50 years University of Mining and Geology "St. Ivan Rilski"
Annual, vol. 46, part III, Mechanization, Electrification and Automation in Mines, Sofia, 2003,pp.253-257

ACCIDENT RISK ASSESSMENT AT THE ELECTRICAL ENGINEERING OBJECTS ON THE LINGUISTIC

Yuliya Podobna, Pavlo Molchanov, Tetyana Holyeva

Department of Environment Safety and Industrial Protection
Vinnytsia State Technical University
95 Khmelnytske shose, Vinnytsia, 21021, Ukraine
E-mail: envrisk@vstu.vinnica.ua

ABSTRACT
The method of accident risk assessment at the electrical engineering objects that including significant uncertainty of the input data is presented in this paper. The expert linguistic evaluation of the parameters of the electrical engineering object with the use of fuzzy sets is offered in the given task. It is suggested to use the method of risk-events when analyzing the risk of the electrical engineering objects. This method allows to get characteristic of the event risk together with the probability of the event occurrence at each stage of accident development. The risk-event method is based on the calculation s of the generalized tree of risk-events.
Keywords: **risk assessment, expert linguistic evaluation, fuzzy probability, tree of risk-events**

INTRODUCTION

Recently actual and complex problem is the estimation of risk of accidents at the atomic power plants. Safety of operation of the reactor installation is very important for a radiation safety at the atomic power plant The failure analysis of the equipment of generating sets for several years, including the period of mastering of generating sets, shows that the down time of generating sets is arranged as follows: because of turbo-installation 35,4 %, because of electrical generators - 31,3 %, because of pipelines - 14,6 %, because of an armature-13,6 %, because of transformers -3,8 %, because of reactor - 1,3 % [1].

The probability of an emergency brake of one of units of the reactor contour is rather small. Nevertheless, it is necessary to take into account the risk of rejection of the reactor, which can significantly exceed the risk of rejection of some other element of atomic plant. The solution of the given problem is complicated as many parameters of electric equipment have the large uncertainty. In such case the use of classical models of risk assessment (e.g. Monte Carlo method) [2] gives the result with uncertainty which exceeds the value of this result.

Instead of parameters with large uncertainty it is offered to use the expert linguistic logic evaluation of the parameters of the electrical engineering objects. The results of simulation have shown that the use of the Fuzzy Sets Theory [3] combined with the expert linguistic logic evaluation of the parameters the electrical engineering objects in a number of cases allows to get the risk assessment with the same accuracy as when using accurate numerical data.

STRUCTURAL IDENTIFICATION OF THE SIMULATION OBJECT

The nuclear reactor is used as the object of simulation in this work. Reactor installation consists of the main contour, reactor contour and the contour of circulation of the heat-carrier. A number of auxiliary systems relates to reactor. These systems and the reactor contour create the first contour: the system of volume compensation, system for clearing the water of reactor, the system of replenishment and damping of the reactor, the system of drains, the system of gaseous blowings, also the system of gaseous completion of reactor laying and the system of periodical disactivation of reactor installation.

Generalized diagram of the possible accident development for the above-described object is represented on the Figure1.

Designing of the structural diagrams of the development of possible accidents at the blocks of this structure represents detail study of the research object with taken into account all the factors that influence the object safety as a whole. The forecasting problem of the development of accidental situation comes to the object identification with one output and many inputs. The particularity of the linguistic evaluation is presentation of variables interdependence "input-output" in the form of expert statements: IF <inputs>, THEN <output>, which are fuzzy knowledge bases.

The basic characteristics of the object, that may course the accident is specified. The input variables is taken as the factors that influence the output event, i.e. the factors influence the accident occurrence. The output variable is the accident occurrence probability. Structural identification of the object "input-output" is made with the help of these variables and their linguistic evaluations based on the logical operations.

When developing the structural diagram of the occurrence and development of accident, the following actions have been done:

1.Collection and investigation of the technological factors that influence to the object safety as a whole.

2.Collection and investigation of the technical factors, such as damage of heat-producing element.

3. Collection and investigation of the human factors in the object's control system.

4. Collection and investigation of the factors which relate to the environment influence on the general safety of the object.

5. Study of the logical links between the influencing factors and its consequences.

As a matter of fact, the identification of the collected factors is the source of information for the development of the event tree of the investigated object.

PRINCIPLES OF THE LINGUISTIC SIMULATION

The logic eventual model of presentation of the input information is used for the determination of fuzzy probability of accident development. This evaluation of presentation of the fuzzy information is the most acceptable as it allows to formalize experts' knowledge represented in the form of linguistic evaluation in convenient and simple way. The basic principles of identification of the objects on the basis of fuzzy databases are represented [4,5]:

1. The principle of linguisticability of the input and output variables. According to this principle, the object's inputs and its output are considered as linguistic variables, which are evaluated by the qualitative terms.

2. ***The principle of structure formation*** of the "input-output" dependence in form of the fuzzy knowledge base. The fuzzy knowledge base is the totality of rules IF "inputs" THEN "output" which reflect the expert's experience and his/her understanding of the cause-and-effect relations for the decision making (forecast) of the investigated problem.

3. The principle of databases hierarchy. The development of system statements about the unknown dependency "inputs-output" becomes difficult, when there are large quantity of the input variables. Due to that, it is reasonable to classify the input variables and, according to the classification, construct an output tree, which specifies the system of nested statements.

4. The principle of the two-stage tuning of the fuzzy knowledge. According to this principle, the model making is done in two stages. These are the stages of structural and parametrical identification. Development of the fuzzy knowledge base based on evaluation of experts corresponds to the structural identification stage. However, the tweaking of fuzzy model can be done in concordance with experimental data for complete coincidence of the expert evaluation with the experimental data. The tuning is the selection of such fuzzy "IF"-"THEN" rules and such parameters of the membership functions that minimize the difference between experimental and simulated behavior of the object.

LINGUISTIC APPROXIMATION

The analytic-linguistic approximation is used to formalize cause-and-effect relations between the "input-output" variables, which are described in natural language with the help of linguistic variables. For this purpose, indefinite parameter q, which may correspond to the probability, reliability or to other characteristic, is transformed into a fuzzy number $\tilde{q}$. I.e., its membership function is specified. Having the expert information about the parameter: title of the parameter q; range [q, q] of alternation of the values of parameter q; number of linguistic terms to evaluate the parameter q; title for each linguistic term; its membership function is constructed. For the triangular form of the fuzzy number q:

$$\tilde{q} = \left\langle \underline{q}, \bar{q}, \hat{q} \right\rangle, \tag{1}$$

where: $\underline{q}(\bar{q})$ is the lower (upper) boundary of the fuzzy number $\tilde{q}$ at zero level; $\hat{q}$ is the value of the fuzzy number $\tilde{q}$ at a single level.

When the number of input variables is large, construction of the fuzzy knowledge base becomes difficult. That is why it is reasonable to do the classification of variables and according to it to build the inference tree, which determines a system of nested fuzzy knowledge bases tied with cause-and-effect relations. Stepwise information's about the logical connections between the events that influence the final result and calculation formulas of the probability of these events are placed into the Table 1.

*Table 1:*Stepwise calculation

INPUT VARIABLES	OUTPUT EVENTS	LOGICAL OPERATION	FORMULAS OF CALCULATIONS	
			$\tilde{P}$	$\tilde{R}$
x_1, x_2, x_3	A	AND	$\tilde{P}_A = \tilde{P}_{X_1} \cdot \tilde{P}_{X_2} \cdot \tilde{P}_{X_3}$	$\tilde{R}_A = \sum_{i=1}^{3} A_{X_1} \cdot M_{ij} + A_{X_2} \cdot M_{ij} - A_{X_3} \cdot M_{ij}$
x_4, x_5, x_6	B	OR	$\tilde{P}_B = 1-(1-\tilde{P}_{X_4}) \cdot (1-\tilde{P}_{X_5}) \cdot (1-\tilde{P}_{X_6})$	$\tilde{R}_B = \max\left(A_{X_4}, A_{X_5}, A_{X_6}\right) \cdot M_{ij}$
A, B	T	OR	$\tilde{P}_T = 1-(1-\tilde{P}_{X_A}) \cdot (1-\tilde{P}_{X_B})$	$\tilde{R}_T = \max(A_A, A_B) \cdot M_{ij}$

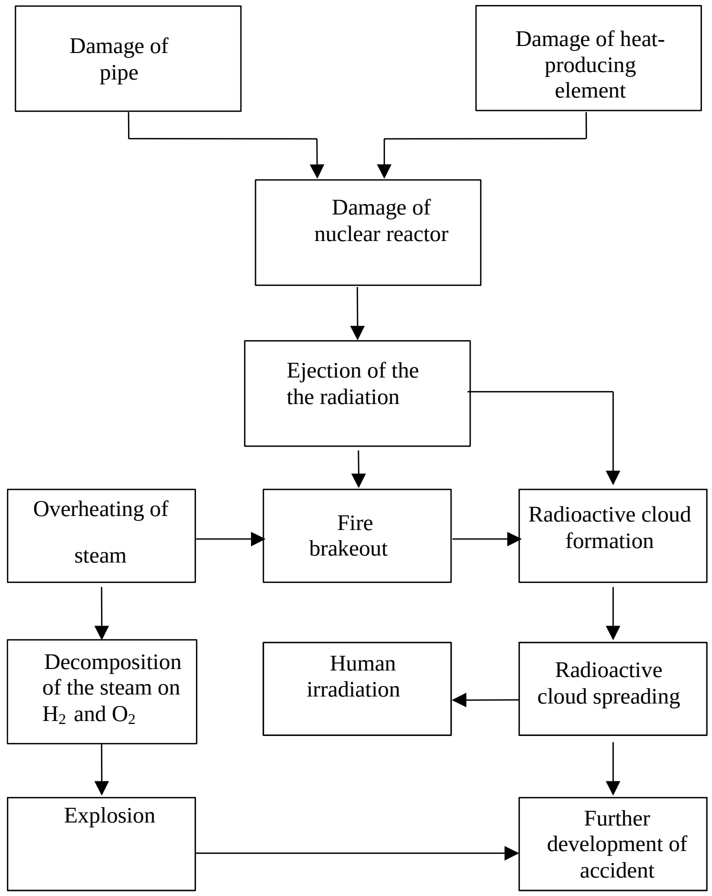

Figure 1. Generalized diagram of the possible accident development

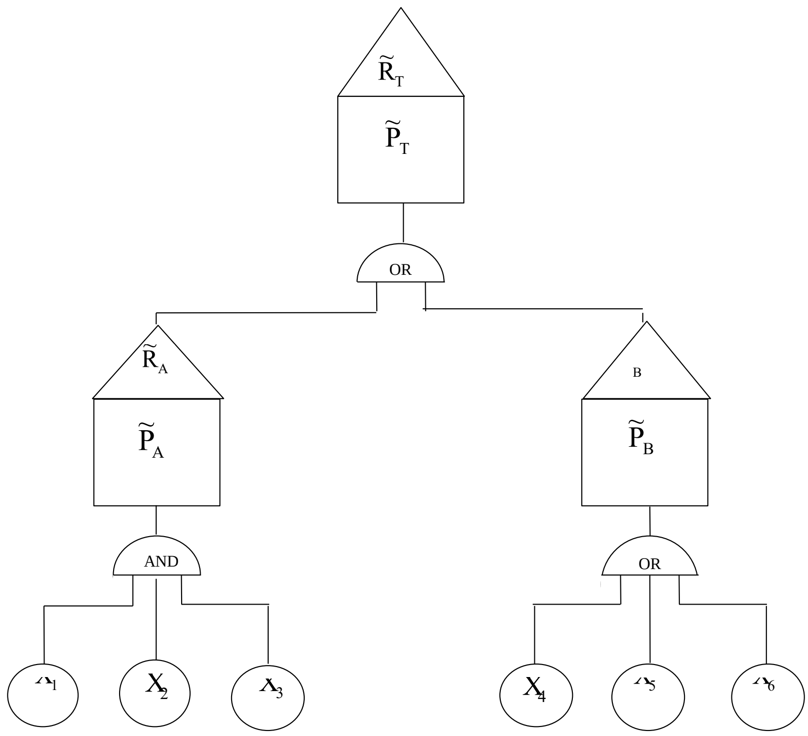

Figure 2. Fragment of the generalized tree of risk-events:

where: X_1-X_6 are basic events determined by the expert evaluation.

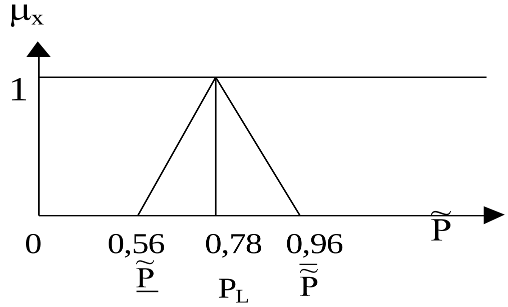

Figure 3. Membership function for $\widetilde{P}$ *.*

Hierarchical interconnection between the input variables, classes of input variables and the output variable is presented in the form of generalized tree of logical inference [3]. The obtained logical structure is described by the mathematical model, which takes into account the logical structure of the tree and number of its levels:

$$\widetilde{P}_n = \left[\left(\bigcup_{i=1}^{K}\widetilde{P}^i_{n-1}\right) V \left(\bigcap_{i=1}^{K}\widetilde{P}^i_{n-1}\right)\right], \qquad (2)$$

where: $\widetilde{P}_n$ is the fuzzy probability of the event occurrence at n-th level; $\widetilde{P}_{n-1}$ is the fuzzy probability of occurrence of the i-th event at level n-1; $\bigcup, \bigcap$ is the signs of intersection and union of the sets;V is the sign of the logical function "OR"; n is the number of the level at which probability is determined; i = 1...k is the number of events at the given level, "~"- sign of fuzziness.

GENERALIZED TREE OF RISK-EVENTS

The generalized tree of logical inference allows to follow up cause-and-effect relations of the accident development. It allows to analyze various scenarios of the accident development and evaluating the occurrence probability of various emergencies. However, in order to make decision about closing an accident - power engineering object or about measures of minimizing the accidental risk, it is necessary to evaluate the greatest eventual risk and accident development scenario, which is connected with it. The generalized tree of the logical inference does not provide the decision of calculation of the risk for the concrete scenario of the accident development, e.g., for the scenario that has the greatest probability and minor losses, or for the scenario that has small probability and major losses. That is why the authors suggested to introduce an additional vertex of risk applied to all basic intermediate and vertex events [5]. It is offered to call the obtained structure as event-risk method. The mathematical model that describes "AND-OR" structure of accident development and risk for the event is represented as follows:

$$\widetilde{R} = \begin{cases} \sum_{k=1}^{m} (\widetilde{A}_k \circ M^k_{ij}) \;, \\ (\max \widetilde{A}_k) \circ M^k_{ij} \end{cases} \qquad (3)$$

where: k = 1-m-i is the number of factors, which influence to the risk; M^k_{ij} is the relations matrix; $\widetilde{A}_k$ is the fuzzy losses (expenditures), $\circ$ is the composition of fuzzy sets.

The fragment of the generalized tree of risk-events is given in Figure 2.

The advantage of the offered method is that it allows at each level of the accident development, together with the probability of the event occurrence, to get characteristic of the event risk. As a result:

- foremost, we are able to determine the event that has the greatest risk and to make appropriate decision concerning it.
- the second, when maximum of the risk is determined at each hierarchical level we can find a scenario that leads to the event with greatest risk and take measures to prevent it.
- the third when scenario of the greatest risk is known it is possible to minimize the volume and, hence, the cost of calculations which should be undertaken before decision making.

ADEQUACY EVALUATION OF THE OBTAINED RESULT

Calculation of the fuzzy probability of the accident occurrence has to the following result:

$$\widetilde{P} = (0{,}56;\ 0{,}96;\ 0{,}78) \qquad (4)$$

The membership function, which reflects the obtained result is represented in Figure 3.

The obtained result can be interpreted as follows: the lower evaluation boundary of the accident occurrence - $\widetilde{P}$ =0.56; the upper - $\widetilde{P}$= 0.96; mean value, which corresponds to the linguistic assessment - $\widetilde{P}$ =0.78. Thus, the span of the accident occurrence is located within 0.56 to 0.96 with the most probable value 0.78.

To evaluate the obtained result, it is necessary to calculate the degree of equality of the fuzzy sets: the set specified by the expert and the set obtained as a result of calculations. The degree of equality $\mu(\widetilde{A},\widetilde{B})$ of the fuzzy sets ($\widetilde{A}$ and $\widetilde{B}$) is described with the following expression [3]:

$$\mu(A,B) = \underset{x\in X}{\&}(\mu_A(x) \leftrightarrow \mu_B(x)),$$

where: "$\leftrightarrow$" - operation of equivalency of fuzzy sentences; "&"- operation of conjunction.

If $\mu(\widetilde{A},\widetilde{B}) \geq 0,5$ then sets $\widetilde{A}$ and $\widetilde{B}$ are fuzzy equal. Meanwhile if $\mu(\widetilde{A},\widetilde{B}) \leq 0,5$, then sets are not fuzzy equal.

A fuzzy set specified by an expert and such that corresponds to the evaluation "High" (it means high probability of the risk of the accident occurrence) - (0,8/0,57; 0,6/0,52; 0,1/0,9). The fuzzy set obtained as a result of calculation: (0,3/0.57; 0,6/0,59; 0,7/0,72).

$$X=\{x_1, x_2, \ldots x_5\}, \quad (5)$$

$$A=\{\langle 0,8/x_2\rangle, \langle 0,6/x_3\rangle, \langle 0,1/x_5\rangle\}, \quad (6)$$

$$B=\{\langle 0,3/x_1\rangle, \langle 0,6/x_2\rangle, \langle 0,7/x_3\rangle, \langle 0,2/x_4\rangle, \langle 0,3/x_5\rangle\} \quad (7)$$

Therefore it is possible to make a conclusion about equality of fuzzy sets: $\widetilde{A} = \widetilde{B}$; $\mu(\widetilde{A},\widetilde{B}) = 0,65$.

CONCLUSIONS

It is offered to use the expert linguistic logic evaluation of parameters of the power-engineering object when evaluating the risk of the objects with large uncertainty of input data. Use of the Fuzzy Sets Theory combined with expert linguistic logic evaluation of parameters of the power engineering object in many cases allows to get the risk assessment degree practically with the same uncertainty as when using accurate numerical data. It is suggested to use the risk-event method when analyzing the risk of the electrical engineering objects. The risk-events method is based on the calculations of the generalized tree of risk-events. The advantage of the suggested method is that it allows to get characteristic of the event risk together with the probability of the event occurrence at each stage of development of the accident. As a result:

- we can determine the event that has the greatest risk

and make appropriate decision regarding it;

- when maximal risk is determined at each hierarchic

level, we can specify a scenario that leads to the event with greatest risk and take measures to prevent the event;

when scenario of the greatest event risk is known it is possible to minimize the volume of calculation and, hence, time and cost of calculations to do the decision making.

REFERENCES

Petrosyants A. Atomic Science and Technique (1987). Moskow,312 pp.

Dennis C. Bley. (May 4, 2000). Accident Risk Assessment. *Presented at NATO ASI : Risk Activities for the Cold War Facilities and Environmental Legacies.* Bourgas, Bulgaria.

Gene Whelan, James G. Droppo. (May 4, 2000) Advantages/Disadvantages of Multimedia Assessments. *Presented at NATO ASI : Risk Activities for the Cold War Facilities and Environmental Legacies.* Bourgas, Bulgaria.

Zadeh L.A. (1965). Fuzzy Sets. Ing. Control. Vol. 18, pp.338-353.

Rotshtayn A.P. (1999). Intellectual Technologies of Identification: Fuzzy sets, Genetic Algorithm, Neural Nets. Vinnytsia, Universum-Vinnytsia, 320 p.

Filinyuk N.A., Molchanov P.A.,Dudatiev A.V. (July 1-3,1998). A Comprahensive Estimaton of Industrial Vehicle Safety. *Int. Conf. On Advances in Vehicle Control and Safety*. Amiens-France.

-