A SMART SOLAR PV MONITORING SYSTEM USING IOT

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ABSTRACT

Renewable energy sources are proven to be reliable and accepted as the best alternative for fulfilling our increasing energy needs. Solar photovoltaic energy is the emerging and enticing clean technologies with zero carbon emission in today's world. To harness the solar power generation, it is indeed necessary to pay serious attention to its maintenance as well as application. The IoT based solar energy monitoring system is proposed to collect and analyzes the solar energy parameters to predict the performance for ensuring stable power generation. The main advantage of the system is to determine optimal performance for better maintenance of solar PV (photovoltaic). The prime target of PV monitoring system is to offer a cost-effective solution, which incessantly displays remote energy yields and its performance either on the computer or through smart phones. The proposed system is tested with a solar module of 125-watts to monitor string voltage, string current, temperature, and irradiance. This PV monitoring system is developed by a smart Wi-Fi enabled CC3200 microcontroller with latest embedded ARM processor that communicates and uploads the data in cloud platform with the Blynk application. Also the Wireless monitoring system maximizes the operational reliability of a PV system with minimum system cost.

KEYWORDS

Solar PV, Internet of Things, Mobile Application, Online Monitoring.

1. INTRODUCTION

Power generation is a major factor in many developing countries. Due to the improvement of the industrial and commercial sector, energy demand reaches its peak. Hence all are poignant towards renewable energy source to produce green energy for meeting out our energy consumption. This can help the society to decrease greenhouse gas emission and ozone layer depletion for future generation. Among this solar photovoltaic technique is gaining popularity due to huge availability, reduced cost, easy installation, and maintenance. Currently, Internet of Things (IoT) is an evolving technology that makes things smarter and user-friendly when connected through the communication protocol and cloud platform. The efficiency of the solar panel is influenced by basic parameters such as current, voltage, Irradiance, and temperature. Hence real-time solar monitoring system is essential for increasing the performance of the PV panel by comparing with the experimental result to initiate preventive action. In recent years there had been a lot of research attempts made in solar energy. A simple forecasting database is modeled using MySQL to collect the raw data, filter un-relevant values and produce forecast without the assistance of any modern automation tools. In addition, machine intelligence techniques are used for forecasting to obtain robust performance [1]. A real-time supervising

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and data acquisition model for Solar PV module is proposed using LABVIEW to determine the performance of different solar PV ratings. This is a powerful tool for exploring the operation of different PV modules with respect to real-time data [2-3]. Microcontroller based displaying system is proposed to monitor the different factors that affect the performance of PV panel. The measured parameters are evaluated with the standard operating condition to provide necessary action for better performance of PV [4].

A low-cost solar panel monitoring is developed based on IoT for online visualization and improving the performance. This helps to take preventive maintenance and tracking the fault location [5]. An IoT based cloud monitoring system is proposed and developed using the Raspberry pi for remote PV plant [6]. The basic characteristics of a PV system are analyzed using LABVIEW tool for real-time measurement to study the fault diagnosis in PV plant [7]. A smart monitoring system is developed with a microcontroller and Labview to gain the maximum efficiency with the use of sun trackers [8]. A remote Solar monitoring and control system is proposed for implementation at the plant level and promotes the decisional process for central control station which has the crucial role for processing, storage, warning and displaying [9].PV monitoring system is developed based on wired and wireless networks to transmit the parameters to a remote coordinator that offers a web-based application for remote access [10]. A practical graphical user interface is developed using Lab view for online monitoring for solar PV. Arduino controller is used for analyzing the measured parameters and sends the data to the server for making a useful decision which improves the performance of PV panel [11]. A cost-effective smart architecture is proposed to optimize the efficiency of the PV panel by detecting the performance degradation through continuous monitoring system [12]. HEM algorithm based smart controller is implemented for choosing the source priority to maximize the use of Solar PV for home power management [17].Therefore, the proposed work illustrate the real-time Solar PV monitoring system using cost efficient Smart Controller communicate with the cloud platform provides large storage space and fast dataaccess.

The paper is structured as follows: Section II describes the conventional work. Section III presents the proposed work and its functionality. Section IV illustrates the results of Solar monitoring system. Section V summarizes the proposed work and its application.

2. RELATED WORK

A virtually reliable Solar PV monitoring system [2] is developed with LABVIEW software is shown in Fig.1 a practical development tool for computing the performance of a 5-Watt Solar Module. The electrical parameters like voltage, current, temperature, humidity and irradiance are measured using sensors and store the data in the DAQ (Data Acquisition) unit, which provide an interface to the PC. LABVIEW tool plot the I-V and P-V graph based on the data acquired and also compute the Maximum voltage, Maximum current, Fill factor and efficiency of the solarpanel.

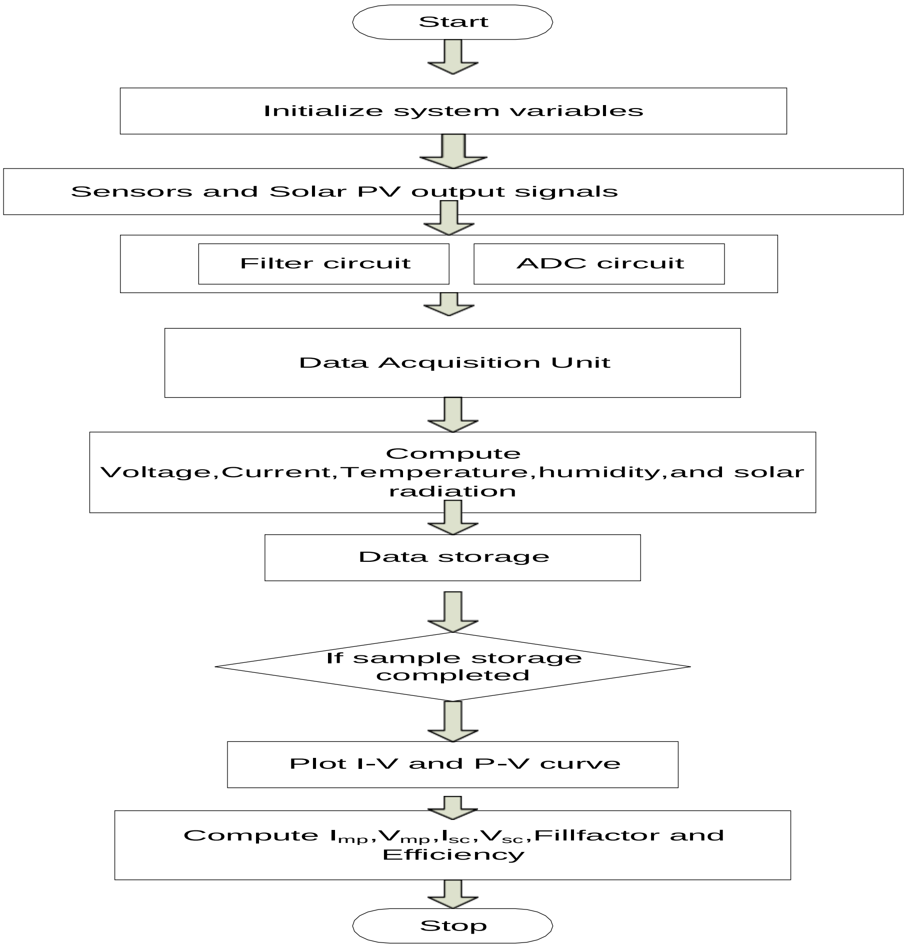


Figure.1 Virtual Solar PV monitoring system using LABVIEW

3. PROPOSED WORK

The real-time solar energy monitoring system is proposed based on the three-layer architecture of Internet of Things (IoT). The three-stage architecture is shown in Fig 2. The lower layer contains sensing and actuating devices like sensors, actuators, RFID, camera, and controllers since it is a combination of sensing and processing layer. The next layer is a middle layer which encompasses network layer with wired and wireless network like LAN, Bluetooth, Zigbee, 4G, Wi-Fi etc., act as a gateway to route the packets (data) to the transport layer that contains TCP/IP, UDP, for further transmission of data to the upper end. The final stage is the application layer deliver user interface and cloud platform for remote access.

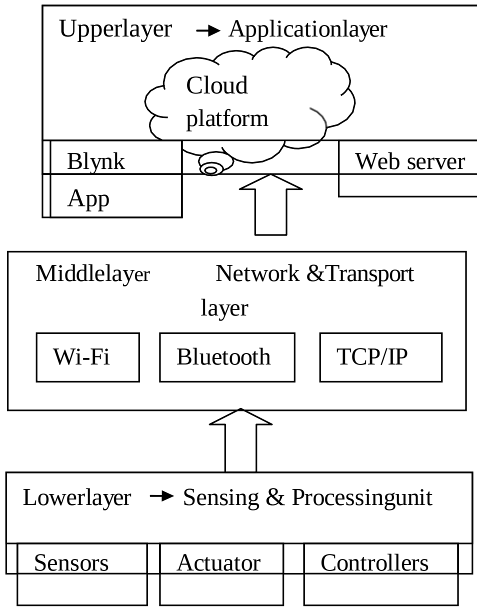


Figure.2 Three-layer architecture of Internet of Things

The block diagram of IoT based solar monitoring system is shown in Fig.3.This illustrates the outline of our proposed work. Poly Crystalline silicon of 125-watt solar panel is used for a monitoring system. The voltage and current sensors are used to measure the respective voltage and current from the panel. The temperature sensor is placed on the solar PV module to measure the current temperature which greatly affects the efficiency of the solar panel. Pyranometer is an instrument to measure the amount of solar irradiance in a planar surface in terms of W/m^2. The Microcontroller plays a pivotal role in handling the measured data for processing and forwards the data to the cloud platform through Wi-Fi module for concurrent observation and decision making.

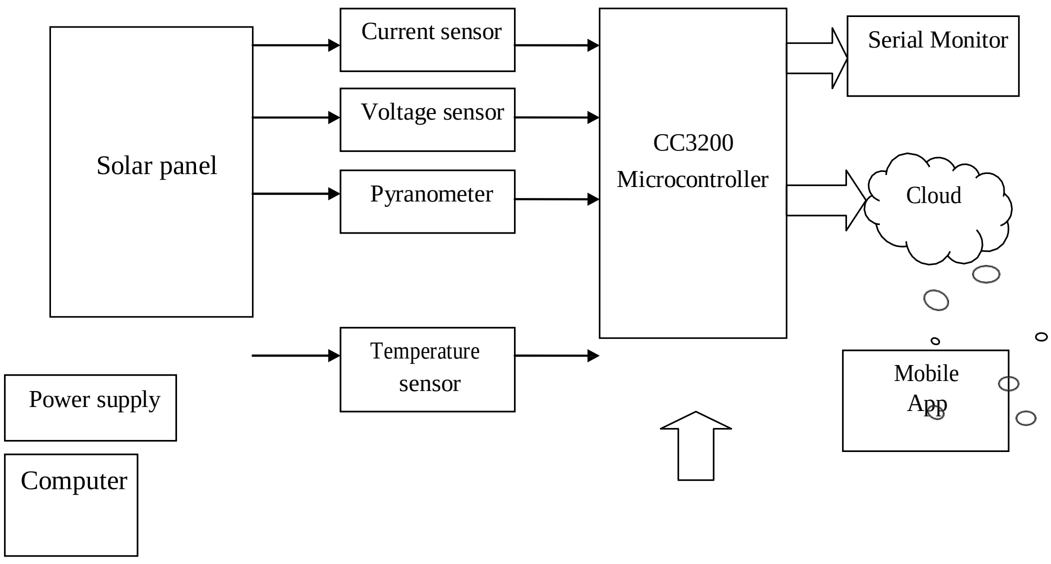


Figure.3 Real-time Solar Energy Monitoring System

3.1. Lower Layer

The sensing units are Voltage sensor, ACS 712 current sensor, pyranometer and temperature sensor. A voltage sensor is a divider circuit that can measure the voltage drop through series resistance. This circuit is useful for measuring voltage above 5 volts. The voltage is calculated based on the resistance factor and reference voltage. The voltage divider circuit is shown in Fig.4 The expression for calculating voltageis

$$Voltage = (Analog\ value / Resistance\ Factor) * Reference\ Voltage$$

Resistance factor is calculated with the value of series resistance R_1 and R_2.

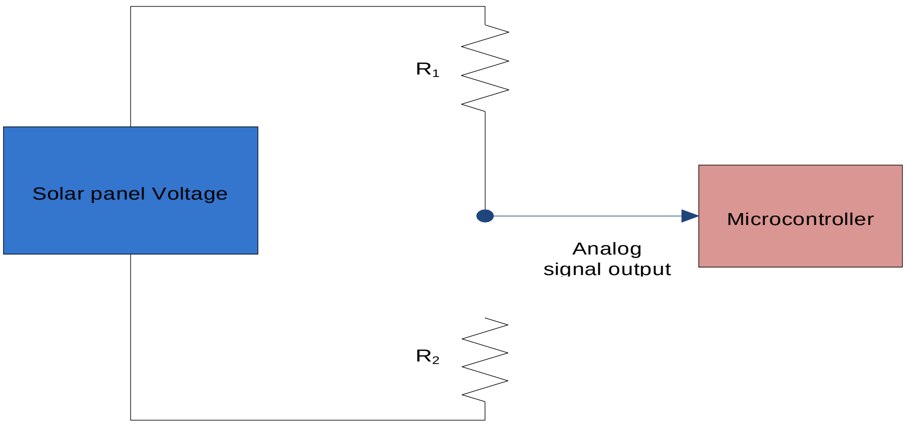


Figure.4 Voltage divider circuit

A current sensor used for measuring solar PV panel is the ACS712 Hall Effect sensor, which can measure up to 20 Amps. This can be effective to measure both DC and AC current. Hall effect sensor connects with the microcontroller through three terminals Analog input, power supply, and ground. The current sensor module is shown inFig.5

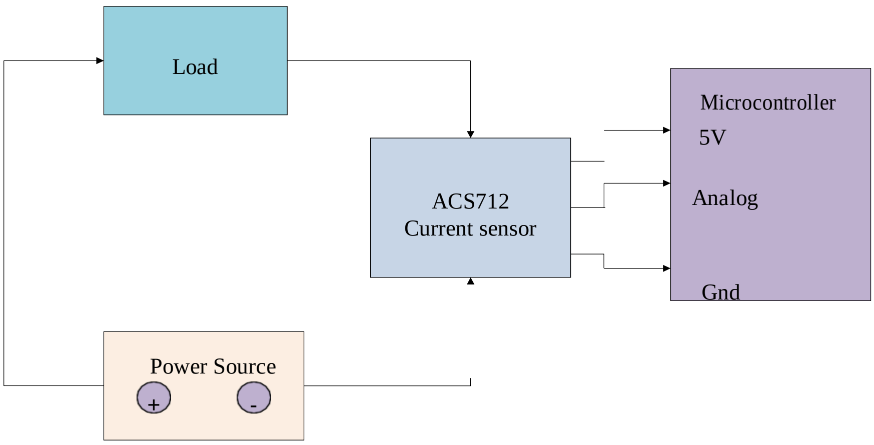


Figure.5 Schematic layout of the current sensor

CM21 pyranometer shows high precision for measuring the solar radiance in a plane surface due to direct and diffused solar radiation. The high quality optical domes help to reduce the directional error less than 10 W/m2. It has high sensitivity for data acquisition system and provides low impedance for interference and noise. It has the maximum spectral range of 300-

1200 nm with sensitivity between 7 and 17 µV/Wm^{-2}. The operating temperature of this instrument is -40°C to +80°C.The construction of pyranometer [13] is shown in Fig.6. In general, the global radiation is determined using the output voltage of pyranometer and its sensitivity. For the calculation of solarirradiance

$E = U_{emf} / Sensitivity$

E = solar irradiance inW/m^2

U_{emf} = output voltage of pyranometer in µV Sensitivity =Sensitivity of pyranometer inµV/W/m^2

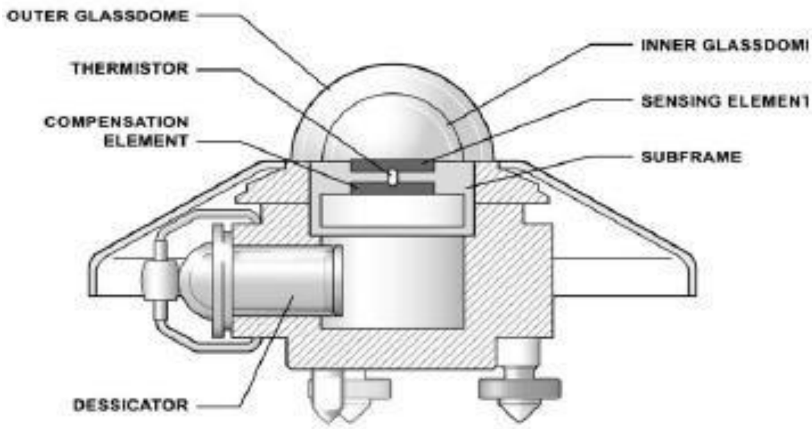


Figure 6. The general structure of CM21 Pyranometer

The sensor for measuring the temperature of the solar panel is LM35 an analog sensor. It is a low cost, a tiny sensor to measure the environmental temperature from -50°C to +150°C. The operating voltage of this IC is 5v. There is an increase of 0.01v for all rise in temperature. The formula for converting the voltage to temperature is

$$Temperature = Voltage / 10mV/°C$$

CC3200 MICROCONTROLLER:

A CC3200 simple link is a system-on-chip (SoC) controller with inbuilt Wi-Fi connectivity designed for IoT Application. The wireless MCU (Microcontroller Unit) includes a high-speed ARM cortex M4 processor to develop a real-time application with the Single IC (Integrated chip). The controllers has embedded memory of 256KB RAM, serial Flash boot loader and ROMdrivers.TheMCUhas12-bitAnalog-to-Digital Converter(ADC)with four channels and 27 programmable general purpose input output (GPIO) pins. The Wi-Fi module contains 802.11b/g/n radio provides a fast and secure internet connection with advanced encryption standards. The power management subsystem includes a DC-DC converter to maintain a broad range of supply voltages. The Fig.7 shows [14] the hardware overview of the controller.

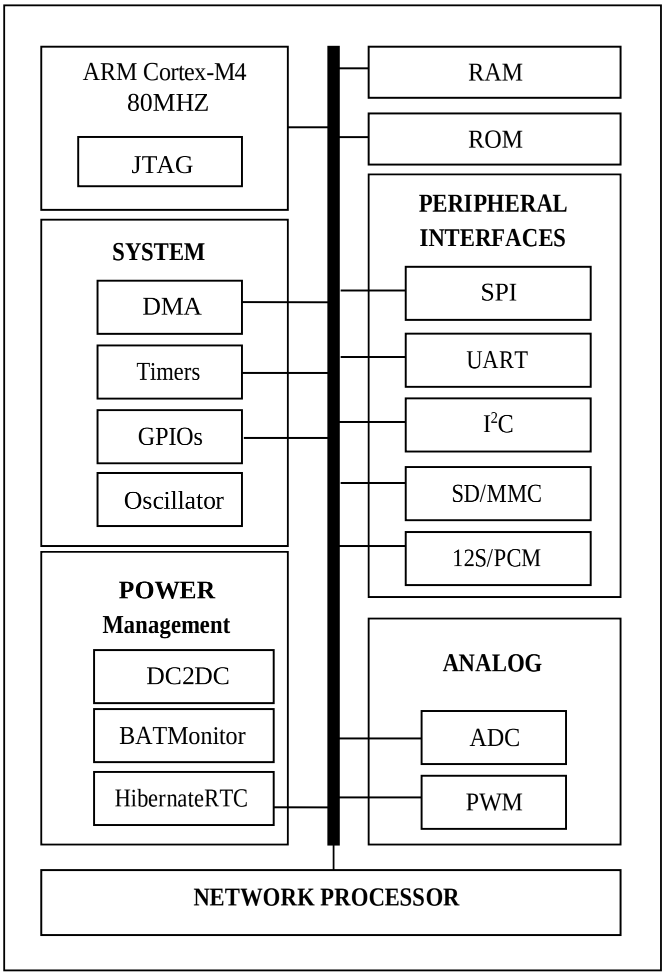


Figure 7. Hardware overview of CC3200

3.2. Middle Layer

In the middle layer, the smart controller processes the sensed data and transmits the information through Wi-Fi protocol which acts as a gateway to communicate with the upper end. The communication protocol like TCP/IP, UDP provides standard rules to ensure secure data transmission to the application layer.

3.3. Upper Layer

The Final layer is the application layer which can store the real-time data in a cloud platform for easier access, data visualization, and right decision making. This proposed work facilitates a cloud-based mobile application; Blynk [15] is used for tracking the operation of solar PV in real-time.

Blynk is a free source cloud platform offers user-friendly IoT application. We can develop a secure scalable and fast application with pre-designed elements to view the data virtually. It supports many hardware platforms and connectivity types for deploying any number of devices online. It gives a continuous solution for the remote application which saves time and resources with the very low cost.

4. RESULTS AND DISCUSSION

A polycrystalline 125-Watt photovoltaic module is taken for the experimental implementation and testing the performance with standard ratings of the solar panel as mentioned in Table 1. The proposed work is carried out in a solar energy testing center at Madurai Kamaraj University. The hardware setup is shown in Fig.8 and Fig.9. A high precision pyranometer is used to measure the solar radiance on a plane surface. LM 35 a sensing device to measure the current temperature in the solar panel. These two parameters highly influence the performance of the solar panel[16].

Since irradiance is corresponding to current and temperature affects the voltage of the solar module. Hence the power generation of the solar panel relies on temperature and irradiance. The proposed system programming codes are developed in C language via Energia IDE. This is a non-proprietary integrated development environment designed for Texas Instruments like CC3200 Microcontroller. The blynk libraries are included in the programming function to communicate and transfer the sensed values to the Cloud platform. The electrical characteristics are monitored and displayed successfully through a mobile application. The result in Fig.10 shows the real-time Solar PV monitoring system through Blynk. The inference of output is the increase in temperature reduces the voltage generation in PV and also the rise in irradiance shows a moderate increase in current. Hence these two parameters become the deciding factor for the performance of solar module. The results shown in Fig.11 are displayed in the Web server. The Fig.13 shows the output in serial monitor of PC. The obtained result is nearer to the Standard ratings of a solar panel.

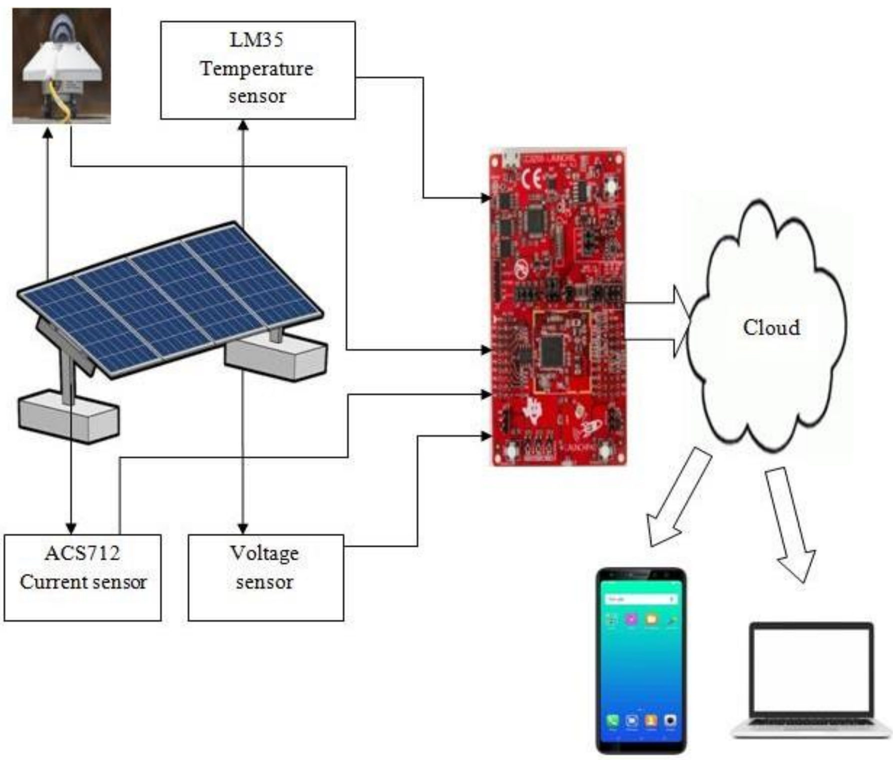


Figure.8 Hardware implementation of proposed work

Figure.9 Experimental setup of Solar PV Monitoring System

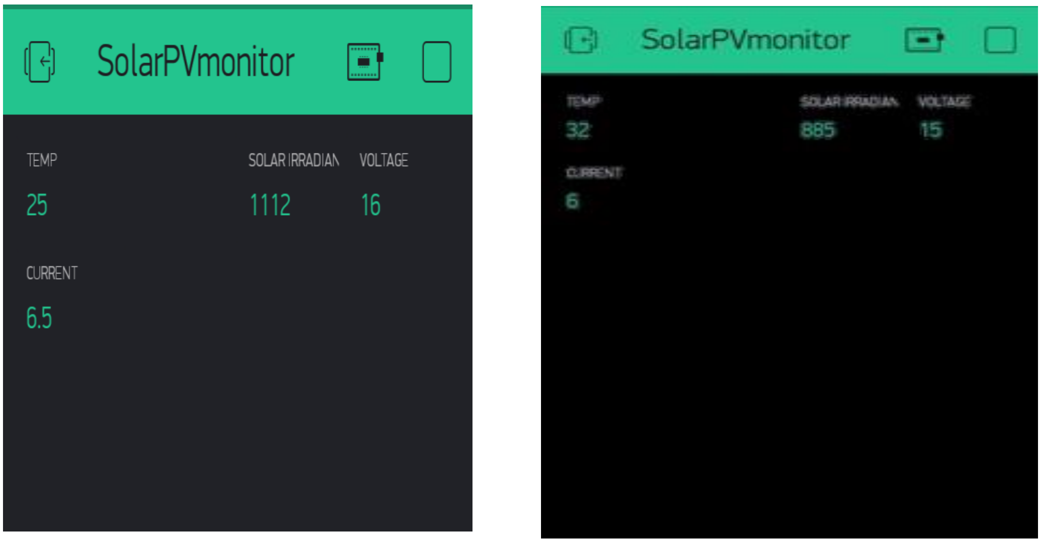


Figure.10 Real-time Solar PV monitoring system using Blynk

Fig.11(a)

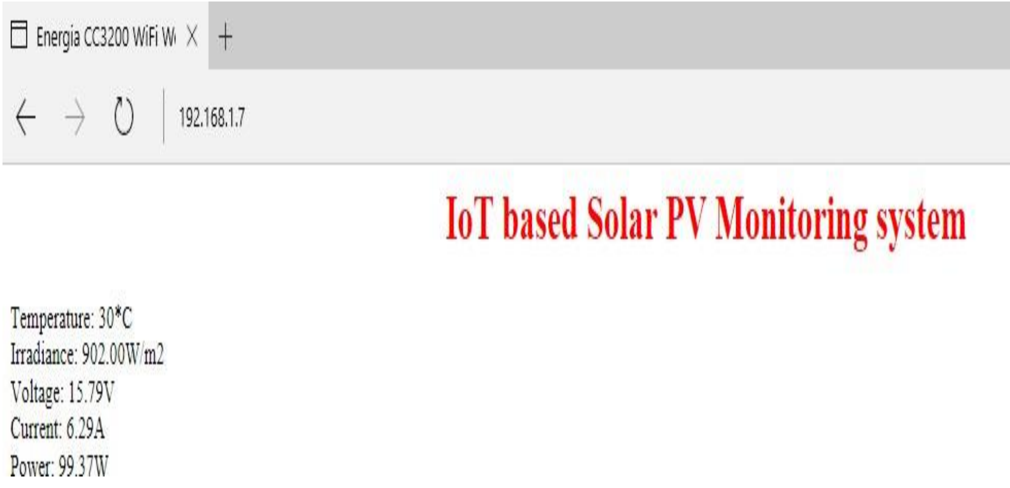
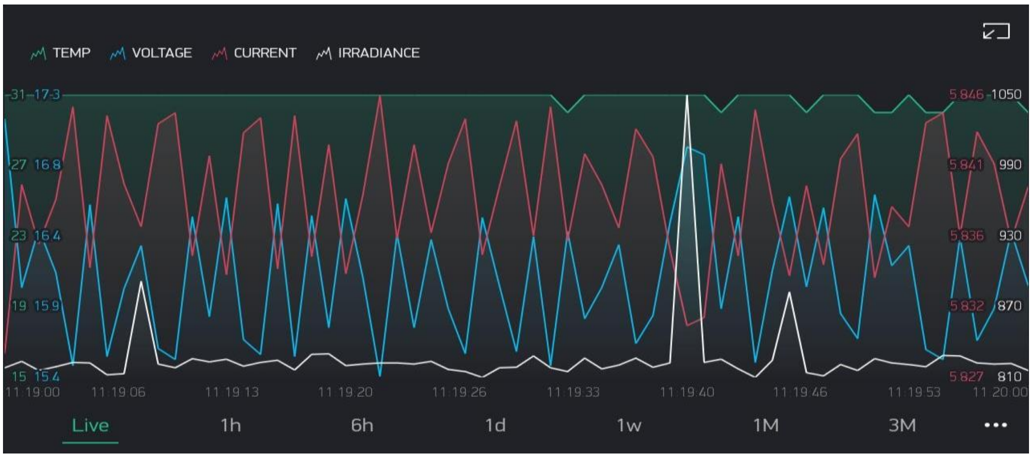


Fig.11(b)

Fig.11 (a-b) Solar PV Monitoring output through Web server

Fig.12 represents graph of solar power monitoring system through blynk application. The experiment is carried out for a week with different time intervals from 10.00AM to 05.00PM in a Solar Energy testing centre at Madurai, India. The electrical parameters of PV module are analyzed by continuous monitoring for estimating the behavior of solar panel. The graph shows the variation in temperature due to climatic condition which influences the voltage generation and irradiance affects the current parameter of PV module. The standard operating temperature of the solar panel is 25°C. Generally, the temperature above the standard test condition may reduce the performance of solar panel [16]. The decrease in temperature shows the rise in voltage as shown in Fig 12(a), (b), (c), (d), (e), (f) and the current directly correlate with irradiance. Hence, the change in solar radiation impacts the current characteristics in PV panel. The temperature reduces from 31°C to 30°C during morning hours from 10.30 AM to 11.30AM; the voltage goes to peak and then oscillates until reaching the stable state, at the instance irradiance is also maximum at this temperature which is shown in Fig.12 (a) and (b). The result of 12(c) represents the fall in temperature after 11.30AM and simultaneously the irradiance shows sharp reduction in spectral range. The Fig.12 (d) display the rise in temperature after 01.00 PM, at this stage irradiance level increase as current increases and the voltage generation reduces when there is a rise in temperature. The graph plotted in 12 (e) and (f) is observed after peak hours (i.e.) 02.00 PM to 05.00 PM. During the interval the temperature changes frequently from high to low and low to high and also solar radiation varies according to environmental condition. Hence the result shows the maximum power generation of solar panel which is nearly close to standard rating ofPV.

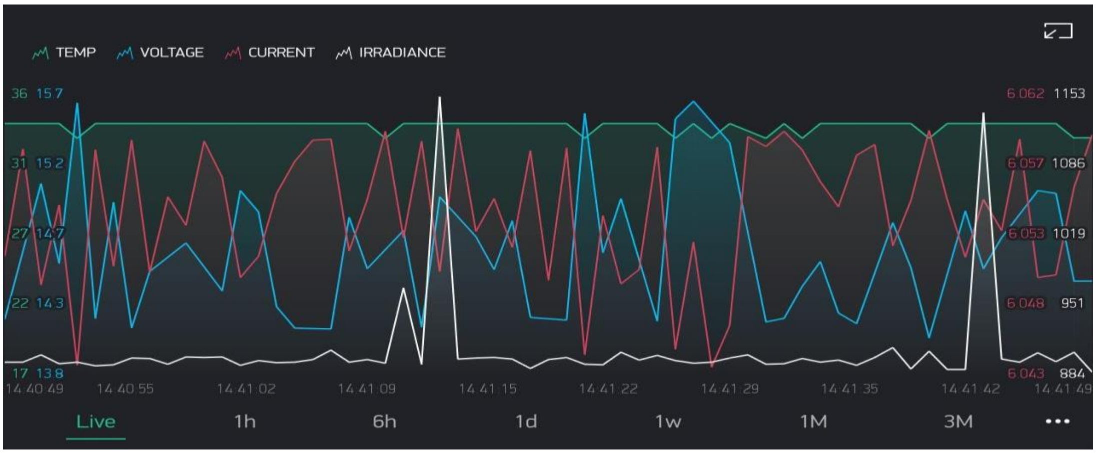
(a) Solar power monitoring at 10.50AM



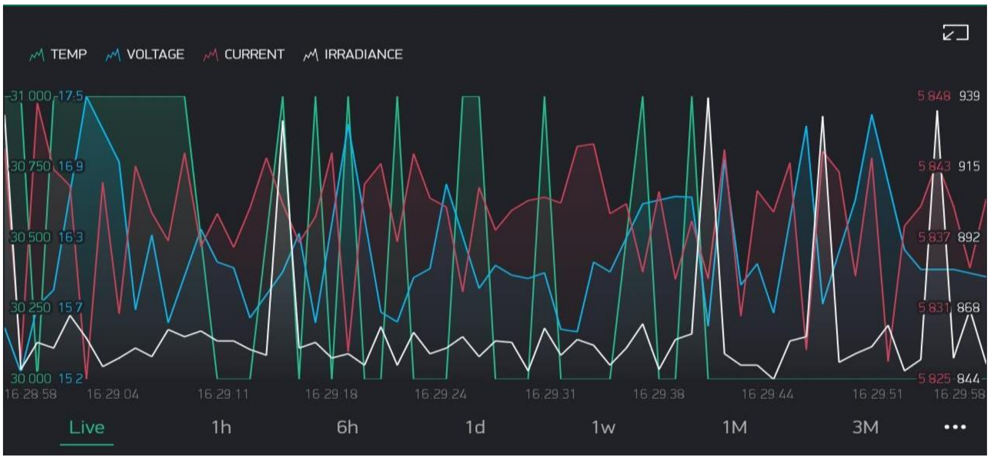
(b) Solar power monitoring at 11.20AM

(c) Solar power monitoring after11.30AM

(d) Solar power monitoring after 1.00PM



(e) Solar power monitoring after 2.00PM



(f) Solar power monitoring after4.00PM

Fig.12(a-f) Graphical view of solar energy monitoring system through blynk application

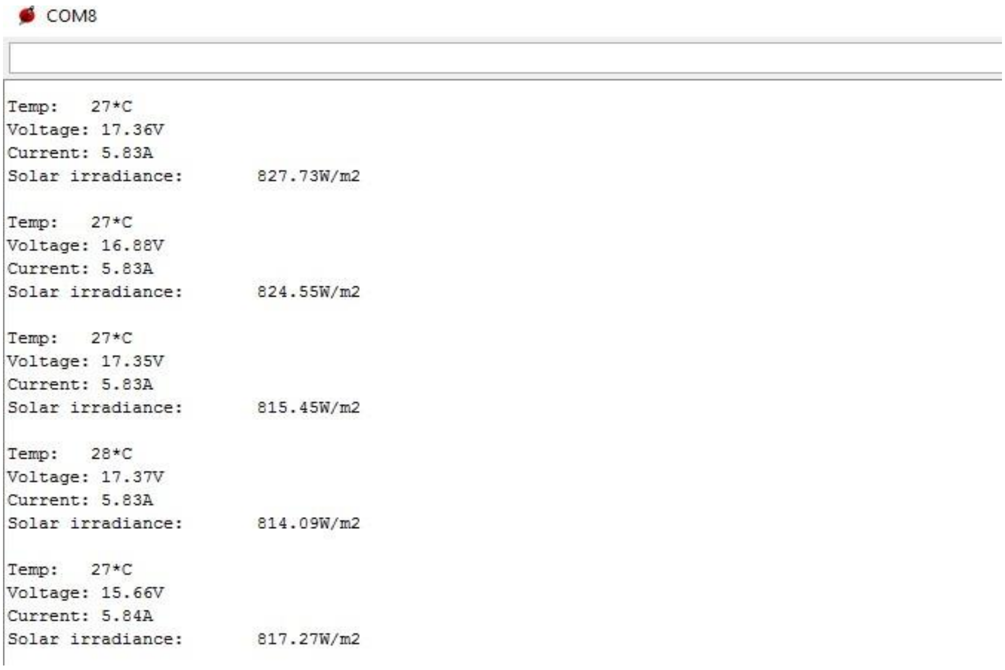


Fig.13 Solar PV Monitoring Output through Serial Monitor

Table.1 125-Watt Solar PV ratings

S.No	Electrical ratings	Value
1.	Rated Maximum power (P_{max})	125Wp ± 3%
2.	Open-Circuit Voltage(V_{oc})	21.6 V
3.	Short Circuit Current (I_{sc})	7.66 A
4.	Voltage at Maximum power (V_{mp})	17.65 V
5.	Current at Maximum Power(I_{mp})	7.08 A
6.	System voltage	1000V_{max}

5. CONCLUSIONS

An IoT based virtual solar energy monitoring system is developed using a low-cost smart microcontroller. The cloud-based Blynk application shows the measured solar parameter in real-time through mobile. The monitored parameters show the optimized result that matches approximately with Electrical ratings of solar module tested under Standard Test Condition (STC). The proposed work helps to predict the performance of the Solar PV module through remote access. This can be extended for a large-scale solar plant to take preventive action by regularly monitoring the performance of the solar plant. It will be highly useful for the industrial and commercial application.

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