AI-Based Renewable Energy Forecasting and Industrial Decision Support Using SARIMA

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Abstract
Renewable energy resources have been gradually being embraced by industries to reduce the cost of operation and make their operations more sustainable; however, natural fluctuations in renewable energy resources renders it difficult to plan the production and energy management. The proposed Industrial Renewable Energy Production Intelligence System is an AI-based decision-support system and the focus of this paper, which attempts to generate the optimal use of energy in industries and decrease reliance on the grid. The proposed system preprocesses historical information on the generation of renewable energy, industrial production, and consumption of power to compute energy intensity measures with regard to production. A Seasonal AutoRegressive Integrated Moving Average (SARIMA) time series model is used to predict the availability of renewable energy resources. The energy demand in the industry is determined in regard to the projected production level and the energy intensity measures of the past. An optimization strategy based on rules is employed and the forecasted renewable supply is compared with the forecasted demand and preferential utilization of renewable energy sources is given alongside supplementation of the grid energy only when necessary to make the total cost of energy as low as possible. The offered solution is created as an interactive Streamlit app that will provide historical analysis, forecasting, energy allocation planning, cost comparison, diesel dependence analysis, and AI-based production adjusting recommendations. The experimental study confirms the fact that the given solution will improve the utilization of renewable sources of energy, reduce the reliance on the grid, and assist in managing industrial energy effectively.

Keywords: Renewable Energy Forecasting, SARIMA, Industrial Energy Management, Energy Demand Estimation, Rule-Based Optimization, Cost Minimization.

I. Introduction

The high rate of industrialization has greatly increased the level of energy needs in different fields. The industries are also adopting the use of renewable energy sources like solar and wind energy in their energy mix to lower the cost of operation and environmental impact. Nevertheless, renewable energy production is quite intermittent and relies on weather, and it is hard to match production with the industrial production time. The results are that it overrelies on grid power or diesel generators, which adds to the costs and sus-

tainability issues.
The management of industrial energy needs proper prediction of renewable energy potential, dependable prediction of the energy demand and the smart energy distribution plans. Conventional methods of energy management are based on past averages or human judgments, and they do not include predictive or optimization. This makes industries unable to optimize the use of renewable energy and reduce grid reliance.
To overcome these issues, the current paper introduces an Industry Renewable Energy and Production Intelligence System that incorporates the concepts of time series forecasting and demand estimation and rule-based optimization into one decision-support system. The contributions of the system are the following:
It involves the use of a Seasonal AutoRegressive Integrated Moving Average (SARIMAX) model to predict the availability of renewable power per day using past records on solar generation.
The production energy intensity measures are based on previous production and consumption data to estimate the energy demand of industry with respect to the level of production.
The rule-based optimization strategy takes a comparison of the forecasted renewable supply with the forecasted demand, where renewable energy is used first, and grid power is used when the supply is insufficient to meet the demand at the lowest possible energy cost.
The system is deployed as an interactive Streamlit dashboard which allows the real-time visualization of forecasts, energy allocation planning, cost comparison and performance monitoring on four separate analytical Tabs.
The paper provides an example of how effective uses of artificial intelligence can be realized to realize sustainable, cost-effective, and data-driven industrial energy management through this integrated strategy.

II. Literature Survey

A number of researchers have discussed machine learning and deep learning strategies in enhancing the accuracy of renewable energy forecasting, with reference to wind power generation. This part is a review of the three important studies applicable to the proposed work.

A. Time-series and deep learning approaches for renewable energy forecasting in Dhaka: a comparative study of ARIMA, SARIMA, and LSTM model.

Mohammad Liton Hossain, S. M. Nasif Shams & Saeed Mahmud Ullah (2025)
This paper is a comparative analysis between time-series models (along with SARIMA) and deep learning models (along with LSTM) in order to use long-term historical data to jointly predict renewable energy. It highlights the capacity of statistical models such as SARIMA to model trend and seasonal aspects, and the possibility of deep learning models to give superior outcomes. This is a response to the SARIMA that was applied to the renewable energy forecasting in your project.

B. Green Energy Management in Manufacturing Based on Demand Prediction by Artificial Intelligence.

Izabela Rojek, Dariusz Mikolajewski, Adam Mrozinski, and Marek Macko (2024)
In this review paper, the author explains how AI-based demand forecasting can be implemented in the management of industrial energy usage, and how advanced machine learning techniques can be used to improve forecasting results, match energy demand with production timetables, and maximize the sustainability of industrial processes. This article has offered a theoretical foundation to the use of AI in energy demand estimation and optimization, which is used in your system.

C. Machine learning-based energy management and power forecasting in grid-connected microgrids with multiple distributed energy sources.

Arvind R. Singh, R. Seshu Kumar, Mohit Bajaj, and Chetan B. Khadse, Levgen Zaitsev (2024).

This paper investigates how advanced methods of machine learning could be used to improve energy prediction and management in microgrids with multi-source renewable energy. The results prove the improved utilization of renewables and the ensuing equilibrium between the energy production and the demand, therefore, determining the effectiveness of ML-based energy systems, which resembles the optimization dimension of your study.

III. Existing System Architecture

The existing energy management systems in industry largely depend on past averages, basic statistical programs, and manual planning to predict the supply of renewable energy as well as the demand of industries. Commonly used tools include SCADA systems, ERP energy modules and spreadsheet-based tracking tools, which provide rudimentary monitoring abilities but not predictive intelligence.

The current forecasting models are not suitable to manage the variability and uncertainty inherent in renewable energy, such as solar and wind energy. The consumption of industrial energy is usually calculated by fixed baseline assumptions as opposed to production-based, dynamic energy intensity measurements, and an untrue forecast of demand.

Besides, the forecasting and production planning of renewable energy are done separately, resulting in poor energy allocation decisions. In times of energy outage or when there is less production of renewable energy, industries fall back to grid power or diesel generators, which promotes cost and carbon emissions to high levels.

There is also no built-in, smart, or AI-driven decision-support system or smart dashboard that would enhance operational visibility and make it possible to engage in real-time optimization. This means that industries cannot optimize the use of renewable energy, reduce grid reliance, and effectively make energy management decisions using data.

IV. Problem Statement

Renewable energy is inherently variable and unpredictable, and this makes it difficult to be managed in an efficient way in industrial sectors. The conventional energy management system is based on the historical averages and manual planning, which cannot precisely predict the availability of renewable sources or match them to the dynamic industrial needs.

Consequently, this causes inefficiency in the distribution of energy to industries, increased cost of operations, reliance on the grid, and increased use of diesel. It is required to have an intelligent, data-driven system capable of predicting renewable energy, estimating the industrial demand, allocating energy efficiently and sustainably, and helping to create a cost-effective and sustainable production plan.

V. Proposed System Architecture

The proposed system is an AI-based decision-support application, the Industrial Renewable Energy and Production Intelligence System, which is meant to optimize industrial energy utilization. It cleanses the historical data relating to industrial and renewable energy and uses a SARIMA time-series model to predict the availability of renewable energy with accuracy.

The production-based energy intensity measures based on the historical consumption and output trends

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are used to estimate the industrial demand. The system forecast against predicted renewable supply and compare against predicted demand and uses rule-based optimization logic to put more priority on using renewable and reducing the grid and diesel dependence.

The solution is implemented in the form of an interactive Streamlit dashboard, which offers forecasting visualization, planning of energy allocation, cost analysis and intelligent production adjustment recommendations to guarantee sustainable and cost-effective management of industrial energy.

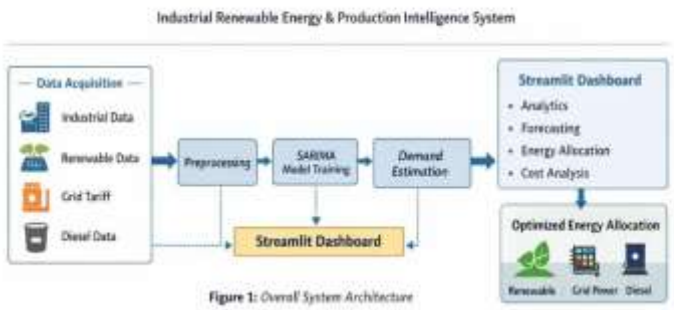

Figure1: Overall system architecture

VI. Methodology

The suggested Industrial Renewable Energy and Production Intelligence System is a five-stage pipeline system driven by data that entails preprocessing of data, prediction of renewable energy, prediction of industrial demand, energy optimization through rules, and visualization of the dashboard.

A. Data Collection and Preprocessing

Daily data in the past were obtained through an industrial manufacturing plant that manufactures clutch parts. The data comprises daily unit consumption of energy, solar energy production in kilowatt-hours, and diesel consumption in litres, cost of diesel per day in INR in units, production output of the clutch, time of power cut in the hours and units used by the diesel generator. Preprocessing of the data was done in Python and Pandas which involved standardization of column names, date field parsing, imputation of missing values with zero-fills and chronological sorting so as to bring uniformity and reliability in the data.

B. Renewable Energy Prediction.

To predict the amount of renewable energy to be available each day, a Seasonal AutoRegressive Integrated Moving average with Exogenous Variables (SARIMAX) was used on past solar generation data. The Augmented Dickey-Fuller (ADF) stationarity test was performed on the solar time series in order to measure whether the time series should be differenced or not. Before fitting the model, the values of solar generation were multiplied by a factor of 1000. SARIMAX model was set to include both seasonal and short-term dynamics by taking order (1,1,1) and seasonal order (1,1,1,30). To run the trained model in real-time and make predictions, the model was serialized with the help of joblib and embedded into the Streamlit dashboard.

C. Industrial Demand Estimation

The energy intensity of production found using historical data to derive industrial energy demand was used to estimate energy demand. Three main figures were calculated; energy units used to produce one clutch, diesel litres used to produce one clutch and the cost of energy in INR per clutch. Such indicators form a straight correlation between the output of production and the energy needed, which allows estimating the demand that is dynamic and is scaled to the operational planning.

D. Rule-based Energy Optimization.

A optimization module is used to compare the predicted supply of renewable energy every day to the projected demand in the industries. In cases where the amount of renewable supply is equal or more than the demand, the entire demand is met by renewable power. In case of the inadequate supply of renewed energy, renewable energy is used and the rest of the demand is met by grid power. The rule-based strategy leads to the optimal use of renewable energy and the minimum reliance on the grid, as well as to a decrease in the overall energy cost of operations. The dashboard has configurable grid cost and renewable cost per kilowatt-hour, which is useful to analyze costs in a flexible manner.

E. Dashboard Visualization

The entire system is deployed as an interactive Streamlit web application with four analytical tabs, including the Executive Overview of KPI monitoring and cost breakdown, Historical Analysis of trend visualization, Forecast and Planning of allocation table and forecast charts, and Production Intelligence of per-clutch KPIs and AI-based energy advice.

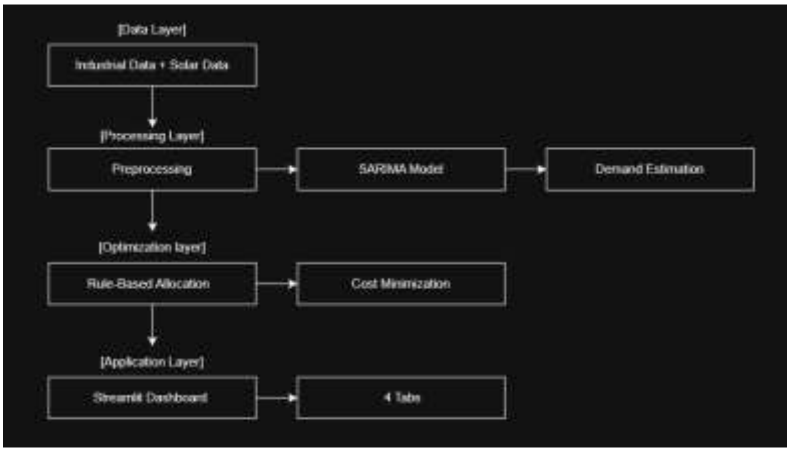

Figure: Forecasting Pipeline Diagram

VII. Results and Discussion

Proposed Industrial Renewable Energy and Production Intelligence System was tested on the basis of the historical data of industrial energy consumption, production output, renewable generation and tariff. The performance of the system was measured regarding the accuracy of the forecasts, the use of renewables, cost-efficiency, and reduction of diesel dependency.

The renewable energy forecasting model using SARIMA model was powerful enough in capturing both seasonal and temporal variations of the renewable generation. Estimation of the industrial energy demand by use of the production-based energy intensity indicators gave realistic estimates of the demand that increased with the production level. This method permitted adaptive planning of energy as opposed to fixed-demand approaches especially in different operational circumstances.

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                                SARIMAX Results
==========================================================================================
Dep. Variable:                   E-Today (KWH)   No. Observations:                  443
Model:             ARIMA(2, 1, 1)x(1, 0, 1, 7)   Log Likelihood               -1651.872
Date:                         Sat, 14 Feb 2026   AIC                           3315.745
Time:                                 14:36:17   BIC                           3340.292
Sample:                             11-16-2024   HQIC                          3325.427
                                  - 02-01-2026
Covariance Type:                           opg
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
ar.L1          0.2583      0.044      5.812      0.000       0.171       0.345
ar.L2         -0.0540      0.043     -1.270      0.204      -0.137       0.029
ma.L1         -0.8910      0.029    -30.522      0.000      -0.948      -0.834
ar.S.L7       -0.5612      0.430     -1.305      0.192      -1.404       0.282
ma.S.L7        0.6237      0.407      1.534      0.125      -0.173       1.421
sigma2       102.9057      5.976     17.219      0.000      91.192     114.619
===================================================================================
Ljung-Box (L1) (Q):                   0.05   Jarque-Bera (JB):                23.47
Prob(Q):                              0.82   Prob(JB):                         0.00
Heteroskedasticity (H):               0.39   Skew:                            -0.32
Prob(H) (two-sided):                  0.00   Kurtosis:                         3.94
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Figure : SARIMAX Results

The optimization policy was built on the rule and aimed at putting in focus the use of renewable energy sources and minimizing the use of grid and diesel operations. The grid energy consumption was reduced during the times of high availability of renewable energy leading to a reduction in the total energy cost. The visualization and analysis of energy trends, forecasts, cost comparisons and energy allocation plans could be effectively made in the interactive Streamlit dashboard. The dashboard facilitated production adjustment recommendations that were informed and sustainable based on AI-supported scenario analysis, which would allow making informed industrial energy management decisions.

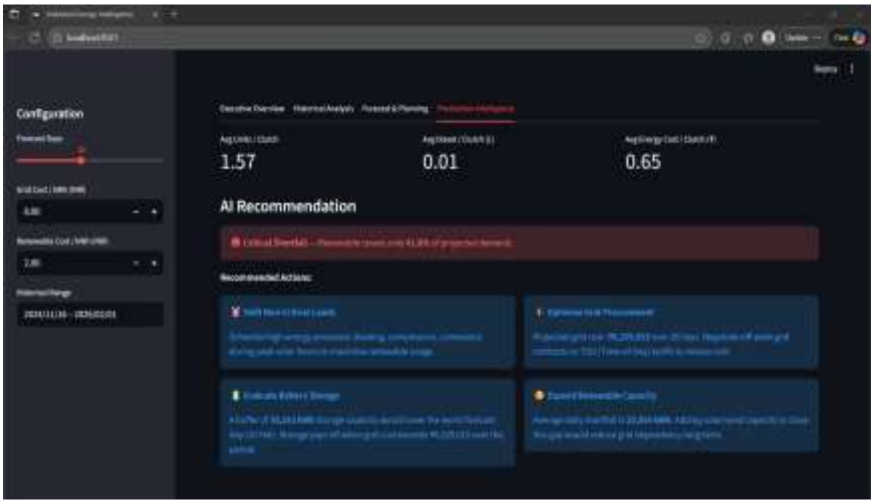

Figure: Streamlit Dashboard

VIII. Conclusion

This piece of work was an Industrial Renewable Energy/Production Intelligence System of efficient and sustainable industrial energy management. The system combines the SARIMA based renewable energy forecasting, production based demand estimation and rule based optimization to maximize the use of renewable energy and minimize reliance on grid and diesel power. The interactive streamlit dashboard facilitates good visualization and decision support. The outcomes illustrate a better use of renewable, a lesser cost of energy, and better operational sustainability, which proves the efficiency of the AI-based decision-support systems to use in industries.

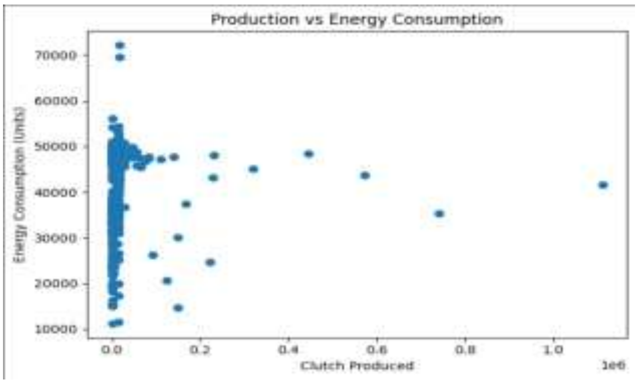

Figure: Production vs Energy consumption

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