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# STUDY OF STATISTICAL DESCRIPTION OF SENSORS FOR THE CONVERSION OF MULTIPHASE CURRENTS OF REACTIVE POWER SOURCES IN ELECTRICITY SUPPLY SYSTEMS

***Abstract***: *In this study, the reactive power of the power supply system is controlled and controlled using secondary voltage conversion sensors, taking into account the interaction of magnetic currents generated by multi-phase primary currents. For control and management of reactive power, the results of the descriptions of multi-phase current conversion sensors are given.*

***Key words***: *Reactive power, multi-phase currents, sensor, control, control, voltage, source, signal, air gap, sensitive element, description.*

***Language***: *English*

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**Introduction**

The study of the static characteristics of the reactive power (RP) multi-phase current-to-voltage conversion sensor of power supply systems (PSS) is carried out in the form of studies of signal conversion processes based on distributed parametric models of magnetic circuits. In the study of static characteristics of sensors that convert the value of the primary current of the RP source to the output voltage, $I_э$ input phase currents $U_{эч}$ output voltages, magnetic currents generated by the input currents to the $S_{CЭ}$ cross section of the sensing element, the number of $w_{CЭ}$ windings of $l_{x.o}$ the sensing element, dipazones and the various parameters of the magnetic core are required to be determined [1-5].

The magnetic currents generated by the currents $I_{A\gamma}, I_{B\gamma}, I_{C\gamma}, I_{A\Delta}, I_{B\Delta}, I_{C\Delta}$ generated by PSS s RP sources are in the magnetic cores (rods) $F_{\mu}$- magnetic driving forces (m.d.f.), they generate $\Phi_\mu$ - sensing based on the magnetic currents passing through the elements, the process of converting primary currents to $U_{\text{Эчик}}$-secondary voltages and a model of the sensor structure is constructed (Figure 1).

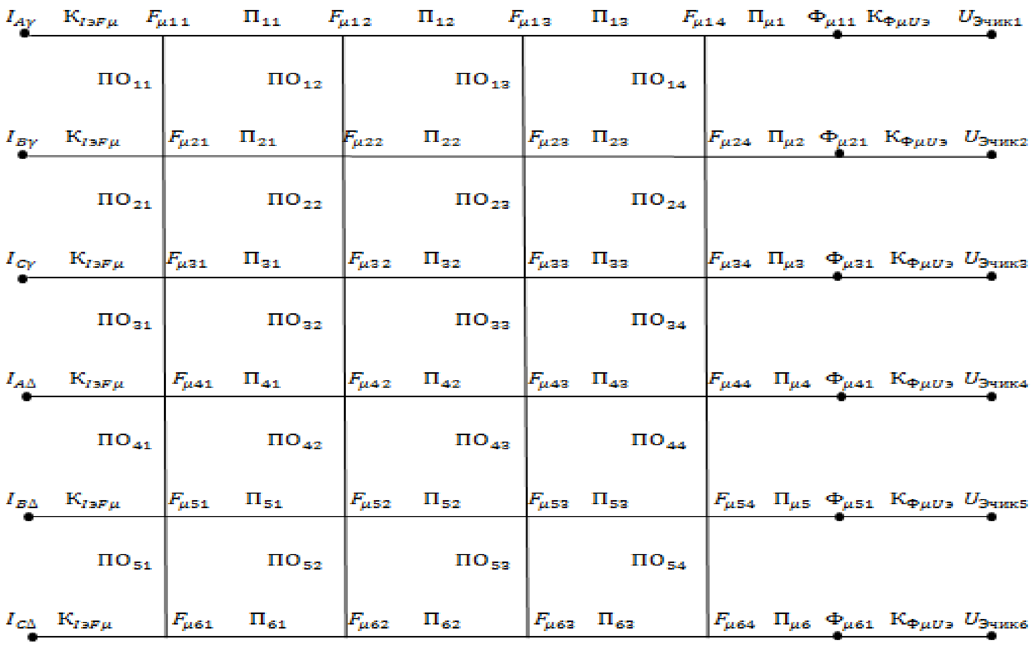



**Figure 1. The process of converting multi-phase current to secondary voltage and the model of the sensor switch section.**

The static characteristics of the multi-phase current-to-voltage conversion sensor used in the RP control of the PSS are investigated on the basis of a distributed parametric graph model (Figure 1) using an analytical expression as follows [6-10]:

$$
\begin{aligned}
U_{aY} = {} & K_{\Phi\mu U\text{э}}\Pi_{\mu1}\big(W(F_{\mu11},F_{\mu14})K_{I\text{э}F\,\mu}I_{AY} + W(F_{\mu21},F_{\mu14})K_{I\text{э}F\,\mu}I_{BY}\\
& +W(F_{\mu31},F_{\mu14})K_{I\text{э}F\,\mu}I_{CY} + W(F_{\mu41},F_{\mu14})K_{I\text{э}F\,\mu}I_{A\Delta} +\\
& +W(F_{\mu51},F_{\mu14})K_{I\text{э}F\,\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu14})K_{I\text{э}F\,\mu}I_{C\Delta}\big),\\
U_{bY} = {} & K_{\Phi\mu U\text{э}}\Pi_{\mu2}\big(W(F_{\mu21},F_{\mu24})K_{I\text{э}F\,\mu}I_{BY} + W(F_{\mu11},F_{\mu24})K_{I\text{э}F\,\mu}I_{AY}\\
& +W(F_{\mu31},F_{\mu24})K_{I\text{э}F\,\mu}I_{CY} + W(F_{\mu41},F_{\mu24})K_{I\text{э}F\,\mu}I_{A\Delta}\\
& +W(F_{\mu51},F_{\mu24})K_{I\text{э}F\,\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu24})K_{I\text{э}F\,\mu}I_{C\Delta}\big),\\
U_{cY} = {} & K_{\Phi\mu U\text{э}}\Pi_{\mu2}\big(W(F_{\mu31},F_{\mu34})K_{I\text{э}F\,\mu}I_{CY} + W(F_{\mu11},F_{\mu34})K_{I\text{э}F\,\mu}I_{AY}\\
& +W(F_{\mu21},F_{\mu34})K_{I\text{э}F\,\mu}I_{BY} + W(F_{\mu41},F_{\mu34})K_{I\text{э}F\,\mu}I_{A\Delta}\\
& +W(F_{\mu51},F_{\mu34})K_{I\text{э}F\,\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu34})K_{I\text{э}F\,\mu}I_{C\Delta}\big),\\
U_{a\Delta} = {} & K_{\Phi\mu U\text{э}}\Pi_{\mu2}\big(W(F_{\mu41},F_{\mu44})K_{I\text{э}F\,\mu}I_{A\Delta} + W(F_{\mu11},F_{\mu44})K_{I\text{э}F\,\mu}I_{AY}\\
& +W(F_{\mu21},F_{\mu44})K_{I\text{э}F\,\mu}I_{BY} + W(F_{\mu31},F_{\mu44})K_{I\text{э}F\,\mu}I_{CY}\\
& +W(F_{\mu51},F_{\mu44})K_{I\text{э}F\,\mu}I_{B\Delta} + W(F_{\mu61},F_{\mu44})K_{I\text{э}F\,\mu}I_{C\Delta}\big),\\
U_{b\Delta} = {} & K_{\Phi\mu U\text{э}}\Pi_{\mu5}\big(W(F_{\mu51},F_{\mu54})K_{I\text{э}F\,\mu}I_{B\Delta} + W(F_{\mu11},F_{\mu54})K_{I\text{э}F\,\mu}I_{AY}\\
& +W(F_{\mu21},F_{\mu54})K_{I\text{э}F\,\mu}I_{BY} + W(F_{\mu31},F_{\mu54})K_{I\text{э}F\,\mu}I_{CY}\\
& +W(F_{\mu41},F_{\mu54})K_{I\text{э}F\,\mu}I_{A\Delta} + W(F_{\mu61},F_{\mu54})K_{I\text{э}F\,\mu}I_{C\Delta}\big)\\
U_{c\Delta} = {} & K_{\Phi\mu U\text{э}}\Pi_{\mu5}\big(W(F_{\mu61},F_{\mu64})K_{I\text{э}F\,\mu}I_{C\Delta} + W(F_{\mu11},F_{\mu64})K_{I\text{э}F\,\mu}I_{AY}\\
& +W(F_{\mu21},F_{\mu64})K_{I\text{э}F\,\mu}I_{BY} + W(F_{\mu31},F_{\mu64})K_{I\text{э}F\,\mu}I_{CY}\\
& +W(F_{\mu41},F_{\mu64})K_{I\text{э}F\,\mu}I_{A\Delta} + W(F_{\mu51},F_{\mu64})K_{I\text{э}F\,\mu}I_{B\Delta}\big)
\end{aligned}
\tag{1}
$$

where: $K_{\Phi\mu U\text{э}} = \omega_{2\text{ч}} - \Phi_\mu$ is the coefficient of interconnection between magnetic currents and $U_{\text{Эчик}}$ output voltages, (assumes values up to $\omega_{2\text{ч}}$=1÷20 windings based on the requirement that the output voltage be rated (20 V) at rated primary currents) [10,11]

$\Pi_{\mu j} = \frac{\mu_0 F_j}{\delta_{\mu j}}$ (j=$\overline{1,6}$) – is the magnetic parameter of the variable part of the sensor generated $U_{\text{Эч}}$ output voltages ($\mu_0$ – magnetic absorption of air gaps with sensing element, $\mu_0 = 1{,}25 * 10^{-6}\text{Г/м}$);

F- log cross-sectional area of air gaps with sensing elements, axb=0.01x0.01 м$^2$;

$\delta_\mu$ – Heights of air gaps with sensing elements (m);

$W(F_{\mu ij}, F_{\mu in})$ – is the transfer function of the magnetic switching part.

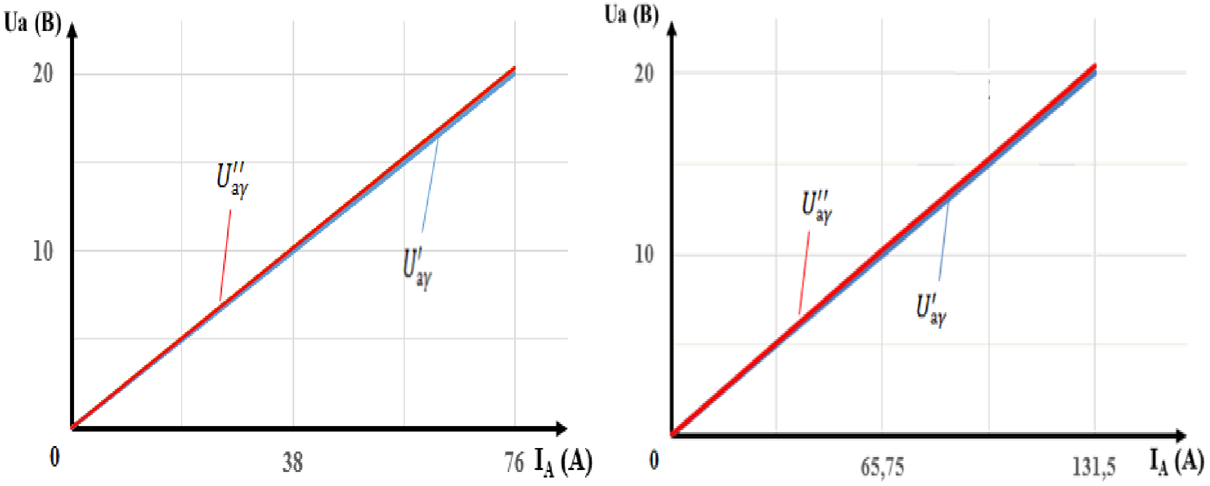
$K_{I\text{Э}F\,\mu} - \omega_{jk} - I_\text{Э}$ –- PSS $F_\mu$ –m.d.f. The coefficient of interdependence between chains is usually$\omega_{jk} = 1$.

Multi-phase primary currents (A) supplied by reactive power sources connected to the $I_{A\gamma}, I_{B\gamma}, I_{C\gamma}, I_{A\Delta}, I_{B\Delta}, I_{C\Delta}$ –QTEM PSS networks according to schemes $\gamma$ ва $\Delta$.

In particular, the magnitude of the output voltages $U_{a\gamma}, U_{b\gamma}, U_{c\gamma}, U_{a\Delta}, U_{b\Delta}, U_{c\Delta}$ depends mainly on the currents$I_{A\gamma}, I_{B\gamma}, I_{C\gamma}, I_{A\Delta}, I_{B\Delta}, I_{C\Delta}$, which they receive from their respective mains phases:

$$U_{a\gamma} = K_{\Phi\mu U\text{э}}\Pi_{\mu 1}(W(F_{\mu 11}, F_{\mu 14})K_{I\text{Э}F\,\mu}I_{A\gamma}$$
$$U_{b\gamma} = K_{\Phi\mu U\text{э}}\Pi_{\mu 2}(W(F_{\mu 21}, F_{\mu 24})K_{I\text{Э}F\,\mu}I_{B\gamma}$$
$$U_{c\gamma} = K_{\Phi\mu U\text{э}}\Pi_{\mu 3}(W(F_{\mu 31}, F_{\mu 34})K_{I\text{Э}F\,\mu}I_{C\gamma}$$
$$U_{a\Delta} = K_{\Phi\mu U\text{э}}\Pi_{\mu 4}(W(F_{\mu 41}, F_{\mu 44})K_{I\text{Э}F\,\mu}I_{A\Delta}$$
$$U_{b\Delta} = K_{\Phi\mu U\text{э}}\Pi_{\mu 5}(W(F_{\mu 51}, F_{\mu 54})K_{I\text{Э}F\,\mu}I_{B\Delta}$$
$$U_{c\Delta} = K_{\Phi\mu U\text{э}}\Pi_{\mu 6}(W(F_{\mu 61}, F_{\mu 64})K_{I\text{Э}F\,\mu}I_{C\Delta} \quad (2)$$

Based on formulas (1 and 2) above, the relationship between the single-phase current of the RP source of PSS networks and the output voltage of the sensor is given in the form of a static description below (Figure 1).



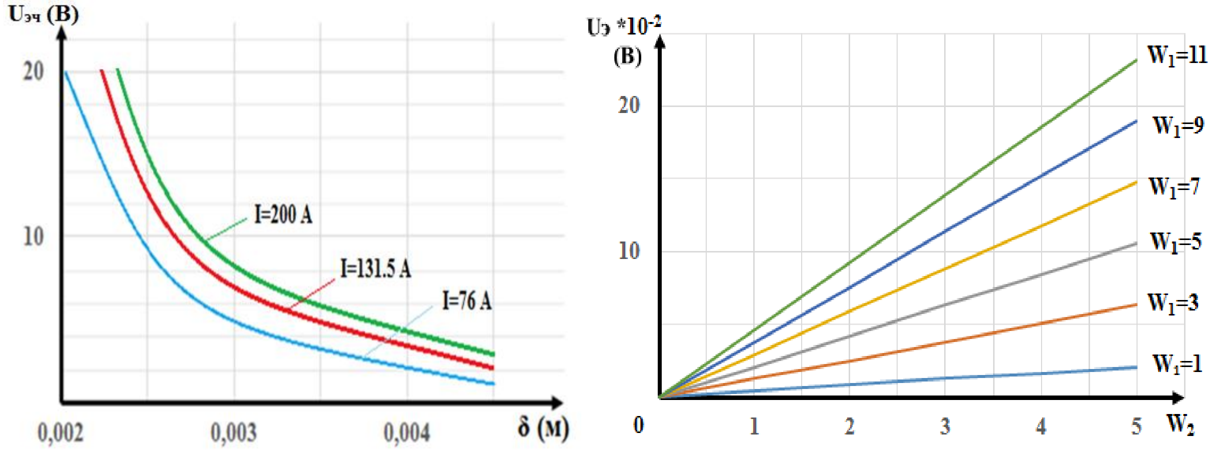

a) b)

**Figure 2 Static characteristics of the relationship between the single-phase primary currents of the ETT network reactive powers and the sensor output voltage**
**a) The reactive power supply is connected in a star shape;**
**b) The reactive power supply is connected in a triangular shape.**

Where: $U'_{a\gamma}$ - description of the change in output voltage obtained on the basis of the collected parametric model,

$U''_{a\gamma}$- a description of the change in output voltage obtained on the basis of the distributed parametric model.

A static description of the effect of the geometric dimensions of the air gap of the sensor on the output voltage is given in Figure 2.




a) b)

**Figure 3. The effect of sensor sizes on output power.**
**a) The effect of airflow b) the effect of the number of packages**

2- Based on the static characteristics shown in Figures (a) and (b), the metrological characteristics of the PSS RP multi-phase primary current conversion sensor to secondary voltage are studied: change accuracy, linearity of the output characteristic, uniformity of the sensor sensitivity throughout the change range.

Based on Figure 2a, the values of the magnitudes $I_{A\gamma}$, $U'_{a\gamma}$, $U''_{a\gamma}$ - are indicators of the change errors corresponding to the points of static descriptions:

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

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

$I_{A\gamma} = 76$ A; $U'_{a\gamma} = 20$ B; $U''_{a\gamma} = 20{,}37$ B

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

For the case of triangular connection of reactive power supply capacitors in the form of a triangle, $I_{A\gamma}$, $U_{a\gamma}$, $U_{a\gamma'}$ are the indicators of conversion errors corresponding to the points of static characteristics based on the quantities and are shown in Figure 2b:

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

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

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

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

Based on the calculated data, it can be concluded that the distributed parametric graph model of the multi-phase current sensor represented by PSS reactive power sources and the analytical expression based on it are adequate 1,8% to the real linear output characteristics of the sensor.

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