Design and Implementation of Photovoltaic Maximum Power Point Tracking Controller

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Abstract

The power supplied by any solar array depends upon the environmental conditions as weather conditions (temperature and radiation intensity) and the incident angle of the radiant source. The work aims to study the maximum power tracking schemes that used to compare the system performance without and with different types of controllers. The maximum power points of the solar panel under test studied and compared with two controller's types. The first controller is the proportional- integral - derivative controller type and the second is the perturbation and observation algorithm controller. The associated converter system is a microcontroller based type, whereas the results studied and compared of greatest power point of the Photovoltaic panels under the different two controllers. The experimental tests results compared with simulation results to verify accurate performance.

Keywords: Photovoltaic panel (PV), Perturbation and Observation (P&O) Algorithm, Greatest Power Point Tracking (GPPT), Proportional- Integral - Derivative Controller (PID).

الخلاصة

تعتمد الطاقة التي توفرها أي منظومة شمسية على الظروف البيئية كأحوال الطقس (درجة الحرارة وكثافة الإشعاع) وزاوية السقوط من مصدر الإشعاع. يهدف العمل لدراسة الحد الأقصى للمخططات التي يمكن أن تستخدم لمقارنة أداء النظام بدون ومع المسيطرات المختلفة. الأول المتحكم النسبي التكاملي – التفاضلي النوع والثاني المتحكم الاضطرابي والتلاحظي. نظام التحويل يرتبط بمتحكم دقيق. حيث تم دراسة ومقارنة نتائج نقطة الطاقة القصوى للوحة الطاقة الشمسية تحت الاختبار مع نوعين من المسيطرات المختلفة وتمت مقارنة نتائج الاختبارات التجريبية مع نتائج المحاكاة للتحقق من دقة الأداء .

الكلمات المفتاحية : منظومة شمسيه(PV)، خوارزمية الاضطرابي والتلاحظي (P&O)، البحث عن أقصى نقطه للطاقة(GPPT)، المتحكم التناسبي–التكاملي–التناسبي (PID).

1. Introduction:

Solar panel generation becoming and more main as a renewable power foundation as it offers many advantages over other sources such as not being polluting, incurring no energy costs, requiring small preservation and emitting no sound. PV panel still have comparatively low change efficiency, so, controlling max power point tracking (MPPT) for the solar board is essential in a PV system. The quantity of generated energy by a PV panel depends on the used voltage of panel. A PV maximum power dot (MPP) varies with the climate rays and temperature. From PV V-I and V-P characteristic curves a unique operating point at which maximum possible power generated, it can be specified. At the MPPT, the PV operates at its maximum efficiency. Therefore, several algorithms developed to determine MPPT. The others employed a novel three point's weight comparison method that avoids the oscillation problem of the perturbation and observation algorithm, which is often employee to track the maximum power point,(Joe-Air *et.al.*, 2005; Chihchiang and Chihming, 1998) solar energy that can be gained by with a photovoltaic panel is able to change sunshine to electricity, the price of PV unit is still expensive and greatest power point of power is easily changed by surroundings factors such as solar rays, temperature, load, etc. In addition, to get the solar energy as much as potential form PV module, the process of maximum power point PV module must be controlled because alteration efficiency of PV module is very low. PV array needs sturdiness control concerning parameters variation due to non- linear characteristic (Chihchiang and Chihming, 1998). Forwarded a study and implementation of real time Estimate Perturb- Perturb algorithm for max power point tracking control in photovoltaic system (Yafaoui *et.al.*, 2007). The MP and O algorithm recover the P and O algorithm at the cost of speed reply to changes of irradiance. In a new system, named the Estimate-Perturb-Perturb algorithm was forwarded through the authors, which displayed a good performance (Liu *et.al.*, 2006). Perturbation –Observation and PID controllers are used in this work to improve the PV panel performance and tracking the maximum power under the weather conditions such as radiation and temperature. Comparison between simulation and experimental results according to Perturbation –Observation algorithm as well as PID controller algorithm was performed.

2. Mathematical sample of PV panel:

Solar cell is the constitutive element of PV arrays, it is essentially a p-n semiconductor connection shown in Figure 1. The V-I special equation of a solar array is given by Equation.1,(Joe-Air *et.al.*, 2005)

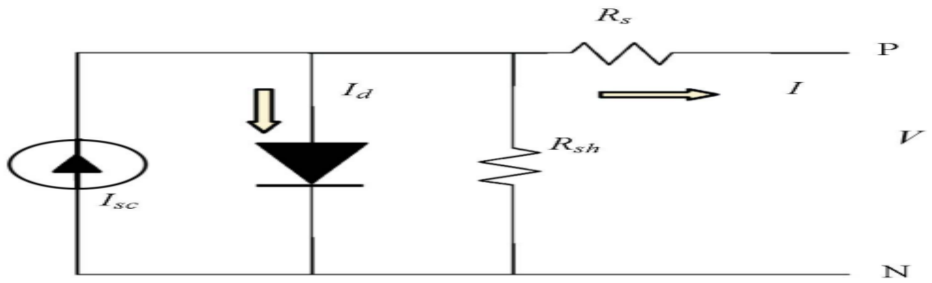

Figure 1 : PV mathematical model.(Joe-Air *et.al.*, 2005)

$$I = I_{SC} - I_O \left\{ \exp\left[\frac{q(V + R_S I)}{nkT_k} \right] - 1 \right\} - \frac{V + R_S I}{R_{sh}} \quad (1)$$

Where as:

V, I : current and voltage for output PV panel, Rs, Rsh : resistance of the panel in series and parallel, q: electronic charge. Isc: light generated current. Io: reverse diffusion current, n : factor for dimensionless. k :Boltzmann constant. Tk: temperature in Kelvin, The cell parameters are shown in the table 1.

Table1. PV array parameters.

Panel number	1	Maximum circuit voltage (v)	37.26
Dimension (cm)	158*8.08*4	Maximum circuit current (A)	5.37
Maximum power (w)	200	Wight (Kg)	15.5
Open circuit voltage (v)	45.62	Short circuit current (A)	5.66

3. DC-DC converter (Buck converter):

The buck converter can be used as step down converter (Mohamed, 2004). The produce voltage in this converter is lesser than the input voltage. The function of ratio (D) of the converter given by equation (2):

$$\mathbf{D = V_O/V_{IN} = t_{on}/[t_{on}+t_{off}]} \qquad (2)$$

Where as:

VO,VIN : The converter output and input voltages respectively, ton,toff : the ON and OFF state times respectively. The buck converter circuit is shown in Figure (2).

$$\mathbf{Lc = \frac{(1-k)R}{2F}} \qquad (3)$$

$$\mathbf{Cc = \frac{(1-k)}{16Lc\,F^2}} \qquad (4)$$

Where as:

Lc and Cc are critical inductance and capacitance values. L=1.2mH. C=1 mF. F=25 KHz. RL=600Ω

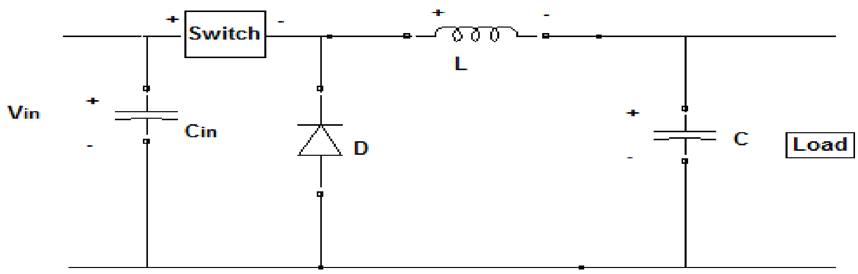

Figure 2 : Ideal Circuit of the Buck Converter (Mohamed, 2004).

This converter utilized to reduce the output voltage of the PV panel. It operates in two modes depending on the switch case. In the first mode, the switch is at on-state and the inductor of the buck converter is in a charging state. In the second mode the switch is at off -state and the inductor of the buck converter is in discharging state.

4. Perturbation and Observation (P&O) Algorithm

This algorithm is based on producing a slight perturbation by the system; the perturbation causes a change in the solar module power. If the power is increased, the perturbation must be kept on in that direction, otherwise reverse the perturbation direction. The power of the panel start decreasing after reaching the peak value for a certain period that is why the perturbation reverses its direction. At steady state case the system oscillates about the peak power point. When the power reaches the peak value, the power variation will be small (Vikrant, 2005; Chun-xia and Li-qun, 2009). The flowchart of the perturbation and observation algorithm of the tracking maximum power is shown in figure 3. Where: V(n), I(n) and P(n): are the current voltage, current and power of the PV panel respectively.

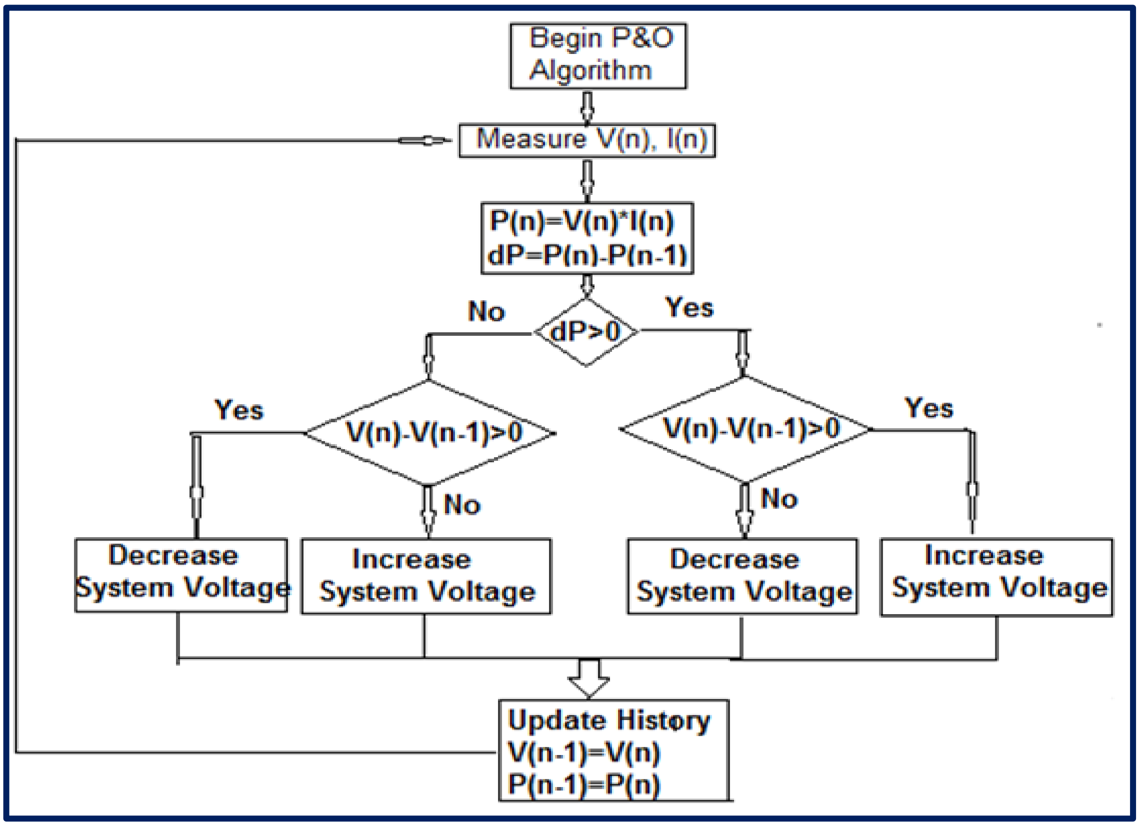

Figure 3 : Perturbation and Observation algorithm

5. The PID Controllers:

PID controller is utilized to get better dynamic restraint of the system as well as to decrease or reduce the steady-state fault. The derivative controller adds a fixed zero to the open-loop plant transfer purpose and improves the passing answer. The important controller adds a pole at the origin, thus increasing system form by one and falling the steady-state error due to a step purpose to zero(Astrom, 2004). The carry job of PID controller is:

$$\mathbf{Gc}=\frac{\mathbf{Ki}}{\mathbf{s}}+\mathbf{Kd\ s}+\mathbf{Kp} \qquad \mathbf{(5)}$$

Kp, Ki , Kd are symmetrical, complete and secondary gains in that order of PID controller. In the figure 4. shown the PID diagram built in MATLAB.

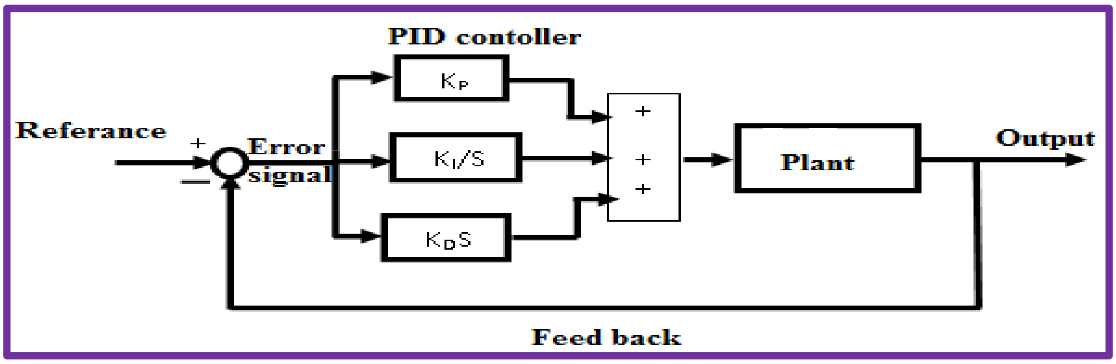

Figure 4 : Block Diagram of PID Controllers with plant.

There are different methods used to get PID regulator such as error and trial, Ziegler-nec holes process and soft check method. In the sitting work the profit of PID controller ware obtained using trial and error method. The PID controller in the present work that used to search of the most energy point tracking under the weather condition at any period depending on the radiation and temperature. The lookup table was designed for a certain range of the radiation and temperature, which gives the maximum power point under these conditions.

6. Simulation and Experimental Circuits

Using MATLAB/Simulink program, the PV panel with the converter and GPPT controller were constructed. The system model using MATLAB is shown in figure 5 (where T is the weather temperature, R is the weather radiation, Rs, Rp are the series and parallel PV panel resistances respectively). The system contained PV panel (mathematical model), maximum power point tracking controller and dc-dc step down buck converter with its load. The experimental system was implemented, whereas the PV panel connected to the buck converter with the microcontroller, which operated MPPT of the PV panel power. The PV panel generates the dc power that supplied to the load. The PV panel factor is given in table 1.The aim of buck converter in system is step down PV panel voltage. The load of the system is resistive and sometimes dc battery. The microcontroller is programmed by using the perturbation and observation algorithm to operate as MPPT controller to track the maximum generated power of the PV panel under the weather condition. The PV panel is punted forward to the sun light to get the maximum radiation. Figure 6 shows the experimental system model.

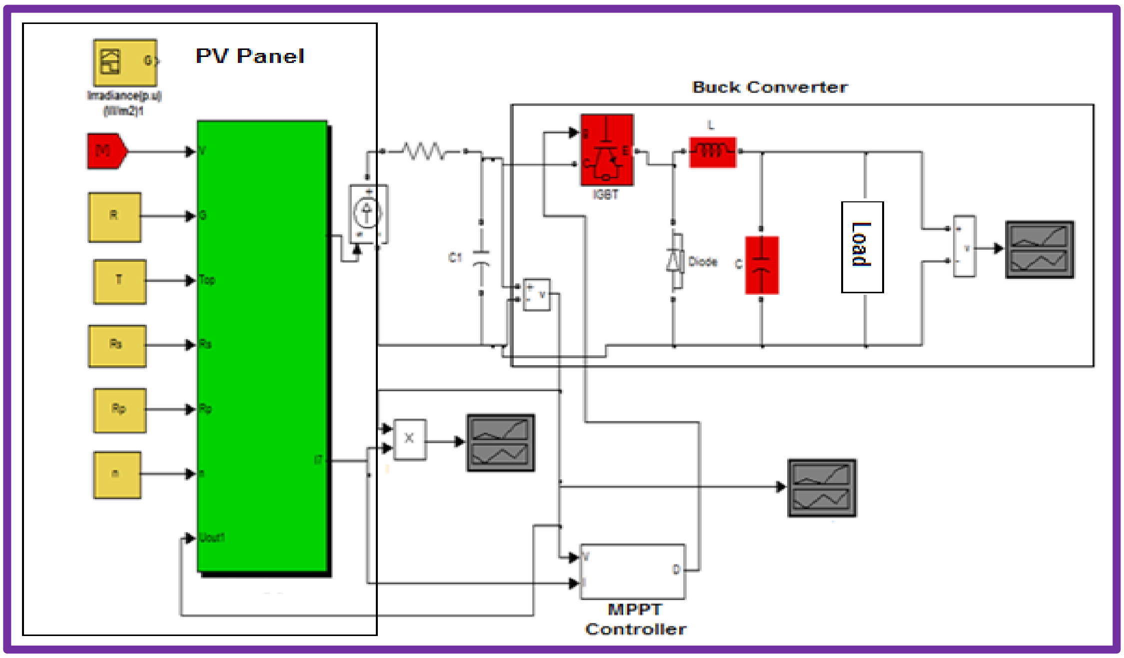

Figure 5 : Method Model using MATLAB/ Simulink

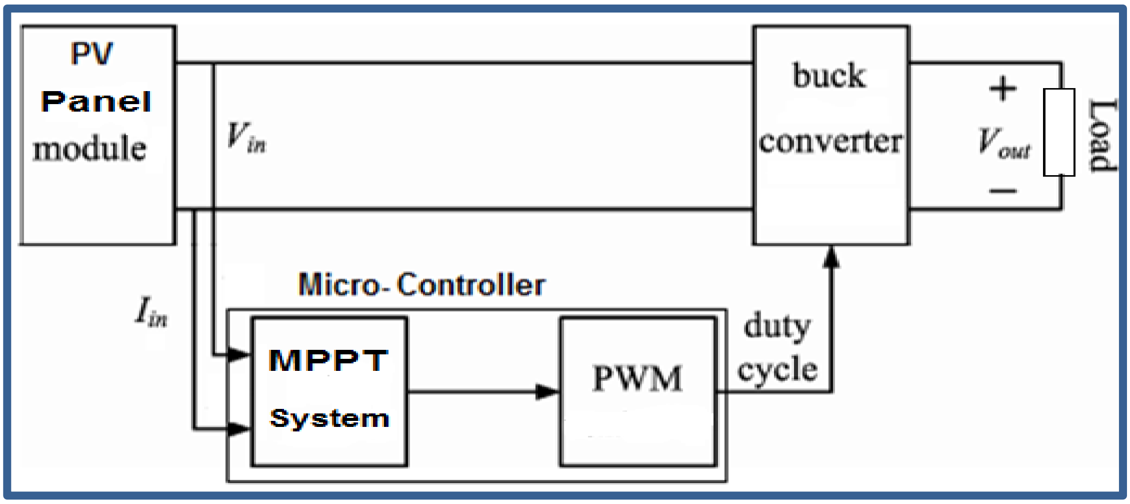

Figure 6 : Experimental System Model.

Figure 7 : Solar Power Plant

Figure 8 : Solar power Plant Board

7. Results and Discussion:

From Figure (9-21) show the simulation and experiment responses.

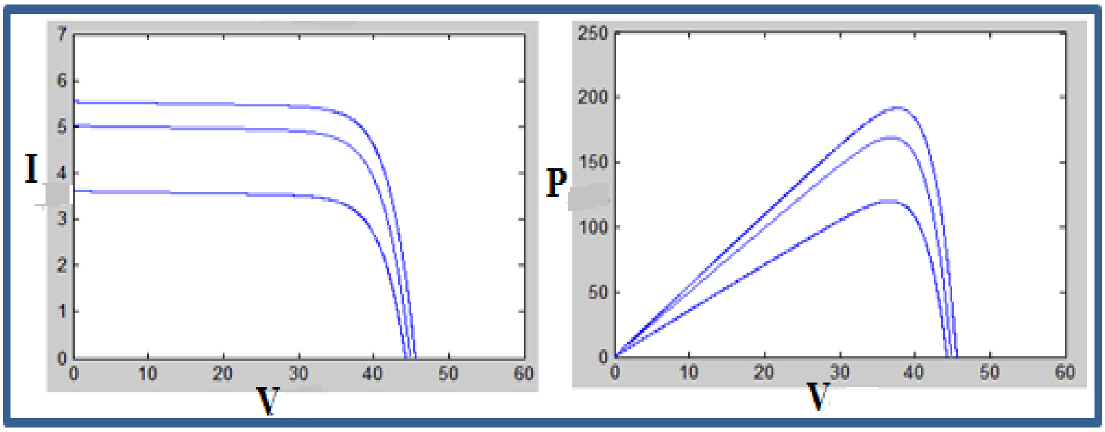

Figure 9 :V – I & V – P Relations of PV Panel.

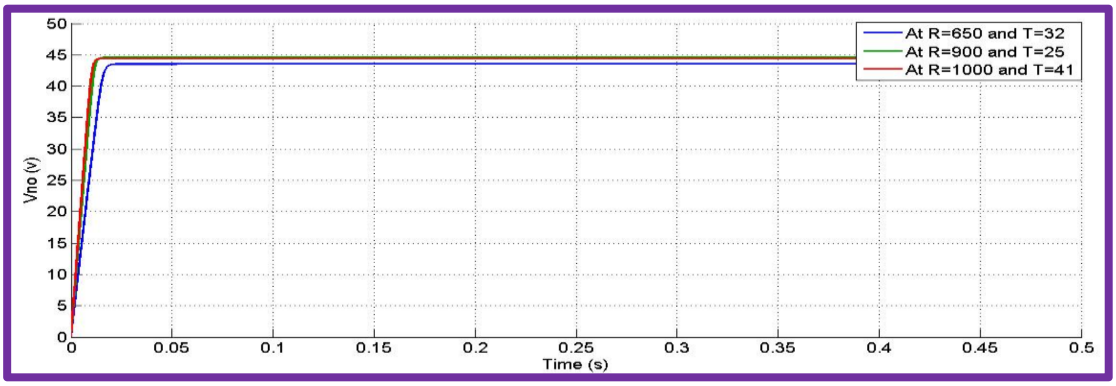

Figure 10 : No Load Voltage of PV Panel.

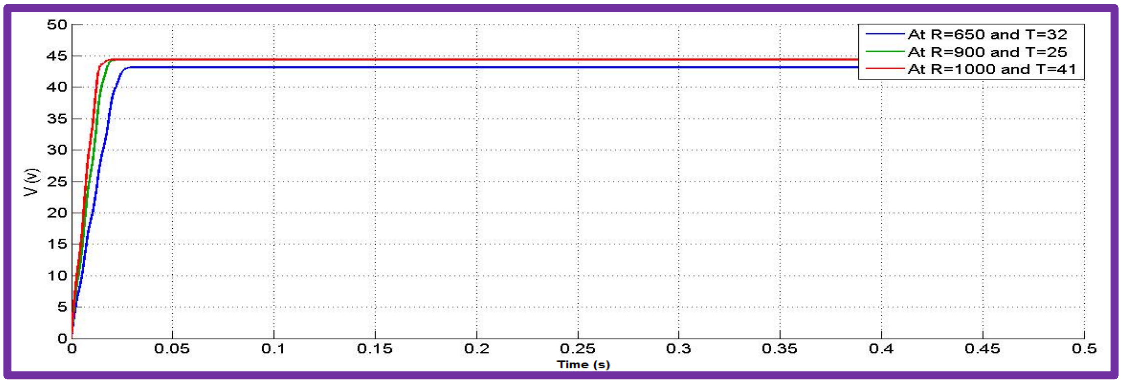

Figure 11: PV Voltage with Buck Converter.

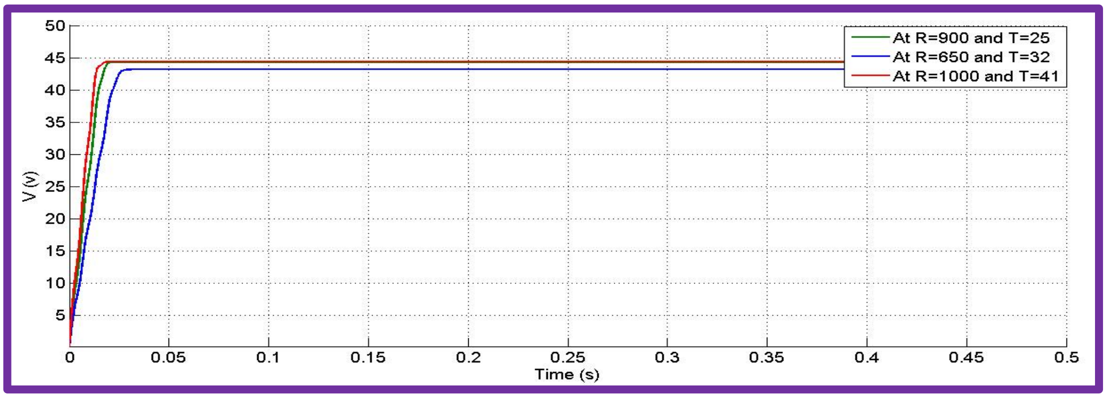

Figure 12 : Output Voltage of Buck Converter without MPPT.

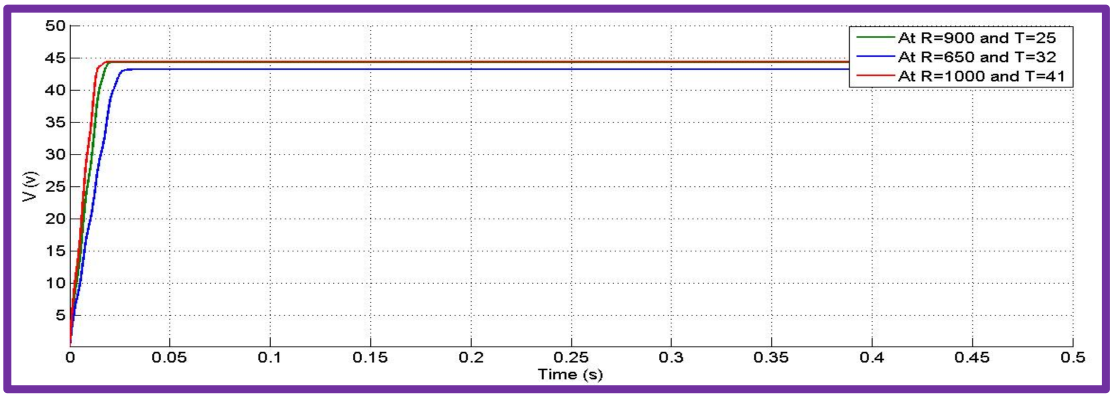

Figure 13 : Output Voltage of PV with PID Controller as MPPT.

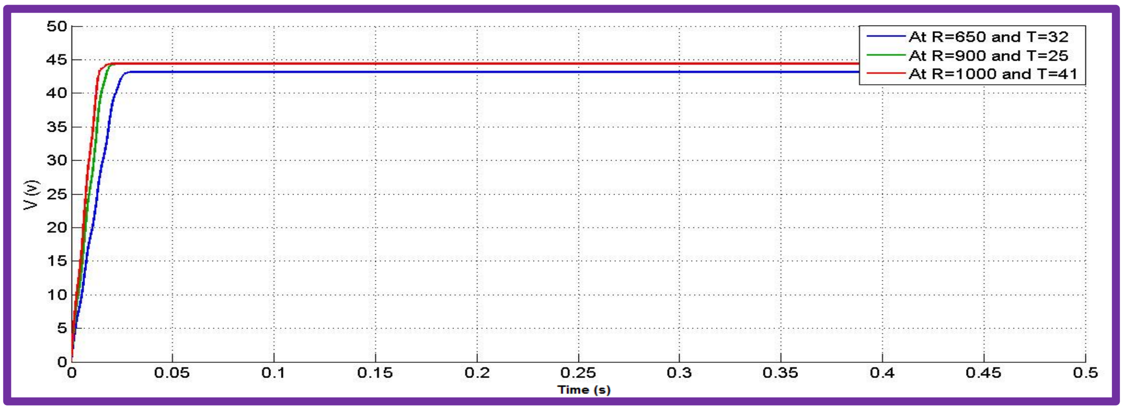

Figure 14 : Output Voltage of PV with P& O MPPT Controller.

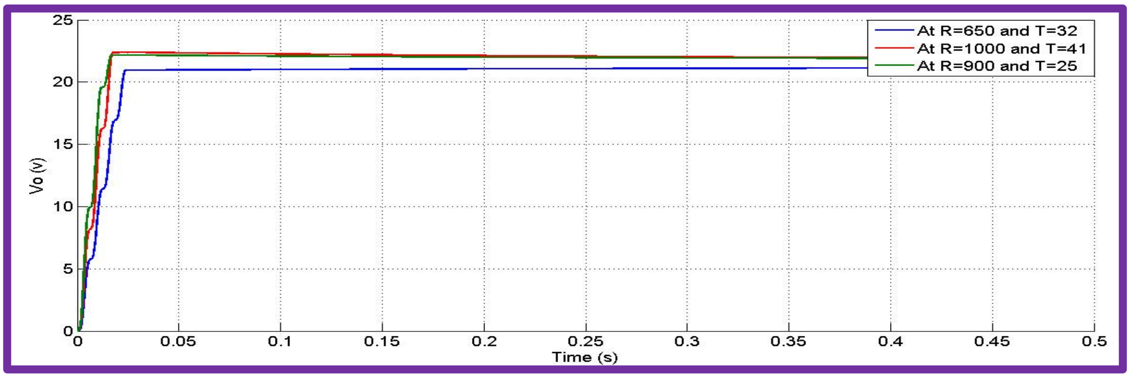

Figure 15 : Output Voltage of Buck Converter with PID Controller as MPPT.

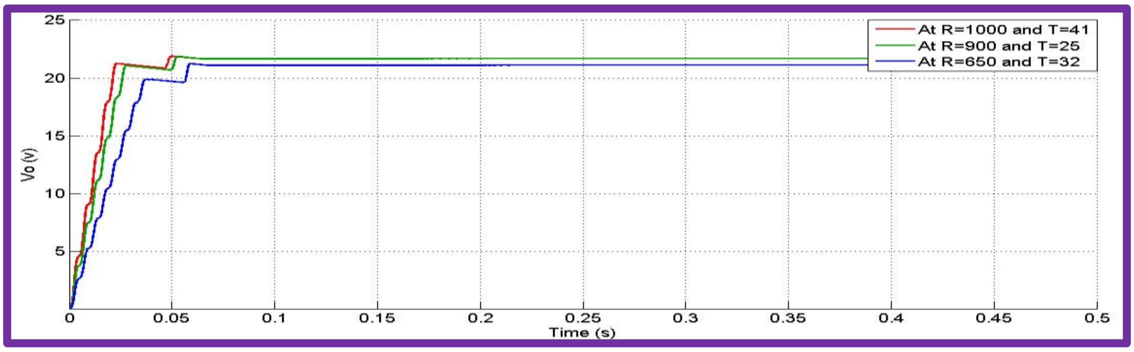

Figure 16 : Output Voltage of Buck Converter with P& O MPPT Controller.

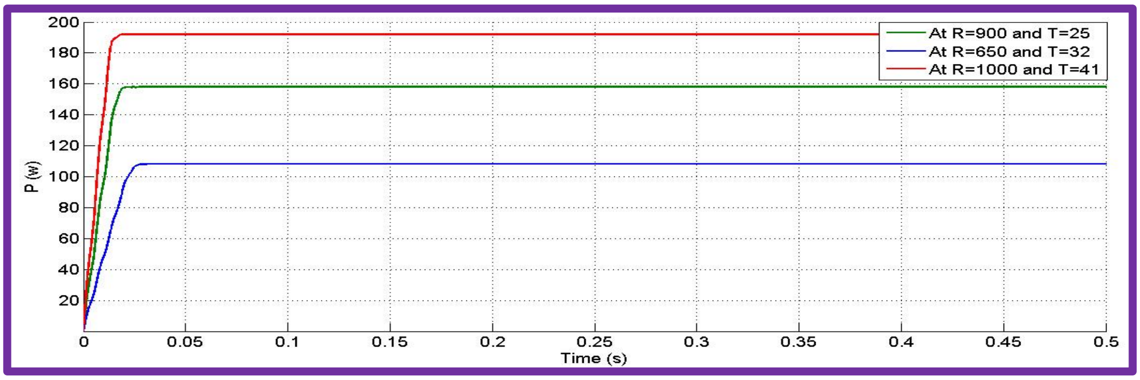

Figure 17 : Output Power of PV with PID Controller as MPPT.

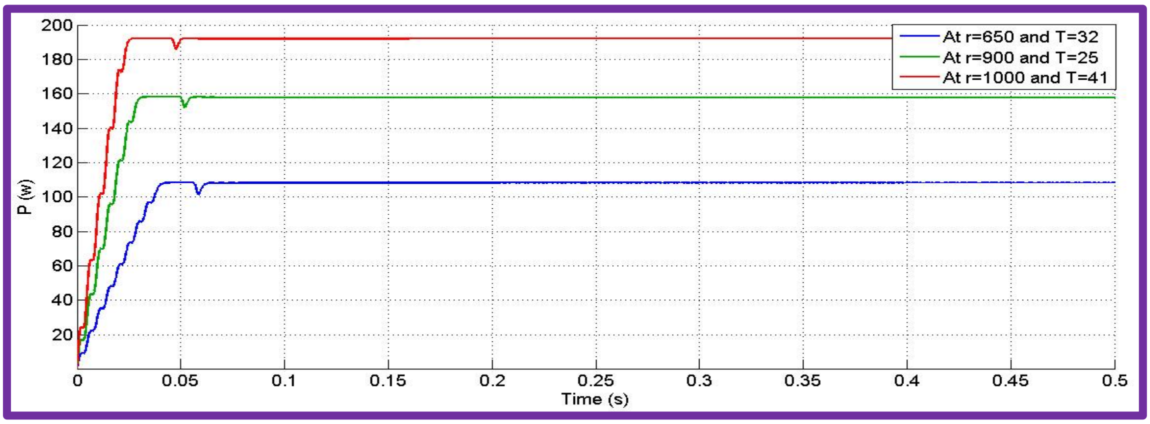

Figure 18 : Output Power of PV with P& O MPPT as Controller.

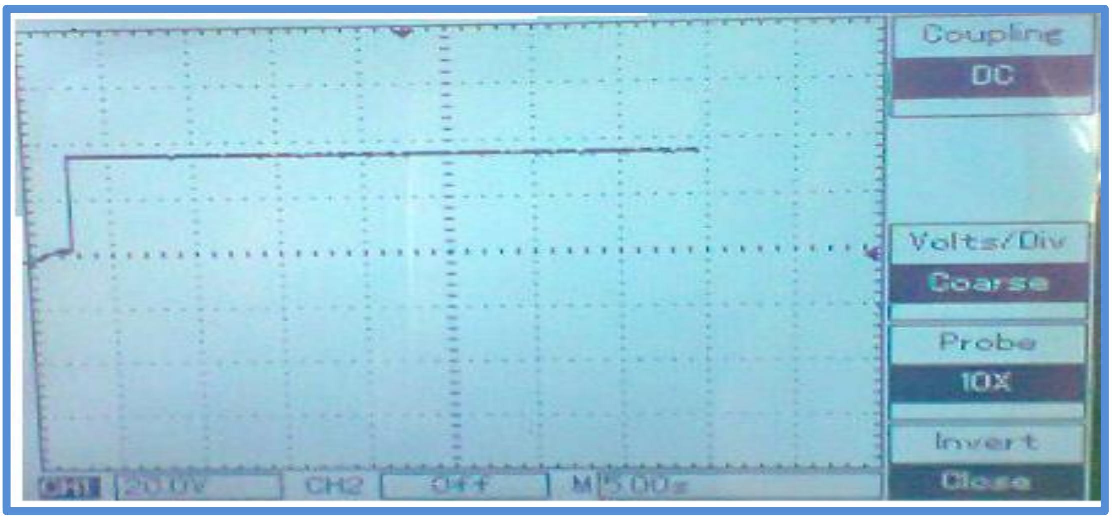

Figure 19 : Output Voltage of PV when T=32 C and R=650w/m2.

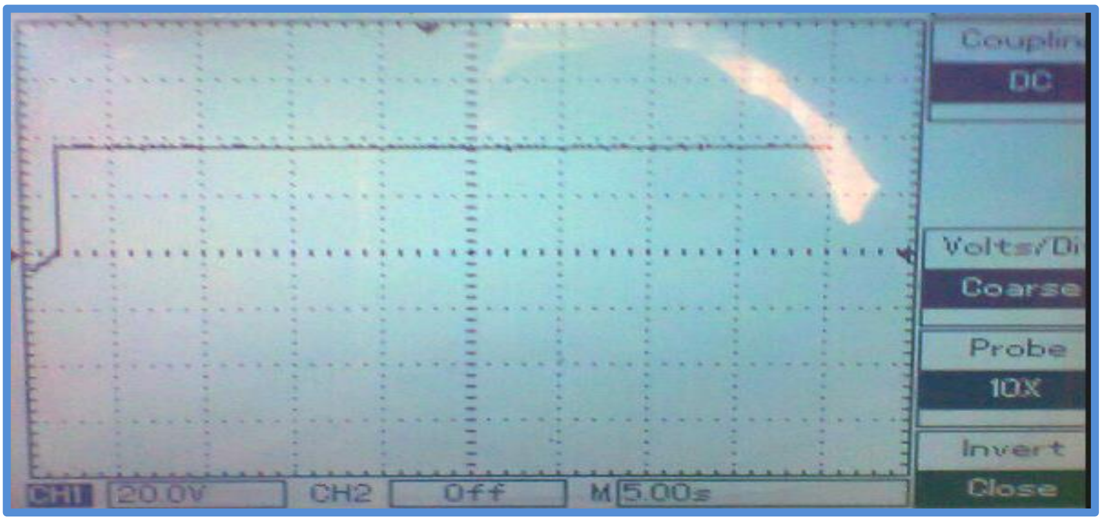

Figure 20 : Output Voltage of PV when T=25 C and R=900w/m2.

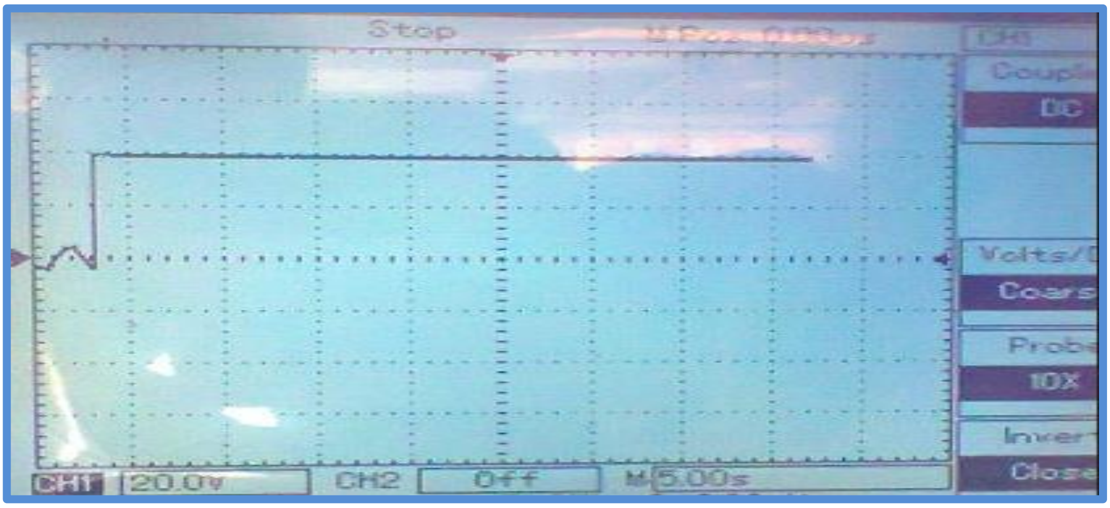

Figure 21: Output Voltage of PV Cell when T=41 C and R=995w/m2.

From figures (9-21), the following notes can be pointed out.

1. Figure 9 shows the relation between PV panel generated voltage with its current and PV voltage with its power denoting that the voltage, current and power are affected by the weather conditions.

2. Figure 10 displays the no load response curve of the PV panel generated voltage with the time.

3. Figure 11 exhibits the reply of the PV panel generated voltage with the time when the buck converter used as a load.

4. Figure 12 represents the response of the buck converter output voltage with the time at a resistive load.

5. Figure 13 shows the response of the PV panel generated voltage with the time when the PID controller used for MPPT.

6. Figure 14 displays the responses of the PV board generated voltage with the time when the P&O algorithm used as MPPT controller.

7. Figure 15 exhibits the response of the buck converter generated voltage with the time at a resistive load when the PID controller used as MPPT.

8. Figure 16 represents the responses of the buck converter output voltage with the time at a resistive load and when the P& O algorithm used as MPPT controller.

9. Figure 17 points to the highest power responses of the PV in the weather condition when the PID controller used as MPPT.

10. Figure 18 shows the responses of the PV panel generated power with the time when the P&O algorithm used as MPPT controller.

11. Figures 19-20-21 display the experimental responses of the PV panel generated voltages with the time when the (P&O) used as MPPT controller at the referees temperature and radiation respectively.

The designed system is constructed practically and its performance is tested for different weather conditions. Table 2. shows a comparison between the actual (experimental) and simulation results.

Table2: Actual and Simulation Results

R (W/ m^2)	T (C)	V (volt) Simulink	V(volt) actual with P& O	P_{Max} (W)	P_{actual} (W) with P&O	$P_{simu\text{-}link}$ (W) with P&O	$P_{simu\text{-}link}$ (W) with PID	day time (hour)
900	25	43.2	38.1	160	157	158	158.2	9
1000	41	43.7	39.3	195	189	192.5	193	13
650	32	42.9	37.5	110	107	107.8	108	18

8. Conclusions:

A PV panel system designed and implemented practically. The system performance studied for MPPT using two controller algorithms, P&O algorithm as microcontroller and PID controllers algorithm. The practical and simulation results produced the maximum obtained power is 193 W when PID controller used, the PID controller algorithm is better than P&O control algorithm. The output voltage of PV cell is proportional with the radiation and inversely proportional with the temperature. The effect of the buck converter resistive load is less than environment parameters effect. The maximum effect of the PV cell system is the radiation density.

9. References:

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