristics of the output values of the current transducer makes it easier to compare the research results with practical results. Also, this research model makes it possible to develop theoretical conclusions and recommendations taking into account the characteristics of the work, physical-technical effects in the dynamic states of the current to voltage transducer, as well as the operating states of the induction motor. When researching the dynamic characteristics of the current transducer, a change in time of the flow of primary currents through the stator winding is observed, and their interdependence remains a sinusoidal signal with a sinusoidal change in voltage to which the stator winding is connected, which is mainly related to the electromagnetic conversion circuit, taking into account the curvature of the magnetization of the stator magnetic circuit. This, it becomes possible to perform operations in the form of sinusoidal quantities over the basic quantities that determine the processes and characteristics of changes in the current transducer circuit.

2. RELATED WORKS

From three-phase asynchronous motor stator windings, $u_{out.1}(t), u_{out.2}(t), u_{out.3}(t)$ voltages are obtained at the outputs of the current transducer measurement windings under the action of magnetic currents generated by the transition of i_1, i_2, i_3 primary currents.The voltages at the output of the current Switch are the position of the measurement loops in the stator wedge, depending on the number and parameters of the wrappers, the output voltages are as follows [1-2]:

$$\begin{aligned}
u_{out.1}(t) &= -R_{m.1} \cdot i_{out.1}(t) - L_{m.1} \frac{di_{out.1}(t)}{dt} + w_5 \frac{d\Phi_2(t)}{dt} + w_6 \frac{d\Phi_3(t)}{dt}; \\
u_{out.2}(t) &= -R_{m.2} \cdot i_{out.2}(t) - L_{m.2} \frac{di_{out.2}(t)}{dt} + w_4 \frac{d\Phi_1(t)}{dt} + w_6 \frac{d\Phi_3(t)}{dt}; \\
u_{out.3}(t) &= -R_{m.3} \cdot i_{out.3}(t) - L_{m.3} \frac{di_{out.3}(t)}{dt} + w_4 \frac{d\Phi_1(t)}{dt} + w_5 \frac{d\Phi_2(t)}{dt};
\end{aligned} \quad (1)$$

here $R_{m.1}, R_{m.2}, R_{m.3}, L_{m.1}, L_{m.2}, L_{m.3}$ – active resistances and inductivities of the three-phase current transducer, respectively; w_4, w_5, w_6 – number of wrappers of measurement elements; $i_{out.1}(t), i_{out.2}(t), i_{out.3}(t)$ – the currents of the measuring wrappers.

An increase in the three-phase primary stator currents at the moment of starting the inductivations of the stator windings of the asynchronous motor at the expense of L1, L2, L3 occurs, and gradually the currents come to stagnant sinusoidal fear due to the coupling of magnetic currents in the stator core [3].

The dependence of magnetic currents on the parameters of the asynchronous motor in the research of dynamic descriptions of the current transducer is as follows [4,5]:

$$\begin{aligned} \frac{U_{m1}\sin(\omega t+\alpha_1)}{w_1} &= \frac{d\Phi_1}{dt}+\frac{R_1}{L_1}\Phi_1; \\ \frac{U_{m2}\sin(\omega t+\alpha_2+120^0)}{w_2} &= \frac{d\Phi_2}{dt}+\frac{R_2}{L_2}\Phi_2; \\ \frac{U_{m3}\sin(\omega t+\alpha_3-120^0)}{w_3} &= \frac{d\Phi_3}{dt}+\frac{R_3}{L_3}\Phi_3; \end{aligned} \qquad (2)$$

here $\omega = 2\pi f$ – network angular frequency; α_1, α_2, α_3 – phase angles, in t=0 ; w_1, w_2, w_3 – asynchronous motor stator winding number of wrappers; R_1, R_2, R_3 – active resistors of asynchronous motor stator winding; L_1, L_2, L_3 – inductivities of asynchronous motor stator winding.

3. MATERIALS AND MODELS.

In order to fully describe the dynamic process, the transition process in the current based on the energy flows and currents that the asynchronous motor is giving to the stator windings should be visualized [6]:

$$\begin{aligned} U_{out.1} &= K_{\Phi_1 U_{out.1}}\begin{pmatrix} \Pi_{\mu_1}\cdot W(F_{111},F_{121})\cdot K_{U_1F_1}\cdot U_1\sin\omega t - \\ -\Pi_{\sigma_1}\cdot W(F_{\sigma111},F_{\sigma121})K_{I_1F_{\sigma1}}\cdot(I_{1p.}\sin\omega t + I_{1ap.}e^{-\frac{t}{T}}) \end{pmatrix}; \\ U_{out.2} &= K_{\Phi_2 U_{out.2}}\begin{pmatrix} \Pi_{\mu_2}\cdot W(F_{213},F_{223})\cdot K_{U_2F_2}\cdot U_2\sin(\omega t+120^0) - \\ -\Pi_{\sigma_2}\cdot W(F_{\sigma213},F_{\sigma223})\cdot K_{I_2F_{\sigma2}}\cdot(I_{2p.}\sin(\omega t+120^0) + I_{2ap.}e^{-\frac{t}{T}}) \end{pmatrix}; \\ U_{out.3} &= K_{\Phi_3 U_{out.3}}\begin{pmatrix} \Pi_{\mu_3}\cdot W(F_{313},F_{323})\cdot K_{U_3F_3}\cdot U_3\sin(\omega t-120^0) - \\ -\Pi_{\sigma_3}\cdot W(F_{\sigma313},F_{\sigma323})\cdot K_{I_3F_{\sigma3}}\cdot(I_{3p.}\sin(\omega t-120^0) + I_{3ap.}e^{-\frac{t}{T}}) \end{pmatrix} \end{aligned} \qquad (3)$$

here $K_{\Phi_1 U_{out1}}, K_{\Phi_2 U_{out2}}, K_{\Phi_3 U_{out3}}, K_{U_1F_1}, K_{U_2F_2}, K_{U_3F_3}, K_{I_1F_{\sigma1}}, K_{I_2F_{\sigma2}}, K_{I_3F_{\sigma3}} -$ respectively, the magnetic and electrical chain magnitudes corresponding to each phase of the bonding coefficients; $\Pi_{\mu_1}, \Pi_{\mu_2}, \Pi_{\mu_3}$, $\Pi_{\sigma_1}, \Pi_{\sigma_2}, \Pi_{\sigma_3} -$ magnetic parameters of asynchronous motor magnetic system and stator paz; $I_{1p}, I_{2p}, I_{3p}, I_{1ap}, I_{2ap}, I_{3ap} -$ periodic and aperiodic organizers of stator current; $U_1, U_2, U_3 -$ voltages being applied to the stator windings of an asynchronous motor; $W(F_{111},F_{121}), W(F_{213},F_{223}), W(F_{313},F_{323})$, $W(F_{\sigma111},F_{\sigma121})$, $W(F_{\sigma213},F_{\sigma223}), W(F_{\sigma313},F_{\sigma323}) -$ transfer functions of the magnetic transformation piece.

A signal in the form of a voltage at the output is generated by the crossing of the main and scattering magnetic currents in the stator section of the sensing element (the measuring winding), which is embedded in the stator wedge of the asynchronous motor. This is the value of the output voltage asynchronous motor stator lead winding number w1, resistance Z1, network voltage U1,.the current force passing through the stator loop depends on i1 and the number of sensing element wraps is w2 (usually w2=1 or 2:

$$U_{out.1} = \frac{w_4}{w_1} \cdot (U_1 - Z_1 \cdot I_1);$$
$$U_{out.2} = \frac{w_5}{w_2} \cdot (U_2 - Z_2 \cdot I_2); \qquad (4)$$
$$U_{out.3} = \frac{w_6}{w_3} \cdot (U_3 - Z_3 \cdot I_3).$$

(4) by expression, the value is equal from the outputs of the three-phase current transducer, and the voltages that differ from the phase bias by 120^0 degrees are obtained.

In the research of dynamic descriptions of the current Switch, a functional blog of the analytical expression (1) was developed in the Matlab program, which provides voltage at the output of the sensing element embedded in the three–phase short-circuit rotor asynchronous motor (Figure 1) and stator wedge (Figure 2).

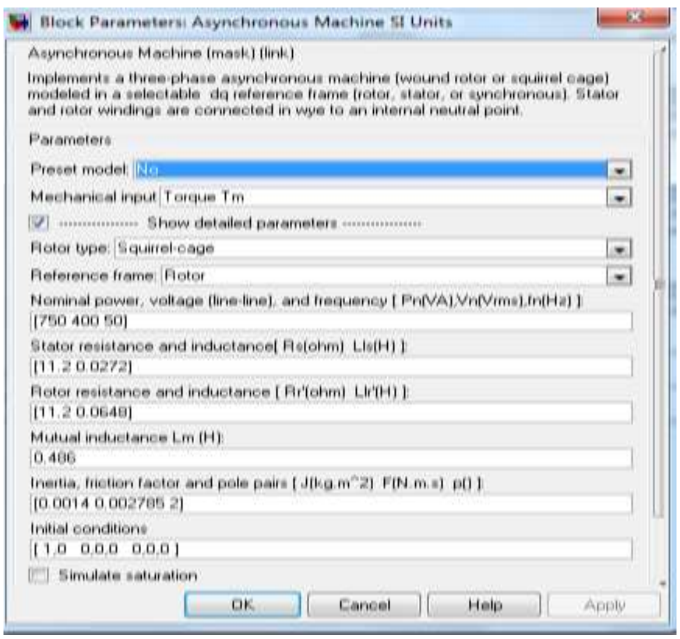

Figure 1. Indicators of a three-phase short-circuit rotor asynchronous motor with a current Switch generating an outgoing signal in the form of a voltage

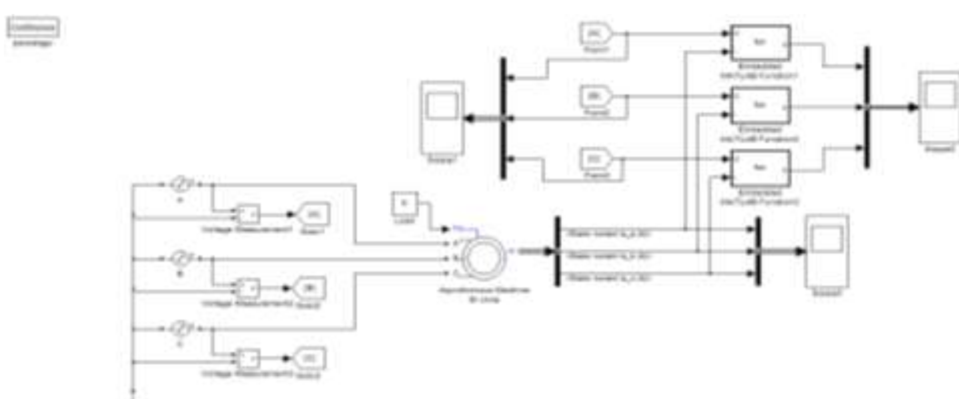

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Figure 2. Research model of the dynamic characteristics of the current transformer of the control and management of the reactive power of the asynchronous motor developed on the basis of the Matlab program

We will consider the process of transition from the start of the asynchronous motor A, V, S connected to a three-phase 50 Hz power source until the voltage output from the sensing element reaches a steady state. 1– after starting the scheme in the picture, after 0.2 seconds, the results obtained from the oscillographs (Scope) were analyzed.

4.RESULTS OF TESTING.

Scope 1 asynchronous motor shows the graphs of the phase voltage A, V, S falling on the stator coils over time (Figure 3).

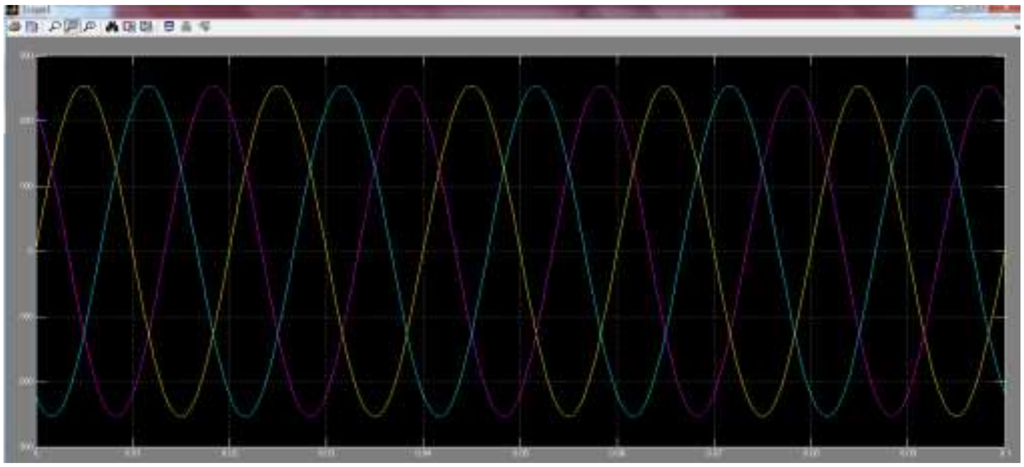

Figure 3. Graphs of changes in time of the voltages supplied to the stator coils of an asynchronous motor

In asynchronous motors, at the first moments of starting, the current passing through the stator coils increases several times over the nominal value (Figure 4).

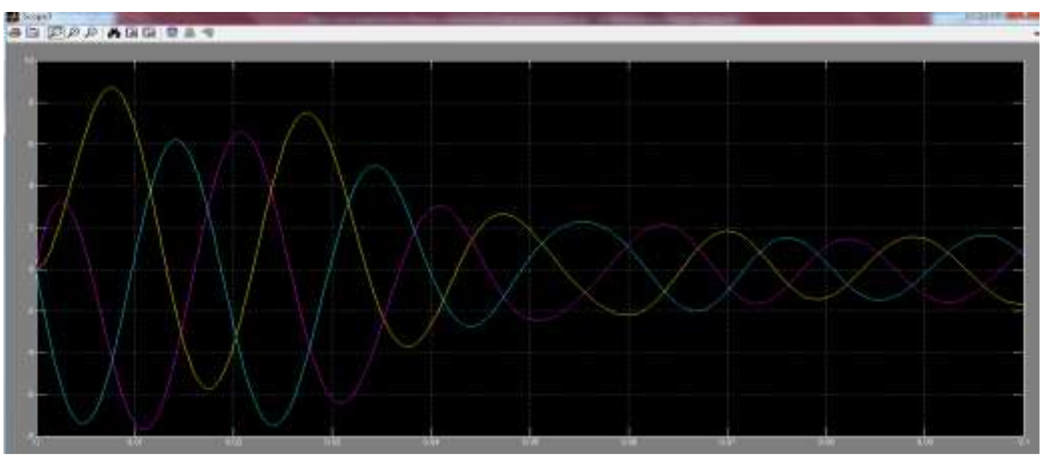

Figure 4. Graphs of changes in time of current forces passing through the stator windings during the start-up period of an asynchronous motor

From Figure 4, we can see that after starting the asynchronous motor, the current slowly starts to reach its stable value from the initial high value. The starting current reached a steady value between 0.08–0.1 sec. The time for the starting current to reach a steady value may vary depending on the parameters of the induction motor..

Depending on the duration of the transient process during the start of the asynchronous motor, the reactive power consumption is also in an unstable state. We study by analyzing the dynamic description of the output values of the sensing element placed in the stator slots in the assessment of the transient process during the start-up period of asynchronous motors[7-8].

Scope 2 in Figure 2 shows the change in the output voltage of the current transformer during the first 0.2 seconds (Figure 4).

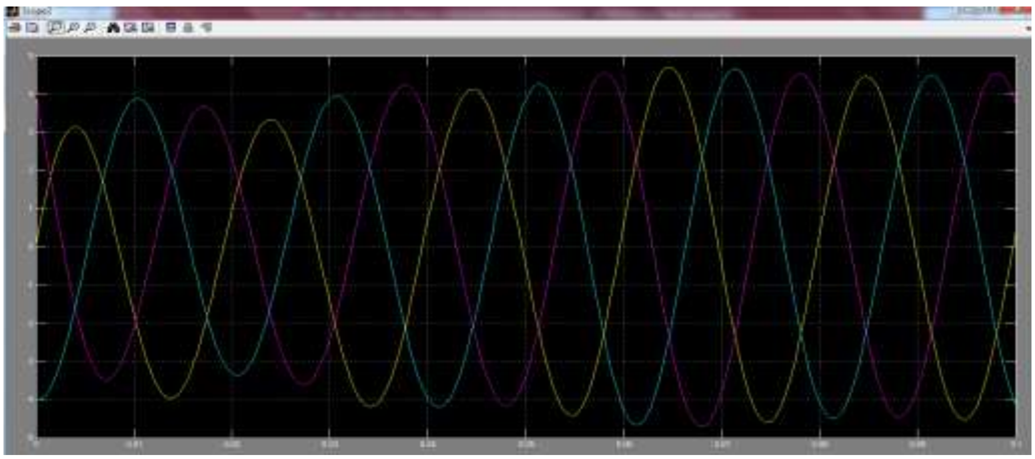

Figure 4. Graphs of changes in the output voltages of sensing elements over time

5. CONCLUSION.

Analyzing the above expressions (3) – (4) and the results presented in figures 3 –, 4 –, we see that the value of the output voltage of the current transformer is a function of the current passing through the stator winding without changing the source voltage and the resistance of the stator winding. If we take into account that the current in the stator winding of an asynchronous motor changes from a maximum to a steady value during the start-up period, the voltage at the output of the sensing element can change from a small value to a steady value.

6. ACKNOWLEDGMENT

From the graphs in Figure 4, it can be seen that after the start of the asynchronous motor, the value of the output voltage of the sensing element placed on the stator blades is small, and the output voltage begins to increase until it reaches a steady value after starting slowly, and after 0.07–0.08 seconds, the output voltage reaches its steady state. reached its status.

From the conducted research, we conclude that the secondary voltages at the output of the sensing elements of the current transducer placed in the asynchronous motor's wedges during the transition period reach their stable value in the time interval of up to a tenth of a second, and the use of this current transducer as an element of the control and management system of the reactive power of the asynchronous motor is effective.

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