Volume 10, Number 2, 2024 73

Analysis of Methods for Leak Detection and Monitoring the Main Gas Pipeline Sections

Bohdan Danyltsiv*, Olha Khymko

Lviv Polytechnic National University, 12 Stepana Bandery St., Lviv, 79013, Ukraine

Received: October 17, 2024. Revised: December 05, 2024. Accepted: December 12, 2024.

Abstract

The paper analyzes the existing methods for leak detection and monitoring the main gas pipeline sections. An extended classification of methods is presented based on the additional parameters: operating mode (steady-state, non-steady-state) and type of leak detection (presence detection, location identification, volume determination). Based on the comparative analysis of methods according to criteria of sensitivity, reliability, localization accuracy, response time, and implementation cost, the negative pressure wave method with an extended real-time modeling system was established to be the most effective combination for non-steady-state operation mode and long pipelines. Promising areas for further development of leak detection systems have been identified, including improvement of mathematical models, integration of artificial intelligence methods, enhancement of technical equipment and software.

Keywords: main gas pipeline; leak detection; condition monitoring; negative pressure wave; real-time modeling; non-steady-state mode.

1. Introduction

The transportation of gas through long main pipelines from gas processing plants to gas distribution networks is termed "Midstream" in the oil and gas industry. Ukraine has approximately 37,000 km of main gas pipelines. By total length of main pipelines, Ukraine ranks 5th in the world [1]. Maintaining such extensive infrastructure requires significant funds, which are scarce during wartime. Due to the depletion of operational resources of main pipelines, gas leak problems arise. Gas leaks are difficult to detect in a timely manner while minimizing costs. Therefore, automatic gas leak detection systems in main pipelines serve as a tool for rapid response to pipeline damage and reduction of gas losses.

Main gas pipelines operate under complex technogenic conditions, encompassing various types of installation, such as underground, above-ground, and underwater placement. Moreover, the pressure of natural gas in pipelines can reach 8 MPa. All these factors have led to main gas pipelines being classified as high-risk facilities, and accidents involving them can lead to large-scale technogenic disasters.

Therefore, the development and implementation of reliable and efficient automated monitoring systems for main gas pipelines based on microprocessor automation tools is an extremely important and urgent task.

2. Analysis of the recent publications and research works on the problem

Paper [2] provides an overview of pipeline monitoring and periodic inspection. Online monitoring methods in [2] include the following ones: gas volume balance analysis method, pressure change monitoring method, real-time model application method, acoustic monitoring, pressure wave monitoring, and fiber optic sensor-based methods.

* Corresponding author. Email address: bohdan.m.danyltsiv@lpnu.ua

This paper should be cited as: B. Danyltsiv, O. Khymko. Analysis of methods for leak detection and monitoring the main gas pipeline sections. *Energy Engineering and Control Systems*, 2024, Vol. 10, No. 2, pp. 73 – 80. https://doi.org/10.23939/jeecs2024.02.073

Periodic inspection methods include the below: non-technical inspection (visual inspection), soil monitoring, vapor sampling, in-line inspection (ultrasonic and magnetic), and optical inspection. The choice of method depends on specific pipeline operating conditions, and often a combination of different approaches is needed for leak detection.

Paper [3] classifies leak detection methods into external and internal methods. External methods are physical leak detections such as visual inspection, fiber optic cables, and acoustic sensors. Internal methods use sensors for internal pipeline parameters. The article provides evaluations of leak detection systems based on two parameters: reliability and sensitivity. A comparative table of different leak detection methods is presented. In conclusion, the choice of the best method depends on the specific pipeline, and it is noted that effective leak detection requires continuous management and maintenance.

Paper [4] reviews modern leak detection methods in pipelines. The authors classify leak control methods by type of diagnosis and diagnostic signal processing algorithm. Special attention is paid to acoustic methods, which are considered promising due to their independence from the transport medium. The article notes that modern leak detection systems often combine several methods to improve accuracy. For example, the PipePatrol system combines real-time dynamic modeling with leak pattern recognition. However, this approach is not universal, especially when changing transport mode. The authors propose expanding the informative components of diagnostic signals in the acoustic method of leak control. They consider the possibility of using information entropy estimates to improve signal processing and increase leak detection efficiency.

Paper [5] presents a classification and analysis of existing leak detection technologies, divided into: external methods (acoustic sensors and fiber optic technologies) with high localization accuracy; internal methods (pressure/flow monitoring and real-time modeling) for leak size assessment; and visual/inspection methods (including the use of drones). Special attention is paid to promising research directions, such as the application of machine learning, generative adversarial networks, and multispectral image classification for improving leak detection systems.

Paper [6] presents an overview of inspection and monitoring methods for oil and gas pipelines in permafrost areas, including in-line inspection technologies (magnetic flaw detection, ultrasonic and electromagnetic acoustic diagnostics) and integrated monitoring systems for tracking ground displacement, temperature, stress, and deformation. Special attention is paid to the comprehensive use of various technologies, such as mechanical displacement monitoring, automated systems, fiber optic sensors, and ground-penetrating radar measurements, to ensure safe pipeline operation in challenging permafrost conditions.

In paper [7], the author uses parallel pipelines, where one pipe has a leak and the other does not, allowing for comparative analysis to determine pipeline leakage. Leak detection is based on analyzing pressure differential and flow rate along the pipeline. A steady-state mathematical model is presented for determining leak locations based on dimensionless parameters. This method is sensitive to changes in fluid properties or leak increase in real conditions, and it can only be applied to parallel pipelines.

Paper [8] uses the volumetric flow and pressure gradient method. A nonlinear adaptive leak detection model was developed based on a combination of pressure and volumetric flow measurements at the pipe inlet and outlet. The leak is identified by the presence of a pressure gradient near the leak point. A real-time model for pipeline state simulation is presented. The method's disadvantages include dependence on parameter measurement accuracy, which significantly affects detection accuracy. The method has low sensitivity to very small leaks. Localization accuracy depends on the resolution of pressure measurements along the pipeline.

Papers [9]-[11] present leak detection methods based on analyzing negative pressure waves in pipelines, using different approaches to signal processing: paper [9] applies adaptive noise cancellation and identification of pressure inflection points; paper [10] uses the adjoint equation method to obtain the reverse equation for pressure wave propagation; paper [11] applies a combination of autoregressive model (ARX), Laguerre filters, and fuzzy PID observer. All methods provide high accuracy in leak localization but share common limitations regarding noise sensitivity and the need for precise measuring equipment.

Paper [12] describes a leak detection method called TMOS Wave, developed by ATMOS International. It is based on the negative pressure wave method. A non-steady-state mathematical model is used. Three complex algorithms are applied for noise filtering and analysis of pressure wave propagation along the entire pipeline length. This implementation allows leak detection within 8 minutes, accurate leak location determination with an error of 100 to 400 meters, low false alarm rate, and independence from flow meters. The approach's disadvantages include the presence of blind zones; system sensitivity varies depending on pipeline segment, detection accuracy depends on pipeline filling level, and the maximum distance between sensors is 200 km.

Papers [13], [14] present acoustic methods for leak detection in oil and gas pipelines, based on analyzing sound signals that occur during gas leakage, using different modifications of the Variational Mode Decomposition (VMD) algorithm for signal preprocessing. The methods differ in subsequent signal processing: paper [13] uses a one-dimensional convolutional neural network (1DCNN) with 96.33% accuracy, while paper [14] employs Lempel-Ziv complexity analysis and Support Vector Machine (SVM) with up to 100% accuracy in experimental verification on a compressed air facility.

Paper [15] presents a gas leak detection system based on a combination of an ultrasonic sensor for monitoring gas pressure in the pipeline and an MQ-135 gas sensor for detecting gas presence in the air, integrated with the IoT Blynk platform for remote monitoring. The system provides early warning based on pressure deviations from normal values and automated actions in case of leak detection, although it has limited accuracy for large pipelines and cannot localize the leak point.

Paper [16] presents a method for gas leak detection in main pipelines based on analyzing dynamic changes in gas pressure differential using convolutional neural networks (CNN) and data from existing SCADA systems. The method showed good results when tested on a real gas pipeline in Taiwan, although it requires a large amount of training data about real leaks, which is difficult to obtain.

Paper [17] presents an acoustic method for leak detection in gas pipelines based on experimental investigation of acoustic signal characteristics (amplitude, root mean square voltage, and acoustic wave attenuation coefficient) at different pressures and distances between leak points. The method allows detection and localization of leaks without pipeline excavation, although it has difficulties with result interpretation in the presence of noise and requires installation of a sufficient number of sensors.

Paper [18] presents a leak detection method based on distributed fiber optic sensor that simultaneously measures vibration and temperature along the pipeline, using phase-sensitive optical time-domain reflectometry (Φ-OTDR) for vibration and Brillouin optical time-domain reflectometry (BOTDR) for temperature. The method provides high leak detection accuracy (98.57%) and processing speed (6.79 ms), although it requires laying fiber optic cable along the entire pipeline.

3. Formulation of the goal of the paper

The purpose of this paper is to analyze methods for leak identification in main gas pipelines, determine their areas of application, advantages, and disadvantages. Special attention is given to methods that can be applied during non-steady-state gas flow in pipelines, as well as those that, in addition to detecting the presence of a leak, can localize the leak and provide the ability to determine the volume of lost gas.

4. Presentation of research results

Based on the processed literature, the main common approaches to classifying pipeline leak detection methods can be identified as follows:

- *By the operating principle:*
  - External-based methods - based on physical detection of substance leakage using special external sensors (acoustic sensors, fiber optic cables, etc.).
  - Internal/Computational-based methods - operate based on models or algorithmic principles that track flow parameters in real-time using sensors built into the pipeline (volume balance, pressure/flow analysis, statistical analysis, etc.).
  - Visual/inspection methods: planned at regular intervals for visual inspection by humans or automated systems.

- *By the operating mode:*
  - Continuous monitoring methods (on-line): provide constant monitoring of pipeline condition.
  - Periodic control methods (off-line): performed at certain time intervals.
- *By the type of measured parameters:*
  - Methods based on flow parameter measurements (pressure, flow rate, temperature): may include balance method (comparison of input and output flow rates) for pipeline operation analysis or pressure analysis (detection of anomalous changes). Use real-time mathematical modeling to predict flow behavior.
  - Acoustic methods: use special sensors to detect sound signals that occur during leakage.
  - Optical methods: can use thermography to detect temperature anomalies, laser scanning to detect gas in the air.
  - Methods using fiber optic sensors: fiber optic sensors consist of optical fiber (light guide) with a core surrounded by cladding. Physical or chemical effects on the fiber change the characteristics of light passing through it, including amplitude, phase, wavelength, polarization, and signal transit time; analyzing these parameters can determine pipeline leakage.
  - Methods based on environmental chemical composition analysis: use gas analyzers or special marker substances for leak detection.
- *By the human intervention requirement:*
  - Automated methods.
  - Partially automated methods.
  - Manual control methods.
- *By the control location:*
  - In-line inspection – uses special diagnostic devices (intelligent pigs or "robots") that move inside the pipeline.
  - External control – includes methods for inspecting the external surface and pipeline surroundings.
  - Remote control – remote observation methods.

It's also worth noting that besides conventional identification methods, there are proprietary leak detection methods, for example, a method based on analyzing gas flow parameters in the pipeline [19]. This proprietary method uses mathematical modeling to create typical curves that show relationships between dimensionless parameters of pressure, flow rate, and leak location. The key feature of the method is conducting multiple tests with different gas flow regimes. Another example of a proprietary approach can be found in paper [20], which describes the development of an in-line inspection robot for pipeline leak detection. It has a hexagonal shape to ensure contact with the pipe's inner surface at a minimum of three points. The robot is equipped with six wheels that touch the pipe's inner surface, ensuring stable movement. The propeller is used not only for forward motion but also to create airflow inside the pipe, helping to detect leaks. Pressure sensors are placed on the robot's body to measure pressure changes inside the pipe. The robot's dimensions are specially selected for movement inside pipes of a certain diameter (about 20 cm in this case). The system showed 83.3% leak detection accuracy on test data. Overall, the robot demonstrates effectiveness in detecting single and multiple leaks in pipelines of various configurations.

Since the purpose of the article is to develop recommendations for selecting a leak localization method under non-steady-state gas flow conditions in the main pipeline, it is necessary to expand the existing classification with additional parameters: by operating mode (steady-state, non-steady-state mode), by leak detection information (leak presence detection, location identification, volume determination). The authors propose a classification of leak detection methods, presented in Fig.1.

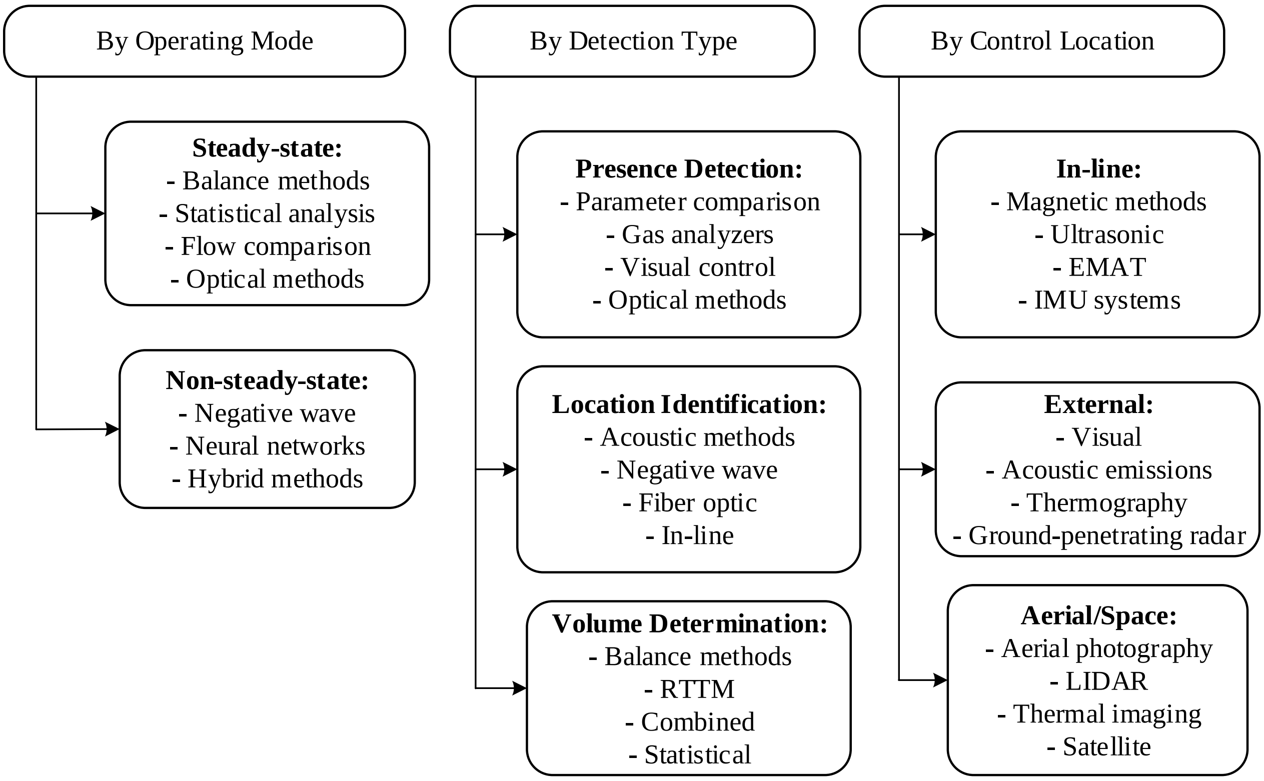

Fig.1. Classification of leak detection methods by additional parameters.

The presented classification will help in selecting a leak detection method, but for more precise selection, attention should be paid to the criteria for evaluating method effectiveness. The main criteria for evaluating the effectiveness of leak detection methods: sensitivity (minimum detectable leak size), reliability (probability of correct leak detection), accuracy of leak location, system response time, implementation and operation costs. Based on the methods analysis, a comparison table of leak detection methods has been developed taking into account the above criteria.

Table 1. Comparison of leak detection methods.

Method	Sensitivity (min. leak)	Reliability (false alarms)	Localization accuracy	Response time	Cost	Operating mode	Leak information
Balance method	~1% of flow rate	Low in transient modes	None	1-24 hrs	Low	Steady-state	Detection, volume
Negative pressure wave method	~0.5% of flow rate	Medium	100-500 m	1-5 min	Medium	Non-steady-state	Detection, localization
Real-time transient modeling (RTTM)	~0.25% of flow rate	High	500-2000 m	5-15 min	High	Both	Detection, localization, volume
Acoustic methods	~0.1% of flow rate	High	50-100 m	1-5 min	Medium	Steady-state	Detection, localization
Fiber optic systems	~0.1% of flow rate	Very high	1-5 m	<1 min	Very high	Both	Detection, localization
In-line inspection	Defects from 0.1 mm	Very high	0.1-1 m	Periodic	High	Steady-state	Localization
Visual inspection	Visible leaks	Medium	Precise	Periodic	Low	Steady-state	Detection
Aerial photography/LIDAR	~1-5% of flow rate	Medium	10-50 m	Periodic	High	Steady-state	Detection, localization

During the development of this table, the following criteria gradations were applied:

- Method sensitivity (% of leak relative to gas flow rate in pipeline): very high (<0.1%), high (0.1-0.5%), medium (0.5-1%), low (>1%).
- Reliability (number of false alarms per year): very high (<1), high (1-5), medium (5-10), low (>10).
- Response time (min): instant: <1 min, fast: 1-5 min, medium: 5-15 min, slow: >15 min, periodic: depends on inspection schedule.
- Implementation and operation cost (USD/km): very high: >500k, high: 100-500k, medium: 50-100k, low: <50k.
- Operating mode: steady-state – works in stable mode, non-steady-state – works in variable modes, both – works in both modes.
- Leak information: detection – fact of leak presence, localization – leak location, volume – quantitative assessment of leak.

Since leak detection in pipelines should be conducted by an automated system, attention should be paid to two main categories of methods: online methods (continuous monitoring systems) and periodic control methods. Online methods provide continuous real-time monitoring of pipeline condition, while periodic methods are applied at specified intervals to check pipeline integrity. For creating effective automated leak detection systems, special attention should be paid to online methods.

Taking into account the classification and existing methods, it can be stated that for non-steady-state mode and long pipelines, the best combination is the Negative Pressure Wave (NPW) method with an Extended Real-Time Transient Modeling (E-RTTM) system. Real-Time Transient Modeling (RTTM) will serve as the main detection and monitoring method, providing reliable leak detection in non-steady-state mode. The negative pressure wave method (supplementary) will improve localization accuracy and response time.

Both methods belong to the online category, and this combination will provide: reliable leak detection in non-steady-state modes, acceptable localization accuracy, ability to determine leak volume, fast response time, medium implementation cost, mutual leak confirmation by different methods. Let's justify this choice in more detail:

- Advantages of RTTM method:
  - Works in non-steady-state mode;
  - High reliability (few false alarms);
  - High sensitivity (~0.25% of flow rate);
  - Can determine leak volume;
  - Capable of working with long pipelines.
- Disadvantages of RTTM method:
  - High implementation cost;
  - Medium localization accuracy (500-2000 m);
  - Requires precise calibration and tuning.
- Advantages of NPW method:
  - Specifically designed for non-steady-state modes;
  - Fast response time (1-5 min);
  - Better localization accuracy (100-500 m);
  - Medium implementation cost.
- Disadvantages of NPW method:
  - Medium reliability;
  - Lower sensitivity (~0.5% of flow rate);
  - May miss slowly developing leaks.

5. Prospects for further research development

Prospects for further research development encompass several key directions.

Mathematical Model Improvement. This includes developing adaptive algorithms for non-steady-state operation, improving noise filtering methods in pressure signals, and optimizing leak localization algorithms. Special attention should be paid to creating models for more accurate leak volume determination and developing methods for predicting their development.

Integration of Artificial Intelligence Methods. Implementation of neural networks and machine learning algorithms will improve data analysis and leak pattern recognition. Creating expert diagnostic systems and decision support systems will increase the overall system efficiency.

Technical Equipment Enhancement. Development of more sensitive pressure sensors, increasing data collection and processing speed, improving transmission systems will allow obtaining more accurate and operational information about pipeline condition. An important aspect is also the optimization of sensor placement on the pipeline.

Software Development. Creating more efficient signal processing algorithms, developing intuitive user interfaces, and improving data visualization methods will significantly enhance operator interaction with the system. Special attention should be paid to improving integration with existing automation systems.

System Reliability Improvement. Reliability can be enhanced through developing self-diagnostic methods, improving false alarm detection algorithms, and creating backup monitoring systems. An important aspect is also improving resistance to external influences and developing automatic calibration methods.

Economic Optimization. This includes work on reducing implementation costs, improving energy efficiency, and optimizing operational expenses. Creating scalable systems will make solutions more accessible for various pipeline scales. Implementation of these research directions will significantly increase the effectiveness of automated leak detection systems, ensuring higher leak detection accuracy, reducing false alarms, decreasing system response time, and optimizing implementation and operation costs.

6. Conclusion

The conducted analysis of leak identification methods in main gas pipelines demonstrates the diversity of existing approaches and their specific characteristics. As a result of the research, the classification of leak detection methods was expanded with additional parameters, including operating mode and type of leak detection, which allows for more precise selection of methods for specific operating conditions.

Analysis of sources indicates that the most effective combination for non-steady-state operation mode and long pipelines proved to be the Negative Pressure Wave (NPW) method with Extended Real-Time Transient Modeling (E-RTTM). This combination ensures an optimal balance between leak detection reliability, localization accuracy, and system response time. The RTTM method provides high reliability and sensitivity (about 0.25% of flow rate), ability to operate in non-steady-state mode, and capability to determine the volume of lost gas. Meanwhile, the negative pressure wave method complements RTTM with high localization accuracy (100-500 m) and short response time (1-5 min).

An important result of the analysis is the identification of promising directions for further development of leak detection systems. Key directions: improvement of mathematical models for gas flow in pipelines and models for analyzing natural gas balance in network sections, enabling real-time pipeline condition analysis; integration of artificial intelligence methods into leak detection systems for adapting such systems to variable operating conditions; enhancement of technical equipment and software for leak detection systems, enabling increased reliability of these systems and reduced costs.

The conducted research confirms the necessity of a comprehensive approach to leak detection in main gas pipelines and combination of different methods, which allows compensating for limitations of individual methods and ensuring maximum monitoring system efficiency.

References

[1] The World Factbook — Central Intelligence Agency. www.cia.gov. Original archive for August 21, 2016.

[2] K. Sachedina and A. Mohany. A review of pipeline monitoring and periodic inspection methods. Pipeline Science and Technology. 2018; 2(3): 187-203. https://doi.org/10.28999/2514-541X-2018-2-3-187-201

[3] Jun Zhang, Peter Han, Michael Twomey. Overview of pipeline leak detection technologies. Atmos International 14607 San Pedro Avenue Suite 290 San Antonio, TX 78232 USA

[4] Bezgachnyuk Yurii, Shtaier Lidiia. Overview of the Current State of Pipeline Leak Control Methods. International Science Journal of Engineering & Agriculture. Vol. 3, No. 3, 2024, pp. 43-50. https://doi.org/10.46299/j.isjea.20240303.04

[5] Naga Venkata Saidileep Korlapati, Faisal Khan, Quddus Noor, Saadat Mirza, Sreeram Vaddiraju. Review and analysis of pipeline leak detection methods. Journal of Pipeline Science and Engineering Volume 2, Issue 4, December 2022, 100074. https://doi.org/10.1016/j.jpse.2022.100074

[6] Chen, P.; Li, R.; Jia, G.; Lan, H.; Fu, K.; Liu, X. A Decade Review of the Art of Inspection and Monitoring Technologies for Long-Distance Oil and Gas Pipelines in Permafrost Areas. Energies 2023, 16, 1751. https://doi.org/10.3390/en16041751

[7] Fu, H., Ling, K., & Pu, H. (2022). Identifying two-point leakages in parallel pipelines based on flow parameter analysis. Journal of Pipeline Science and Engineering, 2(1), 100052. https://doi.org/10.1016/j.jpse.2022.02.001

[8] Riaz, M., Ahmad, I., Khan, M.N., Mond, M.A. and Mir, A. (2020) 'Volumetric flow and pressure gradient-based leak detection system for oil and gas pipelines', Int. J. Oil, Gas and Coal Technology, Vol. 25, No. 3, pp. 340–356. https://doi.org/10.1504/IJOGCT.2020.110386

[9] Boxiang Liu, Zhu Jiang, Wei Nie (2021). Application of VMD in Pipeline Leak Detection Based on Negative Pressure Wave. Hindawi Journal of Sensors Volume 2021, Article ID 8699362, 19 pages. https://doi.org/10.1155/2021/8699362

[10] Chang Chang, Xiangli Li , Lin Duanmu, Hongwei Li, Wenbin Zhou. Locating leakage in pipelines based on the adjoint equation of inversion modeling. Heliyon 9 (2023) e17270. https://doi.org/10.1016/j.heliyon.2023.e17270

[11] Raheleh Jafari, Sina Razvarz, Cristóbal Vargas-Jarillo, Alexander Gegov, and Farzad Arabikhan. Pipeline Leak Detection and Estimation Using Fuzzy PID Observer. Electronics 2022, 11, 152. https://doi.org/10.3390/electronics11010152

[12] Dr Alex Souza de Joode, Andrew Hoffman. Pipeline Leak Detection and Theft Detection Using Rarefaction Waves. 6th Pipeline Technology Conference 2011.

[13] Dandi Yang. Establishment of leakage detection model for oil and gas pipeline based on VMD-MD-1DCNN. 2022 Eng. Res. Express 4 025051. https://doi.org/10.1088/2631-8695/ac769e

[14] Lijuan Zhu, Dongmei Wang1, Jikang Yue, Jingyi Lu and Gongfa Li. Leakage detection method of natural gas pipeline combining improved variational mode decomposition and Lempel–Ziv complexity analysis. Transactions of the Institute of Measurement and Control 2022, Vol. 44(15) 2865–2876 The Author(s) 2022 Article reuse guidelines: sagepub.com/journals-permissions https://doi.org/10.1177/01423312221088080

[15] V. Muralidharan, S. Prabhavathy, L. Pavithra, V. Nithya. IoT Based Smart Monitoring and Controlling System for Gas Leakage in Industries. Volume 9 Issue 9, 38-46, September 2022. https://doi.org/10.14445/23488379/IJEEE-V9I9P105

[16] Te-Kwei Wang, Yu-Hsun Lin, Jian-Yuan Shen. Developing and Implementing an AI-Based Leak Detection System in a Long-Distance Gas Pipeline. Advances in Technology Innovation, vol. 7, no. 3, 2022, pp. 169-180. https://doi.org/10.46604/aiti.2022.8904

[17] Yao-bin Li , Qing-Yun Fu , and Xin Guo. Research on the Propagation of Acoustic Signal and Attenuation Change Law of Gas Pipeline Double-Point Leakage. Hindawi Shock and Vibration Volume 2023, Article ID 7725366, 9 pages. https://doi.org/10.1155/2023/7725366

[18] Feng Wang, Zhen Liu, Xiao Zhou, Shiyi Li, Xinyu Yuan, Yixin Zhang, Liyang Shao c, Xuping Zhang. Oil and Gas Pipeline Leakage Recognition Based on Distributed Vibration and Temperature Information Fusion. Results in Optics Volume 5 , December 2021, 100131. https://doi.org/10.1016/j.rio.2021.100131

[19] Kegang Ling, Guoqing Han and Xiao Ni, Chunming Xu, Jun He, Peng Pei, and Jun Ge. A New Method for Leak Detection in Gas Pipelines. April 2015, Oil and Gas Facilities.

[20] Danial Waleed, Syed Hamdan Mustafa, Shayok Mukhopadhyay, Mamoun Abdel-Hafez, Mohammad A. Jaradat, Kevin Rose Dias, Fahad Arif, Jawwad Imtiaz Ahmed. An in-pipe leak detection robot with a neural-network based leak verification system.

Аналіз методів виявлення витоків та моніторингу стану ділянок магістральних газопроводів

Богдан Данильців, Ольга Химко

Національний університет «Львівська політехніка», вул. С. Бандери, 12 , Львів, 79013, Україна

Анотація

У статті проведено аналіз існуючих методів виявлення витоків та моніторингу стану ділянок магістральних газопроводів. Представлено розширену класифікацію методів за додатковими параметрами: режимом роботи (стаціонарний, нестаціонарний) та типом виявлення витоку (виявлення наявності, локалізація місця, визначення об'єму). На основі порівняльного аналізу методів за критеріями чутливості, надійності, точності локалізації, часу реакції та вартості впровадження встановлено, що для нестаціонарного режиму роботи та довгих трубопроводів найбільш ефективною є комбінація методу негативної хвилі тиску з розширеною системою моделювання в реальному часі. Визначено перспективні напрямки подальшого розвитку систем виявлення витоків, що включають вдосконалення математичних моделей, інтеграцію методів штучного інтелекту, покращення технічних засобів та програмного забезпечення.

Ключові слова: магістральний газопровід; виявлення витоків; моніторинг стану; негативна хвиля тиску; моделювання в реальному часі; нестаціонарний режим.