**Research of Metrological and Reliability Indicators of a   
Three-Phase Current Transducer in Control of Asynchronous Motors**

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**Abstract.** This article explores Metrological and reliability indicators of the primary current voltage transducer to control asynchronous motors normal and no normal operating modes. In this, the current transducer sensitive element depends on the number of wraps to the asynchronous motor primary magnitudes, while the size acting on the change in the value of the secondary output voltage are studied. At the same time, the redundancy of the current transducer is explained Depending on its elements.

**Keywords:** asynchronous motor, control system, current transducer, graph model, three-phase, secondary output voltage.

**INTRODUCTION**

The sensing element of an asynchronous motor’s current-to-voltage transducer plays a crucial role in delivering output signals for control and protection systems. This type of transducer is known for its structural simplicity and ease of manufacturing, making it highly suitable for monitoring the reactive power of asynchronous motors while ensuring a continuous control signal supply to system components [1].

Presently, various types of current transducers exist, each characterized by different operating principles, designs, signal conversion mechanisms, and application areas. These distinctions are based on their physical and technical performance characteristics.

In the control and monitoring systems of asynchronous motors, current transducers can generally be categorized into two groups based on their network interface [2]:

Contact-type current transducers – which operate by detecting voltage drops across resistive, inductive, or capacitive components;

Contactless current transducers – which rely on magnetic fields generated by the measured currents.

Contactless devices are further subdivided based on their sensing elements, including electrometric, electromechanical, induction-based, magnetogalvanic, magnetoresonance, and magneto-optical types.

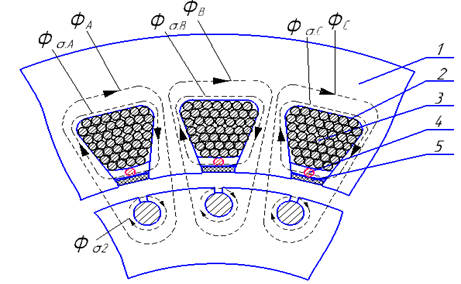
Although contact-type transducers have some advantages—such as immunity to external magnetic fields and ferromagnetic materials, and no need for auxiliary power—they also present several limitations. These include large size and power consumption, lower reliability, and limited scalability. As a result, they are rarely used in modern automation, high-voltage transmission lines, or power distribution systems.

Designing current transducers for asynchronous motor control systems requires balancing several often conflicting demands: high accuracy, standardized output levels, expanded functional range across three-phase networks, reduced size and weight, manufacturing simplicity, and ease of assembly. These design challenges necessitate careful selection of operating principles, optimal synthesis methods, and feasibility-focused engineering solutions.

To enhance transducer performance, structural improvements or novel design principles are applied, especially involving advanced measurement technologies for the sensing element. The development criteria—such as environmental conditions, energy consumption, metrological characteristics, and structural design—form the foundation for evaluating their effectiveness in reactive power monitoring applications.

Despite ongoing advancements, no universal quantitative metric yet exists to evaluate primary current accuracy for asynchronous motor systems. Therefore, specific applications typically rely on an accuracy index that considers current symmetry, reliability, and normalization degree. Recently, economic efficiency has also emerged as an important design consideration [3].

The current voltage transducer, created on the basis of studies, is the 3 rd main loop in 2‒stator wedges and the 4 th additional loop located between the 5 ‒ wedge ponas, consisting of a common magnetic loop with the main stator wedges (Figure 1).



**FIGURE 1**. Position of the current to the voltage transducer in the asynchronous motor stator section and the appearance of magnetic currents

The measurement tube is arranged in such a way that the output magnitude in the form of voltage is obtained from the measurement tube under the action of the main and scattering magnetic currents generated in the stator Section [4].

In the general case of asynchronous motor-consuming Electrical Power Jet Power Control and monitoring systems, the indicator for quantitative quality assessment of primary currents (QAPC) is expressed as follows:

(1)

here: A – generalized indicator of the accuracy of the primary current Switch; R – generalized indicator of the reliability of the primary current Switch; O – generalized indicator that the primary current Switch provides a normalized output magnitude; E – generalized indicator of the economy of the primary current Switch; n-a factor that takes into account the effect of the performance quality indicator of the primary [5].

When creating a specific structure and modification system, the basic requirements for the primary current switches of the Reactive Power Control and monitoring systems consumed by the asynchronous motor are additionally required to take into account the conditions at the junction:

- three-phase primary current asymmetry consuming asynchronous motor;

- load property-dependent nonlinearity;

- link to the electromagnetic principle of current transformation phase shifts between secondary current and voltages;

- controllable power and reactivity of Energy character;

- the complexity of the conditions and sources of the formation of magnetic flux and field in the magnetic system of the Switch.

Analysis has shown that the use of the electromagnetic system of the stator magnetic core to build an asynchronous motor stator current voltage transducer and normalize and generalize the signals at their output ensures high efficiency and accuracy.

**METHOD OF RESEARCH**

To study the asynchronous motor stator currents to voltages variable error, we use a graph model in which the errors for a single phase current of the variable described in Figure 2 are generalized [6, 7, 8].



**FIGURE 2**. Generalized graph model current voltage transducer

The input magnitude of the current transducer is given in graph I1, Fσ, in which the stator current I1 (IA) is changed to the magnetic-conducting force Fσ, as reflected by the KI1,Fσ inter-chain link coefficient. In the Fσ, Ф (0) chain, the Пσ magnetic conducting force is changed to the Фσ (0) magnetic flux, whose schematic function Tσ1, Пσ1 reflects the structure of the chain.

In an asynchronous motor stator magnetic loop, the magnetic flux Фσ(0) in general propagates along the X coordinate, along the stator magnetic loop from x=0 to x, and has the value Фσ(x). In the Фσ(x), Uoutσ loop, there is a change in the Фσ(x) current to the Uoutσ voltage, which is reflected by the KFσ(x), the Uout Inter-loop contact coefficient.

The informant graph takes into account that the modifications to the model are different y1, y2, y3, y4 the independent variables acting on are included. relation of the acting independent variables to the corresponding transformation chains Ky1, Ky2, Ky3, Ky4 is reflected through the coefficients [9, 10, 11].

In the control and monitoring of asynchronous motor reactive power, the mean quadratic error σE of the transducer is determined by the following expression:

(2)

where σ1, σ2, σ3 are the mean quadratic errors of the individual elements.

When the values of the quoted KE and 𝜎∑ errors are known, the value of the σE entropy error is determined from the following expression [12, 13]:

(3)

Summing according to the graph model of the current variable the organizers of the error errors in chains are calculated .

Errors in the input chain current transducer to voltage ‒ I1 current as a result of temperature changes, moisture levels, and external magnetic interference, etc., ω1 changes in the angular frequency, KI1, Fµ changes in the contact coefficient, as well as changes in the physical properties of the materials of Electrical and magnetic conductors [14, 15, 16].

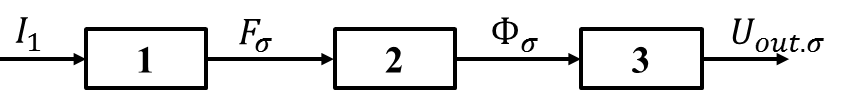
The experimental results indicate that changes in the stator winding resistances due to temperature variations lead to alterations in the voltage waveform signals at the outputs of the three-phase current transducer:

(4)

here: **U1** – the line voltage applied to the ends of the stator windings; **I1** – the current passing through the stator winding; **R1, X1** – the active and reactive resistances of the stator winding; **w1** – the number of turns in the stator winding; **w4** – the number of turns in the measuring winding.

**RESEARCH RESULTS**

Asynchronous motor Jet Power Control the functional circuit outline of the three-phase current transducer will be as follows (Figure 1):



**FIGURE 3**. Functional scheme of asynchronous motor Jet Power Control system transducer

In Part 1, the current of the I1 stator coil is changed to the fσ magnetic-conducting force, in Part 2, the fσ magnetic-conducting force generates the fσ magnetic current in the stator magnetic loop, in Part 3, a triple voltage is generated at the measurement coil output [17].

To assess the general error of the current transducer, let's separately consider the errors that appear in the parts presented.

1. *I1 ‒ Fσ*  change chain error, i.e. *σ1*=0.1 (±0.1% ‒ from the primary face value) ‒ marginal quantity;

2. *Fσ ‒ Фσ* for *σ2*=0.1;

*3. Фσ ‒ Uout* for *σ3*=0.1 is determined based on the low amounts:

(5)

We divide all the organizers of the errors into additive and multiplicative errors, and in accordance with the distribution law of the probability of their occurrence, their mean quadratic deviation is found.

For a current variable *∆* net entropy error is equal to [18, 19, 20]:

(6)

here *KE=*2.07‒ entropy coefficient of the variable element; 𝜎∑‒average quadratic error of the sum of the element.

According to the calculations and studies cited asynchronous motor reactive power control and monitoring three-phase current transducer entropy error Δ=0.36 i.e. ±0.36 is equal to, and the normalized value of the accuracy of the transducer can be selected from the numbers specified in the standard. The normed precision class for the studied three-phase current transducer is 0.5 i.e. ±0.5% [21].

One of the main indicators of reliability of three-phase current transduceres of an asynchronous motor is the continuous improvement of reliability calculation methods. The current transducer is divided into elementary and functional types according to the theoretical basis for calculating reliability. Reliability in the case of work is characterized by taking into account the failure of the current transducer (unexpectedly, completely) and the characteristics of the breakdowns (suddenly, step‒by-step, full, short circuit, open, interruptions, etc.). Reliability is understood as the ability to maintain the elements of the control and monitoring system in the range established in regulatory documents by performing its operating State in certain conditions, volumes, for a given period of time [22].

The classes of current transducer failures are as follows:

1) by the degree of failure of the ability to work: complete and partial;

2) according to the specific appearance of the process: suddenly and gradually;

3) by dependence on other failures: related and unrelated;

4) by Time: stable and unstable (disturbances).

Partial breakdown leads to partial operation of the current transducer, and complete breakdown leads to a failure of the current transducer (to restore the working capacity, the current transducer's sensitive windings will need to be carried out on inspection).

If the failure of some element of the system does not cause the failure of other elements, such a violation is called an unrelated failure.

A sudden failure is caused by a sharp change in the basic parameters and elements of the system. Constant failures, on the other hand, are observed due to the gradual change in parameters that occur due to wear and tear of the elements.

The stable failure of the operating capacity of the current transducer can only be eliminated by repair. Failure to work (failure) is a disorder that can itself recover, leading to a short ‒ term failure condition (which does not require hardware repair).

A permanent failure is a repeatedly repetitive disorder of the same character.

In objects that do not work in constant time, failures may have the following views in time:

- failures that occur as a result of the failure of the required performance from the object;

- production when not required - deceptive performances;

– when the operation of other elements is required, the fall of the object under consideration to work-overwork.

The failure of the transducer does not affect the condition of the work of the asynchronous motor. Considering this, no attention is paid to the mechanical organizer of the reliability of the three-phase current transducer [22].

The parametric and variable reliability indicators of the three-phase current variables are derived from the probability of the variable being in a constant working state of Рpar.(t) =0.99 =0.99 and Рvar.(t)=0.99. The probability of indicators depending on the failure of the transducer will not depend on the time of the change law, and in this case the uniformity of the reliability of the parts of the current transducer is ensured.

The probability that the three-phase current variable does not exceed the normative values established in the working state of the variable, changing the error to secondary output magnitudes in the form of voltages in the real primary stator currents of the asynchronous motor characterizes the Metrological reliability of the transducer and its components [23].

Changing the asynchronous motor stator currents to a magnitude in the form of secondary voltage according to the analysis of the principle of operation of the current transducer, the states of the components of the studied variable determining the reliability and organizers were developed in the form of a table. From the developed table, we come to the conclusion that the reliable working condition of the measuring rod of the current variable is one of the main indicators of the variable determining the reliable working condition.

**CONCLUSIONS**

Based on the probability of working cases of the components of the current transducer, the probability of operation of the general partitions of the transducer is determined (Table 1). Asynchronous motor stator currents to output voltage are likely to be in the working state of the transducer's main changing sections (stator windings, magnetic core, and measuring windings) Рstator wind.  = 0.99; Рmagnetic core  =0.99; Рmeas.wind. =0.99 is obtained as [24].

**TABLE 1. Working status probability of the current transducer pieces**

|  |  |  |  |
| --- | --- | --- | --- |
| № | Current transducer piece position | Working State probability | Replacement pieces and general cases |
| 1 | С1 | P1·P2·P3 | 1‒ asynchronous motor stator winding;  2 ‒ magnetic core ; 3 ‒measuring winding; |
| 2 | С2 | P1·P2· (1‒P3) | 1;2 – measuring winding failure |
| 3 | С3 | P1·P3· (1‒P2) | 1;3 – magnetic core failure |
| 4 | С4 | P2·P3· (1‒P1) | 2;3 – stator winding failure |
| 5 | С5 | P1· (1‒P2)· (1‒P3) | 1 – magnetic core, measuring winding failure |
| 6 | С6 | P2· (1‒P1)· (1‒P3) | 2 – stator winding, measuring winding failure |
| 7 | С7 | P3· (1‒P1)· (1‒P2) | 3 – stator winding, magnetic core failure |

**TABLE 2**. Working condition probability of the current transducer pieces

|  |  |
| --- | --- |
| № | Working State probability |
| 1 | P3P2·P1 = 0,970299 |
| 2 | (1‒P3)· P2·P1= 0,009801 |
| 3 | (1‒P2)·P1·P3· = 0,009801 |
| 4 | (1‒P1)·P2 ·P3· (1‒P1) = 0,009801 |
| 5 | (1‒P3)·(1‒P2) ·P1 = 0,000099 |
| 6 | (1‒P3)· (1‒P1)·P2· = 0,000099 |
| 7 | · (1‒P2)· (1‒P1)·P3· = 0,000099 |

We calculate the working condition of the current transducer using the reliability of the current transducer pieces in the working State, which is presented in Table 2:

Judging from the reliability indicator calculated above, we see that the total probability of the working state of the AC transducer currents to secondary voltages is РƩ =0,95.

This research examined the accuracy and reliability features of a three-phase current-to-voltage transducer applied in the monitoring and control of asynchronous motors. The proposed model demonstrates that the accuracy and reliability of the transducer are significantly influenced by the quality of the magnetic circuit, stator windings, and measurement windings. Through the application of a graph-based modeling approach and the entropy method, it was possible to quantify the transducer’s error sources and overall precision class.

The results confirm that the developed transducer meets standard metrological requirements, with a normalized accuracy class of 0.5 and an entropy-based error margin of ±0.36%. Moreover, reliability analysis shows a high probability (95%) of stable operation under nominal conditions, which validates its practical use in industrial asynchronous motor systems.

In conclusion, the proposed current transducer design offers an effective solution for real-time monitoring and control of reactive power in asynchronous motors. It ensures reliable signal conversion, low measurement error, and a robust structure suitable for integration into automated control environments. Future work may focus on optimizing the transducer structure further to enhance performance under dynamic and non-linear load conditions.

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