MATHEMATICAL MODEL OF A SYSTEM FOR CONTROLLING AND DIAGNOSING THE SAFETY STATE OF OIL AND GAS TERRITORY

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MATHEMATICAL MODEL OF A SYSTEM FOR CONTROLLING AND DIAGNOSING THE SAFETY STATE OF OIL AND GAS TERRITORY

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Abstract. In this article, the way of creation mathematical model of a control system and diagnostics of the security status of the oil and gas territory is considered. For performing diagnostics of the safety status of the oil and gas territory as a mathematical apparatus it is suggested to use a boolean algebra. The main controlled objects and their technological parameters which define safety, integrity of saving, operational carrying out monitoring status as separate objects and all oil and gas territory, prediction of the expected threats, economic social, and economic damage are selected. For the creation of a mathematical model truth diagrams the reflecting dependences of statuses of output parameters of the automatic machine on statuses of input controlled parameters and its internal statuses are made. As a result of a series of transformations, elements of the diagnosis of the dependence of the limiting values of the state of the monitored parameters are displayed in a more compact form: the appearance of smoke, the presence/absence of flame, the appearance/disappearance of objects, changes in levels and pressure in reservoirs, and other parameters of the oil and gas territory from their input states. General Boolean functions — mathematical models of diagnoses that describe the unsatisfactory and satisfactory state of the oil and gas territory in terms of complex parameters, are written in disjunctive and conjunctive normal form.

Keywords: Oil and gas territory, the appearance of smoke, the presence/absence of flame, the appearance/disappearance of objects, changes in levels and pressure of reservoirs, humidity, temperature.

Аннотация. Нефтегазовая территория является объектом, подверженным риску возникновения аварийных ситуаций, связанных с нефтью и газом. Для управления и диагностики состояния этой территории предлагается использовать булеву алгебру. Основные контролируемые объекты и их технологические параметры, определяющие безопасность, целостность и сохранность, а также оперативное мониторинга, предсказывают возможные угрозы, экономические, социальные и экономические ущербы. Для создания математической модели использованы диаграммы истиности, отражающие зависимости состояний выходных параметров автоматической машины от состояний входных контролируемых параметров и ее внутренних состояний. В результате серии преобразований, элементы диагностики зависимости предельных значений состояния контролируемых параметров представлены в более компактной форме: появление дыма, наличие/отсутствие пламени, появление/исчезновение объектов, изменения уровня и давления в резервуарах, и другие параметры нефтегазовой территории от их входных состояний. Общие булевые функции — математические модели диагностики, описывающие неудовлетворительное и удовлетворительное состояние нефтегазовой территории в терминах комплексных параметров, записаны в дизъюнктивной и конъюнктивной нормальной форме (ДКНШ).

Тема: Нефтегазовая территория, появление дыма, наличие/отсутствие пламени, появление/исчезновение объектов, изменения уровней и давления в резервуарах, влажность, температура.
предложено использовать булеву алгебру. Выделены основные контролируемые объекты и их технологические параметры, определяющие безопасность, целостность и сохранность, оперативно мониторинга состояния как отдельных объектов, так и нефтегазовой территории и предсказания ожидаемых угроз экономического, социального и экономического ущерба. Для построения математической модели составлены таблицы истинности, отражающие зависимости состояний выходных параметров конечного автомата от состояний входных контролируемых параметров и внутренних его состояний. В результате ряда преобразований компактно отображены элементы оценки зависимости предельных значений контролируемых параметров: появления дыма, наличия/отсутствия пламени, появления/исчезновения объектов, изменения уровня и давления в резервуарах и др. параметров. На основе таблиц преобразований и минимизации диагностических функций выведены общие булевы функции - в виде математических моделей диагнозов, описывающих состояние территории нефтегазового предприятия по комплексным параметрам, представленных в дизъюнктивной и конъюнктивной нормальной форме (ДКНФ).

**Ключевые слова.** Территория нефтегазового предприятия, появление дыма, наличие/отсутствие пламени, появление/исчезновение объектов, колебания уровня и давления в резервуарах, влажность, температура, исследуемой среды.

**INTRODUCTION**

Nowadays, many technical means are developed: sensors, transformers of the emergency signal device of a remote control system and other tools for safety and security signaling about notifying on change a status of controlling objects. Now, this issue is effectively resolved within the smart house, the smart territory, the smart city, etc. Depending on specifics of creation and work of houses, the territory and subjects to control changes structures of a control system and signaling respectively change requirements to their reliability and reliability of work. Many performed works have local character which need constructions based on reasonable mathematical models. In this regard, the construction of modern intelligent controlling and diagnostic systems with appropriate algorithmic and software based on a mathematical model that takes into account changes in the state of local and complex parameters of objects is relevant.

The safety of the oil and gas territory depends not only on the penetration of intruders into the territory, on the theft of oil and gas, or on the occurrence of other emergencies, but also on unforeseen reasons, for example, changes in the internal temperature or pressure of the tanks beyond the established limits, gas and oil leaks, and also deviations of technological parameters from the set value.

**The purpose of the work** is to synthesize a mathematical model that evaluates changes in the limit values of the parameters of both local guarded monitoring and alarm objects and evaluates the security (reliability) of the territory according to the main states (by complex parameters) of the monitoring and diagnostic objects. According to the developed mathematical model, it is possible to build an intelligent microprocessor-based system for monitoring and diagnosing the safe state of the oil and gas territory as a whole. It is necessary for a solution of an objective: conducting theoretical justification, the choice, and research of the most significant influencing technological parameters and other external and internal factors and according to reasonable theoretical and practical materials to construct a mathematical model precisely estimating safety of a current status of the oil and gas territory or subjects to control.

**METHODS**

We give the basic theoretical provisions based on which could construct the mathematical model of a control system and diagnostics of the safety of the current status of the oil and gas territory on its basic technological parameters. For performing diagnostics of the safety of a status as separate subjects to control, and on all objects of the protected area as a mathematical apparatus, it is suggested to use a boolean algebra [1,2,3].

The basic input data to the construction of a mathematical model. According to [1,5,6,7], there are six oil and gas tanks, one oil tank, one tank for diesel fuel, the main guarded gate with push-button control, an additional gate for entry and exit of personnel, a fire corner with equipment, 6 spotlights with central control, one water tank In the oil and gas territory under consideration. The territory is equipped with four video cameras connected to the central control center. In the territory, it is available buildings
for engineers and technicians, etc. Basic data for performing diagnostics of reliability of a status of the territory are quantity of controlled points: searchlights \( N_p = 6 \), internal \( N_{vtn} = 6 \), and external \( N_{vtn} = 6 \) temperature sensors of oil reservoirs, internal \( N_{vgt} = 6 \), and external \( N_{vngt} = 6 \) temperature sensors of gas reservoirs. In addition to these, flow rate sensors of oil \( R_{n1}, R_{n2}, \ldots, R_{n6} \) corresponding to the oil and gas reservoirs \( R_{g1}, R_{g2}, \ldots, R_{g6} \). The number of sensors of control of internal and external temperatures of oil and gas reservoirs is 24, flow rate sensors of oil are 6, flow rate sensors of gas are 6, sensors of a gas leak are 6, sensors of the leak of oil are 6, sensors existence of a flame (emergence of flash, fire) is 1, the smoke detector is 1, sensors absence lighting are 6, the sensor of movement of a foreign object is 1. The maximum number of pulses generated at the output of each control sensor in the normal state of objects: \( n_{no} = 1 \) (logic signal 1), the minimum number of pulses generated at the output of each control sensor in the non-normal state of objects \( n_{ne} = 0 \) (logical signal 0). The size of the oil and gas territory is about 3 Ha.

Diagnostics, as the reliability of the product, is assessed by the probability of compliance of the parameters of the controlled object with the reference values. The reliability of the controlled nodes is estimated by the probability of their failure-free operation: the state of most control systems, facility management are considered satisfactory if the probability of their failure-free operation is in the range of 0.95 - 1.0 and vice versa. Thus, the diagnosis of the state of the parameters of the oil and gas territory requires the following. An experimental verification (research) of the state of the objects in the initial state i.e. without outside interference (for an ideal case) or when changing the limit values of the parameters of individual controlled objects (in case of violation of the requirements set to the limit values).

In the work for the synthesis of a mathematical model of diagnostics safe statuses of the oil and gas territory, for a start, we select more than 6 controlled technological parameters as basic data: fire safety of oil and gas reservoirs, concentration the content of air, emergence of a flame in the territory of the oil and gas reservoir.

**Application of a logical recognition technique for controlling and diagnosing the fire safety state of oil tanks**

Logical methods are based on establishing logical connections between signs and states of objects, therefore we will consider only simple (qualitative) signs for which only two values are possible (for example, 0 and 1). In the same way, the states of the diagnostic system (diagnoses) in the methods considered can have only two meanings (presence and absence). Two values of the sign or state of the system can be expressed by any two characters (“yes” - “no”, “false” - “true”, 0-1) [1,2]. From the carried-out review of ways and methods of performing diagnostics of parameters of objects and according to [1,2,3], it is possible to conclude that for performing diagnostics of a status of technological parameters of the oil and gas territory and other objects as a mathematical apparatus are possible to select a boolean algebra.

**Creation of a mathematical model of a control system and diagnostics safe status of the oil and gas territory**

For a start, we will construct a mathematical model for carrying out diagnostics of a status of fire safety of oil reservoirs.

Diagnostics of the work of nodes (products) are directly connected with the probability of their trouble-free operation. It is known that for assessment of the probability of system operation, it is possible to apply nodes approximately, preliminary and final settlements of reliability of their work. However, for performing diagnostics of a status of controlled objects there is no need of carrying out wearisome work (numerous options of calculation).

Diagnostics of work of nodes, it is possible to carry out systems, estimating compliance of the most important selected technological parameters (for example, for oil reservoirs the most important parameters) are changes of ground resistance of the tank shell, level variation and oil pressure in the reservoir, temperature changes of oil and the environment, leak of gas-oil, change of concentration of air.
The choice of basic data for performing diagnostics

Fire safety of tanks depends on changes in operational and technological parameters and changes in the state of the environment of gas tanks. Therefore, to conduct fire safety diagnostics of oil reservoirs, for starters, we select three parameters of the oil reservoir: changes in oil temperature inside the reservoir, excess of air concentration, and the appearance of a flame around the reservoir [16, 17]. At the same time, we take for normal operating values: the temperature of the oil in the tank (\(t_{nf} = +20^\circ C \pm 2\)), the ambient temperature of the reservoir (\(t_{nf} = + 25^\circ C \pm 5\)), the change in air concentration around the reservoir \(Q_v = 0.3\%\).

In this work, based on the stated considerations, it is proposed to diagnose the fire safety state of the oil reservoir using the following three technological parameters: 1) oil temperature inside the reservoir; 2) air concentration around the tank; 3) the appearance of flame in the oil and gas territory. At the same time (for an example) behind basic data for performing diagnostics of a status of the fire hazard of oil reservoirs is selected:

I. Oil temperature in the tank with the following parameters:
   1. Number of controlled temperature points in tanks: \(N_{tnf} = 6\);
   2. Number of sensors for monitoring the internal temperature of the tanks: \(N_{it} = 6\);
   3. The maximum number of pulses generated at the output of each temperature sensor: \(n_{tn} = 1\); (at a normal temperature limit, from 20°C to 25°C at one controlled point);
   4. The minimum number of pulses generated at the output of each temperature sensor \(n_{tn} = 0\); (if the temperature rises above the established norm at a controlled point);

II. Concentration of air of the environment of the reservoir with the following parameters:
   1. Quantity of controlled points: \(N_Q = 12\) (6 reservoirs, on 2 controlled - points)
   2. Number of sensors of control of the concentration of air of the environment: \(N_Q = 12\);
   3. The maximum quantity of impulses created in one controlled point: \(n_Q = 1\);
   4. The minimum quantity of impulses, created in one controlled point (in the absence of concentration of air): \(n_Q = 0\)

II. Emergence of a flame around the reservoir:
   1. Quantity of a controlled point: \(N_p = 4\);
   2. Number of sensors of control emergence of a flame: \(N_p = 4\);
   3. The maximum quantity of impulses created on an output of one sensor of control of a flame: \(n_p = 1\);
   4. The minimum quantity of impulses, a flame created on an output of one sensor of control: \(n_p = 0\).

Synthesis of a mathematical model for diagnosing the safety of the state of the oil territory by changing the internal temperature of the tank. The synthesis of a mathematical model for diagnosing the safety of the state of the oil territory by changing the internal temperature of the tank can be carried out for each tank and all six tanks. We carry out the synthesis of a mathematical diagnostic model for one reservoir. According to the theory of the description of boolean algebra, if the internal temperature of the oil and gas reservoir turns out in the set limit (\(t_{nf} = +20^\circ C \pm 2\)) that mathematical models of fire safety of the reservoir satisfying statuses of fire safety, it is possible to describe in the form of a boolean algebra of logic in the following simple look: \(Y_{t1} = x_{t1} = 1\), or on the contrary, if the internal temperature of the oil and gas reservoir is above the set limit (\(t_{nf} = +20^\circ C \pm 5\)), a mathematical model of fire safety of the reservoir unsatisfactory statuses of fire safety of the reservoir can be described in the following simple view: \(Y_{t1} = x_{t1} = 0\) which is possible to implement by means of the single-stage emitter follower.

To build a mathematical model that describes the fire safety of six tanks, it is necessary to use a complex combinational machine or use a modern microprocessor with sufficient data memory.

An analysis of the construction of a mathematical model evaluating fire safety shows that in our case there are several selected input parameters: 6 internal and external temperatures of the oil and gas tanks (24 temperatures in total), the safe state of the oil and gas territory depends on the states of all 12 tanks: \(Y_{t1} = x_{t1}; Y_{t2} = x_{t2} \ldots Y_{t12} = x_{t12}\). T.O. according to [1, 2, 4], we carry out the synthesis of a
mathematical model evaluating the fire safety of the oil and gas territory for six oil reservoirs, from the appearance of four flames and in the presence of 6 air concentrations around the reservoir.

The truth diagram reflecting output statuses of the automatic machine on six various entrance statuses of parameters (sensors) of oil reservoirs are provided in table 1. In the same way, it is possible to construct the truth diagram for other groups of controlled parameters of oil reservoirs (emergence of a flame, concentration of air, etc.).

### Table 1

<table>
<thead>
<tr>
<th>Rate</th>
<th>Conditions of reservoirs on temperature</th>
<th>Possible internal conditions automatic machine (systems)</th>
<th>Output parameters of a system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X2  X3  X4  X5  X6  Z1  Z2  Z3  …  Zi  Y1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0    0    0    0    0    0    0    0    0    0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1    0    0    1    0    0    1    0    1    0    0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0    1    0    0    1    0    0    1    0    0    0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>…</td>
<td>…    …    …    …    …    …    …    …    …    …    …</td>
<td></td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>1    1    1    1    1    1    1    1    1    1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Then, according to the methodology for the synthesis of automata [1, 2, 3, 4] that implement the above sets, you can display in a table form (Table 1).

A table of states of input controlled parameters, internal and output states of the monitoring and diagnostic system for six controlled tank temperatures.

As can be seen from table 1, each reservoir can have two states 0 or 1 (0-unsatisfactory state, 1-satisfactory state). Depending on the input states of the reservoirs, the internal states of the combination automaton have certain values. The combination machine consists of an encoder, storage devices, and a decoder. At the command, the state of the machine is decrypted and at the output of the machine, we will have the corresponding diagnostic value for the given input signals (states) of the tank. If $Y_1 = 0$ the tanks are considered to be in an unsatisfactory condition or if $Y_1 = 1$ the tanks are considered to be in a satisfactory condition.

According to table 1, the value of each input parameter $X1$, $X2$, ..., $X6$ of the oil and gas reservoir by temperature can be written in the following form:

$$
X_1 = f_{1p}(X_{1.1}, X_{1.2}), \\
X_2 = f_{2p}(X_{2.1}, X_{2.2}), \\
X_6 = f_{6p}(X_{6.1}, X_{6.2}).
$$

(1)

The input signals of the state of fire safety of the territory according to the temperature of the tanks of the electronic onboard system are the output signals of temperature sensors installed inside the tanks. These signals are written in binary code and can have the following meanings:

$$
X_1 = 0(1); \\
X_2 = 0(1); \\
f_{6p_t}
$$

(2)

For control of the safety of a status of the reservoir on temperature, it is necessary to diagnose each reservoir as separately, and in a general view.

Status monitoring of safety after the emergence of a flame and concentration of air is in the same way exercise. Values of each input parameter $X7$, $X8$, ..., $X10$ of the oil and gas reservoir after the emergence of a flame, it is possible to write in the following view:

$$
X_7 = f_{1n}(X_{7.1}, X_{7.2}), \\
X_8 = f_{2n}(X_{8.1}, X_{8.2}), \\
X_{10} = f_{6n}(X_{10.1}, X_{10.1}).
$$

(3)
Changes in the states of input signals (parameters) upon the appearance of a flame at the output of an electronic unit can be written in the form of the following system:

\[
\begin{align*}
X7 &= 0(1), \\
X8 &= 0(1), \\
X10 &= 0(1), \\
\end{align*}
\]

(4)

The values of the input signals \(X11, X12, ..., X22\) reflecting the state of the oil and gas territory from air concentration can be written in the form:

\[
\begin{align*}
X_{11} &= f_{1p}(X_{11.1}, X_{11.2}), \\
X_{12} &= f_{2p}(X_{12.1}, X_{12.2}), \\
X_{22} &= f_{6q}(X_{22.1}, X_{22.2}), \\
\end{align*}
\]

(5)

Changes in the states of input signals (parameters) upon the appearance of air concentration at the output of the electronic unit can be described as the following system:

\[
\begin{align*}
X_{11} &= 0(1), \\
X_{12} &= 0(1), \\
X_{22} &= 0(1), \\
\end{align*}
\]

(6)

Given the complexity of presenting such a truth table and according to [2, 5] according to the selected initial data and from the synthesis conditions, the dependence of the mathematical model of diagnosis, evaluating the safety of the oil and gas territory, according to three controlled, three safe groups the state of the oil territory can be described as the following set:

\[
X_{3p}= (f_{6p_{11}}(X1, X2, ..., X6), f_{4p_{1}}(X7, X8, X9, X10), f_{12q}(X11, X12, ..., X22)),
\]

(7)

where \(X1, X2, ..., X6\)-value of parameters, according to displaying a status 1-, 2-, ..., 6 reservoirs on temperature; \(X7, X8, X9, X10\) – the values of parameters displaying a territory status after the emergence of a flame; \(X11, X12, ..., X22\)-value of parameters, territories displaying a status after the emergence of concentration of air.

Table 2

<table>
<thead>
<tr>
<th>Rate</th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
<th>X6</th>
<th>X7</th>
<th>X8</th>
<th>X9</th>
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<th>X22</th>
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</table>

Table 3

<table>
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<tr>
<th>n/n</th>
<th>Z1</th>
<th>Z2</th>
<th>Z3</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>Y1</th>
<th>Y2</th>
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<tbody>
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<td>0</td>
<td>D10</td>
<td>D20</td>
<td>D30</td>
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<td>0</td>
<td>D10</td>
<td>D20</td>
<td>D30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>...</td>
<td>1</td>
<td>D11</td>
<td>D21</td>
<td>D31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>...</td>
<td>1</td>
<td>D11</td>
<td>D21</td>
<td>D31</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Considering the above-stated reference designations and statuses, according to changes a status of entrance signals signs: $X1$, $X2$, $HZ$ we will construct the truth diagram, the displaying combinations internal status of the automatic machine and output various statuses of the diagnosed device (Table 2).

In the simplified tables of statuses (Table 3) of input controlled parameters, an internal and output system status of control and diagnostics (in three controlled parameters safe status of the oil territory) diagnosis elements are displayed: satisfactory and unsatisfactory security status of the territory of oil reservoirs, depending on statuses of entrance oil reservoirs.

In Table 3, the conventions are used to diagnose the safety status of six oil reservoirs. For the reservoir, the diagnosis of D10 is an unsatisfactory safety condition; diagnosis D11 - satisfactory safety status. For the diagnosis of the state of occurrence of a flame, the following conventions have been adopted: diagnosis D20 - unsatisfactory safety condition for the appearance of a flame; diagnosis D21 — satisfactory flame safety;

D30 - assessment of unsatisfactory safety status in the presence of air concentration; D31 - Evaluation of a satisfactory safety condition in the presence of air concentration.

Given the fact that Table 3 shows the dependences of the input states (signals) of the tanks, the appearance of a flame and the presence of a concentration of air in the oil area, according to a logical analysis, it can be reduced to a more compact form (Table 4).

### Table 4.

<table>
<thead>
<tr>
<th>Rate</th>
<th>The general state of the tank by temperature</th>
<th>General condition of the territory upon appearance flame</th>
<th>States of concentration air</th>
<th>Output parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D1i</td>
<td>D2i</td>
<td>D3i</td>
<td>Y1</td>
</tr>
<tr>
<td>2</td>
<td>D10</td>
<td>D20</td>
<td>D30</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>D11</td>
<td>D21</td>
<td>D31</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>16</td>
<td>D11</td>
<td>D21</td>
<td>D31</td>
<td>0</td>
</tr>
</tbody>
</table>

### Results and Discussion

**Building a mathematical model of a monitoring and diagnostic system using complex parameters**

Using the data in Table 4 and according to the method of compiling and transforming logical functions [5], it is possible to compose simplified Boolean functions that evaluate the safe state of the oil and gas territory in simple disjunctive normal forms.

The diagnosis $D_n$ - a safe state of the oil and gas territory will be unsatisfactory under the following conditions of the system of equations (8) generated by the sensors of the internal temperature of the tank, the appearance of a flame in the oil territory and the presence of a concentration of the air content of the oil territory. Recall that in these states the logic signals “0” or “1” are formed at the outputs of each sensor. Recall that in these states the logic signals “0” or “1” are formed at the outputs of each sensor. Logical signal 0 indicates the abnormal state of the monitored object - diagnosis ($D_m$) logical signal "1" indicates the normal state of the diagnosed object ($D_y$). Thus, a system of Boolean functions that do not satisfy the conditions of diagnosis $D_n$ taking into account the state of the above-mentioned controlled objects can write the following system of equations:

$$
\begin{align*}
D_n1 &= D10 \\
D_y1 &= D11 \\
D_n2 &= D20 \\
D_y2 &= D21 \\
D_n3 &= D30 \\
D_y3 &= D31
\end{align*}
$$

(8)
In a system of equations (8), the given reference designations correspond to the following statuses of controlled parameters:

- $D_{n1}$ - to unsatisfactory status of oil reservoirs;
- $D_{n2}$ - to unsatisfactory status after the emergence of a flame in the oil and gas territory;
- $D_{n3}$ - to unsatisfactory status after the emergence of the content or concentration of air in the oil and gas territory;

- $D_{y1}$ - to satisfactory condition of oil reservoirs;
- $D_{y2}$ - to satisfactory condition after the emergence of a flame in the oil and gas territory;
- $D_{y3}$ - to satisfactory condition after the emergence of the content or concentration of air in the oil and gas territory.

Thus, it agrees (8) general boolean function of a mathematical model of the diagnosis describing an unsatisfactory status of the oil and gas territory for three parameters ($D_n$), it is possible to write in the following disjunctive and conjunctive normal form:

$$D_{n1} = f_p(D_{10}) \lor f_n(D_{20}) \lor f_\kappa(D_{30})$$
$$D_{n2} = f_p(D_{10}) \land f_n(D_{20}) \lor f_\kappa(D_{30})$$
$$D_{n3} = f_p(D_{10}) \land f_n(D_{20}) \lor f_\kappa(D_{31})$$
$$D_{n1} = (D_{10}) \land f_n(D_{20}) \lor f_\kappa(D_{30})$$

(9)

It agrees (9) general boolean function of the diagnosis describing an unsatisfactory status ($D_n$) to the oil and gas territory on three groups to controlled parameters, it is possible to write in the following disjunctive and conjunctive normal form:

$$D_{n1} = (f_p(D_{10}) \lor f_n(D_{20}) \lor f_\kappa(D_{30})) \land (f_p(D_{10}) \land f_n(D_{20}) \lor f_\kappa(D_{30})) \land \ldots$$
$$\land .((D_{10}) \land f_n(D_{20}) \land f_\kappa(D_{30})).$$

(10)

From the equations, it is visible that in any status of input parameters the given mathematical model creates an unsatisfactory status of the oil and gas territory on three groups to the considered parameters.

On a system of equations (6), it is possible to write to the only mathematical model satisfying secure state of the oil and gas territory on three groups of parameters:

$$D_{y1} = (f_p(D_{11}) \land f_n(D_{21}) \land f_\kappa(D_{31}))$$

(11)

Conclusions

From the equations (11), it is visible that for providing a secure state of the oil and gas territory all statuses of controlled three object groups should correspond to a condition of the diagnosis ($D_y$). State change of any of these sub-functions leads to non-performance a condition of a status of the diagnosis of $D_y$.

The developed mathematical model of a control system and diagnostics promotes to construct the systems of remote control and diagnostics, estimating the secure state of the oil and gas territory on three groups of parameters and promotes to save invaluable property of the state.

References


16. GOST 31385-2008 “Vertical cylindrical steel tanks for oil and oil-products. General specifications”.

17. GOST 1510-84 “Oil and oil products. Marking, packaging, transportation and storage”.