IIOT for Monitoring Oil Well Production and Ensure Reliability

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Abstract : Unconventional resources challenge the oil industry. Exploration and development of oil and gas reservoirs require new sensors, analytics, and processes. Systems require better connectivity, monitoring and control, and process automation. Previously deployed technology limits the ability to quickly and reliably integrate and robustly operate field-to-cloud systems, especially across large field installations. The Industrial Internet of Things represents the biggest opportunity in re-cent decades for the advancement of industrial technology. This study presents an application of a multivariate regression model to estimate the future production performance of oil wells based on monthly-production time series data. Several engineering techniques that require expertise and data that are difficult to obtain are used currently to predict well performance. In this report, focus is on how innovative networking standards and protocols are enabling revolutionary system-building approaches that greatly ease field operations, how to predict, forecast the value of oil production over time under different condition.

Index Terms **- Multivariate regression model, Industrial Internet of Things (IIOT), Prediction, Forecasting**

I. Introduction

The Industrial Internet of Things (IIOT) is the future of the oil and gas industry. As the Internet of Things' (IoT) network of devices, sensors and software brings about change in consumers' daily lives, this industry is lagging behind.

Oil and gas are key sources of energy that provide a foundation for global economic growth. Firms in the oil and gas industry require complex machinery and a large amount of capital investment. Thus, there are huge barriers for other companies wishing to enter the industry. Over the years, the industry has experienced high profitability, so digitization has largely been a "nice-to-have". However, the recent fall in oil prices due to increasing supply alternatives and slower growth in demand provides motivation for companies to focus on leaner operations and cost reduction. Oil and gas supply chains are composed of segmented and discrete data hubs. There is little transparency across entities in the supply chain. Even within companies, data is stored and managed separately by different divisions and there is discontinuity in process flows. Decisions are taken based on disparate spreadsheets without con-sideration of the full picture. Right digitization strategies could help with supply chain integration and information sharing between suppliers, transporters, storage facilities and customers.

As all of industry undergoes reinvention toward Digital Trans-formation during the next five to ten years, the key to success will be to invest in the right technology at the right time, and to redefine business processes while enabling people to better perform their jobs. In no industry is this more critical than within oil and gas.

Faced with volatile prices that are just rebounding from near-record lows, safety pressures, increasing regulatory burdens and regional skilled labor pressures, all identified in the LNS Research Spotlight Why APM (Asset Performance Management) is Critical to Operational Excellence in the Oil & Gas Industries, the oil and gas sector has a number of additional incentives to invest in the pursuit of Digital Transformation despite margin pressures and capital constraints. Iterations of the "digital" with the advent of the digitization of geo-technical seismic data related to reserves/deposits. This has prepped the industry with an understanding of the value of data, and of how to use analytics to make sense of the wealth of information available with the onset of Smart Connected Assets.

As the second wave of digitization takes hold with the IIoT, no industry has as much experience or better motivation to take advantage of what the IIoT offers, as equipment ranging from compressors, turbines, and other oil field and gas trans-mission equipment becomes smarter.

II. Literature survey

In recent years, new solutions based on the internet of Things are found by utility companies. The IIoT is making energy consumption more efficient, and ultimately energy demand can be decreased. The oil and gas industrial process starts after the crude oil is extracted from the grounds (oilfields) and to use it as a product it must go through the refining process. [1]

The oil and gas industry were at one time, at the forefront of Digital Transformation in industry. Nearly 50 years ago, it was the first industry to use digital distributed control systems (DCS) to control refineries and other downstream plants. Then, with the deployment of the digital oil field concept, it became a leader in adopting digital representations of seismic data representing deposits and reserves. The challenge for the industry now is to implement the next wave of Digital Trans-formation and radically shift the way it approaches Asset Performance Management (APM).

The main three categories of operations in oil and gas industry supply chain are explained and then the definition of IoT is presented.

(i) The upstream industry finds and produces crude oil and natural gas. The upstream is sometimes known as the exploration and production sector.

(ii) The midstream industry processes, stores, markets and transports commodities such as crude oil, natural gas, natural gas liquids.

(iii) The downstream industry includes oil refineries, petrochemical plants, petroleum products distributors, retail outlets and natural gas distribution companies. [2]

In some respects, as an early adopter of digital field instrumentation, the oil and gas industry has set itself up to potentially be late to the table when it comes to the next phase of Digital Transformation. A common refrain LNS Research of-ten hears when talking to clients about the Industrial Internet of Things (IIoT) is the retort that nothing is new and that "we have been doing this for ages" because their companies have had sensors in place on all their key processes. Similarly, the industry also serves as the breeding ground for data historians, so many hold parallel perceptions about their standing within analytics capabilities, opining, "we have been doing Big Data since the 80s, because we have a historian with 100,000 tags."

Production logging and production test are the production Surveillance ways of oil and gas reservoir adopted in most. Oil-field in China, which collect downhole information by regular or periodical measured means and then proceed to process data at processing center. [3]

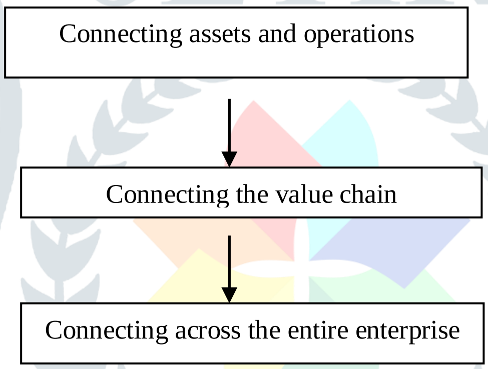
In the 1980s, Oil and Gas companies began to adopt digital technologies, with a focus on better understanding a reservoir's resource and production potential, improving health and safety, and boosting marginal operational efficiencies at oil fields around the world. [4]

There are many problems including too many data sources, complex data types, and the large amount of statistical work by hand in production engineering planning, and that influences the working efficiency. Therefore, there is a need to develop oil-production program planning software supporting systems, to achieve the forecast of workload of oil-production program, improve the efficiency of oil-production program planning.[5]

Information management methods of oil production plant of the traditional way are backward. All the departments are in the stand-alone mode, lacking a unified information network platform, generating large amounts of information islands. This backward working model has seriously hindered the development of oil production plant. [8]

III. IIOT IN OIL AND GAS INDUSTRY

A. Process Flow



1. Connecting assets and operations

The initial two phases focus on connecting field assets and equipment to the industrial internet using sensors that provide automated monitoring and diagnostics. Through the creation of a cloud and IT environment (that can store and analyze incoming data from critical assets), the company begins to build real-time and predictive insights on the operation of individual assets and whole processes comprising multiple pieces of equipment.

2. Connecting the value chain

The next phase of creating a digitally connected oil and gas enterprise centers on connecting operations to both the internal and the extended value chain, which includes transportation, terminals and warehouses. Such interconnectivity must include automated ordering and logistics functions enabled by real-time tracking and predictive analytics of asset performance in the field.

3. Connecting across the entire enterprise

The final phase of digital adoption is achieved when a company connects all of its assets and processes across an integrated value chain. The IIoT and cloud architecture will allow companies to connect their operations on a global rather than local scale, whether it is connecting all subsea wells to optimize production from multiple off-shore platforms

B. Significance:

IIOT in the oil and gas industry shall visually trace the deviation between the production forecast to the actual values, so that one can see how far off one is from meeting projections, to be able to track the events/interruptions that caused the actual production numbers to deviate from the forecast, so that one can manage the outages better.

Production monitoring will allow users to assess production performance against forecasted production and analyze how distant actual production is from the forecast and examine the cause for the deviation.

Workovers or disruptions may be planned maintenance events or unplanned interruptions that stop or curtail production. Production loss analysis helps to analyze on a monthly basis the deviation in production numbers from the forecast and to drill down on the factors that resulted in the missing targets

IV TRAINING ALGORITHM

A. Linear Regression:

Linear Regression is a machine learning algorithm based on supervised learning. It performs a regression task. Regression models a target prediction value based on independent variables. Linear regression performs the task to predict a dependent variable value (y) based on a given independent variable (x).
Fixed Equation forms to relate y and x which establishes relationship between output variable and independent covariates which is explicitly depended on statistical learning.
In order to estimate the coefficient, we need to minimize the difference between actual value Y and predictive model.

$$Y = F(x)=\beta_0\ \beta_1 x$$

The parametric form has reduced the problem of finding the relationship of covariates (X) and response variable (y). It can compute any Y given any unseen X, like compute the price of oil at given cost of index. The parametric form has reduced the problem of finding the relationship of covariates (X) and response variable (y). It can compute any Y given any unseen X, like compute the price of oil at given cost of index.

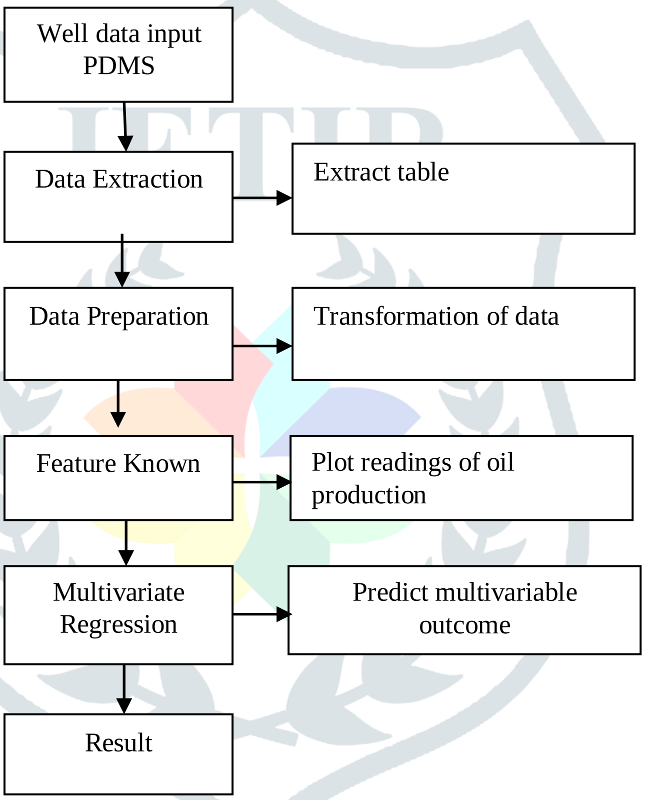


Fig 2. Training algorithm flowchart

B. Multivariate Regression:

Multiple regression is an extension of simple linear regression. It is used when we want to predict the value of a variable based on the value of two or more other variables. The variable we want to predict is called the dependent variable (or sometimes, the outcome, target or criterion variable). The variables we are using to predict the value of the dependent variable are called the independent variables (or sometimes, the predictor, explanatory or regressor variables). The simplest multiple regression model for two predictor variables is

$$y = \beta 0 + \beta 1x1 + \beta 2x2 + e$$

General Parametric Equations:

$$y = f(X) + e$$

$$f(X) = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots . +\beta pXp$$

$$\hat{y} = \hat{\beta} 0 + \hat{\beta} 1X1 + \hat{\beta} 2X2 + .. + \hat{\beta} pX$$

Matrix is used for efficient performance if the data is large.

$$Y = X\beta + \varepsilon \qquad \text{......... (i)}$$

$$\hat{Y} = X\hat{\beta} \qquad \text{......... (ii)}$$

Using (i) and (ii), we get

$$\begin{pmatrix} Y1 \\ Y2 \\ Yn \end{pmatrix} = \begin{pmatrix} \beta 0 + \beta 1X1,1 + \beta 2X1,2 + \cdots + \beta pX1,p + \varepsilon 1 \\ \beta 0 + \beta 1X2,1 + \beta 2X2,2 + \cdots + \beta pX2,p + \varepsilon 2 \\ \beta 0 + \beta 1Xn,1 + \beta 2Xn,2 + \cdots + \beta pXn,p + \varepsilon n \end{pmatrix}$$

Let's consider the matrix form of residual e.

$$Rss = \sum_{i=1}^{0} \varepsilon_i^2 \longrightarrow Rss \in^T \in$$

$$Rss = \varepsilon^T \varepsilon : \text{Replace } \varepsilon \text{ with } y - \hat{y},$$

$$= (y - \hat{y})^T (y - \hat{y})$$

$$\text{Rss: Replace } \hat{y} \text{ with } X\hat{\beta},$$

$$= (y - \widehat{x\beta})\, t\, (y - x\beta)$$

$$Rss = y^t y - y^t x\hat{\beta} - \widehat{\beta x^t y} + \widehat{\beta x^t x\beta}$$

The goal is to find the value of β that minimizes the RSS

$$\hat{\beta} = (x^t x)^{-1} x^t y$$

To determine upon and the equation and predict the value and production of Oil and Gas.

$$\hat{y} = F(x) = x\hat{\beta}$$

Where, $x\hat{\beta}$ *is use to predict the value of y.*

C. ARIMA MODEL:

The acronym ARIMA stands for Auto-Regressive Integrated Moving Average.

A nonseasonal ARIMA model is classified as an "ARIMA (p,d,q)" model, where:

- p is the number of autoregressive terms,
- d is the number of nonseasonal differences needed for stationarity,
- q is the number of lagged forecast errors in the prediction equation.

ARIMA (p,d,q) forecasting equation:

ARIMA models are, in theory, the most general class of models for forecasting a time series which can be made to be "stationary" by differencing (if necessary), perhaps in conjunction with nonlinear transformations such as logging or deflating (if necessary).
A random variable that is a time series is stationary if its statistical properties are all constant over time. A stationary series has no trend, its variations around its mean have a constant amplitude, and it wiggles in a consistent fashion, i.e., its short-term random time patterns always look the same in a statistical sense. A random variable of this form can be viewed (as usual) as a combination of signal and noise, and the signal (if one is apparent) could be a pattern of fast or slow mean reversion, or sinusoidal oscillation, or rapid alternation in sign, and it could also have a seasonal component. An ARIMA model can be viewed as a "filter" that tries to separate the signal from the noise, and the signal is then extrapolated into the future to obtain forecasts.
The ARIMA forecasting equation for a stationary time series is a linear (i.e., regression-type) equation in which the predictors consist of lags of the dependent variable and/or lags of the forecast errors.

That is: Predicted value of Y = a constant and/or a weighted sum of one or more recent values of Y and/or a weighted sum of one or more recent values of the errors.

The forecasting equation is constructed as follows. First, let y denote the d^{th} difference of Y, which means:

$$If\ d = 0:\ yt = Yt$$
$$If\ d = 1:\ yt = Yt - Yt - 1$$
$$If\ d = 2: yt = (Yt - Yt - 1) - (Yt - 1 - Yt - 2) = Yt - 2Yt + Yt - 2$$

Note that the second difference of Y (the d=2 case) is not the difference from 2 periods ago. Rather, it is the first-difference-of-the-first difference, which is the discrete analog of a second derivative, i.e., the local acceleration of the series rather than its local trend.

In terms of y, the general forecasting equation is:

$$\hat{y}t = \mu + \phi 1\, yt - 1 + \cdots + \phi pyt - p - \theta 1et - 1 - \cdots - \theta qet - q$$

Here the moving average parameters (θ's) are defined so that their signs are negative in the equation, following the convention introduced by Box and Jenkins.

V BENEFITS OF IIOT IN OIL AND GAS INDUSTRY

A. Improved Operational Efficiency:
The oil and gas industry will be facing losses in the next couple of years as the Baby Boomer-aged workers begin to retire and there are less people with industry expertise to assume the vacant roles. Big data analysis and remote visibility will help companies better manage their assets and use their findings to optimize production. Leveraging the capabilities of IIoT can reduce troubleshooting time from days to minutes, which leaves more time to spend on other operational aspects of the business.

B. Revenue:
With lower oil prices being the new normal, profit margins have tightened, and oil and gas companies must take this opportunity to invest in innovative technologies rather than con-duct knee-jerk cost cutting. The financial gains of cost reduction and saved time will be invaluable as the industry be-comes even more competitive.

C. Real-Time Data
Big data is not new to the oil and gas industry: Data is crucial for the success of this industry. Efficiency and accuracy are highly valued in the oil and gas industry almost more than any other industry.

Small improvements in efficiency can make a notable eco-nomic difference. Profit in the oil and gas industry is dependent on prompt and accurate production data. With IIoT integration, the oil production can be captured in real-time through embedded sensors and the right automation of data communications systems, enables companies to gather in-formation from assets anywhere and make informed decisions.

D. Decreased Safety Risk
Safety is perhaps the largest industry concern, both internally and externally. IIoT can lessen risk taken by identifying potential issues before it become actual problems or safety hazards.

VI CONCLUSION

With the use of IIOT and machine learning technique deployed on cloud, the visual system developed for analysis based on historical data will provide appropriate visualization that displays the current production and what-if analysis to simulate the best production optimization possible.
It will also allow users to assess production performance against forecasted production and analyze how distant actual production is from the forecast and examine the cause for the deviation along with the estimate of the loss of oil per barrel also helps in study and comparison of live data.
The future of the IIoT must integrate these proven applications into larger systems-of-systems that bring the power of cloud analytics and business intelligence to industrial systems. This is the core vision of the Industrial Internet. DDS is the right standard protocol to fulfill that vision because it provides both the extreme capabilities required by intelligent machines and the needed integration to extend to cloud-based analytics and optimization. Can predict and forecast the values for oil, gas, liquid, water, and many other tags.

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