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To cite this article: A P Rozhok *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **864** 012022

IOP Conf. Series: Earth and Environmental Science **864** (2021) 012022 doi:10.1088/1755-1315/864/1/012022

Methods of monitoring the Ground-Climate-Pipeline system in sections with hazardous processes

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Abstract. The paper considers the concept of combining various means of monitoring of the Ground-Climate-Pipeline system sections exposed to hazardous processes. The concept of "hazardous processes" is described. Sensors selected for monitoring parameters in the Ground-Climate-Pipeline system are described. A monitoring scheme is proposed and described, all elements of which are functionally combined through information transfer networks. The advantages of using artificial intelligence in the proposed monitoring system are explained.

1. Introduction

The traditional approach in the investigation of pipeline network safety level as the main reasons of accident occurrence classifies [1, 2]: corrosion (external and internal, swamping, waterlogging of the territory by aggressive groundwaters); equipment/material/joints defects, equipment failure; external (mechanical) impacts caused by various natural phenomena – mudflows, screes, landslides; erroneous actions of the personnel during operation. Accepted monitoring means are mainly designed to detect and measure the level of these impacts [3]. The desire to record impacts is associated with an increase in the number of sensors installed in hazardous sections. An increase in their number leads to an increase in the probability of false alarm in means of pipeline network control, which reduces the efficiency of its functioning.

This research contains a description of the concept of combining various means of monitoring of pipeline sections, computer modelling, and artificial intelligence to improve the reliability of forecasting the nature of a possible accident while reducing the level of false alarms [4].

The proposed concept allows reducing the potential damage to the environment due to the system approach in analysing the state of the pipeline system section considered as a set of interacting elements [5].

2. Methods

Hazardous processes (HP) should be understood as a change in the physical and mechanical properties of the ground, including the stress-strain state of the Ground-Climate-Pipeline (GCP) system, which depends on the climate, the mobility of the ground (speed, acceleration, and amplitude) and the pipeline state (temperature, pressure, etc.) [6-7].

Thus, the change in the equilibrium state of the GCP system is described by the structure in which the climatic trend contributing to the occurrence of HP affects the bearing capacity and stress-strain state of the soil, which in turn affects the stress-strain state of the pipeline [8].

To control the interaction of elements of the GCP system, the authors recommend using sensors that provide measurements of the parameters of the interacting elements of the system on the sections with HP, presented in Table 1.

Table 1. Offered sensors for monitoring the parameters in the GCP system.

Sensor name	Measured value	Application
inclinometer	angle of deviation value	to control the inclination and shear of the two system elements (soil and pipeline) relative to each other, used to control the deflection of the bearing soil surface in the vertical plane
thermometer	temperature	to measure the temperature of the medium in the vicinity of the sensor element
infrared temperature indicator	temperature	to measure the surface temperature in the vicinity of the sensor element
accelerometer	projection of motion acceleration	accelerations in the process of ground shaking
groundwater level sensor	groundwater level	to control the dynamic groundwater level acts as an alarm device and level sensor
pressure sensor [9]	pressure variation in the medium over time	to prevent possible accidents in the GCP system and to detect leakages
substance flow rate sensor	speed and flow rate of the substance in the set cross-section	to detect and inform about leakages
ultrasonic corrosion sensor	pipeline wall thickness in the most vulnerable places	to prevent pipe failure
psychrometer	relative air humidity	to predict changes in air humidity as part of the system
curvature radius measurement sensor	curvature radius	to determine the stress-strain state of the system

Sensors presented above are placed temporarily or permanently in the places of installation, which are connected to HP in the pipeline, ground, on the surface of measuring equipment [10]. The parameters measured by the sensors are monitored at the control points, each of which is assigned the appropriate geographic and operational coordinates of the pipeline by the parameters under control.

Therefore, measurements from the sensors are collected at a frequency depending on the process intensity and the value of the measured parameters, e.g. once per hour at the control points [11]. After measuring and pre-automatically checking the measured value, it is transferred to the data collection and transmission unit (DCTU) [12]. This block accumulates information obtained from control points and analyses it for the compatibility of individual measurements [13]. If there are no contradictions between the individual portions of data received from different sensors, the information goes to the monitoring database, where it should be checked for consistency of the computer simulation results [14].

The authors propose the following monitoring scheme, all elements of which are functionally combined through information transfer networks (Fig. 1).

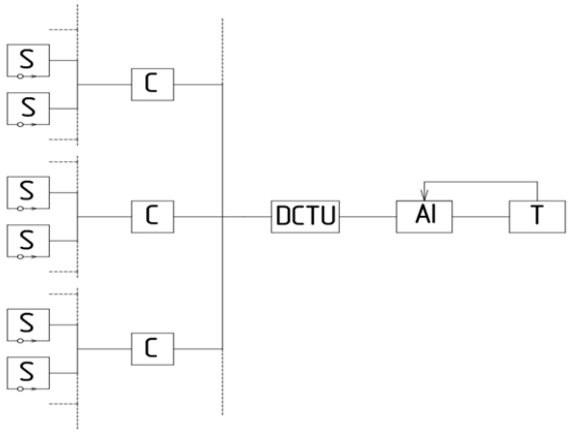

Figure 1. Diagram of the monitoring system.

The received information from the DCTU is transferred further to the information processing and decision-making unit equipped with Artificial Intelligence (AI). This unit has access to the monitoring database, which stores the received data from sensors collected at the control points. The information stored in the monitoring database is processed by the AI block and the obtained values are compared with the parameters obtained from computer simulation. The results of the comparison are processed by AI block, which allows formulating a solution aimed at reducing the probability of the System exceeding the limits of dangerous values of the system state parameters, such as the stress-strain state.

It should be noted that the given monitoring means provide not the only fixation of the current state of the system, but also its forecast depending on predicted climate changes and nature of geological processes. The resulting time gap can be used for preventive risk reduction measures and selection of effective means of situation normalization by computer modelling.

3. Results

The first important result is a new approach to considering a pipeline section as a system combining interacting Ground-Climate-Pipeline media, which allowed classifying its limiting or dangerous states. Parameters, on which classification is carried out, are determined based on indications of a set of different sensors and mathematical simulation of the interaction processes of the system elements.

The number of false alarms during monitoring the system is reduced by the application of multistage control procedure and compliance with the conditions of mutual conditionality of sensor readings, which for each class of conditions are recorded in the complex. Classification of conditions is linked to the risk indicators of an accident, resulting in tangible or severe consequences. Risk indicators are calculated based on the analysis of soil and pipeline stress-strain state, which characterizes the GCP system.

To reduce the probability of false alarms, the authors propose to use an adapted set of sensors when processing information with which the combined readings are considered. For example, a combined reading of inclinometer for groundmass movement control and groundwater level sensor together with an accelerometer for ground shaking control may indicate possible dangerous ground movements.

To consistently improve the quality of recognition of different classes of situations, it is proposed to use the feedback provided by the AI training system.

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4. Conclusion

The monitoring tools proposed by the authors, including the data collection and transmission unit, as well as the information processing and decision making unit (AI), are the basis for information processing and allow creating predictive models of the development of emergency and pre-emergency situations, identifying and clarifying the causal links arising from the interaction of climate, ground, and pipeline, to predict the future state of the system. Prediction of the state is designed to reduce the probability of false alarms and increase the effectiveness of preventive measures to reduce risk.

A combined, adaptable sensor set allows for early detection of the risk of possible accidents, thus reducing potential damage to the environment, which is a particularly important criterion for pipeline construction in hazardous climatic, topographical, and geological conditions.

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