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EXERGOECONOMIC OPTIMIZATION OF POWER SYSTEMS

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Abstract. *Substantive provisions of Exergoeconomic Optimization Method are shown here. And also Algorithms of Estimation of Power and Economic Efficiency Parameters of analysed system are represented in this work.*

Key words: ***energy indicators, economic indicators, ekserhoekonomika, technical system, ekserhoekonomichnyy optimization method.***

Engineering system optimisation provides the analysis of structure and parametres alternatives for the purpose of minimisation of investment and operational expenses at maintenance of functional characteristics of system taking into account matching technical and resource restrictions. Exergoeconomic optimisation method is developing during last decades. This method makes possible to characterise both power, and economic parametres in their complementarity [1..4].

The purpose of research - optimization of energy systems by ekserhoeconomic methods.

Materials and methods. Explore ekserhoekonomichnyy optimization method, which can be described as energy and economic indicators in their interdependence. During the study analyzed the theoretical source of the problems ekserhoekonominoyi optimization of energy systems analysis and conducted ekserhetychnyy ekserhoekonomichnyy defined criteria optimization of energy systems. Here algorithms ekserhetychnoho and economic analysis of energy systems.

As any scientific direction, exergoeconomic optimisation uses its a nomenclature and concepts.

Exergy is the greatest possible useful work (working capacity) made by some substance, which on a chemical compound differs from a circumambient ($\mu \neq \mu_0$), it is at pressure and the temperature which is distinct from analogous characteristics of a circumambient ($p \neq p_0$ and $T \neq T_0$) if given working substance reversible to translate from an initial state (μ, p, T) in final, being in balance with a circumambient (μ_0, p_0, T_0).

Specific physical Exergy of stream of working substance can be found with the equation,

$$e = h - h_0 - T_0(s - s_0)\,. \qquad (1)$$

Where h – an enthalpy; T – temperature; s – entropy; the index “0” gives initial value of the matching parametre.

The concept of exergy as maximum working capacity is convenient for using by consideration of extent of perfection of various processes from the point of view of energy conversion . If process proceeds completely reversible «gained total working capacity» substances (same refers to and to mechanical work) should be equal to "spent working capacity». «Total working capacity» decreases if it is nessesary. This «working capacity decrease» also is a measure of losses. The Exergetic analys of various processes showed that there are processes which proceed absolutely enough, at the same time there is a row of processes which even at the most careful realisation absolutely appears less effective.

Terms of "energy loss" and «losses of exergy» have basic different maintenance. First means an energy loss not in general (energy can not disappear, as it is known), and its loss for the given system or for the given problem, in a case if the part of energy is unsuitable for it under the form or parametres. Second – means exergy disappearrance, connected with a dissipation of energy [5].

Results. Let's observe two power systems between which there is an exchange of energy. It is possible to present Exergy balance of this process as

$$E_{система1} - E_{система2} = \\ = p_0(V_2 - V_1) + \int_1^2 \frac{T - T_0}{T} \partial Q + W_{1\to 2} - T_0 S_{gen} \quad (2)$$

Or

$$E_{система1} - E_{система2} = \\ = \int_1^2 \frac{T - T_0}{T} \partial Q + [W_{1\to 2} + p_0(V_2 - V_1)] - T_0 S_{gen}, \quad (3)$$

Where the composed $\int_1^2 \frac{T - T_0}{T} \partial Q$ presents exergy transport, associated with heat; composed – $[W_{1\to 2} + p_0(V_2 - V_1)]$ exergy transport, associated with work, last composed – $E_D = T_0 S_{gen}$ wears the name of exergy distruction (losses of had work or working capacity loss).

For conducting of the Exergy analys for any (*k* th) element of system many criteria, the base of which is made by the following:

– Exergy balance of ***k*** element

$$E_{F,k} = E_{P,k} + E_{D,k} + E_{L,k} \quad (4)$$

– Absolute exergy distruction as function from thermodynamic process imperfection

$$E_{D,k} = T_0 S_{gen,k}. \quad (5)$$

So, exergy distruction is nothing alse, as additional had work (gained or spent) for positive effect manufacture in comparison with the theoretical;

– Absolute exergy losses $E_{L,k}$ originate at external contact of an element of system to a circumambient, for example, present unperfect insulation of the heat-exchange apparatus etc.

The Exergoeconomic estimation is spent at level of components of systems, using following criteria for ***k*** th component. From exergoeconomic analysis it is known:

– $E_{D,k}$ – absolute exergy distruction ,

$$E_{D,k} = E_{F,k} - E_{P,k} - E_{L,k}$$

– ε_k – exergy efficiency,

$$\varepsilon_k = \frac{E_{P,k}}{E_{F,k}} = 1 - \frac{E_{D,k} + E_{L,k}}{E_{F,k}}. \qquad (7)$$

– y_k – relative exergy distruction,

$$y_{D,k} = \frac{E_{D,k}}{E_{F,tot}}. \qquad (8)$$

Criteria of Exergoeconomic analysis:

– The price of exergy of fuel

$$c_{F,k} = \frac{C_{F,k}}{E_{F,k}}, \qquad (9)$$

– The price of exergy of a product

$$c_{P,k} = \frac{C_{P,k}}{E_{P,k}}, \qquad (10)$$

– The cost connected with exergy distruction:

$$c_{D,k} = c_{F,k} E_{D,k}, \qquad (11)$$

– The cost connected with losses of exergy:

$$c_{L,k} = c_{F,k} E_{L,k}, \qquad (12)$$

– Cost of capital investments Z_k^{CI},

– Maintenance and service cost Z_k^{OM},

– The sum of two last composed Z_k

$$Z_k = Z_k^{CI} + Z_k^{OM}, \qquad (13)$$

– Relative difference of the prices

$$r_k = \frac{c_{P,k} - c_{F,k}}{c_{F,k}} = \frac{1-\varepsilon_k}{\varepsilon_k} + \frac{Z_k}{c_{F,k} E_{P,k}}, \quad (14)$$

– the exergoeconomic factor

$$f_k = \frac{Z_k}{Z_k + c_{F,k}(E_{D,k} + E_{L,k})}. \quad (15)$$

Values $c_{F,k}$ depend on a relative rule of ***k*** component in system and its interconnection with previous and the subsequent components.

When matching functions of the prices are installed, the price of optimum exergy efficiency ε_k^{OPT} for ***k*** component can be defined approximately as:

$$\varepsilon_k^{OPT} = \frac{1}{1+F_k} \quad (16)$$

at

$$F_k = \left(\frac{(\beta + \gamma_k) B_k n_k}{\tau c_{F,k} E_{P,k}^{1-m_k}} \right)^{\frac{1}{n_k+1}}, \quad (17)$$

where β – the factor of restoration of the capital; γ_k – the factor considering the fixed part of operational expenses and expenses for service, depending on the general capital investments associated with ***k*** th component; B_k – the n_k m_k constants used for definition of functions and ε_k $E_{P,k}$ – an average annual time of maintenance of system at rated capacity.

The exergoeconomic analysis and estimation specify and compare real sources of cost in system (The equation. (11-13)), illustrate process of formation of cost within system, define optimum cost on which each stream of a product is made.

Cost of maintenance of power saving up system logically is defined as, d.e./kw,

$$Z = Z^{Cl} + Z^{fuel} + Z^{OM}. \tag{18}$$

The economic model of the valid power reformative system represents the joint solution of equations system:

– Capital (investment) expenses of system, d.e./kw,

$$Z^{Cl} = a\bar{a}\frac{1}{t_A}; \tag{19}$$

For each element of system:

$$Z^{Cl} = a_k x_k^n (1+b)^y / N_k; \tag{20}$$

– Expenses for initial energy for system functioning, d.e./kw,

$$Z^{fuel} wc_F; \tag{21}$$

– Maintenance and service cost, d.e./kw,

$$Z^{OM} = b\frac{1}{t_A} + d; \tag{22}$$

– Depreciation expenses, d.e./kw,

$$a = \frac{q^n(1-q)}{q^n - 1}\left(1 + \frac{i+r}{100}\frac{CP}{2}\right); \tag{23}$$

– Discounting factor

$$q^{-1} = \left(1 + \frac{i+t+v}{100}\right)^{-1}; \tag{24}$$

– Specific power consumption, кДж / (кВт·ч),

$$w = \frac{3600}{\eta}; \tag{25}$$

– Average operating time of system, ch/year,

$$\tau_A = \frac{\text{Annual manufacture of useful effect}}{\text{Standard power}} \tag{26}$$

where c_F – the fuel price (d.e./kDzh); $\bar{a}$ – investment cost (d.e./kw); b – expenses for repair and the service depending on an installed capacity (d.e./kw); d –expenses for repair and the service depending on generation of used technics (d.e./kw); i –bank percent of investment expenses for system creation (% /

year); r – inflationary factor (% / year); n –service life of installation (year); CP - time of creation of installation (year); t_A - annual taxes (% / year); v – the annual insurance (% / year); x –the characteristic of ***k*** element; a – the price of a unit of equipment; n, y – parametres of functions; N – an expected life.

Generally the exergoeconomic criteria of optimisation looks like [1]

$$Z_{\Sigma} = \frac{\sum_{n} C_n E_n + \overline{K_n}}{\sum_{k} E_k}, \tag{27}$$

where C_n, E_n – cost and annual consumption of exergy from external sources; $\overline{K_n}$ – the expenses annual capital and connected with them in ***n*** th element of system; E_k – the annual charge of exergy for reception of **k** th product.

The purpose of complex system of optimisation is sampling of such values of system parametres (technological, constructive and so forth) which would provide optimum or near optimal values of efficiency criterion

$$Z_{opt} = extr\{Z(x_j)\}, \tag{28}$$

$$x_j \in R^n,$$

where R^n – a *n*-dimensional valid linear space.

Let's result exergoekonomic algorithms and the economic analysis of power systems.

Algorithm АП $_{\Sigma}$ – definition of exergy losses in a power system. The algorithm consists of following basic steps:

(I) To build matching to the given system exergoeconomic streaming graph $E = (A, U)$, a matrix of incidence and $\|M_{ij}\|$ to count exergy streams on arches E_j, j = 1, 2, …, n.

(II) For all elements i = 1, 2, …, m to define entering (M_{ij} = 1) getting out (M_{ij} =-1) streams to count: the sum $E_i^{вх}$ and $E_i^{вых}$ of streams of exergy elements and extent of their thermodynamic perfection.

(III) to Count total losses of exergy

$$П_{\Sigma} = \sum_{i=1}^{m} П_i \ . \qquad (29)$$

Algorithm AZ$_e$ – definition of exergoeconomic expenses in system. As exergoeconimic expenses Z$_e$ in system the same as exergoeconomic losses Π_{Σ} are additive, so algorithm AZ$_e$ is similar in many respects with АΠ_{Σ}.

(I) To repeat a step (I) algorithm АΠ_{Σ}.

(II) to count annual expenses that don't belong to power (capital and connected with them) *To* $_i$, i = 1, 2, …, m in each of elements.

(III) to repeat a step (II) algorithm АΠ_{Σ}, but instead of calculation of extent of thermodynamic perfection to count thermoeconomic expenses in a system element

$$Z_i = Ц_i П_i + К_i \, , \qquad (30)$$

where $Ц_i$ – the price of 1 kw exergoeconomic losses in system elements.

CONCLUSIONS

These generalized algorithms can be defined as the thermodynamic and economic characteristics of the power system specific functionality. A ekserhetychnyy analysis and determined ekserhoekonomichnyy criterionoptimization of energy systems. The algorithm ekserhetychnoho and economic analysis of energy systems.

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ЕКЗЕРГОЕКОНОМІЧНА ОПТИМІЗАЦІЯ ЕНЕРГОСИСТЕМ

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Анотація. *Наведено основні положення екзергоекономічного методу оптимізації. Представлено алгоритми оцінки енергетичних та економічних показників ефективності аналізованої системи.*

Ключові слова: ***енергетичні показники, економічні показники, екзергоекономіка, технічна система, екзергоекономічний метод оптимізації.***

ЕКЗЕРГОЭКОНОМИЧЕСКАЯ ОПТИМИЗАЦИЯ ЭНЕРГОСИСТЕМ

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Аннотация. *Приведены основные положения екзергоекономичного метода оптимизации. Представлены алгоритмы оценки энергетических и экономических показателей эффективности рассматриваемой системы.*

Ключевые слова: ***энергетические показатели, экономические показатели, екзергоекономика, техническая система, екзергоекономичний метод оптимизации.***