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ECOLOGICAL AND ECONOMIC CONSEQUENCES OF ACCIDENTS ON MAIN GAS PIPELINES

Abstract

The paper considers the problem of energy security as one of the main factors of sustainable development of European countries. Research results indicate that supply security is an important aspect to be considered when identifying threats to Europe's energy security and ways of countering them. It is necessary to develop a method for determining the sustainable power level of the gas

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transport system, which would reflect the relationship between accidents on main gas pipelines and their economic, environmental and social consequences. The paper presents such a method based on the systematic-functional approach, the decomposition method and the concepts of set theory; its core principles and design are revealed. The informative nature of the power level of the gas transport system development in Ukraine is proved with regards to making regulatory decisions that take into account the economic, environmental and social consequences of their influence.

Key Words:

power level; sustainable development; accidents; gas transportation system; highway.

JEL: L95, O13, O33, Q20.

5 formulae, 13 references.

Problem Statement and Literature Review

In recent years, in European countries, there has been an increasingly rapid development of energy and energy technology complexes, the purpose of which is to solve the energy problems of the customers of the relevant services. Energy security contributes to economic growth, reducing the level of poverty and improving the quality of life of the population in European countries.

In May 2014, the EU Parliament adopted a new European Energy Security Strategy, the main tasks of which are to facilitate the resistance of EU energy security to possible threats and to prevent their negative impact on EU countries. At the same time, one of the most important aspects that must be taken into account when identifying threats to Europe's energy security and countering them is security of supply. The Ukrainian gas transportation system (GTS) is one of the largest in Europe and has immense impact on European energy security. It has

2 main functions, that is, it provides both the natural gas delivery to the domestic market of Ukraine and transportation (transit through the territory of Ukraine) to the countries of Central and Western Europe (Mandryk, 2014). Operational reliability, environmental safety and economic efficiency of main gas pipelines depend on: (1) their technical condition and load, and (2) capital investments and financing maintenance (Sopilnyk et al., 2019). The average depreciation wear of the GTS of Ukraine (according to JSC «Ukrtransgaz») is 61%. About 20 thousand km of MG (out of 33.25 thousand km) has been in operation for more than 33 years (Dolinchuk, 2017). The main cause (> 50%) of accidents and failures at the MG sites is the pipe metal corrosion (Sopilnyk et al., 2019; Dolinchuk, 2017). This situation is accompanied by economic and environmental consequences of accidents at MG (GP) (Mandryk, 2014; Sopilnyk et al., 2019; Dolinchuk, 2017; Hovdiak & Kosnyriev, 2007). In these conditions, the issue of improving the safety and reliability of the main gas pipelines in order to prevent accidents, reduce economic losses and negative impact on the environment is relevant.

Given that GTS is functionally bifurcative, that is, provides gas delivery to the domestic market of Ukraine and gas transits via Ukraine, the accidents on MG and their impacts should be considered in the scope and through principles of sustainable development. This very concept is a symbiosis of environmental, economic and social interests of society. These interests, both global and local, are very specific, in particular, when it comes to environmental threats, economic risks and consumer needs in a certain time period. Therefore, sustainable development of GTS is the development of this system that would allow it to meet the economic, environmental and social needs of the Ukrainian society today and not harm needs of future generations.

Ukraine is an important strategic partner for European countries in terms of ensuring the energy security. It is beneficial for the EU if Ukraine is able to provide and guarantee safe and stable transit of gas through its territory.

In the scientific literature, quite a lot of attention is paid to the gas transport system of Ukraine. The existing research is versatile. Some authors focus on the approaches to the modernization and reconstruction of the gas transport system facilities, taking into account the expected environmental and economic effects of possible design solutions (Perevozova & Lisova, 2018). Other researchers adhere to the internationalist point of view and, at the same time, have openly globalistic beliefs about the causes of problems in the development of the gas transport system of Ukraine (Bilostotska, 2019). Notably, a significant number of studies focus exclusively on the technical problems of the gas transport system of Ukraine, in particular, on the optimization of gas transportation to consumers in Ukraine (Yanul' et al., 2019), rational use of the transfer potential of the gas transport system of Ukraine (Hovdiak & Kosnyriev, 2007), automation of pipeline gas flows and operational reliability of the system (Chekurin et al., 2018). Moreover, within the framework of automated control systems, researchers investigate the problems of forecasting stationary modes of gas supply systems (Grudz et al., 2018), including in specific regions (Kryzhanivskyi et al., 2019).

Some scientific papers are devoted to studying the costs structure allocated to maintaining main gas pipelines in working condition. It has been proven that the structure of economic losses of gas transport enterprises from corrosion (when operating the linear part of the main gas pipelines) includes the cost of corrosion protection and the expanses (losses) of metal corrosion. The extent of economic losses largely depends on the quality of the applied anti-corrosion protection system adn compliance with the rules of safe operation (Sopilnyk et al., 2019). It was found that in general the total economic loss of gas pipelines includes (Mandryk, 2014; Hovdiak & Kosnyriev, 2007): (a) direct and indirect losses of the organization operating the gas pipeline; (b) costs of localization and investigation of accidents or failures; (c) socio-economic losses due to injury or death of people; (d) environmental damage (compensation for losses from pollution of the environment); and (e) losses due to the loss of human resources as a result of the death or disability of people (Hovdiak & Kosnyriev, 2007). The optimal solution to the problem of conducting diagnostics of the technical condition and anti-corrosive protection system of underground pipelines is important here (Kryzhanivskyi et al., 2019; Moroz & Hruntovich, 2018; Dzhala & Yuzevych, 2019). It is also necessary to attract sufficient investment for the development of IT-technologies, innovations introduction and etc. (Skrynkovskyy et al., 2022). Conditions for ensuring the protection of main gas pipelines (from damage and destruction due to unauthorized access, environmental protection, etc.) are determined by the Rules for the Protection of Main Pipelines, approved by the Cabinet of Ministers of Ukraine on November 16, 2002, No. 1747 in accordance with the Law of Ukraine on Pipeline Transport (No. 192/96-BP of May 15, 1996, with amendments and additions). These Rules are in need of improvement and the relevant developments are already on the way.

After analyzing the existing research, we come to the conclusion that the problems of economic and environmental consequences of accidents on main gas pipelines are considered without taking into account the social component, that is, the system of views that comprises the concept of sustainable development.

Methodology

The aim of this research is to propose a method for determining the power level necessary for the GTS sustainable development, which would reflect the relationship between accidents on main gas pipelines and their economic, environmental, and social consequences. To achieve this goal, it is necessary to apply the concepts of set theory, in particular, the elements of the ZFC axiomatics. This will allow us to show the logical relationship between groups of indicators that, on the one hand, characterize the causes of accidents on main gas pipelines, and, on the other hand, indicate the vectors of the consequences of these accidents. We apply a systematic-functional scientific approach, as well as the decomposition method to ensure consistency in the design of the method for determining the power level of the GTS sustainable development.

Research Results

Since the concept of sustainable development is based on three components – economic, environmental and social – a system of indicators determining the power level of the GTS sustainable development must be designed in the context of these components.

Here is a set of indicators that characterize the GTS sustainable development:

$$\left.\begin{aligned} &\bigcup_{\omega=1}^{n} S_{\omega} \equiv \bigcup_{a=1}^{i} N_a \cup \bigcup_{b=1}^{y} B_b \cup \bigcup_{c=1}^{j} E_c; \\ &a \in \bigcup_{a=1}^{i} N_a \Leftrightarrow \bigcup_{a=1}^{i} N_a \in \bigcup_{\omega=1}^{n} S_{\omega}, a \in \bigcup_{\omega=1}^{n} S_{\omega}; \\ &b \in \bigcup_{b=1}^{y} B_b \Leftrightarrow \bigcup_{b=1}^{y} B_b \in \bigcup_{\omega=1}^{n} S_{\omega}, b \in \bigcup_{\omega=1}^{n} S_{\omega}; \\ &c \in \bigcup_{c=1}^{j} E_c \Leftrightarrow \bigcup_{c=1}^{j} E_c \in \bigcup_{\omega=1}^{n} S_{\omega}, c \in \bigcup_{\omega=1}^{n} S_{\omega}, \end{aligned}\right\} \quad (1)$$

where $\bigcup_{a=1}^{i} N_a$ – a set of parameters *a* characterizing the GTS operational reliability; $\bigcup_{b=1}^{y} B_b$ – a set of parameters *b* characterizing the GTS environmental safety; $\bigcup_{c=1}^{j} E_c$ – a set of indicators *c* characterizing the GTS economic efficiency.

The components $\bigcup_{\omega=1}^{n} S_{\omega}$ are a set of quantitative indicators, the logical relationship between which is directly related to the multi-vector and multi-criteria nature of the *sustainable development* and the *GTS sustainable development* concepts. Therefore

$$\left.\begin{aligned} &a = f(a_1; a_2; a_3); \\ &b = f(b_1; b_2); \\ &c = f(c_1; c_2; c_3; c_4; c_5; c_6), \end{aligned}\right\} \quad (2)$$

where a_1 is the sufficiency of gas supply; a_2 is the timeliness of gas delivery; a_3 is the compliance of gas technical parameters provided for in gas contracts; b_1 is safety for gas consumers; b_2 is safety for the environment; c_1 is the gas purchase price for consumers; c_2 is the gas delivery price to the final consumers in Ukraine; c_3 is the gas transit price through the territory of Ukraine; c_4 are the costs for maintaining the GTS in proper technical condition; c_5 are the risks of GTS going out of order due to *force majeure*; c_6 is the risk of changes in gas procurement price, its delivery to the final consumer, as well as changes in the transit price until the deadline for the execution of gas contracts is completed.

These indicators have an equally important impact on the sustainable development of GTS:

$$\because \left\{ \begin{array}{l} \overset{i}{\underset{a=1}{N_a}} \supset a_1 \wedge a_2 \wedge a_3; \\ \overset{y}{\underset{b=1}{B_b}} \supset b_1 \wedge b_2; \\ \overset{j}{\underset{c=1}{E_c}} \supset c_1 \wedge c_2 \wedge c_3 \wedge c_4 \wedge c_5 \wedge c_6 \end{array} \right\} \therefore \subset \cup \overset{n}{\underset{\omega=1}{S_\omega}}. \quad (3)$$

In addition, $\cup \overset{n}{\underset{\omega=1}{S_\omega}}$ is a Boolean, and therefore a combinatiob of subsets in which factorial and resultant indicators are characterized by decomposition. This aspect is important from an analytical and managerial position, in particular, with regard to adopting and implementing the managerial, engineering and technological decisions aimed at preventing or eliminating the environmental and economic consequences of accidents on main gas pipelines.

To implement the provisions of the sustainable development in the management of main gas pipelines, coordination of the solutions aimed at optimizing the values of individual indicators that are components $\cup \overset{n}{\underset{\omega=1}{S_\omega}}$ must be dynamic and swift. Taking this into account, the actual criterion for the GTS sustainable development is its capacity increase. We propose to identify it as follows:

$$\cup \overset{n}{\underset{\omega=1}{S_{\omega_z}}} \setminus \cup \overset{n}{\underset{\omega=1}{S_{\omega_b}}} \sim \Delta \cup \overset{n}{\underset{\omega=1}{S_\omega}}, \quad (4)$$

where $\Delta \bigcup_{\omega=1}^{n} S_{\omega}$ is the capacity increase in a set of indicators that characterize the sustainable development of GTS.

$\Delta \bigcup_{\omega=1}^{n} S_{\omega}$ depends on a number of factors, most of which are of a qualitative nature, namely technology innovations in maintaining GTS (I_t); adequacy of applying the methods and models of monitoring GTS (M_s); permanence of public control over the sustainable development of GTS (G_k); rationality of the public administration of the GTS (R_d); social responsibility of the subjects overseeing the sustainable development of GTS (C_w). As a result,

$$\Delta \bigcup_{\omega=1}^{n} S_{\omega} = f(I_t; M_s; G_k; R_d; C_w). \quad (5)$$

The targeted controlled impact on the positivity of these factors reduces the probability of accidents on main gas pipelines and makes it possible to achieve the expected capacity increase in the sustainable development of GTS.

The proposed method for determining the power level of the GTS sustainable development has a decompositional dendritic structure. This assessment approach should have long been recognized as traditional, yet it has not been used to assess the potential of the GTS sustainable development so far. As a matter of fact, the novelty of the proposed method follows from the novelty of the object of evaluation itself, as the latter determines the criteria for selecting indicators and the expected satisfactory values of these indicators.

The decomposition of the assessment level of the GTS sustainable development provides for three hierarchical assessment levels. At the lower level, analytical data are collected and processed to calculate individual indicators characterizing each of the GTS sustainable development components. The average decomposition level is intended for the integral assessment of the GTS sustainable development, and at the upper level economic, environmental and social assessments are generalized to one all-encompassing indicator. It should be recognized that the generalization of different critical indicators to one common value is always a problem, but it can be solved by transitioning to dimensionless values. Another way out of the situation may also be the transition from assessing the indicator values to the values' changing trends. In fact, determining the potential of the GTS sustainable development is necessary to fully inform management entities about the needs of GTS regulation, taking into account its economic, environmental, and social consequences.

Conclusions

The gas transport system affects the economy, environment and society. All these components are interconnected. Therefore, when making decisions aimed at achieving some specific effects from the operation of GTS, prevention and elimination of accidents should be guided by the sustainable development principles. From the principles' position, one of the most informative indicators for the GTS management is the power level of the GTS sustainable development. Increase in the capacity of GTS sustainable development reduced the frequency of accidents. Monitoring the power levels in certain dynamics indicates the stable balance of indicators reflecting the economic, environmental and social components.

When identifying the need of increasing the capacity level of the GTS sustainable development, it is necessary to take into account the factors that affect the capacity. Identifying these factors, assessing their significance and interconnectedness are the subject of further research.

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