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An Assessment of the State of the Art on the Use of IoT to Anticipate Optimum Gas Use in Foundries

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By fully digitizing their production process with industry 4.0 standards, industries maintain the worldwide standards in the field of industrial automation. With the development of industries, the fourth industrial revolution is being implemented gradually, after the development of Cyber-Physical Systems (CPS), industrial wireless networks, and some other enabling technologies. Methane, or CH4, makes up the majority of natural gas, with trace amounts of other heavier hydrocarbons. Methane burns virtually entirely because it has the lowest carbon to hydrogen ratio possible, making it extremely environmentally friendly. It is obtained from the gas and oil wells and moved via a system of pipelines. Natural gas provided via mild steel (MS) and polyethylene (PE) pipelines to meet the needs of clients in different segments—domestic/commercial and non-commercial/industrial—is known as PNG, or piped natural gas. PNG Gas clients who require gas for their industrial settings are classified as industrial customers. They use piped natural gas mainly as a source of energy for many specific processes from the industry. The primary uses of natural gas in industry are for manufacturing, processing, power, heating, and cooling. This gas consumption is an important catalog to reflect in requirement for industry. The creations of a system to track, manage, and optimize energy consumption characteristics are the main requirement in manufacturing businesses. Furthermore, for the purpose of predicting optimal gas consumption, this work presents the use of polynomial, support vector, decision tree, random forest, and linear regression. The result indicates that the method predicting natural gas consumption is simple and accurate, that the model has good quality flexibility and correctness, and that the technique is significant to optimize the process and united dispatch managing of the transmission and distribution pipeline network. To create an application-based system that has been verified in the business world. The goal of the research paper is to enhance industry performance in energy management through the implementation of smart metering for gas consumption monitoring. Both academics and industry professionals will find the research piece useful in their endeavors.

Keywords: Gas consumption, Prediction, Linear Regression, Polynomial Regression, Decision Tree Regression, Random Forest Regression, Optimization, Internet of things, Energy management system.

1. Introduction

The industrial sector's financial expansion has led to an annual rise in both piped gas production and demand. The utilization of natural gas is impacted by several unidentified factors. The relationship between the influencing elements and natural gas usage is highly complex and non-linear.[1] There are two types of information in this system: known and unknown. It is a "Black" and "white" parameters co-existence system. In order to build forecasting models, various data, including economic parameters, weather data, historical natural gas consumption data, historical energy consumption data, mathematical and engineering calculations, software simulation data, and survey data of homes, were used. These studies looked at forecasting natural gas consumption on an industry level. Natural gas utilization is an essential target to imitate living and spending levels of residents. Carries on the calculation to it, to ensure network ability, carry out the optimization of network arrangement, equipment preservation and so on, is of great significance. Many of the methods is used to prediction of natural gas consumption such as Linear Regression, Polynomial Regression, Support Vector Regression, Decision Forest Regression and Random Forest Regression.

2. Literature Review

Modern manufacturing is the main requirement for industry in order to survive and compete. IoT and cloud manufacturing are two emerging paradigms that have the potential to improve many aspects of the manufacturing sector, including quality, production flexibility, process planning and scheduling, and many more. Various algorithms, models and other solutions are developed for prediction of optimized gas consumption.

Yan Xie et al. [1] introduces, grey modeling method with genetic optimization The result shows that the technique for forecasting natural gas consumption is simple and reliable, that the model is accurate and flexible, and that the technique is essential for streamlining the operation of the conveyance and allocation pipeline network.

Boz idar Soldo et al. [2] give an overview and synthesis of the published research in this field from the foundation through the end of 2010, together with information on the tools, data, and models that were utilized to create results that were valuable. Building forecasting replica uses a mixture of data, including economic consideration, weather data, historical natural gas and energy consumption data, numerical and engineering computation, chronological software simulation data, domestic survey data, and other various parameters, like days of the week.

Faheemullah Shaikh et al. [3] introduces, the Grey Verhulst Model and the Nonlinear Grey Bernoulli Model, two improved nonlinear grey models, were used in this study to build a forecasting model for China's natural gas consumption. Both of these models accurately predicted China's impending 315 billion m3 natural gas demand by 2020 after taking into account the country's actual natural gas consumption.

V. Bianco et al. [4] this article presents a various linear regression mock-up that forecasts Italy's power consumption using the GDP and inhabitants as chosen variables. Later, a model reduction is optional using a basic linear regression model with independent variables being the ratio of GDP to population (GDP per capita). The output of the models is compared to both the official forecast of the Italian government and the forecast of a community/private research association. It is demonstrated that the various projections have a good deal of agreement.

Faheemullah Shaikh et al. [5] the findings of this study are anticipated to help energy planners and policy makers develop appropriate demand-side and supply-side management strategies for natural gas.

Yun Zhou et al. [6] explain, that because China is a growing nation, its country would expand at a specific rate, inevitably causing pollution and carbon emissions to rise in the future. China cannot resolve its environmental issues through a single solution. China must adopt a long-term low-carbon growth plan that includes investments in low-carbon technology research and deployment, energy structure optimization, and the establishment of market-based economic instruments.

Prasad Boggavarapu et al. [7] represents, the thermal efficiency of a traditional home burner for fuels such as liquefied petroleum gas (LPG) and piped natural gas (PNG) is examined in the current work both experimentally and numerically. For the first time in such burners, three-dimensional computational fluid dynamic (CFD) modeling of the steady-state flow, combustion, and heat transfer to the vessel is reported. Worldwide initiatives are also being made to use piped natural gas (PNG) for cooking more frequently. Therefore, systematic studies are required to evaluate the effectiveness of current burner designs using different fuels, such as LPG and PNG, as well as to investigate design modifications for increased effectiveness.

Giuseppe Di Leo et al. [8] introduces the idea of using a smart grid-enabled net metre has been created. Its effectiveness may be able to control peak demand, and consumers may be able to monitor and optimise their energy use based on current power pricing as well as specific requests, thereby lowering their power bills.

Olivier Monnier [9] white paper, increasing the connectivity of the grid infrastructure, metres, houses, and structures. With the help of smart devices like "home gateways, smart plugs, and connected appliances," customers, producers, and service providers will eventually find inventive ways to manage devices through the Internet of Things, conserving resources and saving money. This article discusses the various ways being taken around the world to connect the smart grid.

Fadi Shrouf et al. [10] Using the Internet of Things idea, research strategies to lower energy costs and boost energy efficiency based on the already available technology and its short-term potential advancement paths.

Fei Tao et al. [11] developed the new process for Energy diminution and manufacture drop. This study suggest a “life cycle assessment (LCA)” based on the new perception of Internet of Things and the bill of materials. An “ESER LCA” system based on Internet of Things and Bill of Material with a four-layered creation (1.inspection contact layer, 2.records layer, 3.feature layer, and 4.utility layer) is assemble and explain, as well as the main machinery and functionalities in each tier. To test the planned method, a model appliance system is produced.

Hugo Sequeira et al.[12] a system for monitoring, controlling, and optimizing energy use. Industrial EMS is a complex and expensive system because of the special requirements for display, consistency, and functionality. Additionally, industry is having issues with the current system solutions, such as the traverse energy usage study. Offer a cloud-based system solution using "cloud computing" technology that can handle all of these demands and issues. Researchers believe that by employing this unique approach, they will be able to produce pertinent information more quickly, enabling organizations to react to changing circumstances and identify unseen trends that compromise efficiency.

F. Shrouf et al. [13] this essay covers the key characteristics of these factories with a focus on long-term sustainability and suggests a site design for IoT-related advanced enterprises. Then, based on the IoT paradigm, it offers a solution developed to manage energy usage in well-designed factories: a directive and anticipated advantages are addressed and delivered.

F. Abate et al. [14] created a universal cleave utilising a smart device that estimates power use and provides metre descriptions. A smart grid, which enables intelligent power grid management, is the foundation of a well-kept city. Smart metres that can interface with the system in both ways must be present on the network in order to achieve this.

Ofoegbu Osita Edward [15] in order to enable home owners to remotely change their loads using messages from a mobile phone, this study presents a smart meter reader that blends a build block-based micro - controller logic approach with automation.

Muhammad Waseem Ahmad et al. [16] this article examines the most recent advancements in ecological monitoring and construction energy metering, in addition to the common, industry, trade and industry, environmental, and governmental factors that determine them, and factors that influenced their selection; and future study and improvement guidelines - designed to use as a guideline as well as to catch readers' interest in this quickly developing field.

Amit Bhimte et al. [17] this article demonstrates how an urbanised smart device is used by a household or industrial consumer. The intended smart energy metre is made for LabVIEW and serves as an example of a smart energy metre that is LabVIEW-based. The prototype not only reduces labour costs but also increases the accuracy of metre understanding and saves a sizable amount of time.

Christoph Herrmann et al. [18] this article describes the planning and implementation of an industrial automatic meter reading device as a facilitator for energy-efficient assembly system organisation and management. Information technology-based systems may help with data collection and provide direction for decision-making.Zehra Yumurtaci et al. [19] this study demonstrates how the city's energy use was estimated based on the population growth and per capita energy consumption rates.

Faheemullah Shaikh et al. [20] this study is intended to develop the logistic and logistic-population model based approach to forecast the medium- (2020) to long- (2035) term natural gas demand.

3. Prediction Methods

Linear Regression

Here, information from heat treatment furnaces has been utilized. The main objective of many statistical investigations is to make predictions, preferably on the basis of mathematical equations.

Let(xi,yi); i=1 to n be a given set of n pairs of values,

x = Independent Variable

y = Dependent Variable

Simple linear regression is a statistical method that we can use to find a relationship between two variables and make predictions. The two variables used are typically denoted as y and x. The independent variable or the variable used to predict the dependent variable is denoted as x. The dependent variable, or the result, is denoted as y. A simple linear regression model will produce a line of best fit, or the regression line. The coefficient can be positive or negative and is the degree of change in the dependent variable for every 1-unit of change in the independent variable. After seeing the algorithm of the method data can be plot as per the behavior of the data.

Polynomial Regression

It is a form of linear regression in which the relationship between the independent variable x and dependent variable y is modeled as an nth degree polynomial. As per the data behavior plots the graph:

As compared to linear regression scattered points will most fit the polynomial regression line. But while calculating the number of data the value of C tends to become either negative or zero. It will create the difficulty to plot the graph.

Support Vector Regression

Support Vector Regression (SVRs) are well known in classification problems. SVR gives the flexibility to define how much error is acceptable in our model and will find an appropriate line (or hyperplane in higher dimensions) to fit the data.

As compared to linear regression and polynomial regression scattered points will most fit the support vector regression line. But here the plot again can be improved by choosing the acceptable error margin, and also that can be modified with another type of optimization technique.

Decision Tree Regression

It is a tree-structured classifier, where internal nodes represent the features of a dataset, branches represent the decision rules and each leaf node represents the outcome. Decision Tree is a supervised learning technique that can be used for both classification and Regression problems. As per the data behavior plots the graph:

Here the decision tree regression can be used to prediction of both continuous and discrete values.

4. Co-Efficient of Determination

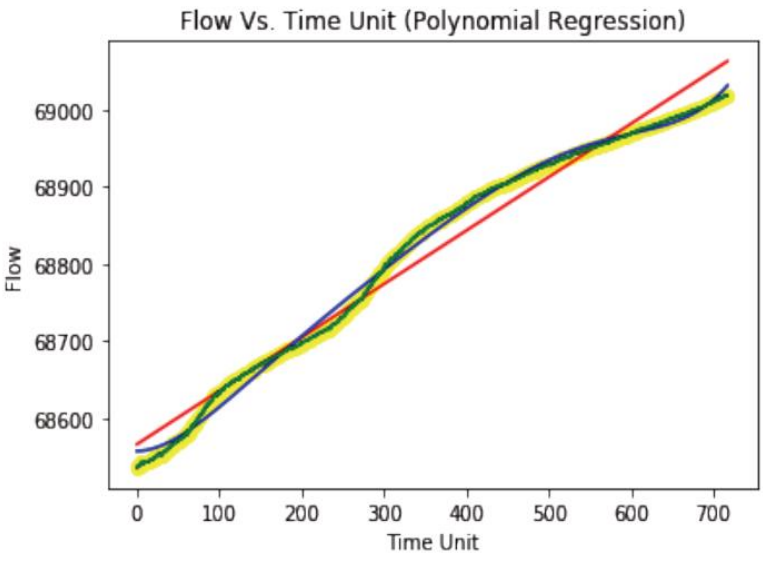
The coefficient of determination is a complex idea centered on the statistical analysis of models for data. The coefficient of determination is used to explain how much variability of one factor can be caused by its relationship to another factor. This coefficient is commonly known as R-squared (or R2), and is sometimes referred to as the "goodness of fit." When the ratio of residual to total nearer to 1 it will show the best fit line, or in worst cast (when ratio becomes negative) it will not show the best fit line. Here, prepare comparative statement is based on the coefficient of determination for both of the furnaces.

5. Result and Discussion

Here, prepare comparative analysis is based on the coefficient of determination for all prediction methods.

Table: 1 Comparative Statement

Optimization Method	Co-efficient of Determination
Simple Linear Regression	0.9722
Polynomial Regression	0.9972
Support Vector Regression	0.9962
Decision Tree Regression	0.9999
Random Forest Regression	0.9999



Graph: Flow Vs Time (Combined Graph for all Methods)

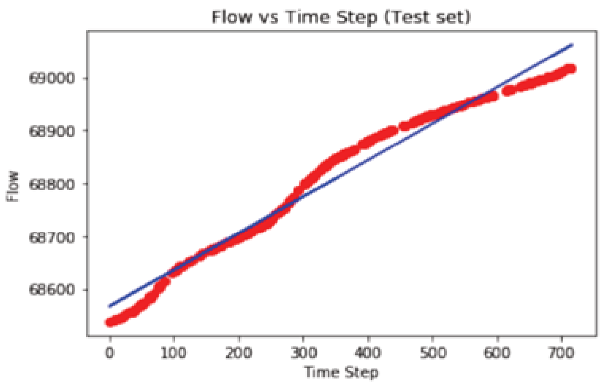
Table: 1 shows Co-efficient Determinations for all the optimization methods. Apart from the five optimization method, decision tree regression and random forest regression shows the coefficient of determination almost nearer to 1. Graph: also reflect the best fit line for decision tree and random forest regression. Hence, it can be concluded that decision tree regression and random forest regression will give the best fit for optimized prediction of gas consumption.

6. Conclusion

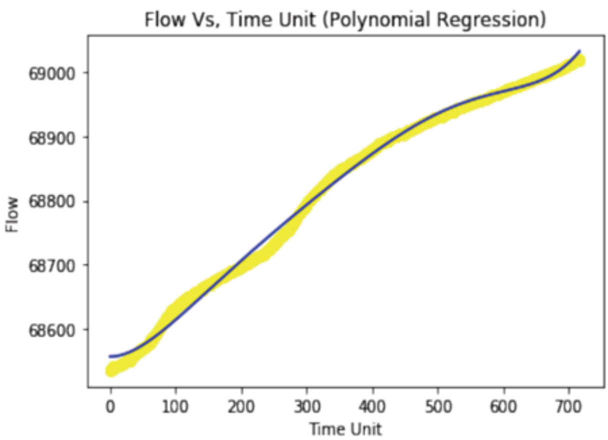
The current article provides information based on the selection of predictive methods for optimized gas consumption. Decision tree regression and random forest regression will provide the best fit for an optimum forecast of gas consumption, according to the overall prediction methodologies. But if you choose the best method, decision tree regression will offer the best gas consumption forecast since it is highly interpretable, performs well on both linear and non-linear situations, and requires less feature scaling than random forest regression. Decision trees have many advantages as well as disadvantages. However, they have more benefits than drawbacks, which is why they are widely used in the sector. The decision tree is very easy to visualize and comprehend.

APPENDIX

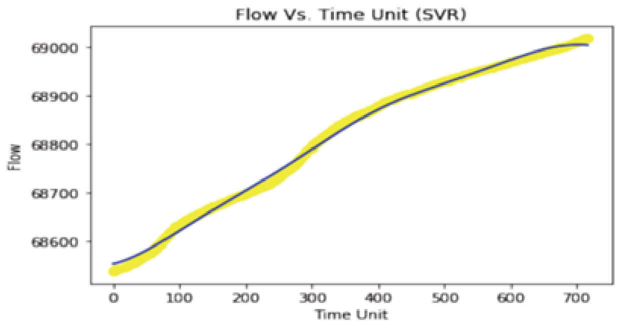
The graph for all the prediction methods represent as here:



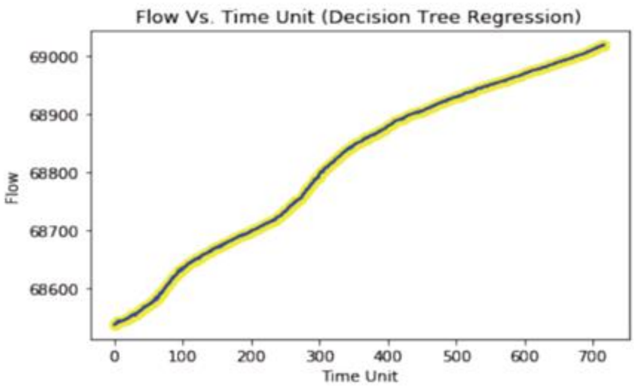
Graph:1 Linear Regression



Graph:2 Polynomial Regression



Graph:3 Support Vector Regression



Graph:4 Support Vector Regression

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