Risk management of oil and gas transportation facilities based on reliability indicators monitoring

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Abstract. The paper considers the methodological aspects of the analysis of technical risk based on real data on the reliability of objects. Today, there is a problem of assessing the probability of technological events of various types based on statistical data of events at various facilities; however, the current state of automatic control systems for production processes allows preventing an accident, transferring it to the category of incidents. In this case, there is a real distortion of information on statistics of dangerous situations. In modern control systems, information for forecasting and preventing accidents is the most valuable. The paper presents a systematic approach to the creation of new generation technical risk management systems.

1. Introduction

Since 2021, enterprises of the Russian Federation have been expecting changes in the field of environmental policy. “Since 2019, 300 industrial enterprises that have a significant negative impact on the environment should switch to environmentally friendly best available technologies, and from 2021 all enterprises with a high-risk category for the environment should do this,” - V. Putin [1].

On April 20, 2017, President of the Russian Federation V. Putin signed a decree on the Strategy for Ecological Safety of Russia for the period until 2025 [2,4]. The document contains an assessment of the current state of environmental safety, a description of the challenges and threats to environmental safety. The Strategy outlines the main goals and objectives of state policy in this area, assessment and monitoring mechanisms. A strategic planning document in the field of ensuring national security of the Russian Federation that defines the main challenges and threats to environmental safety, goals, objectives and mechanisms for implementing state policy in the field of environmental safety.

The new Environmental Strategy noted that threats to environmental safety remain despite strict policies at enterprises and measures taken to reduce environmental impact levels of chemical, physical, biological and other factors, to prevent natural and man-made emergencies, including emergency situations on dangerous production facilities to adapt industries to adverse climate change.

Effective until 2020, "The concept of improving state policy in the field of industrial safety until 2020" [11], approved by a decision of the Board of the Federal Service for Ecological, Technological and Nuclear Supervision in 2011, determines the necessary condition for differentiating industrial safety measures depending on the degree of risk of accidents and the scale of their consequences is the formation of organizational mechanisms for classifying hazardous production facilities.
2. Materials and methods
The urgency of the problem of forecasting undesirable events at oil and gas transport facilities is confirmed by systemic accidents and incidents at facilities. Analysis of statistical data indicates the need to create a new generation risk management system based on a modern methodological and instrumental base.

In 2016-2019, significant changes took place in the regulation of industrial safety issues in the oil and gas transportation industry. Modern methods of analysis and reduction of environmental and technological risks are numerous, depending on the type of facilities and many factors, capacious, however, most of them are focused on the use of statistical data on accidents that have occurred. Along with this, along with the concept of “accident”, there is the concept of “incident”, which is most often encountered in practice.

According to Rostekhnadzor, the statistics of incidents significantly differs from the statistics of accidents, from which the concept of “background” risk acquired special significance (blue, Figs. 1, 2).

The risk of $R_A$ accidents (red, Figures 1, 2) is determined by the following formula.

$$R_A = \frac{N}{K} \times 1000,$$

$N$ is the number of accidents per year, unit; $K$ is the number of hazardous production facilities. Therefore, the methods and technologies for preventing accidents and monitoring precisely the current technical risks in the industry are becoming especially relevant.

![Figure 1. Dynamics of background risks at the facilities of the main pipeline transport of hydrocarbons (318 incidents per 1 accident) [3]](image)

A complex of intellectual technological management of reliability and efficiency of oil and gas systems (CI-TREMS), a fundamentally new technology of intelligent neural network engineering control, forecasting and prevention of emergency situations, incidents, accidents, has been developed at the Department of Hydrocarbon Resources Transport, optimization and ensuring the effectiveness of technical solutions in the process control of industrial enterprises.
As a background risk of accidents at hazardous production facilities of the oil and gas complex, it is recommended to use Rostechnadzor data on accidents and injuries expressed in relative values of the risk level of deaths at hazardous production facilities, as well as in estimates of the average expected material damage and the number of accidents in various sectors of the oil and gas complex.

According to [11], for an indicator of the risk of an accident at a hazardous production facility in the oil and gas complex, reliable estimates of the risk of accidents and incidents at the hazardous production facility under consideration or any of the following values of background hazards (background risk of an accident at a hazardous production facility of the oil and gas complex) must be determined:

- accidents and (or) incidents at a hazardous production facility for which a safety justification is being elaborated;
- accidents at hazardous production facilities of the oil and gas complex;
- loss of life in industrial accidents.

Based on modern requirements, for the high-quality monitoring of accident risk indicators at a hazardous production facility in the oil and gas complex and reliable assessment of accident and incident risk values, modern information processing systems based on the processing of online information and databases should be used. Such a system is developed individually and for its creation the authors have methodologically developed the basics. It requires separate functions of the operator-mechanic and operator-technologist for safety, understanding the features of the process.

To create a system in TIU, methodological support was developed using the apparatus of probability theory and statistics, graph models, neural network technologies and machine learning, which allows assessing indicators of the technical condition, reliability and risk analysis of objects of the oil and gas transport system[6-15]. Some features of the device are shown in Table 1 described in more detail in [5].

The current level of development and scale of transport and storage facilities as dangerous opportunities require a qualitative analysis of reliability and technical risks, the possibility of rapid response, therefore, the system should be accessible and provide a qualitative forecast of the state of the systems.
| Methods and their features | Functions | Assessment Features | Tools | Note, novelty |
|---------------------------|-----------|---------------------|-------|--------------|
| Assessment of technical condition indicators | Elimination of gross system uptime threats | Estimated according to the regulations in the operating mode | Visual inspection, diagnostics | Coefficient method |
| Statistical analysis of accidents and incidents | Analysis of accidents and incidents and their causes | Based on registered data, quality of databases determines assessment results | Mathematical processing of forms or electronic databases | Must be performed in real time |
| Assessment techniques using graph models and probabilistic-statistical analysis | Analysis of accident scenarios taking into account current data, assessment of transition probabilities | Using variable transition intensities based on real reliability data | Online incident and accident logging | Variable event intensity |
| Neural network technology and machine learning | Rapid identification of states and their prediction and prevention | Based on operational information; analysis of a large amount of data using artificial intelligence, identification of states; real-time multivariate analysis | CPCS data arrays | Real-time multivariate analysis |
| Residual life estimation | Long-term life assessment | Long-term limit state forecast | Diagnostic Tools | Take into account real-time changes |
| Structural models of reliability analysis | Assessment of potential threats to elements in complex systems, development of re-equipment solutions | Identification of elements of "weak links", the goal is to identify the element | Analysis of technological schemes | Real-time online analysis of mnemonic diagrams, elimination of threats |
| Factor models for reliability analysis | Assessment of potential operational hazards in complex systems | Identification of the causes of potential threats, the goal is to identify the causes | Analysis of operational information, databases | Real-time online parametric analysis of mnemonic diagrams, elimination of threats |
| Economic models for assessing damage from consequences of accidents and incidents | Assessment of potential threats in material terms | Material risks, damage are assessed | | |
The process of creating and implementing the developed methodology and methodologies in process control systems is very time-consuming and is associated with the following steps:

1) Analysis of the technological scheme of the facility, parameters and characteristics, determination of production features of the project and control of parameters and modes;
2) the creation of a diagnostic architecture to assess the technical condition, reliability and safety of the facility and the reliability of technological processes;
3) the justification of the methodological support of the predictive control system;
4) software implementation of models and the creation of a software package;
5) visualization for the perception of information by operational personnel;
6) testing and updating the system at a specific production facility.

As an example, Figures 3, 4 show a fragment of visualization of a dangerous element of the technical system of the tank farm and pumping station.

**Figure 3.** Simulation and visualization of threats using tank farm equipment as an example

**Figure 4.** Simulation and visualization of threats on the example of pumping equipment
3. Conclusion
Using mathematical software systems, a high-quality methodological apparatus, an automated process control system as a database enables on-line analysis of technical risks and allows security specialists and technologists and operators to respond to possible threats and prevent incidents.

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