International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

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

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

***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_e – input multiphase currents of nets of PSS and output electrical voltages U_{eout} on the basis of cross-sectional surface S_{se} – sensitive elements parameters, magnetic flux Q_{μ} - flowing through sensitive elements - U_{eout}, - sensors and their w_{se} turnovers amount, which depend from geometric parameters of transforming magnetics 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 $U_{a\gamma}$, $U_{в\gamma}$, $U_{c\gamma}$, $U_{a\Delta}$, $U_{в\Delta}$, $U_{c\Delta}$ - signals [7-12].

The sensitive elements of sensors 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 sensitive elements [13-14].

Magnetic forces (m.f.) F_{μ} produced by multiphase primary currents $I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ - 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_{eout} [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].

Revised Manuscript Received on February 28, 2020.
***** Correspondence Author

Ilkhomjon Siddikov Khakimovich*, Professor & Head, Department of Power Supply System Tashkent University of Information Technologies, Named After Muhammad al-Khwarizmi. Republic Uzbekistan.

Akmal Abdumalikov Abdukholik ugli, Deputy Dean for Academic Affairs of Computer Engineering, Tashkent University of Information Technologies Named After Muhammad al-Khwarizmi, Republic Uzbekistan.

Makhsudov Mokhirbek Tolibjonovich, Professor, Department of Power Supply System Tashkent University of Information Technologies, Named After Muhammad al-Khwarizmi. Republic Uzbekistan.

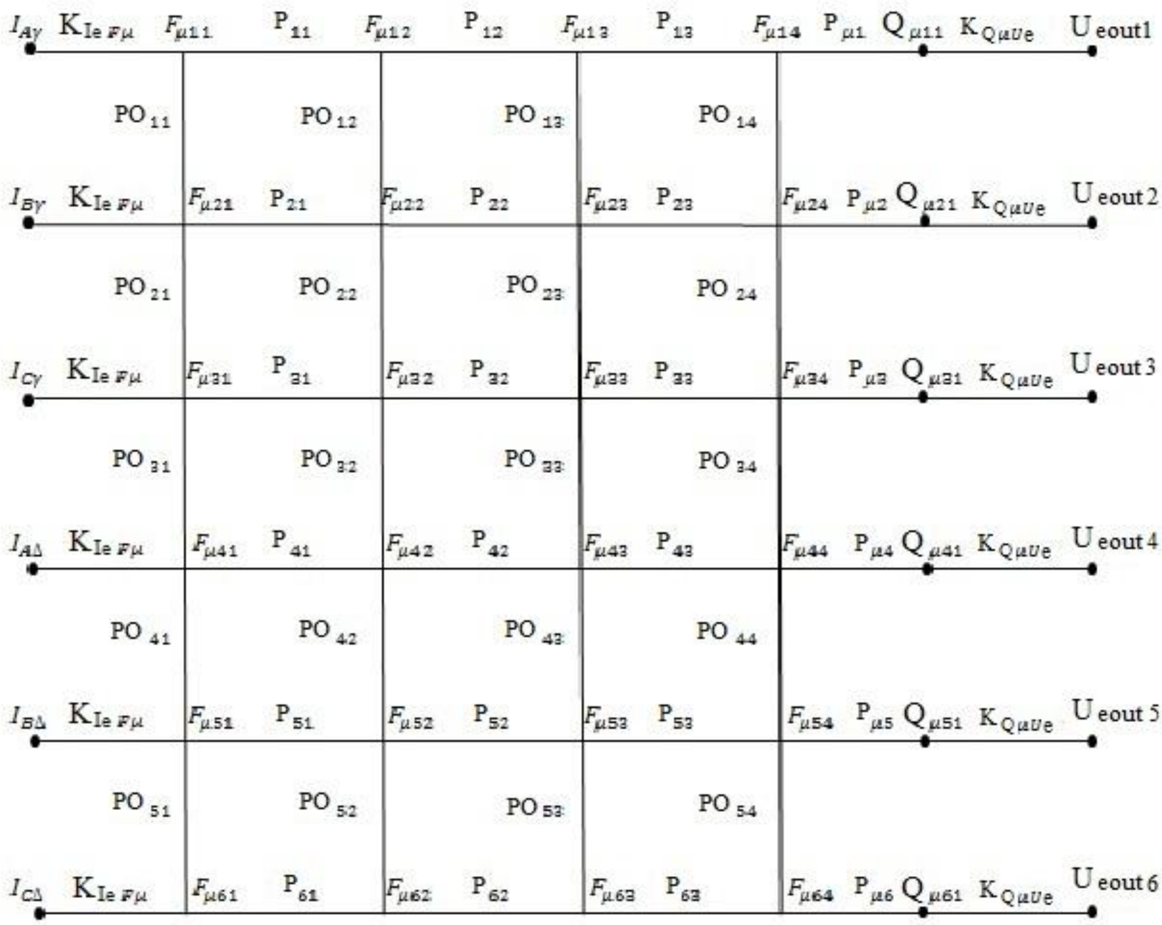


Figure 1. The graph model of the processes of transforming multiphase primary currents to secondary voltages.

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.

$K_{linF\mu}$ - 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.

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 energy flows and currents provided by PSS sources [21,22].

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]:

$$U_{eouta}(t) = -R_{ese1} I_{eouta}(t)$$
$$-\frac{L_{ese1} dI_{eouta}(t)}{dt} + \frac{w_{se2} dQ_B(t)}{dt} + \frac{w_{se3} dQ_C(t)}{dt},$$

$$U_{eoutb}(t) = -R_{ese1} I_{eoutb}(t)$$
$$-\frac{L_{ese2} dI_{eoutb}(t)}{dt} + \frac{w_{se1} dQ_A(t)}{dt} + \frac{w_{se3} dQ_C(t)}{dt},$$

$$U_{eoutc}(t) = -R_{ese1} I_{eoutc}(t)$$
$$-\frac{L_{ese3} dI_{eouts}(t)}{dt} + \frac{w_{se1} dQ_A(t)}{dt} + \frac{w_{se2} dQ_B(t)}{dt},$$
Here:

R_{ese1}, R_{ese2}, R_{ese3}, L_{ese1}, L_{ese2}, L_{ese3} – active resistance and inductance of sensory;

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

Ieouta, Ieoutb, Ieoutc - 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
DOI: 10.35940/ijitee.D1906.029420
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

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 $U_{eA} = U_{eB} = U_{eC} = 220$ V and currents will be equal to $I_{eA} = I_{eB} = I_{eC} = 131$ A, flowing through reactive power sources and primary currents of sensor. Adjusted jet capacities with $Q_{n\,C} = 50$ kVA voltage of capacitor devices $U_{eA} = U_{eB} = U_{eC} = 380$ V, connected to sensor by current in triangular scheme will be $I_{eA} = I_{eB} = I_{eC} = 76$ A. In this case, the inductance of electrical net with have a reactive power supply is $L_{eI} = L_{eII} = L_{eIII} = 10^{-3}$ (Henry), capacitors $C_{eA} = C_{eB} = C_{eC} = 10^{-7}$ (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]:

$Q_{max\,A} = Q_{max\,B} = Q_{max\,C} = U_{max}/(W_I\omega) = 380/(1 \times 2 \times 3{,}14 \times 50) = 0{,}70637$ (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:

$$U_{a\gamma} = K_{Q\mu Ue} P_{\mu 1} w(F_{\mu 11}, F_{\mu 14}) K_{IeF\mu}(I_{A\gamma} \sin \omega t + I_{Am} e^{-\frac{t}{T}}),$$

$$U_{B\gamma} = K_{Q\mu Ue} P_{\mu 2} w(F_{\mu 21}, F_{\mu 24}) K_{IeF\mu}(I_{B\gamma} (\sin \omega t + 120^0) + I_{Bm} e^{-\frac{t}{T}}),$$

$$U_{C\gamma} = K_{Q\mu Ue} P_{\mu 3} w(F_{\mu 31}, F_{\mu 34}) K_{IeF\mu}(I_{C\gamma} (\sin \omega t - 120^0) + I_{Cm} e^{-\frac{t}{T}}),$$

$$U_{A\Delta} = K_{Q\mu Ue} P_{\mu 4} w(F_{\mu 41}, F_{\mu 44}) K_{IeF\mu}(I_{A\Delta} \sin(\omega t) + I_{Am} e^{-\frac{t}{T}}),$$

$$U_{B\Delta} = K_{Q\mu Ue} P_{\mu 5} w(F_{\mu 51}, F_{\mu 54}) K_{IeF\mu}(I_{B\Delta} (\sin \omega t + 120^0) + I_{Bm} e^{-\frac{t}{T}}),$$

$$U_{C\Delta} = K_{Q\mu Ue} P_{\mu 6} w(F_{\mu 61}, F_{\mu 64}) K_{IeF\mu}(I_{C\Delta} (\sin \omega t - 120^0) + I_{Cm} e^{-\frac{t}{T}}),$$

Here: $P_{\mu j} = \dfrac{\mu_0 F_j}{\delta_{\mu j}}$ (j=1,6) – magnetic parameters of sensors part, where output voltages U_{eout}, μ_0 -magnetic absorption of airspaces in sensors, μ_0=1,25*10-6 H/m;

$S_{s.e.}$ - cross-sectional surface of magnetic core with sensitive elements (s.e.), for example a x b=0.01x0.01 m^2;

δ_μ - airspaces heights with sensitive elements (m);

$w(F_{\mu ij}, F_{\mu in})$- transmission function of magnetic part of sensor;

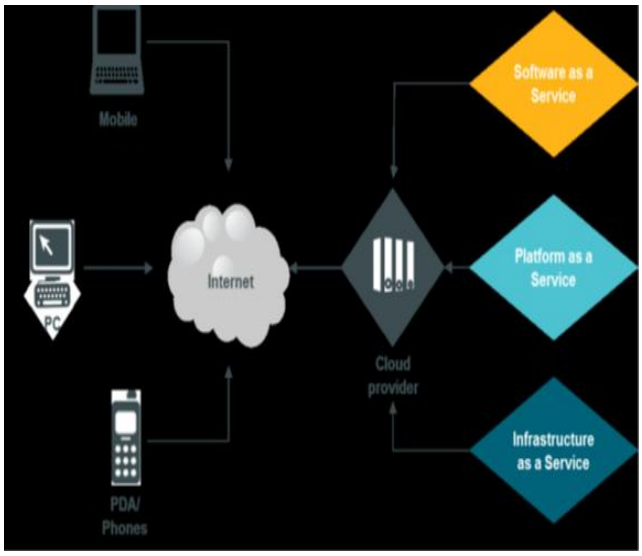
$K_{IinF\mu}$-ω_{jk} - I_{in} interchain coefficient between initial currents, flowing through PSS nets and magnetical forces (m.f.) F_μ, generated by magnetic sourses,

ω_{jk} =1;

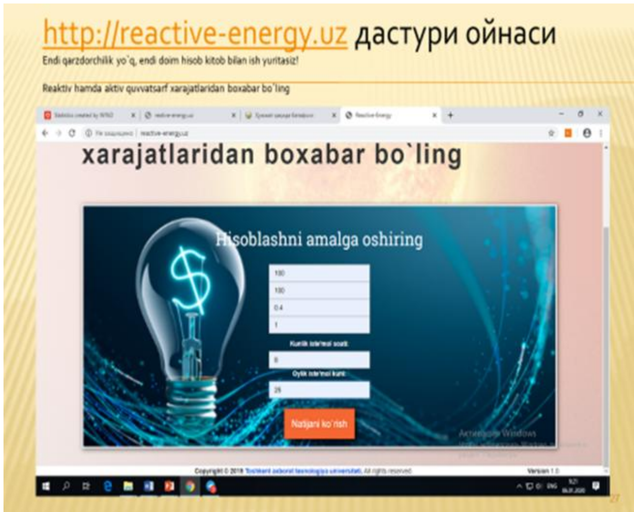
$I_{A\gamma}$, $I_{B\gamma}$, $I_{C\gamma}$, $I_{A\Delta}$, $I_{B\Delta}$, $I_{C\Delta}$ - multiphase primary currents, generated by energy sources, connected to PSS by

γ - star (a) and Δ - 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.



a)



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).

During research used following models and providers of cloud computing technologies:

- Software as a service (SaaS) -is a utility software.
- Platform as a service (PaaS) is a platform for quality of service.
- Infrastructure as a service (IaaS) - Infrastructure as a service.

An Internet address based on the use of cloud computing technology is presented as the website www.reactive-energy.uz and contains information on the efficiency of PSS nets reactive energy sources and receivers (Fig. 3).

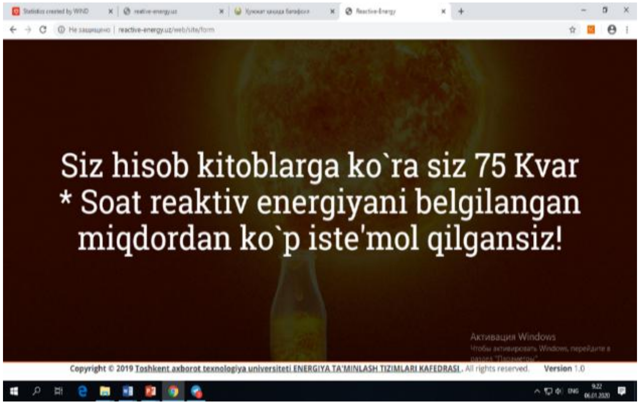


Figure 3. Informations about efficiency of PSS nets reactive energy sources and receivers, obtained on the basis of cloud computing technology.

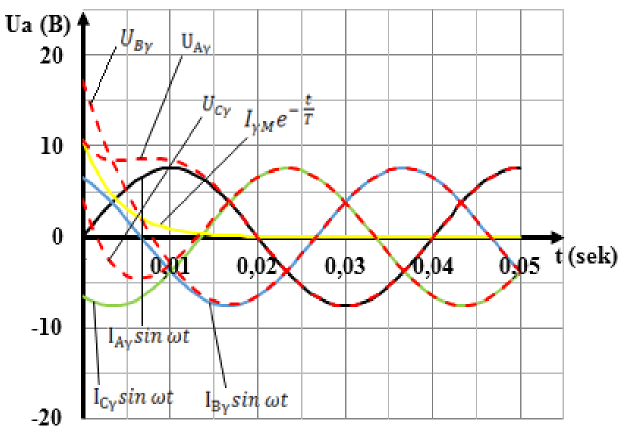
The Complex programs “Algorithms and software for calculating the parameters and efficiency of reactive power in the power supply system” [11-13] on cloud computing technology, are designs have possibilities research selecting and deploying reactive power sources of PSS. Its functionality is explained 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).



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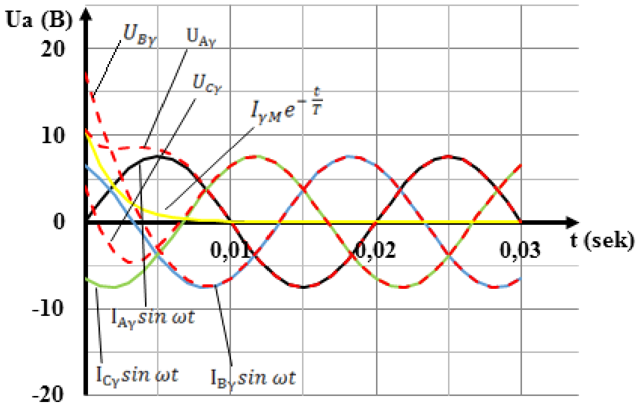
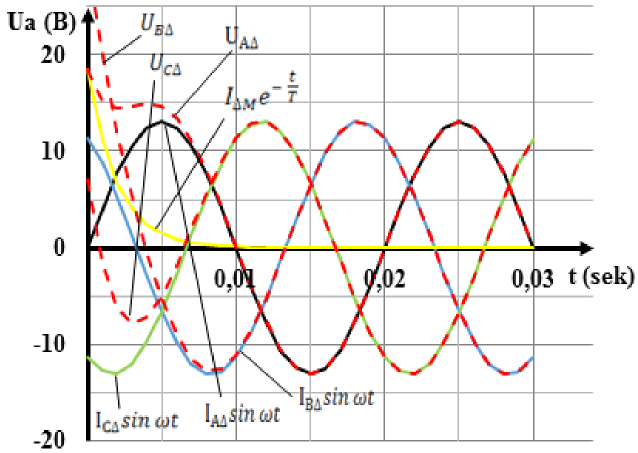
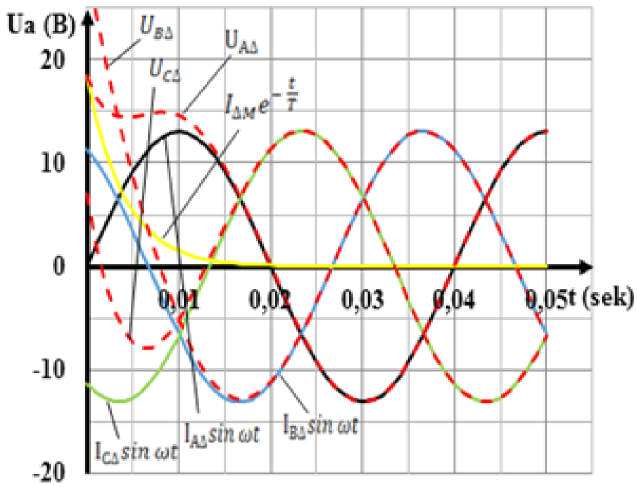


b)



c)



d)

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 high 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.

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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».

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.

Makhsudov Mokhirbek Tolibjonovich, Since 2017 I have been conducting research under the guidance of Professor TUIT Siddikov on "Managing jet power sources based on the control of three-phase currents." More than 10 articles and abstracts were published in this direction. I am a co-author of the research of dynamic descriptions of three-phase three-sensing sensors with distributed parameters. Articles "Bulletin of Science and Practice - Bulletin of Science and Practice" Bulletin of Science and Practice of the Russian Federation. Published in magazines "Universum: Technique Nookie" and Polish East European Scientific Journal.