COMPUTER SCIENCE

METHODS AND MODELS FOR ASSESSMENT OF RELIABILITY OF STRUCTURAL-COMPLEX SYSTEMS

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ABSTRACT

The article presents the main propositions of logical-probabilistic method of analysis the assurance and enhancement of reliability of structurally complex systems, in which the structure of the system is described by means of mathematical logic and quantitative assessment of reliability is performed using probability theory. An example build script the dangerous condition and performed a quantitative investigation of the reliability of complex systems with interdependent basic events. The methods and models are implemented in a computer system that provides the ability to objectively assess the reliability and safety of structurally complex systems and solving problems of operational decision-making in complex emergencies.

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Introduction. To solve successfully the task of ensuring the health and safety of people in modern conditions is possible only for a range of activities and, above all, the prevention of industrial accidents. It is necessary to know their causes, driving forces, nature and stage of development, the nature of these events. A scientific approach to security requires a complex analysis, classifications of accidents and catastrophes, major impressive and influencing factors, behavior, environmental and personnel actions. To address these issues of appropriate methods of mathematical modeling and physical model of the origin and development of the accident.

The mathematical apparatus of logic-probabilistic method (LPM) developed on the basis of theoretical works Georg Boole, who saw a connection between logic and probability, and K.E. Shannon, who created of information theory and communications.

The fundamental principles of scientific and technical apparatus LPM and applied aspects of their application I.A. Ryabinin. In his work [1] LPM was defined as the method of calculation of reliability of structurally complex systems, in which the structure of the system is described by means of mathematical logic and quantitative assessment of reliability is performed using probability theory. In the book by A.M. Polovko [2] outlined the basic ideas of the use of redundancy as a method of improving the reliability.

To date, developed a number of empirical and formal methods, which solve the analysis task of ensuring and improving the reliability of complex systems. Moreover, apart from the logic-probabilistic approach uses the methods of mathematical programming, game theory and other approaches. The results of their use are given in the works by G.N. Cherkesov, A.S. Mozhaeva, L.N. Alexandrovskiy and others [3-5], which reflect the possibilities of the mathematical apparatus of logical and probabilistic analysis for the complex decision of problems of reliability and safety of complex systems in various fields.

Purpose of the study: building the scenarios of the dangerous conditions of complex systems and quantitative analysis of their reliability in interconnections of the basic events using the logical-probabilistic method.

Research results. Most man-made objects belong to the class of structurally complex systems (SCS). Under the structural-complex systems understand system that, when a mathematical description is not limited to a serial, parallel, or tree structures. SCS are characterized by a large number of state elements, are described by the scenarios network with cycles and repetition of the arguments in their formalization [6]. Because of the difficulty of mathematical nature and complexity of structuring such tasks SCS, as a rule, are studied in a descriptive way, which is insufficient for today's level of technology.

Any man-made object has a certain level of risk, which suggests the likelihood of an emergency situation. In complex systems accidents are logical and probabilistic nature, so simple and convenient solution to the challenges of ensuring the reliability and security of SCS in their design and operation is to use a special part of the modern mathematical apparatus of LPM.

Based on these methods to solve problems of reliability and safety SCS has developed a comprehensive model of the cardiovascular system and completed its efficient software implementation. The main efforts were aimed at reducing the time of calculations, while maintaining sufficient accuracy for practical applications [7]. The developed computer system provides the opportunity to objectively assess the reliability and security of SCS and problem solving operational decision making in complex emergencies. To obtain a more complete understanding of the developed model, its advantages and disadvantages should be considered conceptual notion of logical-probabilistic theory of safety and risk that underlies it.

Fundamental concepts in logical-probabilistic theory of safety and risk refers to the notion of the dangerous state of the system characterized by damage to "large scale" and the concept of risk – the system's ability to go to threat condition [8]. In each case it is necessary to give an analytical description of the state of the cardiovascular system, which could lead to disaster. This description begins with a scenario dangerous condition that is carried out using ANDs and OR initiating events and conditions, which serve a variety of external and internal exposure, failures, improper use, storage, human error, etc. [9]. In reliability theory formalization of the concept of efficiency is done using the block diagrams of functioning. In the theory of security, formalization of the concept of dangerous condition is by using a script a dangerous condition.

Agreeing with the concept of acceptable risk and the need for calculating the probability of risk technical systems is to choose a suitable mathematical apparatus. Such apparatus is, as a rule, is the theory of probability, mathematical statistics and mathematical logic. Very promising is the development of logic-probabilistic (LP) theory of security SCS.

LP theory of security is the basic knowledge of calculations of risk of accidents and disasters SCS based on the logical view of the development of dangerous conditions and mathematical methods of calculating truth functions of algebra of logic (FAL). LP methods of security can objectively identify the most dangerous places and conditions. Using logical and probabilistic calculus (LPC) can combine Boolean algebra with the theory of probability not only for the simplest structures, but also structures, the formalization of which leads to the halyard re-type (bridge, network, monotonic). Characteristics (factors) affecting the final event of the system can be stacked arithmetically or logically. The number of such signs to add can be from a few to a dozen.

Let us consider the dependence of the probability of the final event from the probability of signs and their numbers compare the results of arithmetic and logical addition of probabilities of signs. The logical addition function (L-function) of the events $E_1, E_2, ..., E_n$ is written as:

$$L = E_1 \vee E_2 \vee ... \vee E_i \vee ... \vee E_n. \quad (1)$$

The problem is formulated as follows: failure occurs if there is any one, any two, etc events. After orthogonalization of L-functions (1) can be written as a probabilistic function P-function (probabilistic polynomial):

$$P = P_1 + P_2 \cdot (1 - P_1) + P_3 \cdot (1 - P_1) \cdot (1 - P_2) + ... + P_n \cdot (1 - P_1) \cdot (1 - P_2) \cdot ... \cdot (1 - P_{n-1}), \qquad (2)$$

where $P_1, P_2, ..., P_n -$ the probability of events-signs $E_1, E_2, ..., E_n$.

Note that for the final event the value of P is in the range [0, 1] at any values of the probabilities of initiating events $0 \le P_i \le 1; i = 1, 2, ..., n$

If there's one event-sign ($n = 1$), the probability of final event P when the logical addition (2) will linearly depend on the probability of that event-signs P_1 (Fig. 1).

If there are two triggering events-signs $(n = 2)$, when the logical addition of events, (2) the probability of the final event P will have S-shape depend on probabilities of events-characteristics that are imparted to the same value. The steepness of the S-dependence increases with the n. Probability of a final event when the logical addition depends on the number of events-of signs and their probability. The saturation probability ($P = 1$) also depends on these factors. Low probability initiating events-signs of 0.001, ensure low total risk $P = 0,02 \div 0,04$.

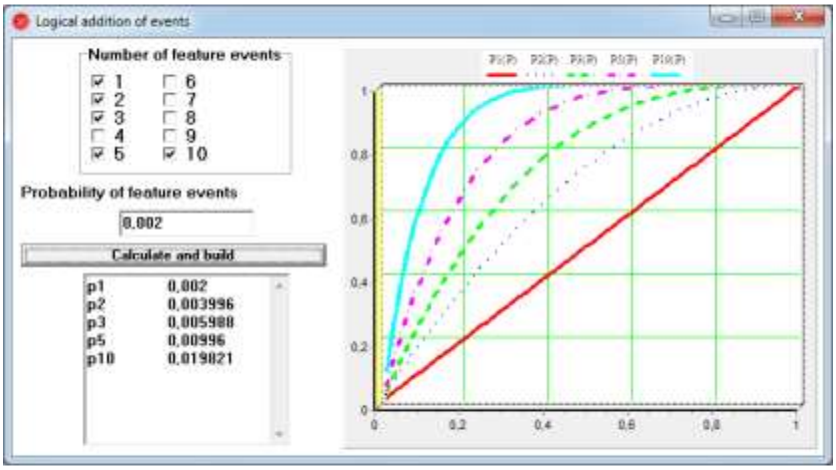

Fig. 1. Risk as a function of the number and probabilities of initiating events for Boolean addition

The results of the logical comparison and arithmetic addition of probabilities of events-signs shown in Fig. 2 when the number of events-of signs 1, 3, 5 and 10.

For large values of the weights of characteristics and a large number of the probability of the final event, calculated as the arithmetic sum of the probabilities becomes absurdly large ($P > 1$). The arithmetic and logical sums are close to each other only at small values of the probabilities of initiating events and small including. Therefore, methods based on the arithmetic addition have satisfactory accuracy only for a small number of features $(n = 1 \div 3)$ at small scales their $P_i = 0,001 \div 0.0001, i = 1, 2, ..., n.$

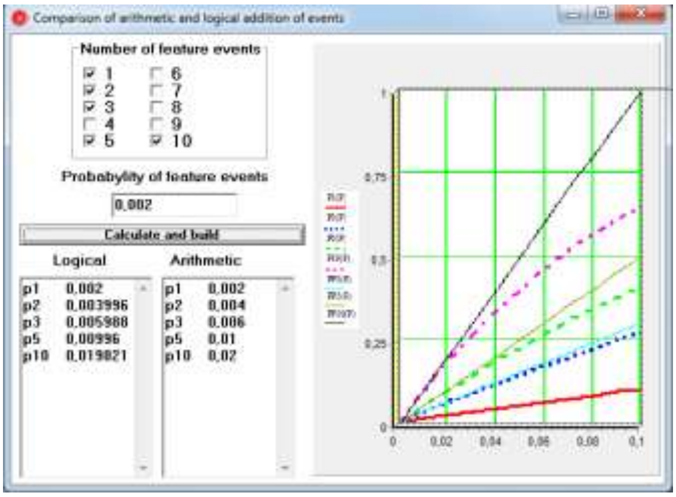

Fig. 2. Risk as a function of the number and probabilities of initiating events when comparing Boolean and arithmetic addition

Compare polynomials to arithmetic (1) logical and (2) the appendix shows that logical and probabilistic polynomial has a more complex structure and therefore provides a great opportunity for an adequate description of the risk source of the event.

For complex structures, described by the tether of arbitrary shape, the transition from the logical functions of risk (of failure) to the probability function (polynomial) is associated with orthogonality L-risk function, written in disjunctive normal form (an expression of the form $c_1 \vee c_2 \vee ... \vee c_i \vee ... \vee c_n$, where c_i – is an elementary conjunction of various ranks, called disjunctive normal form – DNF).

For example, the function $f(a_1,...,a_4) = a_1 a_2 \vee a_1 a_2 \bar{a}_3 \vee \bar{a}_1 a_3 a_4$ is written in DNF, because the terms – elementary conjunction. Only for orthogonal DNF instead of variables E_i and $\bar{E}_i$, you can substitute their probability P_i, and Q_i $(Q_i = 1 - P_i)$ by replacing the sign of disjunction $\vee$, the sign of the addition operation +, and the sign of the conjunction $\wedge$ to the sign of the multiplication "$\cdot$". To obtain P-polynomial consider orthogonality logic functions by the method of conditional probabilities for structural models of the risk of the "bridge" (Fig. 3). The condition denoted by the symbol "$|$ ".

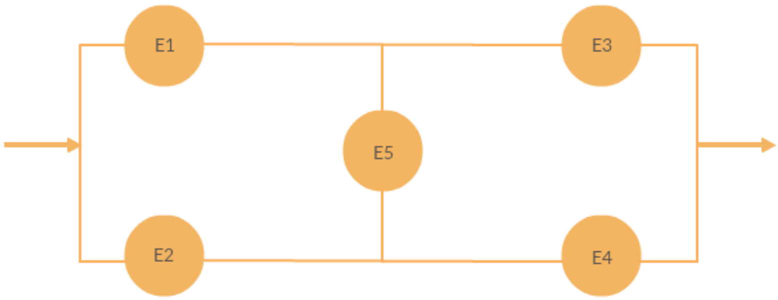

Fig. 3. Structural risk model of the type "bridge"

Then, $l = e_1 e_3 \vee e_2 e_4 \vee e_1 e_4 e_5 \vee e_2 e_3 e_5$; $L = c_1 \vee c_2 \vee c_3 \vee c_4$. The probability of the first logical term:

$$P\{c_1\} = P_1 P_3 = W_1. \qquad (3)$$

The probability of the sum of the first two logical components:

$$\begin{aligned} P\{c_1 \vee c_2\} &= P\{c_1\} + P\{c_2\} - P\{c_2\} \cdot P\{c_1 | c_2 = 1\} = \\ &= P_1 P_3 + P_2 P_4 - P_2 P_4 \cdot P\{e_1 e_3 | c_2 = 1\} = P_1 P_3 + P_2 P_4 - P_1 P_2 P_3 P_4 = W_{12}. \end{aligned} \qquad (4)$$

The probability of the sum of the first three logical components:

$$\begin{aligned} &P\{c_1 \vee c_2 \vee c_3\} = P\{c_1 \vee c_2\} + P\{c_3\} - P\{c_3\} \cdot P\{c_1 \vee c_2 | c_3 = 1\} = \\ &= W_{12} + P_1 P_4 P_5 - P_1 P_4 P_5 \cdot P\left\{\left\| \begin{matrix} e_1 & e_3 \\ e_2 & e_4 \end{matrix} \right\| c_3 = 1\right\} = W_{12} + P_1 P_4 P_5 - P_1 P_4 P_5 \cdot P\left\{\left\| \begin{matrix} 1 & e_3 \\ e_2 & 1 \end{matrix} \right\|\right\} = \\ &= W_{12} + P_1 P_4 P_5 - P_1 P_4 P_5 \cdot P\{\overline{e_2} \cdot \overline{e_3}\} = W_{12} + P_1 P_4 P_5 \cdot (1 - Q_2 Q_3) = W_{12} - P_1 P_4 P_5 Q_2 Q_3 = W_{123}. \end{aligned} \qquad (5)$$

Here we have used the substitution rule variables when considering conditional probabilities and the theorem of de Morgan on the replacement of the negation of the disjunction of the conjunction. The probability of the sum of four logical components:

$$P\{c_1 \vee c_2 \vee c_3 \vee c_4\} = P\{c_1 \vee c_2 \vee c_3\} + P\{c_4\} - P\{c_4\} \cdot P\{c_1 \vee c_2 \vee c_3 | c_4 = 1\} =$$
$$= W_{123} + P_2P_3P_5 - P_2P_3P_5 \cdot P\left\{\begin{vmatrix} e_1 & e_3 & \\ e_2 & e_4 & \\ e_1 & e_4 & e_5 \end{vmatrix} \middle| c_4 = 1\right\} = W_{123} + P_2P_3P_5 - P_2P_3P_5 \cdot P\left\{\begin{vmatrix} e_1 & 1 & \\ 1 & e_4 & \\ e_1 & e_4 & 1 \end{vmatrix}\right\} = \quad (6)$$
$$= W_{123} + P_2P_3P_5 - P_2P_3P_5 \cdot P\left\{\begin{vmatrix} e_1 \\ e_4 \end{vmatrix}\right\} = W_{123} + P_2P_3P_5 - P_2P_3P_5 \cdot (1 - Q_1Q_4) = W_{123} + P_2P_3P_5Q_1Q_4 = W_{1234}.$$

Here we have used the substitution rule variables when considering conditional probabilities, the law of the absorption theorem and de Morgan on the replacement of a negation disjunction conjunction [10].

Making lookup instead W_1, W_{12}, W_{123}, obtain the final expression for the I-polynomial:

$$\begin{aligned} P\{L = 1\} &= W_{123} + P_2P_3P_5Q_1Q_4 = W_{12} - P_1P_4P_5Q_2Q_3 + P_2P_3P_5Q_1Q_4 = \\ &= P_1P_3 + P_2P_4 - P_1P_2P_3P_4 - P_1P_4P_5Q_2Q_3 + P_2P_3P_5Q_1Q_4. \end{aligned} \quad (7)$$

A function written in a matrix form in which a conjunction denoted by the location of the logical characters in a string, and disjunction – their location in the column, called a logical matrix. To the logical matrices are applicable to all known transformations of the algebra of logic. So, perali the law of conjunction allows the permutation of characters in the string, and perali the law of disjunction is a permutation of the rows of a logical matrix. Let the FAL is:

$$f(a_1,...,a_8) = \{\{a_1 \wedge a_3 \wedge [a_5 \vee (a_4 \wedge a_6 \wedge a_8)]\} \vee \{a_2 \wedge a_4 \wedge [a_3 \wedge a_5 \wedge a_8]\}\} \wedge a_7 \quad (8)$$

In matrix form equation (8) can be represented as:

$$f(a_1,...,a_8) = \begin{vmatrix} a_1a_3 & \begin{vmatrix} a_5 \\ a_4a_6a_8 \end{vmatrix} & a_7 \\ a_2a_4 & \begin{vmatrix} a_6 \\ a_3a_5a_8 \end{vmatrix} & \end{vmatrix} = \begin{vmatrix} a_1a_3a_5a_7 \\ a_1a_3a_4a_6a_8a_7 \\ a_2a_4a_6a_7 \\ a_2a_4a_3a_5a_8a_7 \end{vmatrix} \quad (9)$$

A complex system may consist of equipment, sensors, computers, software, instructions and human actions that include management, testing, repair and maintenance. Consider building logical and probabilistic risk models in which the elements are human actions (operator error). This is a simulation, evaluation and analysis of the risk of explosion of the tank, events that characterizes the scenario of the emergence of large-scale accidents – explosion of the tank, the effects of which can be environmental pollution, the appearance of fire-ball, fire Strait.

The scenario of a dangerous state is shown in Fig. 4. The development of such a scenario is a creative part of the safety analysis, the most laborious and ill-structured [11]. The explosion will happen, if there will be increased pressure in the tank due to a faulty pump or excessive load (events e_1, e_2, e_3, e_4) and the failure of the safety valve (the events e_5, e_6, e_7). The FAL has the form:

$$f(e_1,...,e_7) = [(e_1 \wedge e_2) \vee (e_3 \vee e_4)] \wedge [(e_5 \wedge e_6) \vee e_7] \quad (10)$$

The cause of the explosion on the lower level of the event tree $e_1 \div e_7$ is called initiating conditions and they are considered to be independent random events.

When building the tree dangerous condition (Fig. 4) events have on levels (a phenomenon examined top-down: first, formulate a dangerous condition (the explosion), and then determine its possible causes).

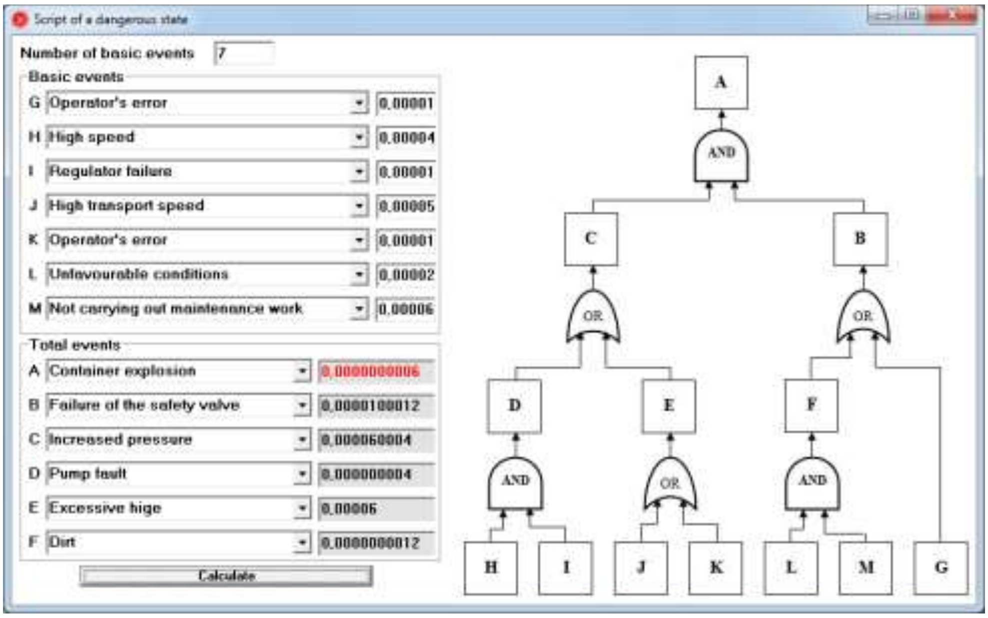

Fig. 4. The scenario of the dangerous condition

The main (final) event is upper 0-level, below event of the 1st level (among them may be elementary), then 2nd level, etc. If on the 1st level there is one or several elementary events combined logical symbol OR, the possible direct transition from the initial event to accident. For each threat the health and analyze the denial of its elements or combinations of failures until, you find the first failure: failure of a single node or human error.

You then need to determine the minimum emergency combinations (minimum emergency call by a combination of the minimum set of input events, wherein the event occurs at the vertex) and the minimal path to build the tree. Minimum emergency combinations are the events D and F, D and G, E and F, E and G. The full set of minimal emergency combinations of the tree represents all combinations of events that may occur accident. The minimum path is the smallest group of events, without which the accident occurs. For example, the explosion of the tank will not happen if will not rise and pressure will not occur the failure of the safety valve. The minimum of the trajectory represent events that are critical for maintaining the object in safe condition. The primary events and events that don’t decompose, linked with event 0-level routes. Complex tree has different sets of initial events, which allow one event at a vertex, are called accidental combinations.

A function of threat condition can be written in the form of a logical framework of events:

$$f(e_1,\ldots,e_7)=\left|\begin{matrix} e_1e_2 \\ e_3 \\ e_4 \end{matrix}\right|\begin{matrix} e_5e_6 \\ e_7 \\ \end{matrix}\right| \tag{11}$$

After opening brackets (logical multiplication) will receive a function of threat condition in six shortest paths of a dangerous operation:

$$f(e_1,\ldots,e_7)=\left|\begin{matrix} e_1e_2e_5e_6 \\ e_1e_2e_7 \\ e_3e_5e_6 \\ e_3e_7 \\ e_4e_5e_6 \\ e_4e_7 \end{matrix}\right| \tag{12}$$

For example a function of threat condition contains no repeated arguments, so bypassing orthogonality, find the probability of an explosion from the expression (11):

$$P_A=\left[1-Q_3\cdot Q_4\cdot(1-P_1\cdot P_2)\right]\cdot\left[1-Q_7\cdot(1-P_5\cdot P_6)\right] \tag{13}$$

In the example scenario threat condition consisted of statistically independent basic events. But for real systems often have the effect of interrelated basic events, so it is advisable to perform a quantitative study of such systems.

If the elements interact in such a way that the transition to the alarm status of each of them leads to a crash of the system, the connection is called consistent (Fig. 5a).

Trouble-free system state in this case can be considered as a random event, is equal to the intersection (product) independent events – the uptime of each of the elements. If the elements interact according to the scheme of the serial connection, the figures for safe operation of the system lower than the corresponding values for any of its elements. With increasing number of elements the performance of the system are rapidly falling and, if the number of items is large, it is impossible to create a system with high security [12].

One of the ways to improve security systems method is redundancy, which consists in the introduction into the system of additional elements or subsystems of more than the amount minimally required to perform the given functions (as is done in Fig. 5b), for example, the inclusion in the system, except the main and additional pump.

The easiest way redundancy is shown in Fig. 5c. Instead of a single element is sufficient to perform certain functions, the system consists of n elements. It is assumed that the breakdown of elements, independent events, system failure occurs if you refuse all n elements. The probability the system is in alarm condition is equal to the product of the probabilities of failures of its elements. The safety function of the system $S(t)$ in this case will be equal to:

$$S(t) = 1 - \prod_{k=1}^{n} \left[1 - S_k(t)\right], \tag{14}$$

where $S_k(t)-$ where security features of each of the elements.

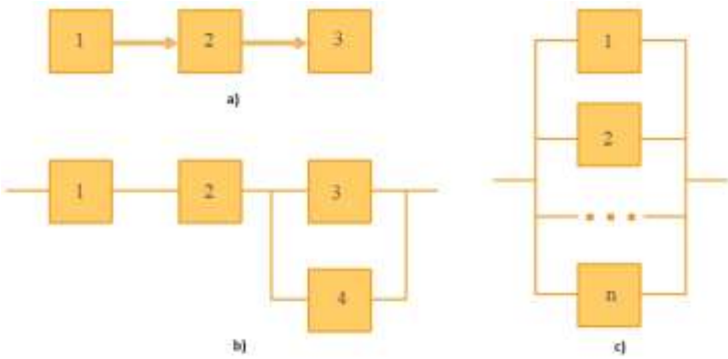

Fig. 5. The structural scheme of the simplest systems in the calculation of technical risk

Interrelated basic events in the tree errors can be in the following cases:

1. Redundancy substitution. The inclusion of the system of equipment elements, which reserve basic equipment, aimed at increasing the probability of failure-free operation of the system and its availability. In the case of failure of the main element instead is connected to the element, who had been in reserve, so the whole system keeps working. Thus, the failure of a component leads to the fact that the reserve component becomes more prone to failure because the unloaded or partially loaded condition it enters the loaded state. And this, in turn, means that the failure of a single element changes the characteristics of reliability, some other system components, so that component failures cease to be statistically independent events.

2. Common causes. General reason, such as, for example, a fire may cause simultaneous failure of a large number of items. Thus, in the presence of common causes of failure the failure of individual components can no longer be considered as statistically independent events.

3. Parallel load components. Suppose that a certain group of system components together resists some of the load, such as, for example, the impact or passing of an electric current, etc. In this case, the failure of one of the elements of this group leads to increased load on other items, so that they, in turn, become more prone to failure. In this case, the component failure, representing the considered group also cannot be considered as statistically independent events.

4. Mutually exclusive basic events. Consider a pair of basic events: "failure circuit breaker" and "failure opening the contacts of the switch". These two basic events are mutually exclusive, so that the occurrence of one of these events leads to the impossibility of occurrence of the other. Hence, mutually exclusive events tree error also can not be regarded as statistically independent events.

The principle of on-off switch, used in conjunction with a Markov's model, enables the quantitative study of systems description which includes the dependent basic events [13]. Generalized procedure for the quantitative study of systems using the principle of inclusion and Markov's model contains the following steps:

1. To represent the parameters of the system based on the use of the principle of on-off. For each member in the presentation of system parameters to determine whether it includes dependent basic events. If the member consists only of independent basic events to meet its quantitative description by the method described above. Otherwise, perform the following steps:
2. To simulate the dependent basic events Markov's chart transitions. To build a system of differential equations for the state probabilities.
3. To perform a quantitative description of the terms containing the dependent basic events and solving the corresponding system of differential equations.
4. Thus, up to this point have a quantitative description of all members in presentation of system parameters based on the application of the principle of on-off. To determine the first and second approximations, and the lower and upper limit values of the system parameters. If possible, it calculates the values of system parameters for detailed formulas and determined by their exact values.

Consider the dependencies between the basic events, introduction to backup system replacement and operation of General causes. System at interconnections of the basic events caused by other factors examined similarly.

The error tree depicted in Fig. 6, contains five times the minimum cross-sections:

$$g_1=\{C\}, g_2=\{E\}, g_3=\{H\}, g_4=\{A,B\}, g_5=\{F,G\}.$$

The main event may be expressed through events g_i :

$$S=\bigcup_{i=1}^{N_c} g_i, \tag{15}$$

where $N_c -$ the total number of minimal sections.

System $Q(t)$ failure through the minimum cross-sections can be calculated by the expression:

$$Q_s(t)=\sum_{i=1}^{N_c}\Pr(g_i)-\sum_{i=2}^{N_c}\sum_{j=1}^{i-1}\Pr(g_i\cap g_j)+\ldots+(-1)^{N_c-1}\Pr(g_1\cap g_2\cap\ldots\cap g_{N_c}). \tag{16}$$

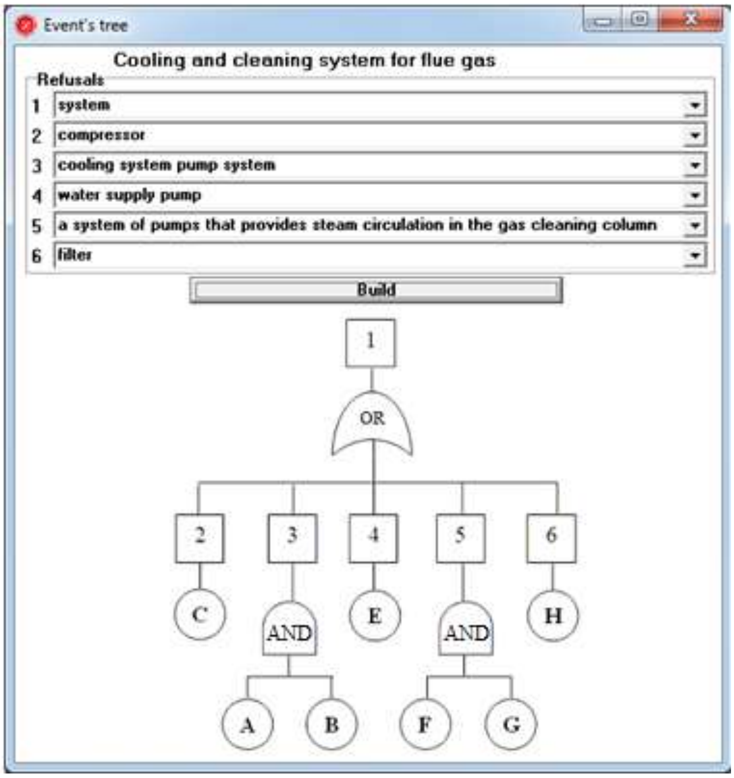

Fig. 6. Tree errors for the cooling and cleaning of associated gas

For large and complex trees, error calculations the exact values of failures is costly time. Often you can use a simple calculation of the upper and lower borders of failures. Analysis of the expression (16) gives the opportunity to build inequality, that is, to determine these boundaries:

$$\sum_{i=1}^{N_c} \Pr(g_i) - \sum_{i=2}^{N_c} \sum_{j=1}^{i-1} \Pr(g_i \cap g_j) \le Q_s(t) \le \sum_{i=1}^{N_c} \Pr(\mathrm{g}_i). \qquad (17)$$

The considered system contains pumps A and B, one of which is in reserve, and the second, which is the main runs.

Suppose at some time t the pump A is works, but the pump B is in reserve. In the event of failure of the pump A, instead of it, the pump B in the reserve is switched on, so that the system as a whole remains operational. Pump A that was refused, repaired and after the repair is transferred to the reserve. Introduction in system of additional elements according to this scheme improves the reliability of the whole system.

With the introduction of the system redundancy by replacing each element can be in one of three states: in reserve, in repair or in the work [14]. The failure of a component can occur if the corresponding component is in operation or in reserve. Depending on the service characteristics of the components in various States of redundancy substitution is divided into these three types:

1. Loaded redundancy. The failure rate of a component does not depend on whether the component is in operation or in reserve. Since each component has its own failure rate, which does not affect the status of other system components, loaded redundancy leads to statistical independence of the component failures belonging to the reservation group.

2. Nanovantage redundancy. It is accepted that a component failure may not occur if the corresponding component is in reserve. Components associated with a nonzero failure rate, only if the corresponding components are in the works. The failure of the primary component lead to the translation reserve component of reserve at work, that is, until the abrupt change in failure rate associated with the corresponding component. Thus, the characteristics of failure of one component depend on other components, not loaded redundancy is the reason for the interdependence of basic fault events (component failures).

3. Part load redundancy. It is assumed that the component that is in reserve may also deny, but the failure rate of a component when finding it in the reserve lower than when it is in operation. The negative characteristics of one component depends on the state of other system components, so that partial load redundancy is also the reason for the interdependence of the state of the other system components. Thus, partially loaded redundancy is also the reason for the interdependence of basic exemption events [15].

The application of the principle of on-off switch allows to define upper and lower bounds of the coefficient of unavailability of the system (system failure):

$$Q_s(t)_{\max} = \textit{first approximation} = \Pr(C) + \Pr(E) + \Pr(H) + \Pr(A \cap B) + \Pr(F \cap G) \qquad (18)$$

$$\begin{aligned} Q_s(t)_{\min} &= Q_s(t)_{\max} - \textit{second approximation} = Q_s(t)_{\max} - \Pr(C \cap E) - \Pr(C \cap H) - \\ &\Pr(C \cap A \cap B) - \Pr(C \cap F \cap G) - \Pr(E \cap H) - \Pr(E \cap A \cap B) - \Pr(E \cap F \cap G) - \\ &- \Pr(H \cap A \cap B) - \Pr(H \cap F \cap G) - \Pr(A \cap B \cap F \cap G). \end{aligned} \qquad (19)$$

Events C, E, N, $A \cap B$ and $F \cap G$ is interrelated by definition. Taking into account the expression (19) can be written in the form:

$$\begin{aligned} Q_s(t)_{\min} &= Q_s(t)_{\max} - \Pr(C)\Pr(E) - \Pr(C)\Pr(H) - \Pr(C)\Pr(A \cap B) - \Pr(C)\Pr(F \cap G) - \\ &- \Pr(E)\Pr(H) - \Pr(E)\Pr(A \cap B) - \Pr(E)\Pr(F \cap G) - \Pr(H)\Pr(A \cap B) - \\ &- \Pr(H)\Pr(F \cap G) - \Pr(A \cap B)\Pr(F \cap G) \end{aligned} \qquad (20)$$

At the same time that equality

$$\begin{aligned} \Pr(A \cap B) &= \Pr(A)\Pr(B); \\ \Pr(F \cap G) &= \Pr(F)\Pr(G) \end{aligned} \qquad (21)$$

characteristic only for the case of loaded redundancy, and for the unloaded and partially loaded redundancy they are not executed.

Conclusions. Active development of risk analysis methodology allows it to become the basis for decision support to ensure an acceptable level of risk in almost all spheres of human activity. Probabilistic presentation of risk is now widely used as a probabilistic risk analysis is complex and takes into account both the causes of accidents and the consequences to which they lead.

Methods of analysis, evaluation and risk management become more and more popular nowadays, so the development of new and improvement of existing approaches, models and methods of evaluation of natural, technogenic and environmental risks, computer implementation of the developed techniques remains an urgent task.

Application LPM to calculate the reliability meets today's requirements, providing basic knowledge for the calculation of risk of accidents and disasters SCS based on the logical view of the development of dangerous conditions and mathematical methods of computation of the truth of FAL representing functions of the dangerous conditions. LPM allow you to objectively identify the most dangerous places, causes and ntsuk conditions. The advantage of this theory is its robustness even in the absence of initial probabilities of initiating events that, as a rule, is a fundamental challenge in quantitative risk assessment of rare events.

LPM of research of problems of reliability and safety SCS help create a different ideology of developers and engineers, encouraging them to consider the whole system, focus on priorities, not wasted on minor issues. A ranking of the elements of a complex system increases in importance to the objectivity of the distribution of forces and attention on the problem of reliability and safety of the SCS.

In modern automated systems there is a tendency for greater use of computers. The increasing complexity of systems leads to the fact that people increasingly only used for approval of decisions, because it is not able to assess the amount of information about the system. This problem is particularly relevant for SCS, so the developed model and computer system for ensuring the reliability and security of SCS is another step on the way to its complete solution.

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