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Method of Applying Fuzzy Situational Network to Assess the Risk of the Industrial Equipment Failure

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Abstract

The method of formation and application of a fuzzy situational network for the solution of problems of an assessment of risk of failure of the production equipment of the industrial enterprise at statement on production of a new product is offered. The method takes into account the main groups of management actions in small and medium-scale production of a wide range of products. The condition of the equipment is represented in the form of a fuzzy situational network with a three-level structure. The following levels are distinguished: situational, network and factor.

Keywords: risk of equipment failure; fuzzy situational network; management strategy; decision-making management system

1. Introduction

Any modern enterprise realizing the main production activity uses a comprehensive system to ensure the reliability and safety of equipment [1]. Currently, one of the priority areas of automation of production processes is the operational sampling of data on the condition and service life of the equipment in the form of a structured image or the history of its operation [2]. Processing of operational data can be represented by the following results:

- specification of single and complex reliability indicators;
- calculation of reliability of complex technical system;
- evaluation of residual operating life;

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- adjustment the algorithm for monitoring the technical condition, diagnostics and reliability testing;
- estimation of forecast terms of equipment failure.

The obtained results require further study at the level of management decisions on the state of the equipment for the current production [2]. Today, such solutions are often associated with the implementation of a project-oriented approach in the management of an industrial enterprise [3]. The introduced into the project equipment may be new or already in operation. Used equipment could be subjected to current and/or overhaul, is in reserve for reconstruction, etc. Performance and the magnitude of the risk of equipment failure in a project will directly depend on these circumstances.

One of the main tasks in making design decisions is to eliminate uncertainty and risk assessment. For example, which of the many reasons leading to the failure of the technological process will manifest itself and cause failure of the equipment, how critical are the consequences of the failure of the technological cycle for the quality of the final product, how the failure affects the time and cost [3]. To make management decisions on the phases of the project life cycle, possible options for equipment configuration, equipment loading, maintenance and repair modes should be taken into account. The assessment of the viability of project solutions is determined by a system of indicators of commercial efficiency, characterizing the financial consequences of the project [4]. Therefore, project management based on the condition of the equipment (the level of reliability of the equipment or the level of risk of equipment failure) requires the development of new methods and tools to make optimal decisions. The decision-making procedure should be cyclical in terms of the risk of equipment failure, determined by potential or current deviations from the desired, expected or planned indicators of equipment condition and project budget [5]. Management decisions should be formed based on the current situation. From this point of view, we consider the development of management actions based on the situational approach. Variants of equipment and project status are described by a set of typical situations, each of which is a set of linguistic values of features. A significant amount of data, poorly formalized nature of the task, the need to attract the opinions of experts implies the use of fuzzy logic.

In the proposed study, project planning and implementation, as well as the evaluation of project results are carried out taking into account the possibility of changing the strategy of equipment loading, maintenance and repair, as well as the formation of a reserve fund of the project depending on the risk of equipment failure.

Management strategy is considered as a sequence of transitions between fuzzy situations within a fuzzy situational network.

Correction of strategies is possible both at the investment phase of the project and at the completion phase. The correction can be done in different ways, but you can choose the best one based on a set of criteria. Thus, in the conditions of the project-oriented approach, an attempt is made to expand the traditional methods of decision-making by attracting intellectual means of data analysis using fuzzy logic. To form the best way of development and implementation of the project, taking into account the risk of equipment failure, it is proposed to create a model "situation management strategy action", with the help of which the search for management strategy on situational fuzzy networks is carried out.

2. Features of the linguistic description of the equipment based on the risk of its failure when used in an industrial enterprise

The production equipment of the enterprise, as an object of management, experiences a lot of heterogeneous impacts on the main technological process and the process of maintenance and repair. On the one hand, the equipment wears out, which adversely affects the reliability and reliability of the equipment. Compensating effects can worsen the performance of the production process on budget and time indicators to critical values. On the other hand, the loading and operation of equipment determines the efficiency of the use of fixed assets. Thus, the simulation of changes in the state of the equipment on the technical and economic parameters is difficult to formalize. And this problem has a wide range of management actions.

From a practical point of view, the condition of the equipment is characterized by the risk of failure [6]. Under the condition of the equipment in this paper refers to the technical condition of the equipment at some point in time the operation for which you want to identify strategies download, maintenance of reserve funds in accordance with the level of risk of hardware failure.

The state of the equipment in the project, taking into account the risk of failure, is represented as a set $S = \{s_1, s_2, ..., s_k\}$. For each state $s \in S$ must be in accordance with some control actions R from the set of controls $R = \{r_1, r_2, ..., r_n\}$. R_j is used in the event of s_i and helps to maintain a predetermined level of production efficiency, taking into account the risk of equipment failure. To represent the state, we use m features, each of which has m_0 fuzzy values. When solving practical problems of production management, taking into account the risk of equipment failure in the investment phase and the mass production phase, the complete set of states S is large enough. The upper bound on the number of states is $S_0 \leq m_0^m$. In practice, there may be a question of reducing the power of the set S. In the set of states S we allocate a minimum subset of the reference states S_0 for the project equipment with its signs of failure risk, which meets the condition $S_0 \subseteq S$.

The subset of reference states S_0 dominates all states represented in S in a certain sense. Thus, we have a linguistic model of situational management of equipment of industrial enterprises, which, on the one hand, is determined by some technological process, and on the other hand, provides the possibility of effective production, taking into account the risk of equipment failure. The model defines its structure, which is given as a triple (S, R, L) . The elements of the structure are: the set of states $S = \{s_1, s_2, ..., s_k\}$, the set of control actions $R = \{r_1, r_2, ..., r_n\}$ and the bijective relation of the form $L\colon S \rightarrow R$.

If we further assume that in the structure (S, R, L) the set of states S is complete, then any situation from this set that occurs when controlling the state of the equipment will necessarily be close in some respects to another situation from the set S. The assumption of completeness of the set of states S allows us to reasonably assume that each state of the set S can be described by a fuzzy set Y, in which each feature y_i is described by a linguistic variable. From a formal point of view, any situation can be written by an expression of the form:

$$\tilde{s} = \{\mu_s(y)/y | y \in Y\} \tag{1}$$

where $\mu_s(y)$ is the rate of closeness or similarity of states on the feature of y.

Naturally, any fuzzy situation and the bijective relation L for each specify some control R_j, which is necessary to involve it in the process of managing the state of the equipment based on the risk of its failure if the state s_i occurs. Therefore, given the property of the bijective relation L, for the correct reduction of the power of the set of situations S it is necessary to form an idea of the reference situation in general and on its basis to form some minimal set S_0. Firstly, it meets the condition $S_0 \subseteq S$, and secondly, it ensures the stable operation of production based on the control of the state of the equipment, taking into account the risk of its failure.

Let's consider some theoretical aspects of fuzzy situational network construction. To construct a Fuzzy Situational Network (FSN), we take into consideration the inverse method, which consists in the fact that in the form of a graph the relation on the set of reference fuzzy situations $\tilde{s} = (i \in I = \{1, 2, .., g\})$. The graph reflects possible transitions from one fuzzy situation to another. Next, we define the control solutions required for each transition $R_j = (j \in J = \{1, 2, .., f\})$ and degrees of preference of their application $\alpha(s_i, R_j)$. The degree of preference for the application of the control solution is selected by experts. The criteria for the selection of experts can be any parameters related to the activities required for the implementation of the management decision. The reverse method of constructing FSN should be used only for objects that have mutual independence of feature values (changing the value of any feature does not affect the rest). Then the relation of generality of situations can be applied to the construction of FSN. Development of control actions using fuzzy situational control assumes the presence of levels in the structure of the situational network, such as situational, network and factor. The situational level is a graphical representation of the set of all types of possible situations $\{\tilde{s_1}, ..., \tilde{s_g}\}$, each of which is characterized by a certain set of factors (features) $\{y_1^l, y_2^l, ..., y_v^l\}$. The arrows connecting the S network and the situation types are needed to show that the situation types belong to a particular network. The number of networks in general may not be the only one. The actual graphical representation of the fuzzy situational network is in the form required by the classical representation of fuzzy situational networks. It is located at the network level. The factor level allows you to specify on a hierarchical fuzzy situational network that set of factors (features) $\{y_1^l, y_2^l, ..., y_v^l\}$, which characterizes a particular type of possible generic fuzzy situations.

3. Application of a three-level hierarchical fuzzy situational network of management decision-making in assessing the risk of failure of production equipment of an industrial enterprise

The situation is a possible condition of the equipment of an industrial enterprise, in terms of the level of manifestation of the risk of its failure. The state of the equipment is described by a set of technological and economic parameters [7]. In the construction of situational network an equipment is represented by a set of parameters, the value of which affects the level of risk of equipment failure. The risk of failure is considered from the position of the importance of failure for the production process:

- increase the time of consignment's production;
- increase budget;
- deterioration of product quality.

Thus, to determine the situations, linguistic variables of the form "risk level of equipment failure"are used. For each piece of equipment used in the main technological process of production, there are procedures for monitoring the condition (requirements of normative documentation for the operation and maintenance of equipment) [8], as well as additional methods for assessing the risk of equipment failure. When describing a piece of equipment, we need specify the risk of equipment failure to increase the time of release of the product batch; the level of risk of equipment failure to increase the budget and the level of risk of failure on quality deterioration. Control of the state of the equipment in the production process, taking into account the risk of failure is an inertial process, that is, the processing of control actions occurs at a certain speed. In the proposed solution, we use the hierarchy of typical situations (clarification of issued control decisions). Along with the directed search for the most similar to $\tilde{s}_0$ situation $\tilde{s}_i \in S$ on the object of control issued management decisions, corresponds to standard situations that are moving between levels of the hierarchy, until the situation $\tilde{s}_i$. Let, for example, to define $\tilde{s}_{61}$ we construct a chain of situations $\tilde{s}_{31}, \tilde{s}_{12}, \tilde{s}_{21}, \tilde{s}_{61}$, where each situation is located at the corresponding level. To change the risk level of equipment failure over time, it is necessary to generate a management solution R_{61} corresponding to the situation $\tilde{s}_{61}$. If the correspondence between situations and solutions is correctly determined, the following happens: the solution R_{61} must be refined by the solution R_{21}, the solution R_{21} is refined by the previous solutions R_{31} and R_{12}. Thus, as the situation most similar to $\tilde{s}_0$ is clarified, first coarsened, then more and more accurate management decisions and corresponding control signals are issued to the control object.

Conclusions

The structure of a three-level hierarchical fuzzy situational network for managing the state of the project equipment taking into account the risk of failure, that has the following features, is proposed:

- three levels of fuzzy situational network factor (time, budget, quality factors), network (types of situations determined by a set of factors) and situational (typical fuzzy situations characterizing the risk of equipment failure to increase the time and budget of the project and the deterioration of product quality);
- the features involved in the formation of reference situations in the manifestation of the risk of equipment failure in the project can be represented graphically;
- at one level there is a set of typical fuzzy situations that characterize a specific state of affairs in the project associated with the risk of equipment failure;
- the resulting graph-like structure is a fuzzy knowledge base.

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