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Big Data and Machine Learning Based Approach to Gas Processing: A Case of Condensate Stabilization

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Abstract

Gas condensate recovered from the natural gas is a valuable liquid product. It must be processed or treated to a commercially acceptable form for its storage or export. The treatment of gas condensate generally involves the separation of any dissolved gases such as light hydrocarbon components (i.e., methane and ethane) along with decreasing the acid contents (i.e., H_2S, mercaptans, etc.), water and salt contents to the desired standards in order to make it environmentally safe for storage and transportation purposes. The process of stripping the light end components from the heavier hydrocarbons is referred as condensate stabilization which is primarily performed to reduce the vapor pressure of condensate liquids to avoid the generation of vapor phase when transferring them to atmospheric tanks. Condensate stabilization can be achieved by either flash vaporization or fractionation. However, condensate stabilization by fractionation is a popular choice in industry as it has the capability to produce condensate liquids of desired vapor pressure in a single tower process. It is a complicated chemical process, thus requires significant efforts to develop accurate and reliable models with the objective to minimize the operational costs. Lately, the modeling approach that deals with input-output operating data has gained significant attention. Machine learning has been emerged as a proven and alternative modeling approach that based on operating data, which is readily available.

This work therefore employs artificial neural network (ANN) in order to build a model that can predict the performance of the condensate stabilizer unit. A large dataset of an industrial condensate stabilizer, comprising of operating data of input-output variables, is used to evaluate the developed model. To develop the ANN model, inlet gas flowrate, inlet gas temperature, column temperature, column pressure, condensate flowrate, condensate temperature, reboiler temperature and steam flowrate are implemented as model inputs, whereas RVP, H_2S contents and water contents are used as network outputs. The dataset is split randomly into two subsets for the purpose of training and testing the model. The training subset of data is employed to train the network by developing the network weights whereas the testing subset is used to estimate and compare the output of developed model against the independent operating data. The main objective of developing this ANN model is to predict the important parameters of the final stabilized liquid, which are RVP, H_2S contents and water contents. The predictions from the developed model are compared with the testing subset of operating data. To evaluate the model performance, mean squared error (MSE) and coefficient of determination (R^2) are investigated. The results obtained from this case study show that the developed model has the potential to offer reliable and accurate predictions. As future work, an integrated framework will be developed where data-driven surrogate models will be integrated into optimization framework to find the optimal values of the variables corresponding to the minimal operational costs or energy demands. The integrated framework will be able to help the gas industry to simultaneously achieve the process efficiency, profitability and safety.

Keywords
Machine learning, Big data, Gas processing, Artificial neural network

Biographies

Muhammad Rizwan is a Postdoctoral Fellow at the Department of Chemical Engineering, Khalifa University of Science and Technology, Abu Dhabi, United Arab Emirates. He holds a PhD degree in Chemical Engineering from Korea Advanced Institute of Science and Technology (KAIST), South Korea. His main research interests are in the area of Process Systems Engineering (PSE) with the focus on energy systems design, modeling, simulation and optimization. He developed methodological frameworks for the superstructure based optimization of biorefinery networks as well as waste-to energy networks. He is currently focusing on big data analytics and the application of machine learning in gas operations to improve the process performance and profitability.

Mohammed Alkatheri holds a BSc degree in Chemical Engineering from United Arab Emirates University, and MSc degree in Chemical Engineering from the Petroleum Institute in Abu Dhabi. During his MSc, he developed research on Modelling and simulation of kinetics and single particle growth for the heterogeneous polymerization of Ziegler-Natta catalyst. From 2015 – 2017, he worked as a research assistant at the Petroleum Institute where he studied the economics of different ultra-sour natural gas sweetening processes, assessed sweeting of ultra-sour natural gas using hybrid process and carried out green-house gases life cycle assessment for the United Arab Emirates electricity sector. In May 2017, he joined PhD program in Chemical Engineering at University of Waterloo. His PhD research is focusing on the application and integration of big-data tools (i.e. Artificial Intelligence and Machine Learning) in chemical process optimization and process system engineering. The scope of his PhD project is to address the challenges associated with chemical engineering process design and operation, namely, uncertainty handling, parameter estimation and unit process equation complexity. Therefore, high-level optimization tasks such as planning and scheduling will highly benefit from information mined from massive data, since optimization has always been based on the interchange between models and data.

Falah Alhameli is currently a research and development engineering at Abu Dhabi national Oil Company (ADNOC). He earned a B.S. and an M.S. in Chemical Engineering from the Petroleum Institute (now part of Khalifa University of Science & Technology) and a PhD from the University of Waterloo. He has published journal and conference papers. Dr Alhameli has completed research projects related to gas processing, planning of power production, and renewable energy integration in gas and oil industry. His current research interests focus on big data analytics and integration in multiscale decision making in oil and gas operations.

Ali Elkamel is a Professor of Chemical Engineering. He holds a BSc in Chemical Engineering and BSc in Mathematics from Colorado School of Mines, MSc in Chemical Engineering from the University of Colorado-Boulder, and PhD in Chemical Engineering from Purdue University – West Lafayette, Indiana. His specific research interests are in computer-aided modelling, optimization and simulation with applications to energy production planning, carbon management, sustainable operations and product design. Professor Elkamel is currently focusing on research projects related to energy systems, integration of renewable energy in process operations and energy production systems, and the utilization of data analytics (Digitalization), machine learning, and Artificial Intelligence (AI) to improve process and enterprise-wide efficiency and profitability. Prof. Elkamel supervised over 90 graduate students and more than 30 post-doctoral fellows/research associates. He has more than 280 journal articles, 141 proceedings, and 33 book chapters.

Ali Almansoori is a Professor of Chemical Engineering at Khalifa University of Science and Technology, Abu Dhabi, United Arab Emirates. During his profession, Dr. Almansoori held several administrative positions including: the Coordinator of President's Duties, Dean of Engineering, and Chair and Deputy Chair of the Chemical Engineering Department. He also was the Interim Senior Vice President for Academic Affairs during the merge between PI, Masdar Institute, and Khalifa University of Science, Technology, and Research. His main research interest is in the area of Process Systems Engineering with the focus on energy systems design, simulation, modelling and optimization. He also conducts general research in the area of renewable energy and fuel cell technology with applications to the oil and gas industry. He has published numerous articles in renowned refereed journals and conference proceedings. He also delivered several presentations in international conferences and is the author of a few book chapters.