ABOUT NECESSITY OF CREATION OF THE INTEGRATED SYSTEM OF AN ESTIMATION OF CAPACITY FOR ELECTRICAL NETWORKS WITH NONLINEAR AND ASYMMETRICAL LOADINGS

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ABSTRACT

To present time strict definition of a reactive power is present for a case of a sine wave mode in a single-phase circuit. One of actual problems for electric power systems is definition of a reactive power at sine not wave modes. In the given report comparison of results of definition of a reactive power by different methods and constructions of systems of measurement in deforming systems is considered (examined).

Keywords: instant capacity, a reactive power, exchange capacity, sine not wave modes.

I. INTRODUCTION

At sine not wave modes interest to definition full, jet and capacities of distortion again are shown. To present time strict definition of a reactive power is present for a case of a sine wave mode in a single-phase circuit. Therefore the problem of definition of a reactive power at sine not wave modes remains actual. In the given work it is considered questions of definition of a reactive power and jet effect of nonlinear loading.

The concept of active power irrespective of forms of curves of a current and voltage is defined unequivocally. The concept of a total output on sense is a derivative from active power and is defined from position of transfer of the greatest possible active power at given values of a garmonic current and a voltage. The reactive power is defined formally, through expressions of active and full capacities. However at the analysis of work of electrical networks and assessments of works of the utilities equipment the big meaning matters a reactive power and energy which shows a degree of use of opportunities of elements of a network. The concept of a reactive power has the even greater meaning at account of distribution of streams of energy on electrical networks. Allocation of an inactive making total output has the big meaningat the decision of many problems of electrical networks.

Absence of a strict methodical basis for a reactive power has resulted in development of numerous approaches to definition of this size [1-13].

II. DEFINITION OF A REACTIVE POWER FOR A SINE WAVE MODE

For a sine wave mode jet and full capacities are defined precisely, and these concepts supplement each other.

If $u = U_m \sin(\varpi t + \psi_u)$, $\quad i = I_m \sin(\varpi t + \psi_i)$,

For the average capacity for the period we have

$$P = \frac{1}{T}\int_0^T uidt = UI\cos(\psi_u - \psi_i) = UI\cos\varphi.$$

In the electrical engineer by analogy to active power, the concept of a reactive power for a sine wave mode in the linear electric circuit is entered.

$$Q = UI\sin\varphi$$

The formula was entered formally, only by analogy to the formula of active power and consequently does not reflect physics of exchange process.

III. DEFINITION OF A REACTIVE POWER ON VIRTUAL VALUES OF A CURRENT AND A VOLTAGE

The concept of reactive power is determined only for a sine wave mode in the linear electric circuit that does not allow making without serious assumptions the analysis of modes of operation of an electric power system with the consumers deforming the form of a current and a voltage.

The mean power of a periodic sine not wave current consisting is equal to the sum of mean powers of all harmonious [7]:

$$P = \sum_{n=0}^{\infty} P_n = U_0 I_0 + U_1 I_1 \cos\varphi_1 + U_2 I_2 \cos\varphi_2 + \cdots$$

By analogy the reactive power is defined.

$$Q = \sum_{n=0}^{\infty} Q_n = U_1 I_1 \sin\varphi_1 + U_2 I_2 \sin\varphi_2 + \cdots \qquad (1)$$

For use of the formula (1) currents and voltage by the submitted sine not wave functions need decomposition of these of function in Fourier series.

For a total output we have [7]

$$S = UI = \sqrt{U_0^2 + U_1^2 + U_2^2 + \cdots} \times \sqrt{I_0^2 + I_1^2 + I_2^2 + \cdots}$$

Generally

$$S^2 \neq P^2 + Q^2.$$

The square of a total output is not equal to the sum of squares of active and jet capacities. In this connection an inequality enter one more kind of capacity describing distinction in the form of curves of a current and a voltage, this capacity name capacity of distortion

$$D = \sqrt{S^2 - P^2 - Q^2}$$

IV. DEFINITION OF A REACTIVE POWER ON VOLT-AMPERE CHARACTERISTIC

For the nonlinear electric circuit the concept of a reactive power is not determined. Therefore at the decision of some practical problems attempts were undertaken to use integrated expressions for an estimation of conservative processes [3,4]. These expressions represent with themselves integrals or from product of a current on function, orthogonal to a voltage, or on the contrary. Such in essence the formalistic approach has resulted in occurrence of two completely equal in rights integrated expressions

$$Q = -\frac{1}{\omega T}\int_0^T i\frac{du}{dt}dt = \frac{1}{\omega T}\int_0^T u\frac{di}{dt}dt; \qquad (2)$$

V. DEFINITION OF A REACTIVE POWER ON INSTANTANEOUS VALUES OF A CURRENT AND A VOLTAGE

The most general formulation of existential transformations of electromagnetic energy is theorem Umov-Poynting that quantitatively allows characterizing a power exchange at currents any way varied in time and voltage

$$\oint \Pi \partial s = p_0 + \frac{\partial w}{\partial t} = p = ui$$

Instant capacity shows size and a direction of movement of a stream of an electromagnetic wave through a surface at present to time. Presence variable-polarity capacities mean change of a direction of movement of this stream.

The electromagnetic energy saved by the consumer can be defined on instantaneous values of capacity and its average meaning P from the following reasons [5,6]. We admit during time t + energy of a source in loading at each moment it will be transformed to other forms p_0. Also it is reserved in stores of electromagnetic energy. During time t-there is a return of energy, energy to everyone the moment of time will be transformed to other kinds $p_0^{'}$, and this process follows the account of the energy reserved in stores of electromagnetic energy.

Similarly active power intensity of exchange processes - exchange capacity is defined by means of averaging exchange energy for a considered interval [5,6]

$$P_0 = \frac{1}{T}\int_0^{t^+} p_0(t)dt, \qquad P_0^{'} = \frac{1}{T}\int_0^{t^-} p_0^{'}(t)dt,$$

$$P^+ = \frac{1}{T}\int_0^{t^+} p^+(t)dt, \qquad P^- = \frac{1}{T}\int_0^{t^-} p^-(t)dt,$$

$$t^+ \in t \text{ при } p \geq 0, \quad t^- \in t \text{ при } p < 0,$$

$$p^+ = p, \text{ если } p \geq 0, \quad p^- = p \text{ если } p \leq 0.$$

Thus, for exchange energy we have equality

$$W_{об} = W^+\frac{t^-}{T} + W^-\frac{t^+}{T} = P^+t^- + P^-t^+. \qquad (8)$$

$$Q_{об} = \frac{W_{об}}{T}, \quad Q = \frac{2\pi}{T}W_{об} = \pi Q_{об}, \qquad (9).$$

Definition of a reactive power on expressions (7-9) requires integration for final repeated space of times. It is necessary to apply numerical methods to account of the given intervals.

VI. DEFINITION OF A REACTIVE POWER APPLICATION OF GILBERT TRANSFORMATION

One of ways of definition of a reactive power of the electric circuit with sine not wave acyclic changes of sizes are application of Gilbert transformation [12]. The image of function f (t) at Gilbert transformation is defined as.

$$F_{HI}f(t) = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{f(\tau)}{\tau - t}d\tau$$

Applying transformation Гилберта it is possible to define expression for a reactive power

$$Q = \lim_{T\to\infty}\frac{1}{T}\int_0^T u(t)\cdot F_{HI}[i(t)]dt$$

VII. COMPARISON OF METHODS OF AN ESTIMATION OF A REACTIVE POWER

Comparison of results of accounts of a reactive power in a sine not wave circuit should locate on physics of the phenomenon and numerically should analytically and be checked on test examples. Test examples for check of accounts of a reactive power in a sine not wave circuit below are resulted.

On expressions (7-9) [6,13] exchange capacity on a mark and a phase shift of a current of harmonics receive different meanings. Average meaning of the module of capacity also varies on a mark and a phase shift of a current of harmonics. Therefore intensity of an exchange, probably to estimate on average meaning of the module of capacity. However its power levels thus has rather smaller meanings. Intensity of exchange processes received on its integrated meanings in difference of meaning on (1), varies on a mark and a phase shift of a current of harmonics.

The estimation of a reactive power under formulas (1) and (5) give a reactive power even at absence in the electric circuit of energy storage units. However the formula (5) in difference of the formula (1) allows to define a reactive power, omitting decomposition of curves of a current and a (voltage) in trigonometrical series.

Formulas (7-9) give meaningof a reactive power adequate to real meaning. It means, that definition of a reactive power for a sine not wave circuit decomposition in Fourier series and without the analysis of physics of processes of an exchange of energy in special cases may result in contradictions.

The reactive power in some electric circuits is caused by the certain properties causing a phase lag between curves of currents and voltage of elements of a circuit, determining disproportionate change of an instantaneous current at change of an instant voltage on conclusions of an element. In circuits with controlled diodes, this component of a total output is caused by mixture of the basic harmonic of a network current concerning a voltage. This making capacities name capacity of shift.

VIII. THE SIMPLIFIED ESTIMATION OF INTERVALS OF CHANGE OF EXCHANGE CAPACITY

Results of the numerical analysis of exchange capacity on expressions (7-9) at various sign a current of harmonics show, that $Q_{обм}$ varies in limits $Q_{обм.\ max} = Q_1 + Q_{\Sigma n}$, $Q_{обм.\ min} = Q_1 - Q_{\Sigma n}$. These dependences can be used at a probable estimation of exchange capacity.

The simplified estimation of intervals of change of exchange capacity in circuits of a sine not wave current at use of known formulas (1) it is possible to make on expressions

$$Q_{об.max} = Q_1 + \sum_{k=2}^{n} U_1 \cdot I_k ,$$

$$Q_{об.min} = Q_1 - \sum_{k=2}^{n} U_1 \cdot I_k ,$$

where U_1 and I_k - a voltage of the basic harmonic and a current of k harmonic.

For an estimation of consumption in deforming systems measurement of the following sizes in addition is required:

Total output in the three-phase system.

Algebraic total output.

$$S_{alg} = S_A + S_B + S_C$$

Geometrical total output.

$$S_{geom} = \sqrt{(P_A + P_B + P_C)^2 + (Q_A + Q_B + Q_C)^2}$$

The valid total output.

$$S_D = \sqrt{\left(U_A^2 + U_B^2 + U_C^2\right) \cdot \left(I_A^2 + I_B^2 + I_C^2\right)}$$

Meaningof energy accrued in the receiver and can be defined the connected capacity of accumulation using modular meaningof capacity

Average meaningof capacity of accumulation can be defined on expression

$$Q_{нак} = \frac{1}{T}\int_0^T \left[|u(t)| \cdot |i(t)|\right] dt - \frac{1}{T}\int_0^T u(t) \cdot i(t)\, dt$$

The valid total energy, which may be received by integration of the valid total output;

$$S_D^2 = \left(U_A^2 + U_B^2 + U_C^2\right) \cdot \left(I_A^2 + I_B^2 + I_C^2 + nI_N^2\right)$$

If virtual values of the basic harmonics to express with the help of components of direct, return and zero sequence Ia1, Ib1, I01 the valid total output in quadriphase four-wire system can be expressed the equation

$$S_D^2 = 3U^2\left[3 \cdot I_{a1}^2 + 3 \cdot I_{ba}^2\, 3 \cdot (3n+1) I_{01}^2\right] + $$
$$+ 3U^2\left(\sum_{\nu=2}^{\infty} I_{A\nu}^2 + \sum_{\nu=2}^{\infty} I_{B\nu}^2 + \sum_{\nu=2}^{\infty} I_{C\nu}^2 + n\sum_{\nu=2}^{\infty} I_{N\nu}^2\right)$$

$$S_D^2 = S_a^2 + S_b^2 + (3n+1) \cdot S_0^2 + D^2$$

or

$$S_D^2 = P^2 + Q^2 + S_b^2 + (3n+1) \cdot S_0^2 + D^2$$

Here S_a - A symmetric total output, S_b - Capacity of pulsations; S_0 - The latent capacity; D - capacity of distortion, n - factor showing, frequency rate of resistance of the neutral line concerning phase.

Capacity of distortion

$$D^2 = 3U^2\left(\sum_{\nu=2}^{\infty} I_{A\nu}^2 + \sum_{\nu=2}^{\infty} I_{B\nu}^2 + \sum_{\nu=2}^{\infty} I_{C\nu}^2 + n\sum_{\nu=2}^{\infty} I_{N\nu}^2\right)$$

Integral of the sum of squares of all currents;

$$\sum\left(I^2\right) = \int_0^T \left(I_A^2 + I_B^2 + I_C^2 + nI_N^2\right) dt$$

- integral of the sum of squares of phase voltage;

$$\sum\left(U^2\right) = \int_0^T \left(U_A^2 + U_B^2 + U_C^2\right) dt$$

- average meaning of electrical power factor cosφ;

$$\cos\varphi_T = \frac{W_P}{\sqrt{W_P^2 + W_Q^2}}$$

- average meaning of the valid electrical power factor λ_T;

$$\lambda_T = \frac{W_P}{\sqrt{\sum\left(U^2\right)} \cdot \sqrt{\sum\left(I^2\right)}}$$

- average meaning of valid electrical power factor λ_{TD};

$$\lambda_{TD} = \frac{W_P}{\sum(S_D)}, \qquad \sum(S_D) = \int_0^T S_D dt$$

- average meaning of resulting distortion coefficient and non-uniformity of consumption q_{TZ};

$$q_{TZ} = \frac{\sqrt{W_P^2 + W_Q^2}}{\sqrt{\sum\left(U^2\right)} \cdot \sqrt{\sum\left(I^2\right)}}$$

For the current estimation of consumption and management of a mode the symmetric total output, capacity of the pulsations, the latent capacity, capacity of distortion are defined**.**

Factor of asymmetry of currents;

$$\varepsilon_b = \frac{I_b}{I_a} = \frac{S_b}{S_a}$$

- factor of a unbalance of currents;

$$\varepsilon_0 = \frac{I_0}{I_a} = \frac{S_0}{S_a}$$

- three-phase distortion coefficient of currents;

$$K_{и}^2 = \frac{\sum_{\nu=2}^{\infty} I_{A\nu}^2 + \sum_{\nu=2}^{\infty} I_{B\nu}^2 + \sum_{\nu=2}^{\infty} I_{C\nu}^2 + n\sum_{\nu=2}^{\infty} I_{N\nu}^2}{I_{A1}^2 + I_{B1}^2 + I_{C1}^2 + I_{N1}^2 + \sum_{\nu=2}^{\infty} I_{A\nu}^2 + \sum_{\nu=2}^{\infty} I_{B\nu}^2 + \sum_{\nu=2}^{\infty} I_{C\nu}^2 + n\sum_{\nu=2}^{\infty} I_{N\nu}^2}$$

On it measurements it is possible to receive other necessary information.

- the current meaning of electrical power factor cosφ;

$$\cos\varphi = \frac{P}{S}$$

- the current meaning of the valid electrical power factor cosö;

$$\lambda = \frac{P}{S_D}$$

- meaning of resulting distortion coefficient;

$$q = \frac{\sqrt{P^2 + Q^2}}{\sqrt{P^2 + Q^2 + S_b^2 + (3n+1)S_0^2 + D^2}}$$

- increase of losses of capacity caused inactive making capacities and expressed in percentage the partial losses, adequate electrical power factor cosφ.

$$\Delta(\Delta P) = \left[\left(\frac{\cos\varphi}{\lambda}\right)^2 - 1\right]\cdot 100$$

IX. CONCLUSIONS

1. At an estimation of a reactive power it is necessary to take into account features of object, physics of processes, and the individual approach in each concrete process is necessary. In this connection it is required specifications by definition of a scope for expressions of a reactive power in linear sine not wave circuits, in nonlinear and asymmetric circuits, in valve inverters etc.

2. Creation of the integrated system of an estimation of capacity in electrical networks with nonlinear and asymmetrical loadings will allow to characterize process of an exchange of capacity on a curve of instant capacity, may become base for the analysis of physics of processes of an exchange of energy and explanations of contradictions in these processes.

3. Proposed expressions for the simplified estimation of probable intervals of change of exchange capacity in circuit's sine not wave.

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