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IMPLICATIONS OF NEW STANDARDS ON TECHNICAL DIAGNOSTICS AND CONTROL IMPLEMENTATION FOR THE GAS TRANSMISSION SYSTEM EFFICIENCY

Introduction. *Ukrainian gas transmision system (GTS) as a part of the whole oil and gas complex takes the important role in energy security of the state. Taking into consideration the aging and physical deterioration procesess, a lot of attentionn today is paid to the question of ensuring GTS relaible operation and maintenance.*

Problem Statement. *All innovations and technicaogical achievements, implemented into GTS are impossible without a detailed study of productivity of GTS facilities, the costs for implementing the new standards, and the costs for eliminating the emergency situations' consequences.*

Purpose. *Assessment and evaluation of data on efficiency of Ukrainian GTS, based on the implementation of new standards on technical diagnostics and control (TDC), influencing significantly on the operation of GTS facilities.*

Materials and Methods. *For the analysis, we chose the complex mathematical model, allowing to determine the qualitative relationship between the productivity of GTS facilities, the costs of implementing new standards for technical diagnostics and control, and the costs for eliminating the consequences of economic, environmental and other impacts. Besides the expert evaluation method and numerical Runge-Kutt methods were applied for practical use of the proposed model.*

Results. *The efficiency of GTS operation, according to the proposed model, depends on the costs, spent for the implementation of standards. Among the benefits for increasing of standards expenditures are the growth of emergency response funding, which tends to decreasing in timely manner. Calculation results showed the adequacy of the proposed experts' assessment model according to the question of objectivity, impartiality and consistency of expert opinions.*

Conclusions. *The complex of mathematical calculations maintained the qualitative picture of the relationship between selected characteristics. The new approach to analysing data on Ukrainian GTS efficiencywas suggeted, presenting the mechanism for establishing the dependencies between costs of implementing new standards and costs for eliminating emergency situations.*

Keywords: efficiency, gas transmission system, mathematical model, technical diagnostics, and standard.

The gas transmission system (GTS) of Ukraine is one of the most important components of the national oil and gas complex. It is an essential element of the energy security of the country and one of the levers of integration into the intercontinental EU gas pipeline [1]. Today, the length of Ukrainian gas pipelines is 38.55 thousand km, the capacity of the GTS is 287.7 billion cubic meters per year at the input (including 21.0 billion cubic meters per year from Europe) and

178.5 billion cubic meters/year at the output. Though, different Ukrainian experts evaluate state of the Ukrainian GTS with different viewpoints. According to *Naftogaz of Ukraine,* NJSC, the main advantages of the GTS are its high throughput, flexibility and reliability. The operation of Ukrainian operator (*UKRTRANSGAZ,* PJSC) is transparent, the data are disclosed online in the ENTSO-G transparency platform, and the company is actively cooperating with the European Commission [2, 3].

At the same time, the operation of the main equipment of the GTS is accompanied by aging and physical deterioration along the whole technological chain, in turn, preceded by accidents and technological failures. That is why the main principles of the state policy in the field of pipeline transport, given its priority in Ukraine, include ensuring the reliable and safe pipeline transportation [4] The pipeline transportation company is also obliged by the regulatory document to provide diagnostic monitoring of the pipeline condition by operating means in accordance with the rules of technical operation and normative documents on technical diagnostics.

Based on the results of such a diagnosis, the operating organization obtains reliable information about the technical condition of the main gas pipeline facilities and, on its basis, ensure the maintenance and operation of potentially hazardous facilities of the GTS in the proper technical condition. And the quality of the technical diagnosis and control of GTS facilities specifies the reliable operation of the entire GTS of Ukraine [5]

The practice of operating the GTS [6, 7]) shows that the efficiency of gas pipelines depends on the construction of a system of low-cost methods of efficient use of existing production capacities. Fundamental modernization of the entire structure of the GTS capacity is also of great concern. However, the implementation and further efficiency of using the latest technologies and technical means, their technical diagnostic and control, the operation of already existing system is impossible without proper regulatory support. For this purpose, it is necessary to take into account two aspects:

1) transition to the European model of standardization — one of the directions for improving the technical state of the GTS is the implementation of new European standards, which Ukraine undertook to adopt within the framework of the Association Agreement [8];

2) peculiarities of the Ukrainian gas transportation network of functioning in the context of modern approaches to the formation of the state energy policy [9], based on strategies to improve security, energy efficiency and competitiveness.

Article 56 of the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and its member states, on the other hand [8], determines that Ukraine needs to take the necessary measures to achieve gradually the compliance with the technical regulations of the European Union (hereinafter referred to as the EU) and the systems of standardization, metrology, accreditation, conformity assessment and market surveillance of the EU and is obliged to observe the principles and practices set out in the relevant decisions and regulations of the EU. In addition, Ukraine is obliged to introduce gradually a set of European standards (EN) as national standards, in particular as harmonized European standards, the voluntary application of which is considered to comply with the requirements of the legislation specified in Annex III to the specified Agreement. Simultaneously with such implementation, Ukraine abolishes all conflicting national standards, in particular the application of interstate standards (GOST), developed before 1992 Besides, Ukraine is going to take the other necessary measures to fulfill the conditions of membership in accordance with the requirements applied to p-members of European organizations.

Within the framework the Strategy for the development of the technical regulation system of Ukraine till 2020 [10], the goal is to modernize the Ukrainian economy and ensure the competitiveness of domestic products through the gradual integration of Ukraine into the EU internal market, overcoming technical barriers to trade between Ukraine and the EU and strengthening its position in the world market as a result of recognition of the system of technical regulation of Ukraine at the European and international level.

At the same time, the GTS of Ukraine faces a particularly pressing problem — a steady reduction in the flow of Russian natural gas transit, caused, above all, by the construction of bypass pipeline [11, 12] That is why the issue of effective use of regulatory documents, especially with regard to technical diagnostics and control, is an important argument and an opportunity to search for and introduce innovative developments in the formation of strategic guidelines for the functioning and further development of the Ukrainian GTS.

For the purposes of this article, the study is limited to the technical effectiveness of standardization [13], where efficiency can be expressed in terms of technical efficiency, and is obtained as a result of the application of the standard/group of standards due to the growth of safety and reliability indicators, reduction of harmful outflow or emission level, reduction of material and energy consumption of the technical cycle, increase of the resource efficiency.

When investigating the effectiveness of implementation of new standards for technical diagnostics and control (TDC) of GTS objects of Ukraine [14], it is important to study the relationship between the costs that arise in this case. A complex mathematical model is proposed, allowing to determine the qualitative relationship between the productivity of GTS facilities, the costs for implementing the new standards on technical diagnostics and control, and the costs for eliminating the consequences of economic, environmental and other impacts that have an impact in case of accidents at the GTS facilities.

When developing a mathematical model, we introduce the functions $x(t); y(t); z(t)$, which have the following meaning:

$x(t)$ is the cost of implementing new standards for diagnosis and control;

$y(t)$ is the costs for liquidation of consequences of emergency situations;

$z(t)$ is the efficiency of the GTS element operation.

A system of differential equations is written, while developing a mathematical model, and describes the nature of specified variables change per unit of time in the assumption of the nature of the relationship between the quantities. In this case, the approaches described in [15—20] are used. As a result, the following system of ordinary differential equations is obtained, associating the variables $x(t); y(t); z(t)$:

$$\begin{cases} \dfrac{dx}{dt} = K_1 x\,(A - x) - K_2 y + K_3 z \\ \dfrac{dy}{dt} = K_4 x\,(A - x) + K_5 (B - y)\, y + K_6 z. \\ \dfrac{dz}{dt} = K_7 x - K_8 y \end{cases} \quad (1)$$

The first summands in I and II equations of the system establish that the values $x(t)$ and $y(t)$ cannot exceed certain established limits. Thus, the costs of implementing new TDC standards $x(t)$ can vary in proportion to the effectiveness $z(t)$ (summand $K_3 z$) and the costs $y(t)$ to eliminate the consequences of emergencies (summand $K_2 y$). A minus sign means that in case of elimination of emergency situations consequences, the funds are used primarily for these needs, so funds allocation in this case is problematic due to the fact that they go directly to combat the consequences.

The value $y(t)$ and its variation over time depends on the existing TDC standard, on how much money has already been spent to eliminate the consequences of accidents, and on how efficiently the GTS is operating.

The value $z(t)$ depends on which TDC standards are used, as well as on how often and with what are the consequences of the occurred emergencies.

System (1) must be supplemented by initial conditions, which are written in the form:

$$x(0) = x_0;\ y(0) = y_0;\ z(0) = z_0. \quad (2)$$

$$t0 := 0 \qquad t1 := 15$$

Given

$$\frac{d}{dt} x(t) = 0.4\, x(t) \times (10 - x(t)) - 0.7\, y(t) + 0.4\, z(t) \qquad x(t0) = 6$$

$$\frac{d}{dt} y(t) = 0.4\,(10 - x(t)) \times x(t) + 0.7\, y(t) \times (6 - y(t)) + 0.3\, z(t) \qquad y(t0) = 0$$

$$\frac{d}{dt} z(t) = 0.8\, x(t) - 0.9\, y(t) \qquad z(t0) = 0$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix} x \\ y \\ z \end{pmatrix}, t, t1\right]$$

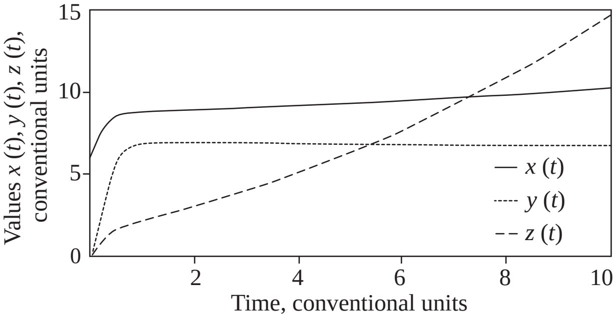

Fig. 1. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i

$$t0 := 0 \qquad t1 := 15$$

Given

$$\frac{d}{dt} x(t) = 0.4\, x(t) \times (9 - x(t)) - 0.2\, y(t) + 0.5\, z(t) \qquad x(t0) = 6$$

$$\frac{d}{dt} y(t) = 0.4\,(10 - x(t)) \times x(t) + 0.2\, y(t) \times (6 - y(t)) + 0.4\, z(t) \qquad y(t0) = 0$$

$$\frac{d}{dt} z(t) = 0.8\, x(t) - 0.4\, y(t) \qquad z(t0) = 0$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix} x \\ y \\ z \end{pmatrix}, t, t1\right]$$

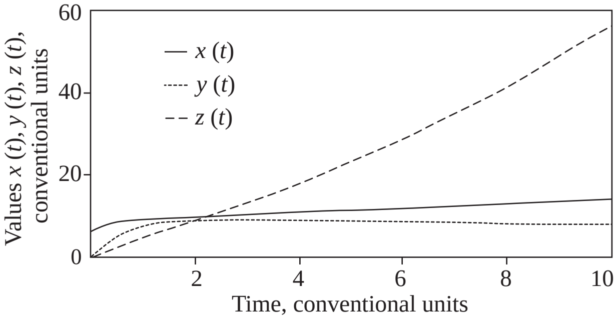

Fig. 2. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change after implementing of new TDC standards

For practical use of the proposed model, which is nonlinear, it is necessary to determine the concept of determining the coefficients K_i.

One of the methods of expert assessment [21, 22] is used, which is as follows. The group of experts, which includes specialists from both the oil and gas industry, and from systems of nondestructive testing and diagnostics, in the number of N people. Their task is to assess the degree of dependence between the variables $x(t)$; $y(t)$; $z(t)$ in each of the aspects simulated by the system (1) with the initial conditions (2) through the coefficients K_i ($i = 1, \dots 8$). At the same time, each expert fills in a table in which, for each of the coefficients, the expert submits an estimate from $U_{\min}$ to $U_{\max}$ (or from 1 to 8). As a result, for each of the coefficients, the sum of points is obtained:

$$U_i = \sum_{j=1}^{N} U_{ij}, \tag{3}$$

where, U_{ij} is the estimate put forward by the coefficient K_i, the expert with the number j. At the same time, for the initial approximation of the coefficient K_i, its value is used, which is calculated by the formula:

$$K_i = \frac{U_i}{\sum_{s=1}^{8} U_s}. \tag{4}$$

Obviously, $0 \le K_i \le 1$. The values of K_i obtained for (4) are the initial approximation of K_i, and for these values, the system (1) with the conditions (2) is solved. There are questions that are related to the need for correction of the model in cases where the collective opinion of experts leads to simulation results that either do not provide the stability and necessary accuracy of the calculation scheme, or do not meet the desired simulation results — the behavior of $x(t)$; $y(t)$; $z(t)$ in dynamics does not correspond to the purpose of simulation, which is to simulate such behavior of these functions, which satisfies the conditions for the

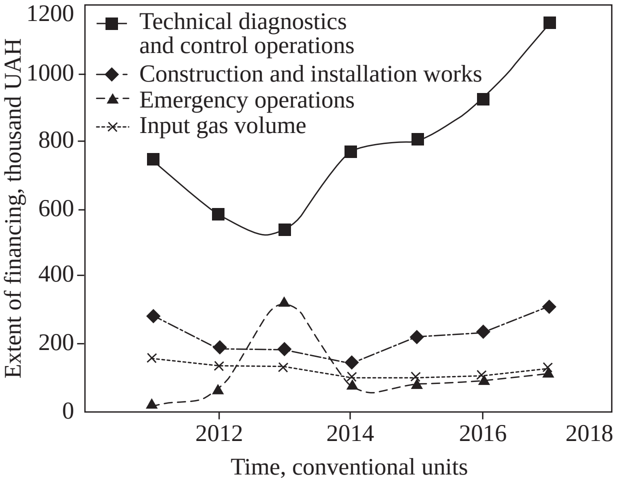

Fig. 3. Changes in GTS performance in 2012—2017

$$t0 := 0 \qquad t1 := 13$$

Given

$$\frac{d}{dt}x(t) = 0.2\,x(t)\times(10 - x(t)) - 0.3\,y(t) + 0.4\,z(t) \qquad x(t0) = 8$$

$$\frac{d}{dt}y(t) = 0.2\,(10 - x(t))\times x(t) + 0.3\,y(t)\times(5 - y(t)) + 0.3\,z(t) \qquad y(t0) = 6$$

$$\frac{d}{dt}z(t) = 0.4\,x(t) - 0.3\,y(t) \qquad z(t0) = 4$$

$$\begin{pmatrix}x\\y\\z\end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix}x\\y\\z\end{pmatrix}, t, t1\right]$$

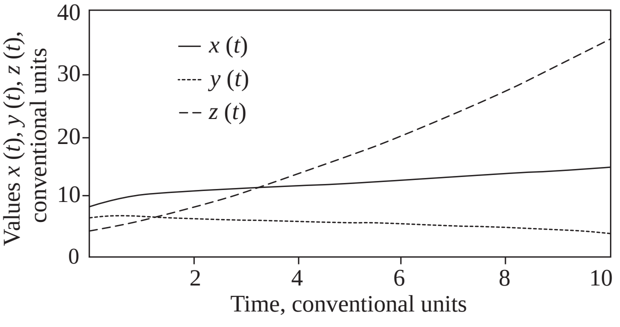

Fig. 4. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i for $x(0) = 8$, $y(0) = 6$, $z(0) = 4$

$$t0 := 0 \qquad t1 := 15$$

Given

$$\frac{d}{dt}x(t) = 0.2\,x(t)\times(10 - x(t)) - 0.3\,y(t) + 0.4\,z(t) \qquad x(t0) = 6$$

$$\frac{d}{dt}y(t) = 0.2\,(10 - x(t))\times x(t) + 0.3\,y(t)\times(5 - y(t)) + 0.3\,z(t) \qquad y(t0) = 3$$

$$\frac{d}{dt}z(t) = 0.4\,x(t) - 0.3\,y(t) \qquad z(t0) = 2$$

$$\begin{pmatrix}x\\y\\z\end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix}x\\y\\z\end{pmatrix}, t, t1\right]$$

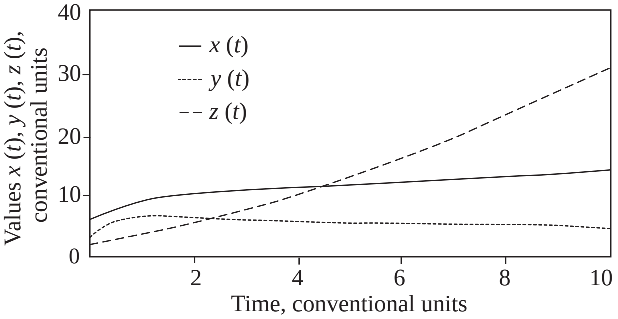

Fig. 5. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i for $x(0) = 6$, $y(0) = 3$, $z(0) = 2$

growth of certain functions, the decline of others, ensuring a stable, close to the constant level of the third — in this case $x(t)$ must be either constant or have tendency to increase, the speed of which is less than growth of $z(t)$, while $y(t)$ is modeled so that it is a declining function in time. Adjustment of coefficients (3)—(4) is carried out either by increasing the number of experts and re-implementing the method of expert assessments, or by correction (4) as follows:

$$K_i = \frac{U_i}{\sum_{s=1}^{8} U_s} + C_i, \tag{5}$$

where C_i are adjusted coefficients, the value of which is determined as follows:

$$C_i = nK_i,\ n = 0.1—0.5, \tag{6}$$

with a step of 0.2. Using the high speed of modern computer technology, it is possible to pick up such adjusted values of the coefficients that best simulate the desired behavior of $x(t)$; $y(t)$; $z(t)$. In the vast majority of models, $K_i = K_4$, $K_i = K_5$, therefore, there are six independent coefficients in the system (1), so if, for model adjustment,

$$t0 := 0 \qquad t1 := 13$$

Given

$$\frac{d}{dt}x(t) = 0.2\,x(t) \times (10 - x(t)) - 0.3\,y(t) + 0.4\,z(t) \qquad x(t0) = 9$$

$$\frac{d}{dt}y(t) = 0.2\,(10 - x(t)) \times x(t) + 0.3\,y(t) \times (5 - y(t)) + 0.3\,z(t) \qquad y(t0) = 4$$

$$\frac{d}{dt}z(t) = 0.4\,x(t) - 0.3\,y(t) \qquad z(t0) = 5$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix} x \\ y \\ z \end{pmatrix}, t, t1\right]$$

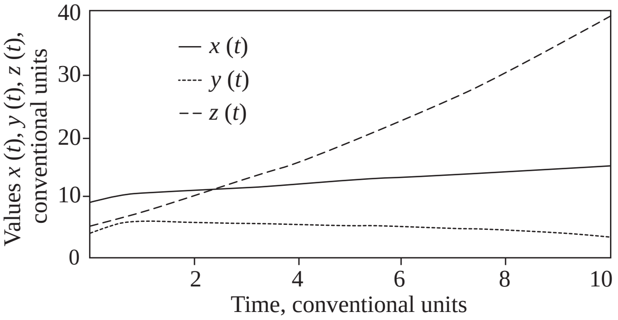

Fig. 6. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i for $x(0) = 9$, $y(0) = 4$, $z(0) = 5$

$$t0 := 0 \qquad t1 := 13$$

Given

$$\frac{d}{dt}x(t) = 0.2\,x(t) \times (10 - x(t)) - 0.3\,y(t) + 0.4\,z(t) \qquad x(t0) = 2$$

$$\frac{d}{dt}y(t) = 0.2\,(10 - x(t)) \times x(t) + 0.3\,y(t) \times (5 - y(t)) + 0.3\,z(t) \qquad y(t0) = 4$$

$$\frac{d}{dt}z(t) = 0.4\,x(t) - 0.3\,y(t) \qquad z(t0) = 3$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix} x \\ y \\ z \end{pmatrix}, t, t1\right]$$

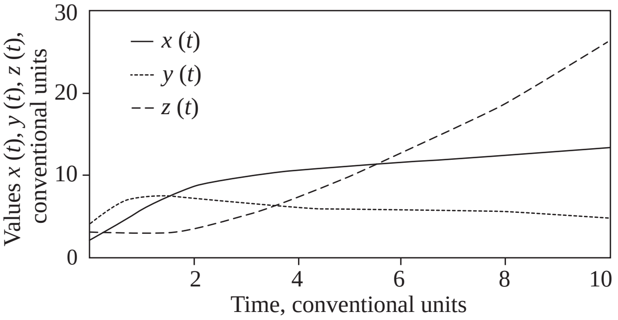

Fig. 7. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i for $x(0) = 2$, $y(0) = 4$, $z(0) = 3$ — costs for the elimination of emergency situation consequences at initial time are the highest

each of these six coefficients may acquire two values, then the total number of variants is sixty four values. One variant is calculated on average three seconds, so it consumes 64 × 3 = 192 seconds — accordingly the required version of the model is chosen for three minutes of machine time, and taking into account the necessary editing, the task of optimizing coefficients K_i is solved by the researcher within 10—15 min of operation with the computer, which indicates the high efficiency of the numerical algorithm.

The values A and B, included into the system (1) are determined on a certain scale, at least until the real values are obtained from the results of statistical data.

The system (1) with the initial conditions (2) is non-linear; and its solution allows to obtain the numerical Runge-Kutt methods of the required accuracy order [23] or the corresponding software products that allow the implementation of these numerical methods.

A wide range of model calculations has been carried out which allow us to establish a qualitative picture of the relationship in qualitative units between the quantities $x(t)$; $y(t)$; $z(t)$. The results of the calculations are shown in Figs. 1, 2.

When analyzing the obtained numerical results, it can be established that when implementing of new TDC standards, a small increase in the costly implementation of new standards (line I — $x(t)$) leads to the efficiency increase of the operation of the GTS in 6 times (from 10 conventional units to 60) (line II — $z(t)$), while the costs of eliminating the consequences of emergencies remain either constant or slightly increase, which is due to the possible increase of the fund (line III — $y(t)$) by obtaining a new profit from the operation of the GTS.

$$t0 := 0 \qquad t1 := 10$$

Given

$$\frac{d}{dt}x(t) = 0.2\,x(t) \times (10 - x(t)) -$$

$$- 0.3\,y(t) + 0.4\,z(t) \qquad x(t0) = 7$$

$$\frac{d}{dt}y(t) = 0.2\,(10 - x(t)) \times x(t) +$$

$$+ 0.3\,y(t) \times (5 - y(t)) + 0.3\,z(t) \qquad y(t0) = 11$$

$$\frac{d}{dt}z(t) = 0.4\,x(t) - 0.3\,y(t) \qquad z(t0) = 13$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix} x \\ y \\ z \end{pmatrix}, t, t1\right]$$

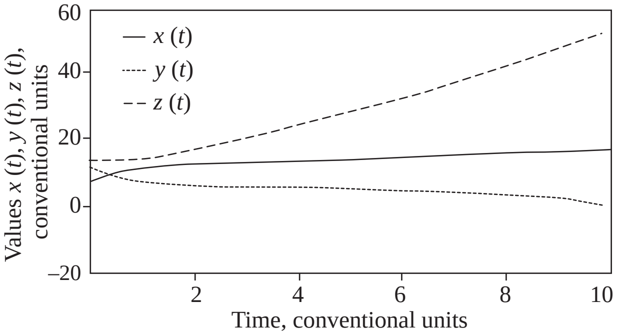

Fig. 8. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i for $x(0) = 7$, $y(0) = 11$, $z(0) = 13$

$$t0 := 0 \qquad t1 := 11$$

Given

$$\frac{d}{dt}x(t) = 0.5\,x(t) \times (10 - x(t)) -$$

$$- 0.5\,y(t) + 0.2\,z(t) \qquad x(t0) = 6$$

$$\frac{d}{dt}y(t) = 0.2\,(10 - x(t)) \times x(t) +$$

$$+ 0.3\,y(t) \times (5 - y(t)) + 0.2\,z(t) \qquad y(t0) = 3$$

$$\frac{d}{dt}z(t) = 0.2\,x(t) - 0.3\,y(t) \qquad z(t0) = 0$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} := \text{Odesolve}\left[\begin{pmatrix} x \\ y \\ z \end{pmatrix}, t, t1\right]$$

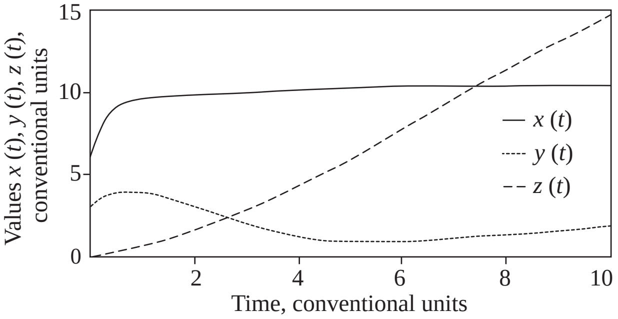

Fig. 9. Dynamic of $x(t)$; $y(t)$; $z(t)$ values change at initial set of parameters K_i for $x(0) = 6$, $y(0) = 3$, $z(0) = 0$

To verify the adequacy of the models, we analyzed the data on *UKRTRANSGAZ,* PJSC for the last 10 years, mainly the following indicators: funding of construction and installation works, emergency response operations, costs for technical diagnostics and control (including the costs for the preparation and implementation of new standards) and volumes gas flowing into the GTS. Fig. 3 shows a graph of the corresponding dependencies by years.

When analyzing the given dependencies, it can be concluded that the costs for elimination of emergency situations consequences increase while the funding of implementation for new TDC standards as well as the volume of construction and installation works decrease. The data shown in Fig. 3, can be used to establish the initial conditions (2) for system (1) in the form of $x(t_0)$ is the costs of technical diagnostics and control, $y(t_0)$ is the cost of eliminating emergency situations; $z(t_0)$ is the reliability of the GTS and the cost of construction and installation work. The following Figs. 4—8 show the results of calculations based on the model (1)—(2) for various initial conditions $x(0)$, $y(0)$, $z(0)$, and also for different values of the model coefficients (Fig. 9), which allow to assess the influence of these conditions on the dynamics of the simulated processes. Particular attention should be paid to the fact that the value of $z(t)$, the efficiency of the GTS element operation, has a stable tendency to grow even with an insignificant increase in the value of $x(t)$ is the cost of implementing new TDC standards. In addition, in some cases, there is a decrease in the cost for elimination of emergency situation consequences with the insignificant increase in $x(t)$ or when these costs are released to some constant level. All values of the initial conditions are taken in relative units, which is due to the requirements for ensuring the stability of calculations.

When selecting model coefficients to test the impartiality of experts, the Kendall concordance criterion [24] is used, including N is the number of model coefficients to be determined, M is the number of experts involved, R_{ij} is the rank of the j-coefficient in the opinion of the j-expert, D_i is the sum of the ranks of the i-coefficient in all experts, W is the Kendall concordance coefficient,

$$W = \frac{12}{M^2 \left(N^3 - N\right)} \sum\nolimits_{i=1}^{N} (D_s - \overline{D})^2, \tag{7}$$

$$D_i = \sum\nolimits_{j=1}^{M} R_{ij}, \tag{8}$$

$$\overline{D} = \frac{M\,(N+1)}{2}. \tag{9}$$

According to the calculations that give an answer to the question of objectivity, impartiality and consistency of expert opinions, the following conclusion can be drawn: since the concordance coefficient varies within $0 \le W \le 1$, the values of W, satisfying the condition $W \ge 0.75$, testify to the good consistency, impartiality and objectivity of the team of experts. If the condition $W \ge 0.75$ is not satisfied, this indicates the need to increase the number of experts N.

Thus, as of today it is necessary to develop a well-organized and balanced system of standardization concerning operation of Ukrainian GTS, by taking into account the transition processes to the European model of standardization.

It is showed that GTS operation requires balancing with the criteria of aging and physical deterioration, which can cause possible significant accidents and technological failures.

While developing the relevant measures for obtaining necessary efficiency of GTS operation authors emphasize on incorporating the technical efficiency of standardization, which can be achieved by implementing relevant standards with high safety and reliability indicators.

It can be concluded that the increase in the costs of implementing new TDC standards leads to the significant gain in the efficiency of the GTS operation, and also increases the funding for emergency response financing, which in time tends to decrease.

The results of the calculations also confirm the adequacy of the developed model (1) for assessing the relationship between the costs of implementing new TDC standards, the costs for elimination of emergency situations consequences and the efficiency of the elements of the Ukrainian GTS.

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ВИВЧЕННЯ ВПЛИВУ НОВИХ СТАНДАРТІВ З ТЕХНІЧНОЇ ДІАГНОСТИКИ Й КОНТРОЛЮ НА ЕФЕКТИВНІСТЬ ГАЗОТРАНСПОРТНОЇ СИСТЕМИ

Вступ. Українська газотранспортна система (ГТС), як складова всього нафтогазового комплексу, відіграє важливу роль у енергетичній безпеці держави. Питання забезпечення роботи та технічного обслуговування ГТС, враховуючи процеси старіння та фізичного зносу системи, насьогодні є актуальними.

Проблематика. Всі нововведення та технологічні досягнення, впроваджені в ГТС, неможливі без детального вивчення питань продуктивності об'єктів ГТС, витрат на впровадження нових стандартів, а також витрат на усунення наслідків надзвичайних ситуацій.

Мета. Оцінювання та аналіз даних щодо ефективності роботи української ГТС через впровадження стандартів з технічного діагностування і контролю (ТДК), що суттєво впливає на функціонування елементів ГТС.

Матеріали і методи. Для аналізу обрано математичну модель, що дозволяє визначити якісну залежність між продуктивністю об'єктів ГТС, витратами на впровадження нових стандартів з ТДК та витратами на усунення наслідків економічного, екологічного та іншого характеру. Для оцінки практичного використання запропонованої моделі застосовано методи експертного оцінювання та чисельні методи Рунге-Кутта.

Результати. Ефективність роботи ГТС, відповідно до наведеної моделі, залежить також від витрат на впровадження стандартів. Серед переваг підвищення видатків на стандарти є зростання обсягів фінансування на випадок надзвичайних ситуацій, що має тенденцію до зменшення у часі. Результати розрахунку показали адекватність запропонованої моделі експертного оцінювання щодо об'єктивності, неупередженості та узгодженості думок експертів.

Висновки. Застосування комплексної математичної моделі дозволяє отримати якісну картину взаємозв'язків між обраними характеристиками. Запропоновано новий підхід до аналізу даних щодо ефективності української ГТС через застосування механізму внесення нових залежностей між затратами на впровадження нових стандартів та затратами на ліквідацію можливих аварійних ситуацій.

Ключові слова: ефективність, газотранспортна система, математична модель, технічне діагностування, стандарт.

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ИЗУЧЕНИЕ ВЛИЯНИЯ НОВЫХ СТАНДАРТОВ ПО ТЕХНИЧЕСКОЙ ДИАГНОСТИКЕ И КОНТРОЛЮ НА ЭФФЕКТИВНОСТЬ ГАЗОТРАНСПОРТНОЙ СИСТЕМЫ

Введение. Украинская газотранспортная система (ГТС), как составляющая всего нефтегазового комплекса, играет важную роль в энергетической безопасности государства. Вопрос обеспечения работы и технического обслуживания ГТС, учитывая процессы старения и физического износа системы, на сегодняшний день актуальны.

Проблематика. Все нововведения и технологические достижения, внедренные в ГТС, невозможны без детального изучения вопросов производительности объектов ГТС, затрат на внедрение новых стандартов, а также расходов на устранение последствий чрезвычайных ситуаций.

Цель. Оценка и анализ данных об эффективности работы украинской ГТС через внедрение стандартов по техническому диагностированию и контроля (ТДК), что существенно влияет на функционирование элементов ГТС.

Материалы и методы. Для анализа использовали математическую модель, позволяющую определить качественную зависимость между производительностью объектов ГТС, затратами на внедрение новых стандартов ТДК и расходами на устранение последствий экономического, экологического и иного характера. Для оценки практического использования предложенной модели применены методы экспертного оценивания и численные методы Рунге-Кутта.

Результаты. Эффективность работы ГТС, согласно приведенной модели, зависит от затрат на внедрение стандартов. Среди преимуществ повышения расходов на стандарты является рост объемов финансирования на случай чрезвычайных ситуаций, имеющий тенденцию к уменьшению во времени. Результаты расчета показали адекватность предложенной модели экспертной оценки объективности, беспристрастности и согласованности мнений экспертов.

Выводы. Применение комплексной математической модели позволяет получить качественную картину взаимосвязей между избранными характеристиками. Предложен новый подход к анализу данных об эффективности украинской ГТС путем применения механизма внесения новых зависимостей между затратами на внедрение новых стандартов и затратами на ликвидацию возможных аварийных ситуаций.

Ключевые слова: эффективность, газотранспортная система, математическая модель, техническое диагностирование, стандарт.