The Information Technology Method for the Monitoring of the Potentially Hazardous Objects

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Abstract: The method of monitoring at the potentially hazardous objects is described. The situation (the state of the object and its environment) is determined by the set of independent factor values that influence the probabilities of the specific types of hazard. The method is based on the monitoring function that characterizes the degree of situation abnormalities. It allows to rank the situations according to the hazard degree. The adjustment of the monitoring session provides the possibility to control the process of preliminary assessment. As a result, the general efficiency of the Automated System for Checking, Analysis, and Prevention of Accidents can be enhanced due to the separation of the normal and quasi-normal situations. That would allow the users to concentrate their attention on the extreme situations and on the suspect situations, which could turn into the extreme ones.

1 Introduction

In the previous paper [Se99], we have developed one of the concepts for creating the Automated System for Checking, Analysis, and Prevention of Accidents (ASCAPA) at the potentially hazardous objects . The main purpose of such systems is the detection of the latent hazard at the early stages of its development in order to take timely measures for the accident prevention. The decision-making in case of accident prevention is performed in accordance with the result of the comprehensive analysis of the existing situation. In some situations, however, it is not always advisable to use the painstaking and complicated procedure of the comprehensive analysis. In case of the situations that are normal or quasi-normal and do not need preventive measures, it makes no sense to conduct such analysis. In order to detect such situations, it will suffice to perform a simplified assessment of their determinant factors. Besides, there could be the opposite cases, when the situations are close to extreme. In the latter case, it is necessary to inform the users about such situations in the most timely manner, without waiting for the end of the comprehensive analysis. For this purpose the ASCAPA structure was provided with the block for preliminary monitoring, which performs the following functions:

collection of data concerning the current state of the objects;

data actualization;

screening of normal situations (i.e. the separation of the normal situations that should be neglected thereafter);

detection of the manifest accidents which need immediate preventive measures;

detection of the suspect situations which need extra analysis.

The purpose of the present work is to study the problem of the monitoring at the potentially hazardous objects. The notion of hazard is being considered in terms of risk. In [MM90], risk has been defined as a value, which is proportional to the potential damage from the accident and to its probability. The factors that influence the probabilities of the specific types of hazard are controlled. The types of hazard being determined include natural, ecological, social and technogenious ones [Bi96]. The occurrence probability of the different accident types depends on the current situation. The situation (the state of the object and its environment) is described by the set of independent factor values. The monitoring of the situations is based on the periodical estimation of the current factor values. The paper [Se99] proposed the Method of Expert Estimated Scales (MEES), the main purpose of which is the formalization of the expert knowledge about the factors and their influence on the hazard types. The given method allows to describe each situation using the set of independent factors. The factors can be quantitative and qualitative. The area of possible values is determined for each factor and ranked in ascending order. Among this area the normal and critical value points are prescribed. For each factor, the function of its influence on the occurrence probability of the certain hazard type is described. The factor influence function is the dependence between factor values and occurrence probability of certain accident. The process of influence function formation can be performed: 1) on the base of statistical data, 2) using expert estimations, 3) using the combination of both procedures. The expert knowledge about the factors and their influence on the hazard is entered into the information database and is reused thereafter for the monitoring and analysis of the existing situations.

2 Method for the monitoring of the situations at the potentially hazardous objects.

We define the criteria for the detection of normal and extreme situations as follows:

A. The situation is normal if

$$x_j^0 \quad x_j^t \quad x_j^N \qquad {}_j \quad J \qquad [1]$$

where x_j^t - are current values of j factor;

x_j^0, x_j^N - are values of j factor for the left and right limits of normal values;

J – is a set of indices of factors, which determine the situation at the object.

As was shown in the work [Se99], the system of factors that was formed using MEES is such that all factors influence the hazard in the same direction. To make things clear, we suppose that the influence functions are monotonely increasing. Then the formula [1] may be rewritten as follows:

$x_j^t \quad x_j^N \qquad {}_j \quad J$ [1]

B. The situation is extreme if the current value even for one of its factors exceeds the limits. In other words, the situation is considered to be extremal if

$$x_j^k \quad x_j^t \quad \text{at least for one j} \quad J \qquad [2]$$

where x_j^k - is critical value of j factor .

__Note.__ The extreme situation (ES) does not mean that the accident has taken place but it points at the necessity of urgent measures for its prevention.

Joint application of [1] and [2] formulas for the set of current situations X divides this set into three non-overlapping subsets:

X_1 - are extreme situations (ES) when the immediate measures for the accidents prevention have to be taken (subset "ES")

X_2 - are normal situations (subset "NS");

X_3 - are situations with the fuzzy degree of the hazard.

The elements of subset X_3 are different according to the degree of their potential hazard. Those of them, which differ little from the normal ones, do not require extra analysis. The method for the separation of such quasi-normal situations (QNS) is proposed below. It allows to increase the efficiency of ASCAPA due to the reduction of the number of situations. To differentiate situations of subset X_3 according to the degree of their hazard we put into use the notion of the monitoring finction. It characterizes the degree of situation abnormalities and shows how much the occurrence probability of hazard type exceeds the same when the factors are normal. The monitoring function $Q_t^{l,i}$ is expressed by the formulas [3] and [3*]:

$$Q_t^{l,i} = \sum_{j \; J} \left(T_j^{t,i} - T_j^{N,i} \; / \; T_j^{N,i} - T_j^{k,i} \right) \; K_j^{l,i} \qquad [3]$$

$$T_j^{t,i} = T_j^{N,i} \qquad \text{for j} \quad \{\text{j}: x_j^t \quad x_j^N\} \qquad [3^*]$$

where $Q_t^{l,i}$ - is the joint deviation of factor influence functions, l - hazard type, i - type of the object ;

$T_j^{t,i}$, $T_j^{N,i}$, $T_j^{k,i}$ - are the values of j – factor influence functions when the J - set of indices of the factors which determine the situation;

factor takes its current, normal and critical meanings, respectively;

$K_j^{l,i}$ - is the contribution of j –factor (as compared to the other factors) to the emergence of the l^{th} hazard type at the i^{th} type of the object; the magnitude of the factor contributions is determined by the experts using the analytic hierarhy process [Sa80].

Definition:

The situation is quasi-normal if

$$Q_t^{l,i} < Q_k^{l,i} / \mathrm{H} \qquad [4]$$

where $Q_k^{l,i}$ - is the meaning of the function $Q_t^{l,i}$ calculated when the factor takes critical meanings;
H- is the value characterizing the stringency of the user's requirements to the assessment of the situation; the user determines H before the preliminary-assessment session.

Using the criteria [4] the set X_3 can be divided into two subsets:

quasi-normal situations which could be neglected;
suspect situations (SS) which need extra analysis.

The final results of the situation classification are presented in Fig.1
The subset X_1 is formed according to the criterion [1]. The subset X_2 is formed according to the criterion [2]. The subset $X_3 = X / (X_1 \quad X_2)$. The subset QNS is formed according to the criterion [4]. The subset SS = X_3 / QNS

3 Brief characteristics of the technological process

The technological process of the monitoring is divided into two stages: the stage of preliminary preparation (the preparation stage) and the stage of the monitoring itself (the monitoring stage)

The preparation stage comprises:

the forming of a set of independent factors, which determine the situation, and the description of the factors (determination of their range, ordering , fixing of the normal and critical values [Se99];
the forming of the estimation scales of factor influences (performed by an expert using MEES [Se99];
the forming of the *j* –factor contribution to the emergence of the hazard (performed by an expert using the Analytic Hierarchy Process (AHP) [Sa80].

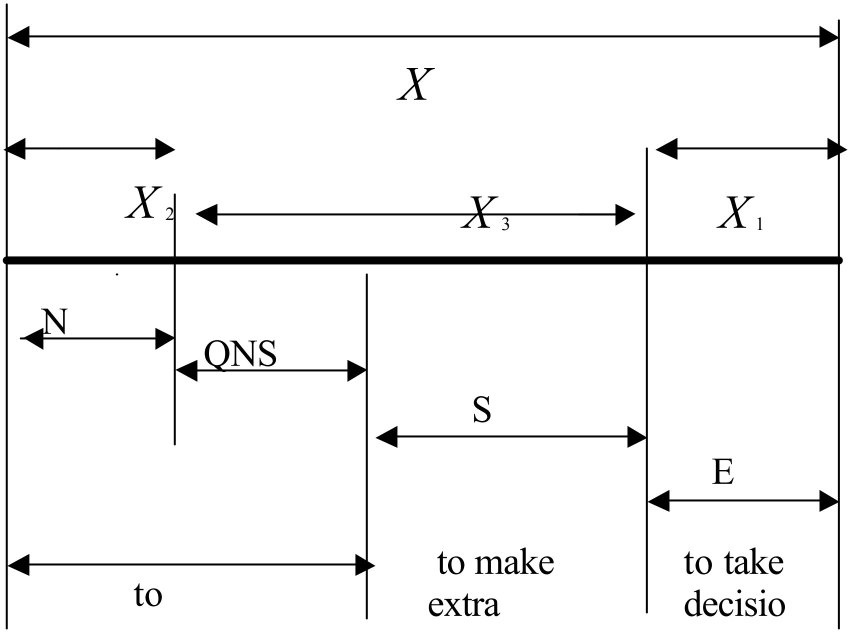

Fig.1. Graphical illustration of classification of situations according to the results of the monitoring sessions.
ES - extreme situation; **SS** – suspect situation; **QNS** - quasi- normal situation; **NS** – normal situation.

The monitoring stage comprises:

data collection about the current situation at the object and actualization of these data;
the adjustment of the monitoring session;
the assessment of the situation and the presentation of the results.

The data collection includes:

the manual input of the verbal reports and of the information that is available on paper;
the automatic input by means of the communication systems.

It is possible to form the input messages on both the periodical and urgent basis. The periodicity of actualization depends on the rate of factor changes.

The adjustment of monitoring session includes:

determination by the user of the lis t of objects subjected to the check;
determination by the user of the list of hazard types subjected to the check;
determination of the degree of stringency of the check (variable H).

Note:

The possible meanings of the variable H are as follows: 1<H<10. For the case where H is close to 1, all suspect situations are indeed close to extraordinary and require extra analysis. However, some part of fuzzy situations might be neglected here. For the case where H is close to 10, many QNS could be estimated as suspect, i.e. the informational superfluity of the check results arises. Depending on the circumstances, the user can control the volume of check results by means of changes of the variable H. The variable H is the control key for the relevancy of the adjusted monitoring session. We suggest the following monitoring tactics: all monitoring is performed in two sessions. Before the first session the sufficiently small meaning of key H is prescribed. Then the first check session is performed. As a result, the situations with explicit deviations are detected. The decision-makers should be immediately informed about such situations, and the additional analysis should be conducted. The second session is performed using the enlarged meaning of key H. As a result of the second session, the less critical situations are detected which have to undergo the latent hazard analysis. The full analysis is beyond the scope of this paper.

The assessment of the situation and the presentation of results.

The initial data comprise the list of objects (I) and the list of hazard types (L) subjected to the check. For each object i I and each hazard type l L, the estimation of hazard degree is performed. The estimation comprises the test of conditions [1*], [2], and [4]. The logic procedure for the assessment of the controlled situation is shown in Table 1. The results of the check are recorded and presented in the form of Check Register (Table 2). For the cases where the situation is assessed as extraordinary, the special out-of-band messages are displayed in order to the decision could be made without waiting for the end of the monitoring session.

+ the condition is met
- the condition is not met
= the condition does not exert any influence
X implementation of the action

$$*Q_t^{l,i} = \mathop{}_{j\varepsilon J} \left(\left|T_j^{t,i} \quad T_j^{N,i}\right| / \left|T_j^{k,i} \quad T_j^{N,i}\right|\right) \quad K_j^{l,i}$$

$T_j^{t,i}, T_j^{N,i}, T_j^{K,i}$ are the values of ***j*** – factor influence functions when the factor takes its current, normal and critical meanings, respectively; ***J*** – is a set of indices of factors which determine the situation; $K_j^{l,i}$ - is the contribution of *j* –factor, in comparison with the other factors, to the emergence of the ***l****th* type of hazard at the ***i****th* type of the object; the magnitude of the factor contributions is determined by the experts.

Table 1. The logic procedure for the assessment of the controlled situation.

Number of conditions	Conditions	Conditions combination in controlled situation			
1'	$X_j \quad X^N_j \quad {}_j \quad J$	+	-	-	-
2	$X_j{}^K \quad X_j$ at least for one j J	=	+	-	-
4	$Q_t{}^{l,i} > Q_k{}^{l,i} / H$ *	=	=	+	-
Number of actions	**Actions**	**Actions combination in controlled situation**			
A1	The registration of normal situation (NS)	**X**			
A2	The registration of extreme situation (ES)		**X**		
A3	The registration of suspect situation (SS)			**X**	
A4	The registration of quasi- normal situation (QNS)				**X**
A5	The display of the alarm message about the necessity of the urgent preventive measures		**X**		
A6	Transition to the next situation	**X**	**X**	**X**	**X**

Table 2. The Check Register for the situations at the potentially hazardous objects

The name of the object	The type of the hazard	The qualitative characteristic of the hazard degree (ES, NS, QNS, SS)	The quantitative estimation of the hazard degree for QNS and SS cases
…………	…………	……………	…………

Note: The rows of the table are positioned according to the quantitative estimation of the hazard degree.

4 Summary

The proposed method is applicable to the cases where the situations are determined by the independent factors the influence of which on a hazard is monotonous. The monitoring function [3] is proposed as a measure of the joint deviation of the factor influence functions. It allows ranking the situations according to the hazard degree. The classification of situations is performed by testing the conditions [1], [2], and [4]. The adjustment of the monitoring session (H-key setting) provides the possibility to control the process of preliminary assessment. Depending on the circumstances, it is possible to detect the situations with different degrees of hazard, in the range from close-to-extreme to close-to-normal. As a result of this, the general efficiency of ASCAPA can be enhanced due to the separation of the normal and quasi-normal situations. That would allow the users to concentrate their attention on the extreme situations and on the suspect situations, which could turn into the extreme ones.

The proposed completed algorithm and the monitoring technology allow implementing the method in the form of the autonomous subsystem as the first stage of ASKAPA.

Bibliography

[Bi96] Bichenok N.N. Regional defense control during extraordinary situations. Controlled Systems and Machines, 1996, #4 - 5, pp. 47-57 (in Russian).

[MM90] Mushik E.; Muller P.: Methods for technical decision-making. Moscow, “MIR”, 1990 (in Russian).

[Sa80] Saati T.L. : The Analytic Hierarhy Process. Mc Grow Hill: New York- 1980.

[Se99] Serebrovsky A.N. : Control and analysis of the situations at the potentially hazardous objects. Mathematical machines and systems, 1999, #1, pp.98-117 (in Russian).