International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Design of a Solar Mpp Tracker with Modified Perturb and Observe Method using Arduino

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Abstract*: *Design of a fast, improved and reliable solar Maximum Power Point Tracker (MPPT) is described in this work. The working algorithm was motivated from the existing Perturb and Observe method for tracking MPP of Solar Photovoltaic (SPV). The tracker was developed using an Arduino Uno development kit which is run by ATMega 328P microcontroller and clocked at 16MHz. Due to high frequency operation the model was fast and accurate and consumes very low power and can be driven by 5V only. Proteus 8.3 simulator was used and further a hardware model was designed in order to realize the operation. MPP was tracked very quickly and accurately in accordance with the change in solar irradiance. The tracker offered an efficiency of ranging from 96.40% -99.25% at different irradiance level.

Index Terms*: *MPPT, Perturb & Observe, Solar Photovoltaic, PWM microcontrollers, Algorithm.

I. INTRODUCTION

Among the two types of energy sources-conventional and non-conventional, renewable sources are gaining popularity now-a-days. The increasing pollution level and depleting levels of conventional energy sources have created a demand for clean sustainable source of energy. As a result, the shift towards renewable energy sources such as solar, hydro and wind are increasing day by day. Among them, solar energy has gathered a lot of attention. Its huge abundance and cleaner nature have motivated scientists, engineers and govt. agencies to invest in it. Although, currently commercially available solar cells are only able to harvest in between 10% - 27% of incoming solar radiation [1-6]. Thus, it is very crucial to operate the PV panels at optimum level and extract maximum power. The output of a PV panel tends to fluctuate with varying atmospheric temperature and incoming solar radiation [7-13]. Thus, in order to obtain a continuous flow of maximum power at output at any conditions, a MPPT technique is used [14-16].

A solar PV system contains an array PV module and a power converter which often includes an MPPT system. Solar charge controllers follow an MPPT algorithm to extract the maximum possible power generated from a PV array. There are numerous MPPT algorithms such as Perturb and Observe (P&O) [17-18], Incremental Conductance method (IC) [19-20], but each has its own advantages and disadvantages [21-22]. Among the various MPPT techniques, P&O and IC are widely used techniques as they are easy to implement and have high efficiency. However, they suffer from the drawback of drifting away from the maximum power point due to changes in incoming solar radiation and their tracking speed is slow. Implementation of other techniques is relatively complex and costlier [23-26].

In this paper, a controller for PV panels is designed with improved MPPT tracking algorithm based on P&O technique. The new algorithm tracks the MPP quickly and with high efficiency. Here, the P-V curve is utilized for finding the MPP. Change in PV panel voltage and current is obtained due to the change in duty cycle of the DC-DC buck converter. As a result, PV panel's output power changes. This change in output power (ΔP) and voltage (ΔV) is used to calculate the slope (ΔP/ΔV) at a fixed point of the P-V graph. Based upon this slope, the next duty cycle is adjusted. This process continues until the slope (ΔP/ΔV) becomes zero or reaches a near about value. The tracking direction changes according to which side the point of slope resides, in accordance with the MPP. The algorithm tracks constantly any change in irradiance and repeats the calculation quickly. Due to its precise nature, the algorithm reaches the maximum power point with high accuracy. The algorithm uses less iteration steps and a finely tuned step size to reach the MPP. To perform the calculation within a fraction of a second, the Arduino UNO microcontroller board with ATMega 328P processor is used. It has an on-board clock frequency of 16MHz which results in high processing speed. It also consumes very small amount of power, which can be provided by a 5V battery.

II. RELATION BETWEEN SOLAR INSOLATION AND PV OPERTION

An ideal solar cell can be considered as an ideal current source where an ideal diode is connected in parallel. As no solar cell is ideal in nature, hence, to make it more realistic, a non-ideal solar cell additionally connects a shunt resistance and a series resistance.

Revised Manuscript Received on 30 July 2019.
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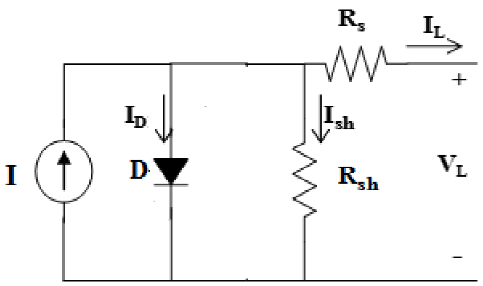

Fig. 1. Circuit representation of a solar cell

$I_L = I - I_D - I_{SH}$ .... (1)

I is the current output, I_L is the photo current, I_D is the current through the diode and I_{SH} is the shunt current in amperes.

$I_D = I_s\left(e^{\frac{q(V_L+I_LR_S)}{nKT}} - 1\right)$ .... (2)

$I_{SH} = \frac{V_L+I_LR_S}{R_{SH}}$ .... (3)

$I = I_{ref}\left(\frac{G}{G_{ref}}\right)[1 - \alpha_T(T - T_{ref})]$ .... (4)

I_{ref}: Photo current at 1000 W/m^2,

α_T : Relative temperature coefficient of the short-circuit current.

G: Solar insolation on the Solar PV,

G_{ref} : 1000 W/m^2,

T_{ref} : 25 °C.

Eq. (4) depicts that the I is dependent on the insolation (G). As a result, the MPP also varies and thus changing the power conversion efficiency (PCE). So, an adequate technique is needed to trace the MPP to deliver maximum power.

III. SIMULATION MODEL AND OPERATION OF THE PROPOSED MPP TRACKER

For simulation purpose, a 67 watt (W) solar panel has to be designed in Proteus 8.3 Professional (Fig. 2). Since, there is no inbuilt solar cell in Proteus 8.3, one has to be created by using a current source of 3.7 A. Each cell generates a maximum of 3.7 A and 0.86 V under Standard Testing Conditions (STC) i.e. at a temperature (T) of 25^{O}C and insolation (G) of 1000 W/m^2. This entire arrangement produces a short-circuit current (I_{sc}) of 3.7A and open-circuit voltage (V_{oc}) of 20.8V. A Voltage Controlled Current Source (VCCS) is used to construct the individual solar cells.

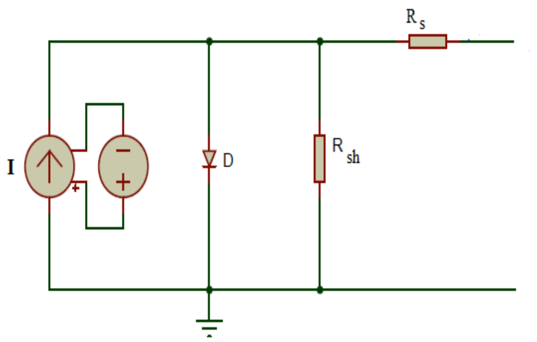

Fig.2. Modeled solar cell in Proteus simulation

In existing P&O method, to obtain maximum power from a SPV system, voltage is periodically perturbed and change in power is observed. MPP is reached when no change in power occurs. The primary disadvantage of the traditional P&O method is that, its tracking speed is limited, as it makes fixed size adjustment to the operating voltage in each iteration. As a result, it oscillates for some time near the MPP region. It also suffers from low accuracy during fast change in incident solar radiation. in this project, a new algorithm (fig. 3) is designed which tracks the mpp within a second or two. it uses variable step size for determining the mpp from the p-v. here, the duty ratio of the buck converter is varied according to the slope$(\frac{\Delta P}{\Delta V})$ of the p-v curve. the value of this ratio is less than zero on the right side of mpp and more than zero on the left side of mpp. as a result, the step size is automatically controlled. thus, increase in tracking speed has been achieved.

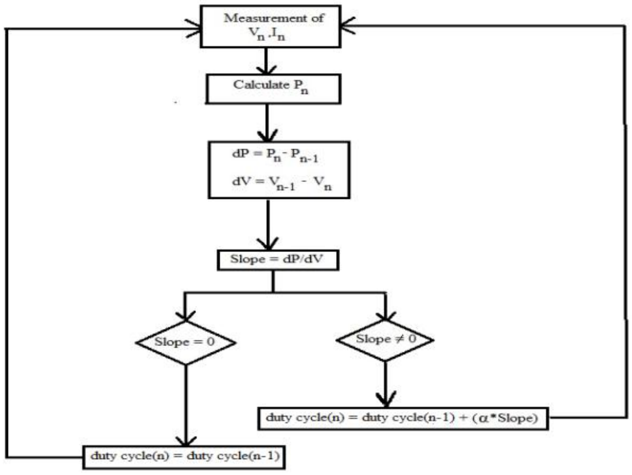

Fig.3. Proposed algorithm

Retrieval Number: B3205078219/19©BEIESP
DOI: 10.35940/ijrte.B3205.078219
Journal Website: www.ijrte.org

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OPEN ACCESS
International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

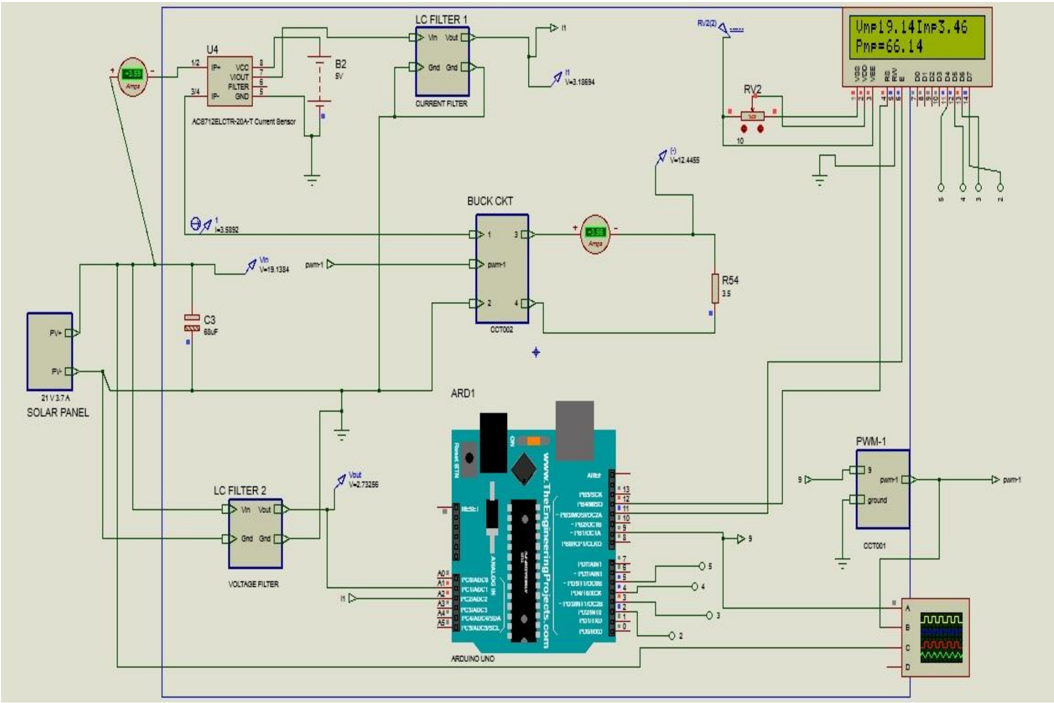


Fig.4. Proposed MPP tracker under simulation

A. DC-DC buck converter

The operating point of a SPV panel is dependent of the impedance connected to it. Thus, by varying the impedance of the load the panel can be operated at MPP. Since, solar cell is a DC source, therefore a DC-DC converter (Fig. 5) Is utilized to change the impedance of the load, as seen by the panel. The change in impedance can be achieved by tuning the duty ratio of the converter. Here, a buck converter is designed with the specifications given in Table:1. The converter bucks the V_{oc} of the PV panel by increasing its duty cycle. Accordingly, the gradient of the P-V curve is calculated by Arduino. After making necessary calculations, Arduino then feds the next duty cycle value to the MOSFET of the buck converter from one of its PWM pins. Thus, the impedance keeps changing and finally settles down at the MPP of the P-V curve. For driving the gate of MOSFET IRFZ44N a driver IC is used.

TABLE I
SPECIFICATIONS OF THE COMPONENTS USED IN BUCK CONVERTER

Inductor	0.5mH
Capacitor	150µF
MOSFET	IRFZ44N Switching Frequency: 50 kHz
Diode	10BQ040

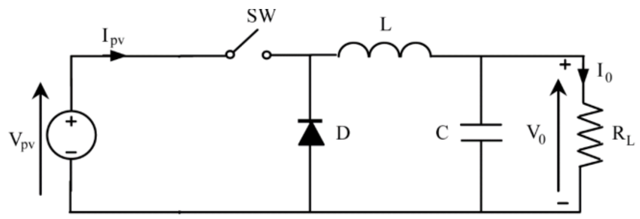


Fig.5. Buck converter

B. Arduino micro-controller

Arduino microcontroller can only sense voltage values. Its analog pins can handle a maximum of 5V. Hence, to collect the values of current, a sensor is employed. The sensor combined with a filter circuit senses the output current of the panel and converts it within a 5V range. This value is then converted to equivalent current value and afterwards utilized by Arduino for computation purposes. The output voltage of PV panel also has to be stepped down in this range. For this, a voltage divider circuit with a resistance ratio of 1:7 has been utilized. This voltage divider can convert a maximum of 34V into equivalent 5V range. As generally the irradiance level changes apace, it's so necessary to work out the MPP at intervals least attainable time. Due to its high processing speed, various inbuilt functions, low noise content (digital operation) and versatile in nature, Arduino is selected for this project. The other advantages of using Arduino are: -

- No need for additional PWM generation circuitry.
- It provides additional 5V power supplies, which can be used for the current sensor and LCD operation.

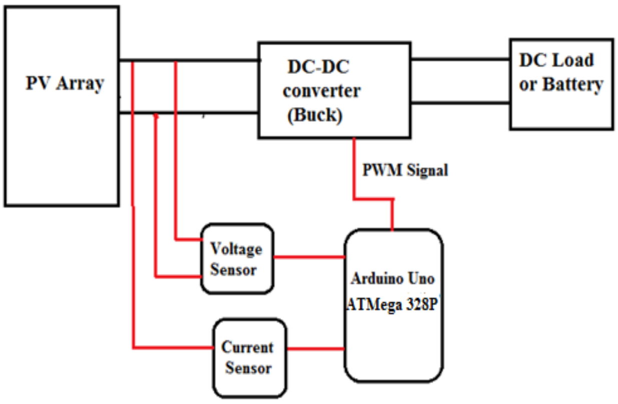


Fig.6. Schematic diagram of the MPP tracker

IV. RESULTS AND DISCUSSION

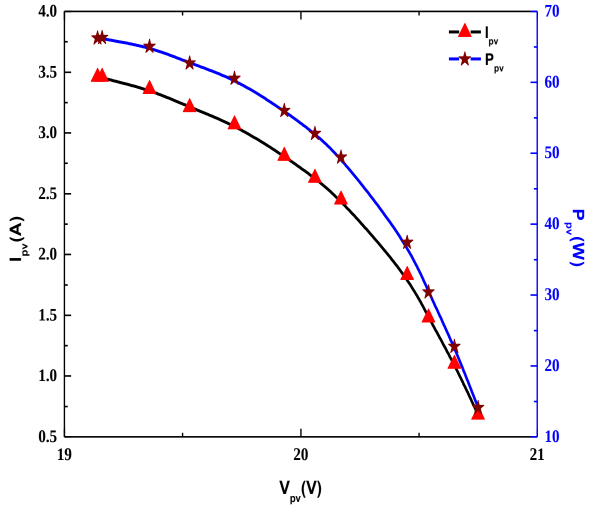
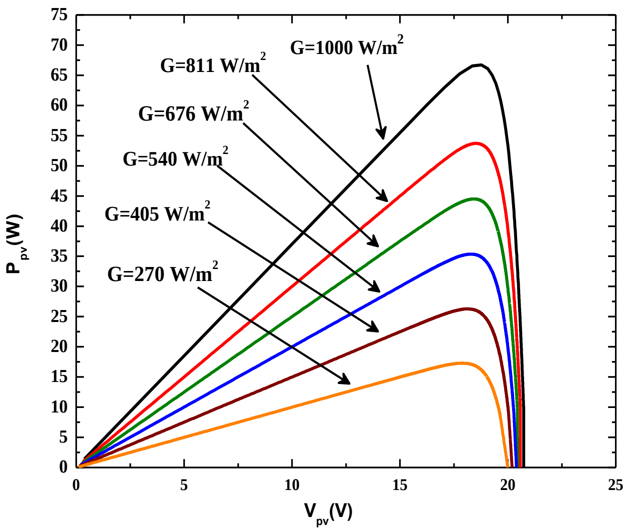


Fig. 7. Output I-V and P-V graphs while tracking the MPP of the SPV module for a particular irradiance



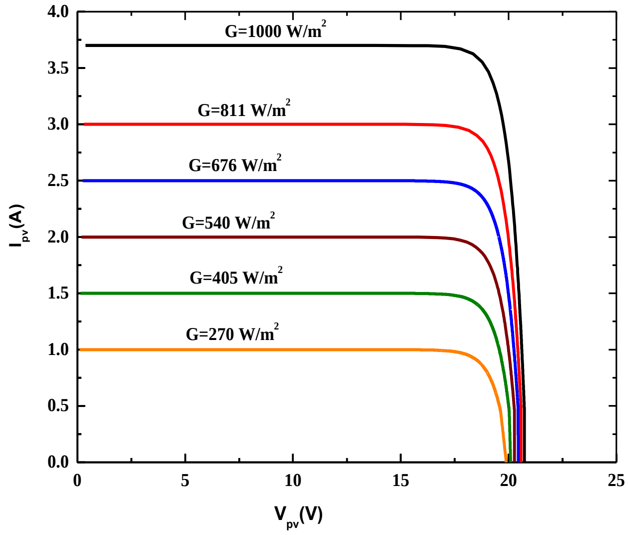


Fig.8. Output I-V and P-V graphs while tracking the MPP of the SPV module for different irradiance

Fig.7 depicts the output I-V and P-V characteristic graphs for the experimental setup for G=100W/m^2. The MPP was tracked successfully and maximum power was deliberated as ~65 W. The I_{mp} and V_{mp} were measured to be ~3.4 A and ~19.1 V respectively. The model was tested in changing irradiance in order to verify whether it can track the MPPs for each case. The model tracked MPPs for every point successfully and precisely which is depicted by Fig.8. The proposed MPP tracker is represented by Fig.9. The tracker was connected to a 67 W solar panel outside. Table II gives an illustration of V_{mp}, I_{mp}, P_{mp} and power conversion efficiency (PCE) of the tracker for different values of irradiance. 1st part of the table represents the values of rated MPPs calculated during simulation while 2nd part illustrates the measured value during outdoor experiment. The efficiency of the tracker

was measured tin between from 96.40% -99.25%.

Retrieval Number: B3205078219/19©BEIESP
DOI: 10.35940/ijrte.B3205.078219
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TABLE II
RATED AND MEASURED MPPs AND EFFICIENCY AT DIFFERENT IRAADIANCE

Solar irradiance (G W/m^2)	Rated Maximum Power Point(MPP) values			Measured MPP values with designed Controller			Power conversion efficiency (η %)
	V_{mp}(V)	I_{mp}(A)	P_{mp}(W)	V_{mp}(V)	I_{mp}(A)	P_{mp}(W)	
1000	18.7713	3.55437	66.72015	19.14	3.46	66.2244	99.25698
811	18.5257	2.90317	53.78326	19.16	2.75	52.69	97.96729
676	18.5206	2.40489	44.54001	19.13	2.26	43.2338	97.06734
540	18.2986	1.93406	35.39059	19.06	1.79	34.1174	96.40246
405	18.1582	1.44788	26.29089	18.85	1.35	25.4475	96.79207
270	17.8755	0.967227	17.28967	18.45	0.92	16.974	98.17425

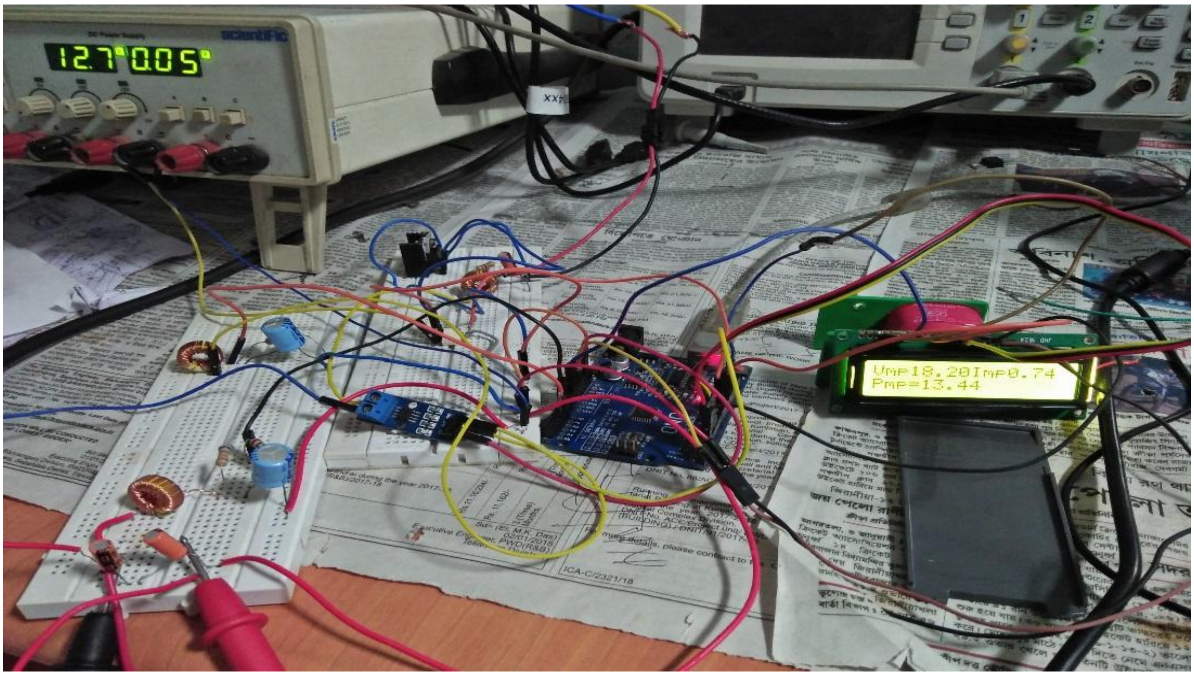

Fig.9. Experimental model of the proposed MPP tracker

V. CONCLUSION

A new approach for tracking MPP of solar panel in a fast and precise manner was demonstrated in this paper. A microcontroller-based board (Arduino UNO) run by a high-speed processor clocked at high frequency was used to design the tracker. The model was designed and simulated in Proteus 8.3 software. A new algorithm was developed based on P&O method. The modified algorithm was coded in terms of Arduino programming language and finally dumped into the microcontroller. The circuit worked independently as per the algorithm and had the provision of decision making in real time scenario. The designed MPP tracker was successfully tested in an outdoor environment with the experimental setup. The circuit delivered desired output in line with the simulation results. The maximum efficiency of the model was measured as ~99.25%.

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