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Developing A Model To Prevent Hydrate Formation In Gas Pipeline, A Case Study Of The Niger Delta.

Anthony Ogbaegbe Chikwe[1], *Charlie Raymond Uyobong[1], Godsgift Gbubemi Osimi[1] & Damilola Deborah Olaniyan[2]

[1]Department of Petroleum Engineering, Federal University of Technology, Owerri
Imo State, Nigeria
[2]Department of Petroleum Engineering, Covenant University, Ota, Ogun State, Nigeria.
*osimigbubemigodsgift@gmail.com

Abstract— *with an emphasis on the difficult circumstances of the Niger Delta region, this paper explores the crucial problem of hydrate development in gas pipelines. Gas hydrates are crystalline substances made of water molecules and hydrocarbon gasses at high pressures and low temperatures. Because hydrate growth obstructs fluid passage, it is a major concern for pipeline operations and requires preventive measures. By taking into account certain environmental elements including temperature, pressure, water content, and gas composition in the Niger Delta region, this work attempts to create a thorough model for preventing hydrate formation in gas pipelines. The study uses secondary data from weather databases and previous pipeline operation records to build a predictive model. The chance of hydrate formation events is calculated by integrating temperature, pressure, water content, and gas composition into a probability equation. The model provides insights into the interplay of variables leading to hydrate formation by analyzing actual data from a gas pipeline in the Niger Delta. A linear regression model yielded a predicted hydrate production probability of roughly 44.7%. The model, which learned from a dataset of known circumstances and hydrate formation probabilities, was fed input parameters like temperature, pressure, water content, gas composition, and flow rate. Based on these inputs, the model then produced an estimate that showed a modest chance of hydrate development under the given circumstances. The model then generated an estimate based on these inputs that indicated a moderate likelihood of hydrate generation under the specified conditions. It can be inferred from the model's prediction that there is a general trend in the data points as you move from left to right along the x-axis (temperature). It seems that the likelihood of hydrate formation tends to decrease with increasing temperature. A negative link is indicated by the scatter plot of hydrate formation probability against temperature. The likelihood of hydrate formation tends to decrease with temperature. This is consistent with the widely held belief that hydrate formation is less likely at higher temperatures. A possible linear trend can be seen in the scatter plot of hydrate formation probability against pressure. This indicates that pressure could influence hydrate formation probability, although other factors might play a role as well. The regression line provides a basic approximation of this relationship.*

Keywords— Hydrate formations, Python Model, Flow Assurance , Hydrate formation in Niger Delta wells, Oil Production in Niger Delta Wells

1. INTRODUCTION

Hydrates are crystalline compounds or substances which contains water molecules [H2O] or its constituent elements. This is formed at certain temperature and pressure condition when water and light from natural gases come in contact. In a subsea flow line system where the direction of flow diverts in pipeline, the riser parts of the system are where hydrates blockages are most likely to occur. This is rarely found in the tubing beneath the downhole safety valve, same with the pipeline after the platform [7]. To prevent hydrate formation in subsea systems, the technique used could include; thermodynamic inhibitors, low dosage hydrate inhibitors, low pressure operation, water insulation and active heating. Technically, since hydrates forms at low temperature, it can easily be disintegrated back to normal hydrocarbon and water if the temperature is increased [warmed up [7]. Similarly, since hydrates forms at high pressure condition, it can generally be disassociated if the pressure is reduced. Also, the high humidity of the Niger Delta, shows increase in water temperature as such reduction of water content is necessary [7] This combined method will help the model to prevent hydrate formation in the Niger Delta. In July, 2020; Zainab T. Al- Sharif (Al- mustansiriya University), Lahieb Faisal Muhaisen (Independent researcher) and Luay Hamad (Al- mustansiriya University) worked on a review of hydrate formation in Oil and Gas Transition pipes. In the year 2010, a group of scholars which include N. Sultan, B. Masset, S. Keep, T. Masset, M. Voisset, A.M Vemant, G. Baton, E. Cauquil, J. Adamy, J.I. Colliat, and D.Drapeay, published a work titled Hydrate dissolution as a potential mechanism for pockmark formation in the Niger Delta. Journal of Geophysical research, vol 115. This gives a background knowledge of the conditional effects at the wells in the Niger Delta. These works gives a background idea on the hydrate formation as such the possibilities of prevention.

As a case study in the Niger Delta region of Nigeria, this research covers the prevention techniques which can be employed to cope hydrate formation and its possible effects. The study is based on the case study of a gas pipeline in the region and it considers factors such as temperature, pressure and water content. The Niger Delta is a large, arcuate delta located in the Gulf of Guinea on the west coast of Central Africa, and in the southern end of Nigeria, with a land area of about 75000 km² [8] The modern delta began its

growth in the late Eocene. The Eocene succession is classified into three. From the top most, they are the Akata formation, the Agbada formation and the Benin formation. [4] It is characterized by a high humidity and low temperature as such the higher tendencies for hydrates to be formed in gas pipelines within this region. It is being considered as a potential future energy resource and it's estimated reserve is believed to be twice as large as the conventional petroleum resources [5].As early as 1811 gas hydrates were reported and was discovered to be responsible for creating pipeline blockage in the early 20's [3]). The formation of hydrates in gas pipelines occupies part of the pipeline diameter, increases pressure drop and when the hydrate particles agglomerate, it creates plugs which can completely block the pipeline's production.

2. METHODOLOGY

2.1 Materials

The materials used in this project include a variety of crucial elements. These include weather data and pipeline operation records from the past, which serve as the basis for our analysis. This project uses Python, a versatile programming language, to employ advanced data analysis and predictive modelling techniques. Additionally, a laptop is the primary piece of equipment utilized to run the software and carry out analyses. Access to the internet is necessary in order to locate updates, more information, and possible collaboration. When combined, these technologies make it possible to create a strong preventative model that effectively addresses hydrate formation in gas pipelines.

2.2 Methods

The modeling process used linear regression, a basic statistical technique. By creating a linear relationship between variables, this method enables us to forecast how one variable will behave based on the values of other variables. By using this method, we may develop a prediction model that promotes proactive decision-making for successful preventative measures.

2.2.1 Hydrate Formation-Related Factors

Hydrate formation is influenced by a number of factors, including temperature, pressure, and the volume of water in the pipeline. The model will consider these variables to accurately predict and prevent hydrate development.

2.2.2 Using Secondary Data

Secondary data from several sources, including historical pipeline operation records and meteorological databases, are used in this study. By integrating many datasets, the model could generate comprehensive insights on hydrate formation trends.

2.2 Case Study: Niger Delta Gas Pipeline

The Niger Delta, which is well-known for its significant oil and gas potential, is an intriguing case study. By analyzing data from a nearby gas pipeline, the computer searches for trends and connections between environmental characteristics and hydrate formation episodes.

2.4 Mathematical Representation of the Proposed Hydrate Formation Prevention Model

Let's
T is the Kelvin temperature.
P is the pressure in kPa.
W is the percentage of water in the pipeline.
G stands for gas composition (mole fractions of various gases).
F is the pipeline's gas flow rate.

The equation for temperature

the temperature equation illustrates how temperature affects the development of hydrates. It may entail an empirical connection that takes into account how temperature affects the threshold for hydrate formation. A condensed version might be:

$T=Tbase+\Delta T$ 2.1, where T is the temperature of the pipeline.
The baseline temperature is denoted by Tbase.
The temperature change brought on by operating conditions is represented by ΔT.

The equation for pressure:

The impact of pressure on hydrate formation is explained by the pressure equation. It could include the gas pressure as well as any other variables that affect pressure. A simple formula might be:

$P = Pbase + \Delta P$ 2.2

Where:
The pipeline pressure is denoted by P.
The baseline pressure is denoted by Pbase.
The pressure change brought on by operating conditions is represented by ΔP.

Equation for Gas Composition:
The mole fractions of the various gasses in the pipeline are included in the gas composition equation. A two-component gas mixture (Gas A and Gas B) could be represented simply as follows:

XA+XB=1 2.3 where XA is Gas A's mole fraction.
The mole fraction of Gas B is denoted by XB.

Equation for Flow Rate
the speed at which gas moves through the pipeline is related to the flow rate equation. This formula may account for variables like pipeline diameter and gas velocity that have an impact on flow rate. A simple formulation could be:

F=A·V 2.4, where F is the gas flow rate.
The pipeline's cross-sectional area is denoted by A.
The gas velocity is denoted by V.

Model of Hydrate Formation:
The multidimensional interactions between temperature, pressure, water content, gas composition, and flow rate are captured by the function f. The following is an extension of the hydrate formation prediction model:

The likelihood of hydrate formation is represented as H (P) = f (T, P, W, G, F) 2.5.
F is the function that links the input variables (T, P, W, G, and F) to the probability of hydrate formation.

Table.1: Secondary Data for Hydrate Formation Prediction Model

Temperature (K)	Pressure (kPa)	Water Content (%)	Mole Fraction of Gas A	Mole Fraction of Gas B	Flow Rate (m^3/s)	Hydrate Formation Probability
273	1000	2	0.8	0.2	0.5	0.15
278	950	1.5	0.7	0.3	0.6	0.12
265	1050	2.5	0.6	0.4	0.4	0.25
280	900	1.2	0.9	0.1	0.7	0.08
270	1100	2.8	0.5	0.5	0.3	0.35

Source: Aimikhe *et al* (2013)

3 RESULT AND DISCUSSION

3.1 RESULT

A linear regression model yielded a predicted hydrate production probability of roughly 44.7%. The model, which learned from a dataset of known circumstances and hydrate formation probabilities, was fed input parameters like temperature, pressure, water content, gas composition, and flow rate. Based on these inputs, the model produced an estimate that showed a modest chance of hydrate formation under the given circumstances.

Table 2: showing Result of hydrate formation probability

Temperature (K)	Pressure (kPa)	Water Content (%)	Mole Fraction of Gas A	Mole Fraction of Gas B	Flow Rate (m^3/s)	Actual Hydrate Formation Probability
275	980	2.2	0.7	0.3	0.5	- 0.447.

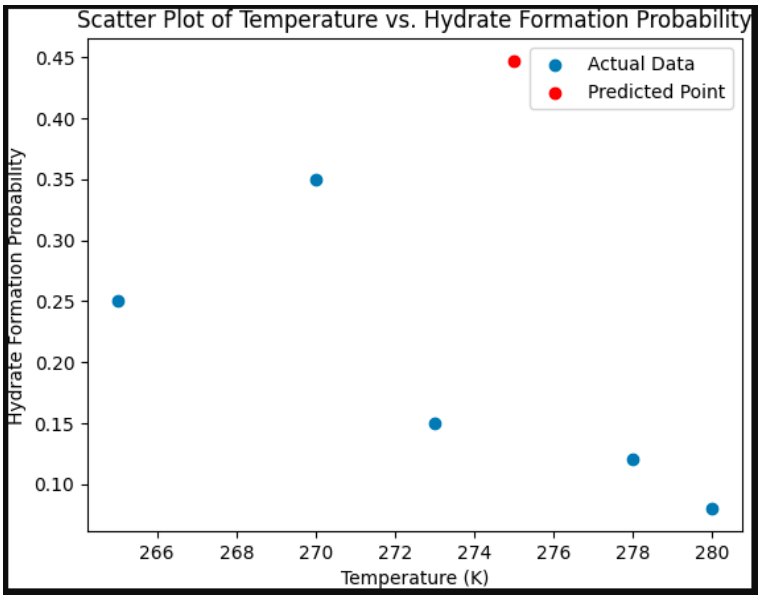


Figure 1: showing Temperature and hydrate formation probability

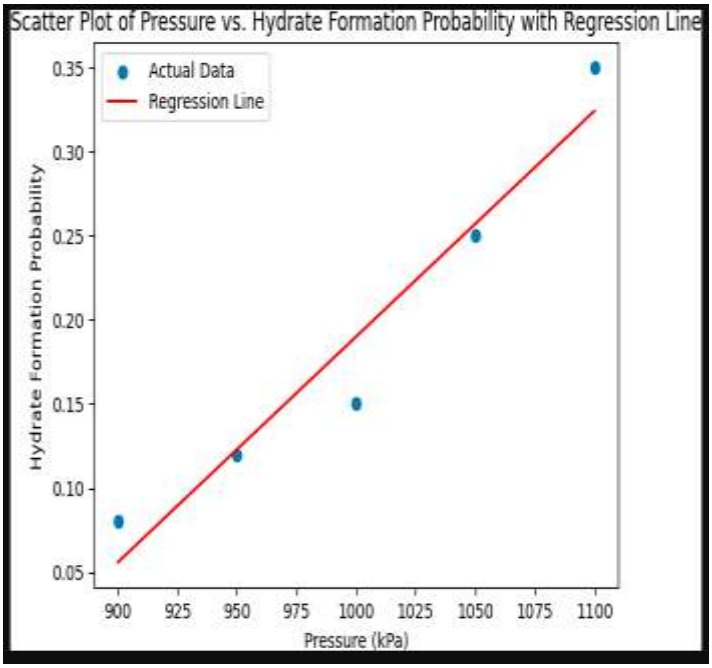


Figure 2: showing Pressure and Hydrate formation probability

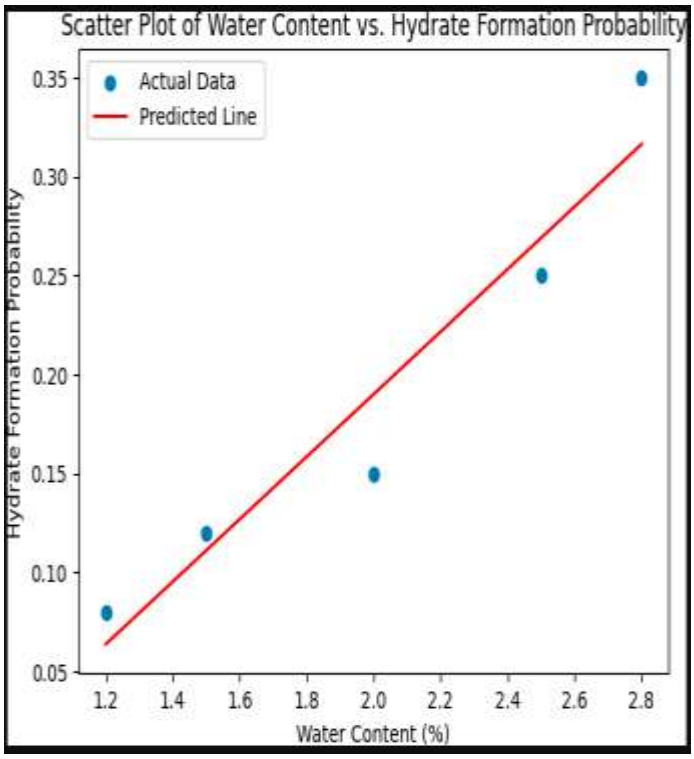


Figure 3: showing Water content and Hydrate formation probability

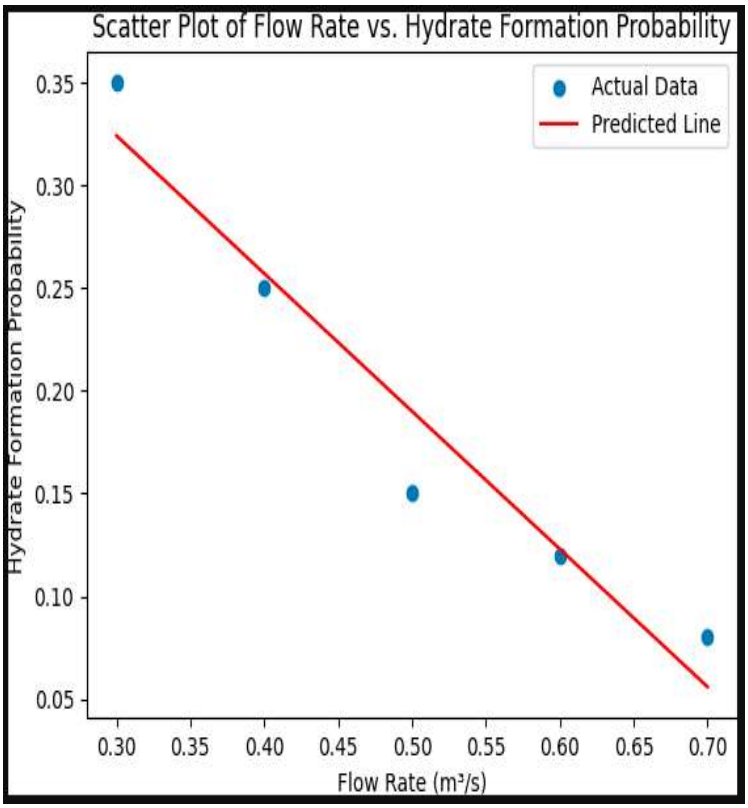


Figure 4: showing Flow rate and Hydrate formation probability

3.2 Discussion

For the table 2 this figure indicates that there is a 44.7% probability that hydrate formation will occur under these conditions. Analysis The temperature (275 K) and pressure (980 kPa) are within a moderate range, suggesting that the circumstances are not extreme. The water content is moderate. Gas B makes up 30% of the gas composition, whereas Gas A makes up 70%. 0.5 m^3/s is the flow rate. The model estimates a hydrate formation probability of 0.447, which suggests a small likelihood of hydrate formation occurring given the combination of these conditions. According to this forecast, in order to guaranty safe and effective pipeline operation, it is necessary to keep a careful eye on these circumstances and take preventative action. The actual data points from the dataset are represented by the blue points in Figure 1's scatter plot. Every point represents a set of input parameters (temperature) and the associated likelihood of hydrate production. As you move from left to right along the x-axis (temperature), you can observe a general trend in the data points. It appears that as the temperature increases, the hydrate formation probability tends to decrease. The red point in the graph represents the predicted hydrate formation probability based on the new input parameters (temperature). It's placed on the graph at the specific temperature provided. This allows you to visualize where the new data point falls in relation to the existing data distribution. The scatter plot from figure 2 graphically illustrates the relationship between pressures and hydrate formation probability using the provided dataset, along with the regression line generated by a linear regression model. As you move along the x-axis (pressure), you can observe a trend in the data points and how they cluster around the regression line. The overall trend of the data is represented by the regression line. Although there is a linear trend, the scatter data points surrounding the regression line show that the chance of hydrate formation varies at each pressure level. Other factors not taken into account in this simple model may be the cause of this fluctuation. The performance depends on the linear regression pattern.. If the data points deviate significantly from the regression line, the model may not be the most appropriate. For pressure values not included in the dataset, the regression line might be used to forecast the likelihood of hydrate formation. Prediction accuracy, however, may differ, particularly for pressure values that are outside of the data range. All things considered, the scatter plot with the regression line provides a visual understanding of the linear relationship between pressures and the likelihood of hydrate formation.

The intricate process of hydrate development in gas pipelines can be better understood by examining the connections between different input factors and hydrate formation likelihood. Several important conclusions and observations can be made using the scatter plots and regression lines:

1. Temperature Influence: A negative association is suggested by the scatter plot of hydrate formation probability against temperature. As temperature increases, hydrate formation probability tends to decrease. This aligns with the common understanding that higher temperatures reduce the likelihood of hydrate formation.

2 Pressure Variation: A possible linear trend may be seen in the scatter plot of hydrate formation probability against pressure. This suggests that other things as well as well as well. This relationship is roughly represented by the regression line.

3 Water Content Impact: Higher water content is linked to higher hydrate formation probability, according to the scatter plot of hydrate formation probability against water content.

4 Flow Rate Consideration: There is no discernible linear pattern in the scatter plot of hydrate formation probability against flow rate. This would imply that flow rate might be a dominant flow rate.

PREVENTION TECHNIQUES REQUIRED:

i. **Chemical inhibitors** that change the thermodynamic conditions necessary for hydrate formation are known as thermodynamic inhibitors. These inhibitors lower the equilibrium hydrate formation temperature and pressure, making it less likely for hydrates to form. For this pipeline, methanol is advised.

ii. **Modest Dosage Hydrate Inhibitors**: Utilize modest dosages of substances that impair hydrate crystallization. These inhibitors minimize the amount of chemicals pumped into the pipeline while effectively preventing hydrate formation. Appropriate for ongoing prevention while the pipeline is operating.

iii. **Maintain pipeline pipeline formation**. Hydrate formation can be prevented by operating at pressures greater than the hydrate equilibrium pressure. However, operational limitations may make this strategy impractical at times. Water Insulation: Insulating the pipeline to minimize heat transfer between the gas and the surrounding water is key. Reducing heat exchange prevents temperature drops that trigger hydrate formation. Thermal insulation materials can be applied to the pipeline to achieve this.

iv. Active Heating: To keep the temperature above the hydrate formation temperature, heating units should be placed along the pipeline. To increase the temperature and stop hydrate crystallization, chemical or electrical heating techniques can be used. Particularly in the external pipelines.

v. Gas Dehydration: It would be beneficial to remove water from the gas stream prior to it entering the pipeline. Because there is less water in dry gas, hydrates are less likely to develop. It is advised to use methods like glycol dehydration. Methane Injection: Small amounts of methane should be injected into the pipeline. Methane has a hydrate inhibition effect due to its ability to displace water molecules from the hydrate structure. This technique can help prevent hydrate blockages.

vi. Pipeline Design Optimization: Design pipelines with larger diameters to reduce the gas velocity and pressure drop. Lower velocities minimize cooling effects caused by rapid gas expansion, reducing the likelihood of hydrate formation.

vii. Monitoring and Control Systems: Implement advanced monitoring systems to track temperature, pressure, and water content in real-time. Automated control systems can adjust operating parameters based on real-time data to prevent hydrate formation.

viii. Flow Assurance Programs: Developing comprehensive flow assurance programs that include a combination of prevention techniques tailored to the specific pipeline's conditions. Regular maintenance and periodic cleaning of pipelines can be part of these programs

Table 3: Comparative Analyses

Parameters	**This Study**	Zainab T. Al-Sharif et al. (2020)	Sultan et al. (2010)
Software Used	Python (Linear regression)	Literature Review	Geophysical observation and analysis
Scope	Gas pipelines in the Niger Delta region	Oil and Gas Transition pipes	Pockmark formation in the Niger Delta
Parameters-checked	Temperature, pressure, water content, gas composition, and flow rate	Hydrate phase transitions and blockage mechanisms	Conditional effects at the wells
Key-Specifications	Predicted a hydrate formation probability of 44.7% for the base scenario; established a negative correlation between temperature and probability	Reviewed prevention and disintegration possibilities for hydrate formation in transition pipes	Provided background knowledge on conditional well effects and hydrate dissolution

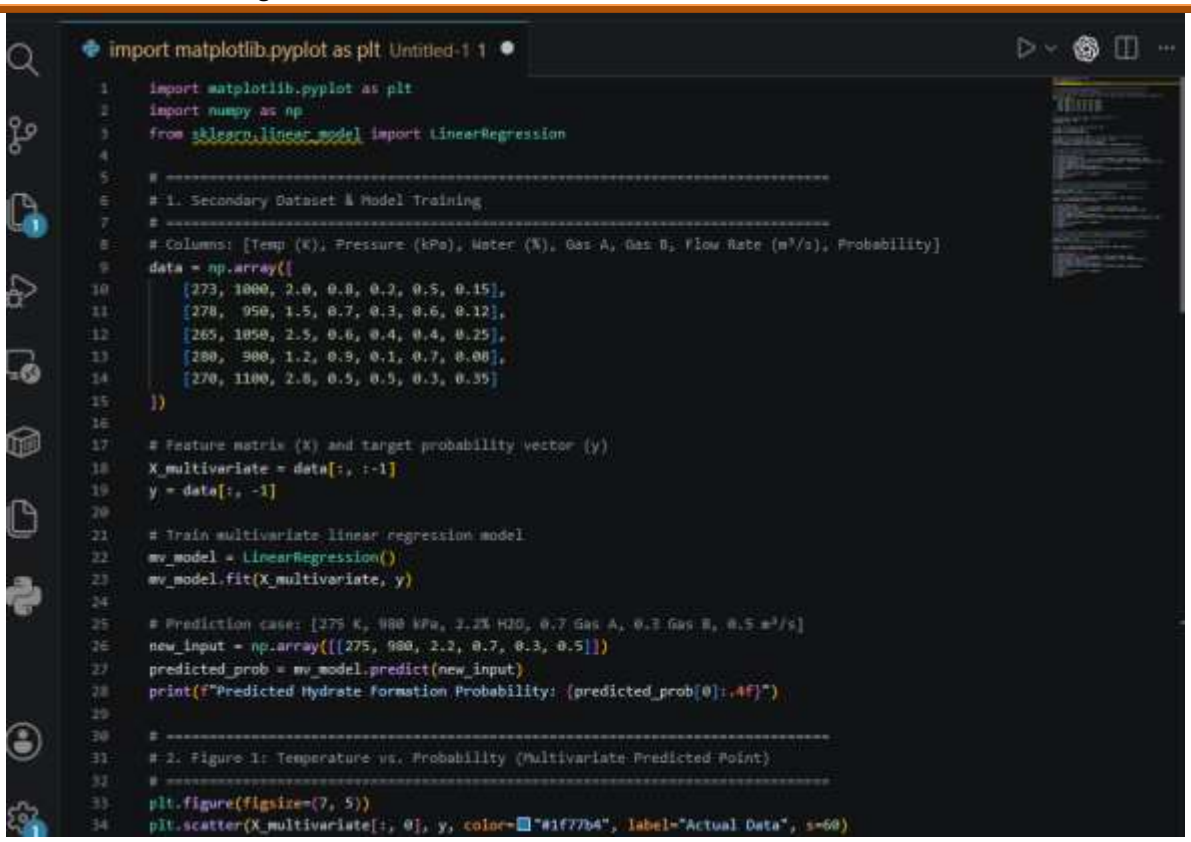


Figure 5: Python Code Snippet Snapshot

4 CONCLUSION

In this search, we conducted an analysis of hydrate formation probability in gas pipelines based on various input parameters, including temperature, pressure, water content, gas composition, and flow rate. Although our results offer useful preliminary insights, it is crucial to acknowledge the intricacy of hydrate formation and the limitations of our models. For the particular Niger Delta well, the model provided us with a chance of hydrate development of 44.7%; it can be further refined and calibrated to accommodate additional formations with more accurate prediction accuracy. This study broadens our knowledge of the potential of automated technologies to address flow assurance problems in petroleum pipelines. It is possible to move nonlinear predictions. Neural networks and ensemble methods are examples of advanced machine learning approaches that could improve performance. Expanding the dataset to incorporate a broader variety of operational settings, real-world occurrences of hydrate formation, and various gas compositions should bolster the models' accuracy and generalizability.

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Conflict of Interest
There was no conflicts of interest between the authors

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AUTHORS



Anthony Ogbaegbe Chikwe, is an Associate Professor in the department of Petroleum Engineering, Federal University of Technology, Owerri. He holds both BSc. and MSc. degree in Petrochemical Engineering from the University of Oil and Gas Moscow. He also holds Post graduate certificate in advance studies in academic practice from Newcastle University upon Tyne, UK and Ph.D degree in Petroleum Engineering from the Federal University of Technology, Owerri. His research interests are in Production,
Reservior, Natural Gas and Drilling Engineering. He is also a fellow of the Higher Education Academy, UK.



Raymond Uyobong Charlie: Production engineering, reservoir engineering, drilling engineering, and gas engineering are among Raymond Uyobong Charlie's areas of interest as a research student in petroleum engineering at Federal



Osimi Godsgift Gbubemi is a Petroleum Engineering research student at the Federal University of Technology in Owerri. Drilling engineering, reservoir engineering, and production engineering are among his areas of interest in research.



Damilola Deborah Olaniyan is an Assistant Lecturer and Researcher in the Department of Petroleum Engineering at Covenant University, Ota. She holds a Bachelor's in Petroleum Engineering from the Federal University of Petroleum Resources, Effurun, Delta State, and a Master's in Petroleum Engineering from the University of Ibadan, Nigeria. She is pursuing a Ph.D. in Petroleum Engineering at the University of Ibadan. Her areas of specialization include Drilling Engineering, Petroleum Economics, and Natural Gas Engineering. She is keenly interested in Local Content and indigenous materials for Sustainable Drilling Fluids, AI & Digitalization of Drilling Fluids, Geothermal Energy Integration, and hydrogen production and utilization in Drilling Operations.