BASES OF THE THEORY OF CAPACITY AND ENERGY OF DISTORTION IN ELECTRICAL CIRCUITS WITH NONLINEAR POWER

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Increase of sensitivity of modern technologies to sinusoidal distortion of a power requires perfection of the mechanism, responsibility of the consumers generated high harmonic component (HHC), where level exceeds normative values. An integrated parameter of quality of electrical energy is the energy of distortion.

However theory of capacity and energy of distortion in networks of an alternating current is not developed. The results of researches allowing to establish essence energy of distortion and to calculate it for any spectrum HHC are given.

Despite of significant number of works devoted to a problem of definition of capacity and energy of distortion, the difficulties of its decision are known. The urgency of a problem grows in connection with the varied relations of the participants of the market of the electric power, by increase of the requirements to quality of the electric power on the part of the consumers [1].

Let's distinguish power *(U)* and current in a circuit (I), having:

- Identical frequency. Let's name as their same harmonics (SH) of power and current. Private, but, it is obvious most important case is U_1 and I_1 of the basic harmonic;
- Various frequency. Let's name them different-name harmonics (DNH) of a power and current.

The variable making of capacities of SH and the capacity DNH as a matter of fact is exchange capacity (EC) and between its complete (S_n), active (P_n) and reactive (Q_n) components the square-law dependence, i.e. $S_n^2 = P_n^2 + Q_n^2$ takes place. To distinguish EC of the basic harmonic from EC HHC it is accepted to name last as capacity of distortion (CD), and energy, appropriate to it by energy of distortion (ED).

Before to define capacity *(S)* and energy *(W)* HHC with the purposes of comparison we shall refer to known results of definition S_1 and W_1, including their active (P_1) and reactive (Q_1) parameters for the basic harmonic [2]. Let

$$u_1(t) = U_{1,m}\sin\omega t \quad (1)$$

$$i_1(t) = I_{1,m}\sin(\omega t + \varphi_1) \quad (2)$$

$$S_1(t) = P_1(t) + Q_1(t) \quad (3)$$

where $P_1(t) = P_1(1-\cos 2\omega t)$, $Q_1(t) = Q_1\sin 2\omega t$

EC of the basic harmonic consists from:

By active component with a maximum equalled $P_{1,m} = |P_1|$, where $P_1 = 0{,}5U_{1,m}I_{1,m}\cos\varphi_1$ and with energy, which for the period T_1 is equalled

$$W_{P,1}^{(+)} = \left|W_{P,1}^{(-)}\right| = P_1T_1\pi^{-1} \quad (4)$$

where the marks (+) and (-) designate a direction of flows *SE*. In the subsequent statement the mark *W* with the purposes of simplification will be specified only if it is necessary.

By reactive component with a maximum equal $Q_{1,m} = |Q_1|$, where $Q_1 = 0{,}5U_{1,m}I_{1,m}\sin\varphi$ and with energy, which for the period T_1 is equal

$$W_{Q,1} = Q_1T_1\pi^{-1} \quad (5)$$

Similarly

$$S_{1,m} = |S_1|,\ where\ \ S_1 = 0{,}5U_{1,m}I_{1,m}$$

$$W_{S,1} = S_1T\pi^{-1} \quad (6)$$

Generally, when in a linear circuit a power

$$u(t) = \sum_{n=1}^{n_m} U_{n,m}\sin n\omega t \quad (7)$$

The current is equalled

$$i(t) = \sum_{n=1}^{n_m} I_{n,m}\sin(n\omega t + \varphi_n) \quad (8)$$

The instant value of complete capacity *S(t)* on sine not wave curves *u(t)* and *i(t)* would seem equally to product of instant values $u(t_i)$ and $i(t_i)$ by analogy to sine wave curves of a power and current. Let's show on a simple example, that such calculation is erroneous. Let at a circuit with linear loading in curves *u(t)* and *i(t)* alongside with the basic harmonic there are the third and seventh harmonic, i.e.

$$u(t) = U_{1m}\sin\omega t + U_{3m}\sin 3\omega t + U_{7m}\sin 7\omega t$$
$$i(t) = I_{1m}\sin(\omega t + \varphi_1) + I_{3m}\sin(3\omega t + \varphi_3) + I_{7m}\sin(7\omega t + \varphi_7)$$

At the moment t_1 at the marked approach

$$S(t_1) = u(t_1)\cdot i(t_1),$$

and the product includes six components, which are deprived physical meaning, since under action of n^{th} of a harmonic of a power in a linear circuit the harmonics of a current can not proceed, where order is differed from *n*. The accounts *S(t)* must make under the formula

$$S(t)=\sum_{n=1}^{n_m}U_{n,m}I_{n,m}\sin n\omega t\sin(n\omega t+\varphi_n)=\sum_{n=1}^{n_m}P_n-\sum_{n=1}^{n_m}P_n\cos 2n\omega t+\sum_{n=1}^{n_m}Q_n\sin 2n\omega t=P_{\Sigma,cp}+S_{1,1}(t)+D_{oг}(t) \quad (9)$$

where, n_m- greatest number HHC; $S_{1,1}(t)$ -EC at $n=1$; $D_{oг}(t)$- CD *SH*; $U_{n,m}$, $I_{n,m}$ and φ_n are calculated by the results of the Furye-analysis of curves $u(t)$ and $i(t)$.

$$P_n=0{,}5U_{n,m}I_{n,m}\cos\varphi_n=P_1K_{Un}K_{I(n)}\frac{\cos\varphi_n}{\cos\varphi_1}=S_1K_{U(n)}K_{I(n)}\cos\varphi_n \quad (10)$$

$$Q_n=0{,}5U_{n,m}I_{n,m}\sin\varphi_n=Q_1K_{U(n)}K_{I(n)}\frac{\sin\varphi_n}{\sin\varphi_1}=S_1K_{U(n)}K_{I(n)}\sin\varphi_n \quad (11)$$

$$S_n=0{,}5U_{n,m}I_{n,m}=S_1K_{U(n)}K_{I(n)} \quad (12)$$

Accordingly, parameters ED SH of a power and current for n^{th} of a harmonic with $n=\overline{2,n_m}$ Can be calculated under the formulas:

$$W_{P,n}=W_{P,1}K_{U(n)}K_{I(n)}\frac{\cos\varphi_n}{\cos\varphi_1}=W_{S,1}K_{U(n)}K_{I(n)}\cos\varphi_n \quad (13)$$

$$W_{Q,n}=W_{Q,1}K_{U(n)}K_{I(n)}\frac{\sin\varphi_n}{\sin\varphi_1}=W_{S,1}K_{U(n)}K_{I(n)}\sin\varphi_n \quad (14)$$

$$W_{S,n}=W_{S,1}K_{U(n)}K_{I(n)} \quad (15)$$

If CD (ED) is compared for n^{th} HHC ($n=\overline{2,n_m}$) (9-15) and EC (EE) of the basic harmonic (3-6), then it is uneasy to notice, that their relation is defined with factors n^{th} HHC of a power *($K_{U(n)}$)* and current *($K_{I(n)}$)*. If $K_{U(n)}$ and $K_{I(n)}$ is as much as possible allowable values then it is possible to conclude, that CD (ED) make from EC (EE) of the basic harmonic no more than one percent.

Let's consider now definition CD and ED for DNH of a power and current. Let in a circuit of a current power source (PS) with a sine wave power is included NP (ventil converters, arc steel-smelting of the furnace and etc.). The current in circuit will be equal a circuit (8), and capacity at n=2, n_m.

$$S_{1,n}(t)=u_1(t)\,i_n(t)=P_{1,n}(t)+Q_{1,n}(t) \quad (16)$$

where

$$P_{1,n}(t)=P_{1,n}\left[\cos(n-1)\omega t-\cos(n+1)\omega t\right] \quad (17)$$

$$Q_{1,n}(t)=Q_{1,n}\left[\sin(n+1)\omega t-\sin(n-1)\omega t\right] \quad (18)$$

$$P_{1,n}=P_1K_{I(n)}\frac{\cos\varphi_{1,n}}{\cos\varphi_1}=S_1K_{I(n)}\cos\varphi_{1,n} \quad (19)$$

$$Q_{1,n}=Q_1K_{I(n)}\frac{\sin\varphi_{1,n}}{\sin\varphi_1}=S_1K_{I(n)}\sin\varphi_{1,n} \quad (20)$$

$$S_{1,n}=S_1K_{I(n)} \quad (21)$$

From the equations (21) and (12) it is visible, that the capacity contains only variable (pulsing) part and on the order more, than $S_n(t)$.

Let's define the moments of time ($t_{1,n,m}$) at which $P_{1,n}(t)$, $Q_{1,n}(t)$ and $S_{1,n}(t)$ reach the maximal values designated, accordingly $P_{1,n,m}$, $Q_{1,n,m}$ and $S_{1,n,m}$. Having calculated derivative of functions $P_{1,n}(t)$, $Q_{1,n}(t)$ and $S_{1,n}(t)$, equate them to zero and having generalized results for n, we have:

1. For function $P_{1,n\,(t)}$ Parameter $\left|P_{1,n,m}\cdot P_{1,n}^{-1}\right|=\left|\gamma_{1,n}^{P}\right|=2$ for all odd harmonics, and for even harmonics $\left|\gamma_{1,n}^{P}\right|$ =2 practically at n≥ 8 (the divergence makes as follows $\beta_{1,n}^{P}=100\left(1-0{,}5\left|\gamma_{1,n}^{P}\right|\right)\le 1{,}5\%$). Thus, by analogy to active capacity $P_{n(t)}$, the parameter $P_{1,n(t)}$, has a maximum (under the marked conditions) equaled $2|P_{1,n}|$. However, if for $P_{n(t)}$ this maximum always positive, the maximum $P_{1,n(t)}$ can be both positive, and negative.

The modular summation of maximal of active capacity HHC gives large mistakes of calculation, since $P_{1,n,m}$ is differed with mark and for even harmonics and a moment of occurrence.

2) For function $Q_{1,n}(t)$

The parameter $\left|Q_{1,n,m}\cdot Q_{1,n}^{-1}\right|=\left|\gamma_{1,n}^{Q}\right|=2$ for all even harmonics, and for odd harmonics $\left|\gamma_{1,n}^{Q}\right|=2$ practically at $n\ge 7$ (divergence makes as follows $\beta_{1,n}^{Q}100\left(1-1{,}5\left|\gamma_{1,n}^{Q}\right|\right)\le 2{,}5\%$). Let's notice, that such change for reactive capacity of the same harmonics $Q_n(t)$ HHC is not present. $Q_{n,m}=\left|Q_n\right|$;

The modular summation of maximal of reactive capacity HHC as well as for active capacity gives large errors of calculation.

Let's define ED $W_{1,n}$ for $P_{1,n}(t)$, $Q_{1,n}(t)$ and $S_{1,n}(t)$.

Empirically by integration of the functions $P_{1,n}(t)$, $Q_{1,n}(t)$ and $S_{1,n}(t)$ and by definition accordingly $W^{(+)}_{P,1,n}, W^{(+)}_{Q,1,n}$ and $W^{(+)}_{S,1,n}$ we have defined what, at $n \geq 3$ for the period of the basic harmonic T_1 with an error no more than 1 %.

$$W_{P,1,n} = 2{,}56\frac{P_{1,n}}{\omega} = 8{,}1\cdot 10^{-3}P_{1,n} \tag{22}$$

$$W_{Q,1,n} = 2{,}56\frac{Q_{1,n}}{\omega} = 8{,}1\cdot 10^{-3}Q_{1,n} \tag{23}$$

$$W_{S,1,n} = 2{,}56\frac{S_{1,n}}{\omega} = 8{,}1\cdot 10^{-3}S_{1,n} \tag{24}$$

If (22-24) are some transformed, we shall receive:

$$W_{P,1,n} = 10^{-2}P_{1,n,cp} = 10^{-2}U_{1,cp}I_{n,cp}\cos\varphi_{1,n} = 8{,}1\cdot 10^{-3}S_1K_{I(n)}\cos\varphi_{1,n} \tag{25}$$

$$W_{Q,1,n} = 10^{-2}Q_{1,n,cp} = 10^{-2}U_{1,cp}I_{n,cp}\sin\varphi_{1,n} = 8{,}1\cdot 10^{-3}S_1K_{I(n)}\sin\varphi_{1,n} \tag{26}$$

$$W_{S,1,n} = 10^{-2}S_{1,n,cp} = 10^{-2}U_{1,cp}I_{n,cp} = 8{,}1\cdot 10^{-3}S_1K_{I(n)} \tag{27}$$

where $U_{1,cp} = \frac{2}{\pi}U_{1,m}; \quad I_{n,cp} = \frac{2}{\pi}I_{n,m}$.

The formulas (25-27) are simple enough and allow to define ED HHC directly by results of decomposition of function $i(t)$ in a trigonometrically number Furye.

Let's proceed to a question of definition summation (S) CD and ED of an any spectrum HHC.

At a sine not sinusoidal power in a circuit with NP the instant value of capacity can be calculated under the formula:

$$\begin{aligned} S_{\Sigma}(t) &= \sum_{n=1}^{n_m}P_n - \sum_{n=1}^{n_m}P_n\cos 2n\omega t + \sum_{n=1}^{n_m}Q_n\sin 2n\omega t + \\ &+ \sum_{n=2}^{n_m-1}P_{1,n}\left[\cos(n-1)\omega t - \cos(n+1)\omega t\right] + \sum_{n=2}^{n_m-1}Q_{1,n}\left[\sin(n+1)\omega t - \sin(n-1)\omega t\right] = \\ &= P_{\Sigma,cp} + S_{1,1}(t) + D^{(SH)}_{\Sigma,S}(t) + D^{(DNH)}_{\Sigma,S}(t) = P_{\Sigma,cp} + G_{\Sigma,S}(t) \end{aligned} \tag{28}$$

where $D_{\Sigma,S}(t)$ - summation instant CD for SH and DNH; $G_{\Sigma,S}$- summation instant EC. In turn:

$$D^{(DNH)}_{\Sigma,S}(t) = \sum_{n=2}^{n_{m-1}}P_{1,n}(t) + \sum_{n=2}^{n_m-1}Q_{1,n}(t) = D^{(DNH)}_{\Sigma,P}(t) + D^{(DNH)}_{\Sigma,Q}(t) \tag{29}$$

The definition of the maximal values $D^{(DNH)}_{\Sigma,S}(t), D^{(DNH)}_{\Sigma,P}(t)$ and $D^{(DNH)}_{\Sigma,Q}(t)$ at practicable in practice spectra HHC requires large analytical calculations.

Before to formulate algorithm of account CD and ED of an any spectrum HHC DNH (in subsequent the indexes DNH is omitted) we shall consider some features of calculations on a concrete example. A graphic illustration of change of an active and reactive component CD and ED, in conditions, when alongside with the basic harmonic, in a circuit the currents of thirds proceed and fifth harmonics is shown in a fig. 1a, and allows to conclude:

1. The functions $P_{1,n}(t)$ and $Q_{1,n}(t)$ are not sinusoidal characterized periodically varied by amplitude and duration of each half-cycle. Nevertheless the maximal values of this function and functions $S_{1,n}(t)$ are connected by square-law dependence. However, $\sum P^2_{1,n,m} + \sum Q^2_{1,n,m} >> \sum S^2_{1,n,m}$ and $\left(\sum P_{1,n,m}\right)^2 + \left(\sum P_{1,n,m}\right)^2 >> \left(\sum S_{1,n,m}\right)^2$.
2. The moments of occurrence of the maximal values $P_{1,n}(t)$ of odd harmonics coincided, and the marks can be opposite. The moments of occurrence of maximal $Q_{1,n}(t)$ of odd harmonics do not coincide, and the marks of the maximal values can be different. Therefore algebraic summation of maximal as $P_{1,n}(t)$ and $Q_{1,n}(t)$ results in the large mistakes of calculation.
3. ED (is shaded) on an interval $T_1/4$ $W^{(+)}_{\Sigma,P} = \left|W^{(-)}_{\Sigma,P}\right|$ and $W^{(+)}_{\Sigma,Q} = \left|W^{(-)}_{\Sigma,Q}\right|$ and is calculated as the sum of the areas limited to an interval T/2 and curves $P_{1,3}(t)$ and $P_{1,5}(t)$ (or $Q_{1,3}(t)$ and $Q_{1,5}(t)$).
4. $W_{S,P} << W_{1,3,P}+W_{1,5,P}$ and $W_{S,Q} << W_{1,3,Q}+W_{1,5,Q}$

Otherwise ED designed as the sum energy of separate harmonics exceeds essentially then the valid value. In a fig.1a, it would be visible from comparison of the areas with longitudinal (designating WS) and cross (designating the sum $W_{1,3}$ and $W_{1,5}$) shading. The basic difficulty of analytical calculation of the valid values CD and ED at an any spectrum HHC alongside with greatness of calculation, consists in formalization of definition of the moments of crossing of functions $D_{\Sigma,S}(t)$, $D_{\Sigma,P}(t)$ and $D_{\Sigma,Q}(t)$ of an axis t. The following algorithm of calculation CD and ED in the single-phase

purpose with NP on an interval T_1 is supposed. The algorithm consists of the following blocks:
1. Are entered 2 (n_m+1) discrete values $u(t)$ and $i(t)$ with an interval $\Delta t_1=T_1/2\ (n_m+1)$.

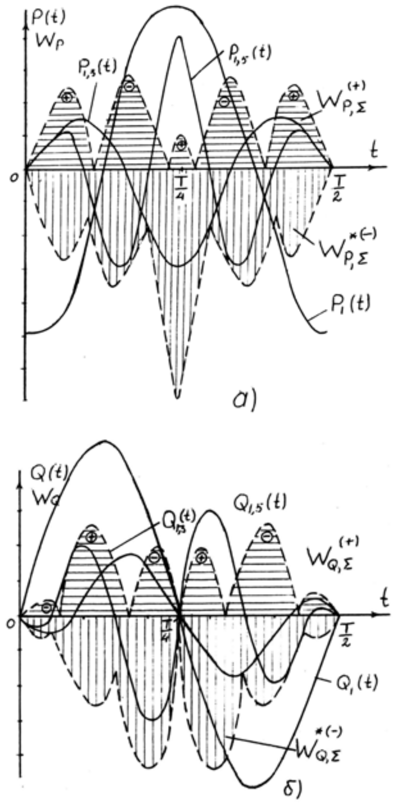

Fig.1. Comparison energies (power) of distortion
a) an active-power; b) reactive-power

2. Under the formulas Furye the amplitudes $(U_{n,m}$ *and* $I_{n,m})$ and corners of shift $\left(\psi_n^U \text{ and } \psi_n^I\right)$ of harmonics for $n=1$, nm are calculated.
3. The factors are calculated: distortions of sinusoidalness of a power K_U and n^{th} of a harmonic of a power $K_{U(n)}$ and current $K_{I(n)}$ with $n=2, n_m$.
4. The harmonics exceeding normative values are allocated. This condition is based on two situations. First ED for a spectrum of harmonics which are not exceeding normative values much less of 0,5 % from energy of the basic harmonic. Second is considered, that to payment should be subject only ED of harmonics, for which the established requirements to the parameters are not carried out. A consequence of this condition is the sharp reduction of number of calculations.
5. Under the formulas (16-21) the instant values $S_{1,n}(t_j)$, $P_{1,n}(tj)$ and $Q_{1,n}(tj)$ with $j=1, M$, $n=1, n_m$, where M=d $n_{m,n}$ are calculated; $n_{m,n}$ number of sections, at which the area sinusoid, calculated by a method of trapezes on an interval $T_1/4$ does not differ practically from the valid parameter ($d=5$); nm, n-greatest number of harmonics exceeding normative value. Let's remind, that the interval $T_1/4$ is a half-cycle of change CD.
6. Are calculated summation CD $D_{\Sigma,S}(tj)$, $D_{\Sigma,P}(tj)$ and $D_{\Sigma,Q}(tj)$ with $j=1, M$ with that difference, that it are taken into account only important of a harmonic.
7. The relative meaning of the maximal CD are defined:

$$\delta D_{\Sigma,S,m}=max\left\{D_{\Sigma,S}\left(t_j\right)\right\}_M\cdot S_{1,m}^{-1},\delta D_{\Sigma,P,m}=max\left\{D_{\Sigma,P}\left(t_j\right)\right\}_M\cdot P_{1,m}^{-1}$$

and

$$\delta D_{\Sigma,Q,m}=max\left\{D_{\Sigma,Q}\left(t_j\right)\right\}_M\cdot Q_{1,m}^{-1}$$

8. The relative meanings(importance) of a complete, active and reactive component ED by everyone important ВГС are calculated.

$$\delta W_{P,1,n}=100\frac{W_{P,1,n}}{W_{P,1}}=\frac{25\pi\sum_{j=1}^{M-1}\left[\left|P_{1,n}\left(t_j\right)\right|+\left|P_{1,n}\left(t_{j+1}\right)\right|\right]}{MP_1} \tag{30}$$

$$\delta W_{Q,1,n}=100\frac{W_{Q,1,n}}{W_{Q,1}}=\frac{25\pi\sum_{j=1}^{M-1}\left[\left|Q_{1,n}\left(t_j\right)\right|+\left|Q_{1,n}\left(t_{j+1}\right)\right|\right]}{MQ_1} \tag{31}$$

$$\delta W_{S,1,n}=100\frac{W_{S,1,n}}{W_{S,1}}=\frac{25\pi\sum_{j=1}^{M-1}\left[\left|S_{1,n}\left(t_j\right)\right|+\left|S_{1,n}\left(t_{j+1}\right)\right|\right]}{MS_1} \tag{32}$$

9. The relative values of complete ($W_{D,S}$), active ($W_{D,P}$) and reactive ($W_{D,Q}$) components ED under the formulas are calculated

$$\delta W_{D,P}=100\frac{W_{D,P}}{W_{P,1}}=\frac{25\pi\sum_{j=1}^{M-1}\left[\left|D_{\Sigma,P}\left(t_j\right)\right|+\left|D_{\Sigma,P}\left(t_{j+1}\right)\right|\right]}{MP_1} \tag{33}$$

$$\delta W_{D,Q}=\frac{W_{D,Q}}{W_{Q,1}}=\frac{25\pi\sum_{j=1}^{M-1}\left[\left|D_{\Sigma,Q}\left(t_j\right)\right|+\left|D_{\Sigma,Q}\left(t_{j+1}\right)\right|\right]}{MQ_1} \tag{34}$$

$$\delta W_{D,S}=\frac{W_{D,S}}{W_{S,1}}=\frac{25\pi\sum_{j=1}^{M-1}\left[\left|D_{\Sigma,S}\left(t_j\right)\right|+\left|D_{\Sigma,S}\left(t_{j+1}\right)\right|\right]}{MS_1} \tag{35}$$

10. The complete, active and reactive exchange energy *(G)* in a circuit with NP is calculated

$$W_{G,P}=5\cdot 10^{-3}M^{-1}\sum_{j=1}^{M-1}\left[\left|P_1(t_j)+D_{\Sigma,P}(t_j)\right|+\left|P_1(t_{j+1})+D_{\Sigma,P}(t_{j+1})\right|\right] \quad (36)$$

$$W_{G,Q}=5\cdot 10^{-3}M^{-1}\sum_{j=1}^{M-1}\left[\left|Q_1(t_j)+D_{\Sigma,Q}(t_j)\right|+\left|Q_1(t_{j+1})+D_{\Sigma,Q}(t_{j+1})\right|\right] \quad (37)$$

$$W_{G,S}=5\cdot 10^{-3}M^{-1}\sum_{j=1}^{M-1}\left[\left|S_1(t_j)+D_{\Sigma,S}(t_j)\right|+\left|S_1(t_{j+1})+D_{\Sigma,S}(t_{j+1})\right|\right] \quad (38)$$

The results of accounts, confirming the structural analysis CD and ED, allow to receive objective quantitative parameters ED at various spectra HHC NP.

Conclusions

1. The energy SH of a power and current *(W_n)* with $n>1$ generators of power stations is proportional to multiplication $K_{U(n)}$ and $K_{I(n)}$, 1 % from energy of the basic harmonic W_1, a rule, do not exceed. The energy DNH ($W_{1,n}$) is generated by nonlinear loading and is proportional $K_{I(n)}$.
2. The basic making energy DNH is the component caused by the basic harmonic of a power and HHC of a current. All other components are within the limits of accuracy of account and measurement.
3. The capacity DNH has pulsing character with varied amplitude and duration of waves of a pulsation.
4. The energy DNH on an interval $T_1/2$ consists from equaled on parameter of positive and negative component (by analogy with EE of the basic harmonic) and is a part of exchange energy of a circuit of an alternating current.
5. The arithmetic addition, as maximal values CD, and ED DNH results in the large error of account.
6. The influence ED DNH is shown in distortion sinusoidalness and change of parameter EE.
7. The recommended algorithm of account allows objectively to estimate ED and EE in a circuit with NP.

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QEYRİ-XƏTTİ YÜKLÜ ELEKTRİK DÖVRƏLƏRİNDƏ TƏHRİF GÜCÜ VƏ ENERJİSİ NƏZƏRİYYƏSİNİN ƏSASLARI

Müasir texnologiyanın gərginliyin sinusoidallığı təhrifinə həssaslığın artması yüksək harmoniyalar generasiya edən işlədicilərin məsuliyyəti mexanizminin təkmilləşdirilməsini tələb edir. Elektrik enerji keyfiyyətinin inteqral göstəricisi təhrif enerjisidir. Lakin dəyişən cərəyan şəbəkələrində təhrif gücü və enerji nəzəriyyəsi işlənməmişdir. Bu işdə təhrif enerjisinin mahiyyətini təyin edən və istənilən harmonik spektrin hesablanmasına imkan verən tədqiqat nəticələri verilir.

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ОСНОВЫ ТЕОРИИ МОЩНОСТИ И ЭНЕРГИИ ИСКАЖЕНИЯ В ЭЛЕКТРИЧЕСКИХ ЦЕПЯХ С НЕЛИНЕЙНОЙ НАГРУЗКОЙ

Увеличение чувствительности современных технологий к искажению синусоидальности напряжения требуют совершенствование механизма, ответственности потребителей, генерирующих ВГС, уровень которых превышает нормативные значения. Интегральным показателем качества электрической энергии является энергия искажения.

Однако теория мощности и энергии искажения в сетях переменного тока не разработана. Приводятся результаты исследований, позволяющие установить суть энергии искажения и вычислить ее для произвольного спектра ВГС.

Received: 16.06.03