Development of ML Model for 3-Phase Horizontal Separator Optimization: A Study from Oman Oilfield

Hanan Taya Al Gharibi, Nasir Khan*

Mechanical Engineering (Well Engineering)Department

University of Central Lancashire UCLan

الكلية الدولية للهندسة والإدارة
International College of Engineering & Management

INTRODUCTION

A silent battle is unfolding inside the oil fields of Oman, especially under the constant changes in temperature, where modern technology must keep pace with nature to unleash the true potential of its equipment. The three-phase separator plays a role in separating mixtures of oil, water and gas based on the different densities of these components. Its high energy consumption and harsh summer and winter temperatures make it less than optimal, which prevents it from operating at its best. By using machine learning algorithms and studying important parameters including pressure, internal and external temperatures, and other operational characteristics, this study focusses on using machine learning approaches to improve the performance of three-phase separators. It is a type of vessel used in the oil and gas field to separate a mixtures of gas, oil and water into three phases. The weir is the barrier that helps control the levels of liquids.

AIM AND OBJECTIVE

The main aim of the project is to develop a machine-learning model for the operation of a Three-phase separator employed in oil and gas fields in the Sultanate of Oman.

1. Use an MS Excel sheet with real field parameters to generate data. Based on the data analysis, features will be selected to identify the most relevant input variables.
2. Improve the performance and refinement of machine-learning models by optimizing feature selection and model tuning.
3. Evaluate and compare the effectiveness of the machine-learning algorithm using statistical tools like RMSE and R^2 (R-squared), to determine the most accurate model.

LITERATURE REVIEW

#	Project / Research Work Done	Authors & Year	Inferences
1	Operational challenges that the separator may face	Lanre et al., 2020	Designing an automatic control system, which can adjust important parameters such as internal temperature of components, internal pressure, and fluid flow to ensure optimal operation under any thermal conditions.
2	Machine-learning: ML-Based Algorithms	Lawal et al., 2023	Knowledge about artificial intelligence, especially machine learning, is the key to develop both applications and smart devices such as the horizontal three-phase separator with weir

CONT.. LITERATURE REVIEW

#	Project / Research Work Done	Authors & Year	Inferences
3	Improvement of the efficiency and monitoring of three phase separator by utilizing python	Ashutosh et al., 2024	Through conducting some studies, the process of improving the separators will be reached by reducing the emission of gas flaring in addition to reducing hydrocarbons in the wastewater. It was also mentioned that in wells with high gas to oil ratio, gas separators may work to expand the operating window of ESP in gas separators
4	Introducing machine-learning models to improve oil recovery in gas-oil separation plants	Ahmed et al., 2021	This study will allow for real-time estimation of gas and oil rates using data available from wellhead chokes without field intervention.
5	A modification to predict the gas-oil ratio under variable temperature condition using AI	Lenre et al., 2020	The trend results indicate that the temperature and LPPT pressures are constant and therefore, oil recovery can be enhanced by increasing the HPPT pressure up to an optimum value of HPPT pressure, and then by reducing it above the optimum value of HPPT pressure.

METHODOLOGY

To conduct this study, the methodology was defined and is depicted in **Figure 1**.

Figure 1 : Methodology flow chart

RESULTS & DISCUSSION

1. Increasing operating pressure within safe limits to improve separation and reduce energy consumption, as the predicted values are considered appropriate for operation.
2. Increasing the operating temperature to enable it to operate below the design temperature, thus improving phase dynamics for smoother separation processes and reducing fluid viscosity.
3. The study was conducted using several ML algorithms, such as linear regression, ridge regression, extra trees regressor, random forest regressor, gradient boosting regressor, and AdaBoost regressor **Figure 1.1**.
4. Using a linear regression model was found to be a reliable method for predicting values as a result of MAE, MSE and RMSE=0, but R^2=1 to increase production efficiency in Oman in real time, **Figure 1.1**.
5. Redesigning the 3-phase separator shown in **Figure 1.2** by modifying:
   - Optimizing the design of the internal weir height to ensure stable separation of the water-oil interface, thus improving separation processes and increasing productivity.
   - Reducing the separator diameter from 2413mm to 2200mm to accommodate a smaller volume to achieve higher operational efficiency.
   - Modifying the nozzles, using a better slope angle to improve flow, thereby reducing flow pressure.
   - Increasing the length of the fluid separation zone by 10%-15% to achieve more optimal oil-water separation.

Models	MAE	MSE	RMSE	R^2	RMSLE	MAPE	TT
Linear regression	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.6720
Ridge regression	0.0418	0.2926	0.1730	1.0000	0.0001	0.0000	0.0190
Extra Trees Regressor	0.2371	0.9776	0.5129	0.9999	0.0004	0.0002	0.1080
Random Forest Regressor	0.8548	1.7153	1.1971	0.9998	0.0009	0.0006	0.1540
Gradient Boosting Regressor	1.5348	1.5348	2.2645	0.9989	0.0016	0.0011	0.0820
AdaBoost Regressor	3.9294	26.5720	4.9486	0.9965	0.0037	0.00029	0.0610

Figure 1.1 Machine learning

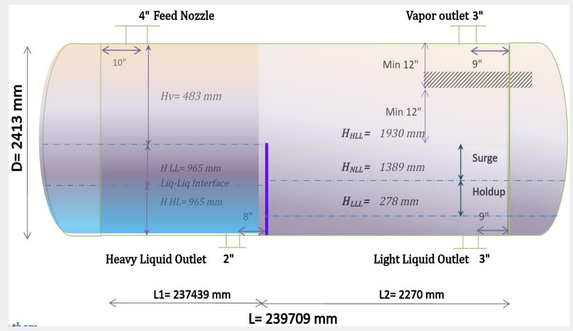

Figure1.2 Three phase separator

CONCLUSION

By applying machine learning techniques to develop the design of a three-phase separator, a highly efficient and accurate predictive model was developed, capable of accurately and reliably simulating the separator behavior through data prediction. The results indicate that they not only enhance the reliability of the new design, but also provide a solid foundation for improving future separator designs in terms of operational efficiency, reducing energy consumption and volume, increasing production, and controlling phase levels. It is recommended that graphical analysis be adopted as a fundamental tool in developing separation systems within the oil and gas industries to ensure maximum stability and operational efficiency, enabling the separator to operate under all operating conditions, whether at low or high temperatures and pressures in the Sultanate of Oman, and to ensure greater stability.

REFERENCES

Olugbenga, A.G., Al-Mhanna, N.M., Yahya, M.D., Afolabi, E.A. and Ola, M.K., 2021. Validation of the molar flow rates of oil and gas in three-phase separators Using Aspen Hysys. *Processes*, *9*(2), p.327.

AL-Dogail, A., Gajbhiye, R., AlNaser, M., AlNajim, A. and Mahmoud, M., 2022. Intelligent approach for gas-oil separation plant oil recovery enhancement. SPE Production & Operations, 37(04), pp.632-653.

Ibrahim, A.F., Al-Dhaif, R., Elkatatny, S. and Shehri, D.A., 2021. Applications of Artificial Intelligence to Predict Oil Rate for High Gas–Oil Ratio and Water-Cut Wells. ACS omega, 6(30), pp.19484-19493.

Zhu, M., Hu, D., Xu, Y. and Zhao, S., 2020. Design and computational fluid dynamics analysis of a three-phase decanter centrifuge for oil-water-solid separation. Chemical Engineering & Technology, 43(5), pp.1005-1015.

Ahmed, T., Russell, P.A., Makwashi, N., Hamad, F. and Gooneratne, S., 2020. Design and capital cost optimisation of three-phase gravity separators. Heliyon, 6(6).

Sharma, A., Osorio Ojeda, L.C., Yuan, N., Burak, T., Gupta, I., Konate, N. and Karami, H., 2024. Predicting Gas Separation Efficiency of a Downhole Separator Using Machine Learning. Energies, 17(11), p.2655.

Olugbenga, A. G., and A. E. Ochayi. "Optimization of Two-Phase and Three-Phase Separator Designs." In *SPE Nigeria Annual International Conference and Exhibition*, p. D022S026R010. SPE, 2023.