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An Improved MPPT Technique Interfaced with Smart & Dry Cleaning of Solar Panels to Improve Photovoltaic Cell Output Power

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ABSTRACT:The aim of the project is to improve the Photovoltaic cell output power using, an improved MPPT technique which automatically determines the suitable duty cycle for a boost converter. The paper also presents a full design and implementation process of a low-cost, smart solar panel cleaning system which will address the adverse impact of soiling on commercial photovoltaic cells without using any liquids thus, contributing towards the increase in efficiency of PV panels for converting solar energy to maximum of useable energy. The improvement in the performance of a conventional solar panel is seen through the simulation using MATLAB R2018a.

KEYWORDS: Photo-voltaic (PV), Maximum power point tracking (MPPT), Pulse width modulation (PWM), Real time clock (RTC), Peak sun hours (PSH), MATLAB/SIMULINK

I.INTRODUCTION

The sun is a free source of energy, renewable, no waste, pollution free and can be used as primary source of electricity in both remote areas and urban areas. Over the past ten years, there is a large increase in the reliance on solar power as a Source of Energy as it is the most abundant and basic source of Energy for all the forms of life. It is very important to operate PV energy conversion systems at maximum power point (MPP), therefore an MPPT control technique is necessary to extract maximum power from the PV arrays.The MPPT controller consists of a DC-DC converter where the duty cycle is varied to track the maximum power pointand charges battery early and efficiently when compared with the standard charge controller technique using PWM.MPPT stands for maximum power point tracking system. In recent years, a large number of techniques have been proposed for tracking the maximum power point.

But since the solar panels are very inefficient, typical peak Efficiency for converting solar Energy to useable Energy is only 13-15% therefore, the efficiency of solar panels has to be maintained to its maximum. but the accumulation of dust over the solar panels and other unwanted obstructions that cover the surface of the panels, drops the panel Efficiency and are one of the major causes for the power loss. The obstruction turns shaded cell in to a resistor, causing it to heat up and consume extra power. Therefore, as the panels are placed in dusty areas, they need to be cleaned several times a week.Most widely used method of cleaning the solar panels is through manual labour. Apart from being time taking and Cumbersome, there is also a risk of damage to the expensive solar panels by the unskilled labour which is involved in this method. Hence the purpose of this project is to develop a smart self-cleaning mechanism for cleaning the solar panel so that the process can become more reliable and faster. thus, increasing the power output of the solar power plant.

II.PV CELL MODELLING

Solar energy is harnessed by using solar electric systems, also known as photovoltaic (PV) systems. The word photovoltaic is derived from the Latin words photo (light) and voltaic (energy). PV devices capture the energy in sunlight and convert it into electricity - that is, they use light energy. The general model of solar (PV) cell consists of Light emitted current, diode, one shunt resistance (R_{sh})and one series resistor(R_{se}).

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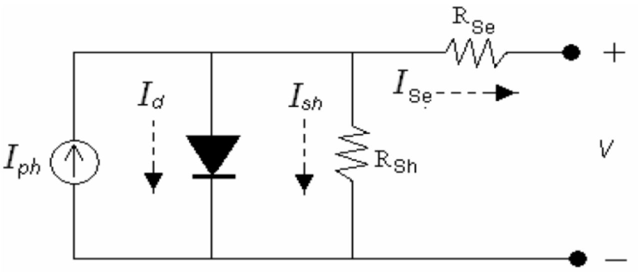

Fig 2.1: Equivalent Circuit of PV Cell

Solar cells work on principle of photovoltaic effect, which is why they are sometimes referred to as PV cells PV cells convert incident solar energy to usable DC electrical power. When incident light consisting of photons fall on a junction between p-type semiconductor and n-type semiconductor, the photons create electron and hole pairs. However, this photon needs to have the same energy as the energy gap between the valence band and the conduction band. Not all photons have the same energy which is why not all photons are completely absorbed and results in lowering of the panel efficiency.

This power can be harnessed and fed into the grid for further use. For the purposes of the circuit simulation, a single diode model of a solar PV cell is used. The equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing leakage current, and a series resistor describing an internal resistance to the current flow in the circuit is shown below in the fig2.1. The simulation is performed under the assumption that the panel operates under Standard Test Conditions (STC).

The solar PV cell equivalent circuit has following parameters:

1. Incident Radiation (G): Incident radiation is the intensity of sunlight that is incident on the solar PV cell. Under STC, this value is taken as 1000 Watts/m2.
2. Photon Generated Current (I_{ph}): It is the current that is generated due to the incident light on solar PV cell. Its unit is Ampere (A). For a lossless circuit model shown in Fig2.1, the value of photon generated current is approximately equal to the short circuit current of the solar PV cell.
3. Diode Saturation Current (I_d): This current is the current that flows due to diffusion mechanism and recombination in space charge. The range of this current is usually in Nano Ampere(nA).
4. Terminal Voltage(V): This voltage is the voltage that appears across the terminals of the solar PV cell.
5. Panel Current(I): It is the current that panel supplies to the load connected/power electronic converter.

The relationship between the Terminal Voltage (V) and Panel Current (I) is given by:

$$I = Isc - Id * (e^{V/(N*Vt)} - 1)$$

The current- voltage characteristic equation of a solar cell is given as:

$$I = Iph - Ise \exp q (V + Irs) / k\, TCA - 1 - (V + Irs) / Rsh \ldots\ldots (i)$$

Where: Iph = Light-generated current or photocurrent, Ise = Cell saturation of dark current, $q = 1.6 \times 10^{-19}$C,k = Boltzmann's constant 1.38×10^{-23}J/K,TC = Cell's working temperature,A = Ideal factor

The photocurrent mainly depends on the solar insulation and cell's working temperature, which is described as:

$$Iph = [Isc + KI\,(TC - T\,ref)] \ldots\ldots (ii)$$

Where, Isc = Cell's short-circuit current at a 25°C and 1kw/m^2, KI = Cell's short-circuit current temperature coefficient,Tref = Cell's reference temperature, α= is the solar insulation in kw/m2.

On the other hand, the cell's saturation current varies with the cell temperature, which is described as:

$$Is = Irs\,(T\,C/T\,ref)\,3 \exp [q\,EG\,(1/T\,ref - 1/TC)/ kA]$$

Table2.1: parameters of the proposed PV module

Parameter	value
Maximum power	213.15 W
Open circuit voltage Voc	36.3V
Voltage at maximum power point Vmp	29V
Temperature co-efficient of Voc (%/deg.C)	-0.36099
Cells per module	60
Short-circuit current Isc	7.84A
Current at maximum power point Imp	7.35A
Temperature co-efficient of Isc (%/deg.C)	0.102

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It is very common for the features of a PV cell to be represented graphically as a current-voltage (or I-V) curve. An I-V curve tracks the PV cell's performance and highlights key features such as Voc, Isc and Pmax. A PV cell will always operate along this curve, i.e., at a given voltage; the current produced will always have the same value and vice versa.

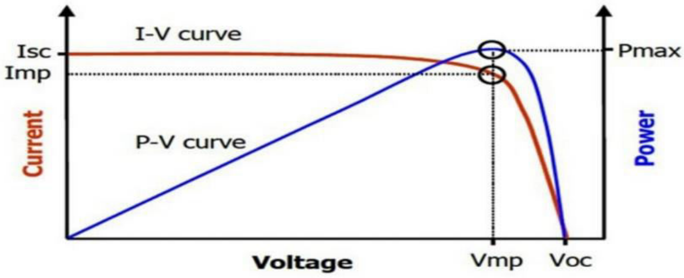

Fig2.2:Pmp is the highest point on the power curve, by extrapolating back to the *x*-axis, Vmp can be found. Vmp is also on the I-V curve and so the corresponding current can be found for this particular voltage (Imp)

A power curve is used to find the maximum power point. A power curve plots the voltage along the horizontal axis and the power (current multiplied by voltage) along the vertical axis. When this is superimposed on the I-V curve for the same cell, it is very clear where the maximum power point lies.

The I-V and power curves are important because it is necessary to know the characteristics of each individual cell when designing a module. Connecting cells with dramatically different characteristics together will have a large (generally negative) effect on the power output of the PV module.

III.PROPOSED METHODOLOGY AND DISCUSSION

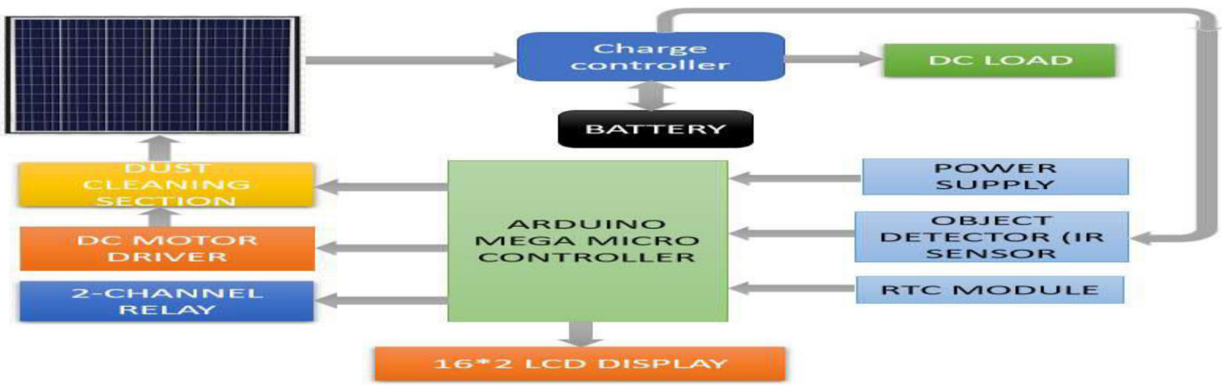

Fig3.1:Block diagram of the proposed system

The solar panel cleaning system consists of two basic units:

1. Locomotion unit
2. Cleaning unit

The locomotion unit consists of a nylon spiral brush and two wipers cleaning system that cleans on set cleaning cycles. The brush rotates to clean as it horizontally translates across an array of panels. The device is mounted on a set of battery powered-motorized wheels. At the end of the panel, there would be a docking station. It also has its own solar panel to charge the battery.

The Controlling unit of a solar panel consists of the microcontroller, relay module, RTC module and an object defector. The RTC provides the real time & date for the microcontroller & microcontroller programmed in such a way that at a certain time in day let's say 6 'o' clock in the morning it triggers an alarm so whenever the alarm triggers the microcontroller activates the relay and at this time power source is taken from battery or from solar panel to DC motor driver the cleaning mechanism runs and then the microcontroller automatically sends a signal for the relay module to initialize the MPPT charge controller which is interfaced with the object detector.

The Maximum Power Tracker uses an iterative approach to finding this constantly changing MPP. This iterative method is called Perturb and Observe or hill climbing algorithm. To achieve MPPT, the controller adjusts the voltage

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by a small amount from the solar panel and measures power, if the power increases, further adjustments in the direction are tried until power no longer increases.

The voltage to the solar panel is increased initially, if the output power increase, the voltage is continually increased until the output power starts decreasing. Once the output power starts decreasing, the voltage to the solar panel decreased until maximum power is reached. This process is continued until the MPPT is attained. This result is an oscillation of the output power around the MPP. During this the object detector contributes in attaining the MPPT by cleaning the panels whenever there is decrease in the voltage and power output of the solar panel because of the dust accumulated on the panels.

The microcontroller is also interfaced with a 16*2 LCD display to display the activities of the object detector, firstly displays the message as "WELCOME" then the IR-Sensor detect the dust accumulated or object detected on the solar panel, when there is no Object is detected the IR Sensor IR Sensor Send logic 0 signal to the microcontroller and it display on LCD display as "No object is detected".

When object fall on solar panel then IR sensor sends logic 1 signal to the microcontroller and hence it displays on LCD display "Object is detected" and at this time microcontroller takes action by turning on the DC motor driver to drive the cleaning mechanism in order to remove the object/dust from the solar panel after cleaning the IR module further check for dust on panel and makes sure the panel is clean and the output is maximum.

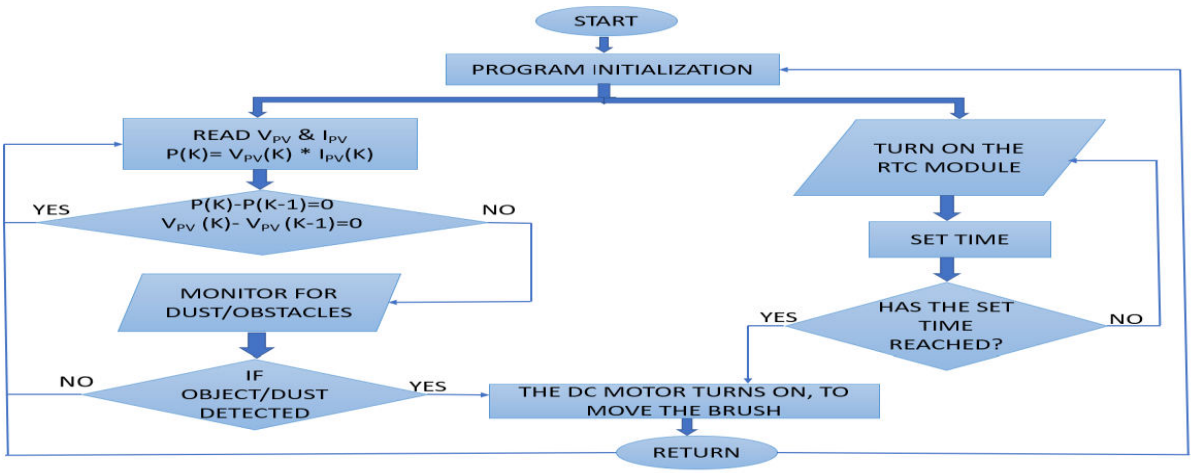

Fig3.2: flow chart of the proposed system

The flowchart of the program is as shown in the Fig The first step is to initialize both the object detector interfaced with the MPPT and the RTC module. Whenever the voltage from the PV cell is below the value required for the charging of battery connected to the PV system, the object-detector turns ON and the work of object detector is to monitor the dust or obstacles (sea salt, bird dropping, pollen) on the solar panel, and these obstacles are detected by an IR sensor. If obstacles detected then the DC motor turns on to move forward and reverse to clean the panel. If no it will go to first step.

As soon as the RTC module is turned on at the set time, according to the customer demand based on the environmental conditions of the installed site. When the set time is reached the RTC module sends signal to the Arduino to initialize the DC motor in order to proceed the process of cleaning. And the two runs of brush over the panel the DC motor stops, And the loop continues.

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VI. DESIGN OF DC-DC BOOST CONVERTER

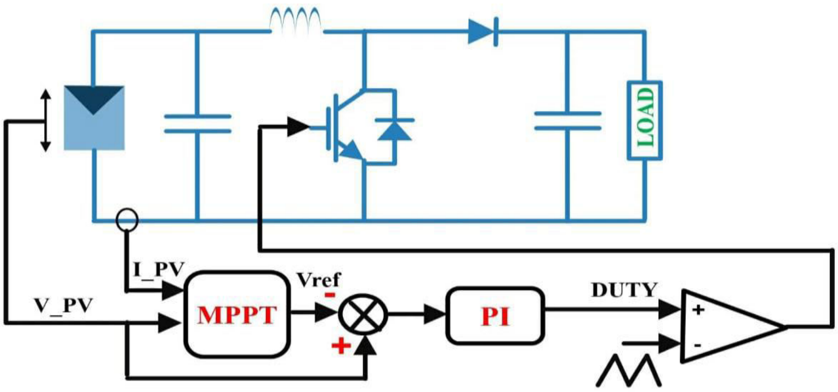

Fig 4.1: MPPT implementation for the proposed PV system

The circuit uses a boost converter connected to the PV cell output; A boost regulator can step up the voltage without a transformer. Due to a single switch, it has a high efficiency. The input current is continuous.The boost converter provides the higher output than input as per the following formula:

Vout= Vin/(l-D) Where, D is the duty cycle of the boost converter.

The output voltage is very sensitive to changes in duty cycle D in equation. This duty cycle (D) is being controlled by PWM output of the proposed algorithm. The duty cycle of the boost converter is controlled in accordance with the varying solar insolation by using a controller algorithm. The average output current will be less than the average inductor current by a factor of (1-D), and a much higher rms current would flow through the filter capacitor.
If the boost converter operates in continuous conduction mode (CCM), then the value of inductance L from the inductor current ripple analysis is given by the below equation,

Lmin=(1-D)2 *D*R/2*f

One way to combat this instability is to choose a large enough inductor so that the ripple current is greater than twice the minimum load current. When this condition is met then the inductor is always in continuous mode. This can be expressed as follows:

$$L = \frac{(V_{out} - V_{in} + V_D)(1 - D)}{\min\,(i_{load})f}$$

minimum value of filter capacitance that results in voltage ripple Vr =ΔVo/Vo is given by equation: C_{min}= D/ R*f*VrAn ideal boost converter is lossless in terms of energy, so the input and output power are equal. In practice, there will be losses in the switch and passive elements, but efficiencies better than 90% are still possible through careful selection of system components and operating parameters such as the switch frequency.

There are basically two methods through which we can implement MPPT in a boost converter. First, we sense both PV voltage and current and using these values we implement the MPPT the output of the MPPT will directly give the required duty ratio for the PWM generation and this value is compared with the carrier signal and given to the gate terminal of MOSFET.In the second method, similar to the previous method first we sense voltage and current and implement the MPPT but here instead of duty ratio we get reference voltage as the output, this reference voltage compared with the actual PV voltage to find the error. This error is then fed to a PI controller the output of the PI controller will give the required duty ratio for PWM generation and this value is compared with a carrier signal and given to the gate terminal of MOSFET compared to the first method, this second method will give a better MPPT tracking performance since it has a closed loop control mechanism. The MPPT system (P&O algorithm) was implemented in MATLAB that was tied to a DC-DC boost converter and the required results were obtained.

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Table2: parameters of the proposed DC-DC boost converter

Parameter	value
Input capacitance (Ci)	100µF
Input Resistance (Ri)	0.0001Ω
Inductance (L) in inductive filter	2mH
Resistance (R) in inductive filter	0.1Ω
Capacitance of capacitive filter (Ci)	100µF
Resistance of capacitive filter (R)	0.0001Ω
Load resistance (R)	20Ω

V.P&O ALGORITHM

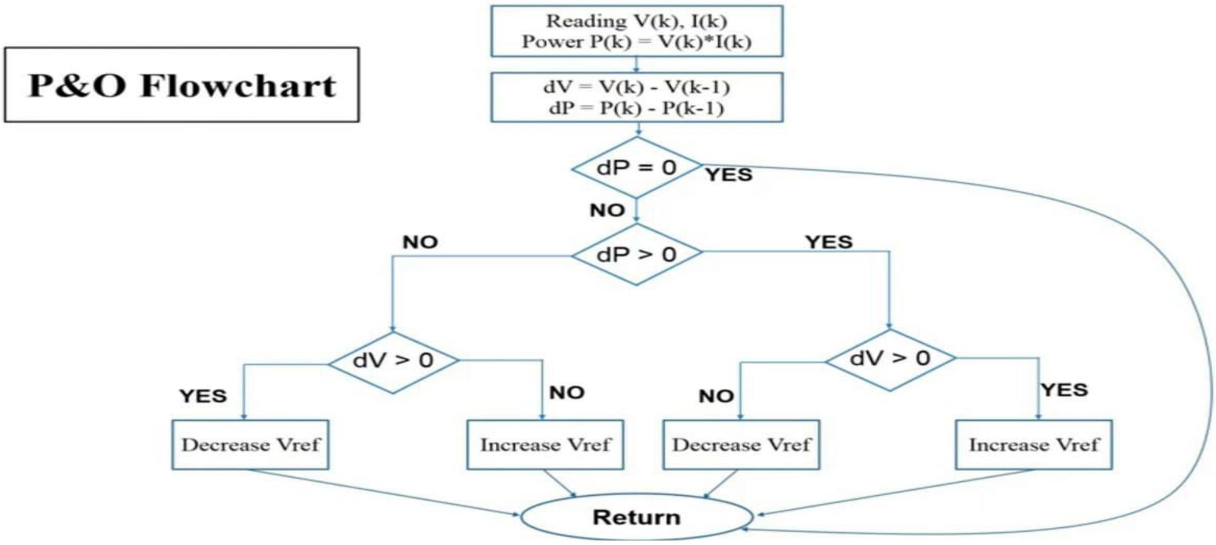

FIG 4.1: Flow chart of the proposed MPPT technique

The perturb and observe(P&O), as the name itself states that the algorithm is based on the observation of the array output power and on the perturbation (increment or decrement) of the power based on increments of the array voltage or current. This algorithm utilizes an iterative approach at each and every sample that is collected by the control system.The algorithm compares the difference between current and previous powers against a predefined constant. This constant is defined within the algorithm to ensure that when the method has identified the Maximum Power Point (MPP) of the PV panel, the duty cycle will remain constant until the conditions change enough to change the location of the MPP. The movement across the MPP is an unwanted oscillation that can be disruptive to power flow and could also cause unwanted loss.
Simulink model of PV energy system with P&O algorithm is shown below,

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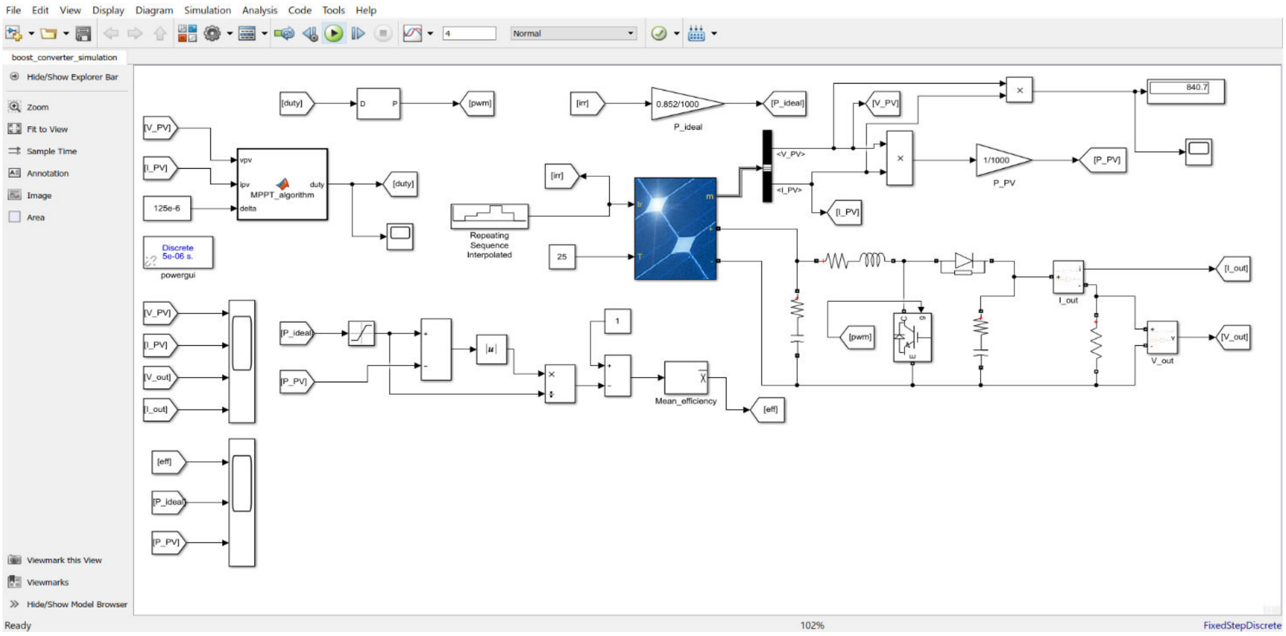

Fig 5.2: MATLAB implementation using R2018a

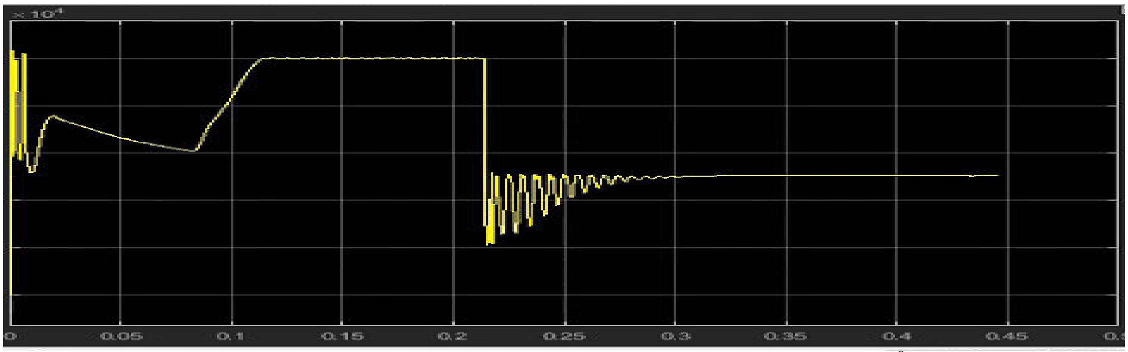

Fig 5.3: MPPT Output for Irradiance =500 and Temperature =25^{0}C

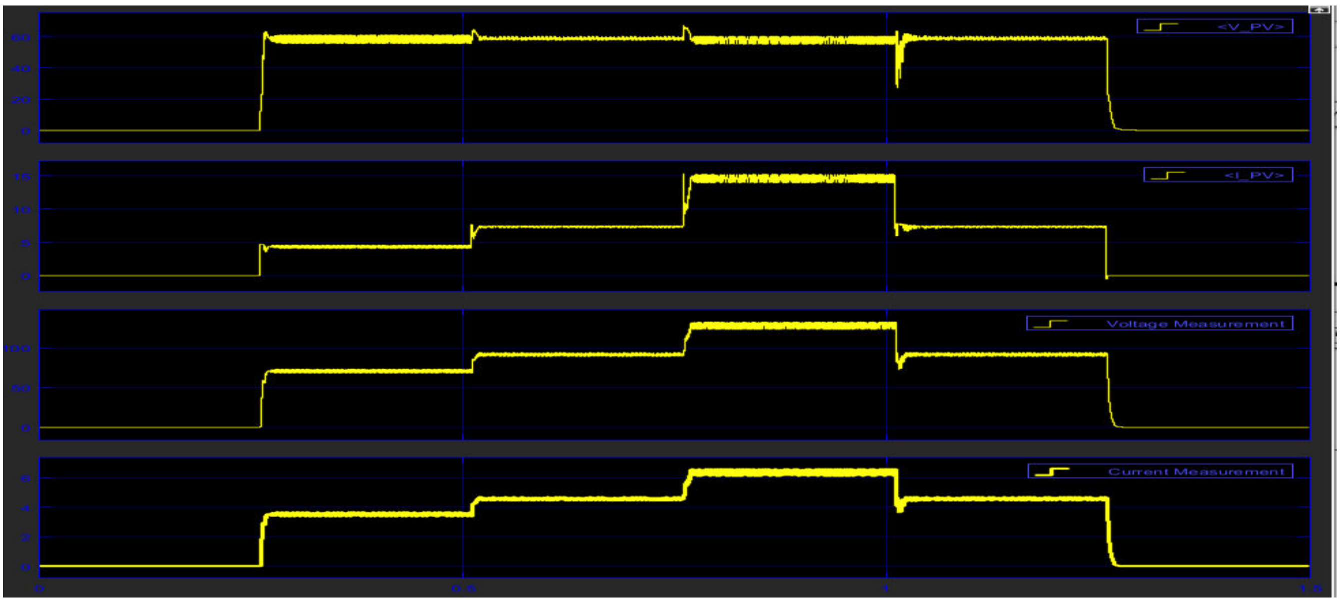

Fig5.4: Voltage and current of PV system and boost converter with P&O algorithm

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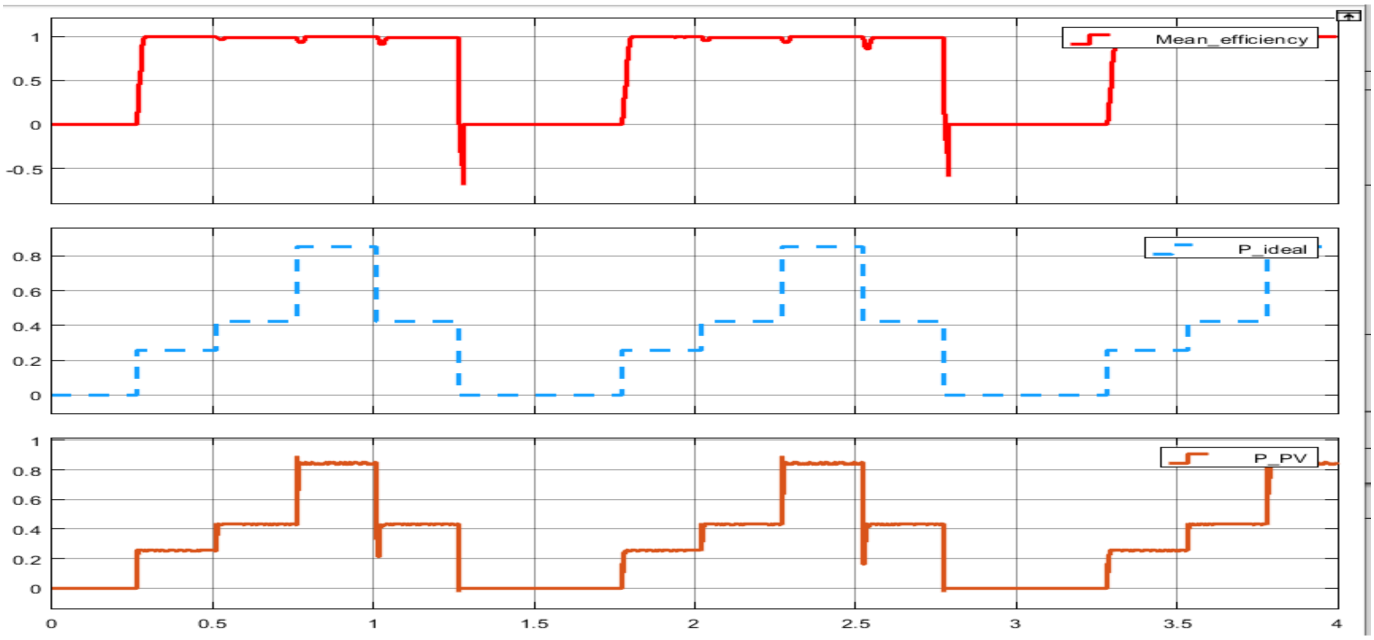

Fig5.5: Tracking efficiency and power output of PV system with P&O algorithm

The above results show that the efficiency of the solar panel decreased with the increase of irradiance. When radiation intensity increases, both the input and output power of the solar panel will increase. On the other hand, the temperature rise of solar panel will reduce the output power. Therefore, output power did not change much. This results in the inverse proportion of efficiency of solar panel to the irradiance.

VI. CONCLUSION

The proposed MPPT control technique improves the Photovoltaic cell output powerby, automaticallydetermining the suitable duty cycle for the designed boost converter. And it can be concluded that the proposed P&O algorithm based MPPT control system is able to achieve the better efficiency in a smaller number of iterations and without any oscillations in, comparison to the other MPPT methods. The proposed algorithm is simulated and analysed in MATLAB.

The system is also designed to study the effects on the efficiency of the PV panels because of the varying temperature and irradiance. The measured average irradiance was 600 W/m^2 and the maximum irradiance was up to 1000 W/m^2 and for temperature ranging from 0^0C to 120^0C, the maximum tracking efficiency achieved is 94% and the maximum power obtained is 852W.

A smart and dry-cleaning system designed increases the output of solar panels by increasing the PV cell efficiency to a great extent. The system designed, cleans the panels regularly and immediately as soon as any object/dust is found on the solar panel by consuming a very low power. and it is designed at minimum cost so that the system can also be implemented on commercial sized solar arrays.

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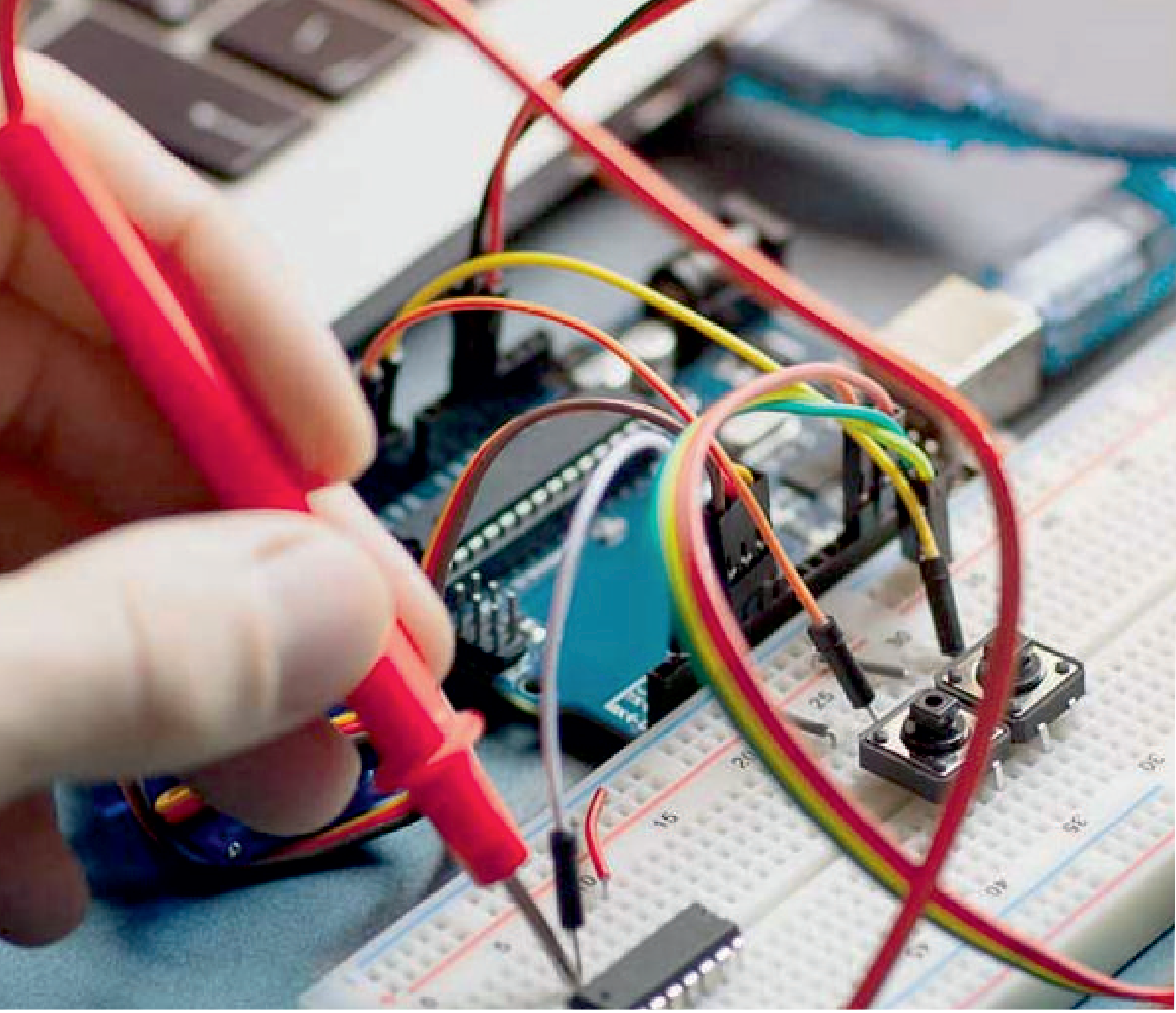

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