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INTEGRATING AI AND IOT IN SOLAR POWER SYSTEMS FOR IMPROVED MONITORING AND PREDICTIVE MAINTENANCE

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Abstract

An AIOT Based solar power monitoring system consists of a solar panel, sensors, microcontroller, Wi-Fi module, server and a computer or smart phone to visualize real time parameters, in an AIOT based solar monitoring system solar panels harness sun light from sun and convert it into DC voltage. This dc voltage is stored in batteries for later use and can be converted into ac by using inverters and to be connected to your load. By using this system, we can measure and monitor the real time output parameters of our solar system, such as solar power, solar voltage, solar current and in software side in dashboard many modules and functionalities are added like battery life predication, weather predication using google API, maintenance and power generation predication. In this some module use AI algorithm like Machine Learning Algorithm to predicate battery life before taking some input from user. This system is built to increase in the power generation and reduce the maintenance cost.

INTRODUCTION

Generating power energy has become a major factor in every sector of industries throughout the world. However, the energy demand reaches at its peak, due to this all the sectors are shifted towards the renewable Energy sources, this can help the sectors to increase in productivity and decrease in costs [1].

Among this solar power system has become increasingly popular source to generate electricity, Due to availability and low cost of solar panels [2]. Currently AIOT (artificial intelligence of things) based technology has been involved which make the things smarter and user-friendly and by using this technology machines can communicate with it selves and can be controlled without enrollment of any humans.

An AIOT based solar power monitoring system is capable of measuring different parameter like voltage, current, temperature and faults of system that can help the system to be more efficient [3]. However, AIOT technology uses advance algorithms to make the sensor's more intelligent which can help to harness more energy from the sun and produce more electricity.it also helps to optimize the performance of the system [4]. For instance, An AIOT based solar monitoring system can also face variety of challenges like increase temperature of solar panels and weather condition that can affect the performance as well as the decrease in production of electricity [5]. so, to encounter all this challenges an AIOT based solar monitoring system plays an important role in all sectors.

This system will be capable of predicating battery life of different type of batteries. And from this feature the system performance will increase more as

compared to other all systems. And user can also perform the tasks if generation is low. All of these capabilities are used to increase the generation and reduce the cost of the system [6].

RESEARCH METHODOLOGY:

Using of Agile model is good for this type of project because agile model is advanced and deals with sprints as compared to waterfall model. An AIOT-based solar power monitoring system is complex system that requires carefully planning and implementation to achieve the goals and objectives.

The methodology for developing this advance monitoring and predication system involves in selecting suitable sensors, microcontrollers, wireless communication route and developing a friendly user interface and also testing the system's functionalities. This requires a deep knowledge and understanding about the principles of solar power systems, sensors technology, microcontroller programming, wireless communication, and user interface with some Knowledge about Artificial intelligence.

The success of building an AIOT-based solar power monitoring and predication system depends on the accurate selection and integration of all components require for developing. The sensors must be reliable and capable of interacting with the microcontroller. The microcontroller must be capable of processing the data and interacting with the user interfaces to fetch the sensor data. The wireless communication module must be reliable and capable of interacting with the microcontroller and different smart phones. The user interface must be attractive and easy to use, and should provide real time data fetch from different sensors. User interface must also have different functionalities like battery life prediction, power generation predication, weather prediction and many more. By following this methodology, it is possible to develop an advance monitoring and prediction system with AIOT technology. By using this technology system can be improved and cost reduction.

The AIOT-based solar power monitoring system comprises of several key steps, as listed below.

1. **Selection of Microcontroller:** Once the sensors are selected, the next important step is to choose an appropriate microcontroller capable of interacting with the sensors and wirelessly transmitting the data Parameters. The microcontroller should be capable of processing the data from sensors interfacing and fetch the values to the user interfaces.
2. **Wireless Communication Selection:** An appropriate wireless communication module should be use to transmit the data values wirelessly to the user interfaces. The wireless communication module should be reliable and capable of interacting with the microcontroller.
3. **Development of User Interface:** Once the data is transmitted wirelessly to the user interfaces, the next step is to develop friendly user interface for displaying the data. This includes a mobile application, and a computer screen.
4. **Maintenance:** The AIOT-based solar power monitoring and predication system should be capable of generating alerts when measured parameters fall below or exceed set threshold values. This requires setting an appropriate threshold value and developing a mechanism for generating alerts and to handle this alert scheduling some tasks to user.
5. **Integration and Testing:** Once all the components have been selected and developed, the final step is to integrate the components into a system and test all the functionalities. This may involve testing the sensors, microcontroller, wireless communication and data user interface.

The assembling of hardware components and developing of user interface in an AIOT-based solar power monitoring and predicating system, enhanced by artificial intelligence (AI), involves a meticulous integration of various technologies to increase the performance and efficiency of the system.

The main component of this system is solar panel, which absorb light from sun to generate electricity. To monitor this energy generation effectively, the system uses several types of sensors: voltage sensors measure the volts, current sensors measure amperes and temperature sensors measures the temperature of the environment. Each sensor plays an important role in capturing data parameters. that is essential for assessing the system's performance. These sensors are connected to an ESP32 microcontroller, a powerful device that acts as the central processing unit of the system.

The ESP32 microcontroller is responsible for gathering data parameters from different sensors and provide platform for communication between the hardware and the software. It transmits the collected data parameters to a software platform, which can be run on smart phones and computers whereas in software user can also see different functionalities on dashboard.

The AI algorithms applied in this software analyze the incoming data parameters in real-time, and by utilizing machine learning techniques the next value of current and voltage is predicted. However, predication of battery life, weather predication and power predication for the next days are also done by this technique predictive maintenance algorithms monitor the system if the system performance gets low it schedules some tasks to user to increase performance. The user interface extends to mobile and web applications, where AI-enhanced dashboards present data. Users can remotely access the system by using smart phone And computers.

1. **Microcontroller:** The ESP32 microcontroller is also known as the central processing unit of the system. It receives data from different sensors, then processes the data and transmits the data wirelessly to the user interfaces dashboard.

Figure 1 (ESP32 Microcontroller)

2. **Solar Panel:** The solar panel is the main component in the overall project that generates electricity from Sunlight. It consists of photovoltaic cells that absorb light from the sun and convert it into electrical energy. Solar panel is made from semiconductor materials such as silicon. When light of sun falls on the PV cells, it releases the electrons in the semiconductor material. The energy generated by the PV cells is in the form of direct current (DC) electricity.

Figure 2 (Solar Panel 3v 8v)

3. **Temperature Sensor:** Temperature sensor is used to measure the temperature of the environment. It provides data of the temperature of the environment, which can affect the performance and efficiency of solar panels.

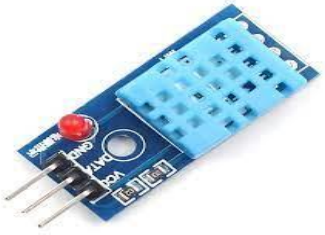


Figure 3 (Temperature Sensor DHT11)

4. **Voltage Sensor:** Voltage sensor is another main component used to measure the voltage of the solar panel. It provides the voltage data generate by the solar panel.

Figure 4 (Voltage sensor ZMP101B)

5. **Current Sensor:** Current sensor is used to measure the current generated by the solar panel. It provides the current data flowing through the solar panel, which can be used to calculate the amperes generated by solar panel.

Figure 5 (Current Sensor ACS712)

6. **Batteries:** The power supply is used to provide power to the system. There are rechargeable batteries and non-rechargeable batteries. The one that can be recharged is also known as a secondary cell, storage battery, or accumulator. Electrical batteries of this kind can be charged, discharged during use, and recharged multiple times. Rechargeable batteries are available in sizes and voltages.

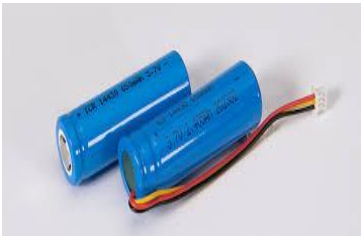


Figure 6 (Batteries)

Block Diagram:

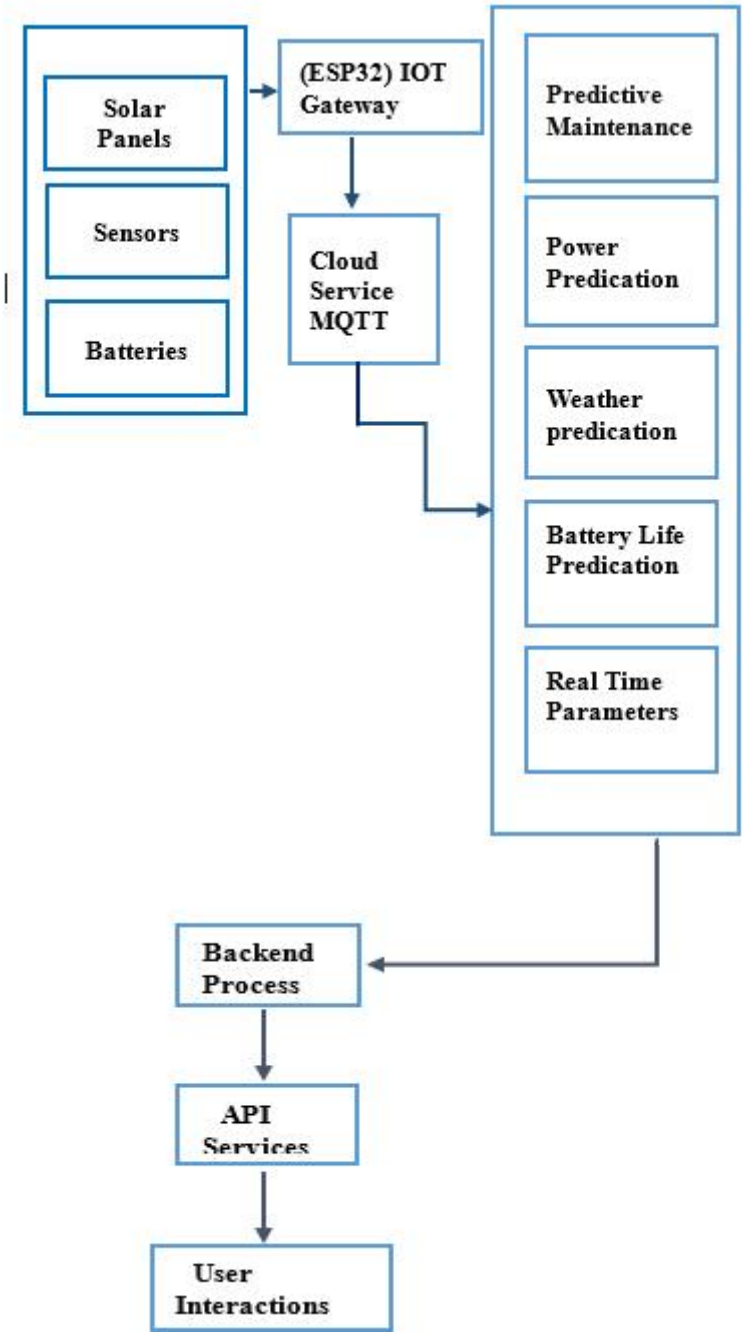


Figure 7 (Overall System Block Diagram)

In Figure 7 the overall system design block diagram, in this block diagram the first block shows the hardware materials, this includes solar panels, sensors and batteries. The next block show ESP32 micro controller (IOT Gate Way). The working of this block is to collect the sensors data from the sensors first block and forward it to the third block which is MQTT Protocol. This block is used to store the sensors data coming from sensors at real time. After then the fourth block show the AI Prediction use in this system. This includes different AI model for different Predictions like Battery Life Prediction

use decision tree model to predict remaining battery life, Power prediction use LSTM model to predict the next power generation based on some previous data, weather prediction to predict the weather forecast and a predictive maintenance use decision tree model etc. and in the backend process block user friendly interface is built by using flutter and the second last block some API are connected to the software like weather API to monitor current weather. In the last block a user interaction interface is built to monitor the system through smart phone and computer anywhere in the world.

Our goal is to use the AI and IOT technology to increase the system performance and decrease the cost.

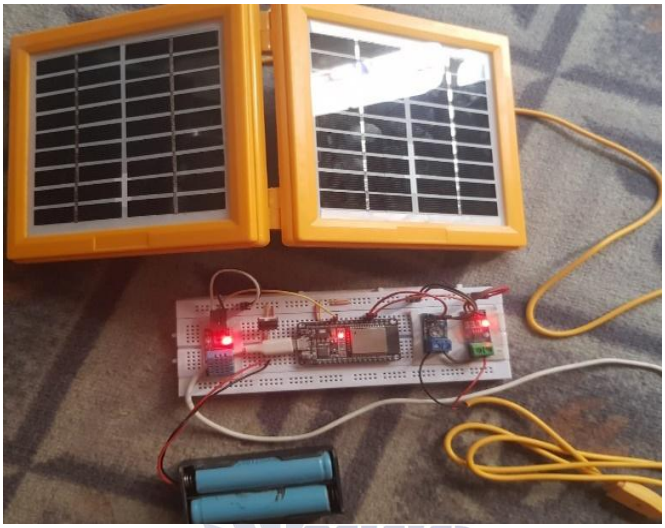


Figure 8 (Hardware Section working)

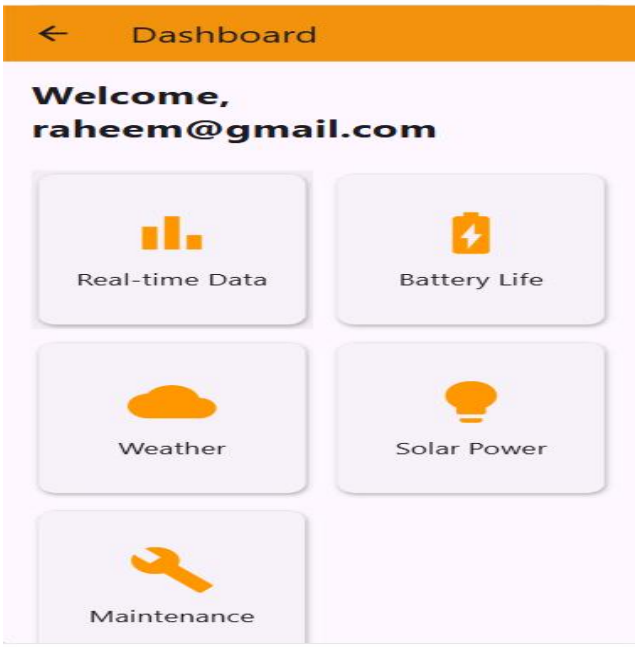
RESULT:

The working of the proposed system is shown in fig 8 and 9, in fig 8 the hardware is shown, in hardware there are three sensors, a microcontroller and a transistor with some wires. The working of the hardware is to fetch the real time parameters from solar like current, voltage and temperature and send the data to ESP32 microcontroller.

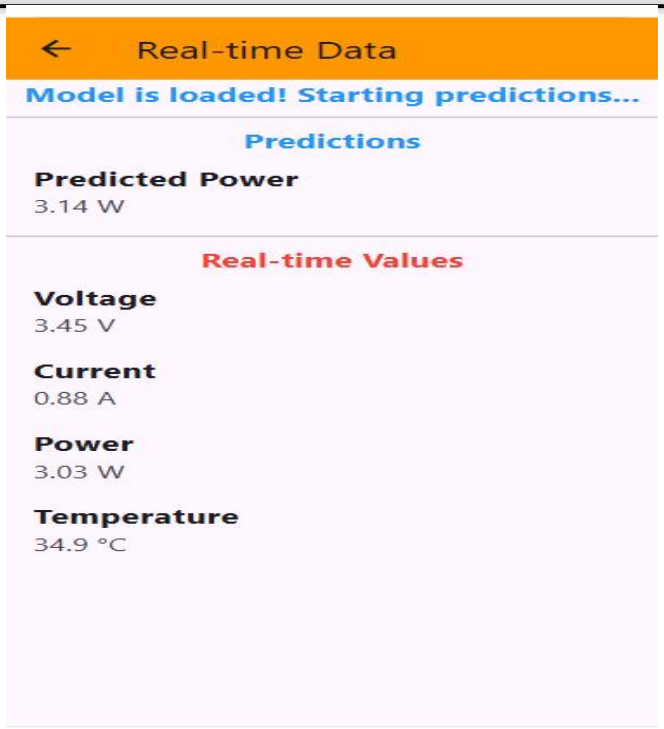
This ESP32 microcontroller is connected to backend MQTT protocol to fetch the values and display to the dashboard. And in fig 9 the software side is shown. In software there are different modules and functionalities like real time, battery life predication, weather prediction, maintenance and power predication.

In this software AI Algorithm is also use for battery predication. It will take some user input depending on that parameter's battery life will be predicted, Power Generation Prediction, based on previous data, Weather Prediction and Predictive maintenance. In predictive maintenance module there is also addition of some tasks for user to perform at the time when the generation is low or it breaches the threshold value.

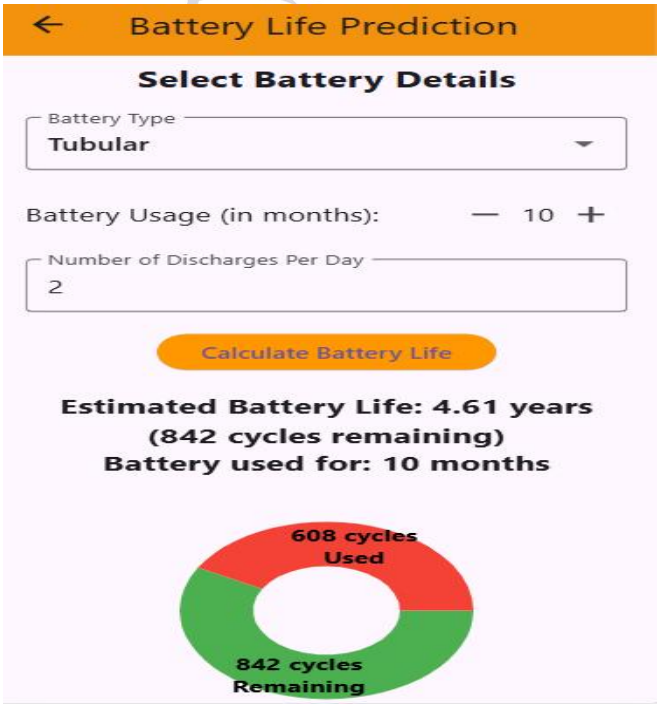
In this as we can see that there is a user authorization page, in this page first user will sign up her/his name than an email and then register itself after he/she can login. The data of the user will be saved in the firebase
Database for authorization.



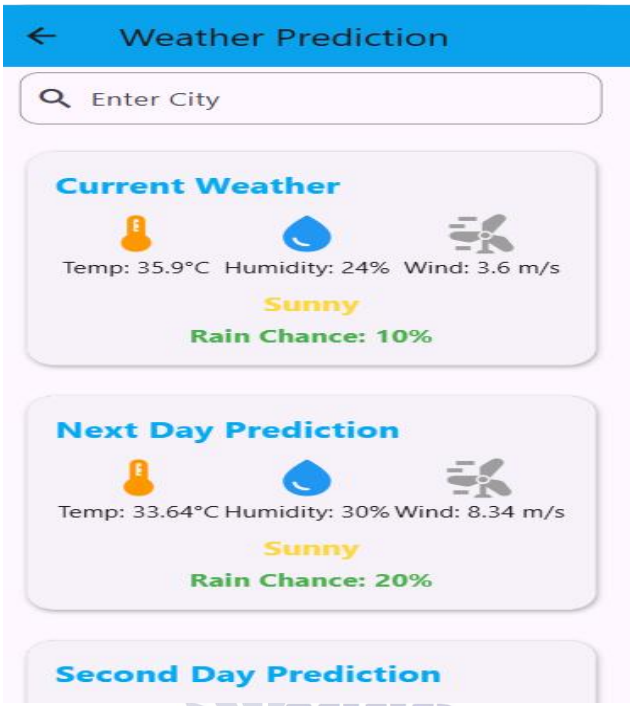
After signup and login user will enter to the dashboard page
In this user can see a dashboard including different features
Including Real- time Data, Battery Life, Weather, Solar Power and Maintenance options.user can visualize any of the option by clicking on the feature.



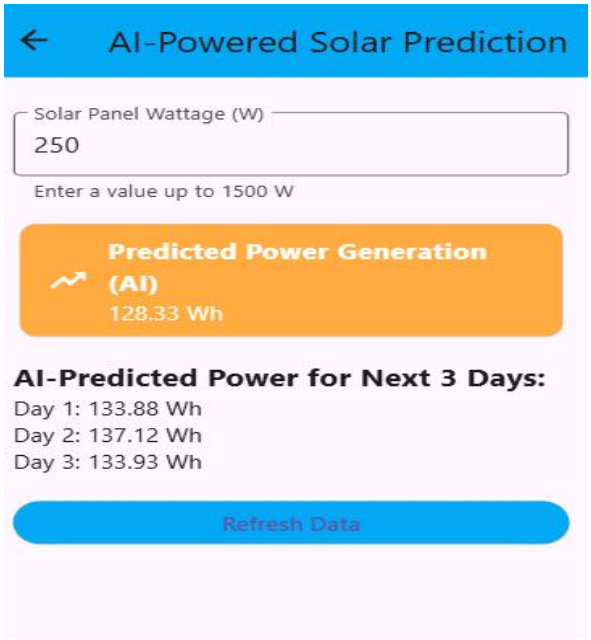
This is the Real-Time Data feature in the user can visualize the real time data coming from different sensors. And based on this data AI model Predicts how much power will be generated.



In this Battery Life Prediction page user can visualize the remaining battery life. User will input some parameter like Battery type, battery usage and after than AI train model will analyze the data and based on this data AI model will predict the remaining battery life.



In this page user can monitor the weather condition as user can also search for the new city. In this page current weather and next 2 days' weather can be seen. This will update a user that how to use your generation after monitoring weather condition.



In this page user can visualize the AI power generation Prediction. User can input solar panel wattage that he installed. After that AI model will predict the power generation based on solar panel wattage. AI model will also Predict power generation for next 3 days.

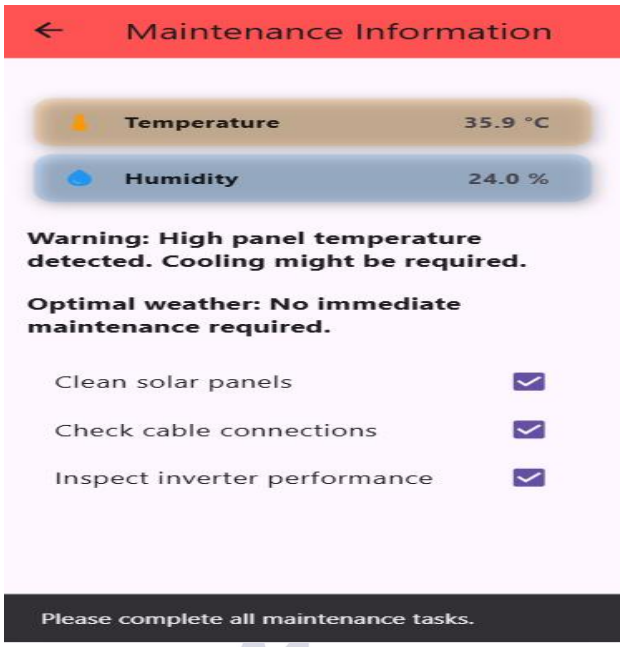


Figure 9 (All Software Section working)

In this Page User can see maintenance information Predictive maintenance is done by AI train Model if the generation is low AI model will assign some tasks to user
On notification. After performing the assign tasks generation may be increased if there is no big problem.

CONCLUSION:

The Combination of artificial intelligence (AI) algorithm with an IOT-based solar power monitoring system represents a significant advancement in the field of solar energy management. This system offers real-time monitoring and analysis of solar panel parameters, delivering a range of benefits that include enhanced solar panel efficiency, reduced maintenance costs, and increased system reliability.
The system's hardware setup features solar panels, voltage and current sensors, and ESP32 microcontroller. The ESP32 microcontroller serves as the central unit, connecting the hardware components to the software applications. It processes sensor data and transmitting it to the mobile and computer applications.
On the software side, the system comprises a mobile application and a computer program that leverage AI algorithms. These algorithms are designed to increase system's performance. By applying machine learning techniques, the AI algorithm can predict battery life, next day power generation based on weather condition, and suggest maintenance actions. This predictive capability allows for more efficient system management and cost savings through timely maintenance.

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