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ANALYSIS METHOD OF STRUCTURAL-COMPLEX SYSTEM INDICATORS BY DECOMPOSITION INTO SUBSYSTEMS

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ABSTRACT:

It is considered the issues of structurally complex systems transformation on a model in the graph form. A method for the system structure decomposition is proposed to simplify further analysis.

KEYWORDS: complex system, graph, model, subsystem, position.

INTRODUCTION:

A system is a functionally interconnected set of elements (objects). Structurally complex systems (or networks) are such systems which structure cannot be represented by serial, parallel or serial-parallel elements connection [1-10]. Most problems of structurally complex systems (SCS) analysis are carried out by such structural model systems research. Methods for the SCS functioning research is carried out by constructing an analytical (mathematical) model or a model in a graph form.

In the SCS research with using various methods there is a problem of adequate representation of systems and their properties by models, obtaining estimates with the required accuracy [2]. The system model complexity sometimes grows exponentially with an increase in the number of elements. Last thing which makes it necessary to resort to various methods with the loss of information and analysis accuracy [6,8]. Analytical models of such systems become cumbersome and complex for further analysis. The use of a model in the graph form makes it possible to apply the graph theory achievements. A graph is a collection of edges (curve) and vertices connected according to certain rules[2,3]. The most systems structure is easily displayed as a graph. Such structures are typical for most modern systems. An example is communication, transport, energy and computer networks.

При исследовании характеристики надежности система считается работоспособной (или частично работоспособной) при наличии хотя бы одного пути между входом системы и его выходом. Путем называется совокупность ребер и вершин соединяющих вход системы с его выходом. System health concept and its refusal depend on the problem setting for the studied system, from its purpose, which are taken into account when building the model.

Let us assume that the system elements and their connections may be in working order (x_i=1) or in a failure position (x_i=0). Failures of system elements are independent and not recoverable. To analyze the SCS reliability most authors propose the minimal paths and minimal sections (cuts) method [1-3,5]. As a research result this method can be used to obtain the maximum and minimum values of the system reliability indicator. To approximate the system reliability indicator to its real meaning various methods of decomposition (decomposition) are applied [2,5]. Most authors consider the bridge circuit (system) as an example.

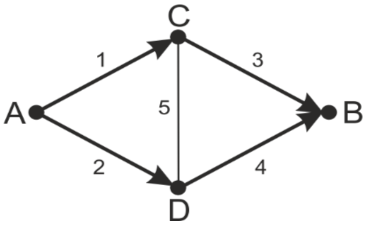

Fig.1

The authors [1,2] propose an expansion method with respect to a singular element based on the expansion method of a Boolean function with respect to its variables. In more complex systems with a large number of elements, the effective choice of the element (edge) relative to which the decomposition should be performed becomes a very difficult task.

Let us consider the system model ordering issue in the graph form to a recurrent form, using the bridge scheme generally accepted for consideration.

Fig 1. Let's replace element 5 with two oppositely directed edges:

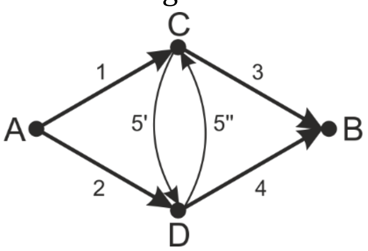

Fig.2

Step 2. Let's divide apex C and D into two apex C1, C2 and D1, D2, respectively:

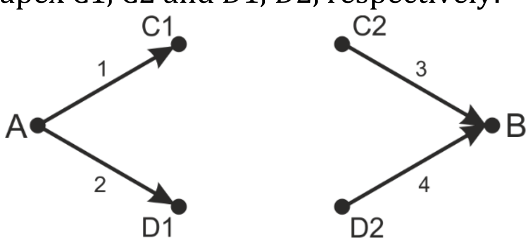

Fig.3

Step 3. Add fictitious edges 6 and 7 connecting the split edges, respectively:

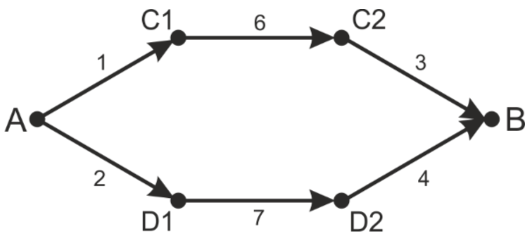

Fig.4

Step 4. We connect vertex C1 with vertex D1 by edge 5', vertex D1 with vertex C2 with edge 5''.

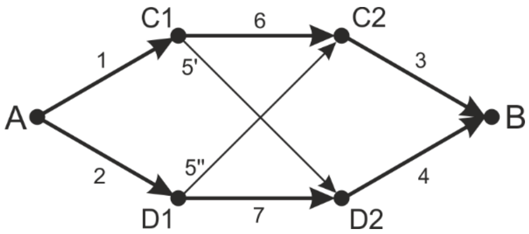

Fig.5

Step 5. We assign edges 5' and 5'' the edge 5 values. The added edges are assigned values that should not change the desired system value. Reliability problems: $P_6= P_7= 1$,$P_{5'}=P_{5''}=P_5$.

As a result, a graph is obtained, which edges are directed strictly from the system A input to its output B.

Let's consider an example of calculating the reliability indicator of the system under study. Let's split the resulting system with a recurrent structure into subsystems. In the first subsystem, we include the system elements connected to the input A - edges 1 and 2. For the first subsystems edges 1 and 2, the input signal is the signal at the system A input.

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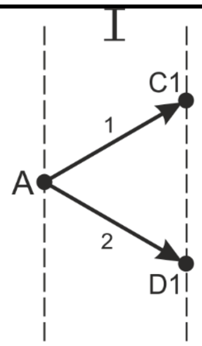

Fig.6

The second subsystem includes the edges associated with the first subsystem elements:

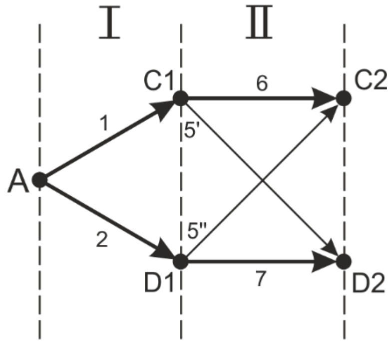

Fig.7

The input for the edges 6, 5', 5'',7 are the first subsystem outputs C1 and D1. The second subsystem output is apex C2 and D2. The third subsystem is formed by the edges associated with the second subsystem elements:

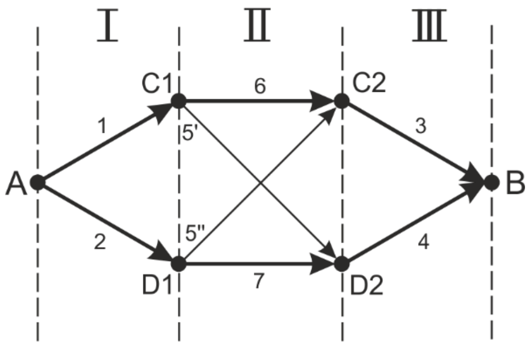

Fig.8

Accordingly, the input signal for the third subsystem elements is the output signals of the second subsystem. This subsystem output is the sought-for result. Let us assume that the system elements failures are independent, for the i-th element $P_i=1$ if it is operational and $P_i=0$ if it fails. The first subsystem has two outputs. The position of a connection presence between the system A input and the vertex C1 and D1 is denoted by 1, the absence of such a connection through 0. The first subsystem outputs can be in four positions – S11, S12, S13, S14. Let's create the positions table for the first subsystem.

Positions	Apex	
	C1	D1
S11	1	1
S12	1	0
S13	0	1
S14	0	0

These positions probabilities can be calculated using well-known methods:

$P(S11)=P_1*P_2$

$P(S12)=P_1*(1-P_2)$

$P(S13)=(1-P_1)*P_2$

$P(S14)=(1-P_1)*(1-P_2)$

The second subsystem also has two outputs C2 and D2 and four positions - S21, S22, S23, S24:

Positions	Apex	
	C2	D2
S21	1	1
S22	1	0
S23	0	1
S24	0	0

Let us calculate these positions probabilities taking into account $P_6=P_7=1$

$P(S21)=(1-(1-P(S11)*(1-P(S12)*P_{5'})*(1-P(S13)*P_{5''}))$

$P(S22)=(1-(1-P(S11))*(1-(PS12))*(1-P(S13)*P_{5'}))$

$P(S23)=(1-(1-P(S11))*(1-P(S12)*P_{5'})*P(S13))$

Further, the third subsystem has only one output, respectively, two positions - S31, S32:

Position	Apex
	B
S31	1
S32	0

Calculate the S31 event probability
$P(S31)=(1-P(S21)*(1-P_3)*(1-P_4))*(1-(1-P(S22) * P_3) *(1-P(S23)*P_4))$

The calculated value of S31 position is the sought-for indicator of the system reliability.

Artificially bringing the system structure to a recurrent form it can be broken down into series-connected subsystems. Further, in such systems, we can apply a simple algorithm for calculating the system reliability indicator.

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