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Membrane method in assessment of organizational and technical reliability of NPP construction projects

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The materials of the presented research paper are based on the analysis of recommendations for improving the organizational and technical reliability of planned solutions in the conditions of system risk at the stage of preparation and the main phase of construction of large industrial complexes, such as a nuclear power plant (NPP). The system analysis carried out by the author forms the basis for methodology recommendations on the selection of a rational option of work plan for the construction of a technically complex industrial facility. The conclusions are made on the basis of the development by the author of his own simulation model of risk analysis using a modern approach to the application of automated systems for scheduling production processes of NPP project implementation, including at the international intergovernmental level.
The research paper characterizes theoretical methods and practical recommendations for the development and selection of a rational variant of work organization at the NPP construction site at all stages of the project life cycle. As a basis for selecting the most rational work organization plan, the author proposes to develop and implement a simulation model on the basis of the Membrane Method, which accumulates data for comparative analysis of the results of all project systems. The essence of this Membrane model is described below.
The paper presents the main requirements to the technical specification for the domestic development of software for processing the data of risk analysis for the NPP construction project realization at each stage of the project life cycle.
Keywords: *nuclear power plant (NPP), NPP construction, NPP reliability management, NPP construction risk management, construction economics, industrial construction, multi-criteria reliability assessment, enterprise economics, mathematical modelling, machine risk modelling, automatic control system*

INTRODUCTION

In the presented research paper, the author identifies the challenges of the modern international market of nuclear energy, analyses domestic and international experience in the construction of technically complex megaprojects, studies and systematizes organizational and technical aspects of the concept of reliability and risks of technically complex industrial facilities, based on the example of an international project for the construction of a nuclear power plant (NPP).

The author seeks to solve one of the most important problems — to define risk and its assessment in an inextricable connection with the life cycle stages of projects in the field of peaceful atom applications.

Both the principles of assessment of organizational and technical reliability of the system under study and the methods of reliability and risk assessment have been systematized. The author developed his own multi-criteria approach to the concept of reliability using modern theoretical methods in the context of the development of NPP construction projects abroad, taking into account global and intergovernmental risks.

Analysing the methodological recommendations for improving the system of preparation and execution of construction works of large and technically complex industrial complexes, the author proposes ways to improve the organizational and technical reliability of design solutions under risk conditions. Thus, the author develops and implements his own concepts and methods of reliability and risk assessment, namely the Membrane Method of NPP risk estimation by Sezemin D.E. This method views each stage of the project life cycle as a layer of membrane, where first one or another risk emerges and then passes, or rather, "germinates" or evolves into the next layer (the next stage of the project life cycle), having the opportunity to pass through all layers of the membrane or, conversely, end on a certain layer, having had its impact. Risks can grow, appear or disappear at any stage, starting from the first and ending at the top of the layers. The development of the software, necessary and recommended by the author of this paper, based on the membrane method will allow visualizing (by adding a contrasting colour) how much the risk affects the final target parameters of the whole system. Introducing the concept of "target parameters of the NPP construction system", the author adopts the following four parameters of the system: timing, economic efficiency, quality, and safety, associating them with the four corners of a square. The presented description of the membrane model in the form of a three-dimensional figure allows visualizing in the form of an image, as well as in the form of a risk dynamics graph, the main aspects of the investigated problem:

- the fact of risk existence;
- the stage of risk occurrence;
- the stage of risk impact termination;
- at all stages of the life cycle, the impact of each of the risks separately on the system of the organizational and technical reliability of the project;

- the impact of all risks on the system, assessed by four angular parameters;
- the assessment of the risk impact can be done before and after taking compensating measures.

THE MEMBRANE METHOD

Having analysed current theoretical and practical problems faced by the executor and the customer of EPC-contracts[1] used as a modern risk management tool[2], the author sees the need for a comprehensive study of the issues related to non-performance, improper performance, liability, and risks of failure to achieve or obtain the full economic effect from the realization of megaprojects that are implemented on the basis of international contracts and intergovernmental agreements. These issues are becoming increasingly relevant in the field of nuclear energy and peaceful atom applications.

At the same time, the very application of the EPC-contract in NPP project realization, on the one hand, allows the transfer and delegation of risks, and on the other hand, the system of risk management itself, mitigation and compensation of their consequences is transferred to the contractor's area of responsibility, while the project risks themselves are retained and even increased, or new types of risks are added. In this publication, therefore, the idea of risk mitigation and management through the EPC-contract is seen as not dominant, and risks are treated in their pure form impersonally and independent of economic agents, Customer or Contractor.

The basis for the preparation of this paper is a thorough long-term analysis of scientific and methodological recommendations for improving organizational and technical reliability of design solutions under risk conditions at various stages of the NPP project life cycle. This work allows the author to develop his own recommendations on selecting a sound risk management option and to develop the terms of reference for a new national automated process control system. As a basis for the terms of reference, it is proposed to apply the newly developed membrane method of risk assessment and management.

When developing the concept of our own methodology of reliability assessment and risk management, it should be noted that one of the fundamentals of such management is the development of a certain management strategy, when an individual reliability and risk management strategy is implemented at the enterprise. The methodology determined by the modern development of the scientific and technical sphere recommends applying long-term, medium-term and short-term strategic planning, which is also acceptable for reliability and risk management of the main phases of the life cycle of the NPP construction project.

Management of both internal and external risks can be carried out on the basis of a specially created ACS TP (automated control system of technical processes) at the enterprise, which is a set of hardware and software that monitors and controls production and technological processes, maintains continuous feedback and actively influences the process in case of deviation from the specified parameters, as well as provides regulation and optimization of the controlled process. On the basis of his own developments and methods described in this publication, the author proposes to take the following requirements for the ACS development as a basis for the technical specification:

- the product should be designed to automate a specific facility;
- the product stabilizes the specified modes of the technological process by measuring and processing the values of technological parameters, visualizing and issuing control actions (in real time) on the working mechanisms in automatic and semi-automatic mode (if applicable to a particular production process, taking into account the technologist-operator's actions);
- the product analyses the current state of the technological process, allows to identify pre-emergency situations and prevent accidents by transferring technological units to a safe state, both automatically and under the control of operating personnel;
- the product provides the engineering and technical personnel of the enterprise with the necessary information about the technological process for solving the problems of control, accounting, analysis, planning and management of the production process.

In a broad sense, the engineered ACS, in our opinion, should be based on a feasibility study of the NPP project, which specifies the capacity of the NPP, the number of power units, the number of reactors within a reasonable feasibility study, specifies the region of construction, estimates the investment volume of investment, and includes calculation of the project payback, project profitability and return on investment.

Further, the author proposes to divide the ACS into levels and suggests the following division acceptable for NPPs:

1. The level of technological process (field level).
2. The level of control and management of the technological process (controller level).
3. Baseline network level (network).
4. The level of man-machine equipment (top level).

As a result of the conducted research, the basic principles of the cybernetic model of a modern Russian-made ACS for NPP projects have been determined. The development stages include the following steps (Note: the presented plan is equally applicable to the development of the proposed risk assessment and management method):

1. Definition of technical requirements to the control and management system.
2. Development of design and cost estimate documentation.
3. Collection and analysis of initial data.
4. Compilation of a complete list of variables.
5. Completion of the ACS system (risk assessment).
6. Division of the control facility into technological sections and subsequent allocation of variables to sections and groups.
7. Creation of in-house databases (libraries).
8. Creation of a graphical interface of the screens of operators and control personnel (links) alternately in dynamics and statics.
9. Creation of transition schemes from static to dynamic images on screens.
10. Development of control algorithms (for all possible modes of operation of the facility, including emergency and post-emergency).
11. Creating the possibility of generating printed documents by sending to printers in subdivisions (in order to save time).
12. Verification of databases.
13. Preparation of operational documentation.
14. Testing of the system in stand-alone mode.

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1 Engineering, procurement, and construction. URL: https://ru.wikipedia.org/wiki/EPC_(контракт)

2 EPC contract. Neftegaz.RU. URL: https://neftegaz.ru/tech-library/menedzhment/141747-epc-podryad-kontrakt/#:~:text=EPC%20-%20контракт%20(Engineering%2C%20Procurement%2C,фиксированной%20цене%20к%20фиксированной%20дате

15. Testing of the system in operational mode.
16. Formal implementation, commissioning, personnel training, issuance of relevant orders and instructions.

In the proposed risk management model, the development of the ACS TP model at the feasibility study is a strategically planned step. In parallel with the risk management model, a system of continuous risk assessment and control is being implemented, leading to the achievement of the main four project objectives, such as:

1) project timeline;
2) costs;
3) project quality;
4) project safety and security.

The membrane method of risk assessment is based on the algorithm for calculating the full economic result of the risk management strategy for each stage of the NPP project life cycle. For the purposes of this study, the following steps or layers of a membrane-based risk management approach are identified, followed by software development based on the membrane method of risk management:

1. Initiation.
2. Planning.
3. Development of criteria and strategy for NPP location (interrelated with items 3–6, 9).
4. Design (interrelated with 1, 3–9).
5. Construction (interrelated with 1).
6. Commissioning.
7. Operation.
8. Extension of operation (modernization).
9. Termination of operation.
10. Shutdown of processes.
11. Decommissioning [1].

Each of the eleven project phases represents a layer of the risk assessment membrane system (Fig. 1, Table 1, 2).

Risk accounting and analysis by membrane method will allow to present calculation of the full economic result of the risk management strategy for each period of project development (Fig. 2).

The 3D representation of the membrane method (membrane model) is as follows: risks by groups form the membrane layers, which, in turn, form the so-called “membrane pie” by stacking layers on top of each other The layers are arranged horizontally in the order of the life cycle stages of the project of a technically complex facility — a NPP. The lattice of stacked membranes has several effects: “spring effect,” “impermeability effect” (hereinafter impermeability is understood as the optimal degree of overall project reliability), and “layer – problem – balance” effect. It should be noted that the description of the membrane method with the help of a 3D picture gives an idea of the significance and relevance of the task of systematization and digitalization of big data in the field

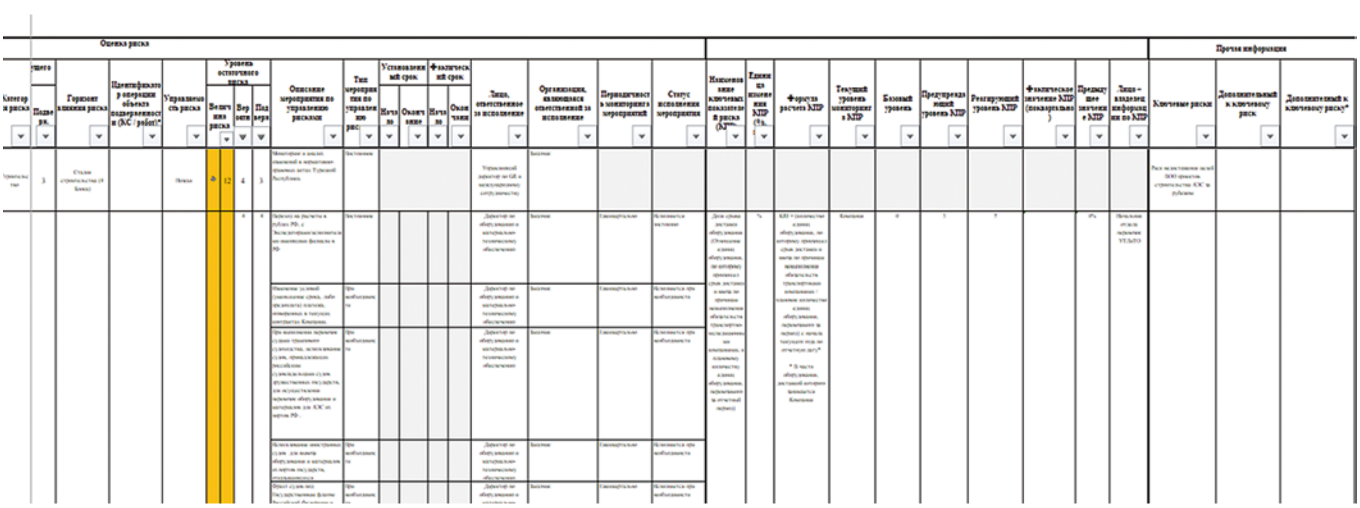

Fig. 1. Example of a risk summary table

Table 1. Example of a summary table of risk factor impact assessment

Impact on volume	Impact on safety	Impact on the public	Impact assessment
Changes in volumes can be covered by current contractual obligations	The assessment of the impact of risks on safety is carried out in accordance with the requirements of current legislation and local regulations. Methods of risk prioritization, scoring scales and significance criteria for environmental safety, industrial safety, occupational safety, information security and other related risks are set out in special documents issued under the Project	The level of decrease in public trust at the local level is insignificant	1
Additional agreements are required within the existing contractual framework		Decrease in the level of public confidence at the local level. Short recovery period	2
Additional agreements with Contractors required		Decline in public confidence at the regional level. Short/moderate recovery period	3
Additional agreements with the Client required		Decline in public confidence at the international/regional level or at the level of important partners. Moderate/long recovery period	4
Revision of substantial terms of EPC contract/ contract with Tier 1 Contractor required		Damage to public trust at international or key partner level. Long recovery period	5

Table 2. Assessment of the impact of risks with background colouring

Probability	Impact assessment				
	1 Very low	2 Low	3 Medium	4 High	5 Very high
5 Very high	5	10	15	20	25
4 High	4	8	12	16	20
3 Medium	3	6	9	12	15
2 Low	2	4	6	8	10
1 Very low	1	2	3	4	5

of assessment and reduction of the maximum possible number of risks in the work of technically and organizationally complex construction projects.

The membrane method of reliability and risk assessment of a technically complex production system is based on the following concepts:

1. Risk value — an indicator that determines the weight (significance) of a particular type of risk in relation to other (accepted in the system) types of risk.
2. Risk register — types of risks defined as significant for a particular technically complex production system.
3. Risk probability degree — probable, unlikely or improbable possibility of occurrence of the given type of risk depending on the possibility of occurrence.
4. Risk expert panel — a collegial body (project team) specially formed for the project realization, which includes experts for each type of risk, as well as staff and engaged specialists for the development and implementation of software representing the corresponding membrane-type simulation model.
5. Acceptable risk — the amount of risk that is tolerated by the simulation membrane model.
6. Compensatory measures — a set of actions leading to reduction of the risk value to an acceptable one.

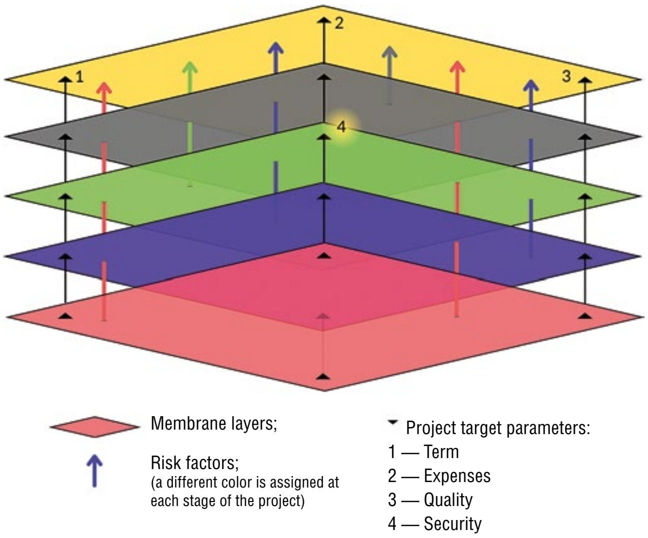

Fig. 2. Illustration of the Membrane Method for assessing the organizational and technical reliability of a project

7. Main risks — the most significant risks in terms of their magnitude.
8. Risk — a possible danger, threat of an adverse event, as well as an unexpected (including favourable) result of actions or event development, measured through the probability of event occurrence and the amount of damage (result adjustment) from a certain action [2].
9. Risk owner — a person responsible for a certain risk or group of risks within the project at all stages of the project life cycle.
10. Risk response strategy — a decision based on the outcome of risk and its economic effect, including such types as (from smaller to larger) reduction, acceptance, increase to an acceptable value, elimination, postponement of the stage[3].
11. Risk management — a system adopted at the enterprise, aimed at influencing the risks identified or predicted and modelled in the course of analysis.
12. Risk factor — cause, event, action (inaction), activity, influencing the occurrence and possibility of risk adjustment.
13. Risk management measures — planned and emergency measures taken to manage risks.
14. Risk immanence — a state of the system, in which the risk, as well as its analysis and management are a permanent internal property of the system, inherent in the project at all stages of its life cycle and requiring continuous ongoing monitoring, due to empirically achieved understanding of the possibility of new unplanned risks at any stage of implementation of a technically complex project.
15. Risk reporting — the process of preparation and approval of data on risk analysis, results of risk analysis, measures taken to manage risks and the economic effect of these measures, formalized (reported) in accordance with the internal regulations of the company, as well as the requirements of GOSTs for each risk or group of risks at each stage of the life cycle of a technically complex project.

In order to form a risk analysis system based on membrane-based reliability and risk management, we propose to divide the process into the following steps:

1. Search and identification of risks.
2. Verification of risks with the help of system methods used in the organization (checklist, decision tree, event tree, "what will happen if" method, as well as the expert method described in detail in Chapter 2 of the presented qualification work).
3. Entering risks into a unified system adopted at the enterprise and using network schedules, test reports, surveys of specialists with data entry into questionnaires, which is described in detail and systematized by the author in Chapter 2 of the presented qualification work.
4. Identification of planned risk parameters, deviations from which are planned to be controlled and, if necessary, corrected subsequently at all stages of the system life cycle.
5. General description of risk is performed for all types of risk and includes:
   - description of risk;
   - possible consequences of risk by options;
   - the impact of risk on the timing of the project;
   - the monetary value of risk, affecting the total cost of the project; in this case, compensation measures,

3 In the presented work the concept of risk transfer to an external counterparty is not considered due to the fact that, regardless of the risk owner, this risk is to be managed as a contractual arrangement and on the basis of labour relations and internal regulations of the company; the risk owner does not change, and his competence is expanded, integrating the function of "risk curator" that is, the person responsible for interaction with the counterparty who technically accepts the risk.

the decision taken, as well as the result of such a decision are formalized at a later stage of the membrane-based risk management process.

The general formulation of the risk should contain, in addition to the name of the risk, its causes, consequences of its occurrence and the degree of impact on the project objectives, according to the membrane method, and an assessment of the impact on the overall economic performance of the project.

It should be noted that to assess the risks of technically complex production systems, the author proposes to abandon the often used so-called pyramidal system of risk accounting, based on hierarchical structuring of risks, because newly emerging risks at any stage of the life cycle of the system can and will claim a more important place in the already formed pyramid of risks. The membrane type of risk stacking allows to supplement the already existing risk structure with risks added to the system and to create an interpenetrating fine-mesh structure of all risks of the project.

6. After determining all risks of the system (with understanding of the immanence of risks of the project system), their classification is carried out, which can be based on the method of TECOP SH — technical, economic, commercial, organizational, political, supplemented by the author of this research qualification work by the classification oh the social-humanitarian principle, including such groups of risks as demographic, the position of the company in society, its reputation, etc., as the basic approach to the classification of risks[4] [3] .
7. Risk assessment — the result of the risk assessment process is the determination of the impact of a certain risk on the project parameters included in the feasibility study. Qualitative risks are divided by the degree of influence on the project; quantitative risks differ on the basis of probabilistic assessment.

Table 3. Risk scale. Layer 1

Type of budget risk for project implementation	Budget growth in % up to 1 %	Budget growth from 1 to 2 %	Budget growth from 2 to 3 %	Budget growth from 3 to 4 %	Budget growth from 4 to 5 %	Budget growth from 5 to 6 % and so on
Design delay						
Delay in construction works						
Delay in equipment delivery						
Level 1 human error resulting in accident and equipment failure (by type of equipment)						
Changes in average annual air temperature by 1° C						
Currency exchange rate fluctuations						
Strike of transport workers for 10 days or more						

Table 4. Risk scale. Layer 2

<table>
<tr><th colspan="2" rowspan="2">Target indicator</th><th colspan="5">Weight/qualitative indicator</th></tr>
<tr><th>Item No.</th><th>Item No.</th><th>Item No.</th><th>Item No.</th><th>Item No.</th></tr>
<tr><td rowspan="2">Budget</td><td>Operational costs</td><td rowspan="2">Increase by 1 %</td><td rowspan="2">Increase by 2 %</td><td rowspan="2">–</td><td rowspan="2">–</td><td rowspan="2">–</td></tr>
<tr><td>Capital expenditures</td></tr>
<tr><td colspan="2">Schedule</td><td>Delayed by 0 month</td><td>Delayed by 1–2 months</td><td>Delayed by 3–4 months</td><td>–</td><td>–</td></tr>
<tr><td colspan="2">Quality</td><td>No deterioration</td><td>Minor impact (on part of project activities), possible adjustment</td><td>Requires Client approval</td><td>Unacceptable</td><td>The project is better not to be implemented in this capacity</td></tr>
<tr><td rowspan="4">Safety</td><td>ecological</td><td colspan="5" rowspan="4">On the basis of a specially created expert panel, legislative requirements and internal regulations and rules, an appropriate membrane layer of risk impact on project safety is described, taking into account the assessment of costs to ensure the required level of safety. It is included in the terms of reference for the development of software for the risk assessment system using the membrane method</td></tr>
<tr><td>industrial</td></tr>
<tr><td>information</td></tr>
<tr><td>labour safety</td></tr>
</table>

4 According to the data collected by the authors of the paper “Development of risk classifier as a stage of successful risk management” published in the scientific and practical journal “Problems of risk analysis”, Rosatom Corporation uses the TECOP classification as a basic approach to the classification of risks. This classification was the basis for the development of the Electronic Risk Classifier as part of the Unified System of Classification and Coding of Nuclear Energy (USCC NE).

For qualitative assessment of risks, the author proposes to introduce weighting of each risk individually and in groups, with a total weight of 100.

The author of the presented research and qualification work proposes to identify four main target parameters, which are affected by risks (groups of risks) and in general the risk exposure of the enterprise, namely:

- project realization timeline;
- budget of the project realization;
- quality of the project and its products;
- project safety.

For the Project Implementation Budget indicator it possible to introduce the following system of data recording on risk analysis types, expert assessment of their impact on the target indicator of the project, and the weight of each risk (Table 3, 4).

8. Risk ranking. The assessment is made by evaluating the impact of the relevant risk on the project targets, having previously determined the magnitude of each risk by applying the previously described scoring system — the probability of risk occurrence and the risk exposure of the system. The formula is straightforward:

$$R = P \cdot V,$$

where R is scoring of the value of a particular risk; P is score risk assessment; V is scoring of the system exposure to the risk.

Here a convenient method is to fill in the table with values of negative consequences of risks or the matrix of possibilities (positive consequences) in the form of a table of risks in the form of a table (it is not the values themselves that matter, but the location of their gradient in Table 5).

9. Identify recommended strategies for the effective impact of risk management activities on project targets.
10. Present the data to the risk expert panel. The results are summarized in a table using the following example (Table 6).

Table 5. Gradient arrangement of risks

Probability	Impact assessment				
	Very low	Low	Medium	High	Very high
Very high					
High					
Medium					
Low					
Very low					

Table 6. Development of strategies and interventions based on the risk score determination

Risk score (determined by experts)	Strategy	Measures
1–4	Acceptance	Control measures
4–15	Control (reduction)	Compensatory measures, continuous monitoring
15–25	Reduction, rejection	Compensatory measures, continuous monitoring

11. Calculation of residual risk after application of compensating measures is the next stage of the algorithm of work with the risk management system. The calculation is recommended to be carried out in two directions: assessment of the possibility of influence on the probability of occurrence of a risk event and assessment of risk on the possibility of application of compensating measures. Here the derived function formula is applied, similar to the risk analysis, when the value of multipliers is reduced by the value of manageability for each type of multiplier. Manageability can also be determined by expert judgment, when each score (on a selected scale) is assigned a degree from 0 to 100.

The final value of residual risk is calculated as arithmetic mean of the normal Gaussian distribution, where the upper and lower values of the studied parameter are not included into the area of analysis.

For quantitative assessment of risks, simulation models are used. Each risk is assigned a rating in the form of a number, the impact of risks on the project is assessed both for each risk separately and for all of them together. After reducing the degree of risk, a second assessment is done, based on the identified trends, and a decision is made on the further implementation of compensatory measures. The Monte Carlo method is used, based on the use of random number sampling. A special algorithm assigns a random event, with the help of which the probabilistic problem is solved. This method replaces complex algebraic computations in the following three cases:

- when modelling complex operations with interaction of many random factors;
- when verifying the applicability of analytical methods of research and clarifying the conditions of their applicability; it should be taken into account that the calculations are carried out repeatedly (e.g., 100 times);
- when developing corrections to empirically derived analytical formulas [4].

Speaking about the proposed method of risk assessment, it should be noted that the author uses the parametric method as a sub-method (for systems that do not have well-defined planned costs and terms of implementation, in particular, for the assessment of projects at the feasibility study stage). An example of a risk assessed by such a sub-method is the probability of failure to build a nuclear power facility in a given location, as in the case of the transfer of the construction site of the Turkish NPP to Akkuyu from another province. In 1980, the planned location for the NPP was Inceburun in Sinop province, and later it was transferred to Akkuyu, the Gulnar district of Mersin; "in 2017, the Turkish Atomic Energy Agency approved the design parameters of the Akkuyu NPP site" [5]. This case is also suitable for risk assessment using the parametric method due to the on-going situation with the postponement of the launch date and, in general, the entire realization of the Turkish NPP project.

Based on the results of identifying all possible types of risks and their assessment using the presented methodological approaches, risk registers are developed, both integrated (for the entire project) and localized (by project subdivisions), and experts on a particular type of risk are involved in the finalization of each of the registers.

The author of the presented research proposes to organize the activity within a single scale from risk acceptance to risk avoidance (exclusion of action) and then divide the risks into groups depending on the degree of riskiness of action:

1. Acceptable risks are those that can be accepted at a given stage of the project life cycle; it should be noted that risks at different stages of the project life cycle are also distinguished

by the degree and the actions that need to be taken to bring the risk to an acceptable level.
2. Risks that should be reduced are those whose management reduces the likelihood of an event. Staff training is a prime example.
3. Risks that should be increased are those leading to positive effects for the project.
4. Planned risks are risks for which it is possible and acceptable to develop and implement an action plan to reduce risk to acceptable levels.
5. Transferable risks, for which the best solution is to transfer them on a contractual basis under certain guarantees and responsibility of the contractor.
6. Avoidable risks are those that result in the avoidance of a given action or such a significant change in the operation of the system that eliminates the risk.

The author believes it is advisable to separately identify and analyse the risks that may hinder the implementation of strategic goals of the State Corporation through the implementation of a specific NPP construction project, namely:

- increasing the share in the international nuclear power markets;
- reduction of production costs;
- reduction of production process time;
- introduction of new products to the market;
- global leadership in the field of technology [3].

Risk analysis through the membrane of strategic goals of Rosatom State Corporation is the most important objective of the methodology developed by the author of the research work.

The introduction of the membrane method of risk assessment allows monitoring of all types of risks at all stages of the NPP construction project life cycle due to the unified systematization of all types of risks in one software program. This constant monitoring is achieved by the idea of development and implementation of a subfunction of regular system queries within a single software product. This software should work similarly to the M2 DSS banking product, which links the registration of a real estate transaction with the fact of its payment by disclosure of a confirmed letter of credit, sending electronic requests to the Russian State Register (operating on an electronic online platform). There can be about twenty such requests per day; after a positive response the funds are unblocked and the transaction is completed. In the described risk assessment system, it independently (without human participation) requests codes (including readings from sensors of temperature, pressure, altitude, chemical composition of the air in the system, and even daily medical examination of employees), the frequency of such readings is determined by expert judgment and passed to the developer for the creation of an algorithm in the form of a protocol of the expert panel and the terms of reference for development.

It is worth mentioning that in the domestic economic science an important place is given to the analysis of risks in the sphere of development and real estate, and since no industrial project is created in isolation from the facility, it is necessary to take into account such risks analysed in the works of scientists as market risk, risk of planning approval, risk of inexperience of the developer, financial risk and risk of construction costs, as well as time risk [6].

CONCLUSIONS

In conclusion, the author would like to highlight the main novelty ideas of the Membrane Method of risk analysis developed by Denis Sezemin:

1. Distribution of risks by membrane layers. Each membrane layer is a stage (and its internal sub-stages) of the life cycle of the system; each risk presented in the membrane system is taken into account and considered a "sprout" that starts its way in the layer where it appears (or manifests itself) and can grow through all membrane layers, affecting the target indicators of the project.
2. The Membrane Method represents a unified system of risk analysis regardless of risk category and degree, based on three — quantitative, qualitative and parametric — methods.
3. By analogy with the medical method of contrast ultrasound (CT), the system allows using the colour contrast function to visually track certain types of risk, a more intense colour will indicate an area of increased risk.
4. It will allow visual and numerical data necessary for making management strategic and operational decisions to be displayed on the monitors of project managers at corporate headquarters.
5. Development of Membrane SDE software product on the basis of Sezyomin's Membrane Method of risk analysis will provide software independent from Microsoft and Apple systems, with the parallel task of creating software-specific libraries.
6. The created libraries (of errors and risks) should be published on a paid basis, including accessibility to foreign users under the condition of their multistage accreditation in accordance with legally defined procedures.
7. Automatic generation of periodic reports (monthly, quarterly, annually, at the end of a stage, as well as for the entire project).
8. The ability to generate any report in one click, taking into account the principle of priorities of managers and technical specialists in accordance with the specified scope of authority in the field of risk management of the company.
9. The system is configured in such a way that the notification about necessity of preparation by risk owners of the updated information on groups of risks for the monthly (quarterly) report is displayed automatically on a personal device of the risk owner and also the head of the company. Such a set of actions minimizes the risk of human factor influence on the execution of simple instructions for preparation of reporting in time (there will be no delay in execution). This is especially important for situations of new risk occurrence at any stage of the NPP project life cycle.
10. The software based on the Membrane Method of risk assessment by Sezemin makes it possible to apply a new concept of internal digital signature in the company, which will allow to transfer materials for studying and collect data confirming that the employee of the subdivision has read the document, in electronic form[5].
11. In the corners of the stacked layers of the membrane system are four target parameters of the project: economic parameters (costs, project budget, rate of return, net profit), time-related parameter — realization of the project within the terms

5 The costs of preparation, printing, collection of signature sheets and archiving in the physical sense of document flow should be estimated in monetary terms and compared with the costs of implementing electronic document flow using internal digital signature in the Corporation.

set by the feasibility study, qualitative parameters, and safety parameters of the project.

Therefore, the purpose of the research presented in the paper was achieved. The problem of risk identification and assessment at various stages of the NPP project life cycle was solved by applying the Membrane Method developed by the author.

REFERENCES

1. Alshraydekh M., Engovatov I., Morozenko A. The issues of NPP life cycle management. Energy Policy. 2023; 1(179):56-71. DOI: 10.46920/2409-5516.2023_1179.56 (rus.).
2. Gavrilov K.A., Krasavina L.N. The Great Russian Encyclopedia, 2004–2017. URL: https://old.bigenc.ru/economics/text/3510546#:~:text=RISK%20(French%20risque%2C%20ot%20it.,in %20 ordinary%20and%20political.%20discourse
3. Brykalov S.M., Trifonov V.Yu., Guryeva E.A. Development of a risk classifier as a stage of successful risk management. Issues of Risk Analysis. 2021; 18(6):44. DOI: 10.32686/1812-5220-2021-18-6-40-53 (rus.).
4. Ramenskaya A.V., Pivovarova K.V. The Monte Carlo method and tools for its implementation : Methodological guidelines. Orenburg, OSU, 2018; 58. (rus.).
5. Sezemin D.E. Complex development of undeveloped territories. Experience in the construction of Akkuyu NPP by Rosatom State Corporation (Turkey). Housing and urban environment : national scientific and practical conference with international participation (in a mixed format) (Moscow, 20–21 October, 2022). (rus.).
6. Grabovyy P.G., Prudko E.A. Risks in development. Forum. 2023; 2(28):110-114. URL: https://www.elibrary.ru/download/elibrary_50383090_28495156.pdf (rus.).

Мембранный метод в оценке организационной и технической надежности проекта строительства АЭС

Материалы представленной научно-исследовательской статьи основаны на анализе методических рекомендаций по повышению организационно-технической надежности проектируемых решений в условиях риска системы на этапе подготовки и основной фазе строительства крупных промышленных комплексов, таких как атомная электростанция. Системный анализ, проведенный автором представленной научно-исследовательской статьи, положен в основу методических рекомендаций по выбору рационального варианта плана организации работ при создании технически сложного промышленного объекта. Выводы, к которым приходит автор научно-исследовательской статьи, сделаны на основе разработки собственной имитационной модели анализа рисков с использованием современного подхода к применению автоматизированных систем календарного планирования производственных процессов реализации проектов АЭС, в том числе на международном межправительственном уровне.

Материалы представленной научно-исследовательской статьи содержат суть теоретических методик и практических рекомендаций по разработке и выбору рационального варианта организации работ на объекте строительства — атомной электростанции — на всех этапах жизненного цикла проекта. Процесс выбора наиболее рационального плана организации работ автор статьи предлагает базировать на сравнительном анализе результатов работы всех систем проекта, полученных на основе разработанной и внедренной имитационной модели под названием «мембранная модель» (здесь и далее — ММд) или «мембранный метод» (здесь и далее — ММт), парадигма которых (модели и метода) изложена ниже.

В статье представлены основные требования к техническому заданию для разработки российской технической наукой программного обеспечения для процессинговой обработки данных анализа рисков реализации проекта строительства проекта АЭС на каждом этапе жизненного цикла проекта.

Ключевые слова: *атомная электростанция, строительство АЭС, управление надежностью АЭС, управление строительными рисками АЭС, экономика строительства, промышленное строительство, многокритериальная оценка рисков, экономика предприятия, математическое моделирование, компьютерное моделирование рисков, автоматическая система управления*

СПИСОК ИСТОЧНИКОВ

1. Альшрайдех М., Енговатов И., Морозенко А. Вопросы управления жизненным циклом АЭС // Энергетическая политика. 2023. № 1 (179). Pp. 56–71. DOI: 10.46920/2409-5516.2023_1179.56
2. Гаврилов К.А., Красавина Л.Н. Большая Российская Энциклопедия, 2004–2017 гг. URL: https://old.bigenc.ru/economics/text/3510546#:~:text=РИСК%20(франц.%20risque%2C%20от%20итал.,в%20обыденном%20и%20политич.%20дискурсе
3. Брыкалова С.М., Трифонов В.Ю., Гурьева Е.А. Разработка классификатора рисков как этап успешного риск-менеджмента // Проблемы анализа риска. 2021. Т. 18. № 6. С. 44. DOI: 10.32686/1812-5220-2021-18-6-40-53
4. Раменская А.В., Пивоварова К.В. Метод Монте-Карло и инструментальные средства его реализации : методические указания. Оренбург : ОГУ, 2018. 58 с.
5. Сезёмин Д.Е. Комплексное развитие незастроенных территорий. Опыт строительства АЭС «Аккую» ГК «Росатом» (Турция) // Жилье и городская среда : нац. науч.-практ. конф. с междунар. участием (в смешанном формате) (г. Москва, 20–21 октября 2022 г.).
6. Грабовый П.Г., Прудько Е.А. Риски в сфере девелопмента // Форум. 2023. № 2 (28). С. 110–114. URL: https://www.elibrary.ru/download/elibrary_50383090_28495156.pdf

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