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THE DEVELOPMENT OF THE THEORY OF INSTANTANEOUS POWER OF THREE-PHASE NETWORK IN TERMS OF NETWORK CENTRISM

Purpose. Information technologies allow multidimensional analysis of information about the state of the power system in a single information space in terms of providing network-centric approach to control and use of unmanned aerial vehicles as tools for condition monitoring of three-phase network. Methodology. The idea of energy processes in three independent (rather than four dependent) curves vector-functions with values in the arithmetic three-dimensional space adequately for both 4-wire and 3–wire circuits. The presence of zero sequence current structural (and mathematically) features a 4-wire scheme of energy from a 3-wire circuit. The zero sequence voltage caused by the displacement of the zero voltage phases. Offset zero in the calculations can be taken into account by appropriate selection of the reference voltages. Both of these energetic phenomena with common methodical positions are described in the framework of the general mathematical model, in which a significant role is played by the ort zero sequence. Results. Vector approach with a unified voice allows us to obtain and analyze new energy characteristics for 4–wire and 3–wire circuits in sinusoidal and non-sinusoidal mode, both in temporal and frequency domain. Originality. Symmetric sinusoidal mode is balanced, even with non-zero reactive power. The converse is not true. The mode can be balanced and unbalanced load. The mode can be balanced and unbalanced voltage. Practical value. Assessing balance in network mode and the impact of instantaneous power on the magnitude of the losses, will allow to avoid the appearance of zero sequence and, thus, to improve the quality of electricity. References 9, figures 3.

Key words: **network-centric technology, instant power, zero sequence, neutral.**

Обеспечение сетецентрического подхода к режиму управления трехфазной сетью и оценка сбалансированности режима сети с учетом влияния мгновенной мощности на величину потерь даст возможность исключить появление нулевой последовательности и, тем самым, повысить качество электроэнергии. Библ. 9, рис. 3.

Ключевые слова: **сетецентрическая технология, мгновенная мощность, нулевая последовательность, нейтраль.**

Introduction and problem definition. Compatibility problems of different types of generation require concentration of efforts on the integration of energy clusters, which must be balanced by primary energy resources with the interaction of the subjects of production, transmission and consumption of electric energy. When comparing the properties of traditional hierarchical and innovative network-centric control systems for the operation modes of a three-phase network, the main advantages of the latter include the use of irregular subsystems (subsystems with variable structure and a changing set of functions) and the use of information in real time. However, this requires the reorganization of not only the attached local power systems, but also the entire set of distributed energy objects [1].

Solving the problem complicates the presence of weak and at the same time extensive information and management connections in large areas [2].

Modern information technologies allow multidimensional analysis of information on the state of the power system in a single information space under the conditions of providing a network-centric approach to the control and use of unmanned aerial vehicles as a means of monitoring the state of a three-phase network [3].

Reactivity, asymmetry and non-sinusoidal mode of consumption for a number of consumers are caused by technological reasons and have a long-term nature, which is the reason for the appearance of pulsations of instantaneous power (IP), which causes additional losses of electricity and contributes to the emergence of dangerous resonance phenomena during operation of a three-phase network [4].

Analysis of recent investigations and publications. At asymmetric voltage, the problem of minimizing losses and creating a balanced power supply regime becomes multi-criteria. Improvement of methods of compensation and load symmetrization with asymmetric voltage requires further development of the theory of power [5].

The goal of investigations. Development of methods of the theory of instantaneous power in the presence of an asymmetric load in the network-centric control of the operating modes of a three-phase network.

Main materials of investigations. In a 4-wire system, the IP is defined as the sum of four pairwise products of instantaneous values (IV) currents and voltages. By the first Kirchhoff law, only three linear currents (out of four) are independent (free) quantities, and IP is invariant with respect to the choice of the reference point (RP) simultaneously for 4 voltages. Such an invariance of the IP leads to the fact that among 4 voltages (three phase voltages and neutral voltage) only three values of the voltages are independent (free).

RP voltage voltages, with respect to which the zero sequence of the phase voltage vector is «0», is called an *artificial point* of grounding (APG). The choice of the APG for the section ‹*a*, *b*, *c*, *n*› makes 4 voltage values conditionally four-dimensional. This leads to the complication of the mathematical description of energy processes and requires an unjustified application of the technique of Lagrange multipliers [6].

The choice of neutral as the voltage RP does not change the value of IP. In this case, the IP clearly depends only on three independent phase voltages and three independent linear currents. This allows us to consider the energy processes (current and voltage) in a 4-wire system by three-dimensional and completely determined three phase values of the cross section of three phases ‹a, b, c› depending on time - by three curves (3-waveforms): $x_a = x_a(t)$, $x_b = x_b(t)$, $x_c = x_c(t)$. The curves of the considered process in three phases determine the radius vector $x(t)=[x_a(t)\ x_b(t)\ x_c(t)]^{\bullet}$ with values in the 3-dimensional space $X^{(3)}$ (3-dimensional curve $x(t) \in X^{(3)}$, abbreviated 3-curve).

Here $X^{(3)}$ is the arithmetic space of three-dimensional real vectors (matrix-columns) with the operations:

– scalar product (SP):

$$(x, y) = x^{\bullet} y = [x_a\ x_b\ x_c] \cdot \begin{bmatrix} y_a \\ y_b \\ y_c \end{bmatrix} = x_a y_a + x_b y_b + x_c y_c\ ; \quad (1)$$

– vector product (VP):

$$x \times y = \begin{bmatrix} x_b y_c - x_c y_b \\ x_c y_a - x_a y_c \\ x_a y_b - x_b y_a \end{bmatrix} = = [x_b y_c - x_c y_b - x_c y_a - x_a y_c - x_a y_b - x_b y_a]. \quad (2)$$

Vectors are orthogonal if their scalar product is zero:

$$x \perp y \Leftrightarrow (x, y) = 0\ . \quad (3)$$

Vectors are parallel (collinear) if their vector product is zero:

$$x \parallel y \Leftrightarrow x \times y = 0\ . \quad (4)$$

The representation of energy processes by three independent (and not four dependent) curve vector-valued functions with values in the arithmetic 3-dimensional space $X^{(3)}$ is adequate both for 4-wire, and for 3-wire circuits.

Analysis of energy processes in a 4-wire network. A vector approach from a single point of view makes it possible to obtain and analyze new energy characteristics for both 4-wire and 3-wire circuits, both in sinusoidal and non-sinusoidal mode, both in the time and frequency domain, mathematically considering 3-wire power supply circuit as a special case of a 4-wire power supply circuit.

Instant power and unbalanced mode. At each moment of time, the local state of the energy processes in the three-phase section ‹a, b, c› is characterized by vectors of instantaneous current and voltage values:

$$\begin{aligned} u(t) &= [u_a(t)\ u_b(t)\ u_c(t)]^{\bullet}, \\ i(t) &= [i_a(t)\ i_b(t)\ i_c(t)]^{\bullet}. \end{aligned} \quad (5)$$

When considering a 4-wire circuit, we assume that the voltages are measured with respect to the neutral. The definition of the norm of a vector in a 3-dimensional space $X^{(3)}$ at each instant of time determines the norm of the vector of the IV of current and voltage:

$$|u(t)| = \sqrt{u^{\bullet}(t)\, u(t)} = \sqrt{u_a(t)^2 + u_b(t)^2 + u_c(t)^2}\ ; \quad (6)$$

$$|i| = |i(t)| = \sqrt{i^{\bullet}(t)\, i(t)} = \sqrt{i_a(t)^2 + i_b(t)^2 + i_c(t)^2}\ . \quad (7)$$

The standard (scalar) IP is defined as the sum of pairwise products of IV of current and voltage of three phases:

$$p(t) = u_a(t) i_a(t) + u_b(t) i_b(t) + u_c(t) i_c(t) = \frac{dW}{dt} \quad (8)$$

and characterizes the energy transfer rate $W=W(t)$ in this section. As follows from (1), at each instant of time it is equal to the SP of vectors (5):

$$p(t) = (i, u) = i^{\bullet} u = [i_a(t)\ i_b(t)\ i_c(t)] \cdot \begin{bmatrix} u_a(t) \\ u_b(t) \\ u_c(t) \end{bmatrix}. \quad (9)$$

Assuming that the processes (5) are T-periodic, that is, $u(t+T)=u(t)$ и $i(t+T)=i(t)$, we can correctly determine the mean IP and isolate the variable component:

$$\begin{aligned} P = \overline{p} &= \frac{1}{T} \int_{\tau}^{\tau+T} p(t) d(t), \\ p(t) &= \overline{p} + \widetilde{p}(t), \end{aligned} \quad (10)$$

where $\tau \geq 0$ is the arbitrary number.

If the MM does not have a variable (pulsating) component $\widetilde{p}(t) \equiv 0$, then the mode is balanced [7]. In general case $\widetilde{p} = p(t) - \overline{p} \neq 0$ and the mode is unbalanced. Symmetric sinusoidal mode is balanced, even with non-zero reactive power. The converse is not true. The mode can be balanced even with an asymmetric load. The mode can be balanced even with asymmetric voltage.

Vector IP and instantaneous power equation. The product of the norms of the vectors (5) determines the apparent IP of the energy mode:

$$s(t) = |u(t)| \cdot |i(t)| = u(t) \cdot i(t)\ . \quad (11)$$

In the 3-dimensional space $X^{(3)}$, for any pair of vectors, the Cauchy-Schwarz inequality [8] holds, which for the vectors (5) gives the implication:

$$\left| i(t)^{\bullet} u(t) \right| \leq |i(t) u(t)| \Rightarrow |p(t)| \leq s(t)\ . \quad (12)$$

We introduce the vector IP as the VP of vectors (5) of currents and voltages [8]:

$$q(t) = i(t) \times u(t) = = \Big[\underbrace{i_b u_c - i_c u_b}_{q_a}\ \underbrace{i_c u_a - i_a u_c}_{q_b}\ \underbrace{i_a u_b - i_b u_a}_{q_c} \Big] = = [q_a\ q_b\ q_c]^{\bullet}. \quad (13)$$

The pairwise SP of vectors (5) form a Gram matrix (2×2):

$$G(i, u) = \begin{bmatrix} i^{\bullet} i & i^{\bullet} u \\ i^{\bullet} u & u^{\bullet} u \end{bmatrix} = \begin{bmatrix} i^2(t) & p(t) \\ p(t) & u^2(t) \end{bmatrix}. \quad (14)$$

The positive values on its main diagonal are equal to the squares of the norms of the vectors (5) of the voltages and currents: $u^{\bullet}u=|u(t)|^2=u^2(t)$, $i^{\bullet}i=|i(t)|^2=i^2(t)$. The determinant of the Gram matrix is equal to the square of the norm of the VP of vectors of the IV of currents and voltages – to the scalar square of the vector of the IP (13):

$$\det[G(i, u)] = \begin{vmatrix} i^{\bullet} i & i^{\bullet} u \\ i^{\bullet} u & u^{\bullet} u \end{vmatrix} \equiv \underbrace{[i \times u]^{\bullet}}_{q(t)} \underbrace{[i \times u]^{\bullet}}_{q(t)} = |q(t)|^2\ . \quad (15)$$

The geometric meaning of the determinant of the Gram matrix: «the square of the area of the parallelogram, which is formed by the vectors of voltage $u=u(t)$ and the current $i=i(t)$» is illustrated in Fig. 1.

The area of such an «instantaneous» parallelogram is:

$$q(t)=|q(t)|=|u(t)|\cdot|i(t)|\sin\varphi(t)=s(t)\sin\varphi(t)\,, \quad (16)$$

where $\varphi(t)$ is instantaneous angle between vectors of the IV of current and voltage in the arithmetic 3-dimensional space $X^{(3)}$ at time t.

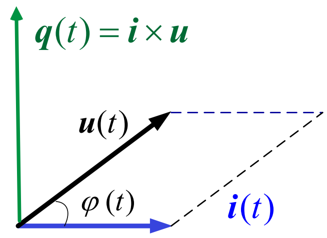

Fig. 1. Vector of current, vector of voltage and vector IP

The area of the parallelogram is zero if generating its vectors are parallel (collinear) $u(t)\|i(t)$ when the apparent power is equal to IP. Therefore, the norm of VP of the current $i=i(t)$ and the voltage $u = u(t)$ can be interpreted as an inactive IP. To emphasize this interpretation, the standard (scalar) IP will be called the active IP. The expansion (15) is invariant under the permutation of the vectors i and u, but $i\times u= -u\times i$. Here the vector (inactive) IP is determined according to (13).

The opposite choice is made in the «pq-theory» and leads to an error [9]. Note that the vectors i, u, $i\times u$ form a right triple.

The Cauchy inequality (12) at each moment is quadratically complemented to equality by the determinant of the Gram matrix [8]:

$$\underbrace{(i^\bullet i)}_{i^2(t)}\cdot\underbrace{(u^\bullet u)}_{u^2(t)}=\underbrace{(i^\bullet u)^2}_{p^2(t)}+[i\times u]^\bullet\underbrace{(i\times u)}_{q(t)}. \quad (17)$$

The identity (17) gives the power equation for instantaneous powers and is illustrated in Fig. 2:

$$s^2(t)=p^2(t)+q^2(t)\,. \quad (18)$$

In the triangle of instantaneous powers (Fig. 2), two legs correspond to active and inactive instantaneous powers. If the inactive IP is due to $\sin\varphi(t)$, then the active MM is due to $\cos\varphi(t)$:

$$p(t)=u^\bullet i=\underbrace{|u||i|}_{s(t)}\cdot\underbrace{\frac{u^\bullet i}{|u||i|}}_{\cos\varphi(t)}=s(t)\cdot\cos\varphi(t)\,. \quad (19)$$

The angle in the power triangle $\varphi(t)$ is equal to the angle introduced earlier between the vectors of current $i = i(t)$ and voltage $u = u(t)$.

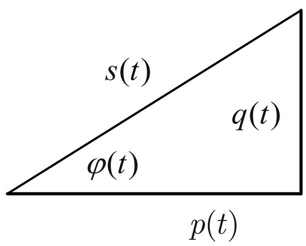

Fig. 2. Instantaneous power triangle

If the active IP (8) characterizes the efficiency of the energy mode, the vector IP (13) characterizes the energy mode losses.

Unbalanced and balanced mode. Like (10) in the vector IP, we can select vector components - a constant and a variable:

$$\bar{q}=\frac{1}{T}\int_{\tau}^{\tau+T}q(t)d(t),\quad \tilde{q}(t)=q(t)-\bar{q}\,. \quad (20)$$

The mode in which the vector IP does not have a variable component $\tilde{q}=\tilde{q}(t)\equiv 0$ will be called the balanced mode [7].

The mode is really balanced if the vector IP (inactive IP) is identically equal to zero:

$$q(t)\equiv 0 \Leftrightarrow (\bar{q}(t)\equiv 0)\,\&\,(\tilde{q}(t)\equiv 0). \quad (21)$$

Thus, the mode is really balanced ($q(t)\equiv|q(t)|\equiv 0$) if at each moment (identically) the vectors (5) are parallel:

$$q(t)\equiv|q(t)|\equiv 0 \quad \Leftrightarrow \quad y(t)\cdot u(t)=i(t)\,. \quad (22)$$

The scalar quantity $y(t)$ (has the conductivity dimension) need not be a constant and the power factor is, in general, less than 1.

Current and voltage of the 0-sequence. In a 4-wire circuit with an asymmetrical load, the neutral current is not zero (the zero sequence (ZS) current is non-zero). It is the presence of the ZS current that is structurally (and mathematically) different from the 4-wire power supply circuit from the 3-wire circuit. The voltage ZS is due to the phase angle shift. The zero offset in the calculations can be taken into account by the appropriate choice of the voltage reference point. Both these energy phenomena are described from the same methodological positions within the framework of a general mathematical model in which an essential role is played by the ZS unit vector (a vector with a unit norm)

$$e_0=\frac{1}{\sqrt{3}}[1\quad 1\quad 1]^\bullet,\quad |e|=1\,. \quad (23)$$

The expansion of the 3-dimensional vector $x=[x_a\ x_b\ x_c]^\bullet \in X^{(3)}$ along the ZS unit vector determines the representation of the 3-dimensional vector by two mutually orthogonal components

$$x=\underbrace{(x^\bullet e_0)e_0}_{x_0}+\underbrace{e_0\times[x\times e_0]}_{x_!}=x_0+x_!;\quad (x_0\perp x_!), \quad (24)$$

where «×» is the symbol of the vector product.

In the expansion (24), the first component:

$$x_0=(x^\bullet e_0)e_0=\underbrace{\frac{x_a+x_b+x_c}{3}}_{\hat{x}}\cdot\begin{bmatrix}1\\1\\1\end{bmatrix}=\hat{x}\cdot\begin{bmatrix}1\\1\\1\end{bmatrix} \quad (25)$$

is the vector projection of the vector $x=(x_a,\ x_b,x_c)$ to the 0-unit (23) and is equal to the 0-component of this vector.

The coordinates of the vector (25) are the same and equal to the average value of the 3-phase quantities:

$$\hat{x}(t)=(x_a(t)+x_b(t)+x_c(t))/3\,. \quad (26)$$

Component without 0-component (double vector product):

$$x_!=e_0\times[x\times e_0] \quad (27)$$

is an orthogonal complement of the component (25) to the full vector (and does not contain 0-component). This component will be called the 0-balanced component.

Vector product of the vector by 0-unit on the left:

$$e_0 \times x = \frac{1}{\sqrt{3}} \begin{bmatrix} x_c - x_b \\ x_a - x_c \\ x_b - x_a \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \quad (28)$$

can be represented using a skew-symmetric matrix

$$K = \frac{1}{\sqrt{3}} \begin{bmatrix} 0 & -1 & 1 \\ 1 & 0 & -1 \\ -1 & 1 & 0 \end{bmatrix} \quad (29)$$

in the form:

$$e_0 \times x = K \cdot x . \quad (30)$$

The vector product on the left and on the right is distinguished by the sign. Product on the right:

$$y \times e_0 = \frac{1}{\sqrt{3}} \begin{bmatrix} y_b - y_c \\ y_c - y_a \\ y_a - y_b \end{bmatrix} = \underbrace{\frac{1}{\sqrt{3}} \begin{bmatrix} 0 & -1 & 1 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \end{bmatrix}}_{K^\bullet} \cdot \begin{bmatrix} y_a \\ y_b \\ y_c \end{bmatrix} \quad (31)$$

$$y \times e_0 = K^\bullet \cdot y \quad (32)$$

is equivalent to multiplying by the transpose matrix $K^\bullet = -K$.

For the second component (27) of the expansion (24) we have:

$$x_! = \underbrace{[e_0 \times x]}_{K \cdot x} \times e_0 = \underbrace{K \cdot x \times e_0}_{K^\bullet K \cdot x} = \underbrace{K^\bullet K}_{D_!} \cdot x = D_! \cdot x . \quad (33)$$

In the matrix form, the components of the expansion (24) are written as:

$$x_0 = D_0 \cdot x, \quad x_! = D_! \cdot x . \quad (34)$$

Matrices:

$$D_0 = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, \quad D_! = \frac{1}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \quad (35)$$

determine the projector D_0 on the unit vector of the 0-sequence and the projector $D_!$ on a 2-dimensional subspace of three-dimensional vectors orthogonal to 0-unit:

$$L_!^{(2)} = \left\{ x \in X^{(3)} : x^\bullet e_0 = 0 \right\} \subset X^{(3)} . \quad (36)$$

The vector $x = D_! \cdot x$ is 0-balanced. By the equivalence of the assertions:

$$x \perp e_0 \quad \Leftrightarrow \quad x_0 = 0 \quad \Leftrightarrow \quad x = D_! \cdot x = x_! \quad (37)$$

an alternative description of the 2-dimensional subspace (36) of three-dimensional 0-balanced vectors is valid (without the 0-sequence)

$$L_!^{(2)} = \left\{ x \in X^{(3)} : x = D_! \cdot x \right\} . \quad (38)$$

of 2-dimensional subspace (36) as the set of 3-dimensional vectors that do not change under the influence of the matrix $D_!$.

The matrices (35) satisfy the following conditions:

– the square of the matrix coincides with the matrix itself (the idempotency property)

$$D_0^2 = D_0, \quad D_!^2 = D_! ; \quad (39)$$

– the product of matrices is equal to zero (orthogonality):

$$D_0 D_! = 0 ; \quad (40)$$

– the sum of the matrices gives an orthogonal decomposition of the unit third-order matrix

$$D_0 + D_! = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} . \quad (41)$$

The orthogonal decomposition (24) is valid at each instant of time, i.e. (24) is identically satisfied for the 3-dimensional curve:

$$x(t) \equiv x_0(t) + x_!(t) \equiv D_0 x(t) + D_! x(t) . \quad (42)$$

Since the above formulas are identically satisfied for 3-dimensional curves (valid at each instant of time), then, in order not to overload the formulas, the dependence on time will not be indicated. In particular, for the 3-current and voltage curves (5), we write the expansion (42) (obviously not indicating the time dependence) as (Fig. 3):

$$i = \underbrace{D_0 i}_{i_0} + \underbrace{D_! i}_{i_!} = i_0 + i_! ; \quad u = \underbrace{D_0 u}_{u_0} + \underbrace{D_! u}_{u_!} = u_0 + u_! . \quad (43)$$

The voltage (potential difference) is a relative value that depends on the RP. From the representation (43) for the voltage vector, it follows that with the change in the voltage RP, only the ZS of the voltage vector u_0 changes, and 0-balanced component of the vector $u_!$ does not change.

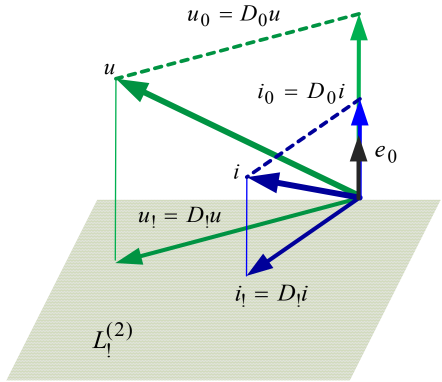

Fig. 3. Orthogonal decomposition of vectors of voltage and current along the ZS in a 4-wire circuit

The vector of phase voltages $u_! = D_! \cdot u$ is 0-balanced and (at each instant of time) is equal to the voltage vector, all phase components of which are measured relative to the APG.

All three coordinates of the voltage vector of 0-sequences

$$u_0 = D_0 u = (\hat{u}_a(t), \hat{u}_b(t), \hat{u}_c(t))^\bullet \quad (44)$$

are the same:

$$\hat{u} = (u_a(t) + u_b(t) + u_c(t)) / 3 \quad (45)$$

and equal to the voltage difference between neutral and APG. If the voltage is symmetrical, then it does not contain ZS, in this case the APG coincides with the neutral.

Conclusions. The network-centric technology of three-phase network management is the idea of integrating all forces and means in a single space, which allows increasing the efficiency of their application to the destination. One of the components of this process is the estimation of the balance of the network mode and the influence of IP on the amount of losses, will make it possible to eliminate the occurrence of the zero sequence and, thereby, to improve the quality of electricity.

REFERENCES
1. Sokol Y.I., Gryb O.G., Shvets S.V. Network centrism optimization of expeditious service of elements of the power supply system. *Electrical engineering & electromechanics*, 2016, no.3, pp. 67-72. (Rus). **doi: 10.20998/2074-272X.2016.3.11.**
2. Sokol Y.I., Gryb O.G., Shvets S.V. The structural and parametrical organization of elements of a power supply system in the conditions of network centrism. *Electrical engineering & electromechanics*, 2016, no.2, pp. 61-64. (Rus). **doi: 10.20998/2074-272X.2016.2.11.**
3. Shvets S.V., Voropai U. G. Mariechantal aspects of the use of unmanned aerial vehicles. *Bulletin of Kharkiv Petro Vasylenko National Technical University of Agriculture*, 2016, no.176, pp. 33-34. (Ukr).
4. *Sirotin Iu.A., Ierusalimova T.S.* Instantaneous and integral power equations of nonsinusoidal 3-phase processes. *Electrical engineering & electromechanics*, 2016, no.1, pp. 69-73. **doi: 10.20998/2074-272X.2016.1.13.**
5. Zhezhelenko I.V., Saenko Yu.L. *Voprosy kachestva elektroenergii v elektroustanovkakh* [Issues of power quality in electrical installations]. Mariupol, PSTU Publ., 1996. 173 p. (Rus).
6. Willems J.L, Ghijselen J.A. The relation between the generalized apparent power and the voltage reference. *Energia elettrica*, 2004, vol.81, pp. 37-45.
7. Shidlovskii A. K., Mostovyak A.G., Moskalenko A.G. *Uravnoveshivanie rezhimov mnogofaznykh tsepei* [Balancing the modes of multiphase circuits]. Kiev, Naukova Dumka Publ., 1990. 181 p. (Rus).
8. Korn G., Korn T. *Spravochnik po matematike dlia nauchnykh rabotnikov i inzhenerov* [Mathematical handbook for scientists and engineers]. Moscow, Nauka Publ., 1973. 832 p. (Rus).
9. Peng F.Z., Lai J.S. Generalized instantaneous reactive power theory for three-phase power systems. *IEEE Transactions on Instrumentation and Measurement*, 1996, vol.45, no.1, pp. 293-297. **doi: 10.1109/19.481350.**

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