RESEARCH ARTICLE | NOVEMBER 04 2025

Modelling and research of three-phase transducer for remote monitoring of reactive power nets based on IoT FREE

Ilkhomjon Siddikov; Mokhirbek Makhsudov ✉; Dilyorbek Karimjonov; Mamurjon Yigitaliyev

AIP Conf. Proc. 3331, 030078 (2025)
https://doi.org/10.1063/5.0305664

Modelling and research of three-phase transducer for remote monitoring of reactive power nets based on IoT

Ilkhomjon Siddikov [1], Mokhirbek Makhsudov [2, a)], Dilyorbek Karimjonov [2], Mamurjon Yigitaliyev [3]

[1] National Research University TIIAMME, Tashkent, Uzbekistan
[2]Andijan Machine-Building Institute, Andijan, Uzbekistan
[3]Andijan Institute of Agriculture and Agrotechnologies, Andijan, Uzbekistan

a) Corresponding author: mohirbek2702@mail.ru

Abstract. This article contains information about the induction motor three-phase electromagnetic current transducer. A practical and theoretical static description of the differential connection between the sensitive element loops of the asynchronous motor's three-phase electromagnetic current transducer and its output values is developed. Based on the static description, a comparison examination of the transducer's output voltage signals with differentially linked sensitive element loops was performed. At the same time, the effect of stator temperature on the current transducer's output voltage signal is discussed, as well as the technical specifications of the asynchronous motor three-phase electromagnetic current transducer.

INTRODUCTION

Analyses demonstrate that electric drives using asynchronous motors consume a considerable portion of the electricity produced in businesses. The rule of electromagnetic induction governs asynchronous motors, which operate at variable voltage. This demands that the voltage consumed by asynchronous motors meet defined requirements. As a result of the flow of asymmetrical and high harmonic currents from the stator coil of the asynchronous motor, magnetic currents are formed that negatively affect the operating modes of the asynchronous motor, which leads to an increase in the asynchronous motor reactive power, therefore, it is necessary to develop technical solutions for the monitoring and control of asymmetrical and high physical models of asynchronous motor three-phase electromagnetic current loops connected in series, parallel and differential circuits with one sensitive element loop or two sensitive element loops in monitoring and control of asynchronous motor reactive power compensating filter-compensation constructions have been researched in appropriate order. According to the description of these asynchronous motor three-phase electromagnetic current transducer models, it was determined that the output signals of the three-phase electromagnetic current transducer with two sensitive elements and mutual differential connection accurately describe asymmetrical and non-sinusoidal currents of asynchronous motor reactive power.

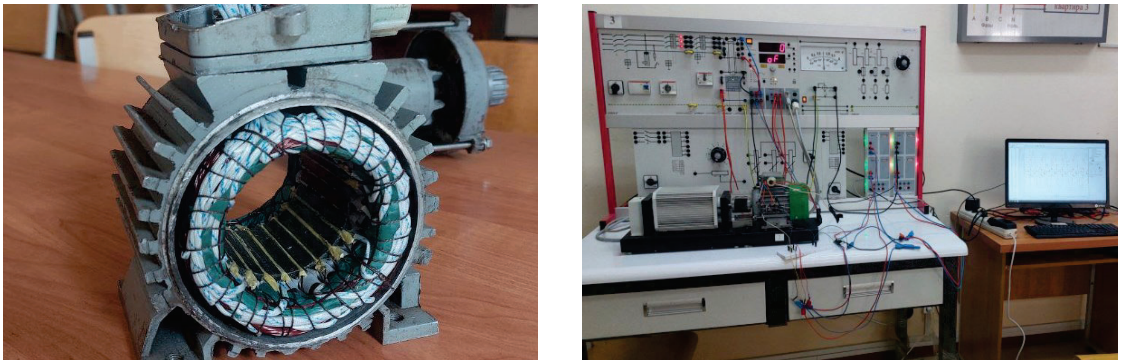
EXPERIMENTAL RESEARCH

The input and output ends of the three-phase electromagnetic current transducer, which are wedge-shaped and positioned in a suitable order with the stator clamps, are extended out of the stator to monitor and regulate asynchronous motor filter compensating devices. A three-phase electromagnetic current transducer with one sensitive element loop suitable for each phase has six input and output ends. A three-phase electromagnetic current transducer with two sensitive element loops has twelve input and output ends when stator phases are used. Figure 1 depicts the sensitive element loops and stator outside, which are compatible with the asynchronous motor's stator wedges and mounted on them [1-5].

The asynchronous motor monitors and controls the filter-compensation devices of the asynchronous motor's reactive power via the output signals of the three-phase electromagnetic current transducer, providing information about the asymmetrical and high harmonic currents generated in the asynchronous motor. This asynchronous motor three-phase electromagnetic current transducer is considered constructively simple and

IV International Scientific and Technical Conference "Actual Issues of Power Supply Systems"
AIP Conf. Proc. 3331, 030078-1–030078-7; https://doi.org/10.1063/5.0305664

convenient to install in stator wedges, as it can provide information about asymmetric and non-sinusoidal currents affecting asynchronous motor reactive power in the form of a continuous signal (FIGURE 1) [6, 8].



a) b)

FIGURE 1. a) asynchronous motor three-phase electromagnetic current transducer is the appearance of the stator in which the sensitive element loops are located, b) a research stand for determining the asymmetrical and non-sinusoidal currents of the asynchronous motor reactive power.

The equivalent scheme for the investigation of a three-phase electromagnetic current transducer with differentially connected two sensitive element loops compatible with the stator coils and situated between the poles, is shown below (Figure 2).

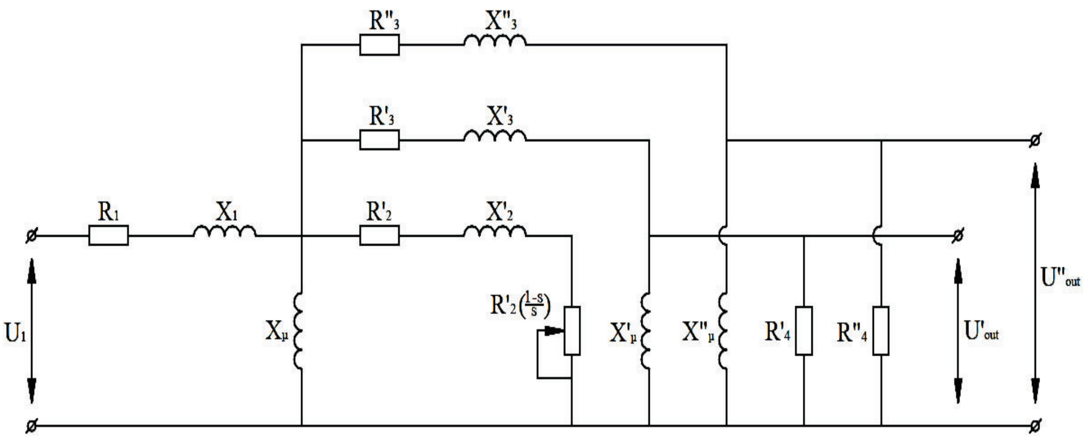


FIGURE 2. Equivalent scheme of a three-phase electromagnetic current transducer with two sensitive element loops per phase.

The value of the asymmetrical and high harmonic currents of the reactive power of the asynchronous motor is calculated using a voltage of 5 V from a three-phase electromagnetic current transducer that is standardized for monitoring and control devices. The amount of this 5 V rated voltage is directly proportional to the number of windings of the electromagnetic current transducer and the techniques of connecting two or more sensitive element loops. The number of windings in sensitive element coils is determined by the size of the space between the stator coil and core. High harmonics and secondary currents created in the stator interfere with the output voltage signal, preventing precise information about the measured quantities.

As a result, the principle of receiving a signal from an asynchronous motor three-phase electromagnetic current transducer, which compensates for these currents, consists of loops of two sensitive elements suitable for each phase, which are placed oppositely and differentially connected to one another. The research findings indicate that the asynchronous motor three-phase current electromagnetic transducer with two sensitive element loops and differentially coupled to each other has adequate and accurate output signals [4, 6].

RESEARCH RESULTS

The practical and theoretical static characteristics of an asynchronous motor three-phase electromagnetic current transducer with two sensing element loops suitable for each phase and mutually differentially connected for monitoring and controlling asynchronous motor reactive power filter-compensation devices are described below (Figure 3, Figure 4) [7, 9].

The reactive power of an asynchronous motor fluctuates during its transient operation. The electrical and electromagnetic mechanical parameters of the asynchronous motor have an effect on the three-phase electromagnetic current transducer's output voltage. The number of loops of sensitive materials placed in the stator slots, as well as their connectivity methods and location, all have a direct impact on the sensitivity of the electromagnetic current transducer and output signal accuracy [4].

During the start of an asynchronous motor, the number of rotor spins and the inductance of the stator coils cause the stator currents to increase numerous times (Figure 5).

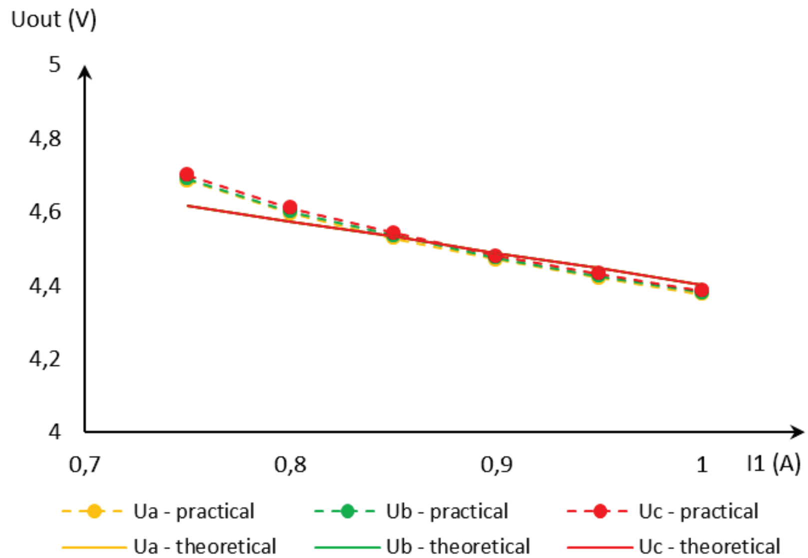


FIGURE 3. Static description of asynchronous motor three-phase electromagnetic current transducer with sensitive element circuits differentially connected (based on the condition U_1=const).

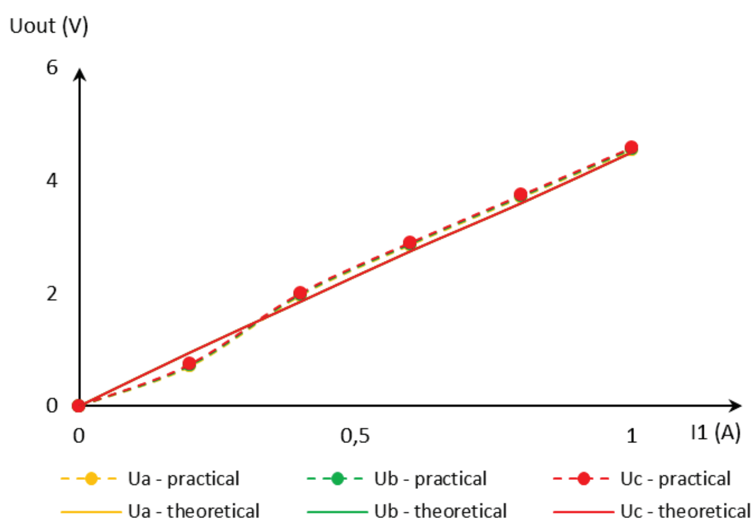


FIGURE 4. Static characteristics of the dependence of output signals of an asynchronous motor three-phase electromagnetic current transducer with two sensitive elements and connected in a mutual differential circuit on the stator current (based on the condition M_1=const).

Based on the static description of the three-phase electromagnetic current transducer with differentially linked sensitive element loops reflecting asymmetrical and high harmonic currents generated in an asynchronous motor, the adequacy of its output voltage signals is determined below:

Adequacy of the output voltage signals in the mode of operation of the asynchronous motor:

$$\delta = \left| \frac{U_{practical} - U_{theoretical}}{U_{practical}} \right| \cdot 100\% = \left| \frac{4.685 - 4.616}{4.685} \right| \cdot 100\% = 1.472\%$$

Adequacy of the output voltage signals in the nominal operating mode of the asynchronous motor:

$$\delta = \left| \frac{U_{practical} - U_{theoretical}}{U_{practical}} \right| \cdot 100\% = \left| \frac{4.473 - 4.462}{4.473} \right| \cdot 100\% = 0.245\%$$

Adequacy of the output voltage signals in the load (I_{load}=1.15I_{nom}) operation mode of the asynchronous motor:

$$\delta = \left| \frac{U_{practical} - U_{theoretical}}{U_{practical}} \right| \cdot 100\% = \left| \frac{4.375 - 4.402}{4.375} \right| \cdot 100\% = 0.617\%$$

According to the findings of the study, the difference between the practically determined and theoretically determined values of the output voltage signals of the asynchronous motor three-phase electromagnetic current transducer depends on the reactive power of the asynchronous motor and ranges from 1.472 % to 0.245 % between the normal and nominal operating modes of the asynchronous motor, as well as 0.245 % between the nominal and load modes. A change of 0.617 % was discovered.

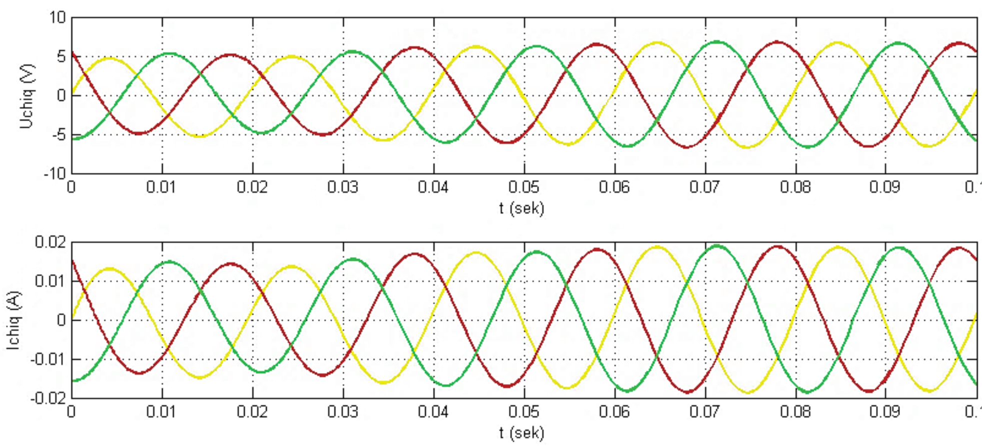


FIGURE 5. Dynamic characteristics of a three-phase electromagnetic current transducer with differentially connected sensitive element loops calculated using the Matlab program by equivalent scheme.

To monitor and control the filter-compensation devices of the reactive power of the asynchronous motor, the voltage generated in the asynchronous motor is based on the output voltage signals of the three-phase electromagnetic current transducers, which are connected in series, parallel, and differentially, consisting of one sensitive element loop and two sensitive element loops, suitable for each phase. The physical model for determining asymmetric and higher harmonic currents was created at an educational and scientific laboratory. The values of asymmetrical and higher harmonic currents were determined using an Arduino microcontroller, with programming code generated in the Arduino IDE environment [10, 12-14].

During the operation of the asynchronous motor, the heating of the stator coils due to external humidity or load has a direct effect on the output voltage signals of the three-phase electromagnetic current transducer. Based on the results of the conducted research, it was determined that the temperature in the stator part before starting the asynchronous motor is t=31.2^o C and the active resistances of the stator coils are equal to R_A=8.23 Ohm, R_B=8.25 Ohm, R_C=8.28 Ohm. In the nominal operating mode, after 25 minutes, the temperature in the stator part was t=52.7^o C and after 35 minutes, it was t=60.3^o C. At the end of the study, it was found that the active resistance of the stator coils changed to R_A=9.18 Ohm, R_B=9.21 Ohm, R_C=9.25 Ohm [2, 15-18].

In order to monitor and regulate the filter-compensation devices of the asynchronous motor's reactive power, the output voltage signals must be corrected for the influence of stator temperature. According to the research findings, the relationship between temperature and the resistance of the sensitive element is as follows:

$$R = R_0\left(1 + \alpha(t_2 - t_1) + \beta(t_3 - t_2)^2\right)$$

Based on the determined experimental results, the temperature of the asynchronous motor stator winding has been determined to change linearly up to t=50° C and nonlinearly at higher temperatures, and it can be expressed by the above formula. Based on the results of the research, the main parameters of the three-phase electromagnetic current transducer of an asynchronous motor are as follows [19, 20]:

TABLE 1. Parameters of the three-phase electromagnetic current transducer of an asynchronous motor.

Source voltage, (V)	380
Nominal output voltage signal, (V)	5
Change interval, A	0÷3000
The number of sensitive element loops	1 or 2
Number of sensitive element loops	2
Nominal output voltage signal frequency, (Hz)	50
Static description	linear
Accuracy, %	0.372
Size, mm	0.04-1.5
Mass, kg	0,082 – 0,169

When monitoring the filter-compensation devices of the asynchronous motor's reactive power via wireless networks, the output voltage signal from the three-phase electromagnetic current transducer placed in the stator slots is connected to the analogue pins of the microcontroller control unit, resulting in variable output voltages from the current transducer.

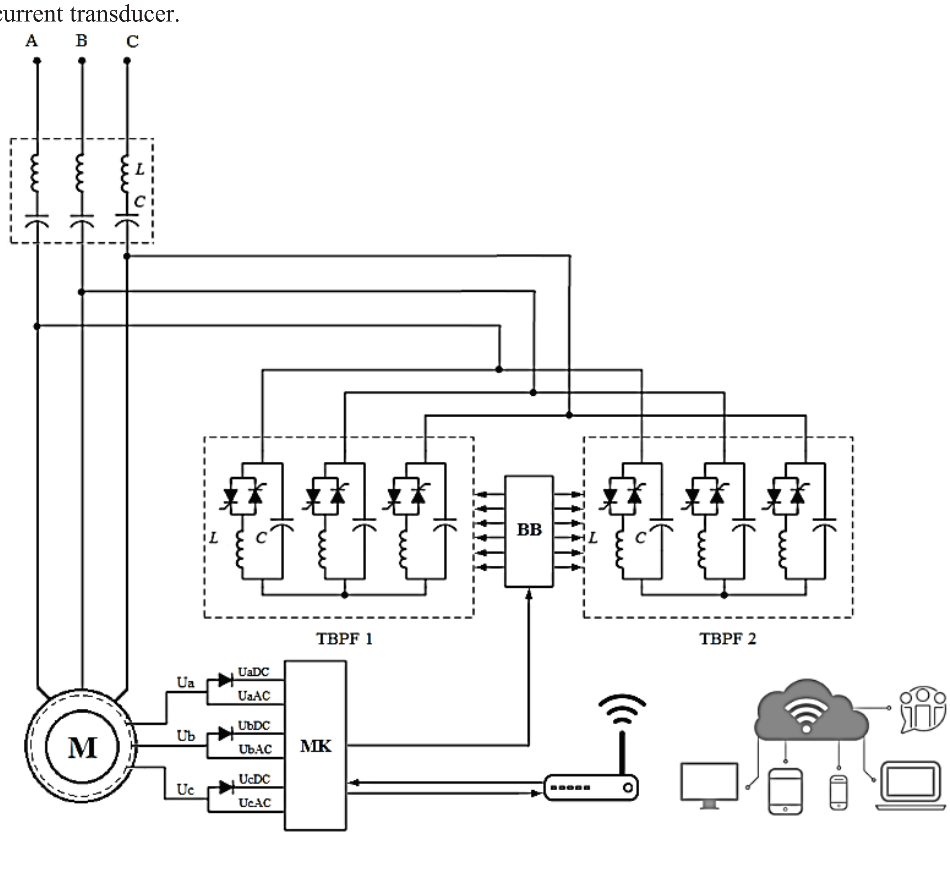


FIGURE 6. Filter-compensation devices are monitored using cloud technology based on the data from an asynchronous motor three-phase electromagnetic current transducer.

The microcontroller determines each information based on the real-time timer module and delivers pulse signals to the control unit of the filter-compensation device's thyristors via digital pins, allowing for remote control. The specified information is transmitted to the Web page and other forms by SMS message or the

Internet via the GSM or Ethernet module. The information provided to the SMS message or the Web page via cloud technology includes the efficiency of the asynchronous motor, three-phase electromagnetic current converter, output voltage signal, symmetrical and high harmonic current values, and filter-compensation device efficiency (Figure 6) [20].

CONCLUSIONS

The possibilities of incorporating three-phase current electromagnetic transducers in the monitoring and control of the reactive power consumed by the asynchronous motor were investigated, and the analysis of the asymmetrical and non-sinusoidal currents of the asynchronous motor's reactive power was considered on the basis of domestic production enterprises. The installation of asynchronous motor filter-compensation devices, as well as the use of the proposed three-phase current electromagnetic transducer as a monitoring and control element in each production enterprise, resulted in a 5 % reduction in electrical energy consumption for devices with an asynchronous motor electric drive.

Depending on the asynchronous motor's reactive power, the difference of the output voltage signals of the asynchronous motor three-phase electromagnetic current transducer between the practically determined values and the theoretically determined values was determined, resulting in a change of 1.472 % to 0.245 % between the asynchronous motor's idle and nominal operating modes and 0.245 % to 0.617 % between the nominal and load modes.

The effect of stator temperature on the output voltage signals of the asynchronous motor three-phase electromagnetic current transducer was investigated. As a result, the effect on the output voltage signals was determined based on the linear change in stator winding temperature up to t=50 ^{o} C and the nonlinear change at higher temperatures.

REFERENCES

1. Karimjonov D.D., Siddikov I.X., Azamov S. S., & Uzakov, R. Study on determination of an asynchronous motor's reactive power by the current-to-voltage converter // In IOP Conference Series: Earth and Environmental Science 1142. 2023. 012023. http://doi.org/10.1088/1755-1315/1142/1/012023.
2. Wang, P., Zhang, G., Zhu, X., & Luo, C. Planar Rogowski coil current transducer used for three-phase plate-form busbars // IEEE Instrumentation & Measurement Technology Conference IMTC, 2007. pp, 1-4. http://doi.org/10.1109/IMTC.2007.378988.
3. M.García-Gracia, M.Villén, M.A. Cova, N. El Halabi. Detailed three-phase circuit model for power transformers over wide frequency range based on design parameters // Electric Power Systems Research 92. 2012, pp, 115-122. https://doi.org/10.1016/j.epsr.2012.06.015.
4. M. H. Samimi, A. A. S. Akmal and H. Mohseni, Optical Current Transducers and Error Sources in Them: A Review // IEEE Sensors Journal, vol. 15, no. 9, 2015. pp. 4721-4728. doi:10.1109/JSEN.2015.2428652.
5. Amirov S.F., Babanazarova N.K. Mathematical models of the new remote transformer current transducers // IOP Conference Series: Earth and Environmental Science 808, 2021. PP, 012001. https://doi.org/10.1063/5.0114557.
6. Siddikov I.Kh., Karimjonov D.D., Abdigapirov A.A. Research of three-phases current's transducers of filtercompensation devices for control reactive power's consumption of asynchronous motor // Chemical Technology, Control and Management. 2023. Iss. 1, Article 5. DOI: https://doi.org/10.59048/2181-1105.1423.
7. Siddikov I.Kh., Makhsudov M. T., Karimjonov D. D. Method of determination of stator current and power factor based on asynchronous motor three-phase current sensor // Chemical technology control and management. 2022. 2, 30-38.
8. Abubakirov A.B., Najmatdinov Q.M., Kurbaniyazov T.U., Kuatova S.B. Sensor characteristics monitoring and control of single and three-phase currents in electric networks // ACADEMICIA: An International Multidisciplinary Research Journal.2022. 11(3), 2282-2287. http://doi.org/10.5958/2249-7137.2021.00856.9.
9. Makhsudov M., Karimjonov D. Research algorithm and dynamic characteristics of three–phase electromagnetic current transducers in filter–compensation devices // E3S Web of Conferences 461. 2024. PP, 01056. https://doi.org/10.1051/e3sconf/202346101056.
10. I. K. Siddikov, M. A. Anarbaev, A. A. Abdumalikov, M. A. Sobirov, M. T. Maxsudov and I. M. Xonturaev. Technological aspects of modelling and research of smart grid // 2019 International Conference on Information Science and Communications Technologies (ICISCT). 2019. PP, 1-5. https://doi.org/10.1109/ICISCT47635.2019.9011936.
11. I.K. Siddikov, M.A. Anarbaev, A.A. Abdumalikov, A. B. Abubakirov, M.T. Maxsudov and I.M. Xonturaev, Modelling of transducers of nonsymmetrical signals of electrical nets // 2019 International Conference on

Information Science and Communications Technologies (ICISCT). 2019. PP, 1-6. https://doi.org/10.1109/ICISCT47635.2019.9011981
12. Abubakirov A., Kurbaniyazov A., Bekimbetov M. Analysis of three-phase asymmetrical currents in the secondary voltage of signal change sensors in the power supply system using graph models // E3S Web of Conferences 525. 2024. PP, 03013 https://doi.org/10.1051/e3sconf/202452503013.
13. J. Faiz, B.M.Ebrahimi and T.Noori. Three- and Two-Dimensional Finite-Element Computation of Inrush Current and Short-Circuit Electromagnetic Forces on Windings of a Three-Phase Core-Type Power Transformer // IEEE Transactions on Magnetics, vol. 44, no. 5, pp. 590-597, May 2008. https://doi.org/10.1109/TMAG.2008.917819.
14. I. Kh. Siddikov, Kh.A. Sattarov, A.A. Abdumalikov. The static characteristics of primary current transducers of current of specific electrical loads of renewable power sources // AIP Conf. Proc.15 March 2023; 2612 (1): 050002. https://doi.org/10.1063/5.0115211.
15. I. K. Siddikov, A. A. Abdumalikov and M. T. Makhsudov. Modeling and Research Multiphases Signal Transducers of Power Control Systems // 2020 International Conference on Information Science and Communications Technologies (ICISCT). 2020. PP, 1-4. https://doi.org/10.1109/ICISCT50599.2020.9351482.
16. M.Makhsudov, O.Zaripov, N.Akbarova, Sh.Zaripov. Asynchronous in motors reactive power current for monitoring and control modifiers scientific, ETC // AIP Conf. Proc. 17 June 2024; 3152 (1): 050021. https://doi.org/10.1063/5.0218837.
17. Siddikov I. K., Abdumalikov A.A., Makhsudov M.T. The Dynamic Characteristics of Sensors of Primary Currents of Energy Sources to Secondary Voltages // International Journal of Innovative Technology and Exploring Engineering. 2020. PP, 2529-2534. http://doi.org/10.35940/ijitee.D1906.029420.
18. Siddikov I. K., Boikhonov Z. U., Makhsudov M. T. Uzaqov. R. Features productions reactive power on systems electrical supply with renewable sources energies // Academicia: an international multidisciplinary research journal. (2020). 10(6), 292.
19. S. Jing, Q. Huang, F. Tang, W. -J. Lee and Z. Zhang. Study on Additional Dynamic Component of Electronic Current Transducer Based on Rogowski Coil and Its Test Approach // IEEE Transactions on Industry Applications, vol. 56, no. 2, pp. 1258-1265, March-April 2020. https://doi.org/10.1109/TIA.2020.2965866
20. Karimjonov, D. D. Research of asymmetrical and nonsinusoidal currents of asynchronous motor reactive power // ISJ Theoretical & Applied Science, 10 (126). 2023. PP, 345-351. https://doi.org/10.15863/TAS.2023.10.126.27