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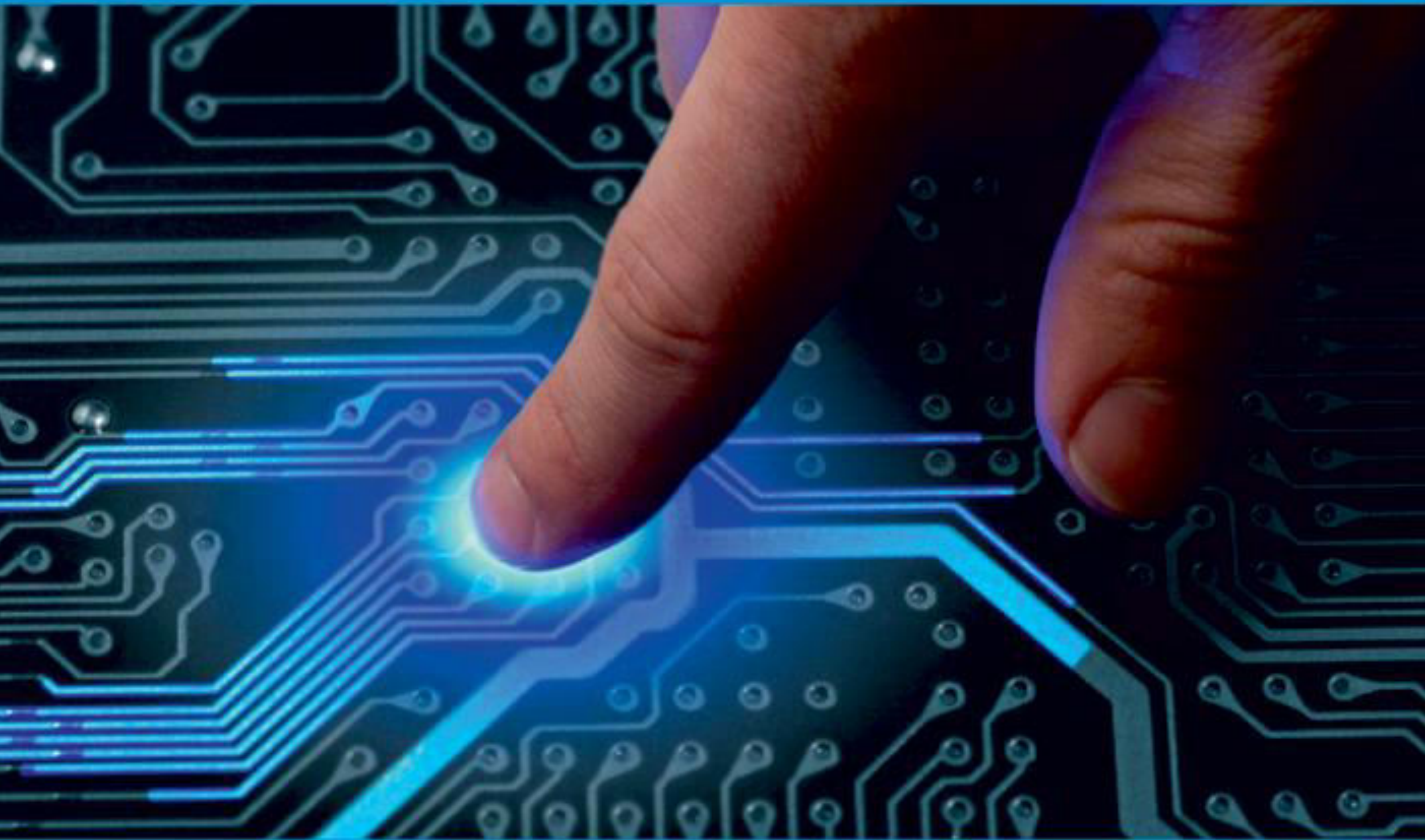

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AI Based Solar Uninterrupted Power Supply System

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ABSTRACT: In this research, we present the evolution of a cutting-edge Uninterruptable Power Supply (UPS) system with AI capabilities for managing solar energy efficiently. The system tackles challenges in maximizing power generation and distribution from solar panels in various environmental conditions. The UPS system integrates predictive models to predict solar irradiance levels, a crucial factor affecting PV power generation.

Initially, environmental sensors gather real-time irradiance data, which are inserted into a Long Short-Term Memory (LSTM) neural network model. The LSTM model leverages historical irradiance data to anticipate future levels, facilitating proactive adjustments of power management strategies. Following that, the anticipated irradiance values are given as an input to a Linear Regression (LR) model to approximate the PV output. This predictive ability enables proactive load management and ensures optimal utilization of solar energy resources. Additionally, the system includes a fall back mechanism utilizing an XGBoost model for solar radiation prediction in the absence of irradiance sensors, utilizing environmental parameters like temperature, pressure, humidity, and sunrise/sunset times.

Moreover, the UPS system contains a flexible control unit accessible through multiple interfaces, including a web-based interface, BlynkApp, Bluetooth application, manual switches, Solar Tracking System, Battery Charger based on solar and AC and Pure Sinewave Inverter. These interfaces enable users to remotely observe and control the UPS system, ensuring smooth operation and adaptability to user preferences. This project consists of solar panel which consist solar cell which convert solar energy into electrical energy that is the DC (direct current) power, it charge the lithium ion battery, then we converted DC(Direct Current) into AC (alternating current) using a Pure Sinewave DC to AC inverter. It also shows that solar UPS can be highly efficient and successful in electrical UPS market. the proposed UPS system signifies a notable progression in solar energy management, leveraging AI-driven predictive models and versatile control interfaces to enhance reliability, efficiency, and user experience in power supply management.

I. INTRODUCTION

Solar Energy Management using AI-Integrated UPS System. The increasingly demand for renewable energy sources have propelled innovation for efficient energy management with advanced technology. Solar energy offers a sustainable alternative to traditional fossil fuels, but it faces challenges due to sunlight intermittency and environmental variations.

Uninterruptible Power Supply (UPS) systems play a critical role in ensuring reliable power supply amidst fluctuations. Regarding, Artificial Intelligence in Solar Energy Management. Our research focuses on designing and implementing an AI-integrated UPS system for optimal solar energy management. The system uses AI for the prediction of solar irradiance levels, crucial for photovoltaic (PV) power generation. Accurate forecasting helps adjust power distribution and load management strategies effectively, maximizing efficiency and reliability. Predictive models like Long Short-Term Memory (LSTM) neural networks; and Linear Regression (LR) models helps anticipate changes in solar irradiance. The system also includes a XGBoost model as a fallback for solar radiation prediction using environmental parameters to improve accuracy.

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The Versatile Control Interface provided for Enhanced User Experience. The UPS system features a versatile control unit accessible through web-based platforms, smartphone apps like BlynkApp, Bluetooth connectivity, manual switches, Solar Tracking System, Battery Charger based on solar and AC and Pure Sinewave Inverter. These interfaces allow remote monitoring and management, improving flexibility, convenience, and user experience. Overall, our research aims to tackle solar energy management challenges using AI-driven predictive models and versatile control interfaces.

By optimizing power generation, distribution, and utilization, the proposed UPS system contributes to sustainable energy advancement and future renewable energy innovations. Solar panel converts sun light energy into electrical energy through an electrochemical process also known as photovoltaic process. Solar panel produce direct currents (DC), it charge the lithium-ion battery, then we converted DC(Direct Current) into AC (alternating current) using a Pure Sinewave DC to AC inverter. The conversion from DC to AC is essentially accomplished by means of DC-AC inverter, which is major component in the system. The Arduino IC controls the servo motors through PWM (Pulse Width Modulation) signals, ensuring precise and smooth movement to track the sun's movement accurately the Arduino-based solar tracker effectively maximizes solar panel output by continuously adjusting their orientation to capture the maximum amount of sunlight throughout the day. The system offers a cost-effective and efficient solution for enhancing the energy yield of solar photovoltaic systems, contributing to the promotion of renewable energy utilization and sustainability.

1.1 MOTIVATION

In recent years, Solar is the most used renewable energy. Solar panel convert the solar energy into an electric energy but there are too many conditions to affect the efficiency of solar panel. Such as Weather, Irradiance.

II. PROBLEM STATEMENT

To design and implement an AI-Based power forecasting system integrated into Solar Uninterrupted Power Supply technology with solar tracking system.

III. WORKING

The working principle of an AI-based solar UPS (Uninterruptible Power Supply) system revolves around the integration of artificial intelligence (AI) algorithms with solar power generation and energy storage systems. This innovative approach aims to optimize energy utilization, improve system efficiency, and ensure uninterrupted power supply in both off-grid and grid-tied solar installations. Another essential aspect is load monitoring and forecasting. The system monitors the electrical load demand, which includes the power requirements of connected devices or appliances. In this modal we are developing AI-based UPS system with integrated solar panels and a mobile application for remote access offers a cutting-edge solution for optimized and sustainable power management. The system continuously collects data from solar panels, UPS units, and environmental sensors, which is then processed by the AI-powered prediction module.

The UPS component of the system harnesses solar energy through integrated solar panels, incorporating solar direction tracking for maximum efficiency. Solar panels continuously capture energy from the sun, and the system optimizes the collection process by tracking the sun's movement for increased energy generation. This green energy is then utilized to provide a reliable backup power source during outages or grid fluctuations, contributing to reduced electricity costs and a smaller environmental footprint. The system is scalable and adaptable, compatible with various UPS units, ensuring seamless power management and reliability for diverse applications.

Overall, the working principle of an AI-based solar UPS system combines intelligent energy management, adaptive control, and continuous optimization to maximize the efficiency, reliability, and sustainability of solar power generation and energy storage. By leveraging AI algorithms, the system can adapt to dynamic conditions, optimize energy utilization, and ensure uninterrupted power supply, thereby contributing to the advancement of renewable energy technologies and the transition towards a more sustainable energy future.

3.1 LSTM Model:
LSTM Neural Network Model for Time Series Forecasting of irradiance value
The implementation of a Long Short-Term Memory (LSTM) neural network model which is tailored for time series

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forecasting, specifically focusing on predicting beam irradiance values. It initiates by importing essential libraries, and defining functions for crucial data preprocessing tasks, including making the time series data stationary through differencing and scaling it using Min-Max scaling. The LSTM model architecture, orchestrated via Keras, unfolds with an LSTM layer accompanied by dropout regularization, followed by batch normalization, and densely connected layers integrated with activation functions. The model training phase ensues, leveraging the fit lstm function to optimize model parameters across a specified number of epochs. Post-training, the model embarks on forecasting future beam irradiance values on the test data, employing a walk-forward validation methodology wherein the model's output at each time step feeds back as input for subsequent predictions. Evaluation entails measuring performance using mean absolute percentage error (MAPE) between predicted and actual values, alongside generating a line plot visualizing observed versus predicted values. The model persistence is done by serializing the trained LSTM model using pickle, ensuring its retention for future utilization without necessitating retraining. Overall, the model underscores the application of LSTM neural networks in time series forecasting, particularly illuminating the significance of data preprocessing, model training, forecasting, evaluation, and model persistence within the machine learning pipeline
LSTM networks excel greatly at handling the temporal dynamics present in sequential data, making them particularly well-suited for modeling the complex patterns inherent in time series datasets such as beam irradiance values.

One of the key advantages of LSTM networks lies within their ability to addresses the vanishing gradient problem encountered in traditional recurrent neural networks (RNNs), Because of their gated structures. This gating mechanism enable LSTMs to selectively retain or discard information over time, facilitating the capture of long-term dependencies crucial for forecasting future values accurately. Additionally, LSTMs exhibit robustness to overfitting, courtesy of techniques like dropout.
The LSTM model developed for predicting beam irradiance values yielded a mean absolute percent error of 62.600. Despite the relatively high error rate, the model demonstrates its potential for forecasting beam irradiance values based on historical data. The model's ability to provide forecasts based on historical observations underscores its utility as a valuable tool for supporting decision-making

3.2 BEAM vs HR
The true value line (representing the actual beam irradiance values) closely follows the predicted value line, mimicking a sine wave pattern with beam irradiance ranging from 0 to 800
indicates that the Linear Regression model is capturing the underlying relationship between irradiance and PV power quite well. A sine wave pattern suggests that as irradiance increases from 0 to 800, the PV power output also increases in a smooth, periodic manner, which aligns with the behavior of solar panels. This close alignment between the true and predicted values implies that the model is accurately capturing the variations in PV power output corresponding to changes in irradiance levels

3.3 LR model:
The Linear Regression model was conducted to predict PV power based on irradiance information. The dataset, containing of irradiance (Gb(i)) and PV power (PV POWER) values, was first split into training and testing sets utilizing a 80:20 ratio. The model was train on the training data and later used to predict PV power values for the testing data. Evaluation of the model's performance was carried out using the Mean Squared Error (MSE), producing an MSE value of around 47.12. Moreover, the coefficients and intercept of the linear regression model was received, with the coefficient approximately 0.093 and the intercept approximately 3.134. A scatter plot was generated for visualize the real PV power values versus the predicted values based on irradiance, highlighting the model's aptitude to catch the underlying relationship between the two variables. Overall, the Linear Regression model exhibited a reasonable performance in predicting PV power from irradiance data, providing valued insights into the association between these variables.

3.4 Error Pic:
The Linear Regression model achieved a Mean Squared Error (MSE) of approximately 47.12 when predicting PV power based on irradiance data. The coefficients obtained from the model were approximately 0.093 for irradiance, indicating that a unit increase in irradiance corresponds to a 0.093 increase in predicted PV power. Moreover, the intercept of the linear regression model was approximately 3.13, representing the estimated PV power when irradiance is zero. These results underscore the model's ability to capture the relationship between irradiance and PV power, providing valuable insights for solar energy forecasting and system optimization.

3.5 LR Graph:
With a coefficient of approximately 0.093 and an intercept of about 3.13, the model indicates that for each unit increase

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in irradiance, the PV power is expected to increase by around 0.093 units. The intercept represents the estimated PV power when irradiance is zero. This result suggests that the model captures a linear relationship between irradiance and PV power, providing a reasonable estimation of PV power output based on environmental conditions.

Block Diagram

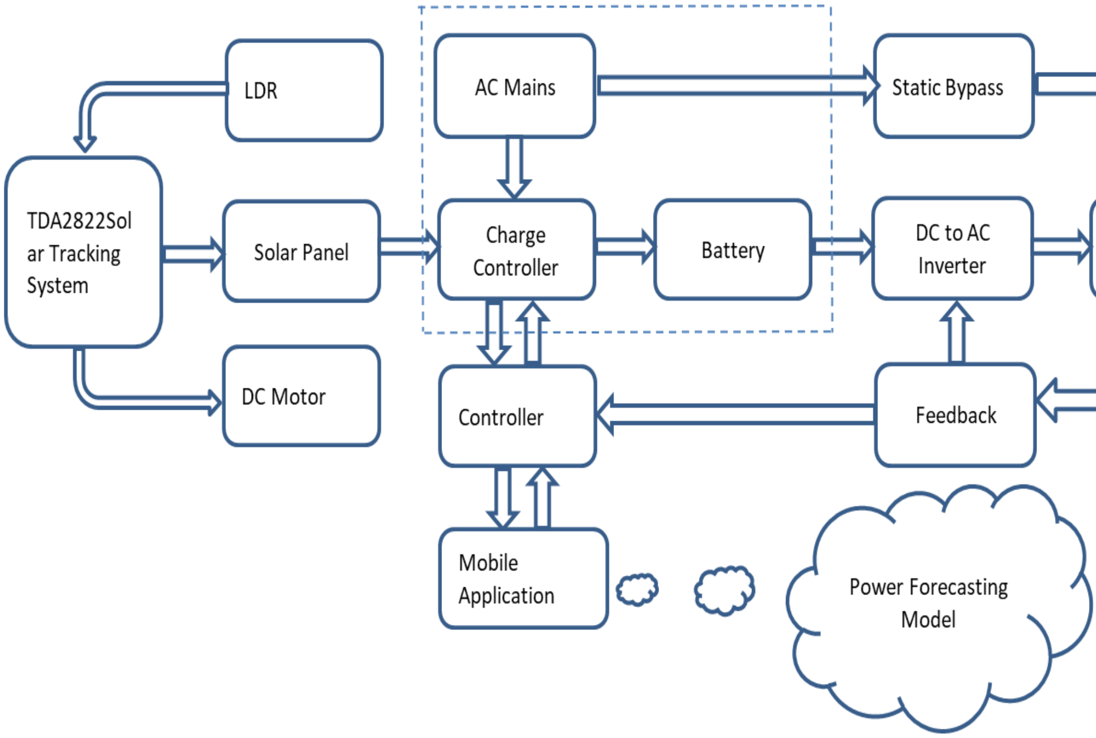

Fig. 4.1 Block Diagram

Hardware consist of Solar Tracking system which keep track on position of sun, then power of solar is connected to lithium ion battery by using BMS (Battery management system). At night battery will get charged through the AC supply and also main grid will be AC mains but at the day time main grid will shift to solar if it is generating sufficient power to run the appliances. If both solar and AC mains is not available, the system use the battery to convert DC (Direct Current) to AC (Alternating Current). Pure sine wave inverter is used to converter from DC to AC.

IV. RESULT

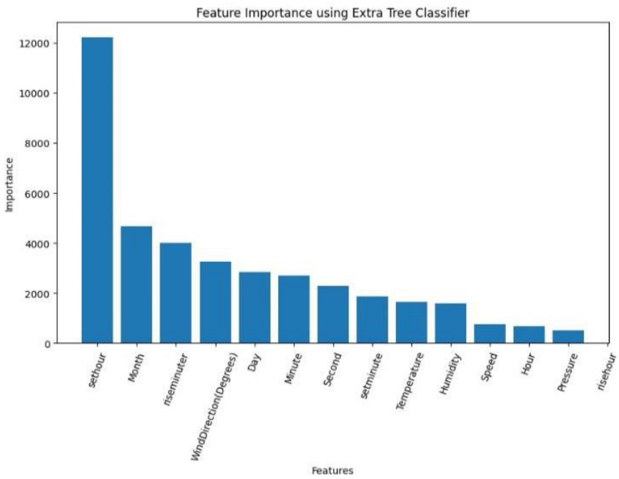

Fig. 5.1 Tree Classifier

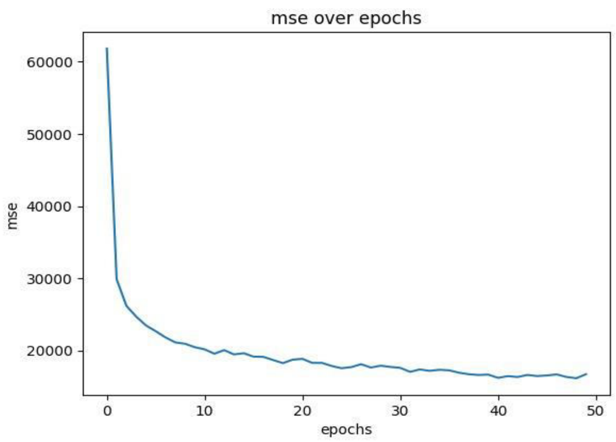

Fig. 5.2 MSE over epochs

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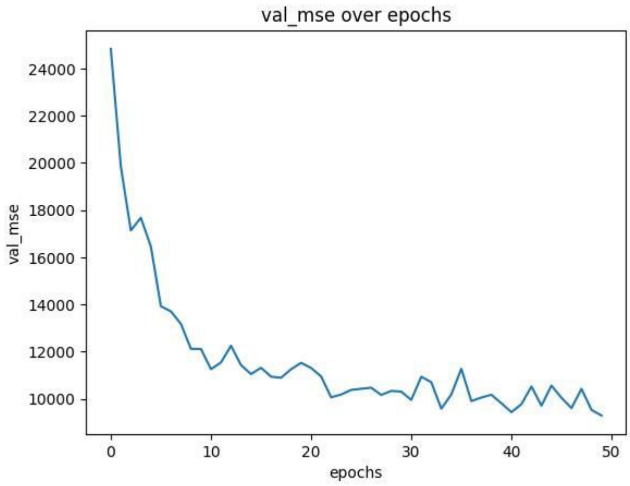

Fig. 5.3 val_mse Over epochs

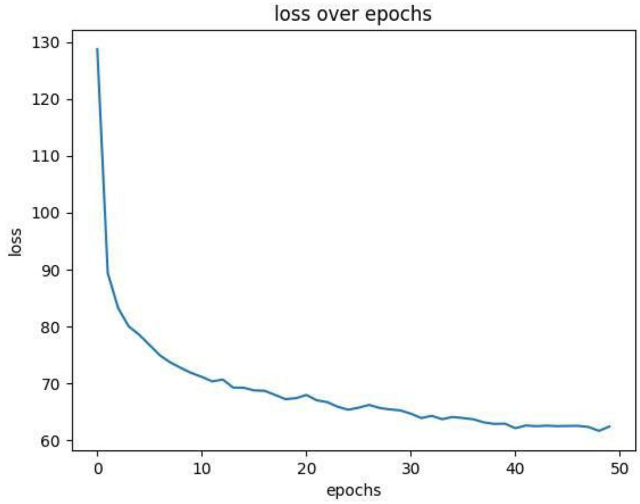

Fig. 5.4 Loss over epochs

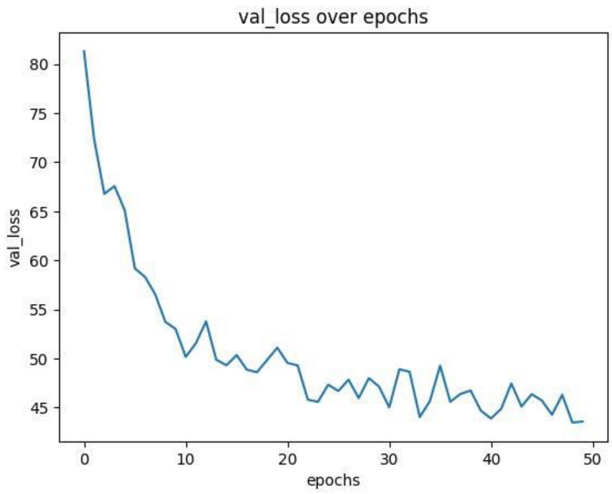

Fig. 5.5 val_loss over epochs

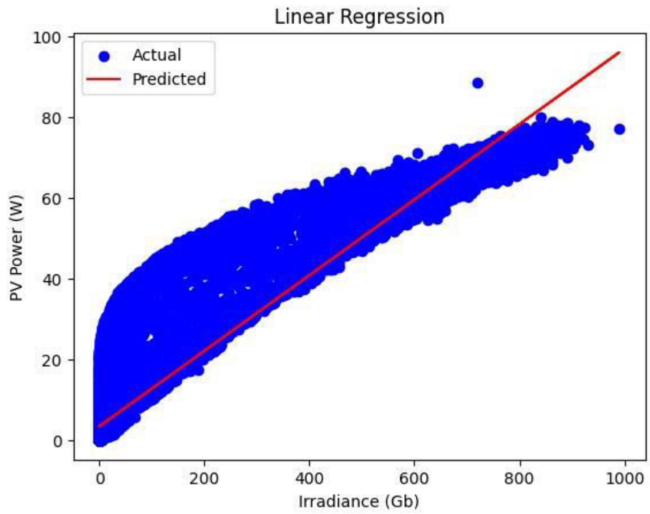

Fig. 5.6 Linear Regression

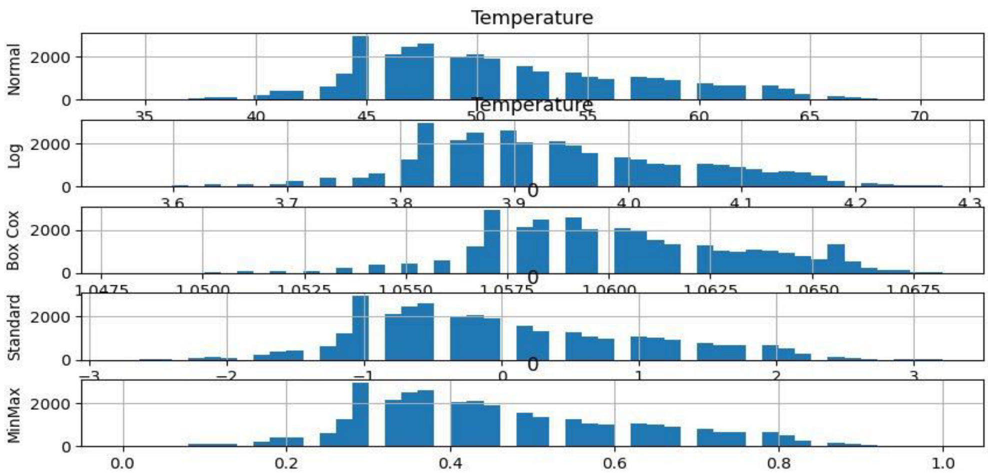

Fig. 5.7 XGB result

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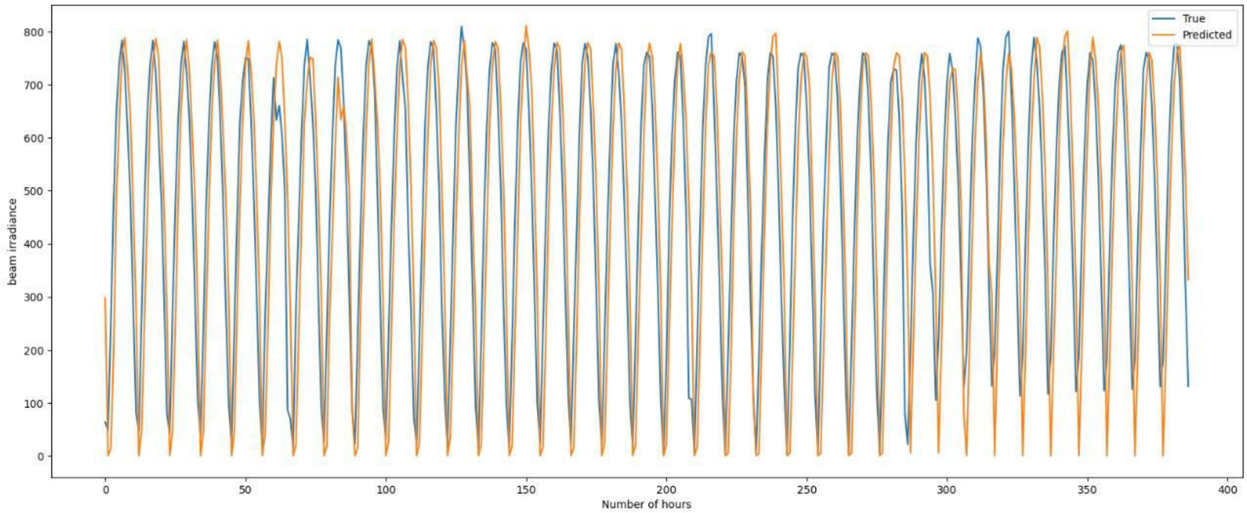

Fig. 5.8 Final Result

V. CONCLUSION

In conclusion, implementing an AI-based solar UPS system using Arduino hardware presents a compelling solution for optimizing energy utilization, enhancing system efficiency, and ensuring uninterrupted power supply in off-grid or grid-tied solar installations. As renewable energy adoption continues to grow, AI-based solar UPS systems have the potential to play a pivotal role in maximizing the efficiency, reliability, and sustainability of solar power generation and energy storage. By intelligently managing energy flow, adapting to changing environmental conditions, and optimizing system performance, these systems contribute to the advancement of clean energy technologies and the transition towards a more resilient and environmentally friendly energy future.

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