Abstract of the PhD thesis

„Modeling the variability of the composition of natural gas using the artificial neural networks method"

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In recent years, the Polish natural gas transmission network has undergone significant development through the expansion of the national gas grid and the construction of new inter-system connections with other countries. The development of the transmission infrastructure will continue in the future, also as a result of the introduction of alternative fuels in the form of hydrogen and/or biomethane into the network. Such actions, related to the diversification of natural gas suppliers, are the cause of mixing gases of different qualities in the pipelines. The multitude of suppliers ensures the security of gas supply, but also generates the need for increased verification of the quality parameters of the transmitted fuel, mainly the heat of combustion value, the knowledge of which is essential to ensure the proper transport of gas through the network and the settlement of consumers and balancing of the gas system. The heat of combustion value of the gas transported through the network is determined based on the composition of the flowing gas mixture.

The composition of natural gas mainly depends on its place of origin, while its variability in the pipeline network is additionally influenced by the variable demand for gas by consumers, dependent on calendar factors and weather conditions. The load on the gas network, being the sum of gas withdrawals from the network by consumers, changes in a daily, weekly, and seasonal cycle, which is the cause of uneven gas flow in the pipelines over time. In a situation where natural gas of various qualities, coming from several suppliers, is delivered to the gas network, there is a need to track changes in the composition of the resulting gas mixture at different points in the network. In addition to time-consuming and costly laboratory tests using gas chromatography, the most commonly used methods for tracking the composition of natural gas are gas flow simulations. However, the composition of natural gas can also be forecasted.

In this doctoral dissertation, the development of a model for forecasting the composition of natural gas using an artificial neural network model, not previously used for forecasting the proportion of components of the gas mixture in the network transporting gas from various suppliers, is proposed. The main thesis of the doctoral dissertation assumes the possibility

of training an artificial neural network model to forecast the content of selected components of natural gas depending on selected calendar and weather factors.

The dissertation is divided into a theoretical and experimental part. In the theoretical part, the causes of variability in the composition of natural gas transported through the pipeline network, methods of modeling systems and data analysis, and the construction and types of artificial neural network models were analyzed. Based on the analysis of research results from other authors, in terms of examples of the application of neural network models for forecasting selected parameters, eight research hypotheses were formulated.

In the experimental part, preliminary and main studies were distinguished. As part of the preliminary studies, based on an extensive set of measurement results of the content of selected components of the natural gas mixture in the network, characteristic of different points of composition measurement in the Polish natural gas transmission network, a statistical analysis of the variability of the composition of natural gas over time was conducted. The result of the analysis was the selection of five components of natural gas (output variables of the model: methane, ethane, propane, nitrogen, and carbon dioxide), which were then forecasted. Factors that have a direct or indirect influence (input variables of the model: month, day of the month, day of the week, ambient temperature) on the variability of the content of these components in natural gas at a given measurement point were also identified.

Within the four stages of the main studies, a total of 26,200 artificial neural network models were trained, using sets with different numbers of data. Models in the form of a feedforward multilayer perceptron (MLP), trained to forecast the contents of five components of natural gas, differed in: the number of neurons in the hidden layer, the learning method, the activation function of neurons in the hidden and output layer, and the structure. Calculations were performed in the STATISTICA Neural Networks program. Training and verification of models and forecasting of gas component contents were carried out based on real data, representing the composition of natural gas in successive hours of the day over a period of five years, provided by the Gas Transmission Operator GAZ-SYSTEM S.A. Based on the results of forecasts of natural gas components, the best quality MLP 17-37-5 model for forecasting the composition of natural gas was selected, characterized by the best fit of the model to real data (RT = 0.9711), correctly reflecting the relationships between the forecasted components of natural gas, and the lowest forecast error (nRMSEśr = 0.3210). It was shown that the developed model for forecasting the composition of natural gas can also be applied in the case of the introduction of hydrogen into the natural gas transported through the pipeline network. Moreover, the forecasted contents of natural gas components using the selected MLP model allow determining the heat of natural gas combustion with an error of less than 2%.

07.06.2024r.
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