SELECTION OF THE OPTIMAL CONTROL SYSTEM ACCORDING TO THE INTEGRAL EVALUATION CRITERION

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Abstract: One of the problems faced by the developers of such systems is the formalization of expert knowledge. This article discusses the problems associated with the assessment of the developed options for process equipment control systems. A technique is proposed that allows searching and selecting the optimal control system by ranking options according to the value of the objective function. To determine the value of the objective function, it was proposed to use groups of criteria that include various characteristics that describe the control system. To form weight coefficients, it is proposed to use the hierarchy analysis method based on pairwise comparison of control system characteristics. An example of calculating weighting coefficients is given.

Keywords: control systems, development, optimality, objective function, hierarchy analysis method.

1 Introduction

Today we can note the rapid development of systems related to the use of artificial intelligence. Decision support systems are not designed to work without the participation of a person, but they are necessary to help him in making various kinds of decisions (Karpushin, 2014). Especially these systems have proven themselves well in those areas where a huge number of external factors have a bearing on decision-making, and high speed of reaction to events such as finances, computer technology, healthcare, etc (Alter, 2011; Borne, 2013; Morozov, 2010; Merkert & Hubl, 2015). Depending on the scope and purpose of the decision support system, they can use various tools and their combinations.

One of the areas where an assessment of the solution is required is the development of process equipment control systems. The control system for technological equipment can be evaluated by various indicators, such as: cost, speed, accuracy, technical support, etc. These indicators have different dimensions and include both quantitative and qualitative values, which complicates the process of comparing the obtained options and choosing the best one from them. Therefore, in this paper, we consider the question of evaluating such options.

2 Methods

Various methods can be used at the base of decision-making: Model-Driven - they are based on classical models (linear models, inventory management models, transportation, financial, etc.). Data-Driven - Based on historical data. Communication Driven - systems based on group decision-making by experts (facilitation systems for the exchange of opinions and calculation of average expert values). Document Driven is essentially an indexed (often multi-dimensional) document repository. Knowledge-Driven — based on knowledge. Moreover, the knowledge of both expert and Machine-derived (Turban, 1995).

A developer who has rich experience in development most often builds on existing solutions and does not take long to select elements.

But the assessment, as a rule, takes place only according to those parameters that are associated with the automation object and does not include such characteristics that are not within its competence, for example, MTBF, warranty, price, etc., which does not allow a diversified assessment developing the management system.

Thus, in this area, the most optimal is the development of a system based on expert knowledge and, taking into account the speed of the system, will increase labor productivity and reduce the number of errors.

To reduce the time of equipment selection and reduce the requirements for the developer, a solution was proposed based on solving the multi-criteria problem of finding the best option, and it is carried out by the method of additive convolution of a vector criterion into a scalar criterion and its subsequent ranking. To do this, using an expert method, it is necessary to highlight the characteristics by which a decision is made on the choice of a specific version of a control system.

The control system consists of many elements, such as controllers, starters, sensors, etc.

Each of the elements of the control system is described by a combination of various characteristics, such as speed, error, cost, reliability, etc (Volkov & Filippov, 2009). These characteristics can be divided into three groups: technical, operational and characteristics that determine consumer properties. Therefore, the following criteria were selected as a criterion for choosing an ACS variant: P1-technical characteristics, P2-operational characteristics, P3-consumer properties. Additionally, criterion P4 was introduced taking into account the quality of the control process of the developed self-propelled guns. Criterion P4 is formed according to the quality of work of the control system and can be evaluated by various criteria, for example, by the number of temperature exits beyond the specified range of the developed control system or the number of operations of the emergency protection system. In each case, the assessment should be carried out by an expert, taking into account the characteristics of the process.

In turn, each criterion is a set of characteristics of individual elements. Typically, particular criteria have different physical nature and, in accordance with this, a different dimension, therefore, in the formation of a generalized criterion they operate not with “natural” criteria, but with their normalized values. The normalization of particular indicators is done by relating the “natural” criterion to a certain normalizing value, measured in the same units as the criterion itself. As normalizing values, the maximum values of the criteria achieved in the corresponding areas are used. Rationing, in particular, is necessary to reduce the influence of dimensionality, for example, the cost of a developed control system can be expressed in millions of rubles, and speed is calculated in microseconds. Indicators that should tend to the minimum value inherently, for example, cost are taken with a minus sign (Sobol & Statnikov, 2006).

The analysis showed that among the technical characteristics that describe the control system, the criterion P1 is most influenced by the performance (Shabaev, 2009): speed (B_i) and the error of the control system (P_i), therefore, criterion P1 will be determined by the formula (1)

$$P1 = \frac{\text{Б}_i}{\text{Б}_n} C_1 + \left(-\frac{\text{П}_i}{\text{П}_n} C_2\right) \tag{1}$$

where B_n, P_n - normalizing values,

C_1, C_2 - weights taking into account the importance of the criteria.

Criterion P2 is formed by the values of the characteristics describing the operating conditions. Such characteristics include temperature, humidity, atmospheric pressure, the presence of pollutants in the air, vibration. The produced elements of self-propelled guns are operational in a wide range of pressure changes. Most often, the range of atmospheric pressure changes in those conditions where the production is located is less than the range of operation of the elements, therefore this characteristic can be neglected. The greatest influence on the control system is exerted by the temperature and humidity of the environment. Therefore, the criterion P2 will include characteristics that determine the range of operating temperatures (ДРТ$_i$) and relative humidity (ОВВ$_i$) (2).

$$P2 = \frac{ДРТ_i}{ДРТ_n} C_3 + \frac{ОВВ_i}{ОВВ_n} C_4 \quad (2)$$

where DRT$_n$, OVV$_n$ - normalizing values,

C 3, C 4 - weights taking into account the importance of the criteria.

Criterion P3 describes the consumer properties of a control system. The consumer properties of the control system are described by many characteristics, the most important of which are: MTBF (VNO$_i$), equipment cost (STO$_i$), warranty period (GS$_i$), power consumption (PM$_i$), mass (M$_i$), dimensions (Г$_i$). The resulting value of criterion P3 will be determined by the formula (3).

$$P3 = \frac{ВНО_i}{ВНО_n} C_5 + + \frac{СтО_i}{СтО_n} C_6 + \frac{ГС_i}{ГС_n} C_7 + (-\frac{ПМ_i}{ПМ_n}) C_8 + \\ + (-\frac{M_i}{M_n}) C_9 + (-\frac{Г_i}{Г_n}) C_{10} \quad (3)$$

where VNO$_n$, STO$_n$, GS$_n$, ПМ$_n$, M$_n$, Г$_n$ - normalizing values,

C_5, C_6, C_7, C_8, C_9, C_{10} - weighting factors that take into account the importance of the relevant criteria.

After determining the component criteria P1, P2, P3, it is necessary to determine the values of the weighting coefficients C_1-C_{10}, taking into account the importance of various criteria. This work should be carried out by an expert since it is the selected coefficients that will determine the specific set of elements of the control system.

The scalar criterion for the considered parameters will have the following form:

$$K = -P_1 y_1 + P_2 y_2 + P_3 y_3 - P_4\ y4, \quad (4)$$

where P1, P2, P3, P4 are the values of the corresponding criteria,

y_1, y_2, y_3, y_4- weighting coefficients of the corresponding criteria.

To facilitate the work of the expert, it is proposed to use the hierarchy analysis method when determining weight coefficients (Sologubova et al., 2018). This method consists in using a numerical preference scale (Table 1).

Verbal expression of preference	Score
Lack of preference	1
Moderate preference	2/3
Medium preference	4/5
Strong preference	6/7
Very strong preference	9

Table 1. Grade Scale

Using these estimates, the expert fills in the initial matrix of pairwise comparison for each and particular criteria.

Next, the adjusted value of the fields (b_i) is calculated by the formula:

$$\frac{a_i}{\sum a_i} \quad (5)$$

where $a_i$is the expert's assessment,

$\sum a_i$- the sum of all expert assessments for one parameter.

Weighting factors are calculated by the formula (c):

$$\frac{1}{n}\sum b_i \quad , \quad (6)$$

where n is the number of characteristics

b_i- adjusted field value.

An example of determining weights is shown below. For criterion P1, the matrix of pairwise comparisons is shown in table 2, and the matrix of adjusted values is shown in table 2.

Criteria	Performance	Accuracy
Performance	1	3
Accuracy	1-3	1

Table 2. Matrix of pairwise criteria P1

Criteria	Performance	Accuracy	Weighting factor
Performance	3-4	3-4	0.75
Accuracy	1-4	1-4	0.25

Table 3. Adjusted matrix of pairwise comparisons of criterion P1

Similarly, weights were determined for particular criteria included in P2. The matrix of pairwise comparisons for the particular criterion P2 is shown in table 4, and the adjusted matrix of pairwise comparisons and the values of the weight coefficients - in table 5.

Criteria	Working temperature range	relative humidity
Working temperature range	1	1
Relative air humidity	1	1

Table 4. Adjusted matrix of pairwise comparisons of criterion P2

Criteria	Working temperature range	relative humidity	Weighting factor
Working temperature range	1-2	1-2	0.5
Relative air humidity	1-2	1-2	0.5

Table 5. Adjusted matrix of pairwise comparisons of criterion P2

For criterion P3, the matrix of pairwise comparisons is shown in table 6 , and the matrix of adjusted values is shown in table 7.

Criteria	Mean Time Between Failure	Cost of equipment	Warranty period	Consumed power	Dimensions	Weight
Mean Time Between Failure	1	1-7	1-3	4	9	9
Cost of equipment	7	1	6	7	9	9
Warranty period	3	1-6	1	3	7	6
Consumed power	1-4	1-7	1-3	1	7	7
Dimensions	1-9	1-9	1-7	1-7	1	4
Weight	1-9	1-9	1-6	1-7	1-4	1

Table 6. Adjusted matrix of pairwise comparisons of criterion P3

Criteria	Mean Time Between Failure	Cost of equipment	Warranty period	Consumed power	Dimensions	Weight
Mean Time Between Failure	36/413	18/211	14/335	28/107	36/133	1/4
Cost of equipment	36/59	126/211	252/335	49/107	36/133	1/4
Warranty period	108/413	21/211	42/335	21/107	4/19	1/4
Consumed power	9/413	18/211	14/335	7/107	4/19	7/36
Dimensions	4/413	14/211	6/335	1/107	4/133	1/9
Weight	4/413	14/211	7/335	1/107	1/133	1/36

Table 7. Adjusted matrix of pairwise comparisons of criterion P3

The weighting coefficients for the considered characteristics are as follows (table 8).

Mean Time Between Failure	Cost of equipment	Warranty period	Consumed power	Dimensions	Weight
49/295	404/825	165/866	61/591	24/589	21/890

Table 8. Weighting factors criterion P3

A matrix of pairwise comparisons was compiled for the complex criteria P1, P2, P3 (table 9).

Criteria	P1	P2	P3	P4
P1	1	6	3	6
P2	1/6	1	1/6	2
P3	1/3	6	1	4
Totals	9/6	13	25/6	12

Table 9. Matrix of pairwise estimates of criteria P1, P2, P3

The adjusted matrix of pairwise estimates is shown in table 10.

Criteria	P1	P2	P3	P4	Weight
P1	0.60	0.44	0.68	0.46	0.55
P2	0.10	0.07	0.04	0.15	0.09
P3	0.20	0.44	0.23	0.31	0.29
P4	0.10	0.04	0.06	0.08	0.07

Table 10. Matrix of pairwise estimates of criteria P1, P2, P3

Weight coefficients for all particular criteria are determined in the same way.

After determining the scalar criteria for all options, they are ranked and the option that has the maximum value of this parameter is selected: K → max.

3 Results and Discussion

Using the method of pairwise comparisons when choosing a set of the best option for a control system allows you to reduce the requirements for developers, but does not cancel their basic knowledge, since it only allows you to simplify and speed up the work of finding weight coefficients when evaluating various parameters and their impact on the integral indicator.

4 Summary

Using the proposed methodology, it becomes possible to implement decision support systems aimed at improving the productivity of developers of process equipment control systems. A comprehensive assessment of the control system when choosing it will reduce the influence of the human factor on the selection procedure and make the best decision.

5 Conclusions

The use of human knowledge allows us to implement systems for various purposes and designed to solve a wide range of problems. The main direction of development of such systems is to increase flexibility in the decision-making process and the methodology considered in this paper allows to increase efficiency in decision-making.

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