Model of evaluation of the efficiency of the ship's diesel generator control system

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Abstract. The main trend in the development of control systems in industry is to transit from centralized to distributed intelligent systems based on network technologies. With the development of microprocessor technology and telecommunications, the opportunity has appeared to place the information processing means near the automation objects. It allows you to create effective control systems with locally distributed equipment – so called distributed control systems. Operation of power plants and many other objects determines the subject area of the control systems for such objects in real time.

Keywords: ship, generators, control system, Kolmogorov-Gabor.

1. Analysis of the published data and the formulation of the problem

Quality control of ship's diesel generators is a difficult task requiring a high performance of the control system (CS). One of the stages of decision-making is the formation of criteria for the performance evaluation, i.e. metrics, which compares the "quality" of possible solutions $x \in X$. In terms multicriteriality the most promising approach to the assessment of the problem is the formation of a generalized multi-scalar evaluation of $P(x)$ on a set of particular criteria $k_j(x)$, $j = \overline{1,m}$. To do this, one must solve the problem of structural-parametric identification of models of formation of $P_1(x)$. The effectiveness of the CS is an integrated feature for the set of technical, operational and economic performance of the equipment. It requires continuous improvement of both individual indicators and approaches to the integrated assessment of the CS efficiency. The analysis of literature data concerning ship's diesel generators control systems allowed to formulate the research problem namely increasing the efficiency of ship's diesel generators control system [1-7]. By the selected number of requirements, the assessment of their conformity to these methods was carried out.

2. The purpose and tasks of research

The purpose of this research is to improve the effectiveness of ship's diesel generators CS using the method of arguments group accounting (AGAM).

Research objectives. To achieve the objectives, the following items should be developed:

1. A method to develop mathematical models of the operational control system for the ship's diesel generators.

2. Systematization of methods of formation of the elements in the operational control system for the ship's diesel generators.

3. The implementation of the decision-making stages by the person engaged in decision making (DM) in the operation of the ship's diesel generators

4. Development of the functional structure of the decision-making system (DMS) using the controlling action adoption system

The target of research in this paper is management information systems for the ship's diesel generator operation.

The scope of research is the method of complex solution for the problem of decision-making using the group accounting of the arguments while assessing the efficiency of the operational control system.

Materials and methods of research. When carrying the tasks outlined in the paper, methods of system analysis and mathematical modeling were used. The main research tool was a software package MatLab.

3. The results of research

In this study, a comprehensive approach to evaluating the effectiveness of the control system is considered from a unified point of performance evaluation, since evaluation of CS without its prediction as incomplete as the forecasting efficiency CS without assessing its current state. Due to the limited knowledge about the processes of intellectual activity in the implementation of decision-making procedure by the decision maker, it is advisable to determine the structure of the multi-criteria model for evaluation of the CS effectiveness within the class of polynomial models and, in particular, on the basis of the Kolmogorov-Gabor polynomial [2-5]:

$$F[k_i(x),\lambda] = \lambda_0 + \sum_{i=1}^{n} \lambda_i k_i(x) + \sum_{i=1}^{n}\sum_{j=1}^{n} \lambda_{ij} k_i(x) k_j(x) + \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{l=1}^{n} \lambda_{ijl} k_i(x) k_j(x) k_l(x) + \dots , \quad (1)$$

where $F[k_i(x),\lambda]$ is unknown functional model of productivity of solutions $x \in X$; $k_i(x)$, $k_j(x)$, $k_l(x)$ are particular criteria characterizing the decision; λ_i, λ_{ij}, λ_{ijl} are isomorphism factors reducing all the summands of a polynomial in one dimension and taking into account the importance ("weight") of each of them. However, even within the Kolmogorov-Gabor polynomial a variety of different models can be synthesized. Therefore, it is necessary to formulate a criterion for selecting a single version of the model. The most important indicator of the "quality" of the model is the accuracy of the approximation of the experimental data, by which the model and its predictive capability are identified, i.e. the accuracy of calculation of output variables for input variables, which are not included in the original (training) pilot sequence. This means that it is necessary to synthesize such a model that approximates the objectively existing relationship between the input and output variables, i.e. minimizes some functional of the form:

$$\Delta = \min_{S,\lambda} \Theta(Y_m - Y_e), \quad (2)$$

where S, λ is the structure and parameters of the model respectively; Θ is the operator characterizing the structure of the criterion; Y_m is a value of the output variable calculated by the model $Y_m = S(X,\lambda)$; Y_e is an experimentally estimated value of the output variable.

As an operator Θ either quadratic estimate in the form:

$$\Delta_i = \min_{S,\lambda} \sum_{i=1}^{n} (Y_{im} - Y_{ie})^2 , \quad i = \overline{1,n}, \quad (3)$$

known as the least squares criterion [4] or absolute estimate, i.e. absolute error criterion are used:

$$\Delta_i = \min_{S,\lambda} \sum_{i=1}^{n} |Y_{im} - Y_{ie}| , \quad i = \overline{1,n}, \quad (4)$$

where n is the number of experimental data.

Due to the particular specific features of the object being modeled, other accuracy estimates may be used. As with any complex system, the "quality" of a mathematical model cannot be described adequately by means of the single criterion. The accuracy of the model, though being important, is the local (particular) assessment of its "quality".

Therefore, let us introduce an additional particular criterion such as relevance and complexity of the model. The adequacy of the model will be regarded as the validity of the model, i.e. the stability of its accuracy at all feasible set of input variables. The complexity of the model will be treated as a relative measure, characterizing features and dimensions of the model structure. The relative valuation indicates that compared to the complexity of the models of the same class, for example, the model described by the Kolmogorov-Gabor polynomial is compared

In this case the evaluation of the model complexity should take into account the dimensions of the input variables $X \in E^n$, the dimensions of the output variables $Y \in E^m$, the total number of the polynomial members being characterized by the dimensions of the non-zero coefficient tuple λ, and the maximal order of the polynomial. Then the complexity assessment of the polynomial model will be as follows [2-4, 7-11]:

$$Q = n + m + \alpha + \beta, \tag{5}$$

where α is the number of the polynomial summands; β is the maximum power of the polynomial terms; n is the number of input variables; m is the number of output variables.

The complexity of the model is determined by its accuracy and adequacy. In particular, if the number of Kolmogorov-Gabor polynomial terms is equal to the number of experimental samples by which the model is identified, so the approximation error, i.e. model error, is zero. However, this does not mean that the model has good predictive qualities, i.e. the ability to predict accurately the value of the output variable for any value of the input variables. This is due to the fact that the initial experimental sample, which is used to identify the model, contains information not only on the actual relationship between input and output, but measurement errors, random interferences, etc.

Determination of the model with optimal complexity is associated with the implementation of the principle of external addition [4, 9-12], which means that the predictive accuracy of the model should be determined based on the "independent" experimental data, which are called test statistics and are not used in solving the problem of the model identification. Thus, all the raw experimental data are divided into two sets – a training one that the model is identified and testing one, which is determined by its prognostic quality.

The approach above is accepted as a basis for solving the problem of the comparative structural-parametric identification of the model of the multi-criteria evaluation for the scalar utility function Eq. (1). When implementing the comparative identification of the assessment model the set of inequations is used as "experimental" data Eq. (6):

$$F\left[k_i\left(x_j\right), \Lambda\right] - F\left[k_i\left(x^{\Lambda}\right), \Lambda\right] \leq 0 \ \ \forall x_j \neq x^{\Lambda} j = \overline{1, m}. \tag{6}$$

This set is divided into two subsets: a training one, which incorporates about 70 % of inequations, and testing one with 30 % of inequations. For each fixed version of the model structure for the training sample, one of the methods (average or Chebyshev point) pointwise values of the assessment model parameters are determined. Prognostic "quality" of the assessment model is determined by the test sample of inequations, with a model perfection criterion appearing to be the number of satisfied inequations. The model of the minimal structural complexity that meets all the testing inequality is accepted as a solution to the problem of the comparative identification of multi-criteria evaluation model.

To generate the variants of the model structure, a scheme of the consecutive sophistication of the model can be implemented when to a certain initial reference variant of the structure, e.g. to the additive structure of the following type:

$$P(x) = \sum_{i=1}^{n} \lambda_i k_i(x), \tag{7}$$

such multiplicative pairs and if required more complicated terms are consistently added:

$$\sum_{j=1}^{n} \sum_{i=1}^{n} \lambda_{ij} k_i(x) k_j(x). \tag{8}$$

However, this approach is too cumbersome. The use of techniques of evolutionary self-organization seems more promising to solve the problem of searching for optimal complexity evaluation model, such as the method of argument group accounting [4, 11-13], which provides an objective character of modeling and structural identification of the object. Objectivity is achieved by the fact that when constructing models of CS not a predetermined numerical value to some limits but the criterion of the general form, so-called a criterion of minimum offset [4, 7, 9] is the guideline.

As a selection criterion (selection of structure of the model with optimal complexity) the criterion of the minimum offset was used, which allows to solve the problem of restoring the law, concealed in noisy experimental data and therefore used to identify the problem:

$$\eta_{cm}^2 = \frac{\sum_{i=1}^{N} \left(q_{A_i} - q_{B_i}\right)^2}{\sum_{i=1}^{N} q_{T_i}} \to \min, \tag{9}$$

where N is a number of source data table points; q is an output value; q_A are values q, estimated by the model the assessments of whose parameters are derived by points with the greater quantities of output value dispersion; q_B is the same, but by points with less quantities of output value dispersion; q_T is the table value of the variable.

The method of argument group accounting implies two main structures to generate a set of efficiency models, assessed by the criterion of selection:

1. Combinatorial (not threshold) models of the method of argument group accounting.
2. Multi-row (threshold) models of the method of argument group accounting.

In the first case it is required to set inherently complicated mathematical relationship between the output value and the vector of input variables, for example, as a high degree polynomial from which mathematical models with various structures are obtained by equating to zero those or other factors. The best structure is defined by a particular selection criterion.

In the multiple-row model, mathematical relationships (particular descriptions) are formed initially on the first row of the selection; each of them connects the output value with two variables. These particular descriptions are compared by the criterion of selection and among them F_1 best are selected. In the second row of selection particular descriptions are formed; each of them connects the output value with two variables, which act as partial descriptions obtained in the previous row of selection. Among new particular descriptions F_2 best are chosen to be used in the next third row of selection. For each row the best (according to the criterion of selection) model is found. The rows of selection are generated, while the assessment of the criterion is reduced (the stopping rule).

4. Conclusions

The output of the research is as follows:

1. A method of designing the mathematical models of organizational objects of the control system, which provides the definition of combinatorial group method of data handling model structure. Moreover, costs are functionally dependent on the complexity of the object.

2. Methods of forming the composition of the decision-making stages for the ship's handling are arranged.

3. The implementation of the stages of decision-making for the ship's handling vessel allowed to optimize the processes of stabilization.

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