

AI Powered Smart System for Forecasting and Optimizing Solar Energy Usage

Kokkula Varshini¹, Kasiojjala Meghana², Madugani Sai Chandana³, Gurralla Harshitha⁴, E. Shireesha⁵

^{1,2,3,4}UG Student, Department of Computer Science and Engineering,
Jyothishmathi Institute of Technology and Science, Karimnagar, Telangana, India

⁵Assistant Professor, Department of Computer Science and Engineering, Jyothishmathi Institute of
Technology and Science, Karimnagar, Telangana, India

¹varshinikokkula60@gmail.com, ²meghanakasiojjala@gmail.com, ³maduganisaichandana@gmail.com,
⁴harshithareddy0573@gmail.com

Abstract—Solar power is among the most widely used sources of renewable energy due to its cleanliness, sustainability, and ease of access. However, the generation of electricity from solar energy can fluctuate throughout a day due to changes in sunlight intensity, temperature and weather conditions which creates difficulties for properly utilizing the generated solar energy without accurate assessment/forecasting through adequate monitoring as to how much solar energy will be produced at any given moment. Also, many existing solar systems do not have smart capabilities that provide the user with important information on how to utilize their available solar power or what would be the best way to use it. The proposed project details research into an AI based smart system that forecasts and optimizes how solar energy will produce, through the collection of various environmental data (sunlight intensity, temperature, date, time) to provide a prediction of how much solar energy will be produced by plants and offer valuable information and guidance on household appliances that are ideal for usage when solar energy is abundant. Additionally, the proposed system includes a simple user interface, designed to provide the user with an easy way to track their solar energy production and manage their energy consumption. The proposed smart system aims to increase the efficiency of using solar power and improve the energy use of households by providing users with reliable forecasts of how much solar power will be generated so that users can save on electricity costs and will make better use of renewable energy.

I. INTRODUCTION

Solar power is considered one of the major renewable resources because of its environmentally friendly nature and availability. The increase in demand for power and the need to reduce the effects on the environment have led to an increase in the use of solar energy as a means to produce electricity in business as well as in the home. The amount of solar energy produced will vary from hour to hour each day depending on a number of different environmental variables (e.g., sun intensity, temperature, weather conditions, and time). Due to these environmental variables it is often difficult to utilize solar energy in an efficient and effective manner without having advanced monitoring and prediction systems.

Traditional solar systems primarily produce electricity, rather than having an intelligent capability to monitor and optimize. As a result, it is difficult for users to know the amount of solar energy produced at any point in time, and therefore users do not utilize the produced energy in an efficient manner. Thus, poor energy management occurs and large quantities of electricity are used from non-renewable sources instead of solar energy. To maximize the utilization of solar energy systems, a smart system needs to be developed that will predict solar energy generation potential and assist users with an accurate manner to efficiently utilize energy.

The objective of this research project is to design and implement a smart forecasting/optimising system powered by artificial intelligence (AI) to maximise the use of solar energy. The proposed system collects raw environmental data (e.g., the intensity of sunlight, ambient temperature, date and time) that are used to generate an estimation of the total amount of solar energy that will be generated during the day. In turn, this will provide users with recommendations on how they can use their appliances based on when peak generation is expected. The main purpose of this system is to allow users to be more efficient with their solar energy production and to decrease their reliance on traditional electricity.

In addition to this, the system includes a user interface (UI) with a standard web-browser front-end where users can sign in to see forecasts for solar energy and recommendations for usage of appliances (based on the forecasted energy generation). The primary purpose of the UI is to provide users with up-to-date information regarding the status of solar generation and recommended times of use for specific appliances, as well as displaying the current environmental conditions and the amount of solar energy that is expected to be generated in the near future. The combined functionality of prediction and optimisation provided by the proposed system is intended to improve energy efficiency through improved management of renewable energy generation resources.

II. LITERATURE REVIEW

Numerous researchers have investigated the forecasting of solar energy through AI methods. For example, Putri Nor Liyana Mohamad Radzi et al. (2023) identified various machine learning techniques for predicting photovoltaic performance in order to demonstrate how AI models can enhance the precision of forecasting and aid in the management of renewable energy[1]. The contribution of K. Sudhakar and P. Srivastava (2023) was the use of AI and machine learning methods to understand solar energy productivity as well as to develop accurate forecast models for photovoltaic arrays[2]. Wei Guo and colleagues (2024) created deep learning algorithms based on weather related data in order to forecast energy from photovoltaic sources with higher accuracy than existing models provide[3]. C. Nithya et al. (2024) implemented LSTM type systems for real-time solar energy forecasts in buildings, demonstrating that using time series forecasting can enhance the ability to monitor solar energy in buildings[4]. V. Gayathry et al. (2024) demonstrated that AI can aid in forecasting solar irradiance using AI models and thus improve the accuracy of forecasts for solar energy[5]. Md Asif and B. Spoorthi (2025) created hybrid machine learning types of predictive models for photovoltaic systems, enhancing the efficiency of solar arrays under changing weather patterns[6].

III. PROBLEM STATEMENT

Solar power is a commonly used form of renewable energy, but it requires certain environmental conditions (e.g., sunlight amount/intensity, temperature, or changes in weather) for it to be generated. Therefore, it is difficult to estimate how much solar power will be produced at any given future point in time. Due to the environmental variables that influence solar energy production, many of the more standard solar energy systems do not have the accuracy and/or capabilities in terms of forecast/output monitoring necessary for them to function optimally. As a result, many users do not know how to best use electricity based on the estimated production of solar energy, resulting in reliance on fossil fuel-based electricity production systems and inefficient use of energy from multiple electrical sources.

To address these issues the developer has designed an intelligent systems level approach for either directly monitoring the environmental conditions associated with solar energy generation (as well as predicting future outputs of solar energy based on past solar output measurements) or using advanced prediction/forecasting and optimization methodology for solar electricity consumption based on real-time environmental conditions. With this approach; users will be provided with information regarding the best electricity consumption and utilization patterns based on the availability of potential solar electricity generation. This solution will enable users to make wiser decisions about their electrical consumption and, as result, the efficient utilization of solar-related electric energy generation systems will increase.

IV. EXISTING AND PROPOSED SYSTEM

A. Existing System

Currently, renewable sources of energy can be generated from the collection of light via solar panels; however, many existing systems are unable to efficiently monitor and predict how much energy will be produced from this type of system due to the rapidly changing environmental conditions that ultimately determine how much solar energy will be produced (i.e., sunlight and temperature). Due to the limitations of most* conventional systems, accurate data regarding the amount of solar energy availability is typically not provided, making it difficult for users to effectively utilize or plan their energy consumption. This causes users to utilize both renewable sources of energy and conventional electricity, despite the availability of renewable sources of energy. Additionally, the ineffective forecasting and optimization aspects of solar energy systems limit the efficiency of these systems, as measured, maximized, and minimized by the total amount of solar energy utilized.

B. Proposed System

An AI Intelligent forecast framework for forecasting and maximizing solar energy consumption is proposed. The system gathers environmental variables (light intensity, temperature) and from this information has the ability to predict How much solar energy will be produced.

User login/authentication capabilities Provides users secure access to the system and enables them to review solar energy usage. Real-time monitoring for solar energy parameters Helps users view current availability of solar energy based on climate change/weather parameters. Recommendations on efficient energy consumption, i.e. will provide the best time to utilize electrical devices based on solar energy availability. Dashboard to provide solar energy information Will show key metrics related to solar energy, will include solar energy levels, date, time and predicted values.

V. SYSTEM ARCHITECTURE

Several parts make up the system architecture for the proposed solar energy optimization system. All these components need to work together in order to collect data to be processed into useful information for a user. There are specific functions for all of these components.

A. User Interface (Frontend)

The user interface is that part of an application in which the user is interact with the application; for example, the login page and dashboard would make up the user interface of the application. At the dashboard, the user would access all the solar energy information, such as sunlight, temperature time, date, and estimated energy. Therefore, the front-end has been created to be easy and friendly for users to understand the information presented.

B. Data Collection Component

The data gathering element will collect environmental data like sunlight intensity, temperature, day of week, and time. These variables can impact the solar energy produced from PV panels and acquiring accurate data is essential to that end.

Once the data is collected, it will be sent to the processing portion of the system for further evaluation and analysis of the accumulated data.

C. Processing Component

The collected data is processed to prepare it for prediction. This includes organizing the data and making sure it is in a suitable format for input into the predictive systems. The processing component also helps the entire predictive system run smoothly by coordinating the flow of data among different areas of the predictive system.

D. Prediction Component

The solar energy estimate component checks how much solar energy is produced by checking the weather data collected from the surrounding environment to find out how much solar energy will be available. Using this estimate helps users determine how much solar energy will be produced at any given moment in time.

E. Recommendation Component

The recommendation section provides information on how to improve energy efficiency through the suggestions provided by the recommendation engine. It uses the anticipated output of solar energy in making its recommendations for when you should operate your electric appliances. This allows for maximum benefit from solar energy and cost savings on your electricity bill.

F. Database Component

User information and solar energy data are maintained in the database as stored or recorded items. Previous predictions and their associated environmental data are maintained in the database using historical information for future system enhancements.

G. Output Display Component

The display output section has results. You will see information about energy from the sun, weather data, and advice about how best to use solar energy to consume lots of energy in very simplified formats. This allows end-users to monitor and manage their usage of solar energy much more effectively.

Architecture of the proposed AI-powered smart solar energy forecasting and optimisation system is structured in such a way as to efficiently collect process analyse and optimise solar energy usage. This is achieved through the use of multiple layers in the architectural design; that is data collection layer, data processing layer, machine learning modelling layer, and user interface layer.

The data then flows to the machine learning modelling layer where machine learning algorithms are applied to forecast

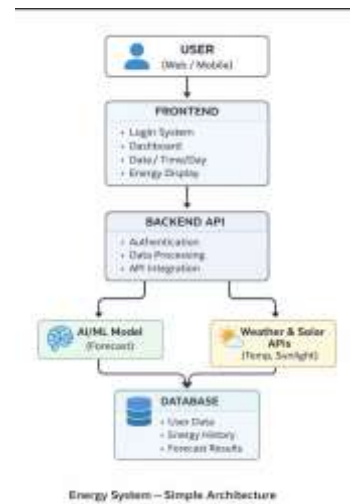


Fig. 1. system architecture

solar energy generation as well as predict energy consumption patterns based on the historical and real time data.

Using the results from the forecast (from the machine learning modelling layer) an optimal usage schedule is created by the optimisation module which communicates how best to utilise the available solar energy based on when to schedule the use of household appliances as well as when to charge/discharge energy storage devices.

Finally, the results are displayed to users through a web-based graphical dashboard which displays solar forecast energy consumption, AI based recommendations for household appliances and estimated cost savings. Therefore, the overall system architecture provides a means of providing an efficient management solution for solar energy by reducing waste and offering a smart sustainable solution for solar energy optimisation.

VI. IMPLEMENTATION AND ALGORITHMS

The suggested AI driven Smart Solar Energy System calculates future estimates through the aggregation and estimation of how much Solar Power will be generated using existing date collected from estimated Solar Insintenty, temperature and the time of day.

A. Solar Energy Estimation Algorithm

Calculation of Solar Energy:

The Solar Energy Estimation Algorithm makes an estimate about how much solar energy will be generated given the amount of sunshine available. This algorithm calculates the amount of sunlight that falls on a solar panel (the Physical Area) and how much of that amount can be converted into electrical energy based on the way the solar panel is made.

Formula for Estimate of Solar Energy:

$$Esolar = I * A * n$$

Where: I = Amount of Sunshine, A = Amount of Solar Panel Area, n = Amount of Efficiency the Solar Panels are Expected to provide.

B. Sunlight Intensity Analysis (SIA) Algorithm

SIA Algorithm Analyzes Sunlight Intensity The SIA Algorithm enables the system to determine the amount of sunlight for any given time of day. This is accomplished by comparing the measured amount of sunlight for any instant with the highest level of sunlight for the day to determine the current level of sunlight based on low, medium, or high levels of light. This information will also be used to help develop visual representations of the pattern of sunlight using charts.

Mathematically:

$$Slevel = I_{current}/I_{max}$$

Where, $I_{current}$ = Current amount of sunlight intensity//
 I_{max} = Maximum amount of sunlight intensity for the day.

C. Smart Appliance Scheduling Algorithm

The Smart Appliance Scheduling Algorithm allows for scheduling appliances' usage while maximizing the use of solar energy. To estimate total energy consumption of all the appliances, we can calculate the total energy consumption (L_{total}) as follows: Total Appliance Load = P_i , where P_i = power required by each appliance.

By comparing L_{total} to the useable solar energy available, we can suggest running appliances at times where there is an abundance of solar energy available to power our appliances.

D. The Energy Savings Calculation Algorithm

Energy Savings Calculation Algorithm: The Energy Savings Calculation Algorithm estimates how much money a user can save by utilizing solar energy. It calculates the daily electricity cost and then estimates the savings based on the portion of energy replaced by solar power.

Formulas:

$$Cost_{daily} = E_{daily} \times C_{unit}$$

$$Savings_{daily} = Cost_{daily} \times O$$

$$Savings_{monthly} = Savings_{daily} \times 30$$

Where: E_{daily} = Daily energy consumption C_{unit} = Cost per unit of electricity O = Solar energy offset ratio

VII. RESULT AND ANALYSIS

The AI-based Solar Energy Optimization Software project was finalized and ready for implementation after going through an exciting development and launch process. The software has been tested and is functioning successfully. The software creates predictive values based upon information it collects from real-time environmental data (sunlight intensity, temperature, current date/time) to forecast how much energy will be produced from solar panels. Forecasted values of solar power will be displayed on the dashboard in an easily readable format.

Illuminating suggestions for how to efficiently utilize energy will also be generated from the forecasted solar energy values. Testing results showed that solar energy forecasts were greatest during peak hours of sun, with lower estimates for before sunrise and after sunset. Knowing when solar energy will be available provides exact guidance on optimal times to operate electrical devices, which leads directly into major



Fig. 2. Solar Mind interface



Fig. 3. AI Energy forecasting

energy conservation efforts that could result in significant monetary savings for end-users. This project presents a smart system for forecasting and optimizing solar energy usage using AI and machine learning techniques. The system analyzes environmental data such as sunlight and temperature to predict solar energy generation and provide useful suggestions for efficient energy utilization. The results show that intelligent prediction models can help improve solar energy management and reduce dependence on conventional electricity. Overall, the proposed system provides a simple and effective solution for better utilization of renewable energy.



Fig. 4. AI-based energy optimization interface



Fig. 5. Visualization of solar and grid energy consumption



Fig. 6. Smart appliance scheduling based on solar energy



Fig. 7. Solar system configuration settings

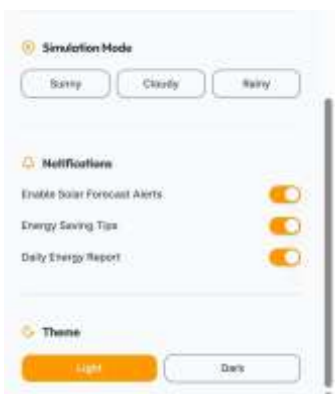


Fig. 8. Notification and theme customization settings

VIII. CONCLUSION

This paper describes a solar energy forecasting and optimizing intelligent system powered by AI. This intelligent system will use solar intensity, temperature, and time information to provide estimates of the amount of solar energy generated and predictions on how much solar energy will be available in the future, based on the applicable algorithms. The algorithms that are executed by the intelligent system will calculate the solar power generated, total energy generated, energy consumed, and energy remaining, and these values will appear on the intelligent system dashboard. The study's results demonstrate that this intelligent system forecasts solar energy well and assists end-users in managing energy usage. The intelligent forecasting and estimation methods improve energy operations and minimize energy waste. This intelligent system offers a dependable and intelligent solution for the most efficient utilization of solar energy and environmentally sustainable energy management solutions for residential applications.

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