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Method for Ensuring Continuous Functioning of Multichannel Systems for Control and Recording of Water Composition in Seismic Wells

ShipulinYu.G., Raimzhonova O.S., Ergashev O.M., UsmanovZh.K

Professor, Department of Information Processing and Control Systems, Tashkent State Technical University, Tashkent, Uzbekistan
Professor, Department of Telecommunication technologies, Tashkent University of information technologies, Fergana, Uzbekistan
Assistant Professor, Department of Information technologies, Tashkent University of information technologies, Fergana, Uzbekistan
Deputy Head of the Department of the Chirchik Higher Tank Command Engineering School, Chirchik, Uzbekistan

ABSTRACT: The method and issues of ensuring the continuous functioning of multifunctional intelligent systems for monitoring and recording water parameters flowing from self-flowing seismic wells are considered. Functional diagrams of a multichannel system and its main functions, a block diagram of the device program algorithm are given, an analysis of methods for ensuring the continuous operation of this system is given, that in order to maintain a given level of system reliability, it is necessary to replace the failed measuring system with a serviceable one. Systems of differential equations showing that the recovery process and the loss process are independent and obey the Poisson distribution law with variable parameters are considered.

KEYWORDS: Earthquake forecast, multifunctional monitoring and recording system, seismic wells, basic functions, data collection from various sensors, operability, program flow diagram, continuity of operation, probability, time interval, differential equations, spare stock of serviceable measuring systems, Poisson's law.

I. INTRODUCTION

An earthquake forecast consists of predictions of the place, strength and time of their manifestation. The problem of predicting the time and place of occurrence of strong earthquakes has not yet been solved due to its exceptional difficulty (the need to obtain information about the processes in the earth's interior at great depths, the low speed of differentiated tectonic movements leading to earthquakes, etc.). Work in this direction is associated with the search for earthquake precursors (variations in time of the propagation velocity of seismic waves, the rise or fall of the ocean level several hours before strong earthquakes, changes in the electrical resistance of rocks, etc.).

II. LITERATURE SURVEY

To a certain extent, seismic zoning serves as an element of the forecast, which makes it possible to indicate the areas of possible maximum strength and average frequency of earthquakes. Clarification of seismic microzoning based on engineering-geological surveys and seismometric instrumental observations [1, 2, 3].

III. SIGNIFICANCE OF THE SYSTEM

The authors have developed a multichannel intelligent system for monitoring and recording (MISKiR) the composition of water from self-flowing seismic wells. On the territory of the Republic of Uzbekistan there are 8 hydrogeological stations and more than 70 self-flowing wells, which are used to predict the seismic activity of earthquakes. Based on the analysis of measurement data, control and registration of the main parameters of water (temperature, level, pressure, flow rate, pH and EP, etc.), the forecast for determining seismic regimes by intensity, determining the distance of the center of impact, frequency of earthquakes and attenuation of seismic energy is increased [4].

IV. SYSTEM ANALYSIS

A multichannel intelligent system for monitoring and recording temperature, pressure and water level in seismic wells, shown in Fig. 1, is the main device in the Center for Integrated Monitoring of Earthquake Precursors. This device is designed to perform the following basic functions:
- collection of data from various sensors;
- storage of received information for a long time;
- operational control of power supply of sensors;
- forwarding of the accumulated information to external devices via the RS-485 interface;
- automatic determination of the number and frequency of connected sensors, the sequence of their connection to the input channels of the data collection and processing device;
- power control of electronic components of the system.

The principle of operation of multichannel systems for control and recording (MSCR) is based on the analysis of the characteristics of temperature, pressure and water level from the corresponding sensors. The characteristics parameters are processed by the microcontroller, stored in external RAM and displayed on the external display. In fig. 2 shows a block diagram of the algorithm of the main program of the device, the continuous operation of transmission systems for the main seismic parameters of earthquakes.

The water level is measured by the ultrasonic sensor unit 3. A pulsed ultrasonic signal is sent from the transmitter. The receiver records the reflected signal. The water level is determined from the time difference between the output and received impulses [5].

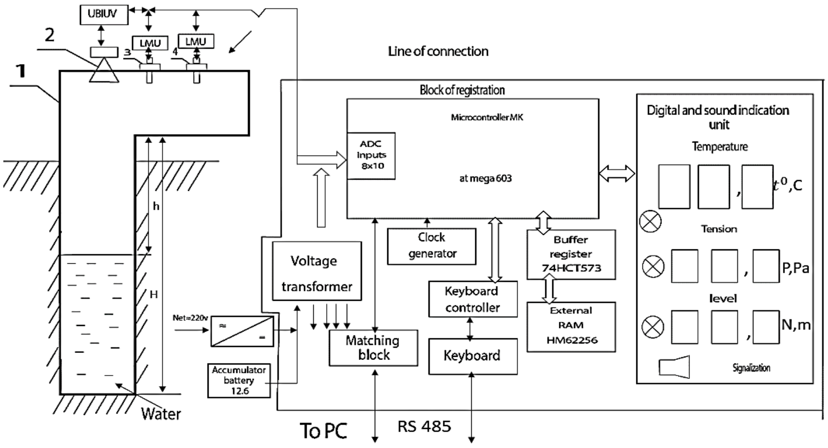

Fig. 1. Multichannel intelligent system for measuring, monitoring and recording temperature, pressure and water level in seismic wells.

The signal from the temperature sensor enters the input of the linear scaling amplifier 2 and then enters the communication line.
The signal from the pressure sensor is fed to the input of the linear scaling amplifier 1, from the output of which it is fed into the communication line.

Linear - scaling amplifiers 1, 2 perform amplification and correction of analog signals for transmission to the registration unit via a communication line. From the communication line, analog signals are fed to the analog inputs of the ADC of the microcontroller. When starting the program, the MC includes a self-diagnostic program that determines:
1) Connection of measuring sensors. If there is no mechanical connection of any circuits (i.e., any connectors of the measurement circuits are not connected), then this information is transmitted to the digital or sound indication unit.

2) The performance of the measurement sensors. The program for preliminary testing of sensors is launched and their readings are analyzed in the real range. In case of deviations in the readings of the sensors beyond the boundaries of the real range, the corresponding information is set in the digital and sound indication unit. In the event that a malfunction is detected by the self-diagnostic program, the main program waits for the operator's decision: to start the control program without any sensors or wait for the measuring circuits to be brought into a certain serviceable state.

3) The functioning of the external RAM is tested.

4) The self-diagnostics program includes the process of checking all digital and sound indicators at the request of the operator (pressing the "Check indication" button). The digital and sound indication unit displays the current state of all supply voltages. In the absence or change within unacceptable limits of any supply voltages, the MC sends an alarm to the indication unit and blocks the start of the control program until the malfunction is eliminated.

The MC control program linearizes the measured data for monitoring temperature, pressure and water level in the well.

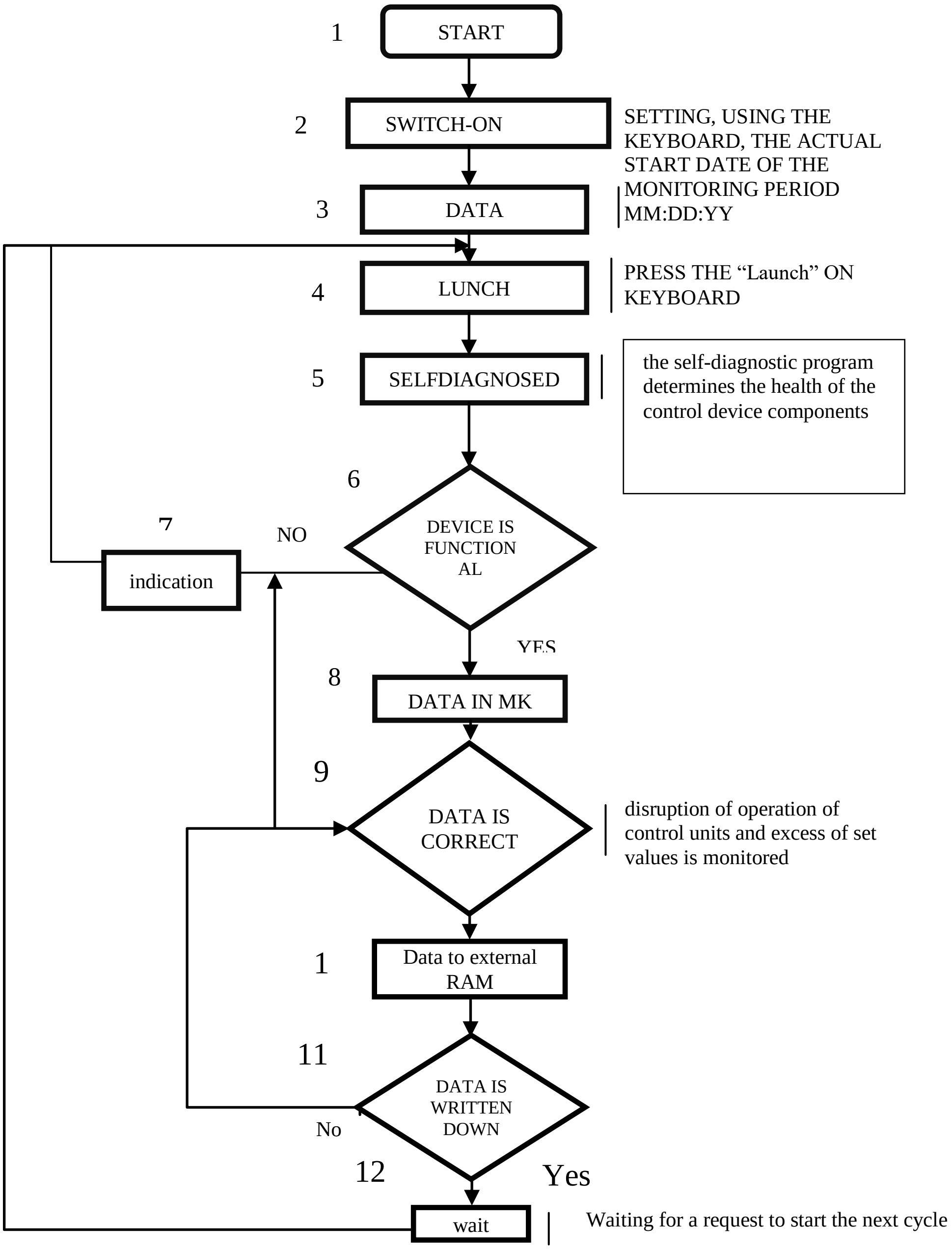

Figure: 2. Block diagram of the algorithm of the main program of the measuring device for monitoring and recording water parameters in seismic wells

The clock generator determines the timing of the functioning of the microcontroller. The processed data of water parameters is received:
1) Via a bidirectional buffer register to external RAM.
2) In the block of digital and sound indication of water parameters in the well. The display unit reproduces the current state of the monitored parameters. When the threshold values of the monitored parameters are exceeded, sound and light indication is triggered.

Controlled information is displayed in two modes:
1) Displaying information about water parameters in wells on the display unit by calendar dates of the month, day and time of day. The required time data is typed on the keyboard and transmitted to the MC through the keyboard controller. MC removes the necessary data from external RAM and transfers them to the display unit.
2) Data on monitored water parameters for the selected monitoring period are transferred to a personal computer PC. The monitored period is set on the keyboard and entered into the MC through the keyboard controller. The MC selects the required database from the external RAM and, through the matching unit, organizes the data transfer to the PC using the corresponding RS 485 channel protocol.
3) The voltage converter organizes the formation of all the corresponding supply voltages for the functioning of all nodes and blocks of the control and registration device.

To ensure the continuous functioning of the measuring system, a method is proposed to ensure the uninterrupted operation of a certain number of measuring systems, an earthquake forecasting center. At the same time, it becomes necessary to carry out a number of measures [5] aimed at maintaining a given level of system reliability, for example, replacing a failed measuring system with a serviceable one, which allows maintaining the required number of measuring systems in the earthquake forecasting center, ensuring its normal functioning. At the same time, the failed system goes to recovery, and after recovery it goes to the reserve fund or into operation. The measuring complex is serviced according to the block diagram shown in the figure:

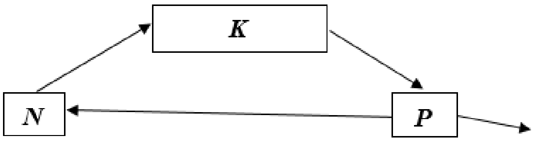

Figure: 3 Block diagram of the measuring complex.

K-measuring complex, consisting of *r* microprocessor systems; *P* - an organization that restores failed systems coming from the measuring complex (this transition is shown by an arrow going from *N* to *P*). After the system is restored, they go to replenish the reserve fund of the complex *N* (as indicated by the arrow going from *P* to *N*), from where, in the event of a system failure in the complex, the system from the reserve fund goes to its place. It may happen that the system during the restoration process turned out to be unrepairable, then it can be considered "lost" for operation (indicated by the arrow going to the right of *P*). Usually their number is a fraction of the restored systems. This circumstance cannot be ignored when calculating the reserve fund, the uninterrupted functioning of the complex. Therefore, it is necessary to add an additional number of systems to the existing reserve fund, based on the consideration of irrecoverable losses in the recovery process. The processes of failure, recovery, losses are random in nature, therefore the most convenient for their assessment is the mathematical apparatus of the theory of probability.

V. METHODOLOGY

In order to take into account irrecoverable losses, we introduce the concept of system loss rate, similar to the concept of failure rate, recovery rate [6, 7], which is statistically defined as the ratio of the number of lost systems Δn_i over the time interval Δt_i to the number of systems being restored (under repair) to the moment $(0, \Delta t_{i-1}) – N_i$.If γ_m is the intensity of losses of the complex; β_m is the intensity of complex recovery; λ_m is the failure rate of the complex; $P_{m,n}$ is the probability that at time t the repair of m systems is entered and n systems are lost, then it seems possible to consider the states in which a complex of measuring systems can be.

1. By the time t, there are m systems under repair and n systems are lost, and during the time $(t,t+\Delta t)$ not a single failure, not a single loss, not a single recovery has occurred. The probability that the complex remained in the state (m, n), is determined by the expression

$$P_{m,n}(t)\,[1 - (\lambda_m + \beta_m + \gamma_m)]\,\Delta t. \tag{1}$$

2. By time t, $m+1$ computer systems are under repair and n systems are lost. In time $(t,t+\Delta t)$ one recovery occurred. The probability that the complex will pass into the state (m, n), will be:

$$P_{m+1,n}(t)\,\beta_{m+1}\Delta t. \tag{2}$$

3. By the time t, $m - 1$ computer systems are under repair with n systems lost. During the time $(t,t+\Delta t)$, the complex of systems passes into the state (m, n) due to the failure of the system; the probability of the state (m, n) is characterized by the relation.

$$P_{m-1,n}(t)\lambda_{m-1}\Delta t. \tag{3}$$

4. By the time t, $m+1$ systems were under repair and n-1 systems were lost. In time $(t,t+\Delta t)$, the computing complex has one loss, then the probability of the state (m, n)will be

$$P_{m+1,n-1}(t)\gamma_{m+1}\Delta t. \tag{4}$$

Let us find the probability that during the time interval $(0,t+\Delta t)$ the complex of systems will be in the state (m, n), i.e. m systems will be under repair, and n - will be lost. Considering two time intervals $(0, t)$ and$(t,t+\Delta t)$, according to the formula of total probability, taking into account the previously obtained possible states, we have

$$\begin{gathered} P_{m,n}(t+\Delta t) = P_{m,n}(t)\,[1 - (\lambda_m + \beta_m + \gamma_m)\,\Delta t] + \\ +P_{m-1,n}(t)\lambda_{m-1}\Delta t + P_{m+1,n}(t)\beta_{m+1}\Delta t + P_{m+1,n-1}(t)\gamma_{m+1}\Delta t, \\ 0 \le m \le r; \quad 0 \le n \le r \end{gathered} \tag{5}$$

Dividing the resulting expression by Δt and passing to the limit as $\Delta t \to 0$, we obtain the system of differential equations

$$\begin{gathered} \frac{dP_{m,n}}{dt} = \lambda_{m-1}P_{m-1,n} + \beta_{m+1}P_{m+1,n} + \gamma_{m+1}P_{m+1,n-1} - \\ -(\lambda_m + \beta_m + \gamma_m)P_{m,n} \\ 0 \le m \le r; \quad 0 \le n \le r \end{gathered} \tag{6}$$

Based on the problem statement, the complex can be characterized by the following parameters:

$$\lambda_m = \lambda = r\bar{\lambda}; \quad \beta_m = m\beta; \quad \gamma_m = m\gamma,$$

where $\bar{\lambda}$,β, γ - parameters inherent in this type of measuring systems;
r is the number of measuring systems operated in the complex.
To solve the resulting system of differential equations, we use the method of generating functions, setting

$$\Phi(t,x,y) = \sum_{m,n=0}^{\infty} P_{m,n} x^m y^n \tag{7}$$

We multiply the system of equations (6) by $x^m y^n$ and, summing over m, n (we assume for generality $P_{-1}(t) \equiv 0$), we obtain

$$\begin{aligned} &\frac{\partial}{\partial t}\sum_{m,n=0}^{\infty} P_{m,n}(t)x^m y^n = \\ &= x\lambda \sum_{m,n=0}^{\infty} P_{m-1,n}(t)x^{m-1}y^n + \beta \sum_{m,n=0}^{\infty}(m+1)P_{m+1,n}x^m y^n + \\ &+\gamma y \sum_{m,n=0}^{\infty}(m+1)P_{m+1,n-1}x^m y^{n-1} - \beta x \sum_{m,n=0}^{\infty} mP_{m,n}x^{m-1}y^n - -\gamma x \sum_{m,n=0}^{\infty} mP_{m,n}x^{m-1}y^n \\ &-\lambda \sum_{m,n=0}^{\infty} P_{m,n}x^m y^n. \qquad (8) \end{aligned}$$

Therefore, under condition (7), after elementary transformations, we have

$$\frac{\partial \Phi}{\partial t} + (\beta x + \gamma x - \gamma y - \beta)\frac{\partial \Phi}{\partial x} = \lambda(x-1)\Phi. \tag{9}$$

To solve the resulting equation, it is necessary to consider the system

$$\frac{dt}{1} = \frac{dx}{(\beta+\gamma)x - \gamma y - \beta} = \frac{d\Phi}{\lambda(x-1)\Phi}, \tag{10}$$

from which it follows that

$$\Phi(t, x, y) = e^{Bx - B}e^{Cy - C} \tag{11}$$

where

$$C = \frac{\gamma\lambda}{(\beta+\gamma)^2}\left[e^{-(\beta+\gamma)t} - 1 + (\beta+\gamma)t\right];$$

$$B = \frac{\lambda}{\beta+\gamma}\left[1 - e^{-(\beta+\gamma)t}\right].$$

Expanding (11) in series separately in *x*and *y* and multiplying the series, we obtain

$$\Phi(t,x,y) = \sum_{m,n=0}^{\infty} \frac{B^m}{m!}e^{-B}\frac{C^n}{n!}e^{-C}x^m y^n. \tag{12}$$

The function $\Phi(t,x,y)$ is also defined by expression (7). Comparing expressions (7) and (12), we have

$$P_{m,n} = \frac{B^m}{m!}e^{-B}\frac{C^n}{n!}e^{-C} = P_m P_n, \tag{13}$$

i.e., the recovery process and the loss process are independent processes and obey the Poisson distribution law with a variable parameter (because *B*,*C* depend on *t*):

$$P_m = \frac{B^m}{m!}e^{-B}, \qquad P_n \frac{C^n}{n!}e^{-C}. \tag{14}$$

To ensure the correct functioning of the measuring complex, the average number of lost and being recovered systems should be equal to the number of systems in the reserve fund. Taking into account the property of Poisson's law [8, 9], we obtain

$$N = B + C,$$

where*N* is the number of computing systems in the spare fund. Expanded

$$N = r\left\{\frac{\bar{\lambda}}{\beta(1+\alpha)^2}\left[1 - e^{-\beta(\alpha+1)t}\right] + \frac{\bar{\lambda}\alpha}{1+\alpha}t\right\} =$$

$$= r\left\{\frac{T_{\text{p}}}{T(1+\alpha)^2}\left[1 - e^{-\frac{1}{T_{\text{p}}}(1+\alpha)t}\right] + \frac{\alpha}{T(1+\alpha)}t\right\}, \tag{15}$$

whereT_{p} is the average repair time for the computing system ($T_{\text{p}} = 1/\beta$); *T* is the average operating time of the system ($T_{\text{p}} = 1/\bar{\lambda}$); α is a number characterizing the share of decommissioned (lost) systems from the total number of recovered measuring systems ($\gamma=\alpha\beta$); *t* is the estimated operating time of the systems in the complex.

VI. CONCLUSION AND FUTURE WORK

The multichannel system for monitoring and recording the composition of water from outflowing seismic wells allows for the prompt collection of data from temperature, pressure, water level and concentration sensors, long-term storage of current information, analysis and comparison with specified parameters, which makes it possible to increase the predictability of the primary earthquake parameters.

Considering that the system should function for a long time, the authors proposed a method for ensuring the uninterrupted operation of the entire measuring complex, maintaining a given level of reliability, replacing a failing measuring system with a serviceable one. It is shown that the process of losses are independent and obey. Poisson distribution law with variable parameter.

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