COMPUTER MODELING OF THE RELIABILITY OF FUNCTIONALLY COMPLEX SYSTEMS

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Abstract

The probabilistic-algebraic method of the definition of characteristics of reliability of functionally complex systems judging by the characteristics of the reliability of their components is offered. The changes occurring to each of components are modeled, their mutual influence and influence on system as a whole is considered.

1   Introduction

Requirements of modern science and practical activities put forward a problem of working out the system approach to research the problems of reliability in various applied areas. As the term "system" is usually understood as the set of the operating components interconnected among themselves and considered the uniform structural whole.

The abundance of functional and logic communications between the components making system, a lot of system modes, possibility of restorable and no restorable refusals of components, a great number of components allow to carry system to a category of the complex.

To research the characteristics of the reliability of structurally-complex systems, the classical logic-probabilistic method [2] and variants of its development and improvement [1,3] is used. Their essence consists of the description of systems structure by the means of mathematical logic and definition of a quantitative estimation of reliability of system with the usage of probability theory.

There is a class of complex systems which structurally include an insignificant number of elements. Interaction between them will be organized under complex laws. Relations between elements of such systems cannot be described by operations of a logic-probabilistic method and are defined by the functions corresponding to semantics of investigated system. Taking in consideration the specified feature such systems can be carried to a class of is functional-complex systems. Besides, during the definition of characteristics of the reliability of such systems, it is necessary to consider the changes occurring to each of the components, to consider their mutual influence and influence on system as a whole. Frequently such system, considered as a whole, possesses new qualities which may be unusual for its separate components.

In the report the possibilities of a method of is probabilistic-algebraic modeling [4] to research the probabilistic characteristics of the reliability of the is functionally complex

systems are shown, based on computer modeling of the processes of deterioration of its separate components and allowing in dynamics to estimate evolution of separate components and all system as a whole.

2 The formal description of is probabilistic-algebraic modeling

Object of is probabilistic-algebraic modeling are complex systems. Structurally they include a set of components $\{K_1, K_2, \ldots, K_n\}$. System components are described by a set of conditions $\{S_1, S_2, \ldots, S_n\}$. The probabilities of finding the components of the system in each of conditions are set by vectors of probabilities:

$$||P_i|| = ||p_{i1}, p_{i2}, \ldots, p_{in}||, \sum_{j=1}^{n} p_{ij} = 1. \tag{1}$$

Between the components there are functional communications. The formalization of the communications between the system components allows to establish the operations setting compositions of components. We will say that component K_3 is a composition of components K_1 and K_2 if display F unequivocally defining condition S_k of component K_3 on conditions S_i and S_j of initial components K_1 and K_2, where $k = F(i, j)$. Thus display F unequivocally defines probabilities of conditions of the resulting devices on probabilities of conditions of initial devices:

$$P_{3k} = \sum_{k=F(i,j)} (P_{1i} \cdot P_{2j}). \tag{2}$$

Operation $*$, defined on a set of vectors P_i, generates algebra A^*, that is for any P_1 and P_2 is carried out:

$$P_3 = P_1 * P_2. \tag{3}$$

The algebra is set by structural factors a_{ijk}, satisfying the condition:

$$\forall i, j, k \, a_{ijk} \geq 0 \, and \sum_{k=1}^{n} a_{ijk} = 1. \tag{4}$$

Thus elements of the resulting vector P_3 are calculated under the formula:

$$p_{3k} = \sum_{j=1}^{n} \sum_{i=1}^{n} a_{ijk} p_{1i} p_{2j}, \; k = \overline{1, n}. \tag{5}$$

The probabilistic-algebraic modeling is realized by carrying out computer analytical calculations on each step of modeling. It allows defining probabilistic characteristics of investigated system on vectors of probabilities of conditions of its components. Characteristic features of the probabilistic-algebraic modeling are: the same probabilistic description of components of system and all system; presence of the algebraic basis allowing also to describe communication between components.
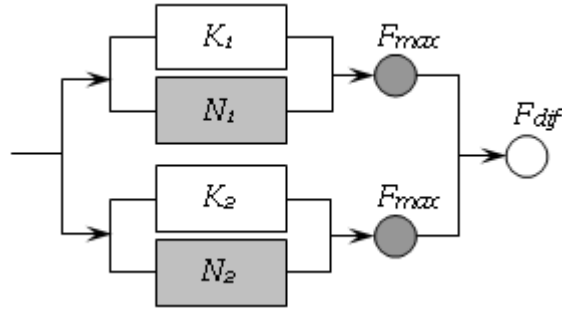
Figure 1: The block diagram of the functionally complex system

3 An example of the definition of probabilistic characteristics of the reliability of system

As an example we will consider the system including two components K_1 and K_2 (Figure 1). The presence of functional communication F_{dif} between these components makes the system complex and distinguishes it from a simple set of parts. We will consider that the system in the course of repeated performance of certain function accumulates mechanical damages which lead eventually to the reduction of the reliability of the system and its refusal.

The loading which has influence on each of the components while in service of the system, probabilistically changes in time. In drawing it is presented by elements N_1 and N_2. Interactions of the components of the system and loading elements are realized by functions F_{max} and define changing mode of operation of system.

The components of the system K_1 and K_2 and the elements setting loading, N_1 and N_2 are described in the same image. They are characterized by a set of conditions. The probabilistic change of conditions of components and loading elements is described by processes Markova with discrete conditions and discrete time.

The components are described by a set of conditions $\{S_1, S_2, \ldots, S_{10}\}$, corresponding to a certain level of deterioration. Deterioration of components of system is a casual process which influences the initial level of damages, environmental conditions and probabilistic character of changes of properties of a material of a component. The probabilities of transition of components from a condition to a condition are set by matrixes of transitions $QK_i[10 \times 10], i = 1, 2$. Loading elements characterize the rigidity of loading components which amplifies in the process of accumulation of damages by components in the course of a repeating cycle of their functioning. They are characterized by set of conditions $\{S_1, S_2, \ldots, S_5\}$, describing the loading level. Parametres of Markovsky process of change of size of loading are set by matrixes of transitions $QN_i[5 \times 5], i = 1, 2$.

During the computer modeling evolution in time of a vector of probabilities of conditions of deterioration of the system is analyzed at its cyclic functioning. For this purpose on the next step of modeling ($t = 1, \ldots, 100$) which corresponds to a cycle of functioning of system, are formed probabilities of conditions of components,

$||P_i^t = ||p_{i1}^t, p_{i2}^t, \ldots, p_{i10}^t||, i = 1, 2$, change the vectors of probabilities defining loading on components of system, $||P_i^t = ||p_{i1}^t, p_{i2}^t, \ldots, p_{i10}^t||, i = 3, 4$.

Further, by the probabilistic-algebraic multiplication of vectors of probabilities of components on corresponding a vector of probabilities of elements of loading influence of changing loading of system on each of system components is realized. The function $F_{max} = F(i, j) = max(i, j)$ which sets operation $\vee$ is thus used and allows to define structural factors of algebra $A^\vee$. Conditions of the resulting device presented by a composition of components $K_i \vee N_i, i = 1, 2$ are defined by various combinations of conditions of components and loading levels.

At last, as a result of is probabilistic-algebraic multiplication of the transformed vectors of probabilities of components of system, we receive a vector of probabilities of conditions of deterioration of investigated system. Function $F_{dif} = F(i, j) = |i - j|$ which sets operation $\otimes$ is thus used and defines structural factors of algebra of $A^\otimes$. The conditions of the system are defined by a difference of conditions of initial components. At the decision of problems of reliability she allows to estimate a difference between conditions of deterioration of components of investigated system.

The probabilistic character of occurring changes in system components causes probabilistic character of changes of parametres of all the system. For preservation of comprehensible reliability of all system the changes occurring to separate components are analyzed, their influence on all system is estimated, and recommendations about replacement of the refused components stand out.

4   The conclusion

Rather simple and effective enough device of the probabilistic-algebraic modeling of characteristics of reliability allows to carry out researches of systems of any complexity. Problems of designing of the components, defining necessary level of reliability of system, and also a problem of optimisation of parametres of components can be thus solved during operation of operating of functionally complex systems.

References

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