IoT enabled Solar PV Maximum Power Tracking System

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Abstract: There have been significant technological growth in photovoltaic systems worldwide in recent years. It has increased environment-friendly electricity production. The Internet of Things (IoT) is one of the developing technologies with huge probabilities. IoT's association with renewable energy systems increases reliability and improves the controlling applications. Similarly, a solar PV system with IoT tracking is presented and analyzed in this work. Maximum energy production from solar cells is a preferable required criterion. This condition required a better leading power point tracking scheme which maximizes the power production of the photovoltaic cell in various odd conditions. Accordingly, the full proficiency of the solar power system can also increase by improving MPPT schemes. Over the past decade, many methods have been anticipated to implement maximum power tracking in a solar PV system. A novel idea of interfacing an IoT system and a photovoltaic system under partial shading conditions is proposed in this article.

Keywords: Solar PV, Internet of Things, P&O, MPPT,

1. INTRODUCTION

With the rising rate of power consumption and greenhouse emissions worldwide, many clean and environmentally friendly alternative renewable sources of energy generation have been. It has expanded the demand for renewable resources like solar photovoltaic devices [1]. Solar PV systems are executed either in off-grid or on-grid applications. Solar panels can be implemented on the rooftop or a plainer surface, according to system size and space availability [2]. Maximum power point tracking (MPPT) is a significant technical advancement used for the ultimate energy tapping from the solar PV system. Solar PV MPPT maintains the alignment of solar panels in the direction of maximum solar radiation fall. The MPPT method is efficiently performed under partial shading situations. Recently, several MPPT techniques have been projected for solar PV systems [3]. The performance of the solar photovoltaic system can be improved by adding different MPPT techniques. Currently, the Internet of Things (IoT) is a rising technology. It provides a connection between computing strategy and physical devices (such as mechanical devices, devices for animals, or human beings) through the internet for telemetric controlling. In the present scenario, the association of the Internet of Things with Solar PV MPPT schemes increases the performance of the whole arrangement. IoT technology collects the panel's statistics and is despatched to the cloud through the internet. The MPPT controlling devices utilize the IoT and additionally monitor many parameters of the Solar PV Monitoring System. It sends the command to start or stop the system scheme according to calculated records by the person from a remote place through the internet [4]. This paper presents a solar PV monitoring system using IoT-based MPPT techniques. The work given here shows better solar energy tracking performance than the other method.

2. METHODOLOGY

The solar energy application is growing at a rapid rate globally. In general, solar cells show nonlinear characteristics with changes in the weather. The power-voltage and current-voltage curves of the solar PV scheme keep a nonlinear property that primarily relies upon surroundings temperature, solar irradiance, and connected load [5]. The MPPT techniques have been developed for obtaining the Maximum Power from the photovoltaic cell. Several methodologies are used for tracking the maximum power and operating the solar PV panel at MPP more efficiently. Recent works include incremental conductance, perturb and observe, inherent neural networks, AI-based schemes and fuzzy logic control [6-8]. A combined operation of Solar PV systems with IoT-based MPPT tracking is proposed in this work. The complete procedure of the whole system follows the flow chart shown in figure1.

3. SOLAR PV SYSTEM

It is widely known that the Solar PV panels are made of solar cells. The solar cells are carrying the properties of semiconductors as they are basically member of semiconductor diode family sensitivity to the solar radiations. Therefore output of photovoltaic cells, responds for the solar irradiance, temperatures, shades, and dirt. At present, several models for solar cells are used for analysis by the different scholars [6-9].

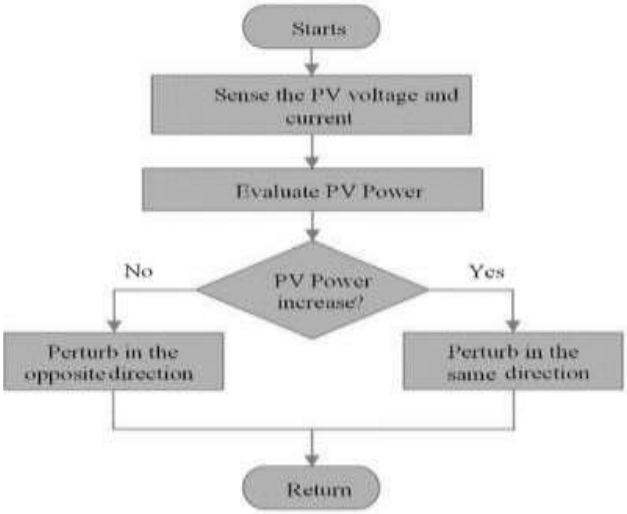


Figure 1: Flow chart of proposed system.

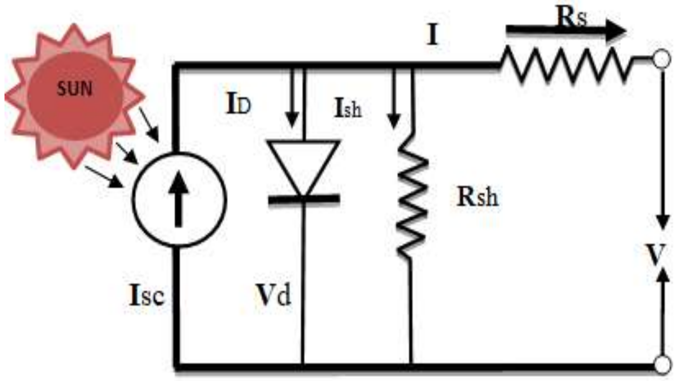


Figure 2: Schematic representation of a solar PV cell in Single diode model [11].

The single diode version is observed more efficient as compared to the double diode model. Therefore, a schematic arrangement of single-diode based photovoltaic scheme is considered for the solar cells study as illustrated in Figure 1. The short-circuit current also known as photo-current is presented by equation (1).It is generated by the fall of solar radiations on the solar modules.

$$I_{sc} = G/1000\ [I_{scr} + K_i\ (T_c - T_r)] \quad (1)$$

Where,

I_{sc} = Photo-current, G = solar irradiance, K_i= Temperature coefficient, I_{scr} = Reverse saturation current, T_r = Reference temperature, T_c = Cell temperature,

The output (V_{oc}) in the single diode model of the solar PV cell can be given by equation (2).

$$V_{oc} = \ln\ (I_{sc}/I_o + 1)\ (nkT_c) \quad (2)$$

Where,

V_{oc}= Open circuit voltage, n = Ideality factor, I_o = Saturation current, k = Boltzmann constant, T_c= Cell temperature,

The voltage and current relation of the solar cell is given by Equation (3)

$$I = I_o\ [\exp\ (qV/kT) - 1] - I_{ph} \quad (3)$$

Where,

V= voltage across the diode, T = absolute temperature, I_{ph} = light generated current.

$$I = Isc - I_0\left[\exp\left(\frac{V+R_S I}{\frac{N_S kT}{q}a}\right) - 1\right] - \left(\frac{V+R_S I}{Rsh}\right) \quad (4)$$

Where,

Ns = series-connected cell, T = temperature of the PN junction, , Rs = Series resistance, Rsh = Shunt resistance

If the thermal voltage of the solar array is V_t = Ns KT/q, then Equation (4) may be rewritten as:

$$I = I_{sc} - I_0\left[\exp\left(\frac{V+R_S I}{V_t a}\right) - 1\right] - \left(\frac{V+R_S I}{Rsb}\right) \quad (5)$$

4. MPPT(Maximum Power Point Tracker)

In general, the solar panel tried to be inclined toward the solar rays to get the highest absorbance. The accurate tracking of solar rays may be possible by using the MPPT mechanism. The axis of the solar panel is connected with the MPPT controlling technique. The tracking action occurs in the direction of the maximum tapping solar radiation [8]. The solar PV module uses tracking schemes for collecting solar radiation and moving structures among different periods of flexibility used to manipulate the oblique angle. The tracking motion can be controlled via either an inherent or a remote controller. The most common popular MPPT techniques are P&O and incremental conductance. Most of the researcher proposes the Perturb and observe algorithm as the best and most cost-effective method for implementing MPPT in solar panels. In this scheme set of rules can be easily adapted together with the software program and the hardware platform [10]. As a result, the Perturbed and observe algorithm is used in many cases to implement solar tracking. When P&O is turned on, the voltage in the panel array is completely disrupted. Figure 3 represent the P–V curve whilst the Perturbed, and observed algorithm and flowchart given in 4 is active. The output energy of a maximum power point constantly oscillates around the MPP. By decreasing the perturbation step rate, the oscillations of the P–V curve can be minimised.

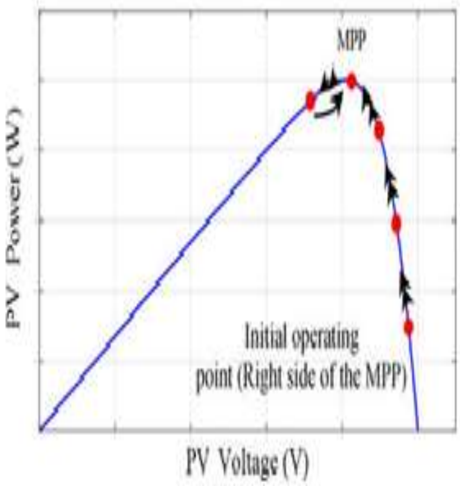


Figure 3 P-V curve of the Solar PV arra

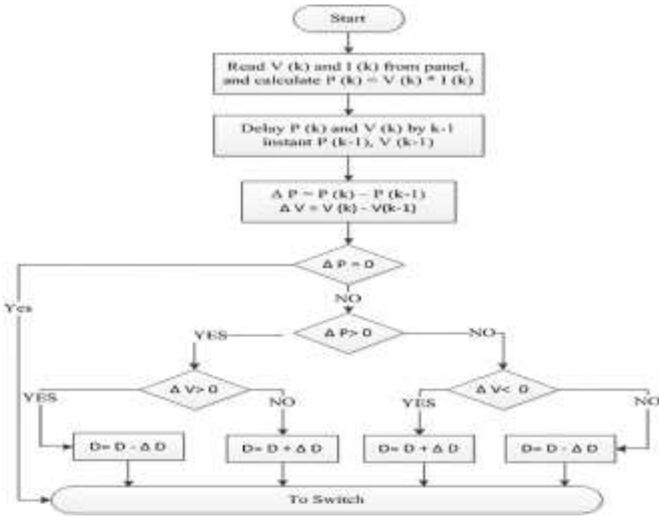


Figure 4. Proposed flowchart of P&O [10]

5. IoT (Internet of Things)

IoT has the capability to connect or control information without any human-to-human or device-to-computer physical interface. It works with the generation of unique ID, transmitted through wireless connection and operated by smartphone or any other device. The IoT is a rising technology have a tremendous ability to be applied for renewable energy, mainly solar photovoltaic cells. Maximum energy manufacturing is the general standard for any solar PV cell. The IoT is a spectre that combines numerous technologies in the conflux of power systems, data generation, elixirs, nanotechnology, and biotechnology. The Internet of Things system is primarily based on information apprehension systems, which include RFID, infrared sensors, GPS, laser scanners, and other different sensors, that can companion with the Internet to deal with teaching according to the protocol, which fetters sensible identification, locality and path, supervision, and management. In the intended system, we start the stain enumerate technique for monitoring sensors [10]. Cloud-based computing can also be accessed for different applications of IoT over the Internet. Cloud estimation is a large-scale processing opportunity that advances the system, as well as a complete generation that is entirely based on IP [12].

6. DESIGNING OF SOLAR ENERGY MONITORING SYSTEM USING IOT TECHNIQUES

The IoT-based monitoring and controlling solar devices using this device's online display makes use of power, voltage, current, temperature, climate changes, monitoring daylight, and dirt cleaning with the assistance of wipers. In the present work, IoT is used to track the MPP for the solar PV array. The application of this device tracking is to analyse daily data and controls solar wipers and daylight towards the motion of the solar panel [13]. The tracking and controlling are executed with the Arduino controller, the RPi, and sensors.

The implementation of an IoT-based monitoring and controlling system for PV panels is presented in figure 5. The components' features are then accumulated through a set of commands applied to a utility server to interrupt the solar energy tracking, determine the maximum power, and pick out uncommon occasions. This segment presents the framework of the Solar Energy tracking System using IoT techniques. Figure 5 depicts the observation of data transfer to the cloud via RPi. The schematic details of each block are discussed below.

6.1. Solar Panels

The Solar panels are made of solar cells arrangements. These cells are carrying the properties of semiconductors as they are basically member of semiconductor diode family sensitivity to the solar radiations. Therefore output of photovoltaic cells, responds for the solar irradiance, temperatures, shades, and dirt [14].

6.2. Sensor Unit

To recognize the alignment of the solar modules, an LDR was used as a light sensor, converting an alteration in resistance into a change in voltage [15].

6.3. Arduino Unit

An Arduino Uno is used to implement the sun tracking algorithm and controlling the motor. The voltage outputs of the LDR circuits are fed to the Arduino analog pins which are used for two servo motors. The Arduino board controlling scheme determines the voltage and once implemented, the solar panel block diagram determines the direction the panel should move.

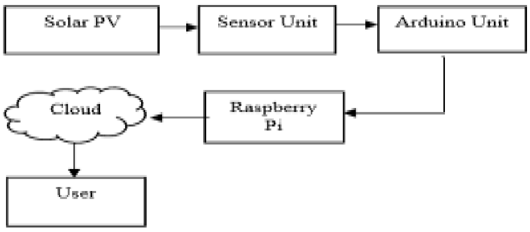


Figure.5: System Design of IoT based MPPT.

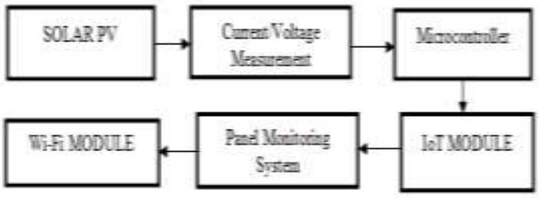


Figure 6. Solar PV Panel tracking Using IoT

7. WORKING SCHEME OF SPV TRACKING USING IOT

The schematic arrangement of SPV Tracking Using IoT is shown in Figure 6. The proposed hardware system is shown in Figure 7. Arduino detected the electrical parameters through a current and voltage sensor. The Raspberry PI provides information on Arduino output through the interface. Raspberry sends a review for the cloud. The cloud presents confirmation data in the form of signals that the entire patron can understand. The system design primarily ensures the observation of maximum power output in terms of the current and voltage estimation of the PV cell. The tracking information is transmitted between the controller and the PV server through the IoT channel. The controller unit processed the information about current and voltage to facilitate the server using the remote transmission.

The evaluation of current and voltage is checked and sent to the IoT module. In this work, the rural location of village Dasauli is considered for the hardware application situated at26°57.5’N, 80°60.0’E in the Tehsil BK Talab Distt Lucknow (UP) [13]. The annual solar radiation, clearness index and observed temperature are given in Figures 9 and 10. The peak season of solar radiation and temperature in May is considered for the study. The comparative values of load and power produced are displayed at the controlling location [19]. From this server, the current and voltage values of the PV panels can be controlled anytime, anywhere in the established PV system. The proposed solar system is tested by implementing an improved solar tracking P&O algorithm in hardware. Two servo motors are used for moving the solar panels. One is north-south, and the other is east-west. The controlling signal causes the servo-motor to move toward maximum radiation. Although the solar tracker monitors and adjusts the leading position of the solar modules, the solar output is constantly changing due to cloudy weather and solar radiation. The proposed improved P & O algorithm is applied for low-voltage solar systems using Arduino-UNO [14-15]. The outcome is transferred to software over the serial port and data from the Arduino output. It is observed that MPPT successfully tracked the maximum power from Solar panels. The PV characteristics of the solar panel traced the continuous operation of the PV module at that MPPT point.

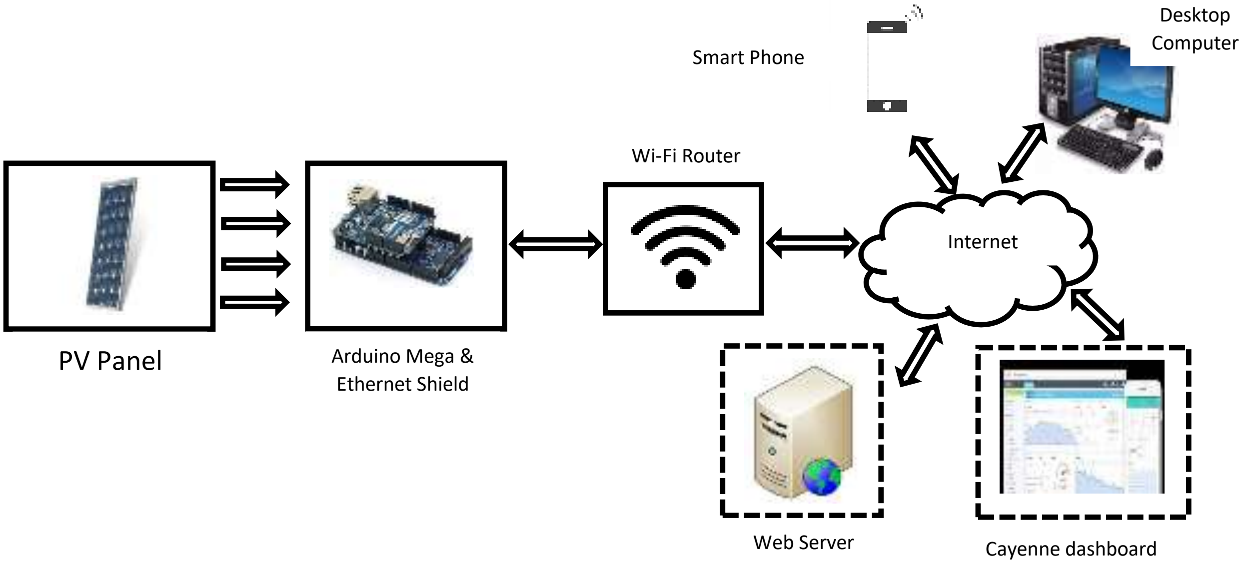


Figure 7: The experimental installation

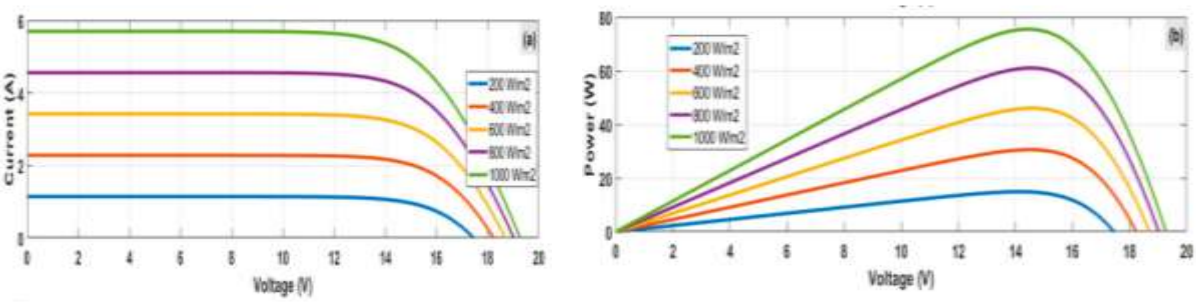
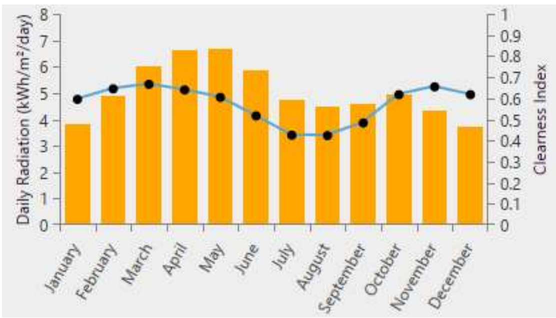


Figure 8: PV, VI characteristics of Working setup



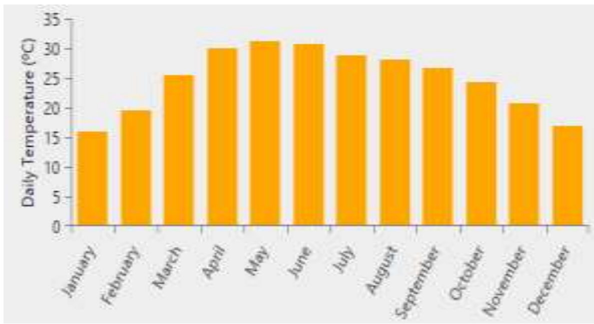


Figure 9: Solar radiation and clearness Index at considered location [20].

Figure 10: Annual Temperature at considered location [20]

8. RESULT AND DISCUSSION

The hardware scheme has arranged as shown in the schematic diagram. The system is performed for two conditions: the first condition is obtaining the result without IoT association in MPPT tracking. In the second, the monitoring is performed for the IoT-based arrangements. The obtained results are assimilated in Table 1 for both the conditions without IoT on the same day and with IoT performed in terms of voltage, current, and Power produced. There are many differences between the obtained result while using IoT and without IoT. Hardware system without IoT at 07:00 AM, gives the voltage and current as 10.80 V and 0.70 A, while it gives the voltage and current as 14.80V and 13.32A with IoT. A similar gap continues in both situations from 07:00 AM to 05:00 PM in voltage and current, as presented in Table 1. In addition, the power production also shows the gap between conditions with and without IoT: at 07:00 AM, the Power in both cases is 07.56 W and 13.32 W. The Power produced is approximately double the value without IoT. The comparative power curve for 24 hours is presented in Figure 11. It is very much clear from the figure that the system with IoT is more valuable because of getting the high value of the Power than the without IoT system.

Table 1: Comparative analysis of Power output with and without IoT association

Time in Hrs.	Case 1 (Without IoT)			Case 2 (With IoT)		
	V(V)	I(A)	P(W)	V(V)	I(A)	P(W)
07:00 AM	10.80	0.70	07.56	14.80	0.90	13.32
08:00 AM	10.70	1.00	10.50	14.60	1.20	17.52
09:00 AM	11.10	1.18	13.09	14.70	1.30	19.11
10:00 AM	11.30	1.20	13.56	15.20	1.40	21.28
11:00 AM	11.40	1.22	13.90	15.70	1.50	23.55
12:00 PM	11.50	1.30	14.90	16.00	1.60	25.60
01:00 PM	12.00	1.35	16.40	16.30	1.70	27.71
02:00 PM	12.80	1.42	18.15	16.80	1.75	29.40
03:00 PM	12.20	1.36	16.60	16.20	1.71	27.70
04:00 PM	11.40	1.25	14.25	15.80	1.62	25.59
05:00 PM	11.10	1.16	12.88	15.30	1.52	23.60

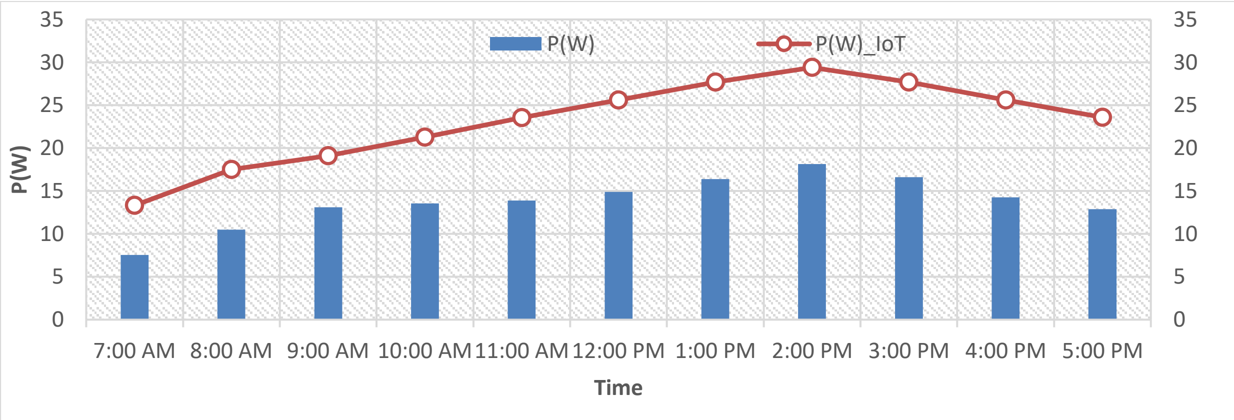


Figure 11: Comparative Power curve at considered location.

9. CONCLUSION

Renewable energy resources are gaining popularity as compared to traditional energy. It became helpful in degrading fossil fuel consumption and greenhouse gas emissions. The efficiency and reliability of renewable energy are continuously improving through the research and development processes. The current work presents a suitable solution for green energy production from solar PV. In this paper, an advanced MPPT technology for photovoltaic applications has discussed. Different methods of solar PV tracking have been explored, focusing on various parameters. A real-time data-based comparative analysis is presented using the necessary features to choose the suitable MPPT for the specific application. The proposed system is an efficient way to obtain the desired results. This IoT-based system can be advantageous for rural Solar PV applications. The P-V and V-I characteristics of the proposed MPPT methodology for PV panels are comparatively analysed. The IoT-based MPPT scheme has been successfully implemented to extract maximum power from solar PV. The present work also allows precise monitoring of the maximum output of solar PV arrangement.

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