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DESIGN ISSUES OF THE CONCEPT OF EMERGIENCY MONITORING AND CONTROL SYSTEM BUILDING

Abstract. This article is devoted to the development of the concept of building an automated emergency monitoring and control system and determines its structure and territorial distribution. Examples of monitoring facilities have been presented and the urgency of the development and implementation of such systems has been shown. The proposed concept includes a multi-level hierarchical structure of the monitoring system with an open architecture, on the lower level, where multifunctional sensors of physical quantities established in controlled facilities or areas are located. It is proved that it is more sensors determine the reliability and data of all the monitoring system. With regard to the danger of debris flow monitoring system, the range of sensors in use has been defined. The problems of improvement of information content and control and warning efficiency have been considered. It is shown that the proposed concept can be implemented and function smoothly only if there is a modern software and hardware equipment. The problems solved at its various levels are described in detail by the example of the 3-level monitoring system.

Keywords: environment, monitoring, control, sensors, accident, technogenic, mudflow, pollution, the interface.

Introduction. The environment means the financial situation, which is in contact with humanity, and allows each human body to function on the planet. The environment includes: water, air and land. And if these environment components will not meet certain requirements, the population habitation in the area with broken or environmental conditions will be difficult or generally impossible.

Environmental disturbances may be caused by the influence of both human and can be technogenic. Human impact is most often seen in the pollution of water and air, deforestation in mountain and foothill areas, river basins, steppe areas.

Technogenic disasters are associated primarily with the seismic activity in the mountains and foothills, as well as floods of rivers, snow melt, overflow and breakthroughs of moraine lakes and so on, which finally cause a considerable economic damage in territories [1, 2].

With regard to Kazakhstan, a special damage from natural emergency situations falls on the mudflows. Mudflows are usually sudden and short-lived, often characterized by catastrophic after-effects, they cause huge material damage and are often accompanied with victims [3].

The current emergency monitoring and control system (EMCS) does not stand up to scrutiny in terms of problem solving, openness, reliability and efficiency [3].

Thus, the creation of multi-level emergency monitoring and control system is an extremely urgent task not only for Kazakhstan, but also for many countries with mountain and foothill areas. The relevance of the problem is confirmed by the Law of the Republic of Kazakhstan "About emergency situations of natural and technogenic character" [4], which provides research, observation, the situation control, forecasting and warning about the threat of accidents, disasters and catastrophes. There we can also point out that the main objectives of research in the field of emergency situations of natural and technogenic character is to develop methods for monitoring and establishment of the emergency data bank, forecasting methods, prevention, control and protection measures, targeted scientific and technical programs for forecasting, assessing the impact, preventing and elimination of emergencies.

It should be noted that the creation of a whole complete emergency monitoring and control system is extremely difficult and time-consuming task, which is to be solved with the traditional methods only by specialized development teams with specialists in hardware, programmers, designers, systems analysts, engineers, and so on. But, as a result of the development of the theory and practice of modern MIS, SCADA and other control and monitoring systems, there was adopted the open systems approach, which uses standard technology platforms, standard interfaces, and so on, that allows to decentralize the development of the environment monitoring and control system. The main level of the emergency monitoring and control system is the level of converters of physical quantities sensors (PQS), on the reliability, accuracy and information content of which depends the throughout work of the monitoring system [5]. And in order to increase and decrease the number of informative PQS type, they should be multifunctional which means the simultaneous measurement of several values with a single sensor [6].

From the standpoint of the theory of complex systems and automatic control, the EMS (Environment Monitoring System) belongs to a class of automated, information, human-machine systems that implement advanced mathematical methods and information and communication technologies for the collection, transmission and processing of information on the state of technically complex objects. At the same time, the process of operation of such systems includes monitoring the state and dynamics of the controlled objects and territories.

It should be noted that monitoring is a system of regular, long-term observations of the physical condition of the distributed object in space; it allows accumulating information about the object in order to assess its current state and forecasting. From the general theory of systems it is known that most of the natural and man-made objects belong to a class of complex systems, i.e. systems that consist of many interacting elements (subsystems), at that, the complex system has properties that are absent in its components [7].

The objects of monitoring and control are technically complex objects (TCO), technological processes, livelihood and security subsystems: heating, ventilation and air conditioning, water supply and sewerage, electricity, gas, engineering and technical complex fire safety facility, alert system, as well as engineering structures (structural elements) of objects of residential buildings, bridges etc.

The essence of the TCO MS operation is as follows. It automatically transmits messages of abnormal parameters and the actual state of various objects and systems of buildings and structures, livelihoods and security equipment, fire alarm, chemical and gas hazards, etc. on the basis of the data received from a control object in real-time mode. A number of monitoring systems in addition to sending text messages provides the video transmission from the place of violation in real time. In case of receiving warning messages from the TCO MS about violations in normal operations, pre-emergency changes in engineering, load-bearing structures, the regulations provide realization of appropriate activities to eliminate the causes of violations and/or survey the structures with the issuance of conclusions about their engineering status and proposals for their strengthening.

An example of using this TCO MCS concept is the multi-channel analogue-digital system of monitoring the status and operation of the bridge structure, shown in Fig. 1. The specificity of the MCS is to have procedures on neural network identification of the bridge state, which is carried out in the block IS [8].

The introduction of modern multi-parameter sensors with multi-component replacement scheme calls for the need, along with the solution of measurement tasks, to solve more general problem of identification, as various TCO processes are being carried under real-life conditions.

The information received through sensors in the form of signals are transmitted with conditioning amplifiers (CA), which convert the signals from the sensors into a unified signal, which acts as a voltage to be converted in the future into a digital code through the analogue-digital code (ADC). The received digital code is processed and stored in a digital processing unit (DPU). The scheme also shows the intermediate nodes in the system: microcontrollers (MC) and interfaces. These total blocks represent a classic generalized structure of a multi-channel monitoring and control system. Its main purpose is the allocation of an informative component in a background of an uninformative one, so in addition to the classic multi-channel measuring and MCS system included a neural network identification subsystem (IS) that performs identification of the information received with an informative component.

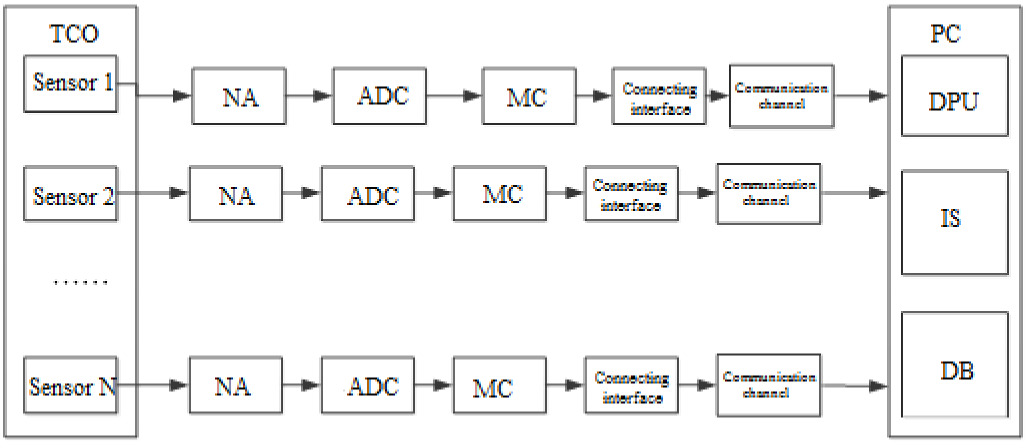

Figure 1 – The MCS generalized block diagram of bridge structures.

NA-normalizing amplifier, ADC – analogue-digital converter, MC – microcontroller, PC – processing center, DPU – digital processing unit, IS – neural network identification subsystem, DB – database.

Typically, the MCS developers prefer to use standard solutions, the basic technology platform and a wireless interface that allows to reduce costs, accelerate the development of manufacturing and installation of the MCS, as well as to simplify their subsequent operation. At the same time they focus on the ON-LINE system.

Currently, intelligent systems and devices are rapidly developing which allow monitoring and managing the processes of collection, processing and delivery of information on the status of products, systems and facilities, including special equipment facilities. It's obvious that for the diagnosis and management of complex objects in real time, it is necessary to handle very large amounts of rapidly changing telemetric information received on the various physical channels: radio, wire, optical [9, 10].

Another typical example of the difficulties of using existing channels and methods of information collection and transmission is dependence on the "visibility" areas of a controlled object with regard to the control points. A typical example of this is the monitoring of the status of spacecraft (SC), which is carried out with the help of ground-based radar tracking stations, which "cover" only a specific area and cannot communicate with the object of telemetric information on the entire orbital path. Here there is a risk of loss of control over the object, which can lead to an emergency situation (that is confirmed by the last carrier-rockets accidents) [11, 12]. The concept of creation of the automated environmental and emergency monitoring system should be based on the received state and departmental laws, standards and the geographically distributed hardware and software structure, which provides continuous monitoring, control and timely public notification and warning each person of signals and emergency information about the threat or occurrence of emergency situations, as well as the rules of procedures and safety methods in such situations.

It should be noted that at the present stage of environment monitoring systems development the information content and timeliness of monitoring and alerting can be increased by:

- Computerization of information processes;
- Minimizing the influence of the human factor;
- Unifying and engaging current and new hardware and software and information technology in an integrated system.

This conception can be implemented and operate under normal conditions with following elements of hardware and software equipment:

- A set of mathematical models including dynamics that describes the occurrence and development of emergencies on a controlled object or territory;
- Distributed telecommunications networks, local systems of control and diagnostics of existing sources of natural and technogenic emergencies, including the Internet, mobile communication, multifunctional sensors and autonomous measuring system coupled with hardware and software systems of a higher level;
- Automated systems for reception and transmission of information about the multivariate state of the controlled object;
- Decision-making software-hardware expert system based on the use of technologies of artificial neural networks and mathematical apparatus of fuzzy sets.

The structure of the proposed automated multi-level environmental monitoring system applied for mountain and foothill regions of Kazakhstan is shown in Fig. 2 [5].

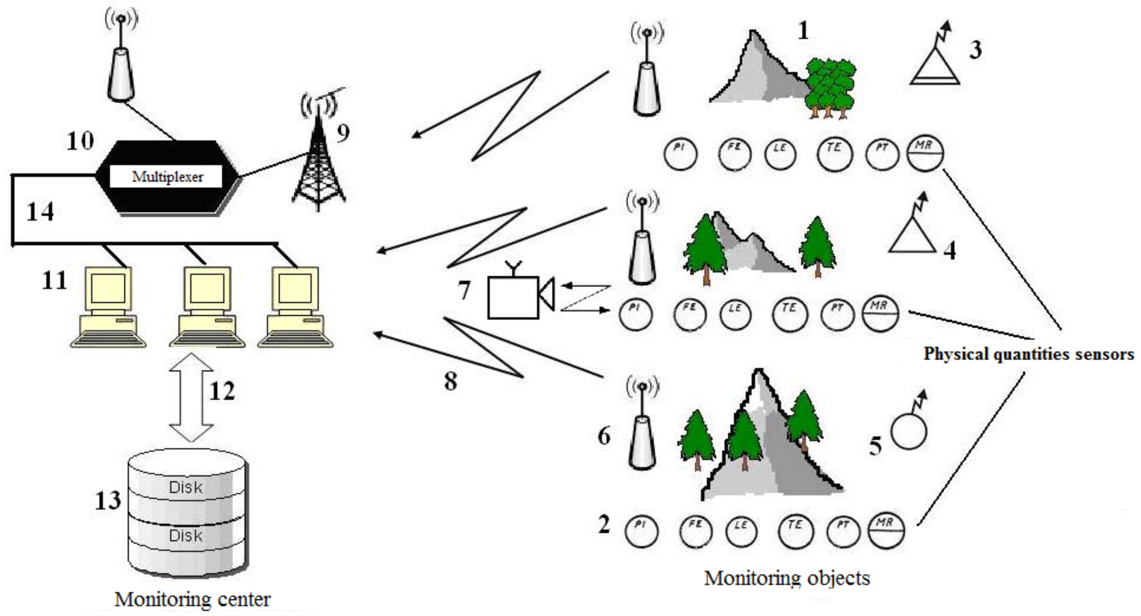

Figure 2 – Block diagram of emergency monitoring system.

1 – monitoring objects; 2 – physical quantities sensors; 3 – fixed radio station; 4 – mobile station; 5 – pack radio set; 6 – radio modem; 7 – camcorder with the transmission over the air; 8 – radio channel; 9 – the VHF base station; 10 – radio converter/distributor; 11 – monitors of the information processing points of emergency monitoring center; 12 – internal interface; 13 – a database; 14 – internal link.

The monitoring system presented in Fig. 2 consists of three conditional hierarchical levels:

- The first the grassroots level presents specific monitoring objects with mounted sensors of physical quantities (pressure, temperature, level, humidity, etc.)
- The second – radio transmitters and receivers with antenna-feeder facility. They serve as the organization of regular channels of information between the sensors and the monitoring center for receiving and processing information about the disaster;
- The third – the highest level on which all the information coming from the monitoring object is received, processed, stored and analyzed.

Let's briefly consider the functions and features of all levels of hardware and software for the environment monitoring system with the indication of technical requirements and their feasibility.

The first lower system level. The first level responds for the work of the whole system, as it is physical quantities sensors (PQS) perform a fundamental role to provide reliable information about the state of the primary monitoring object for any effects of many external factors. Let’s formulate on this basis the quality requirements for the basic parameters of PQS and ways to achieve them:

1. The PQS list should be sufficient to measure the main factors of the environment, which are, for example, to monitor the mudflow risk: the water level in moraine lakes and reservoirs, snow cover, humidity and soil, water temperature, air and snow cover, water consumption in mining effluents, the water pressure in the reservoirs, etc.

To implement these requirements directly and close to monitoring facilities will be installed the following PQS:

- Air pressure
- Air temperature
- Relative air humidity
- The number of past precipitation
- Water temperature
- Water level
- Water consumption
- Snow height
- Water muddiness
- Snow mantles temperature
- Snow surface temperature
- Snow surface height
- Earthquake activity

The exchange of information between the PQS network installed at monitoring sites and monitoring center can be done either over the air or using an unmanned aerial vehicle (UAV), which, when flying over the monitoring zone, scans and stores information accumulated with sensors. This embodiment is preferable in the case where the signals in the monitoring area have strong attenuation, which often happens in a mountain terrain. To improve the reliability and information content of monitoring object state, UAVs are often equipped with web cam, which in real time captures a monitoring object with the time and coordinate referencing on-site.

The second interface level. As the medium for the transmission of data to the PQS monitoring center, it is advisable to use high-frequency radio modem line connection. This is due to a large volume of transmitted information, including video cameras.

To control the sirens and loudspeakers warning of disaster, it is advisable to use VHF radio, because it is less expensive, but also because of the fact that portable VHF radio is widespread in the agencies of the Ministry of Emergency Situations. Other modern means of communication: mobile, satellite and others are inappropriate to use due to the high cost, since the two-way radio systems must operate around the clock. To increase the stability and reliability of communication, the star type systems approved in practice and the ZigBee type standard can be used for PQS equipped with radio transmitting modules [13]. Optimization of the interface parameters depending on conditions of use, including the terrain and distances, requires a separate consideration out of this article.

The third upper level. At this level there is reception and processing of signals received from the first system level. Here, using original methods, algorithms and programs, an analysis of the controlled object parameters (single factors or criteria) is performed and the generalized criteria (integral), which serve as the main indicators of the state and behavior of the controlled system, are developed. The mechanism of integrated criteria development is based on the use of mathematical apparatus of artificial neural networks (ANN), fuzzy sets and expert methods.

The implementation of this concept in the form of a multi-level structure is not always feasible due to the complexity and high cost, so if the tasks and monitoring objects are not very bulky and less significant, it is advisable to use local systems which are less complex with hardware and software equipment, including mobile. Such MCS can function in a stand-alone mode or can be combined into a more complex multi-layered EMS equipped with multi-functional sensors [14-17].

Conclusion. Creation of automated multi-level system for monitoring and control of emergencies arising in the environment is extremely urgent problem not only for Kazakhstan, but also for all the countries of the Central Asian region and Russia. This is due to the constant seismic activity, the formation of debris flows and the probability of accidents on technically complex objects. The proposed concept of the construction of EMCS involves the modularity of construction, open architecture, the use of multi-function sensors of physical quantities, distributed to controlled objects or territories. The aims and tasks solved with EMCS are posed, the function of each MCS level is marked, types and assignment of physical quantities sensors are defined.

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ТӨТЕНШЕ ЖАҒДАЙЛАРДЫ БАҚЫЛАУ ЖӘНЕ МОНИТОРИНГ ЖҮЙЕСІН ҚҰРУ КОНЦЕПЦИЯСЫН ДАМЫТУ МӘСЕЛЕЛЕРІ

Аннотация. Мақала төтенше жағдайларды бақылау мен мониторингтің автоматтандырылған жүйелерін құру концепциясын дамыту, оның құрылымын және аумақтық орналасу ретін анықтауға арналған. Мониторинг объектілерінің мысалдары келтірілген, бұндай жүйелерді құру мен іске асыру өзектілігі негізделген. Ұсынылған концепция ашық архитектуралы, көпдеңгейлі иерархиялық құрылым ретінде қарастырылған, оның төменгі деңгейінде бақыланатын объектілерде не аумақта орнатылған көпқызметті физикалық шамалар датчиктері орналасады. Мониторинг жүйесінің ақпараттылық толымдылығын және сенімділігін датчиктер анықтайтындығы дәлелденген. Сел ағынын мониторингтеу жүйесіне қатысты қолданылатын датчиктер номенклатурасы анықталған. Бақылау мен хабар таратудағы ақпараттылық толымдылық пен жылдамдықты арттырудың сұрақтары талданған. Ұсынылған концепция қазіргі заманғы бағдарламалық-аппараттық қамтамасыз ету негізінде жұмыс атқара алатындығы көрсетілген. Үш деңгейлі мониторинг жүйесі мысалында әр деңгейде шешілуге тиісті сұрақтар талданған.

Түйін сөздер: қоршаған орта, мониторинг, бақылау, датчиктер, апат, техногенді, сел, ластау, интерфейс.

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ВОПРОСЫ РАЗРАБОТКИ КОНЦЕПЦИИ ПОСТРОЕНИЯ СИСТЕМЫ МОНИТОРИНГА И КОНТРОЛЯ ЧРЕЗВЫЧАЙНЫХ СИТУАЦИЙ

Аннотация. Статья посвящена разработке концепции построения автоматизированной системы мониторинга и контроля чрезвычайных ситуаций и определения ее структуры и территориального размещения. Приведены примеры объектов мониторинга и показана актуальность разработки и реализации таких систем. Предложенная концепция подразумевает многоуровневую иерархическую структуру системы мониторинга с открытой архитектурой, на нижнем уровне которой располагаются многофункциональные датчики физических величин, устанавливаемых на контролируемых объектах или территориях. Доказано, что в большей степени именно датчики определяют надежность и информативность всей системы мониторинга. Применительно к системе мониторинга селевой опасности определена номенклатура используемых датчиков. Рассмотрены вопросы повышения информативности и оперативности контроля и оповещения. Показано, что предложенная концепция может быть реализована и штатно функционировать только при наличии современного программно-аппаратного оснащения. На примере 3-х уровневой системы мониторинга подробно описаны задачи, решаемые на ее различных уровнях.

Ключевые слова: окружающая среда, мониторинг, контроль, датчики, катастрофа, техногенный, сель, загрязнение, интерфейс.

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