IOP Conf. Series: Materials Science and Engineering **122** (2016) 012020 doi:10.1088/1757-899X/122/1/012020

To the question about the states of workability for automatic control systems with complicated structure

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Abstract. The article discusses the reliability of automated control systems. Analyzes the approach to the classification systems for health States. This approach can be as traditional binary approach, operating with the concept of "serviceability", and other variants of estimation of the system state. This article provides one such option, providing selective evaluation of components for the reliability of the entire system. Introduced description of various automatic control systems and their elements from the point of view of health and risk, mathematical method of determining the transition object from state to state, they differ from each other in the implementation of the objective function. Explores the interplay of elements in different States, the aggregate state of the elements connected in series or in parallel. Are the tables of various logic States and the principles of their calculation in series and parallel connection. Through simulation the proposed approach is illustrated by finding the probability of getting into the system state data in parallel and serially connected elements, with their different probabilities of moving from state to state. In general, the materials of article will be useful for analyzing of the reliability the automated control systems and engineering of the highly-reliable systems. Thus, this mechanism to determine the State of the system provides more detailed information about it and allows a selective approach to the reliability of the system as a whole. Detailed results when assessing the reliability of the automated control systems allows the engineer to make an informed decision when designing means of improving reliability.

Keywords: reliability, states, faultlessness, workability.

I Introduction. Reliability of the systems with complicated structure is the sphere of research with wide range of various methods and computations. According modern approach reliability is the property of the object, allowing it to keep the entire parameters characterizing the ability to perform the required functions constant in time. [1, 2, 3, 4].

Reliability of each element can be expressed in value of P_i – possibility of faultless operations, and state – by the traditional logical variable S_i, taking the value 1 if the element serviceable and 0 in case of failure.

Random event, expressed by the number of R_i. taking the value in interval (0…1), determines the switching of states. Thus, for determining of element state is possible to use expression:

$$S_i = 1, \text{ if } R_i<P_i \quad (1)$$

$$S_i = 0, \text{ if } R_i>P_i \quad (2)$$

The state of entire system expresses by the calculating of the logical formula of the system, which arguments is the states of its elements. Traditionally these states called “workable” and “unworkable”. This dualistic approach allows to apply usual Boolean logic to the calculation of the current state of the system.

II Safety point of view to the states of the system The very set of states is not something absolutely true and certain. It is possible to expand the idea of the state of the elements / systems. Indeed, apart from the usual idea of the state as a “workable” and “unworkable”, there are other classifications of states [6].

In accordance with the approach of the safety of the systems, increasing the reliability of the elements by introducing structural and temporal redundancy, applying interchangeability, maintainability and other measures to increase the reliability of a complex system, fault tolerance is provided. But it is characteristic of complex systems is the possibility of multiple combinations of failures, each of which is improbable, but the amount of such incredible states accumulates enough to hit the system in a dangerous state - a state in which there is damage to "large scale."

In [7] presented the basic definitions that are used in this issue. But along with that assess the state of security of the system, a plurality of states can be considered in assessing the health of the system.

III System of states calculating For the operating of the various states specific state calculating system, based on Boolean logic, is required. The difference of the proposed system is a greater number of possible values of state variables.

To illustrate the versatility of this approach consider several states V_1. V_2, V_3, V_4, which can exist as a system and its individual elements.

State V_1 - inoperable. In this state, the element is not fully perform its function, and all parameters are not as desired.

State V_2 - defective. In it the element performs its function, but with some kind of error, mistake.

State V_3 - workable. In it meet the requirements of normative-technical documentation and design values of all technical parameters of elements, qualities which characterize their ability to perform a given function. Values of other parameters may not match the documentation.

State V_4 - good state. In it the element meets all the regulatory, technical and engineering documentation [1, 8].

Elements of the system can be interconnected in various ways. The complexity of the system can provide increase its reliability by applying the principle of redundancy. By redundancy is understood the application of certain technical means to ensure the health facility in case of failure. [9] In systems with redundant primary and backup isolated elements: the first is an element of the structure of the object, whose failure in the absence of a reservation leads to a loss of efficiency of the object, the second - a component designed to provide health facility in case of failure of the basic element [10, 11].

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IV Tables of the state of serial and parallel connected elements Based on the foregoing, we describe how to calculate the state of the different connected elements. When elements connected serial the logic function is similar to the conjunction of elements and the state table is as follows:

Table 1. State of serial connected elements.

S_1	S_2	S_1 & S_2
V_1	V_1	V_1
V_1	V_2	V_1
V_1	V_3	V_1
V_1	V_4	V_1
V_2	V_1	V_1
V_2	V_2	V_2
V_2	V_3	V_2
V_2	V_4	V_2
V_3	V_1	V_1
V_3	V_2	V_2
V_3	V_3	V_3
V_3	V_4	V_3
V_4	V_1	V_1
V_4	V_2	V_2
V_4	V_3	V_3
V_4	V_4	V_4

In a case of parallel connection states calculating according the next table

Table 2. State of parallel connected elements.

S_1	S_2	$S_1 \parallel S_2$
V_1	V_1	V_1
V_1	V_2	V_2
V_1	V_3	V_3
V_1	V_4	V_4
V_2	V_1	V_2
V_2	V_2	V_2
V_2	V_3	V_3
V_2	V_4	V_4
V_3	V_1	V_3
V_3	V_2	V_3
V_3	V_3	V_3
V_3	V_4	V_4
V_4	V_1	V_4
V_4	V_2	V_4
V_4	V_3	V_4
V_4	V_4	V_4

Each element of the system can move from state to state with a certain probability. Therefore, the calculation of system reliability can be performed on existing states, and on the probability of hitting the elements in these states.

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V Example of the state calculation for the system of differently connected elements

System, depicted on Fig.1 illustrates an example of the calculation. This system consists of some elements M1, M2, M3 are connected in series and in parallel

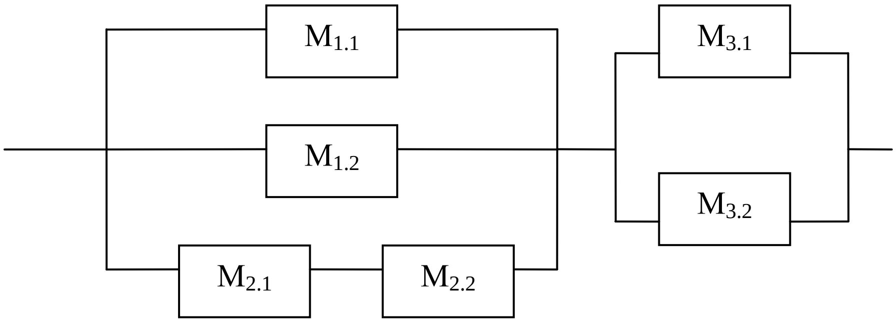

Figure 1. Structure of the example system

For the calculating of the state of the system probability of each state of each element is required.

Table 3. Probabilities of each state of each element

	P_{s1}	P_{s2}	P_{s3}	P_{s4}
M_1	0,001	0,05	0,45	0,4990
M_2	0,0001	0,02	0,5	0,4799
M_3	0,0005	0,03	0,6	0,3695

P_{sn} – probability of n-th state.

Analytically, the probability of the system in any state P_{tot} expressed by the formula

$$P_{tot} = (1-(1-P_{m1})^2 \cdot (1- P_{m2}^2)) \cdot (1-(1- P_{m3})), \quad (3)$$

Results of calculation presented in table 4

Table 4. Probabilities of each state of the system

P_{s1}	P_{s2}	P_{s3}	P_{s4}
0,000002	0,005784	0,483825	0,5104

To illustrate the interaction of the system states run the simulation to generate a set of random states.

We generate the set of states and calculate the combination of states in accordance with our logic.

Table 5. Results of imitation modeling of the states

State of $M_{1.1}$	State of $M_{1.2}$	State of $M_{2.1}$	State of $M_{2.2}$	State of $M_{3.1}$	State of $M_{3.2}$
2	3	4	3	2	3

Logical function of the system

$$(M_{1.1} \vee M_{1.2} \vee (M_{2.1} \wedge M_{2.2})) \wedge (M_{3.1} \vee M_{3.2}),$$

$$M_{2.1} \wedge M_{2.2} = V_4 \wedge V_3 = V_3, \quad (5)$$

Parallel connected elements M_2 will have state V_3, workable.

$$M_{1.1} \vee M_{1.2} \vee (M_{2.1} \wedge M_{2.2}) = V_2 \vee V_3 \vee V_3 = V_3, \quad (6)$$

First parallel connection will result workable state.

$$M_{3.1} \vee M_{3.2} = V_2 \vee V_3 = V_3, \qquad (7)$$

Second will have workable state too.

Thus

$$(M_{1.1} \vee M_{1.2} \vee (M_{2.1} \wedge M_{2.2})) \wedge (M_{3.1} \vee M_{3.2}) = V_3 \wedge V_3 = V_3,$$

System will be in the workable state.

VI Conclusion This differentiated approach to safety has many advantages. First, the traditional approach, defining only two states of the system - workable and unworkable, too rough. Knowing that the system is operational, we gain a sense of confidence in it, which is often false, since system with workable condition could have important non-functional parameters been out of normative.

Secondly, there is the possibility of a more detailed examination of states. Selectivity in the approach to system performance allows it accurately select desired items, and subsequently, the estimated state of the system. After all, the system is often classified according to their importance in a wide range. And a certain condition may not be satisfactory for a single system, for example, control the spacecraft, but satisfactory for another, such as household system.

Thus, definition, provided by this paper determines the more detailed state of the system. gives more information about it and allows a selective approach to the reliability of the system as a whole.

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