The Dynamic Characteristics of Sensors of Primary Currents of Energy Sources to Secondary Voltages

I. Kh. Siddikov, A. A. Abdumalikov, M. T. Maksudov

Abstract: In this article representation of analytical equations, mathematical description of the dynamic processes and result of researches of sensors-transducers of multiphase primary currents to secondary voltage are given. The base of the researches of dynamic characteristics of sensors of multiphase primary currents to secondary voltages is graph model of sensors with distributed parameters and digital-based cloud computing technology, that are three services, SaaS, PaaS and IaaS.

Keywords: electrical energy, reactive power, power supply systems, primary current, sensor, secondary voltage, source, signal, dynamic characteristics.

I. INTRODUCTION

The dynamic characteristics of sensor of transforming of primary currents of power supply systems (PSS), nets to secondary voltage – signals need organized on the basis of mathematical models and modern computing technologies. Now, very many researches, orienting to research of static and dynamical processes, transducing secondary voltage – signals on the basis of magnetic flows, produce signals by primary currents of active and reactive powers of electrical nets PSS [1-2].

Provision of reliable and continuous power energies with hybrid PSS on the basis of renewable energy sources (RES) requires not only choosing of power sources, electrical nets and equipment’s, but also measuring, controlling and adjusting devices and sensors, which provide reliable performance and monitoring of PSS. Control and monitoring on the base of multiphase currents sensors provides transformation of electricity measuring values-signal, based using different physical and technical effects [3-5].

During research of dynamic characteristics of primary measure current sensors required to determine relations between \( I_p \) – input multiphase currents of nets of PSS and output electrical voltages \( U_{out} \) on the basis of cross-sectional surface \( S_{se} \) – sensitive elements parameters, magnetic flux \( Q_m \) - flowing through sensitive elements - \( U_{out} \) - sensors and their \( w_{se} \) turnovers amount, which depend from geometric parameters of transforming magnets value, sensitive elements and possible values range, also variable parameters of magnetic core [6-8].

Multiphase input currents from power sources of SPP nets, flow through line - primary windings of sensors, generate magnetic fluxes in magnetic cores, which flows through the airspace, which installed sensitive elements - secondary windings of sensors. The sensors control and adjust multiphase currents of nets of PSS and electrical values form transformed via sensors provide a secondary voltage - signals about magnetic fluxes, on depended connection of sources: when star connection with phase or linearity currents of PSS nets with output voltage \( U_{ap}, U_{bp}, U_{cp}, U_{aA}, U_{bA}, U_{cA} \) - signals [7-12].

The sensitive elements of sensors are designed as motionless on insulated sheets and produce normalized \( U_{ap}, U_{bp}, U_{cp}, U_{aA}, U_{bA}, U_{cA}, U_{a}, U_{b}, U_{c} \), voltages up to 20 V in sensitive elements [13-14]. Magnetic forces (m.f.) \( F_p \) produced by multiphase primary currents \( I_{ap}, I_{bp}, I_{cp}, I_{aA}, I_{bA}, I_{cA} \) - of PSS sources, generate magnetic flux, which flowing via sensitive elements in magnetic circuit, and cross magnetic flux, which influence each other and to primary currents to secondary voltage \( U_{out} \) [15-18].

II. METHODOLOGY

The dynamic characteristics of the sensors of primary currents to secondary voltage are investigated using the following analytical equations, which formed on the basis of graph model (Fig.1) [6,7-12].
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Here:  $I_{A1}$, $I_{B1}$, $I_{C1}$, $I_{A2}$, $I_{B2}$, $I_{C2}$ - multiphase primary currents, depended from connection of active or reactive power sources PSS, by y - star and Δ - triangle schemes.

$K_{in}$, $w_{ik}$ - intercircuit coefficient between primary currents, flowing via nets of PSS and magnetic forces (m.f.) $F_{ij}$, produced by magnetic sources;

$w(F_{ij})$, $P_{ij}$ - transmission function of magnetic circuit;

$P_{ij}$ - parameters of magnetic transforming circuit;

$F_{ij}$ - magnetic force (m.f.);

$Q_{ij}$ - magnetic flux;

$K_{out}$ - intercircuit coefficient between magnetic flux and output voltage - secondary signal.

The dynamic characteristics of PSS nets of active and reactive currents sensors are one of main characteristics, which reflects in time variation and dependence of output signals, which have form different with input values and parameters, external values, voltage parameters and voltage, itself [2,4, 18-20].

The analytical method of research based on graph model, describing of dynamic operations in sensors, allows to research whole complex of physical and technical processes occurring, as well as adjusting conditions of electrical net of reactive power sources. In article, review a switching process of the sensor based to conditions of electrical net of reactive power sources. In technical processes occurring, as well as adjusting sensors, allows to research whole the dynamic operations in sensors.

![Graph Model](image)

**Figure 1. The graph model of the processes of transforming multiphase primary currents to secondary voltages.**

The analytical equations of the output voltage on the sensor structure based on location of multiphase primary current fluxes, shape of magnetic flux’s and a type of sensors, a number of rolls and transforming parameters and formed as follows [4-10]:

$$U_{outa}(t) = -R_{outa}I_{outa}(t)$$

$$- L_{outa} \frac{dI_{outa}(t)}{dt} + w_{se1} \frac{dQ_{e1}(t)}{dt} + w_{se2} \frac{dQ_{e2}(t)}{dt},$$

$$U_{outb}(t) = -R_{outb}I_{outb}(t)$$

$$- L_{outb} \frac{dI_{outb}(t)}{dt} + w_{se1} \frac{dQ_{e1}(t)}{dt} + w_{se2} \frac{dQ_{e2}(t)}{dt},$$

$$U_{outc}(t) = -R_{outc}I_{outc}(t)$$

$$- L_{outc} \frac{dI_{outc}(t)}{dt} + w_{se1} \frac{dQ_{e1}(t)}{dt} + w_{se2} \frac{dQ_{e2}(t)}{dt},$$

Here:

$R_{out1}$, $R_{out2}$, $R_{out3}$, $I_{out1}$, $I_{out2}$, $I_{out3}$ - active resistance and inductance of sensory;

$w_{se1}$, $w_{se2}$, $w_{se3}$ - number of windings;

$I_{outa}$, $I_{outb}$, $I_{outc}$ - secondary output currents from sensitive elements units.

When PSS's electrical nets inductance is LEI = LEII = LEIII =0, nets will an increase in initial value of multiphase currents, then magnetic fluxes will attain a steady-state sinusoidal value [4,8].

Retrieval Number: D1906029420/2020©BEIESP

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The capacitors of reactive power (C), commonly used of PSS nets for compensation reactive energy, have a rated reactor capacity of 50 kVA, connected on a star-like scheme, and a single-circuit conductor, and when voltage equals to \( U_{E_A} = U_{E_B} = U_{E_C} = 220 \) V and currents will be equal to \( I_{A} = I_{B} = I_{C} = 131 \) A, flowing through reactive power sources and primary currents of sensor. Adjusted jet capacities with \( Q_{cA} = 50 \) kVA voltage of capacitor devices \( U_{E_A} = U_{E_B} = U_{E_C} = 380 \) V, connected to sensor by current in triangular scheme will be \( I_{A} = I_{B} = I_{C} = 76 \) A. In this case, the inductance of electrical net with have a reactive power supply is \( L_{eA} = L_{eB} = L_{eC} = 10^3 \) (Henry), capacitors \( C_{eA} = C_{eB} = C_{eC} = 10^2 \) (Farad), with full resistance \( Z_{eA} = Z_{eB} = Z_{eC} = 0.289 \) (Ohm) the maximum magnetic fluxes in a magnetic field are determine as a follows [4,19-22]:

\[
Q_{max} = Q_{maxn} = \frac{Q_{max}}{W} = 380/(1 \times 2 \times 3.14 \times 50) = 0.70637 \text{ (Weber)}.
\]

Research of dynamic characteristics of sensors of primary currents to secondary voltages of electrical nets of PSS with RES, connected by star and triangular schemes based in next analytical equations:

\[
U_{\alpha\gamma} = K_{Q\delta\epsilon}\mu_{\alpha\gamma}\mu_{\alpha\gamma}^{(j)}K_{\delta}\mu_{\delta\gamma}^{(j)}(I_{\alpha\gamma} \sin \omega t + I_{\alpha\gamma}^{(j)} e^{\frac{\omega t}{T}}),
\]

\[
U_{\beta\gamma} = K_{Q\delta\epsilon}\mu_{\beta\gamma}\mu_{\beta\gamma}^{(j)}K_{\delta}\mu_{\delta\gamma}^{(j)}(I_{\beta\gamma} \sin(\omega t + 120^\circ) + I_{\beta\gamma}^{(j)} e^{\frac{\omega t}{T}}),
\]

\[
U_{\gamma\gamma} = K_{Q\delta\epsilon}\mu_{\gamma\gamma}\mu_{\gamma\gamma}^{(j)}K_{\delta}\mu_{\delta\gamma}^{(j)}(I_{\gamma\gamma} \sin(\omega t - 120^\circ) + I_{\gamma\gamma}^{(j)} e^{\frac{\omega t}{T}}),
\]

\[
U_{\alpha\Delta} = K_{Q\delta\epsilon}\mu_{\alpha\Delta}\mu_{\alpha\Delta}^{(j)}K_{\delta}\mu_{\delta\Delta}^{(j)}(I_{\alpha\Delta} \sin(\omega t) + I_{\alpha\Delta}^{(j)} e^{\frac{\omega t}{T}}),
\]

\[
U_{\beta\Delta} = K_{Q\delta\epsilon}\mu_{\beta\Delta}\mu_{\beta\Delta}^{(j)}K_{\delta}\mu_{\delta\Delta}^{(j)}(I_{\beta\Delta} \sin(\omega t + 120^\circ) + I_{\beta\Delta}^{(j)} e^{\frac{\omega t}{T}}),
\]

\[
U_{\gamma\Delta} = K_{Q\delta\epsilon}\mu_{\gamma\Delta}\mu_{\gamma\Delta}^{(j)}K_{\delta}\mu_{\delta\Delta}^{(j)}(I_{\gamma\Delta} \sin(\omega t - 120^\circ) + I_{\gamma\Delta}^{(j)} e^{\frac{\omega t}{T}}),
\]

Here: \( P_{\epsilon\delta} = \frac{\mu_{\epsilon\delta} F_{\epsilon\delta}}{S_{\epsilon\delta}} \) (j=1,6) – magnetic parameters of sensors part, where output voltages \( U_{\text{out}} \), \( \mu_{\delta\epsilon} \) - magnetic absorption of airspaces in sensors, \( \mu_\epsilon = 1.25 \times 10^{-6} \) H/m; \( S_{\epsilon\delta} \) - cross-sectional surface of magnetic core with sensitive elements (s.e.), for example a \( b=0.01 \times 0.01 \) m²; \( \delta_{\epsilon\delta} \) - airspaces heights with sensitive elements (m); \( w(F_{\epsilon\delta}, F_{\min}) \) - transmission function of magnetic part of sensor; \( K_{\text{m}A} \) - interchain coefficient between initial currents, flowing through PSS nets and magnetical forces (m.f.) \( F_{\mu} \), generated by magnetic sources, \( \omega_{\mu} = 1 \);

\( I_{A\alpha}, I_{B\beta}, I_{C\gamma}; I_{A\Delta}, I_{B\Delta}, I_{C\Delta} \) - multiphase primary currents, generated by energy sources, connected to PSS by \( \gamma \) - star (a) and \( \Delta \) - triangle schemes (b).

An overview of cloud computing services provided by the Internet to research of reactive powers on the bases of sensors primary currents to secondary voltage for monitoring and controlling of multiphase currents of PSS nets with renewable energy sources are shown in Fig. 2.a. An overview of cloud computing services provided by Internet for research of multiphase AC sources and renewable energy sources of PSS and controllers shown in Fig. 2.a. - input windows of data are shown in Fig. 2.b.

![Figure 2. A review of cloud computing services (a) and the implications of introducing developed software for selecting reactive power sources of PSS nets (b).](image-url)
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Figure 3. Informations about efficiency of PSS nets reactive energy sources and receivers, obtained on the basis of cloud computing technology.

The Complex programs “Algorithms and software for calculating the parameters and efficiency of reactive power in the power supply system” [11-13] on cloud computing technology, are designs have possibilities research selecting and deploying reactive power sources of PSS. Its functionality is explained by:
- taking account of reduction for identification and implementation of quantitatively measured sources of reactive power of PSS, determine of losses of power in transformer and cable, due to flowing of reactive power in nets, calculation of annual energy efficiency, savings and determination of amount of reactive power, available during management researches;
- design research changes in size and control parameters, while reducing the cost of introducing reactive energy sources of PSS.

III. RESULTS

The results of research of dynamic characteristics of three-phase sensors on the basis of web-site www.reactive-energy.uz on Android operational systems of cloud computing technology, given in fig. 4 (when connections of power source as star schemas (a) and (b) when T = 0.02 and (c) and as triangular (d) when T= 0.04).

Figure 4. The dynamic characteristics of the sensor of multiphase currents, on connections of reactive power source: as star schemas (a) and (b), when inertia’s of nets of PSS equally to T = 0.02 and triangular schemas (c) and (d), when T = 0.04.
IV. CONCLUSION

1. The researched model of multiphase sensors and analytical equations for research of dynamic characteristics of primary sensors of PSS sources and nets based on highly formalized and transparent physical and technical effects, with structure involved in transforming process oriented to Android adjusting systems of cloud computing, have high possibilities during research static and dynamic characteristics of three-phase sensors with distributed parameters and highly efficiently during use of mobile equipment.

2. On the basis of diagrams of dynamic values of multiphase currents sensor, which depend of magnitude and parameters of magnetic fluxes and output voltages, diagrams, may be concluded, that a currents flowing from primary power supply nets and transforming to output voltage stabilizes at inertial of loads is $T = 0.02$ during $0.008 - 0.012$ sec. after connection primary nets, and at inertial $T = 0.04$, during $0.015 - 0.025$ sec. after switching currents of PSS nets.

REFERENCES

1. I.Kh.Siddikov, Kh.A.Sattarov, A.B.Abuibakirov, M.A.Anarbaev, I.M.Khonturaev, M.Maksudov. Research of transforming circuits of electromagnets sensor with distributed parameters, 10th International Symposium on Intelligent Manufacturing and Service Systems 9–11 September 2019. Sakarya, Turkey. c. 831-837.
2. I.Kh. Siddikov, A.B.Abuibakirov, K.M.Najmiddinov, A.J. Yesenbekov Three-phase electromagnetic asymmetry converters with advanced functionality, Bulletin KB ASRU (KOANRuki), No2. Nukus, Uzbekistan. 2017. 66-68 p.
3. I.Kh.Siddikov. The Electromagnetic Transducers of Asymmetry of Three-phases Electrical Currents to Voltage. Universal Journal of Electrical and Electronic Engineering, Horizon Research Publishing Corporation USA. 2015, Vol.3, N5, p.146–148. http://www.hrppub.org
4. I.Kh. Siddikov, A.B.Abuibakirov, A.A. Yuldashev, G.Z. Babaxova, I.M. Xonturaev, N.N. Mizroev. «Methodology of calculation of technoeconomic indices of application of sources of reactive power». European science review, Scientific journal. No 1–2. Austria, Vienna. 2018. 248-251 p.
5. I.Petrova, V. Zaripova, Yu. Lezhnina, I.Kh.Siddikov. Automated system for synthesis of sensors for smart cities. XXII International Scientific Conference on Advanced In Civil Engineering “CONSTRUCTION THE FORMATION OF LIVING ENVIRONMENT”, Tashkent, Uzbekistan, 18-21 April, 2019 EIS World Wide Conferences –ISSN: 2267-1242. https://www.scopus.com/record/display.uri?eid=2-s2.0-85067281218&origin=resultslist
6. R.K.Azimov, A.A.Choriev, Sh.A.Khimmatkulov, O.X. Saidakbarov. Information - probability methods for estimating errors of sensors of various quantities. STANDARD No3. Tashkent, Uzbekistan. 2010. 30-31 p.
7. S.F.Amirov, A.M.Safarov, Khubosov B.X. Current converters for secondary electrical energy systems// Current conditions and perspectives for the development of energy. Abstract of reports. International scientific and technical conference. December 18 – 20, 2006. Tashkent,Uzbekistan. 2006. 206-208 p.
8. I.Kh.Siddikov, Kh.E.Khujamatov. The principle of desing of electromagnetic transducers of one, three and multiphase currents of electrical nets to secondary voltage. Matyrgay XII MNTK «Перспективы развития строительного комплекса: образование, наука, бизнес» г.Астрахань, 10–11 октября 2018 г. с.350-353. http://arac.yz/pnau22/7464-xi-mezhduhnarodnaya-nauchno-prakticheskaia-konferentsiya-perspektivy-sotsialno-ekonomicheskogo-rozvitiya-stran-i-regionov.html
9. M.F. Zaripov, N.R. Zaynulis, I.Yu. Petrova. Graph method of scientific and technical creativity. Moscow: VNIPKI GKN, 1988. 124 p.
10. M.F. Zaripov, I.Yu. Petrova. Subject-oriented environment for searching new technical solutions for «Intellekt». St. Petersburg International Conference. «RI-95»: Abstract of reports. St. Petersburg, 1995. 60-61 p.
11. Patent of RUz. №64185. Three-phase current asymmetry converter to voltage/Amirov S.F., Azimov R.K., Siddikov I.Kh., Khakimov M.Kh., Khubosob B.Kh., Sattarov Kh.A. Official newsletter. 2010.
12. DGU No.20191450. Software for the study of the dynamic characteristics of three-phase three-sensor converters with distributed parameters. Siddikov I.Kh., Abdumalikov A.A., Mazadov M.T., Sobirov M.A., Abuibakirov A.B., Anarbayev M.A. 2019.
13. DGU No. 20190482. Algorithm and software for calculating the occupancy period for introducing reactive power sources in power supply systems. Siddikov I.Kh., Abuibakirov A.B., Khuzaamvatov H.E., Khasanov D.T., Anarbaev M.A. 2018.
14. DGU No. N 20190478. Algorithm and software for reducing losses of electric energy in a power transformer. Siddikov I.Kh., Abuibakirov AB, Khuzaamvatov H.E., Khasanov D.T. 2019.
15. I.Kh.Siddikov, Kh.A.Sattarov, Kh.E.Khujamatov, O.R.Dexhomov, M.R.Agranomova Modelling of Magnet Circuits of Electromagnetic Transducers of the Three-Phases Current.Collection of the materials.14th International Scientific Technical Conference On Actual Problems Of Electronic Instrument Engineering (APEIE-2018) 44894 Proceedings, V.1, P.5, 2-6 October 2018. – p. 419-422. https://www.scopus.com/record/display.uri?authorId=5620037700
16. I.Kh.Siddikov, Kh.A.Sattarov, Kh.E.Khujamatov Modeling of the elements and devices of energy control systems // Materials of the XII MNTK “Prospects for the development of the building complex: education, science, business” Astrakhan, October 10–11, 2018. 348-349 p.
17. I.Kh.Siddikov, Kh.A. Sattarov, M.Anarbaev, G.Ayamedova. Modeling and research of transformation of the three-phases primary current in electrical equipment of control systems // 10th International Symposium on Intelligent Manufacturing and Service Systems Industry 4.0/5.0: Future Minds and Future Society, Sakarya University - Sakarya/Turkey 9-11 September 2019. P.340-346. file:///C/Users/User/Downloads/IMSS2019_Proceedings_Book%2031.pdf
18. I.Kh. Siddikov, Kh. Sattarov, A.B. Abuibakirov, M.A. Anarbaev, I.Khonturaev, M.Khaksanov. Research of transforming circuits of electromagnets sensor with distributed parameters // 10th International Symposium on Intelligent Manufacturing and Service Systems Industry 4.0/5.0: Future Minds and Future Society, Sakarya University-Sakarya/Turkey 9-11 September 2019.p.831-837. file:///C/Users/User/Downloads/IMSS2019_Proceedings_Book%2031.pdf
19. I.Kh.Siddikov, Kh.E. Khuzhamatov, D.T.Khasanov, Sh.B Olimova, Kh.S. Khasanov. Telecommunications tizimlar hybird enerjiyam taminotini manashchari masofali monitoring wa bosharowu // Scientific-practical and informational-analytical technical magazine “Muhammad al-Kurazmiy avlodli TUIT” Tashkent, 2019. №3(9). C.55-59.
20. I.Kh.Siddikov, Kh.A.Sattarov, Kh. Khujamatov, LKontuaraev, Maksudov M., Najmatdinov K., Abuibakirov A., Boganic Slobodan. Modeling of magnetic circuits of electromagnetic transducers of the three-phases current // Materials of the XII MNTK “Prospects for the development of the building complex: education, science, business”. Astrakhan, October 10–11. 2018. 331-336 p. http://arac.yz/pnau22/7464-xi-mezhduhnarodnaya-nauchno-prakticheskaia-konferentsiya-perspektivy-sotsialno-ekonomicheskogo-rozvitiya-stran-i-regionov.html
21. I.Kh.Siddikov, M.A.Anarbaev, M.T. Maksudov. Signal converters of current magnitude for control systems of reactive power sources // Scientific and technical journal "Engineering and Construction Journal of the Prikaspia" (ISSN:2312-3702). http://arac.yz/pjnp/issn/1-23-2018/informacionsyy-sistemy-tehnologii-3
22. I.Kh.Siddikov, H.A.Sattarov, H.E. Khuzhamatov. Algorithms and methods for calculating the technological consumption of electricity during its transportation through electric networks and compensation of reactive power // Materials of XII MNTK “Prospects for the development of the building complex: education, science, business”, Astrakhan. October 10–11. 2018. 341-347 p. http://arac.yz/pnau22/7464-xi-mezhduhnarodnaya-nauchno-prakticheskaia-konferentsiya-perspektivy-sotsialno-ekonomicheskogo-rozvitiya-stran-i-regionov.html
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