An IOT based Smart Solar Photovoltaic Remote Monitoring System

Monika P. Tellawar
PG Scholar, Department of Electrical Engineering
Ballarpur Institute of Technology
Balharshah, Maharashtra, India.

Nilesh Chamat
Assistant Professor, Department of Electrical Engineering
Ballarpur Institute of Technology
Balharshah, Maharashtra, India.

***Abstract*— Data logger and monitoring systems are very crucial for the efficient, robust and smooth operation of PV solar energy system. Data logger and monitoring system enables the proper operation and contributes to identifying system malfunctioning before any major breakdown. In this thesis, a low-cost, user-friendly, reliable data logger and monitoring system has been developed mainly for a pico solar home system in a rural area of a developing country. This ESP 32 microcontroller based data logger stores all monitoring parameter in a micro SD card and displays that on a Blynk App. Data can be downloaded directly from the webpage to analyze and verify the system operation.**

The developed data logger hardware prototype uses only four sensors for humidity, temperature, voltage, and current sensing. An already developed Android app is use for cell phone to display all parameters in real time basis for an efficient monitoring which can also able to give important information to maintenance personnel for any issues in battery charging. To accomplish the task, we have developed the hardware implementation of remote data acquisition architecture of photovoltaic systems based on the Internet of Things. The overall cost of this prototype is economical.

***Keywords*— Photo-voltaic (PV), Remote monitoring, Internet of things (IoT), Maximum power point tracking (MPPT), Cloud.**

I. INTRODUCTION

In this modern world, Electricity is also added to the most basic needs in everyone's life. The graph of energy consumption is getting increased day by day where as the energy resources are diminishing parallel. In order to balance the scarcity for electricity, various sources are used to generate electricity. For the generation of electricity, there are two ways: one is by conventional method and other one is nonconventional method. Some of the energy carriers like fossil fuels and nuclear fuels are also used, but they are not renewable resources (i.e., they are not 'refilled' by nature) and it is said to be non-conventional. In its broadest sense, sustainable power source can be achieved by using the solar power as source. The wide availability of solar energy has throughout the world. Even The sun has produced energy for billions of years. The sun's rays may cat as an important source for the generation of electricity by converting it into a electric power. Such application is called as solar thermal energy, which is conventional.

Even though various sustainable sources are available such as wind, rain, tides and geothermal, natural based bio fuels and conventional biomass, solar power have huge benefits.

Nowadays in India, frequent power cut is very common. For that it is primary to use the renewable energy and monitoring it secondarily. The rapid growth in renewable energy applications have been empowered by a critical drop in cost over the earlier decades and specialized change in their productivity, unwavering quality and lifetime. And by means that of monitoring the energy prediction, households and communities, the productivity gets increased.

In case of India's development and economic growth, electricity plays a vital role. In energy consumption, India is the fourth biggest country after China, USA and Russia. The electrification rate in India is 64.5%, while 35.5% of the population still lives without access to electricity. Internet of things means that merely the network of Physical objects. This provides the connection of each and every object in the world by means of wireless sensor network. Some devices, buildings, vehicles and other objects embedded with software, network connectivity and sensors can enables these objects to collect and exchange data.

This IoT (Internet of Things) is achieved by wireless sensor networks, sensor networks, 2G/3G/4G, GSM, GPRS, RFID, WI-FI, GPS, microcontroller, microprocessor, etc. Empowering advancements for the Internet of Things are considered and gathered into 3 classifications. They are,

- Advance that empower "things" to accept contextual information or Data.
- To process the relevant data, and
- Innovation to enhance security and protection.

Accepting the information and processing the relevant data can provide an understanding which is needed to build the "intelligence" into "things". This is the highlighted feature that differentiates IoT from standard internet. The need for using IoT concept in this solar tracing system is to overcome the major disadvantages of electricity generation from the solar energy. The range of sun's radiation that reaches the ground surface is not in a fixed value. Because the range may varies according to location, time and climatic conditions. For that the solar panel can be completely exposed to the sun's radiation always. And hence the solar panel can be monitored by using Internet of Things. Among all techniques which have been studied for the solar panel tracking system by using IoT.

This paper is organized consisting of these sections: Section II discusses the literature survey in this area. Section III discusses the proposed work done. Section IV discusses the Results and Discussions. Section V summarizes the conclusion and lastly, the references used in writing this paper.

II. LITERATURE SURVEY

P. C. M. Carvalho [5] proposed design and development of a monitoring system get information on the defected solar panels for timely repair and maintenance. Based on a low-cost wireless sensor network; the design, development and the work of monitoring system of distributed solar panels along with automated data logging has been reported to help the current situation. This system can be used up to 146 V and 15.5 A solar cell systems with an automatic selection of best resolutions. The overall cost of their system is rupees 12000.

Lab-VIEW based real-time interface system in paper [6] presents, a detailed characterization of the performance and dynamic behavior of photovoltaic systems. They developed a software tool that integrates several types of instruments into a single system which can offer online measurements of all data sources and compare simulation results with monitored data in real-time. The proposed method provides a fast, secure and reliable system by making the system database-ready for performance analysis of PV systems. The integration methodology of robust simulation and monitoring data in real-time can be used to study the fault diagnosis of a PV system.

To solve the current problem of monitoring photovoltaic (PV) systems especially for regions in developing countries or remote areas; an Arduino based open-source electronic platform data logger was developed [7]. This data logger meets the International Electro technical Commission (IEC) standards requirements with a resolution of 18-bits, including 8 analog inputs for measuring up-to 8 PV modules. They mentioned that this data logger can be customized for the specific needs of each project at low-cost and the cost is around 6000 rupees.

Jongbae Kim, [8] designed a remote intelligent monitoring system based on Tiny OS for monitoring and management for PV power generation. This system had implemented remote monitoring and reverse control by the host computer, ARM gateways, wireless sensor networks, and other components.

A simple sensor-based microcontroller data acquisition system for monitoring the temperature data in solar installations is developed by Gad et al. [9]. The system can easily change the date; time of experiment start and end, sampling rate and deals correctly with corruption such as power failure. The proposed data acquisition system can handle up to 16 sensors, has user interface system (4 buttons LCD screen), own storage systems such as flash memory or SD card; therefore, it doesn't require any external computer to store the sensors data. This system automatically creates a new file on the SD card every day and records data on it and data can be handled and analyzed easily by any mathematical software such as Excel or MATLAB. The system monitors the sensors remotely by using the internet.

Shri hari prasath et al., presented their research in [10] to design and implement a Smart Remote monitoring system using IOT that can monitor the Solar PV PCU and stores data in the cloud database through an easily manageable web interface. The proposed system has flexibility by using GPRS technology to interconnect the Solar PV Power Conditioning Unit to the Remote server.

Another designed with the help of Lab VIEW and DAQ card is presented in [4]. The solar panel is connected to the battery and then with sensors. The proposed system is connected by four sensors with Lab VIEW via DAQ hardware to acquire data. Lab VIEW has shown a high performance in communicating with several devices simultaneously and high capability of displaying several variables behavior at a time.

An android based design of an electronic system for the measurement and control of the physical parameters like water temperature, solar collector's fluid temperature, solar radiation level, etc. to monitor and consequently optimize thermal-solar plant functioning is presented in [6]. The designed control unit can monitor and program the device functionality by means of a touch-screen graphical display that to check or correct operation and quickly reveal any fault, to manage and view locally the plant functioning by serial connection to PC with terminal role, and also remotely viewing and monitoring actions, by Android-based mobile devices, through RS485/Ethernet adapter and modem/router device connected to internet network.

Soham et al. proposed a conceptual system in [7] to monitor the state of a photovoltaic system through an IoT based network to control it remotely. Through the the mobile radio network, the information from the sensors is transmitted. To send data to the remote server a GPRS module is employed. Starting with the sensing layer at the bottom, an IoT application schematic have three layered comprises of current sensors, voltage sensors, pyrano meter for irradiance measurement and other sensors which also includes microcontroller-based data processing of data acquired from sensors. The microcontroller communicates with a wireless module to initiate and transmit data to the server. Layer 2 as envisaged is the network layer where data logging from the plant for real-time processing is done which includes a database for storage. Then after the network layer, this processed and stored data is used in the application layer. In this layer sophisticated web-based services are designed based on the data collected, processed and stored. Graphical user interfaces will help to monitor the performance of the plant, the console will also advise the administrator with decision-based on historical data that will significantly reduce the decision-making time.

S. Adhya, D. Saha [2] proposed a Renewable Energy Monitoring System (REMS), a new concept of an open source and low-cost data acquisition and transmission system using multi-user cloud remote monitoring, Raspberry Pi, and IoT, applied to decentralized RE plants. REMS architecture, based on the Internet of Things (IoT) and Cloud computing principles, consists of three main parts San USB microcontroller, Raspberry Pi (Rpi) Embedded Linux System (ELS) and Online Web Monitor for real-time cloud monitoring.

III. PROPOSED WORK

The main objective of this proposed work is to monitor the output of PV system using the current and voltage value sensed by the arduino. To implement in smart grid, this system helps for efficient usage. In this section we present the IoT based monitoring system design of the Solar Energy Monitoring System.

A. System Design

The proposed system is for monitoring and controlling the output of solar energy using IoT. Solar panel helps to store the energy in the battery. Battery has the energy which is useful for the electrical appliances. Battery is connected to the Arduino. To read the sensor values Arduino, which is a micro controller, is used. Current sensor and voltage divider are connecting to the Arduino.

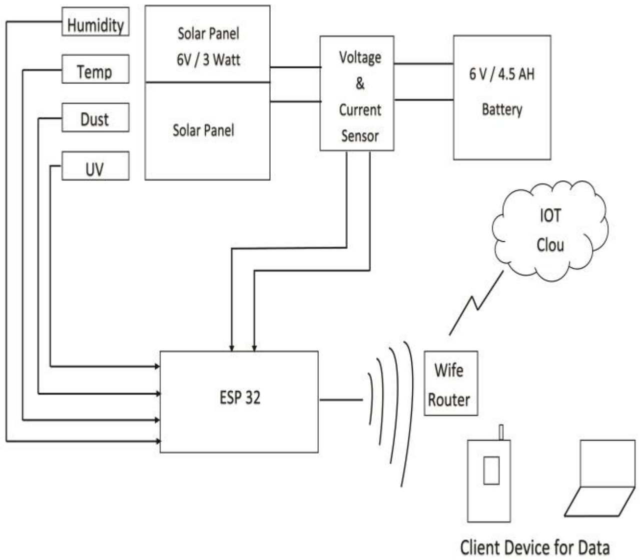


Fig. 1. Block Diagram of IOT Based Solar Monitoring.

The data from the arduino is display on a Blynk App. The monitoring data upload to the cloud through ESP32 as shown in the Fig 1.

B. Arduino IDE

Arduino integrated development environment (IDE) is a cross-platform application which is written for both Windows and Linux operating systems using Java programming language. Arduino IDE is developed by Arduino and it originated from the IDE for the languages Processing and Wiring [29]. The IDE consists of a text editor for writing code, a compiler, and debugger to compile the code and checking errors in the code. It supports the languages C and C++ using special rules of code structuring.

A software library from the Wiring project is supplied by Arduino IDE, which offers many common input and output procedures. In this IDE a code only requires two basic functions, one is set up which initializes all modes and setup of different pins. The other function is a loop which executes in the cyclic order of its commands. The Arduino IDE uses the avrdude program to convert the executable code into a text file in a hexadecimal encoding which is loaded into the microcontroller board by a loader program in the board's firmware [30].

C. ESP32

ESP32 is a microcontroller from Espressif and the Spark Fun ESP32 Thing is a WiFi-compatible comprehensive development platform. It has 28 GPIO pins, 802.11 B/G/N integrated WiFi transceiver. ESP32 is a WiFi-compatible microcontroller, but to that, it adds support for Bluetooth low-energy, and nearly 30 I/O pins.

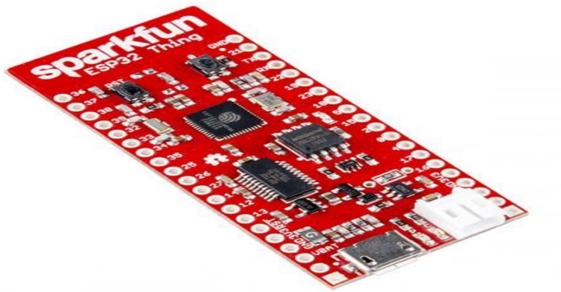


Fig. 2. Block Diagram of IOT Based Solar Monitoring.

D. Current and Voltage Acquisition Circuit

Up to 5V can be measure by the analog inputs of Arduino. Even when connect to a 5V circuit, to help to protect the Arduino from short-circuits or unexpected voltage surges, one should use the resistors. The circuit of voltage divider as shown in the fig 3.

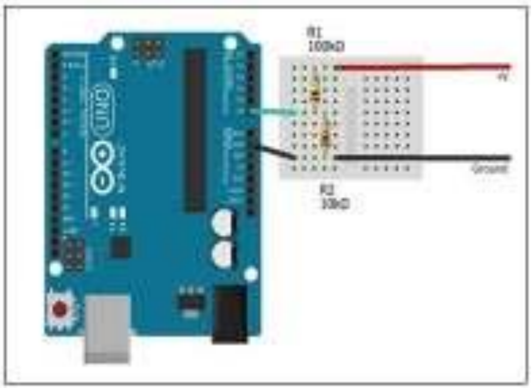


Fig. 2. Voltage Divider.

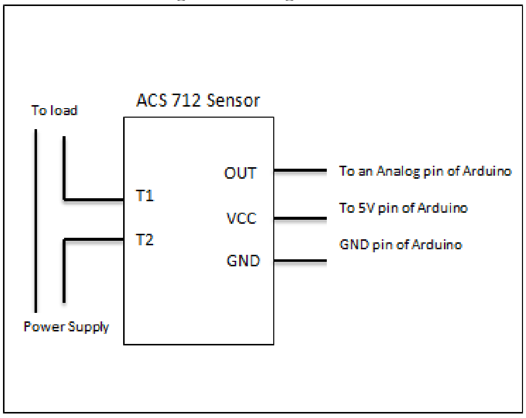


Fig. 3. Current Sensor circuit.

This two resistors form a potential divider which is used to lower the voltage being measured to a level which the Arduino can read. Fig 3 shows the voltage divider circuit. To reduce the voltage circuit to 5V two 10 kohm and 100 kohm register are used. PCB is used to build this circuit. The voltage value is given by the Analog pin of arduino. The formula for calculating values in a potential divider is:

$$Vout = (R2 / (R1 + R2)) * Vin$$

Vout will be a maximum of 5V only when the divider for the Arduino voltmeter is functioning correctly. The maximum input voltage to the circuit is given by:

$$Vmax = 5.0 / (R2 / (R1 + R2))$$

Hall Effect current sensor ACS 712 (30 A) is used here for current measurement. ACS 712 measure positive and negative 30Amps, corresponding to the analog output 66mV/A. This current sensor gives the readings of the current. Those values are used in the proposed system for calculating power. In this setup two DC motors are consider as a load. Battery is considered as the power supply. Other pins of sensor is connects to the Arduino. Once the connection is done as shown in the fig 4, Arduino display the values of current flow.

IV. IMPLIMENTATION

A. *Work Flow*

The work flow of the PV monitoring system is given in the form of step below:

Step 1: Arduino display the power usage using sensed values through current sensor and voltage divider.

Step 2: ESP32 fetch the arduino output data through serial port and display on Blynk App.

Step 3: ESP32 sends the monitoring data on to the cloud.

Step 4: Cloud display the data in the form of graph, which is visible to the entire user.

B. *Hardware Setup*

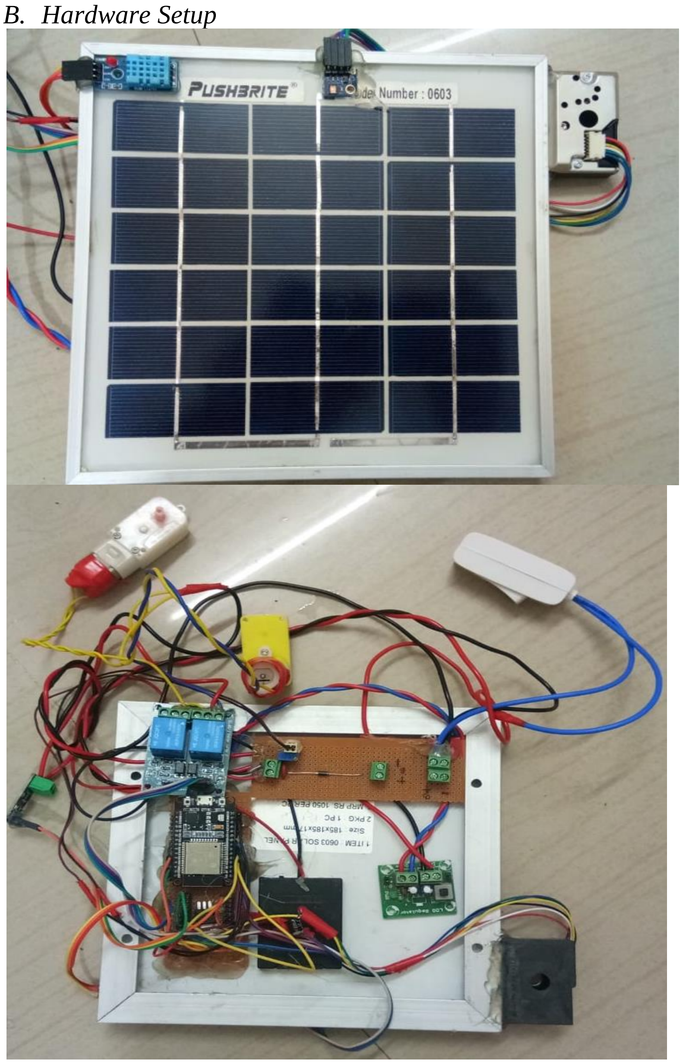


Fig. 7. Hardware setup of the proposed system.

Fig 6 shows the Hardware setup of the proposed system. The solar energy stored in battery by solar panel is DC current. Arduino sense all the parameters like temperature, humidity, UV radiations, load current and voltage value through the senser connected to Analog pins. Output is send to the EPS32. EPS32 is considered as the server. The monitor displays the web page and cloud data.

C. *Software Setup*

Blynk is a Platform with an Android app to control Arduino. It's a digital dashboard where by simply dragging and dropping widgets one can build a graphic interface for project. Instead, it's supporting hardware of your choice. Whether your Arduino or Raspberry Pi is linked to the Internet over Wi-Fi, Ethernet or this new ESP32 chip, Blynk will get you online and ready for the Internet Of Things.

Blynk was designed for the Internet of Things. It control hardware remotely, display sensor data, stores the data and vizualize it. There are three major components in the platform:

Blynk App - allows to create interfaces for projects using various widgets.

Blynk Server - responsible for the communications between the app and hardware. one can use once own Blynk Cloud or run onces private Blynk server locally.

Blynk Libraries – enables the communication with the server and process all the incoming and out going commands.

Now imagine: every time you press a Button in the Blynk app, the message travels to the Blynk Cloud, where it magically finds its way to your hardware. It works the same in the opposite direction and everything happens in a blynk of an eye.

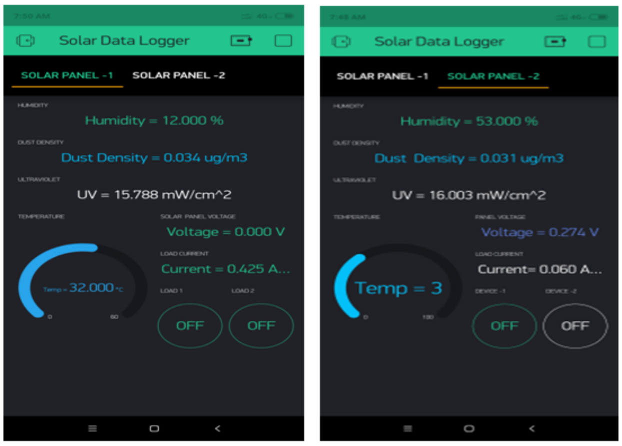
V. RESULTS AND DISCUSSIONS

Fig 5 represents the entire hardware setup of the proposed system. The result of the system is displayed on the Blynk webpage in the form of the table contains current in amperes, voltage in volts, humidity, temperature, UV radiation and dust density with respect to date and time.

The monitoring data sent to the cloud is store in separate fields. Each fields display the individual graphs, the output of the monitoring system obtained in four different cases as shown in the Fig 7.

Case 1- Solar Panel 1
Device 1 OFF, Device 2 OFF.

Case 1-Solar Panel 2
Device 1 OFF , Device 2 OFF



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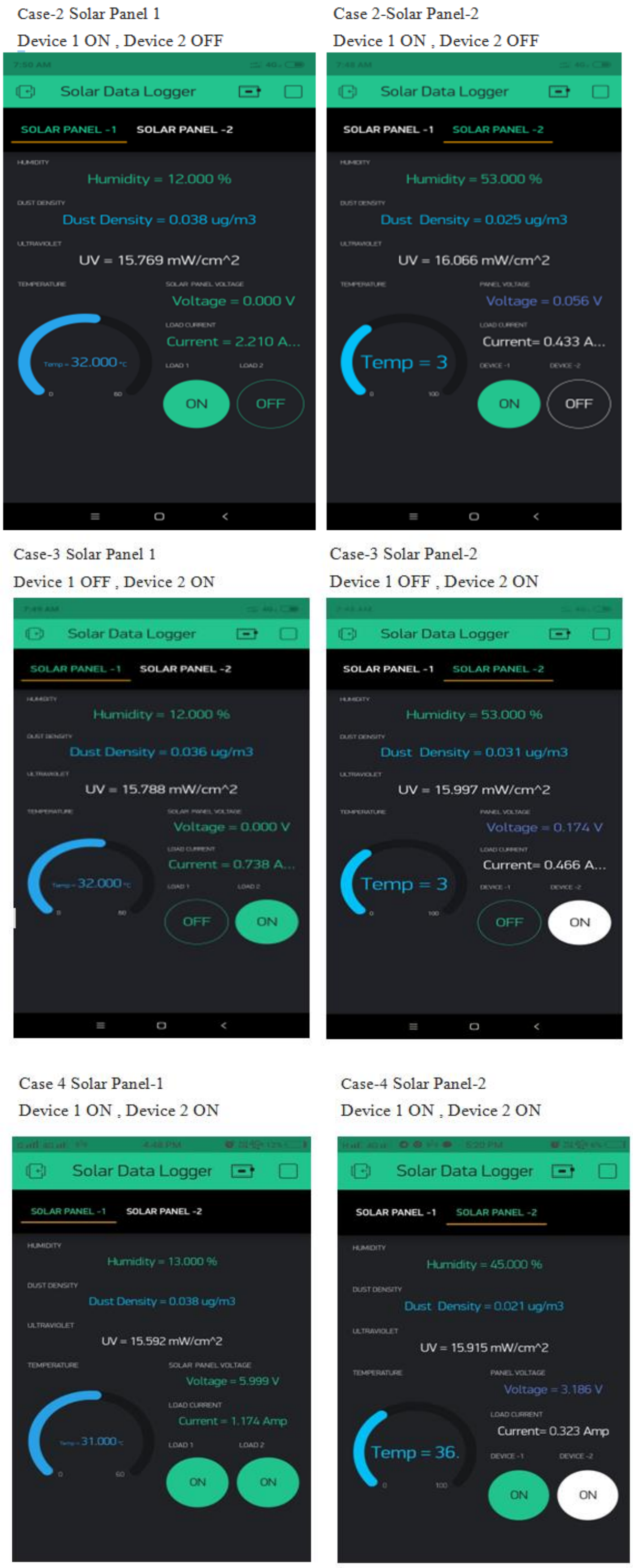

Fig. 8. Output results of solar panel 1 and 2 in different cases.

IOT-based monitoring improves the energy efficiency of the system, reduce supervision time and facilitate the network management. The Various cases for the IoT based data acquisition system has been tested successfully and the simulation analysis results are shown in table I.

TABLE I. DIFFERENT PARAMETER OF SOLAR PANAL IN DIFFRERENT CASES

S.N.	Cases	Parameter	Solar Pane-1	Solar Panel-2
1	DEV 1 OFF DEV 2 OFF	Humidity Temperature Dust Density Ultraviolet Load Current Panel Voltage	12.00% 32 °c 0.034 ug/m3 15.788 mw/cm2 0.425 A 0.257 V	13.00% 33.00 °c 0.031 ug/m3 16.332 mW/cm2 0.060A 0.274 V
2	DEV 1 ON DEV 2 OFF	Humidity Temperature Dust Density Ultraviolet Load Current Panel Voltage	12.00% 32 °c 0.038 ug/m3 15.769 mw/cm2 2.210 A 4.660 V	11.00% 30 °c 0.025 ug/m3 16.066 mW/cm2 0.433 A 0.056 V
3	DEV 1 OFF DEV 2 ON	Humidity Temperature Dust Density Ultraviolet Load Current Panel Voltage	12.00% 32 °c 0.036 ug/m3 15.788 mW/cm2 0.738 A 2.444 V	13.00% 31 °c 0.031 ug/m3 15.997 mW/cm2 0.174 A 2.466 V
4	DEV 1 ON DEV 2 ON	Humidity Temperature Dust Density Ultraviolet Load Current Panel Voltage	13.00% 31 °c 0.038 ug/m3 15.592 mW/cm2 1.174 A 5.99 V	45.00% 36 °c 0.021 ug/m3 15.997 mW/cm2 1.323A 3.186 V

VI. CONCUSION AND FUTURE WORK

The integration of renewable energies into the electricity distribution network has become a necessity and consequently the search for new and effective solutions for remote monitoring and control is required. In this project, an IOT-based solar panel remote monitoring system has been proposed to collect data on important parameters of solar panels. The continuous record of performance data and failure data enables by IoT, so that it can be used for analytics for predicting and forecasting the future power generation possibilities, income production etc. The frequent maintenance of the photovoltaic systems also gets prevented by it. IoT will play a major role in accessing the control over the photovoltaic system installed at remote locations or far away from the control center. IOT-based monitoring will improve the energy efficiency of the system, reduce

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intervention and supervision time, and facilitate network management.

After studying the remote monitoring architecture for solar panels, the next step will be to implement, test and achieve this IOT-based system in order to obtain a reliable and secure system which will allow data collection in real time. Apart from that by using various Machine Learning algorithms and model it is possible to make system smart enough to take decision about data and performance.

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