UDC 519.715

V.V. Dovgal′ (1), associate professor, c.t.s.

MULTICRITERION ESTIMATION OF EFFICIENCY FOR SYSTEMS AUTOMATIONS OF METALLURGICAL PLANTS

Zaporozhe state engineering academy, Ukraine

There are considered the methods of multicriteria search for optimal technical solutions of automation systems. It is proposed an analytical procedure for finding promising technical solutions, which can be used in selecting the optimal variant of modernization for technological equipment of metallurgical plants.

Keywords: automation system, efficiency of system, criteria's of effectiveness, the cost of updating, vector-comparable systems, analytical procedure

Introduction. It is known that quality of products, made by a plant, directory depends on the state and reliability of work of existent technological equipment. The metallurgical plants of Ukraine differ by enough the high (more than 50 %) wear of basic equipment, considerable specific expenses of material and power resources on making of products, and also by the subzero productivity, that reduces possibilities for producing of competitive products.

Updating of production capacities of plant can be carried out by acquisition of modern equipment or modernization of existent equipment. A modern technological equipment consist the built-in systems automations (BSA), allowing to promote its productivity and substantially to improve quality of the making products.

Decline of expenses on updating of production it is possible to attain by a preliminary estimation efficiency of different variants of its updating with the purpose of choose of optimal decision. Thus the followings factors are used: expenses on acquisition of equipment; duration of works on dismantling of existing and mounting of new equipment; cost mounting and starting-checkout works; areas for placing of equipment; expenses on its technical service and repair; energy-intensity of equipment; reliability of BSA; increase eventual output product from the same quantity of raw material; required quantity of technological personnel; level of decline of expenses on making of products; productivity of equipment; a part of transport charges is in the structure of prime cost; profited on unit of material costs; level of decline of contaminations of air environment at the use of new equipment and other.

Thus, at comparison of different variants of updating of technological equipment it is necessary to use a multicriterion analysis which allows to carry out the choose of the best decision, id est. it is required to execute optimization of technological equipment.

Analysis of the known methods of optimization. For the quantitative estimation of descriptions of the difficult system concept «efficiency» is used [1,2], under which the degree of adaptation of the system to implementation of the put tasks is understood. The quantitative estimation of efficiency is execute with use criteria, compliable from the factors of efficiency, each of which is description of one property of the system.

Every difficult system or its part is characterized by the totality (by a vector) of factors of efficiency:

$$K = \langle k_1, k_2 \ \dots \ k_m \rangle \ , \tag{1}$$

where $[k_i], i = \overline{1,m}$ are private factors of efficiency, its quantity m can be considerably anymore unit.

Methods optimizations, based on carrying out vectorial optimization over to scalar are widely used, for example, method, offered in work [3]. Such methods foresee entered of resulting (generalized) factor of efficiency K_p, which is determined by a next functional:

$$K_p = \Phi\left(k_1, k_2, \ \dots \ k_m; \ \gamma_1, \gamma_2 \ \dots \ \gamma_m\right) , \tag{2}$$

where Φ is a functional, providing bringing an aggregate over of private factors of efficiency to the resulting factor; γ_i are gravimetric coefficients of private factors.

However the generalized factors of efficiency can appear in consistency, as a presence of defect in one factor can be compensated due to advantage of other factor.

In many cases substanfiated establishment of analytical type of dependence $K_p = f_p\left(k_1, k_2 \dots k_m\right)$ appears impossible. Thus for the decision of task of optimization the analytical type of functional (2) is formed by the use of method of expert estimations, for which inevitable is an element of subjectivism.

Among the methods of vectorial optimization most distribution was got principle of Poreto, allowing to limit a search of optimal decisions area. Entity of method consists in that vectors $K(S_1)$ and $K(S_2)$ are compared, characterized efficiency of the systems S_1 and S_2, id est. implementation of condition is checked up:

$$K\left(S_2\right) \le K\left(S_1\right) \ . \tag{3}$$

If this condition is executed, then a preference gives oneself up to the system S_2. If is executed outside, because vectors are incomparable, then systems S_1 and S_2 behave to the perspective variants (area of Poreto).

At the choose of decision from the limited area of decisions methods, based on the resulting factor of efficiency, which allows to minimize worsening of results of optimal search, are used.

For the search of perspective decisions in area of possible decisions in work [4] the method of working descriptions, which allowing, using property of monotony, to find in possible decision space a working surface, which is the border of area of perspective decisions is offered. The offered analytical procedure for search of area of perspective decisions is applicable in the case when the number of private factors of efficiency does not exceed two ($m = 2$).

Broblem formulation. It is required to work out effective analytical procedure of search of perspective decisions for m-variate area of possible decisions.

Basic part. The task of search of the optimal system is decided as follows. On the first stage on the set vectors of efficiency K (1) in area of possible decisions W there is find the area of perspective decisions $\Omega \subseteq W$. On the second stage in area Ω

choose the best variant of the system $S_{opt} \in \Omega$, which provides a minimum of functional for resulting factor of efficiency K_p:

$$K_p\left(S_{opt}\right) = \min_{S \in \Omega} K_p\left(S\right), \Omega \subseteq W \quad . \qquad (4)$$

For oxtract of comparison of values of vector K from a formula (1), which correspond to the different variants of the system, all factors over of quality k_i are brought to the standard kind: $k_i \geq 0, \ \left(i = \overline{1,m}\right)$ here, than less than size k_i, so much the better system.

Systems S_1 and S_2 are comparable on the vector of quality $K = K(\mathrm{S})$, if one of the stated below conditions is executed:

- every factor of quality $k_i\left(S\right)$, $\left(i = \overline{1,m}\right)$ the systems S_2 not worse (no more), than systems S_1, including., one of these factors better (less than), than for the system S_1; the system S_1 is better, than system S_2 then, id est. $K\left(S_2\right) \leq K\left(S_1\right)$;

- all factors of quality $k_i\left(S\right)$, $\left(i = \overline{1,m}\right)$ the systems S_2 are not better (not less than), than systems S_1, including., one of these factors worse (anymore), than for the system S_1; the system S_1 worse, than S_2 then, id est. $K\left(S_2\right) \geq K\left(S_1\right)$;

- equality $k_i\left(S_2\right) = k_i\left(S_1\right), \left(i = \overline{1,m}\right)$ takes place, and, consequently, the examined systems have identical quality and belong to one and volume class, id est. $K\left(S_2\right) = K\left(S_1\right)$.

For the vectorial-comparable systems the concept of absolute criterion of preference is entered: when vectorial inequality $K\left(S_2\right) \leq K\left(S_1\right)$ is executed, id est. $k_i\left(S_2\right) \leq k_i\left(S_1\right)$ for all $\left(i = \overline{1,m}\right)$, including. even for one factor inequality is executed strictly $k_i\left(S_2\right) < k_i\left(S_1\right)$, and system S_2 surely better than system S_1.

At development of analytical procedure of search of the perspective systems concepts are accepted in m-variate area of possible decisions:

- the basic system is examined on the current step of procedure as initial;
- the consecutive system, compared to the basic system on the consecutive step of procedure.

The sequence of implementation of analytical procedure of search of optimal variant of the system is below presented on steps.

Step 1. All variants of the system and value of their factors of efficiency write down in the table of kind:

Variant of the system	Factors of efficiency					Result
	k_1	k_2	k_3	…	k_m	

Step 2. As a basic system accepts it is choose the first system, written in a table, as a consecutive system the second system and pass to implementation Step 3.

Step 3. The factors of quality of the basic and consecutive system are compared.

Step 4. If in the process of comparison it is educed surely the worst consecutive system (in relation to base), then in a column «Result» is marked it’s by the sign

«-». As a consecutive system choose next unnoted a sign «+» or «-» system, not consilient with the basic system, and pass to Step 3. If a table is looked over to the end, then pass to the step 8.

Step 5. If in the process of comparison it is educed surely the best consecutive system (in relation to base), then in a column «Result» is marked basic system by the sign «-». As a basic system is accept found surely the best system, and as a consecutive system is next system, unnoted by sign «+» or «-», not consilient with the basic system, and pass to Step 3. If a table is looked over to the end, then pass to the step 8.

Example of the use of analytical procedure with an exposure surely of the best system is made an in a table. 1, surely the best system is here marked by sign «+», and by the sign «-» - surely worst systems.

Table 1 - Result of application of analytical procedure for search optimal variant of system

Variant systems	Factors of efficiency					Result
	k_1	k_2	k_3	k_4	k_5	
S1	2,5	4,2	2,5	3,7	4,2	-
S2	7,2	6,3	7,2	5,2	4,7	-
S3	3,1	4,2	3,1	4,3	4,4	-
S4	4,2	5,3	4,2	4,8	4,3	-
S5	2,4	3,6	2,5	3,6	4,0	+

Step 6. If in the process of comparison the consecutive system of vectorial incomparable with the basic system found out, then as a consecutive system choose the next system, unnoted by sign «+» or «-», which does not coincide with the basic system, and pass to Step 3. If table. 1 looked over to the end; pass to implementation of Step 7.

Step 7. If in an initial table one or a few unnoted the sign «-» or «+» systems remains, then in a column «Result» is marked their by sign «+» and complete procedure.

On the basis of described higher the analytical procedure the program which allows automatically to execute the process of search of the perspective systems in area of possible decisions is worked out. Results of the program performances are presented on a table 2.

Variant of system	Factors of efficiency					Results
	k_1	k_2	k_3	k_4	k_5	
S_1	2,5	4,2	2,5	3,7	4,2	-
S_2	7,2	6,3	7,2	5,2	4,7	-
S_3	3,1	4,2	3,1	4,3	4,4	-
S_4	4,2	5,3	4,2	4,8	4,3	-
S_5	2,4	3,6	2,5	3,6	4,0	+

Table 2 - Results of the program work on the search of rational decision

In the case when a few systems are perspective, id est. for them «Result» is characterized by sign «+» (fig. 1), it is pass on to the second stage optimizations, when for completion of search process use the self-weighted sum of factors of efficiency, determined by an additive function. The best value is accepted value of vector K, which corresponds to the minimum value of foregoing sum:

$$K_p = \sum_{i=1}^{m} c_i \cdot k_i \Rightarrow \min, \quad (8)$$

where $\sum_{i=1}^{m} c_i = 1$, $c_i \left(i = \overline{1, m} \right)$ are some gravimetric coefficients, certain by the method of expert estimations.

Conclusions. There is worked out the method of multicriterion choose of the best variant of the system of automation from the great number of possible variants, allowing to improve quality acceptance decision at updating of production capacities of metallurgical plant.

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