***N.Ya. Drin, PhD in Technical Sciences******Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk  
Department of Storage and Transportation of Energy Carriers***

*ORCID ID: 0000-0002-2386-6996*

**ENERGY-EFFICIENT AND COST-EFFECTIVE OPERATION STRATEGIES FOR MODERN GAS TRANSMISSION NETWORKS**

The efficient operation of gas transmission systems (GTS) under conditions of partial load has become a vital objective due to declining transit volumes, volatile demand, and the increasing importance of energy efficiency. Traditional fully-loaded models fail to accurately represent the energy consumption dynamics in such scenarios.

This study proposes a novel approach to identify optimal operational modes by minimizing the combined consumption of fuel and process gas. A comprehensive mathematical model was developed that reflects the non-stationary behavior of gas flow and integrates both hydraulic and thermodynamic factors.

Regulatory compliance and environmental constraints must also be factored into operational strategies, as they may impact the cost structure and overall economic return. Analytically, this relationship can be expressed as follows:

**** (1)

де - the throughput capacity of the gas transmission system over a period of time ; - the difference in gas price at the end and the beginning of the pipeline;  - the cost of gas transportation.

During transportation, pressure losses occur due to friction and changes in pipeline elevation. To reduce these losses, compressor stations are used to maintain the required pressure level. Optimizing the system's operation helps reduce energy consumption and increase transportation efficiency.

This approach is important for ensuring the reliable and cost-effective operation of the gas transmission network.

 (2)

де (x) – gas pressure as a function of the linear coordinate; - linear velocity of the gas;  - density;  - hydraulic resistance coefficient.

Based on (2), the specific energy consumption for gas transportation through a pipeline of length *L* is determined by the following equation:

**** (3)

From equation (3), it follows that energy consumption for gas transportation increases with the square of the linear gas velocity.

At the pipeline outlet, a boundary condition of constant pressure or pressure gradient is assumed. This formulation enables accurate modeling of the transient process and assessment of the impact of the initial disturbance on the evolution of flow parameters within the pipeline.

, (4)

where - pressure at a distance from the beginning of the gas pipeline of length ;  - pressures at the beginning and end of the pipeline, respectively.

At specified pressures  a certain mass capacity of the gas pipeline is ensured , which, under conditions of incomplete load, can be changed at any time in the direction of increase or decrease by a certain amount . Suppose that starting from the moment of time  gas supply to the pipeline has not changed, and the withdrawal at the end of the route has changed by .

Then the boundary conditions for the realization equation will be as follows:

  (5)

where .

Using the first equation of the system (3) and neglecting all types of energy consumption except for hydraulic resistance, we obtain:

 (6)

 (7)

The solution of (6) under the initial (7) and boundary (5) conditions is sought by the Fourier method



 (8)

The research findings are applicable in real-world operations by:

- Providing gas transmission operators with clear parameters for mode selection.

- Supporting SCADA-based decision-making and predictive control systems.

- Enhancing cost efficiency by reducing unnecessary compressor activity.

- Improving environmental performance through lower fuel gas consumption.

- Ensuring pipeline integrity through better understanding of transient dynamics.

The study demonstrates that accurate modeling of transient processes and separation of gas types in consumption analysis are critical for optimizing GTS performance. The proposed approach significantly enhances the energy and economic efficiency of gas transportation under partial load.

References

1. Ya. Grudz, I. Prokopiv, K. Novikov, N. Drin, A. Vitushynskyi, L. Kachan, *Energy efficiency and reliability of gas transport and distribution networks*, Procedia Structural Integrity, Volume 59, 2024, Pages 750–756. <https://doi.org/10.1016/j.prostr.2024.04.107> (SCOPUS)
2. М.D. Serediuk Peculiarities of the operation of the oil pipeline in the process of its cleaning from paraffin deposition. Journal of Achievements in Materials and Manufacturing Engineering. 2021. Volume 106, Issue 2, p. 77-85. <https://doi.org/10.5604/01.3001.0015.2419>.