Development of Intelligent Technologies and Systems of Adaptive Vibration Control of the Beginning of the Latent Period of Accidents at Critical Economic Facilities

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Abstract. At present control and management systems at such economic facilities as urban water supply systems, wastewater pumping stations and treatment plants, pumping stations of irrigation systems, etc. do not provide signaling of the beginning of the latent period of accidents and this state is not reflected in the readings of measuring devices of control systems. In addition, signaling of the beginning of the latent period, change of the technical condition and seismic stability of construction facilities in seismically active regions is not supported. Continuous control of the technical condition of the railroad track is not maintained either, as the number of track measuring cars used for this purpose is limited. At the same time, the beginning of the latent malfunction period of all mentioned facilities is clearly reflected in the estimates of various characteristics of noisy vibration signals, which emerge at the beginning of their various malfunctions. We will propose technologies of formation of informative attributes and technical means for controlling the beginning of the latent period of malfunctions at these facilities. The possibility of using the proposed informative attributes in the systems of control of the beginning of malfunctions of other various economic facilities will also be shown.

Keywords: accident, malfunction, control, signaling, construction facilities, seismic stability, pumping stations, railroad track, vibration signal, noise, informative attribute.

1 Introduction

At present, in pumping stations in any technological water supply and wastewater disposal systems, as well as in municipal cold and hot water supply systems, sewage pumping stations of wastewater pumping and treatment facilities, automatic control systems are used for monitoring and control, which allows the facility to operate for a long time without repair [1-3]. They carry out processing of analog and discrete information according to the set algorithm and formation of necessary signals for control of technological equipment, display of information on parameters and state of technological process, on preparation of transfer of information on current state of equipment, on parameters and state of technological process, detection of emergency situations or malfunctions of technological equipment, automatic connection of additional pump units in case of insufficient productivity of the plant. Thanks to this, the vital problem of the population related to water supply, water supply, wastewater pumping, irrigation of agricultural crops, etc. is reliably and successfully provided [3-6]. Monitoring and control systems are also used to control the seismic stability of urban construction facilities, strategic facilities, infrastructure facilities and other critical facilities, and due to this, a high level of accident-free operation is ensured [1, 4, 5, 6].

Railroads have always been and still are the most profitable and economical mode of transportation, second only to pipeline and water transport. Rail transport has no seasonality or dependence on weather conditions. Rail transport is effective due to the high speed of the rolling stock, large amounts of transported cargo, versatility, and so on. One of the main advantages of railroads is the very low cost of energy required to move steel wheels along steel rails.

With the development of high-speed train traffic, the requirements for objects and devices of railroad infrastructure are becoming more stringent, both for the quality of determining the occupancy of the track and for the condition of the rail line, the track superstructure (ballast), on which the qualitative characteristics of performance, safety and uninterrupted operation of trains depend. At present, the control of technical condition of the railroad bed of each track crossing is practically carried out according to the plan, i.e. "in turns", with the help of railroad test cars, geometry cars, flaw detector cars, as it is believed that no significant changes occur between the checks, when no control is carried out. At the same time, in real life, due to the impact of various factors, certain changes take place even a day after control. Therefore, in addition to the existing ones, it is advisable to create simple and inexpensive intelligent technical means of monitoring, which can be installed on one of the cars of each rolling stock for continuous control of the beginning of changes in the technical condition of the track. In this case, the “Safety center” on the basis of the information received from trains in the corresponding hauls, can make a decision on the expediency of their “out of turn” control [1, 9-15].

2 Problem statement

The importance of the issue of controlling the beginning of the latent period of accidents of economic facilities is associated with the fact that any accident is preceded by the emergence of certain defects, after which its latent period begins. After some time, it develops and only after that it is reflected in the readings of measuring devices of control and management systems. The duration of the latent period depends on the dynamics of the defect development. Due to the above, in the measuring devices of the control systems of the above mentioned facilities the beginning of their emergency state is detected at the moment of time when it takes on a pronounced form. Therefore, in practice there are cases when it turns out to be late and the accident cannot be prevented. Naturally, in order to eliminate this shortcoming, it is necessary to create new technologies and intelligent systems that allow controlling and signaling the beginning of the latent period of the emergency state of the above facilities [1-3, 10-14].

Studies have shown that vibration process occur in many of the most important economic facilities as a result of continuous operation under heavy load. Therefore, to control the beginning of the latent period of malfunction of these facilities, it is advisable to use vibration sensors, since the beginning of their malfunction is largely reflected in the vibration signals $g(i\Delta t)$. This process is normally reflected in the form of noises $\varepsilon(i\Delta t)$, which have correlation with useful signals $X(i\Delta t)$ at the onset of the malfunction [1, 4, 5]. Consequently, during this period, the total noise $\varepsilon(i\Delta t)$ is formed from the noise $\varepsilon_1(i\Delta t)$, which arises from the influence of external factors and from the noise $\varepsilon_2(i\Delta t)$, caused by the occurrence of various malfunctions.

Experimental studies have shown [1-3] that in the process of operation of the equipment of the facilities under consideration the occurrence of the latent period of accidents is due to the fact that in the operating conditions in the equipment there are fractures, fatigue cracks, residual stresses, fatigue damage, fatigue, wear, friction and abrasion. Because of the above estimates of the cross-correlation function $R_{X\varepsilon}(\mu)$ between the useful signal and the noise and the noise variance $R_{\varepsilon\varepsilon}(\mu)$ of the vibration signals are perceptible values, i.e. there is an inequality:

$$\begin{cases} R_{X\varepsilon}(\mu) \gg 0 \\ R_{\varepsilon\varepsilon}(\mu) \gg 0 \end{cases}$$

Due to this fact, it is difficult to ensure the adequacy of the results of vibration control of the beginning of the latent period of accidents of the equipment under consideration using traditional technologies. Therefore, it is required to create alternative effective technologies and intelligent technical means of control and signaling of the beginning of the latent period of accidents at the above-mentioned important economic facilities.

3 Algorithm for determining the estimates of informative attributes to control the onset of accidents at economic facilities

Analysis of the causes of accidents have shown [1-3] that in the process of operation of equipment of the considered facilities the occurrence of the latent period of malfunction is due to the fact that continuous rotary motion under high pressure in the equipment leads to fractures, fatigue cracks, residual stresses, fatigue damage, fatigue, wear, friction and abrasion. The beginning of the latent period of these malfunctions of the specified facilities is clearly reflected in the estimates of various characteristics of noisy vibration signals, caused by their long-term non-stop operation.

Analysis has shown that to determine the estimates of the most important informative attributes which arise at the beginning of the specified malfunctions in the considered facilities it is expedient to use the following technologies:

1. Technology of determination of the estimate of the variance $D_{\varepsilon\varepsilon}$ of the noise $\varepsilon(i\Delta t)$ of the noisy vibration signal $g(i\Delta t)$:

$$D_{\varepsilon\varepsilon} \approx R_{\varepsilon\varepsilon}(0) \approx \frac{1}{N}\sum_{i=1}^{N}\left[g^2(i\Delta t) + g(i\Delta t)g\big((i+2)\Delta t\big) - 2g(i\Delta t)g\big((i+1)\Delta t\big)\right]$$

2. The technology of determining the estimate of the cross-correlation function $R_{X\varepsilon}$ between the useful vibration signal $X(i\Delta t)$ and the noise $\varepsilon(i\Delta t)$:

$$R_{X\varepsilon} \approx \frac{1}{N}\sum_{i=1}^{N}[g(i\Delta t)g\big((i+m-1)\Delta t\big) - 2g(i\Delta t)g\big((i+\mathrm{m})\Delta t\big) + \\ +g(i\Delta t)g\big((i+\mathrm{m}+1)\Delta t\big)]$$

3. Technology of determining the estimate of the relay cross-correlation function $R^*_{X\varepsilon}$ between the useful vibration signal $X(i\Delta t)$ and the noise $\varepsilon(i\Delta t)$:

$$R^*_{X\varepsilon} \approx \frac{1}{N}\sum_{i=1}^{N}[\mathrm{sgn}g(i\Delta t)g\big((i+m-1)\Delta t\big) - 2\mathrm{sgn}g(i\Delta t)g\big((i+\mathrm{m})\Delta t\big) + \\ +\mathrm{sgn}g(i\Delta t)g\big((i+\mathrm{m}+1)\Delta t\big)]$$

4. Technology for determining the estimate of the variance of the useful signal $\mathrm{X}(i\Delta t)$

$$D_{\mathrm{X}} = D_g - D_{\varepsilon\varepsilon},$$

where

$$D_g = \frac{1}{N}\sum_{i=1}^{N} g^2(i\Delta t).$$

5. The conducted analysis has shown that as informative attributes about the beginning of malfunction of the considered facilities it is reasonable to use also estimates of coefficients, K_1, K_2, K_3, K_4, K_5, K_6 which are determined by the formulas

$$K_1 = \frac{D_{\varepsilon\varepsilon}}{D_X} \qquad K_4 = \frac{R_{X\varepsilon}}{D_{\varepsilon\varepsilon}}$$
$$K_2 = \frac{D_{\varepsilon\varepsilon}}{D_g} \qquad K_5 = \frac{R^*_{X\varepsilon}}{D_{\varepsilon\varepsilon}}$$
$$K_3 = \frac{D_X}{D_g} \qquad K_6 = \frac{R^*_{X\varepsilon}}{R_{X\varepsilon}}$$

As it is obvious from the above, in the vibration control of the beginning of the malfunction of facilities of the applied algorithms of analysis of noisy vibration signals, the noise $\varepsilon(i\Delta t)$ is considered as a carrier of diagnostic information. In this case, ensuring the adequacy of the control results in the proposed control systems at analog-to-digital conversion of vibration signals $g(i\Delta t)$ requires the use of algorithms and technologies for adaptive determination of the noise sampling interval Δt_ε in real time. This is due to the fact that, for example, depending on the speed of the rolling stock, the spectrum of vibration signals changes in time within a large range, and this affects the adequacy of the control results. Therefore, taking into account the time variation of both the spectrum of useful signals $X(i\Delta t)$ and the noise $\varepsilon(i\Delta t)$ from the influence of train speed in order to obtain the desired estimates with the necessary accuracy, the sampling interval should be determined adaptively in real time. Only in this case, the estimates of the desired informative attributes can be determined with sufficient accuracy. In [1, 4, 9] it is shown that this can be achieved by using the frequency properties of the low-order bit $q_0(i\Delta t)$ of the samples $g(i\Delta t)$ of vibration signals, at its analog-to-digital conversion with excess frequency f_v which is much higher than the traditional sampling frequency f_c

$$f_{q_0} \approx \frac{N_{q_0}}{N} f_v,$$

where N_{q_0} is the number of transitions of the low-order bit $q_0(i\Delta t)$ of the sample $g_V(i\Delta t)$ from one to zero state, N is the total number of samples of the analyzed signal $g(i\Delta t)$, f_{q_0} is the frequency of the low-order digit $q_0(i\Delta t)$which is a reasonable sampling frequency of the vibration signal $g(i\Delta t)$.

4 Possibilities of building intelligent systems of control and signaling of the beginning of accidents at pumping stations

According to the above, to control the technical condition of the facilities under consideration, it is possible to create simple and inexpensive intelligent technical means, which can be installed in small rooms. At the same time, it is often required to provide control and signaling of malfunctions at sufficiently large distances, i.e. to control the facility remotely [1-4].

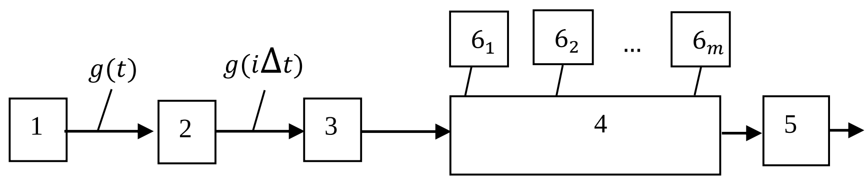

Fig. 1. Intelligent system for signaling the onset of accidents.

Fig. 1 shows a block diagram of one of the possible variants of building an intelligent accident signaling system (IASS) by analyzing the vibration signals occurring at the beginning of all typical accidents in the operation of economic facilities.

The system consists of the following modules:

1- Vibration sensor.
2- Module for adaptive analog-to-digital conversion of vibration signals, $g(t) = g(i\Delta t) = X(i\Delta t) + \varepsilon(i\Delta t)$.
3- Modules for determining estimates of current informative attributes.
4- Identification module at the beginning of the latent period of malfunctions.
5- Information and signaling module.
6_1 -6_m- Modules for memorizing threshold estimates of informative attributes.

In the process of operation of the IASS, the vibration signal $g(t)$ from the vibration sensor 1 arrives at the input of module 2, i.e. at the input of the adaptive analog-to-digital converter, where it is converted into digital code $g(i\Delta t)$. By means of module 3 the current set W_t is formed, consisting of the corresponding estimates of the current informative attributes $W_t = \{D_g, D_X, D_{\varepsilon\varepsilon}, K_1, K_2, K_3, K_4, K_5, K_6,\ R_{X\varepsilon}, R^*_{X\varepsilon}\}$. If they exceed the threshold values of the corresponding informative attributes set on modules 6_1, 6_2, ..., 6_m, then the signal from module 4 is transmitted to module 5. In this case, if all the current estimates are greater than the corresponding reference estimates, then modules 4 and 5 form a warning signal about the beginning of the malfunction and also trigger the alarm about the beginning of the accident. However, in cases where some estimates are greater than the reference ones and others are smaller, then only a warning signal is generated. As a result, during the operation of the system, by comparing the reference and current informative attributes, the results obtained allow to assess the technical condition of the facility and to carry out signaling of the beginning of the malfunction.

Analysis of real facilities has shown the possibility of practical control of the beginning of the latent period of accidents of the system shown in Fig. 1 at commonly used pumping stations.

As was mentioned above, vibration processes occur on pumping units as a result of long continuous operation under heavy load and the most information about the beginning of the latent period of emergency condition is contained in vibration signals [5-10]. Despite this, the existing monitoring and control systems detect the beginning of accidents when its latent period is completed and the facility enters the emergency mode. This leads to loss of time, because of this it is not possible to eliminate the malfunction in the period of its initiation. As a result, much more resources and time are required. Therefore, the use of the above proposed informative attributes as carriers of diagnostic information to control the beginning of the latent period of accidents is the most appropriate option. Importance and expediency of wide application of intelligent control system is also connected with the fact that in real life commonly used pumping stations, artesian wells and other important equipment are intended, as a rule, for small farms, which cannot purchase and operate expensive equipment with very sophisticated and expensive control and management systems. In these cases, it is advisable to use equipment with inexpensive and simple control systems. Here, to ensure accident-free operation, first of all, remote signaling of the beginning of the latent period of accidents is advisable [4].

Based on the analysis of possible applications of various vibration sensors, one of the possible options to control the beginning of changes in the technical condition of pumping units is the Bean Device AX-3D type sensors, which are easily installed on the pumping unit. The choice of this sensor is due to the fact that it allows implementing remote collection of measuring information by means of Wi-Fi, by means of a Bean CetanWay type controller. The range of Wi-Fi signals from the BeanDevice AX-3D sensor is up to 650 meters, which is quite sufficient when operating pumping stations. Technical parameters of the BeanDevice AX-3D sensor are given in [1]. Thus, in this variant of the IASS the signal from the vibration sensor BeanDevice AX-3D, installed on the pump body, is transmitted via Wi-Fi to distances up to 650 m, where it is captured and analyzed on the Bean CetanWay Contoller. An alarm is instantly triggered if the resulting estimate is greater than the reference informative attributes.

5 Possibility of controlling the beginning of the latent period of seismic stability of socially critical facilities in seismically active regions

In countries located in seismically active zones, regular control of seismic stability of residential buildings and strategic facilities is required to ensure the safety of the population. The importance of this problem increases manifold in cases where, in addition to seismic hazard, there is also a possibility of a landslide. Studies have shown that in many seismically active regions, strong destructive earthquakes are rare, at an interval of more than ten years. However, in these places, as a rule, weak earthquakes occur for a certain period of time (1-2 months), which can be used to create a system for controlling changes in the technical condition or seismic stability of construction facilities [1, 5]. This can lead to a significant reduction in the amount of destruction in catastrophic earthquakes. In this regard, it is obviously expedient to create a technology and a control system (which can be used for regular monitoring) of the beginning of the latent period of change in the seismic stability of socially critical construction facilities during each weak earthquake.

The conducted studies have shown that in seismically active regions in case of weak earthquakes the estimates of informative attributes of seismic signals received from seismic sensors installed on socially critical construction facilities, if they do not change, it indicates a stable state of these facilities. At the same time on those facilities in which there is a change in the estimate of informative attributes, they can be referred to the group in which there is the beginning of the latent period of change in seismic stability. Taking into account this specific feature of seismic regions, a diagram of one of the possible variants of building a city-wide intelligent system of monitoring the beginning of change of seismic stability of construction facilities at weak earthquakes is proposed below in Fig. 2.

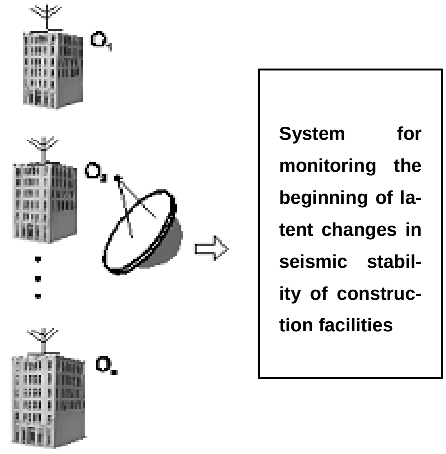

Fig. 2. Schematic diagram of the system for monitoring the beginning of changes in seismic stability of construction facilities at low magnitude earthquakes.

In the considered variant of the system for monitoring the beginning of changes in seismic stability, each construction facility O_1, O_2,..., O_N is equipped with a local unit based on a controller and with corresponding seismic sensors D_1, D,..., D_m, installed in the most vulnerable parts of the facility structure. During weak earthquakes the signals $g_1(i\Delta t)$, $g_2(i\Delta t)$,..., $g_n(i\Delta t)$ from seismic sensors of each facility are transmitted to the monitoring system through communication means. Due to this, at each weak earthquake from the facilities the monitoring system receives seismic signals, which are practically noisy vibration signals, with the help of which it is possible to determine the state of seismic stability of construction facilities. For this purpose, by analyzing seismic signals. $g_1(i\Delta t)$, $g_2(i\Delta t)$, $g_3(i\Delta t)$,..., $g_m(i\Delta t)$ received from sensors of corresponding facilities during the periods of time when weak earthquakes occur, informative attributes $\{D_X, D_{\varepsilon\varepsilon}, R_{X\varepsilon}, R^*_{X\varepsilon}\ K_1, K_2, K_3, K_4, K_5, K_6\}$ are determined.

In the practical application of the system, first the reference estimates for earthquake-resistant facilities are determined and memorized. After that, current estimates are calculated during weak earthquakes. If the difference between the current and reference estimates does not exceed the accepted minimum ranges, it is considered that the seismic stability and technical condition of the corresponding facilities O_1, O_2,..., O_N have not changed. Otherwise, information about the beginning of change in the technical condition of the corresponding facility is formed. In this case, the current estimates, which differ from the reference ones, indicate that the seismic stability of the controlled facility is compromised. By the value of the difference between the current and reference estimates, the degree of seriousness of the situation is determined, which shows that their technical condition should be monitored using standard equipment and technologies.

6 Possibilities of building intelligent systems of control of malfunctions on railroad tracks

Modern geometry cars, flaw detector cars and other railroad test cars provide reliable control of technical condition of all track hauls of the railroad bed in a "certain interval" of time. Their quantity is limited and therefore "continuous control" of all track crossings is practically impossible. At the same time in real life from the influence of various factors, for example, from the influence of torrential rains in hurricane winds, from the influence of seismic processes malfunctions of the railroad tracks can occur even a day after the control. The conducted analysis has shown that one of the possible options for "continuous" monitoring of the beginning of changes in the technical condition of the track by analyzing the noise of the signal received from ground vibration arising from the impact of the rolling stock, to form informative attributes of identification of technical condition of a track. Application of traditional technologies of correlation, spectral analysis and other methods for this purpose due to the influence of noise on useful vibration signals does not allow for adequacy of control results. Therefore, it was expedient to use the technology of selection and analysis of useful vibration signal, noise vibration signal, and the relationship between them. In this case it is expedient to use noise as the main carrier of diagnostic information.

The analysis of the possibilities of control of the technical condition of the railroad bed of the railroad tracks has shown the possibility of creating simple and inexpensive intelligent technical means, which can be installed on one of the cars of each rolling stock, which allows identifying the hauls that should be controlled “out of turn” [1-4].

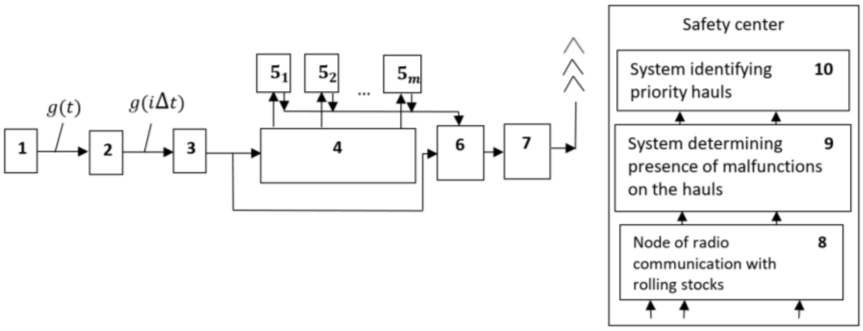

Fig. 3. Intelligent system for identifying railroad track hauls requiring out-of-turn control.

Fig. 3 shows the block diagram of one of the possible variants of building an intelligent system of malfunction control by analyzing the vibration signals of the dynamic process from the vibration of the railroad bed, arising at the beginning of all characteristic accidents during the movement of trains on the railroads.

The system consists of the following modules:

1 - Vibration sensor.

2 - Module of adaptive analog-to-digital conversion of vibration signals $g(t) = g(i\Delta t) = X(i\Delta t) + \varepsilon(i\Delta t)$.

3 - Module for determining estimates of current informative attributes

4 - The module of formation of reference informative attributes.

5_1-5_m - Reference informative attribute memorization modules.

6 - Module for identifying the beginning of the latent period of malfunctions.

7 - Module of formation and transmission of information via radio channel.

In the process of operation of the control system, the vibration signal $g(t)$ from the vibration sensor 1 arrives at the input of the module 2, i.e. at the input of the adaptive analog-to-digital converter, where it is converted into digital code $g(i\Delta t)$ with adaptive determination of the sampling interval. In practical application of the system, a training stage is carried out from the beginning for a certain period of time. Here, during the movement of trains in all hauls during the occurrence of a malfunction on the track sets $\{D_X, D_{\varepsilon\varepsilon}, K_1, K_2, K_3, \ K_4, K_5, K_6, R_{X\varepsilon}, R^*_{X\varepsilon}\}$ consisting of corresponding estimates of informative attributes are determined and memorized. This continues for some time, when by analyzing vibration signals on different trains all possible reference informative attributes are determined and memorized. Then, at the end of the training period, a period of railroad malfunction monitoring and identification of "problematic hauls" begins. Here, during the movement of all rolling stocks by analyzing vibration signals $g(i\Delta t)$ at the current time instant, the current estimates are determined $\{D_X, D_{\varepsilon\varepsilon}, K_1, K_2, K_3, K_4, K_5, K_6, R_{X\varepsilon}, R^*_{X\varepsilon}\}$and they are compared with the reference ones. If they exceed the threshold values set on the modules 5_1, 5_2, ..., 5_m, a signal is generated on module 6 about the beginning of the malfunction. After a second comparison, if the current estimates are greater than the corresponding reference estimates, then the module 7 forms a warning signal on the beginning of the malfunction, which is transmitted to the "Safety Center" via radio channel. Thus, as a result of functioning of the "system of detection of control hauls" in each rolling stock the information about the beginning of the malfunction is transmitted on the distances where there is a track malfunction.

Thanks to this, during the movement of trains on the hauls where there is a malfunction, the information through the "node of radio communication with rolling stock" is successively received by the "System determining the presence of malfunctions on the hauls" of the "Safety Center". In this case, the set of informative attributes about the presence of malfunctions from all rolling stock, for a day, from these "problematic" hauls will have the following form

As they are received, they are periodically analyzed and from the received combination of a set of informative attributes estimates, the final decision on the presence of a malfunction at the corresponding railroad haul, where it is advisable to send "test cars" out of turn, is formed. At the same time, the degree of reliability of the control results is achieved by paralleling the control process with the use of several algorithms. According to the number of coinciding results on the presence of malfunctions from rolling stock in each haul in the "system identifying priority hauls" the degree of their reliability is assessed. Thus, in the simplest case, from those sections of the tracks from which rolling stock transmit alarm information in the "system identifying priority hauls" the "problematic" hauls are finally determined and it is proposed to correct the schedule of their control. In case of simultaneous occurrence of several such problematic hauls, schedules of their out-of-turn control can be proposed.

7 Conclusion

1. At present, thanks to the application of monitoring and control systems in such critical facilities as water supply pumping stations, as well as in municipal cold and hot water supply systems, sewage pumping stations of wastewater pumping and wastewater treatment plants, the vital problem of the population in the respective areas of life support is reliably and successfully ensured. However, despite the many advantages of existing control systems, they do not provide signaling of the beginning of the latent period of accidents. The importance of this issue is due to the fact that any accident is preceded by certain defects, after which the latent period of accidents begins and develops after some time. Only after that it starts to be reflected in the readings of measuring devices of monitoring and control systems. The duration of the latent period depends on the dynamics of defect development. Because of this, the beginning of their emergency state is registered when the accident cannot be avoided.

2. At the present stage it is important to develop and create a city-wide system of control of seismic stability and technical condition of construction facilities in order to ensure public safety. This is due to the fact that when using traditional control technologies, the change in the seismic stability of a construction facility is established at the moment of time when it acquires a clearly expressed form. At the same time, it is vital to detect this change in the latent period of the initial stage. In this case, by detecting this process in advance, it is possible to organize timely preventive measures and prevent the occurence of serious defects, which allows to significantly reduce repair costs and reduce the number of sudden destruction during catastrophic earthquakes. The particular importance of creating a city-wide system for monitoring seismic stability in seismically active regions is largely due to the fact that if during weak earthquakes the ranges of deviations of the values of the corresponding estimates of informative attributes obtained from sensors of construction facilities exceed the established threshold values, it allows detecting the initial stages of emergency conditions of facilities reliably enough and to make decisions on appropriate repair works, which will allow to avoid catastrophic destructions during earthquakes.

3. In recent years, as part of the intellectualization of rail transport, intelligent trains have been created, which consist of a multifunctional control system and a traffic safety system. In order to increase the degree of safety of rail transport operation, first of all, it is necessary to create intelligent technologies for monitoring the beginning of the latent period of malfunctions both on the running gear of rolling stock and on the railroad bed, bridges and tunnels. At the same time, vibration diagnostics is of particular importance to ensure a high level of safety. This is due to the fact that the signals received from vibration sensors have a great diagnostic information potential. However, despite this, in practice there are cases when the adequacy of vibration control and diagnostics results is not ensured. This is due to the fact that traditional algorithms for analyzing noisy vibration signals $g(i\Delta t)$ do not use noise as a carrier of diagnostic

information. At the same time in the vibration signals received from rail transport facilities, noise occurs as a result of the occurrence of a malfunction and contains significant diagnostic information. And the noise $\varepsilon(i\Delta t)$ correlates with the useful signal; without taking into account the influence of noise on the result of vibration diagnostics it is impossible to ensure the adequacy of control results.

4. Studies have shown that the use of the proposed technology in other critical facilities can also increase the degree of accident-free operation.

- Possible application of the technology and system for monitoring the onset of accidents on offshore platforms and drilling rigs
- Possible application of the technology and system at oil and gas production facilities
- Possible application of the technology and system at power engineering facilities

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