APPLICATION OF DIGITAL TECHNOLOGIES FOR PLANNING MEASURES TO PREVENT HAZARDOUS PRODUCTION FACILITIES ACCIDENTS

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Abstract

Hazardous production facilities operational safety is ensured by risk of emergency situations effective management, such as planning and implementing technical measures, namely safety and reliability measures. These measures are planned according to project specific hazards to prevent accidents and incidents on technological processes. The focus of such decisions should take into account the facilities life cycle stages and phases of beginning and amplification of probable emergency situations. This article discusses basics and results of application of artificial intelligence and machine learning technologies for planning measures to improve the reliability and ensure the safety of oil and gas production and transportation facilities during their full life cycle.

Keywords: technological processes, productions safety, risk management, artificial intelligence, platform solutions

I. Introduction

Automation today is typical for most of the processes that accompany the stages of design, construction and operation of hazardous production facilities.

Such significant stages as engineering surveys, identification of key design solutions, actual up-to-date process data collection, processing and transmission are undergoing significant modernization through the introduction of digital systems. In these processes, machine learning is of particular importance.

The fourth industrial revolution opens up new options for improving each stage envisaged in the implementation of significant investment projects for the hazardous production facilities design, construction and operation. At the same time, it defines new requirements for justifying the sufficiency of hazardous production facilities design solutions, such solutions implementation control and also effective structural condition monitoring throughout facilities complete life cycle.

II. Methods

The safety of facilities is ensured by the planning and timely implementation of technical and organizational measures, the main task of which is to ensure effective management of the risk of emergency situations occurrence and development at each stage of the life cycle of buildings and structures that are part of fuel and energy facilities, namely, at the stages of hazardous production facilities design, construction, commissioning operation and operation.

To evaluate design decisions, assessment of the need for introduce additional technical and organizational measures, improve the efficiency of the measures planning stage, and enhancement the efficiency of decisions made in terms of their priority, the use of machine learning and the introduction of decision support systems based on artificial intelligence are proposed.

Application of artificial intelligence for these purposes provides:

1) using the full data potential;

2) reliable forecasting;

3) automation of complex tasks.

In particular, the use of artificial intelligence at the stages of sampling, systematization and classification of key data, that are used for risk analysis, significantly increases the efficiency of identifying, predicting and evaluating probable accidents.

Accident risk management effectiveness is ensured by objectively assess the risk and identify factors that affect the occurrence and development of emergency situations. This factors called "influence factors" ore "factors" [1].

In this case not only to the prevention of probable emergencies should be provided: timely forecasting and detection of emergencies and, in some cases, localization and liquidation of emergencies consequences must be applied.

For identification and analysis of all probable accidents, and then planning effective reliability and safety measures a large amount of data is used.

For the purpose of orderly storage of such data and their further use, the following indicators are proposed to classified:

1) Buildings and structures designed and operated as part of hazardous production facilities, on the basis of the danger of such buildings and structures in the context of the likelihood of beginning and development of probable accidents and incidents;

2) Influence factors;

3) Probable emergencies;

4) Measures that ensure the prevention, timely detection, localization and elimination of the consequences of accidents.

III. Results

As a result of the buildings and structures classification (1) the following hazard signs of buildings/structures were identified:

1.1) The building/structure is vulnerable to external influences. For example, underground tanks and pipelines are more secure than above and below ground structures.

1.2) Explosive and flammable substances are handled in the building/structure. The amounts of a hazardous substance, as well as physical processes of its release and distribution are analyzed.

1.3) Probable escalation of the accident to neighboring buildings/structures: the actual distance between buildings/structures, the presence of hazardous substances in neighboring buildings/structures are analyzed.

1.4) An accident in a building/structure will lead to a long-term disruption of the facility functioning: it is analyzed to what extent the building/structure is involved in the process cycle at the facility.

1.5) The consequences of an emergency situation in a building/structure can lead to human casualties, cause damage to the environment.

The above sings are taken into account in the decision-making process on planning measures to predict probable emergencies.

The occurrence of an accident is not always due to a combination of influence factors. At the same time, the degree of a single factor influence may turn out to be more critical than their combination. For this reason it is especially important to classify the influence factors (2) according to the following criteria:

2.1) The possibility of preventing/reducing the negative impact of the influence factor at the stages preceding operation.

2.2) Features of defects, caused by the influence factor.

2.3) The possibility of timely identification of the factor causing the emergencies.

2.4) The influence of a defective hole, formed as a result of the influence of a factor: the volume of probable leaks and a forecast for the further development of a defective hole, taking into account the building/structure construction materials.

2.5) The scope of work to restore the building/structure after the influence of the factor.

It is most preferable to prevent the influence of the factor at the stage of development of design documentation by including appropriate measures in the design decisions. But the nature of the influence factors is such that they appear in the process of operation of buildings and structures. Moreover, most influence factors often occurs imperceptibly, but can lead to sudden emergency situations.

For this reason, it is necessary to provide building/structure high-quality structural condition monitoring during their operation, and also prompt transmission of monitoring results in order to process them and make decisions on the implementation of additional measures.

Probable emergencies (3) were classified according to the following criteria:

3.1) Accompanied by the release and controlled distribution of a hazardous substance.

3.2) Accompanied by the release and uncontrolled distribution of a hazardous substance.

3.3) Leading to complete or partial shutdown of the technological process.

3.4) Leading to complete or partial destruction of the building/structure.

3.5) Affecting neighboring buildings/structures.

3.6) Leading to workplace injuries and fatalities.

Not every accident will lead to a shutdown of the technological process. For example, a traffic accident on inter-site or on-site roads of oil and gas fields. But, in some cases, for example, accidents on quarry roads can lead to significant delays in the implementation of facility logistics.

For effective risk management, measures provided for the prevention, timely detection, localization and elimination of the consequences of accidents are implemented. It is necessary to systematize, classify and store these measure in an orderly manner for the purpose of further use.

Measure classification (4) based on the Classifier [3] developed for main gas pipelines.

The following classification criteria have been adopted:

– multiplicity of options for compensation of one influence factor;
– the possibility of using one measure to compensate for various factors;
– possibility of interchangeability of measures taking into account the specifics of the project;
– the multiplicative effect of two or more influence factors and the need to revise the set of measures in the presence of this effect.

In addition to taking into account the specifics of events in the classification, the following additional requirements were imposed:

– measure classification depending on the stage of implementation of the investment project;
– taking into account many aspects in the measure classification;
– ensuring the possibility of updating the classifier;
– flexibility of the classifier structure and the possibility of updating it with new measures;
– classifier clarity.

The following facets are accepted as unifying classification features:

4.1) Focus of the proposed measures. For determining the sufficiency of a set of measures relevant to specific conditions, it is necessary to take into account the focus of measures to prevent an emergencies, as well as at all stages of minimizing damage from an emergencies.

4.2) Type of compensatory measure: technical, average and non-technical.

4.3) Stage of the building/structures life cycle at which the measure is implemented.

4.4) Scope of implementation of compensatory measures.

The facet method was used to classify measures (Table 1)

Table 1: *Facets for measure classifier*

Facets			
№ of Facet	Facet name	Subcategory	Subcategory name
I	Focus of the proposed measures	IA	Emergencies prevention
		IB	Timely detection of accidents
		IC	Incident consequences localization
		ID	Accidents consequences elimination
II	Type of compensatory measure	IIA	Technical
		IIB	Average
		IIC	Non-technical
III	Stage of the building/structures life cycle	IIIA	Engineering survey
		IIIB	Design
		IIIC	Construction
		IIID	Operation
		IIIE	Reconstruction
		IIIF	Preservation
		IIIIG	liquidation
IV	Scope of implementation of compensatory measures	IVA	Applied elements of building structures
		IVB	Design features, accessories
		IVC	Devises and methods of diagnostics, testing, control
		IVD	Site preparation
		IVE	Devises of localization and liquidation of the accident consequences

Classifier is a part of developed Safety and reliability measures planning and implementation (SARM PI) system, using artificial intelligence for generate effective solutions.

SARM PI System stages shown in Figure 1.

Artificial intelligence and digital technologies application ensures the impartiality of risk assessment results: generated reports contain analytics, based on key indicators of probable hazards, caused by influence factors, and recommended measures planned according to approved criteria, such as:

– the advantage of technical measures over organizational ones;
– the advantage of preventing an accident over its localization;

– the advantage of focusing measures directly on the buildings/structures of the hazardous production facilities.

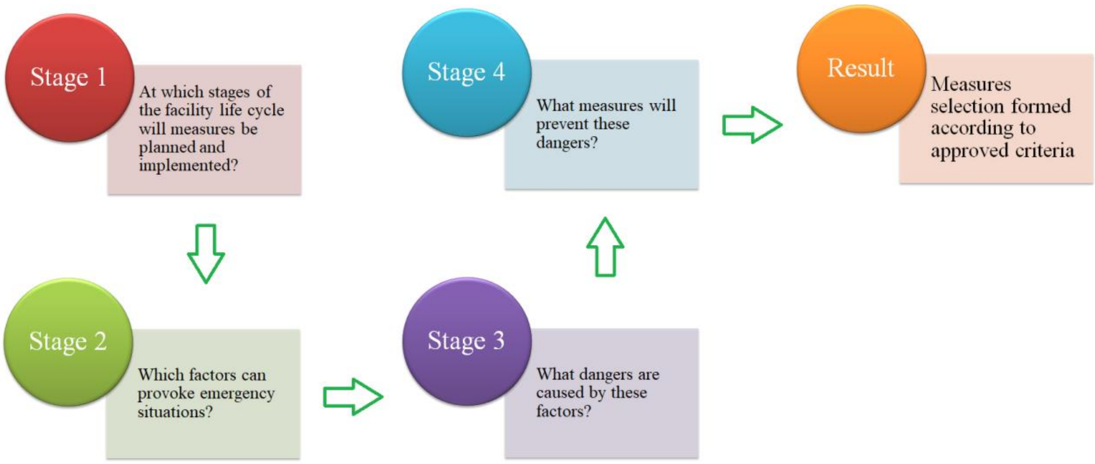

Figure 1: *Safety and reliability measures planning and implementation (SARM PI) System stages*

Formed selection is not final: artificial intelligence offers priority measures, but the final decision is made by a person. Decisions quality and validity significantly improved by using artificial intelligence, machine-learning systems and integrated databases.

Effective risk management is guaranteed by using comprehensive information about influence factors, which provoking emergency situations, and parameters (preconditions) of such factors.

SARM PI System was applied to plan and implement measures to ensure the ensure safety and reliability at all stages of the facilities life cycle.

IV. Discussion

I. Examples of developed databases used in SARM PI System

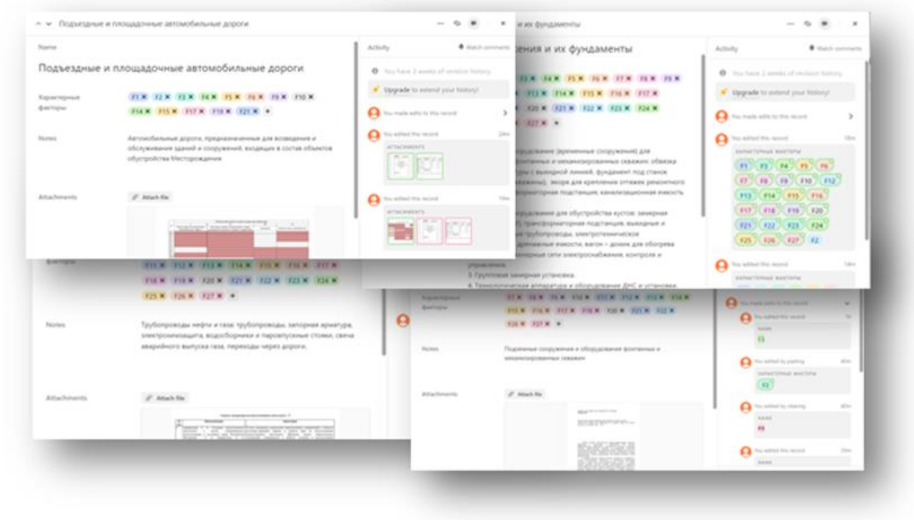

Figure 2: *Influence factors database*

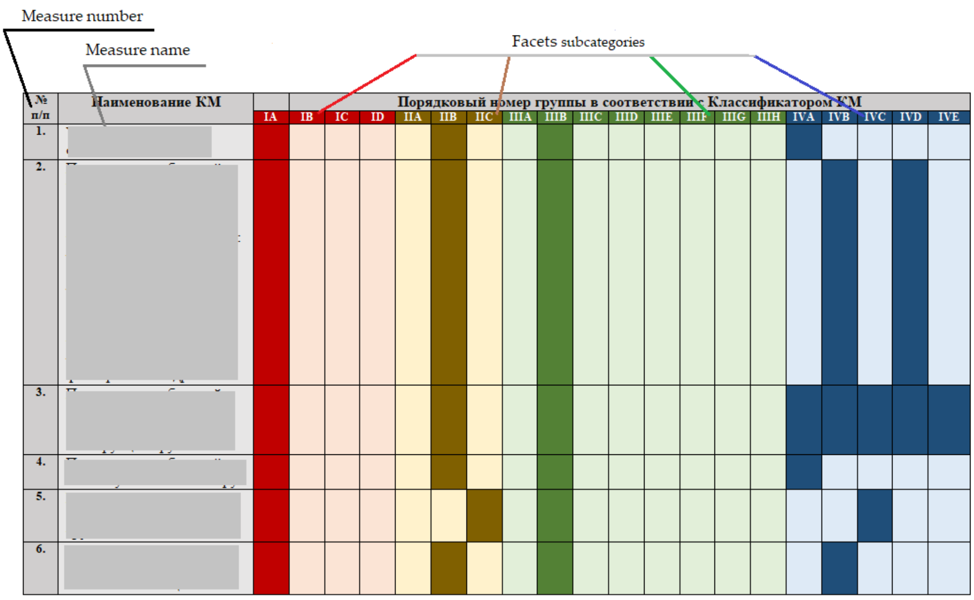

Figure 3: *Measure Classifier Structure*

I. Benefits of using the SARM PI System

Application of SARM PI System provided:

1. Expansion accounting and assessment of probable hazards that can lead to emergency situations.
2. Detailed analysis of predicted emergencies.
3. Improvement of priority measures decision-making.
4. Formation of a step-by-step description of the decision-making algorithm in order to make adjustments, comments and clarifications.
5. Improvement the impartiality of the decisions made. Measures (combinations of measures) hade only be approved if the actual reduction in risk indicators is confirmed. At the same time, the risk analysis itself was also objective and impartial.
6. Improvement of acceptable risk criteria.
7. Formation of variations of combinations of measures, taking into account the investment feasibility of their implementation for the actual conditions of construction and operation of fuel and energy facilities.
8. Security and reliability of reports generation and provision.

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