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Research of Static Characteristics of the Sensors of Multiphase Primary Currents to Secondary Voltages on the Basis of Cloud Computing

I. Kh. Siddikov, I. M. Khonturaev, A. A. A bdumalikov

Abstract: ***In this article represent results of research of construction, algorithms, graph model, analytical expressions, and descriptions of the static parameters of sensors of multiphase primary currents to secondary voltage based on cloud computing technology are given. The bases of research of static characteristics of sensors is digital-based cloud computing technology are three services, as SaaS, PaaS and IaaS.***

Keywords: electrical energy, multiphase, primary current, sensor, graph model, controlling, secondary voltage, source, signal, static characteristics.

I. INTRODUCTION

The Static characteristics of the sensor transforming multiphase primary currents flowing through power supply systems (PSS) nets to secondary voltage - signals, define according to parameters of construction of sensors and mathematical models, analytical researches of formation processes of secondary voltage, forms and designs main elements: primary and secondary windings and magnetic core with distributed parameters [1-2]. Provision of reliable and continuous energy from nets of PSS with renewable energy sources (RES) requires not only choosing the power sources and electrical nets, but providing reliable performance of the controlling and adjusting elements, devices and sensors, also real time monitoring. Sensor elements and devices of PSS with RES provides transformation of the primary electricity values as currents and voltage, transformed on the basis of physical and technical effect to secondary control signals [2].

The principal schema of nets PSS with RES, directions of multiphase primary currents - $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ from reactive energy sources, the element and devises of cloud computing for control and adjusting them, shown in presented in Fig. 1.

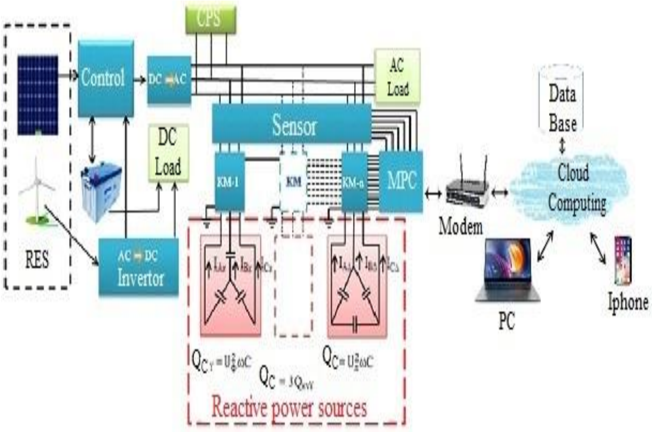

Fig.1. The principal schema of nets PSS with RES, directions of multiphase primary currents - $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ from reactive energy sources, the elements and devises of cloud computing for control and adjusting them:

Here, DC→AC converter, that transforming direct current (DC) to the alternating current (AC), DC load – DC load of devices, AC → DC is invertor, that transforming alternating current (AC) to the direct current (DC), CPS – centralized power supply, КМ-1,…, КМ-n- contactors, MPC - microprocessor control, AC load – alternating current load, RES – renewable energy sources, Q_c - Reactive power courses, modem, nets, SaaS, PaaS, IaaS - Software as a service (SaaS) Platform as a service (PaaS) Infrastructure as a service (IaaS), data bases, mobile phone, PC – personal computer.

During research of static characteristics sensors of multiphase primary currents to secondary voltages require to determine relations between the I_{ein} – multiphase primary currents with secondary voltage - signals on the basis of geometrical parameters of cross-sectional surface S_{se}, which are magnetic flux detectors Q_μ, flowing via appeared through magnetic core and air gaps and transform to output voltage U_{eout}. Sensitive elements - secondary windings, lunge of air gap lair, where installed it element, their variable parameters is depended from geometric measures of magnetic core - main element of sensor [1-5]. The sensitive elements (s.e) are designed as motionless on insulated sheets and produce normalized $U_{a\gamma}$, $U_{в\gamma}$, $U_{c\gamma}$, $U_{a\Delta}$, $U_{в\Delta}$, $U_{c\Delta}$, voltages up to 20 V in the sensitive elements.

Magnetic forces (m.f.) F_μ produced by the multiphase currents $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ in PSS and the magnetic fluxes generated by them,

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* Correspondence Author
I.Kh.Siddikov*, Tashkent university of information technologies named after Muhammad al-Khwarizmi
I.M.Khonturaev, Tashkent university of information technologies named after Muhammad al-Khwarizmi
A.A.Abdumalikov, Tashkent university of information technologies named after Muhammad al-Khwarizmi

cross the sensitive elements on the magnetic circuit, and transformation between the magnetic currents influencing each other and the primary currents to the secondary voltage U_{eout}.

The main part of sensor - magnetic core, which is direction of magnetic flux transforming from multiphase primary currents $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ to secondary voltage, presents in fig. 2.

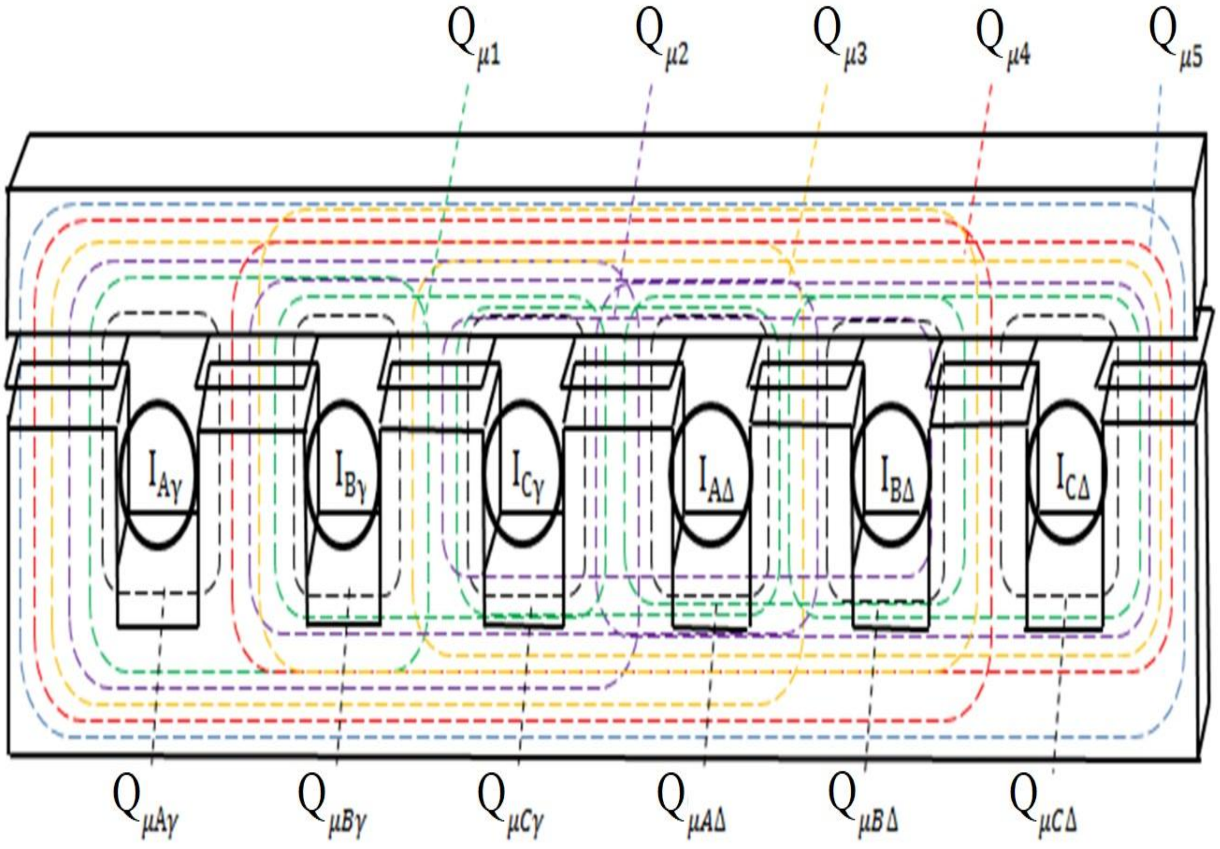


Fig.2. The main part of sensor - magnetic core, which is direction of magnetic flux transforming from multiphase primary currents $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ to secondary voltage.

Due to Multiphase primary currents of power sources in nets SPP with RES - flowing via primary windings of sensors, in magnetic core occurs magnetic fluxes - $Q_{\mu A\gamma}$, $Q_{\mu B\gamma}$, $Q_{\mu C\gamma}$, $Q_{\mu A\Delta}$, $Q_{\mu B\Delta}$, $Q_{\mu C\Delta}$, which flow through air gap, which installed sensitively elements.

The sensitive elements (s.e) are designed as motionless on insulated sheets and produce normalized $U_{a\gamma}$, $U_{B\gamma}$, $U_{c\gamma}$, $U_{a\Delta}$, $U_{B\Delta}$, $U_{c\Delta}$ - voltages up to 20 V, when in nets of PSS with RES flows a nominale multiphases primary currents. Magnetic moving forces (m.f.) F_{μ} produced by the multiphase currents in nets of PSS and the magnetic fluxes generated by them, cross the sensitive elements on the magnetic circuit, and transformation between the magnetic currents influencing each other and the primary currents to secondary voltage U_{eout}.

II. MODELING

The structure of graph model of magnetic part of sensor, transforming multiphase primary currents to secondary voltage and transforming process are shown in Fig. 3 [6].

The static characteristics of sensors, transforming multiphase primary currents to secondary voltage are investigated using the following analytical equations, based on graph model, shown in Fig.3 [6,7-12]:

Here: $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ - multiphase primary currents, depended from connection of active or reactive power sources PSS, by y - star and Δ - triangle schemes.

$K_{IinF\mu}$ - w_{ik} - intercircuit coefficient between primary currents, flowing via nets of PSS and magnetic forces (m.f.) F_{μ}, produced by magnetic sourses;

$W(F_{\mu ij},F_{\mu in})$- transmission function of magnetic circuit;

P_{ij}. $P0_{ij}$ – parameters of magnetic transforming circuit;

$F_{\mu ij}$ – magnetic force (m.f.);

Q_{ij} – magnetic flux;

$K_{Q\mu Ueout}$ - w_{ik} - intercircuit coefficient between magnetic flux and output voltage - secondary signal;

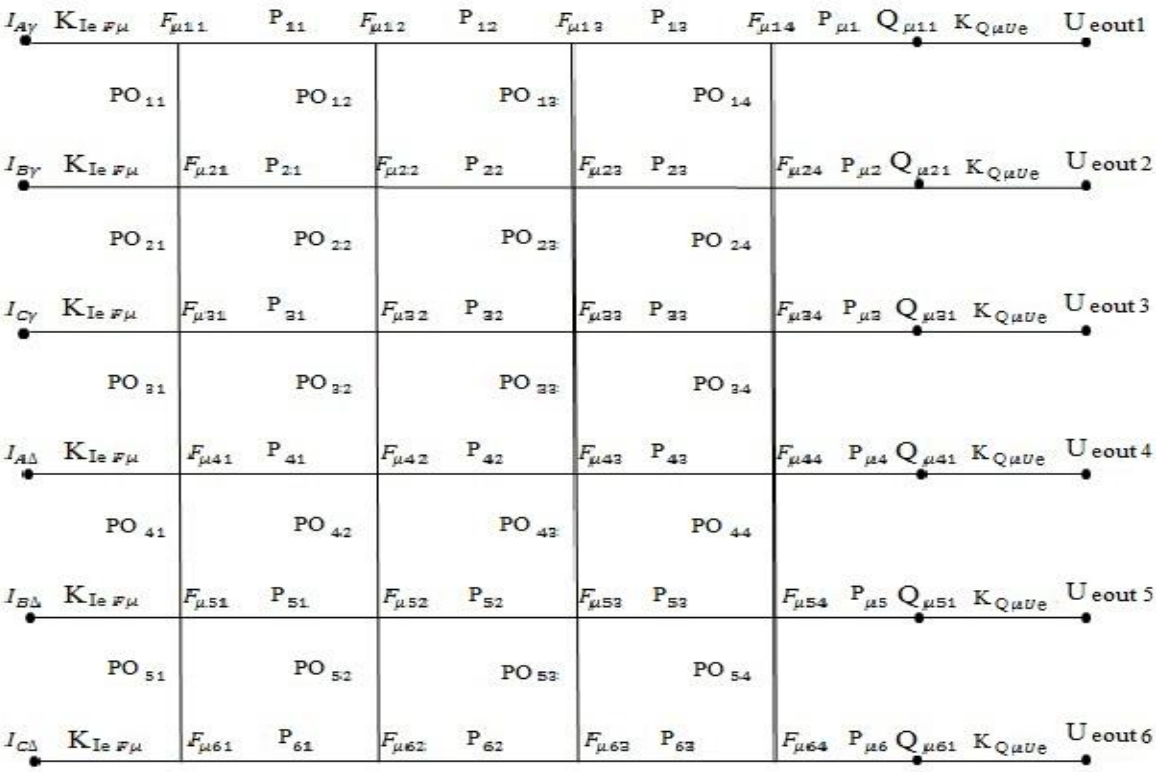


Figure 3. The graph model of the processes of transforming multiphase primary currents to secondary voltages.

In the research model: $K_{FmUeout} = w_{2out}F_{\mu}$ accepts as w_{eout}= 1 ÷ 20 packets based on the requirement that the output voltage be normalized at magnetic flows and output voltage (20 V).

In the research model: values of the correlation coefficient of magnetic flux $K_{Q\mu Ueout} = w_{2out}Q_{\mu}$ and voltage output U_{eout} circuits receives the values up to w_{eout}=1÷20 (based on the requirement to be the normalized output voltage (20 V) in certain values of the primary currents) [7,9-11].

$$U_{a\gamma} = K_{Q\mu Ue}P_{\mu1}(W(F_{\mu11},F_{\mu14})K_{IeF\mu}I_{A\gamma} + W(F_{\mu21},F_{\mu14})K_{IeF\mu}I_{B\gamma} + W(F_{\mu31},F_{\mu14})K_{IeF\mu}I_{C\gamma} + W(F_{\mu41},F_{\mu14})K_{IeF\mu}I_{A\Delta} + W(F_{\mu51},F_{\mu14})K_{IeF\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu14})K_{IeF\mu}I_{C\Delta}),$$

$$U_{b\gamma} = K_{Q\mu Ue}P_{\mu2}(W(F_{\mu21},F_{\mu24})K_{IeF\mu}I_{B\gamma} + W(F_{\mu11},F_{\mu24})K_{IeF\mu}I_{A\gamma} + W(F_{\mu31},F_{\mu24})K_{IeF\mu}I_{C\gamma} + W(F_{\mu41},F_{\mu24})K_{IeF\mu}I_{A\Delta} + W(F_{\mu51},F_{\mu24})K_{IeF\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu24})K_{IeF\mu}I_{C\Delta}),$$

$$U_{c\gamma} = K_{Q\mu Ue}P_{\mu2}(W(F_{\mu31},F_{\mu34})K_{IeF\mu}I_{C\gamma} + W(F_{\mu11},F_{\mu34})K_{IeF\mu}I_{A\gamma} + W(F_{\mu21},F_{\mu34})K_{IeF\mu}I_{B\gamma} + W(F_{\mu41},F_{\mu34})K_{IeF\mu}I_{A\Delta} + W(F_{\mu51},F_{\mu34})K_{IeF\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu34})K_{IeF\mu}I_{C\Delta}),$$

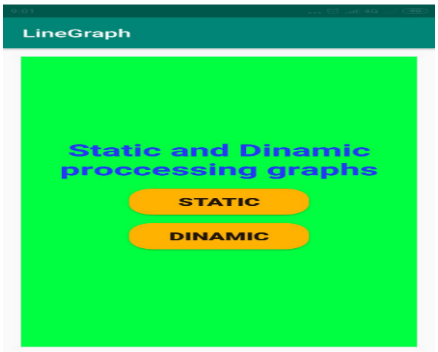
$$U_{a\Delta} = K_{Q\mu Ue}P_{\mu2}(W(F_{\mu41},F_{\mu44})K_{IeF\mu}I_{A\Delta} + W(F_{\mu11},F_{\mu44})K_{IeF\mu}I_{A\gamma} + W(F_{\mu21},F_{\mu44})K_{IeF\mu}I_{B\gamma} + W(F_{\mu31},F_{\mu44})K_{IeF\mu}I_{C\gamma} + W(F_{\mu51},F_{\mu44})K_{IeF\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu44})K_{IeF\mu}I_{C\Delta}),$$

$$U_{b\Delta} = K_{Q\mu Ue}P_{\mu5}(W(F_{\mu51},F_{\mu54})K_{IeF\mu}I_{B\Delta} + W(F_{\mu11},F_{\mu54})K_{IeF\mu}I_{A\gamma} + W(F_{\mu21},F_{\mu54})K_{IeF\mu}I_{B\gamma} + W(F_{\mu31},F_{\mu54})K_{IeF\mu}I_{C\gamma} + W(F_{\mu41},F_{\mu54})K_{IeF\mu}I_{A\Delta} + W(F_{\mu61},F_{\mu54})K_{IeF\mu}I_{C\Delta}),$$

$$U_{c\Delta} = K_{Q\mu Ue}P_{\mu5}(W(F_{\mu61},F_{\mu64})K_{IeF\mu}I_{C\Delta} + W(F_{\mu11},F_{\mu64})K_{IeF\mu}I_{A\gamma} + W(F_{\mu21},F_{\mu64})K_{IeF\mu}I_{B\gamma} + W(F_{\mu31},F_{\mu64})K_{IeF\mu}I_{C\gamma} + W(F_{\mu41},F_{\mu64})K_{IeF\mu}I_{A\Delta} + W(F_{\mu51},F_{\mu64})K_{IeF\mu}I_{B\Delta}),$$

An Internet elements of researching of static characteristics of multiphase primary currents sensors with distributed parameters on the basis of cloud computing technology is shown, as Internet web-site www.reactive-energy.uz in fig. 4.a and 4.b.

a)



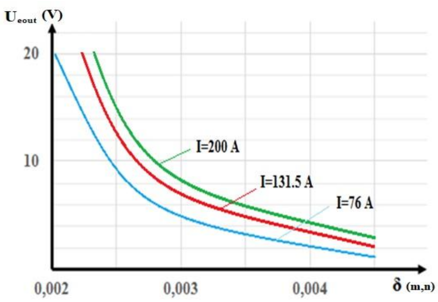
b)

Figure 4. Elements of researching of static characteristics of multiphase primary currents sensors with distributed parameters on the basis of cloud computing technology is shown, as Internet web-site www.reactive-energy.uz.

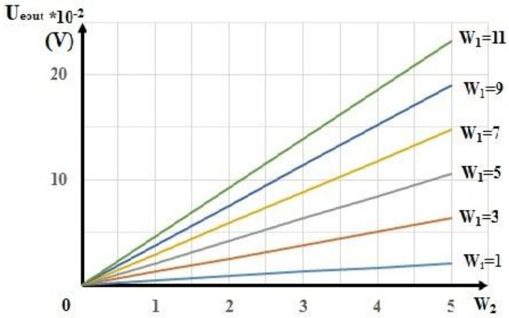
III. RESULTS

The results of research of the static characteristics of sensors with distributed parameters on the basis of as web- site www.reactive-energy.uz of cloud computing shown in Fig. 5.a. and 5.b.

The static characteristics of connection between current of nets PSS and the sensor output voltage, shown in figures 6.a and 6.b.

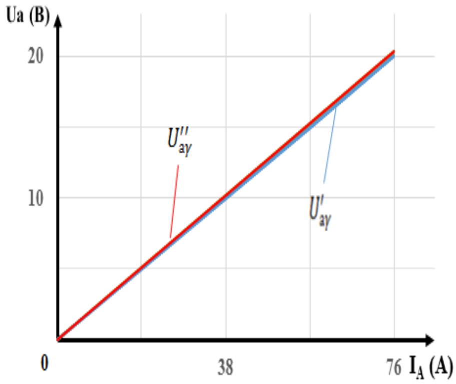


a)

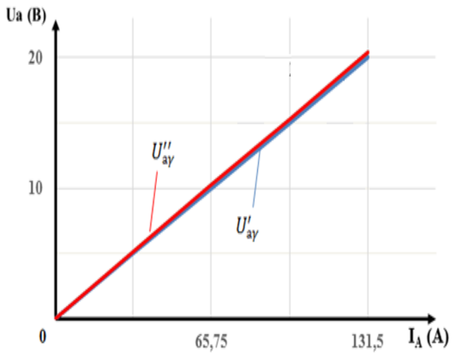


b)

Fig. 5. Influence of sensor parameters on output voltage. a) effect of airspace; b) effect of the number of primary windings



a)



b)

Figure 6. The static characteristics of sensor. a) star-shaped connected source of PSS, b) triangle-shaped connected source of PSS.

Here:

U' - output voltage from collected parameter model;

U'' - output voltage from distributed parameters model;

IV. ERROR ANALYSIS

The Metrological characteristics of sensors of multiphase primary currents of nets of PSS to secondary voltage based on the static characteristics illustrated in figures 6.a and 6.b, is characteristics as accuracy, linearity of output characteristics, identical sensitivity among in range of change.

$$I_{A\gamma} = 38A;\; U'_{a\gamma} = 10V;\; U''_{a\gamma} = 10{,}18V;$$

$$\Delta = \frac{(U''_{a\gamma} - U'_{a\gamma})}{U'_{a\gamma}} * 100\% = \frac{(10{,}18 - 10)}{10} * 100\% = 1{,}8\%;$$

$$\Delta = \frac{(U''_{a\gamma} - U'_{a\gamma})}{U'_{a\gamma}} * 100\% = \frac{(20{,}37 - 20)}{20} * 100\% = 1{,}81\%;$$

The static characteristics of $I_{A\gamma}$, $U_{a\gamma}$,, and $U_{a\gamma'}$ values for the PSS sources are connected in triangular form, as shown in Fig.6.b, and the corresponding error indicators are calculated as follows:

$$I_{A\Delta} = 65{,}75A;\; U'_{a\Delta} = 10V;\; U''_{a\Delta} = 10{,}184V;$$

$$\Delta = \frac{(U''_{a\Delta} - U'_{a\Delta})}{U'_{a\Delta}} * 100\% = \frac{(10{,}184 - 10)}{10} * 100\% = 1{,}8\%;$$

$$I_{A\Delta} = 131{,}5A;\; U'_{a\Delta} = 20V;\; U''_{a\Delta} = 20{,}369V;$$

$$\Delta = \frac{(U''_{a\Delta} - U'_{a\Delta})}{U'_{a\Delta}} * 100\% = \frac{(20{,}369 - 20)}{20} * 100\% = 1{,}8\%;$$

In the multiphase primary currents sensors of nets of PSS as sources of errors are various factors - temperature, humidity, external magnetic fields, ω_e – frequency, $W[I_{ein}, F_\mu]$-correlation coefficients of different nature change values, physical parameters of excitation materials conductors of current, affected and other factors effects, which influence to as multiphase primary currents - I_{ein} and also to secondary voltage - U_{eout} [16].

During research of accumulated errors of sensors of multiphase primary currents of PSS consist: input magnetic transform part, i.e. primary currents transform to m.f. F_μ, , i.e. $I_e \rightarrow F_\mu$, in this case transformation errors is δ_1= 0,15 (± 0.15% deviation from the nominal value of electrical and magnetic values due to elements of transforming - conductors and magnetic core [14]); due to distribute parameters of transforming parts of m.f. F_μ to magnetic fluxes Q_μ transforming parts, i.e. $F_\mu \rightarrow Q_\mu$, change errors consist δ_2=0,15), which determines based on the deviation of the magnetic magnitudes at the thresholds ± 0.15% of nominal value based on the scattering of the parameters [24] and last due to transform errors of Q_μ magnetic fluxes to U_{eout} output voltage, i.e. $Q_\mu \rightarrow U_{eout}$, were in this case errors is δ_3 = 0,1 [2,15]:

$$\delta_\Sigma = \sqrt{\delta_1^2 + \delta_2^2 + \delta_3^2} = \sqrt{0{,}15^2 + 0{,}15^2 + 0{,}1^2} = 0{,}18$$

In multiphase current sensor's all errors components are classified into additive and multiplicative errors; and the probability of their occurrence is found by their mean squared deviation according to the distribution principle. The value of entropy of error for investigated sensor category is determined by the following formula [15]:

$$\Delta = K_e \delta_\Sigma \cdot = 2{,}07 \text{ x } 0{,}18 = 0{,}38$$

As a result of calculations and experiments, the electromagnetic multiphases currents sensor of nets PSS to voltage is Δ = 0.38, i.e ± 0.38%, for which normalized sensitivity value can be selected from standard values. The class of accuracy for this type of multiphase primary currents sensors determined as 0.5, which is ± 0.5% on nominale currents of netes of PSS [2, 16].

V. CONCLUSION

1. Designed graph model for Research magnetic fluxes, generated by multiphase primary currents $I_{A\gamma}, I_{B\gamma}, I_{C\gamma}, I_{A\Delta}, I_{B\Delta}$ and $I_{C\Delta}$, produced by PSS sources of active and reactive powers, generated m.f. F_μ and magnetic fluxes Q_μ in magnetic cores, which are involved in the process of transforming primary currents to U_{eout}–secondary output voltages, Q_μ -magnetic fluxes, generated by m.f., based on the formalized and transparent physical and technical effects, sensor structure, which is have place in process of transforming and using cloud computing, and gave possible exploring of static characteristics.

2. The graph model of sensors of multiphase current and analytical expression are adequate to the experimental static characteristics of sensor and as results of researches shown that the sensitivity of the sensor can be increased by 1.8% on the basis of graph model with distributed parameters.

3. On the base of cloud computing technology theoretically and practically researched the influence of ambient temperature changes on sensitivity of sensor, which be less than ± 0.5% during process of transforming multiphase primary currents to a secondary voltage - signal.

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AUTHORS PROFILE

Ilkhomjon Siddikov Khakimovich , Doctor of Science (T), Professor, Head of the Department «Power supply system’s», Tashkent University of Information Technologies named after Muhammad Al-Khwarizmi, Chairman of the Scientific Council awarding Scientific Degrees of Technical Science DSc.13/30.12.2019.T.07.02 of Republic Uzbekistan. His research areas are Smart Grid, Control and adjusting of the Power Supply Systems and Equipment’s, Relay Protection, Renewable Energy Sources (Solar, Wind), Accumulators, UPS, Diesel Generators, Compensation of the Reactive Power of Energy Nets and Systems, Metrology, Standardization and Certification, Life safety and Ecology. He is leading a scientific project VN 81182259 «Pilot project of Uzbekistan: Climate Change mitigation in rural areas of Uzbekistan - demonstration project at private farm Furqat of Pakhtakor district in the Mirzachul steppe».

Ikromjon Khonturaev Munavvarovich, Senior teacher of department “Power electricity” at the Djizak Polytechnic Institute. Since 2014, he has been working under the guidance of Professor Ilkhom Siddikov at TUIT on "Functional and parametric control of power sources based on three-phase current sensors". More than 10 articles and abstracts were published in this direction. He has a patent owner of "Voltage switch" and co-author of the study of dynamic characteristics of three-phase three-sensing sensors with distributed parameters.

Scientific articles have been published in the Russian Federation "Injenerno-stroitelnyi vestnik Prikaspiya", Polish East European Scientific Journal, Austrian "European Science Review". In addition, theses were published at conferences in Uzbekistan, Russia and Turkey.

Akmal Abdumalikov Abdukholik ugli., Deputy Dean for Academic Affairs of Computer Engineering faculty, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi. He is studying for Telecommunication and computer systems, telecommunication networks and devices, Distribution of information. His scientific areas are Smart Grid, Control and adjusting of the Power Supply Systems and Equipment’s, Relay Protection, Renewable Energy Sources (Solar, Wind), Accumulators, UPS, Diesel Generators, Compensation of the Reactive Power of Energy Nets and Systems, Metrology, Standardization and Certification, Life safety and Ecology. Besides that, he is working under the two scientific project, which is leading by Professor Ilkhom Siddikov at the TUIT.