



# IoT Based Solar Charge Controller with Auto Adjustable Panel Using Image Recognition

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## Abstract—

Despite the increasing demand for PV energy, the output from panels and cells is often suboptimal due to the unpredictable nature of the environment. In this work, we focus on IoT connectivity, remote monitoring using an Android app, and graph plot visualization with our developed Python software. To address the variability in environmental conditions affecting PV output, we have developed an IoT-based solar charge controller (SCC) with remote monitoring capabilities.

Our system utilizes IoT-based sensors to continuously monitor and upload vital performance data, such as voltage, current, and temperature, to the cloud. This data is then accessible in real-time, allowing for effective remote management and tracking. The incorporation of IoT technology facilitates proactive maintenance and quick troubleshooting, significantly enhancing the reliability and efficiency of the solar power system.

The core of our system is the PIC16F73 microcontroller, which handles the power (MPPT) algorithm to ensure the solar panels operate at their optimal power output. The Android app we developed provides a user-friendly interface for monitoring the system's performance. Additionally, our Python software offers advanced graph plot visualization, enabling detailed analysis of the system's data over time.

By leveraging IoT connectivity and robust remote monitoring tools, our solution not only optimizes the performance of photovoltaic systems but also simplifies the management process for users. This integration of technology ensures that PV systems can adapt to varying environmental conditions and continue to deliver efficient and reliable power.

**Keywords—** IoT, Charge Controller, Remote monitoring, Solar Charge Controller

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## I. Introduction

There has to be more dependable and efficient solar power systems because the demand for photovoltaic (PV) energy is on the rise. Unfortunately, because environmental factors are notoriously difficult to estimate, PV panel and cell performance is frequently subpar. In order to guarantee optimal performance, PV systems require specialized methods to deal with factors like changing solar intensity, shade, and temperature variations.

Because of these external variables, traditional PV systems frequently fail to sustain full power output. Consequently, systems with the ability to adapt to

new circumstances in real time are urgently needed in order to optimize energy harvesting.

In this work, authors concentrate on improving the efficiency of PV systems by connecting them to the internet of things (IoT), allowing remote monitoring through an Android app, and visualizing graph plots with our own Python program. Not only does this system streamline user management and maintenance, but it also accounts for the fact that environmental conditions might be unpredictable, which affects PV output.

## System Overview

Authors system uses sensors that are based on the Internet of Things to constantly track and upload



critical performance data to the cloud. This data includes things like voltage, current, and temperature. The PV system's operating status may be thoroughly assessed with the help of real-time data collected by these sensors, which are strategically distributed throughout the system. An Android app makes it possible to remotely access the collected data stored in the cloud server. The ability to access data in real-time allows for efficient remote tracking and management, letting users keep tabs on the system's performance regardless of their location.

#### **IoT Connectivity**

Authors system's functionality relies heavily on the integration of IoT technology. The Internet of Things enables the PV system's components to communicate with the remote monitoring platform without any hitches. With this connection, data is constantly transferred to the cloud server, giving you the most recent stats on how well the system is doing. Connectivity to the internet of things also allows for preventative maintenance and rapid troubleshooting, which greatly improves the solar power system's efficiency and dependability.

#### **Remote Monitoring**

The main interface for remote monitoring is the Android app that authors built. Among the many useful performance indicators shown on the app's intuitive dashboard are the current power output, voltage levels, and system temperature. Users can also see trends and historical data, which helps them spot patterns and make smarter decisions when managing the system. In the event of an anomaly or a decline in performance, the app's alert system will notify users so that they can take immediate action to restore the system to peak performance.

#### **Data Visualization and Analysis**

Our solution incorporates sophisticated graph plot visualization features built using Python software, in addition to real-time monitoring. With this function, users can analyze the system's data in great detail over time. Data trend visualization allows users to understand the PV system's health and performance over time. The power output over time, temperature fluctuations, and efficiency curves are just a few of the charts that the Python script can provide, giving you a better picture of how the environment affects the system's performance.

#### **Graph Plot Visualization**

A potent method for evaluating complicated data sets is graph plot visualization. Data acquired by the Internet of Things (IoT) sensors is processed and shown in an easily understandable way by our

system's visualization module, which is based on Python. Individual parameters can be highlighted in the plots, multiple time periods can be compared, and the visualizations can be exported for report writing. Improving the efficiency of the PV system and organizing its upkeep both necessitate this degree of research.

#### **System Architecture**

The PIC16F73 microcontroller is important to our system; it is responsible for controlling the maximum power point tracking (MPPT) algorithm, which maximizes the output power of the solar panels. In order to get the most out of the PV modules, the microcontroller is always adjusting their operating point. To cope with the ever-changing environmental factors that impact solar energy generation, this dynamic adjustment is crucial.

Easy integration with various types of PV systems and sensors is made possible by the modular and scalable nature of the system architecture. There is no need for lengthy cabling and installation is simplified because the Internet of Things sensors connect with the microcontroller through a wireless network. All acquired data is centrally stored on the cloud platform, making it easy to access and analyze.

Not only does our technology streamline management for users, but it also optimizes the performance of solar systems by utilizing IoT connection and robust remote monitoring features. To make sure PV systems can adjust to different weather conditions and keep delivering efficient and dependable power, we've integrated real-time data monitoring with user-friendly mobile interfaces and powerful data visualization. The results of this study show that renewable energy systems can be improved with the help of Internet of Things (IoT) technology and cutting-edge software solutions, which could lead to better and more efficient energy management in the future.

A major step forward in PV system management is our newly-developed internet-of-things (IoT) solar charge controller that can be remotely monitored. It allows users to keep the system running smoothly and fix problems quickly by giving them access to data in real-time and powerful analytical tools. This new method is an important step in making PV energy as efficient as possible and paving the way for a greener energy future.

#### **II. Literature Review**

**Wallies Thounaojam et. All (2014)** This study suggests a microcontroller-based solar charge controller that is both inexpensive and very effective. The proposed

setup accepted a solar PV module as input and output a DC load. The suggested system's regular UPS might be modified into a solar inverter/UPS, prioritizing the solar charger while both are in use. [1]

**A. I. Edeoghon et.All (2022)** This research was conducted to determine the optimal method for remotely monitoring and controlling a solar-powered inverter via the internet. This objective was accomplished upon completion of the project. The user may remotely turn off the machine through his smartphone if the load exceeds a specific threshold. This initiative will be very helpful for those who use alternative energy since it will encourage people to invest in and assume responsibility for these systems, which offer a greener source of energy that is safer for the environment. As this method matures, it will become more comprehensive and provide a more practical answer than what is now possible. [2]

**P. Selvabharathi et.All (2022)** Using the sun's rays to generate electricity is the most sustainable and environmentally friendly option available. Simulations of the proposed architecture are performed in MATLAB Simulink. Using an incremental conductance method, we tracked the solar cell inputs' maximum peak power (MPP). The voltage was raised thanks to a signal from the MPPT controller, which was received by the boost converter. Next, we'll take a look at the simulation results. The proposed architecture has been modeled using a number of input characteristics, such as lighting and temperature levels, and a varying duty cycle. The results of these iterations have been compiled and analyzed. When compared to another MPPT method, the P&O algorithm, the proposed system was determined to be more efficient. [3]

**Osaretin C.A. et.All (2015)** As a consequence of our work, a cheap and reliable solar charge controller is now available in the area. The technology worked as planned, and it may be adapted for use in a solar home power system to meet the electricity demands of the Nigerian populace. This project's objective is to construct a solar charge controller using mostly custom-made components. The charge controller's output will be set for a 200Ah battery in 12V increments. The four parts of the design are the PSU, the battery charge controller, the battery level indicator, and the current booster. The suggested system is feasible because to its low cost, extended lifespan, and the ease with which it can be implemented using already available tools. This work is a proof-of-concept for a commercial solar charge controller that incorporates safety features to prevent

batteries from being harmed by incorrect charging or discharging. [4]

**Tianxiang Jiang et.All (2014)** In this research, we provide a high-tech controller for charging electric vehicles (EVs), and we prove its effectiveness by theoretical evaluation, simulated testing in Matlab/Simulink, and actual EV charging. The suggested controller has many benefits over the most advanced commercial charging controllers on the market today. Information from the electric vehicle user (time available for charging, anticipated range), the battery management system (BMS) (battery health status), and the distribution network operator (level of network voltage or reference signal based on dynamic pricing) is used to determine the optimal charging regime. The charging current for electric cars is calculated by the fuzzy logic controller based on a number of factors, including user needs, battery life expectancy, and minimum network voltage. In this research, we provide a model for lithium-ion batteries that accounts for capacity fade and may be used to make reliable predictions about charging and battery deterioration. To convert the intended trip duration into a SOC goal, the smart charging controller consults a lookup table created from the battery model. [5]

**Md. Rokonzaman et.All (2020)** Here, we show how to design, build, and test an MPPT-SCC that can communicate with the Internet of Things. The MPPT-SCC method is based on a buck-boost converter that has been tweaked somewhat from the original P&O formulation. We developed a model of the recommended hardware and tested it for 30 days to make sure the results from the simulation were accurate. To ensure the proposed setup was valid, experimental data was compared with the model. Results from testing the proposed SCC show that it works reasonably well (around 99.74%). With the proposed charge controller's Internet of Things (IoT) infrastructure, the SCC's health may be remotely monitored. Greater performance benefits can only be attained with additional research and tuning. A smart home's Internet of Things (IoT) platform may teach AI new skills using the information it collects. If ML and P&O can be combined, the device's speed, stability at peak power, and overall efficiency could be significantly improved. [6]

**Dinesh Rawal et.All (2021)** Finally, the paper concludes with a detailed analysis of the parts and algorithms of several maximum power point tracking solar charge controller modals. The improved performance of the Perturbation and Observation (P&O) algorithm is consistent regardless of whether

or not environmental conditions are steady. Under varying atmospheric conditions, the Perturbation and Observation Method produces more power than other methods. The objective is to address the shortcomings of traditional P&O and INC algorithms, such as their inability to adapt to changing conditions, their lack of directionality in sequences, and their inability to generate enough power in partial shadow. Integration of military warranty tests and partial testing in a MATLAB simulation supports the proposed strategy. Incremental conductance, optimizationperturb & observe are demonstrated to produce the greatest results when comparing the algorithm's performance to the four most prominent MPPT techniques. [7]

**S. S. S. Ranjit et.All (2014)** We present the background and methodology for creating a system to track the health of solar PV panels using the Internet of Things (IoT) in this paper. You can access the temperature, voltage, and current data recorded by the Raspberry Pi Zero Wireless in real time by uploading it to the cloud. As a result of environmental factors, voltage and current measurements reveal information about the general status of every solar panel. By all accounts, Google was able to successfully upload the data stored on the SD card of a Raspberry Pi Zero Wireless to the cloud. The use of an Internet of Things (IoT) system to track the condition of solar panels has also demonstrated promise in lowering photovoltaic panel fatigue and detecting any signs of fatigue in real time. [8]

**Rabia Parveen et.All (2018)** Using sunshine monitoring devices, solar power plants may be able to maximize their output. An automated solar tracking system is the best way to collect solar energy no matter where the sun is. since a result, it is the most flexible technology, since it can be deployed almost anyplace to provide significant energy benefits. Due to solar trackers' ability to steadily increase the amount of collected energy, they come highly recommended from an efficiency aspect, regardless of location. There are two degrees of freedom in terms of body positioning. DC geared motors, under the direction of an Arduino Uno controller, are used to produce point-to-point intermittent motion. Being self-sufficient and able to interact wirelessly through computer or mobile device increases the system's reliability and transparency. Using LDR sensors in conjunction with a high precision voltage and current sensor enables a more accurate and reliable tracking system. Now, the user may see the sensors' settings online. An effective program that not only alerts users

when certain thresholds are surpassed by connected sensors. This facilitates easy remote monitoring of solar systems, leading to optimal energy output. [9]

**Prof. A.A. Pathare et.All (2020)** As the population grows and more individuals need access to the grid, it stands to reason that more power will be squandered or abused. That's why it's so important to find ways to harness this energy and put it to use. Many other types of electrical gadgets sprang to prominence with the development of technology. The reliability of conventional power plants is deteriorating. Smart inverters, developed by private companies and research laboratories, are offering the next step in synchronizing energy production and consumption in response to the proliferation of systems that include nonconventional energy sources and rising power costs. The battery is maintained at an optimum level of charge thanks to the PWM charge controller. [10]

**Miss. Bharti Telrandhe et.All (2019)** The study's principal objective is to create a solar-powered lighting option. The testing apparatus consists of a 10W solar panel, 12V battery, and solar charge controller. The battery is protected from extreme voltage swings and overcharging by the charge controller. As a viable renewable energy option, solar inverters are in high demand. Both residential and off-grid inverters are widely utilized. These inverters lack both internet connectivity for remote monitoring and a backup battery bank. To increase the battery's service life and reduce maintenance needs, we propose a method that may be utilized in conjunction with these inverters to activate not one, but two banks of batteries. [11]

**MR.AJAY B. MOHITE et.All (2019)** In this piece, we suggest a cheap Arduino-based solar power monitoring device. The major objective is to create solar power designs that are efficient and kind on the environment. While Idr and solar data are utilized for control and management. The mechanism is programmed to operate only during the day and in bad weather, during which it will rotate through a full 180 degrees. Despite India's frequent power disruptions, it is typical to see solar panels with inefficient energy use. [12]

**Nilakshi Chandratre et.All (2022)** To conduct this research, we monitored the 25-watt solar array's power production, current, voltage, and temperature. In order to run a 10W DC servo motor, the solar energy is stored in a 12V 5Ah lead acid battery. The outputs of our sensors for the monitored parameters were graphed using the Thingspeak platform. This

paper demonstrates the value of the Internet of Things for solar energy applications by facilitating the tracking, analysis, and prediction of solar panel output. The results of this study might be used to future endeavors of a similar kind. The observed values may help in predicting the values of parameters for the operating system, such as the current voltage and maximum solar output by the system. The user may then act or make choices depending on the predicted outcomes. Most solar energy monitoring applications, such as large and small solar power plants, rely on inverters as the unsung heroes behind the scenes. This study's findings suggest that smaller solar applications, such as streetlights, agricultural pumps, and water heaters, might benefit from and be made viable by systems like the one constructed here. [13]

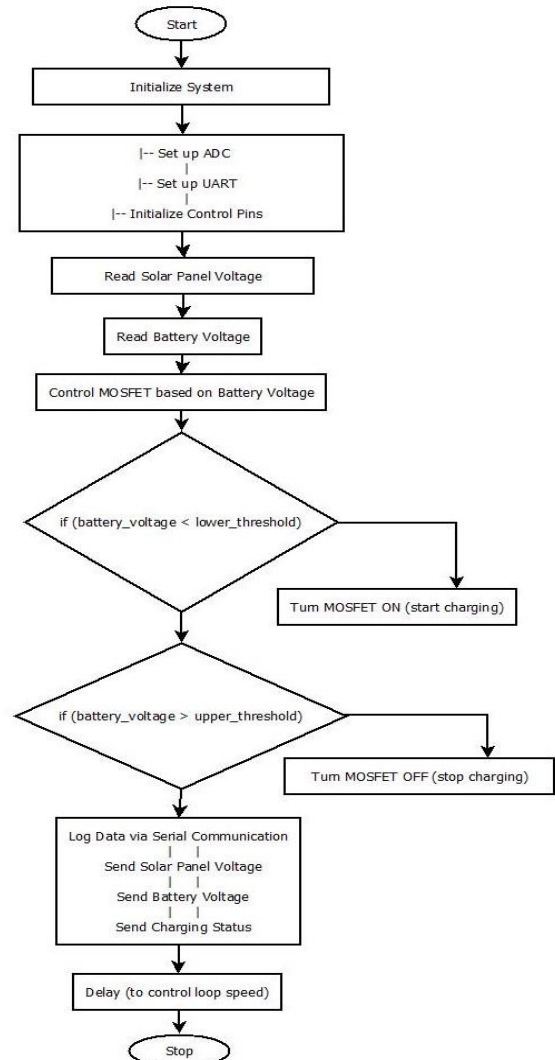
**S S P M Sharma et.All (2018)** We have made the move to renewable energy sources since the current control grids in India cannot provide for the demands of every person in every region of the nation. Because of their limited efficiency in adapting to new environments and their high production costs, solar panels are best used in conjunction with a solar charge controller. An internet-connected maximum power point tracking (MPPT) solar charge controller is recommended. Hardware dedicated to battery charge management is employed to enhance the quality of the system rather than software. Research is needed because various IoT nodes have varying power supply needs. The device might potentially be powered by a consistent 5V supply from a standard USB port. Another clever strategy for prolonging battery life is to reduce the number of charge-discharge cycles. There is a minimum voltage that must be reached before a battery may be charged. In addition to being easy to set up, the proposed system also boasts excellent levels of homogeneity, capacity, and minimal power loss. [14]

**Dr. H Ravishankar Kamath et.All (2018)** Due to the inability of the current infrastructure in India to suit everyone's needs, we have resorted to alternative energy sources. While solar energy is clean and requires little maintenance, it does have some drawbacks, including low conversion efficiency and high fabrication costs; for instance, solar panels have a low conversion efficiency, but we may be able to lower the cost of the entire system by employing a solar charge controller. It's possible that the proposed technology might self-charge. This approach use the PWM method to switch on and off when a load is applied, which may increase the lifespan of solar

charge controllers. There is still room for development in hardware efficiency. [15]

### III. Methodology

#### 3.1 Solar Charge Controller Algorithm



**Figure: 3.1 Solar Charge Controller Algorithm Flow Chart**

The hardware of the solar charge controller is designed to regulate the flow of energy from the panels to the batteries in a safe and efficient manner, ensuring safe charging. Most notably, it contains a PIC 16F73 microcontroller, batteries, and a solar panel. Electronic parts like diodes, transistors, capacitors, and resistors are also present.

The solar panel converts sunlight into power, which is then sent to the charge controller. Controlling the flow of power from solar cells to the battery is the job of metal-oxide semiconductor field-effect transistors. These MOSFETs are activated or deactivated by the microcontroller in reaction to variations in the battery voltage. The use of capacitors to reduce voltage

fluctuations allows for a more stable voltage supply to the battery. Using resistors to find operating points and limit current flow helps prevent injury from high current.

By preventing current from flowing backwards from the battery to the solar panel, diodes play a crucial role in ensuring that energy can only flow in one direction. On the interior of the circuit, transistors serve as amplifiers and switches, allowing for greater regulation and control of the charging process. The PIC 16F73 microcontroller is like the brains of the system; it controls and coordinates everything. It optimizes charging in real-time by monitoring the solar panel and battery voltage levels through its Analog-to-Digital Converter (ADC) channels. The microcontroller is also responsible for data logging, which involves sending analysis and monitoring-related information regarding the battery, charging state, and solar panel voltages via UART.

In order to make higher voltages more consistently detectable by the microcontroller, voltage dividers are incorporated into the circuit architecture. Gate resistors are placed between the microcontroller and the MOSFET gates to control the charging rate and prevent oscillations at high frequencies. A flyback diode protects the MOSFET from voltage spikes when switching inductive loads.

In order to make the most of the energy that the solar panels provide, the solar charge controller is made to avoid overcharging or undercharging the battery. The key to accomplishing this is the efficient combination of these components. Careful consideration and integration of these hardware components yields a highly dependable system that can endure various climatic conditions.

To ensure the safe and effective charging of batteries by solar radiation, the solar charge controller's microcontroller code is designed with this objective in mind. A portion of the code is dedicated to initialization, during which all of the required hardware components are configured. The microcontroller may make use of the digital data read by the Analog-to-Digital Converter (ADC), which reads the voltages from the solar panels and batteries. With its initialization set for serial connection, the system's Universal Asynchronous Receiver-Transmitter (UART) allows it to log and transmit data. Because the microcontroller has the control pins used to operate the MOSFETs set up as output pins, it can regulate the charging process.

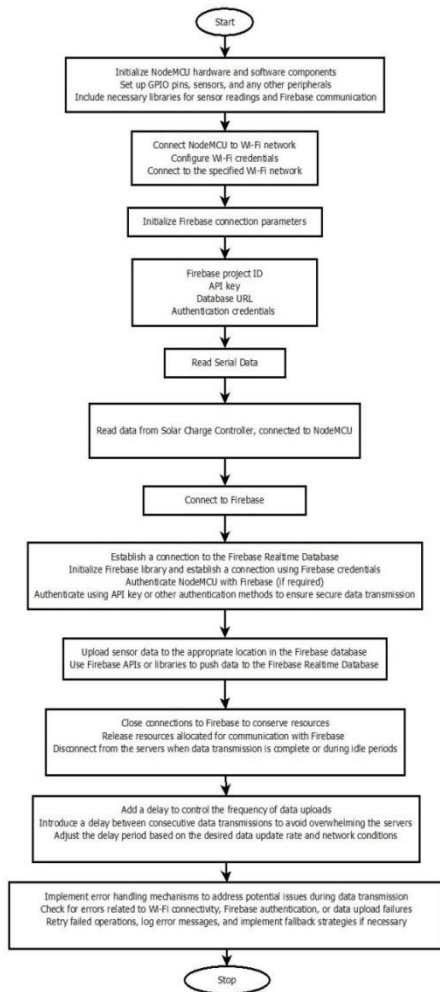
As part of its main loop, the microprocessor continuously checks the battery and solar panel

voltages. The ADC measures these voltages to determine the charging status. The voltage readout from the battery determines whether the CPU activates or deactivates the MOSFET. If the battery voltage falls below a certain lower threshold, the microcontroller will activate the MOSFET, allowing electricity to flow from the solar panel to the battery. This indicates that the battery needs to be charged. When the battery voltage hits a specific upper threshold, it means the battery is fully charged, and the microprocessor turns off the MOSFET to prevent overcharging.

In addition, the system includes a data logging function. This function involves the microcontroller communicating with the serial port in order to monitor and evaluate the charging status, solar panel voltage, and battery voltage. This logging is crucial for keeping an eye on the system's performance and finding any issues. The main loop's speed is regulated and steady operation is guaranteed by inserting a delay. What this delay is adjusted to depend on is the system's required response time. By adhering to this structured approach to controlling the flow of energy, the solar charge controller safeguards the battery and ensures optimal charging.

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### **3.2 Send Data from NodeMcu to IoT Server for Retrieve Data Using Android App.**

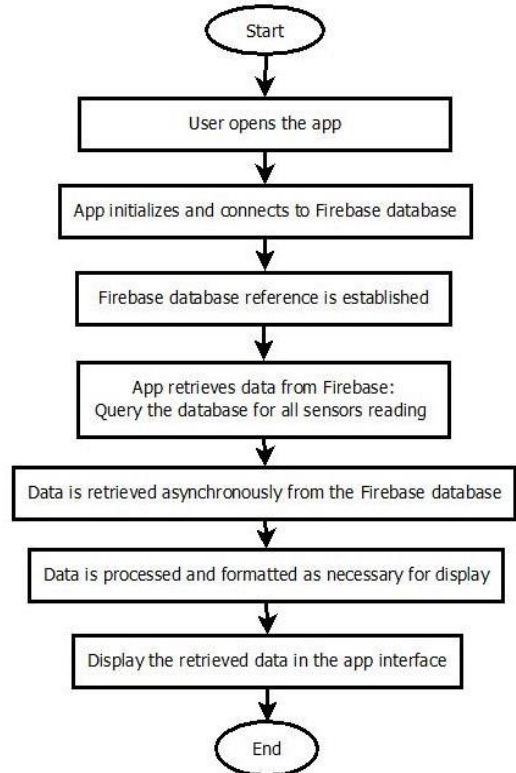


**Figure: 3.2 Flow Chart for Send Data to IoT Web Server**

The NodeMCU's software and hardware components, including its sensors, GPIO pins, and communication libraries, are setup beginning with the initialization stage. Afterwards, the NodeMCU connects to the local wireless network and configures its Wi-Fi credentials. Also, the API keys, project IDs, and database URLs needed to connect to the Firebase platform have been configured. Inside the main loop, the program continuously reads data from the connected solar charge controller, which includes various solar charge controller and battery properties. After the NodeMCU has collected SCC data, it connects to the Firebase Realtime Database and, if necessary, authenticates to provide secure transmission. Metadata, such as timestamps, is applied to data in a Firebase-specific format before it is uploaded to the database. Internal error handling mechanisms deal with potential transmission errors, such as those concerning Wi-Fi connections, Firebase authentication, or failed data uploads. After each communication cycle, the NodeMCU disconnects from

Firebase to conserve power. The main loop remains active until the program is terminated, and the update rate between data broadcasts is controlled by a delay. By constantly monitoring and transmitting sensor data to the Firebase platform, this comprehensive solution enables real-time data analysis and visualization for our developed android applications.

**3.3 Android Application Flow Chart**



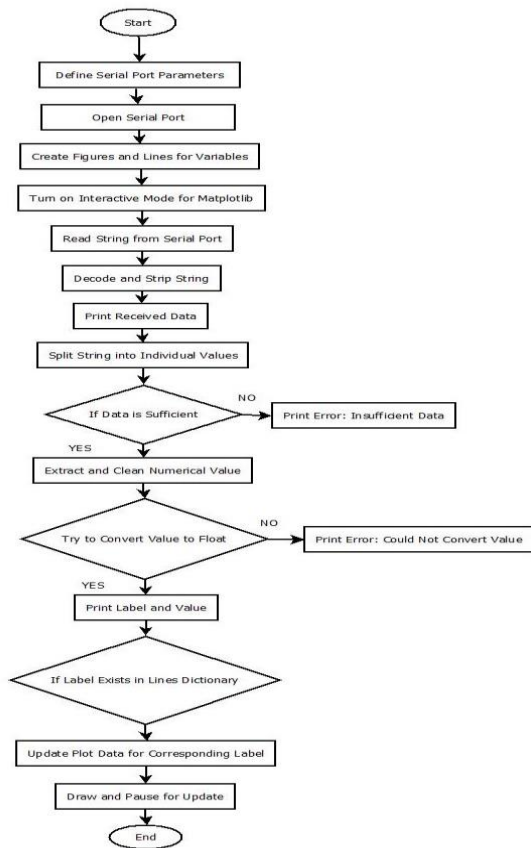
**Figure: 3.3 Android Application Flow Chart**

It all starts with the user launching the app on their device. From there, the app is initialized and connected to the Firebase database. The program creates references to different data types stored in Firebase, including the solar charge controller data, after a secure connection is established. An asynchronous method retrieves the data from Firebase, allowing the app to continue running without any interruptions. The data is processed and prepared after successful retrieval in order to be displayed in the program's user interface. After the user has done interacting with the app and obtained the desired insights from the shown data, the procedure concludes. The program's user-friendly design immediately connects users to real-time data insights upon launch. Thanks to the app's ability to retrieve a wide range of environmental parameters via its connection to the Firebase database, users have access to comprehensive information. We handle every data query with care, and we have



robust error-handling algorithms to deal with any potential disruptions in data retrieval. Users can interact with the user interface (UI) without interruptions since the application remains responsive while data is asynchronously downloaded from Firebase. Users may get a good grasp of SCC data with this feature, which helps them make smart choices and be proactive. The application's focus on the user also means that they can interact with the displayed data. Businesses and individuals alike can benefit greatly from the app's ability to track and analyze SCC data in real-time.

### 3.4 Real Time Graphical Visualization Software Flow Chart



**Figure: 3.4 Real Time Graphical Visualization Software Flow Chart**

The objective of the provided Python script is to read data, process it, and update real-time charts for various variables via a serial connection. The script specifies the ports and baud rates for the serial port, beginning with "COM" and 9600. After you make these changes, the serial port will be opened. Next, the script gets the charting environment ready by generating lines and figures for the four important variables: power, voltage, current, and temperature. We assign a color to each variable and set the limits of the y-axis for the visualization. We turned on

Matplotlib's interactive mode to have the graphs update in real time.

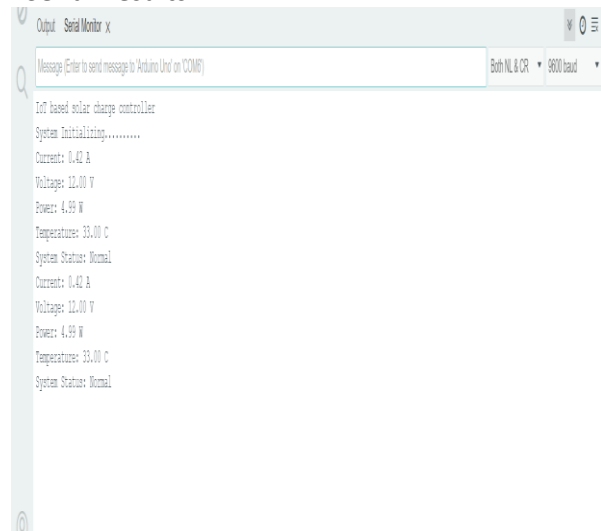
To keep the core functionality contained, data is continuously read from the serial port using an infinite loop. Decoding and cleaning up each string of any extra whitespace follows data reading from the serial port. It is necessary to print out the acquired data for debugging purposes. Once the data string has been broken into individual values, the script verifies if there is sufficient data received. When there is sufficient data, the numerical value is converted to a float after being removed and cleaned of any non-numerical characters. Printed underneath this float value is a label for verification purposes.

After that, the software checks the defined lines dictionary to see if the name is there. After a short break, all the plots are redrawn to include the latest data. If the label is found, the corresponding plot is updated with the new data point. The most up-to-date data points are shown by adjusting the x-axis boundaries and adding the current time and new value to the plot data. We can close the serial port, remove all plots, and see a notice saying it when you manually stop the loop by pressing Ctrl+C on your keyboard.

This systematic process ensures accurate charting and continuous updating of serial port data in real-time, providing a visual representation of the variables being studied.

## 5. Results

### 5.1 Serial Results



**Figure: 5.1 Serial Result 1**



Figure: 5.2 Serial Result 2

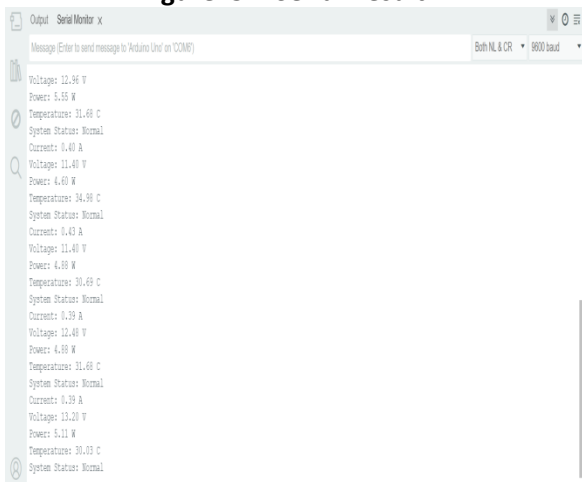


Figure: 5.3 Serial Result 3

The capacity of the solar charge controller, which is controlled by the PIC 16F73 microcontroller, to log serial data is an essential component of the system's performance monitoring and analysis, as seen in the figures above. Since the Universal Asynchronous Receiver-Transmitter (UART) is configured to allow serial connection during initialization, data transmitted by the microcontroller can be received by an external monitoring system or computer. The ADC channels on the microcontroller are constantly reading the analogue signals from the battery and solar panel so that the microcontroller can process them. For example, the microcontroller can tell if the battery is completely charged, needs charging, or is being charged by looking at the voltage. A serial data stream containing the recorded data was transmitted via UART. Adding a delay to the main loop ensures that the logging intervals are constant. In order to gain real-time insights into the system's performance, diagnose issues, and catch anomalies early on, frequent logging is essential. Analysis of collected data allows for optimization of the charging process,

resulting in total efficiency benefits. Keeping track of the system's performance over time enhances the solar charge controller's long-term dependability. This ensures the optimal operation of the parameters and enables predictive maintenance.

### 5.2 Reporting Data on Server

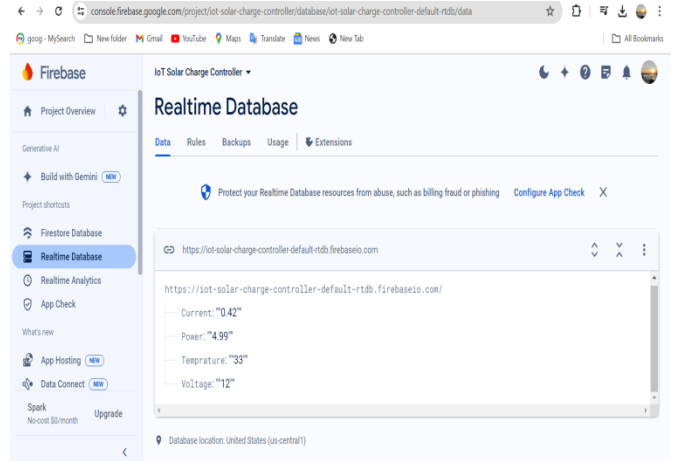


Figure: 5.4 Real Time Database 1

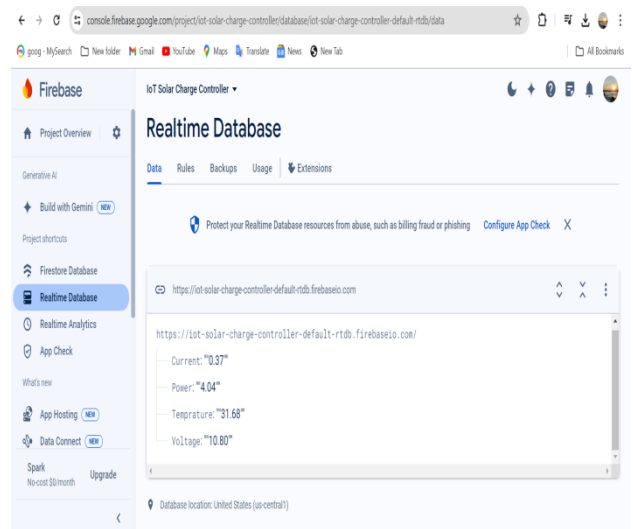


Figure: 5.5 Real Time Database 2

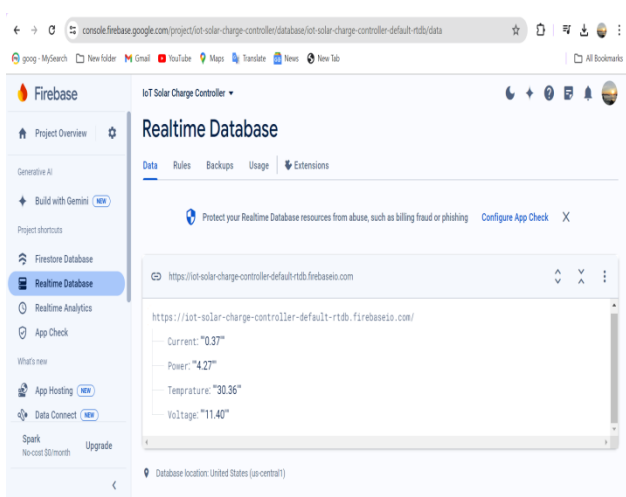


Figure: 5.6 Real Time Database 3



Figure: 5.7 Remote Monitoring Using Android Application 1

The NodeMCU, acting as an intermediary device, is programmed to receive this serial data and establish a connection with Firebase. Using its built-in Wi-Fi capabilities, the NodeMCU connects to the internet and authenticates with the Firebase Realtime Database. Upon receiving the data from the microcontroller, the NodeMCU parses the serial data, ensuring it is correctly formatted for Firebase. The parsed data, including labeled values like "Voltage: X.XX V", "Current Voltage: Y.YY A", "Power: Z.ZZ W" and "Tempraure", is then uploaded to Firebase.

This setup allows for real-time data updates in the Firebase database, enabling continuous monitoring and analysis of the solar charge controller's performance. The logged data provides real-time insights, aids in early anomaly detection, and is invaluable for diagnostics. By leveraging Firebase, the data is accessible from anywhere, facilitating remote monitoring and management. Analysis of this data can lead to optimizations in the charging process, enhancing overall efficiency. Maintaining a log of system performance over time contributes to the long-term reliability of the solar charge controller, enabling predictive maintenance and ensuring optimal operation parameters.

### 5.3 Remote Monitoring Using Android Application

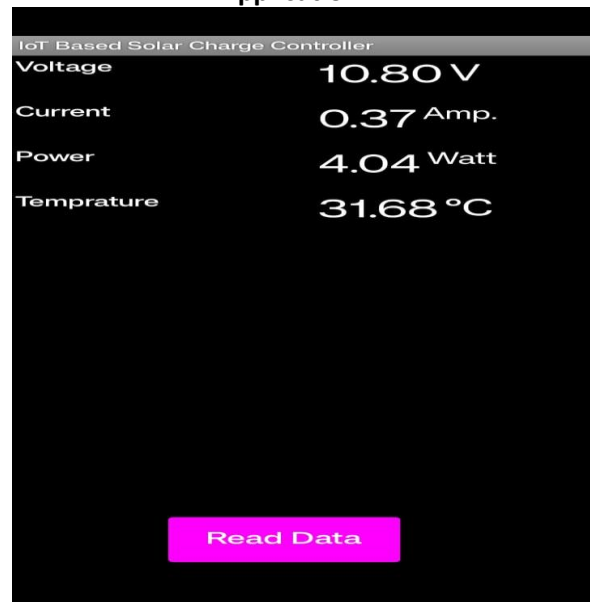
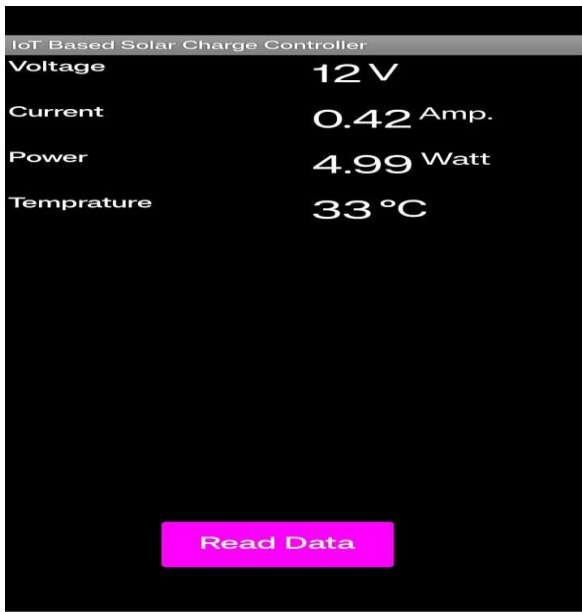


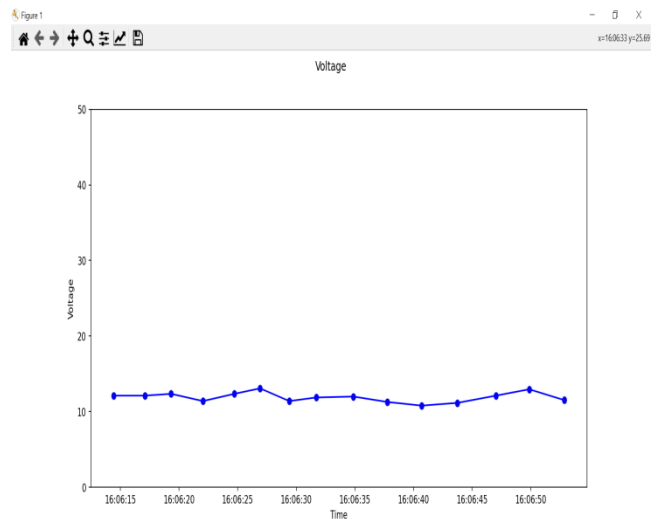
Figure: 5.8 Remote Monitoring Using Android Application 2



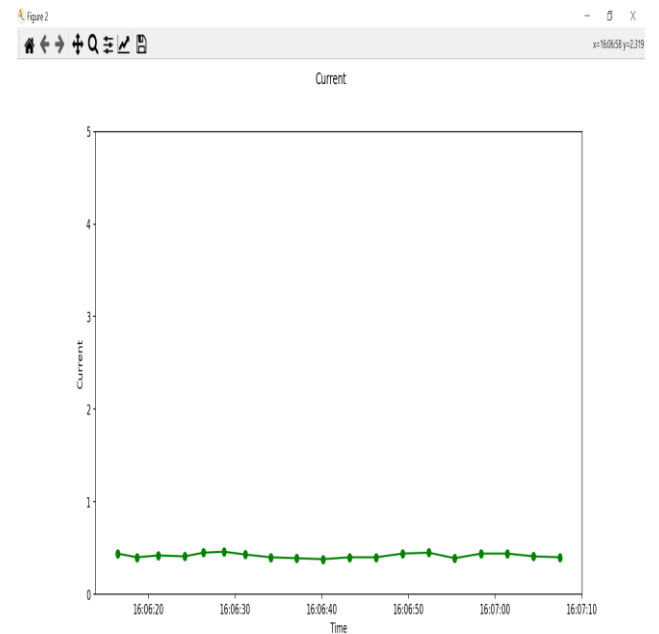
**Figure: 5.9 Remote Monitoring Using Android Application 3**

The data can be accessed in real-time by proposed Android app after the NodeMCU uploads it to the Firebase Realtime Database. Through the use of Firebase's SDK for Android, the developed Android app establishes a connection to the Firebase database, guaranteeing safe authentication and constant synchronization. The program can immediately incorporate any changes made by the solar charge controller thanks to this real-time data retrieval. The data that was collected is parsed by the app and shown in a straightforward and easy-to-understand numerical format with labels like "Voltage: X.XX V", "Current Voltage: Y.YY A", "Power: Z.ZZ W", and "Temperature: T.TT °C". This is especially helpful for off-grid applications because the data is accessible from anywhere thanks to the interface with Firebase, which lets users remotely monitor and manage their systems. All things considered, this configuration allows for proactive management and crucial insights, which in turn improve the solar charge controller's efficiency and dependability.

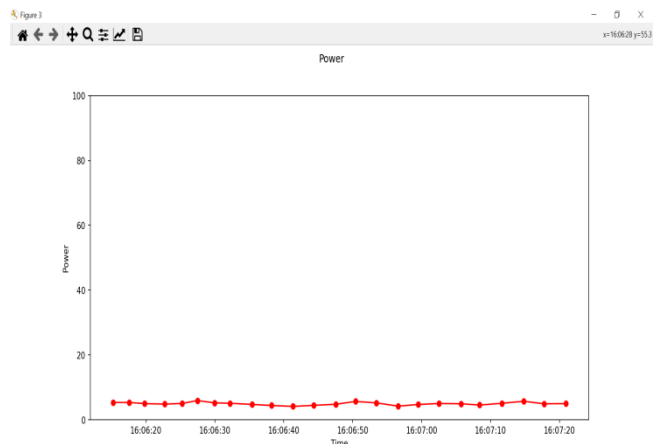
**3.4 Real Time Monitoring Visualization**



**Figure: 5.10 Real Time Voltage Visualization Graph Plot**

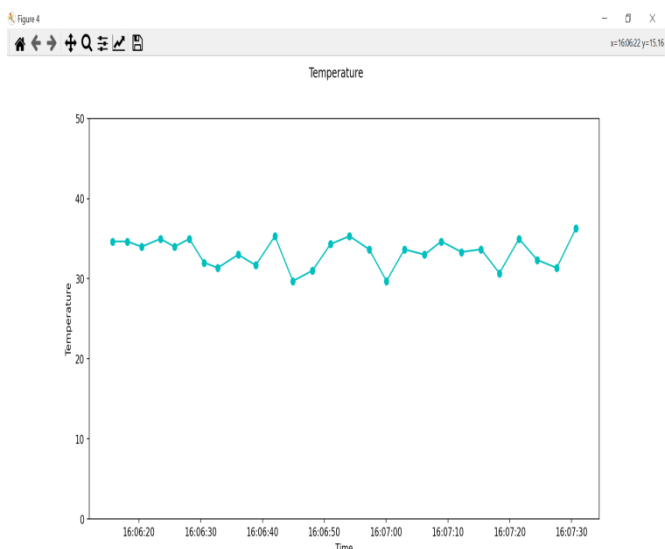


**Figure: 5.11 Real Time Current Visualization Graph Plot**



**Figure: 5.12 Real Time Power Visualization Graph Plot**

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**Figure: 5.13 Real Time Temperature Visualization Graph Plot**

The figures above demonstrate the substantial practical effects of performing the proposed work. These outcomes include the ability to monitor and analyze graphs of solar charge controller performance metrics in real time. Users are able to visually track many data in real-time, including voltage, current, power, and temperature. This enables them to immediately identify any problems or abnormalities. Data that is continuously plotted allows for the observation of patterns over time, which is useful for optimizing and analyzing performance. Users can conduct better diagnostics with the help of viewing these metrics; for example, unexpected spikes or drops in values might suggest possible issues that need to be investigated. A solar charge controller and other systems can be effectively monitored and analyzed with the help of this code since it provides a complete solution for real-time data collecting, parsing, and visualization.

#### VI. Conclusion

This research addresses the pressing need for enhanced performance and efficiency in solar photovoltaic (PV) energy systems, particularly in light of the intermittent nature of ambient conditions affecting PV panel output. To overcome this challenge, we developed a novel Internet of Things (IoT)-equipped solar charge controller (SCC). The core objective of our work was to design and implement a hybrid SCC capable of remote monitoring and control through an Android application. Leveraging IoT technology, our SCC system enables seamless data reporting to a cloud server, facilitating remote monitoring and intervention as needed. This research

contributes significantly to advancing renewable energy technologies by addressing key challenges in PV energy utilization and offering practical solutions for improved performance and reliability in solar energy systems with remote monitoring facilities.

#### VII. Future Scope

Our internet of things (IoT) solar charge controller (SCC) with remote monitoring capabilities has a lot of potential for growth and new uses in the future. Dynamic optimization and predictive maintenance, which lessen maintenance expenses and downtime, might be made possible with the integration of sophisticated machine learning algorithms, which would allow for automated decision-making and predictive analytics. A more consistent and dependable energy supply, especially in off-grid and distant places, could be achieved by enhancing the system to handle hybrid energy sources, including integrating wind and solar power. More user-friendly dashboards and cross-platform support for platforms like iOS and web apps will further improve usability and accessibility. One potential next step is to include smart grid technologies into PV systems. This would enable them to react on the fly to grid demands, improving grid stability and efficiency. We can learn more about the system's functioning as a whole if we build better sensor networks to assess more environmental variables and if we make our sensors more accurate and long-lasting. The technology would be more accessible if efforts were made to lower costs and enhance scalability, such as designing modular components and optimizing hardware design. Energy optimization solutions that take the whole picture into account could be achieved through the integration of blockchain technology for safe data management and the improvement of data integrity and transparency through cooperation with larger energy management systems. With these updates, renewable energy management will reach new heights, paving the way for a greener energy future.

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