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IMPLEMENTATION OF PERTURB AND OBSERVE MPPT OF PV SYSTEM WITH DIRECT CONTROL METHOD USING BUCK AND BUCK-BOOST CONVERTERS

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Abstract

The Maximum Power Point Tracking (MPPT) is a technique used in power electronic circuits to extract maximum energy from the Photovoltaic (PV) Systems. In the recent decades, photovoltaic power generation has become more important due its many benefits such as needs a few maintenance and environmental advantages and fuel free. However, there are two major barriers for the use of PV systems, low energy conversion efficiency and high initial cost. To improve the energy efficiency, it is important to work PV system always at its maximum power point. So far, many researches are conducted and many papers were published and suggested different methods for extracting maximum power point. This paper presents in details implementation of Perturb and Observe MPPT using buck and buck-boost Converters. Some results such as current, voltage and output power for each various combination have been recorded. The simulation has been accomplished in software of MATLAB Math works.

Keyword

Maximum Power Point Tracking, Perturb and Observe, DC-DC Converters, Photovoltaic System .

1. Introduction

The usage of modern efficient photovoltaic solar cells (PVSCs) has featured as an masterminding alternative of energy conservation, renewable power and demand-side management. Due to their initial high expensive, PVSCs have not yet been an exactly a tempting alternative for electrical usage who are able to purchase less expensive electrical energy from the utility grid. However, they have been used widely for air conditioning in remote , water pumping and isolated or remote areas where utility power is not available or is high costly to transport. Although PVSC prices have decreased considerably during the last years due to new developments in the film technology and manufacturing process [1]. The harnessing of solar energy using PV modules comes with its own problems that arise from the change in insulation conditions. Those changes in insulation conditions strongly influence the efficiency and output power of the PV modules. A great deal of research has been accomplished to improve the efficiency of the photovoltaic system. Several methods to track the maximum power point of a PV module have been suggested to solve the problem of efficiency and products using these methods have been made and now commercially available for consumers [2-3].

As the market is now flooded with species of these MPPT that are intentional to improve the efficiency of PV modules under different isolation conditions it is not known how many of these can actually provide on their promise under a diversity of field conditions. This research then seems at how a different kind of converter affects the output power of the module and also achieve if the MPPT that are said to be highly efficient and do track the true maximum power point under the different conditions.

A maximum power point tracker is used for obtaining the maximum power from the solar PV module and conversion to the load. A non isolated DC-DC converter (step up/ step down) offers the purpose of conversion maximum power to the load. A DC-DC converter acts as an interface between the load and the module. By varying the ratio of duty cycle the impedance of load as it appears by the source is varied and matched at the peak power point with the source so as to conversion the maximum power [4-5].

Therefore maximum power point tracker methods are required to maintain the PV array's working at its MPP. Many MPPT methods have been suggested in the literature ; example are the Perturb and Observe (P&O) methods, Incremental Conductance (IC) methods and constant voltage methods.. etc. [6-12]. In this paper the most popular of MPPT technique (Perturb and Observe (P&O) method, Buck and Buck- Boost DC-DC converters will involve in Implementation study (Figure 1) [13].

Some results such as current, voltage and output power for each various combination have been discussed. The MPPT technique will be implemented, by using Matlab tool Simulink, considering the variant of circuit combination.

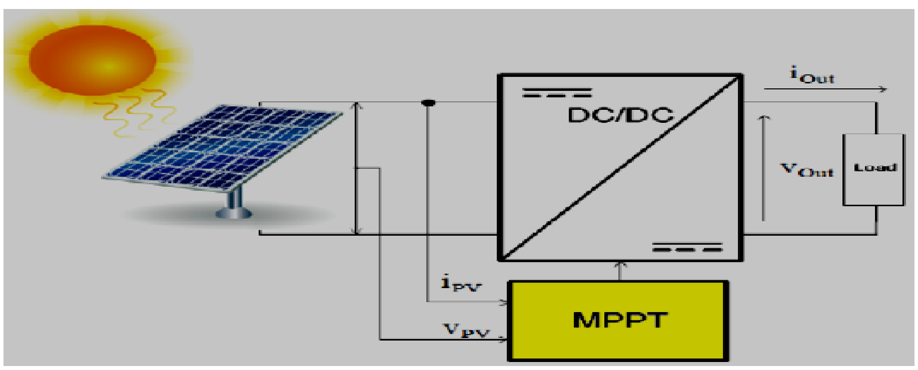

Figure 1. PV module and dc/ dc converter with MPPT

2. Photovoltaic Cell

Photovoltaic generators are neither fixed current sources nor voltage sources but can be approximated as current generators with dependant voltage sources. During darkness, the solar cell is not an active device. It produces neither a current nor a voltage. A solar panel cell essential is a p-n semiconductor junction. When exposed to the light, a current is generated (DC current).The generated current change linearly with the solar irradiance. Figure 2 show the equivalent electrical circuit of an ideal solar cell.

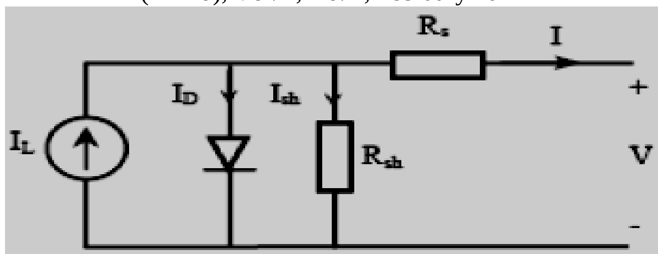

Figure 2. Equivalent circuit of a solar cell

The I-V characteristics of the solar cell circuit can be sets by the following equations [14]. The current through diode is given by:

$$I_D = I_O\,[\exp(q(V + I R_S)/KT)) - 1] \quad (1)$$

While, the solar cell output current:

$$I = I_L - I_D - I_{sh} \quad (2)$$

$$I = I_L - I_O\,[\exp(q(V + I R_S)/KT)) - 1] - (V + IR_S)/R_{sh} \quad (3)$$

Where,

I : Solar cell current (A)
I_L : Light generated current (A)
I_O : Diode saturation current (A)
q : Electron charge (1.6×10-19 C)
K : Boltzman constant (1.38×10-23 J/K)
T : Cell temperature in Kelvin (K)
V : solar cell output voltage (V)
R_S: Solar cell series resistance (Ω)
R_{sh}: Solar cell shunt resistance (Ω)

3. DC-DC Converter Analysis

3.1 Buck Converter

A buck converter or voltage regulator is also called a step down regulator since the output voltage is lower than the input voltage. In a simple example of a buck converter, a diode is connected in parallel with the input voltage source, a capacitor, and the load, which represents output voltage. A switch is connected between the input voltage source and the diode and an inductor is connected between the diode and the capacitor, shown in Figure 3 [15].

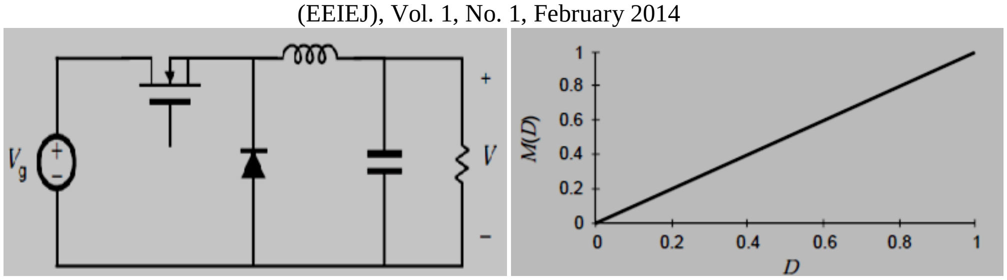

Figure 3. Basic buck converter and its dc conversion ratios M(D)

3.2 Buck-Boost Converter

The last and most important type of switching regulator is the buck-boost converter. In this converter, the buck and boost topologies covered earlier are combined into one. A buck-boost converter is also built using the same components used in the converters covered before. The inductor in this case is placed in parallel with the input voltage and the load capacitor. The switch or transistor is placed between the input and the inductor, while the diode is placed between the inductor and the load capacitor in a reverse direction, shown in Figure 4.The buck-Boost converter provides an output voltage that may be less than or greater than the input voltage [15].

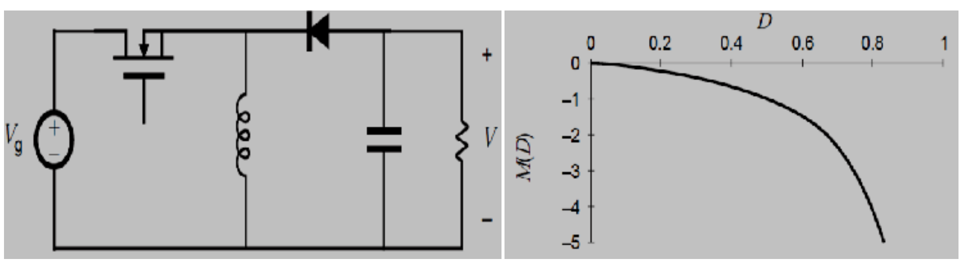

Figure 4. Basic buck-boost converter and its dc conversion ratios M(D).

4. Problem Overview

The MPPT method consider is to automatically find the current I_{MPP} or voltage V_{MPP} at which a PV array should work to extract the maximum output power P_{MPP} under a given temperature and irradiance. Most of MPPT methods respond to variations in both irradiance and temperature, but some are precisely more useful if temperature is approximately constant. Most MPPT methods would automatically respond to various in the array due to aging, though some are open-loop and would require periodic fine tuning. In our context, module will typically be connected to a power converter that can vary the current coming from the PV array to the load [6, 11, 14, 16].

5. MPPT Control Algorithm

The weather and load changes cause the operation of a PV system to vary almost all the times. A dynamic tracking technique is important to ensure maximum power is obtained from the photovoltaic arrays. The following algorithms are the most fundamental MPPT algorithms, and they can be developed using micro controllers.

The MPPT algorithm operates based on the truth that the derivative of the output power (P) with respect to the panel voltage (V) is equal to zero at the maximum power point. In the literature, various MPP algorithms are available in order to improve the performance of photovoltaic system by effectively tracking the MPP. However, most widely used MPPT algorithms are considered here, they are:

1. Perturb and Observe (P&O)
2. Incremental Conductance (InCond)
3. Constant Voltage Method.

5.1 Perturb and Observe (P&O)

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle [17]. In this algorithm a slight perturbation is introduce to the system. This perturbation causes the power of the solar module various. If the power increases due to the perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses as shown in Figures 5(a) and 5(b).

When the stable condition is arrived the algorithm oscillates around the peak power point. In order to maintain the power variation small the perturbation size is remain very small. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts to transfer the operating point of the module to that particular voltage level. It is observed some power loss due to this perturbation also the fails to track the maximum power under fast changing atmospheric conditions. But remain this technique is very popular and simple [7].

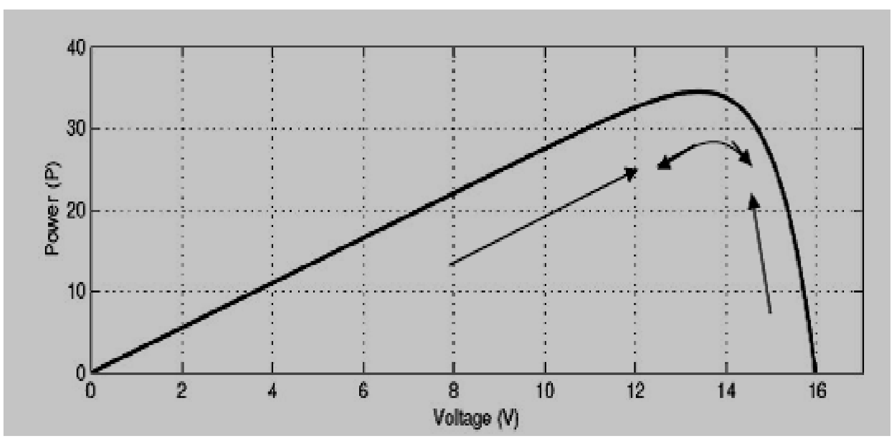

Figure 5(a). Graph Power versus Voltage for Perturb and Observe Algorithm

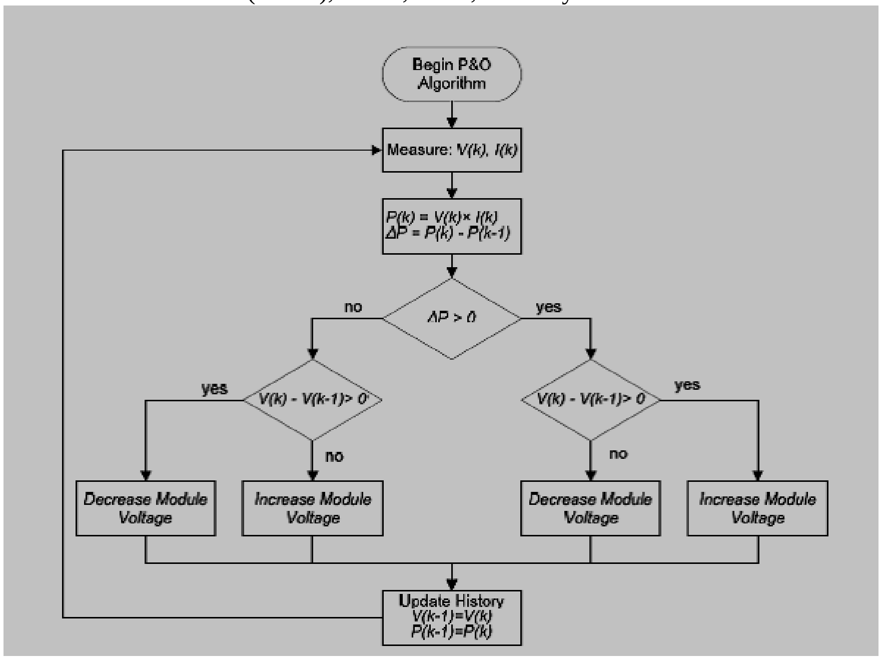

Figure 5(b). P&O Algorithm

5.2 Incremental Conductance (IC)

The perturb oscillation around peak power point of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method. The Incremental Conductance can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dI/dV and –I/V This relationship is derived from the truth that dP/dV is negative when the MPPT is to the right side curve of the MPP and positive when it is to the left side curve of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher precision than perturb and observe. The disadvantage of this algorithm is the increased complexity [7, 18, 19, 20, 21].

5.3 Constant Voltage Method

The Constant Voltage method (CV), also in some literature called Open voltage Ratio method, uses the fact that the MPP voltage at different irradiance is approximately equal, as shown in Figure 6.

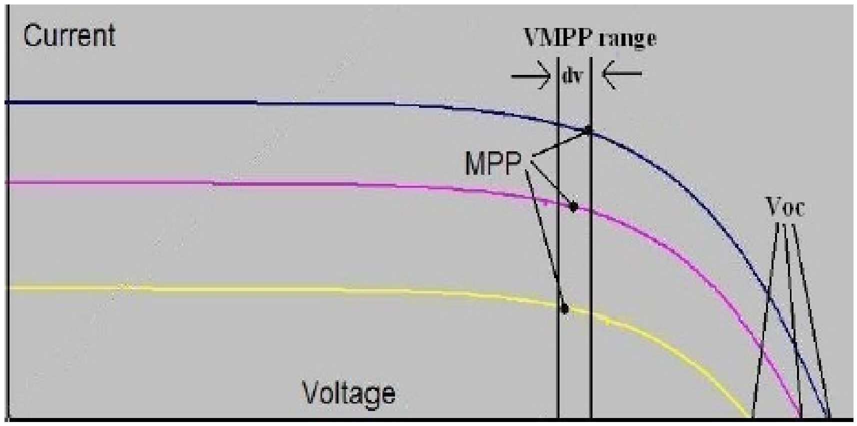

Figure 6. Constant Voltage Method in V-I curve

VOC represented the open circuit voltage of the PV panel. VOC depends on the property of the solar cells. A commonly used VOC/VMPP value is 76%. This relationship can be described by equation (4) below [22]:

$$V_{MPP} = k * V_{OC} \quad (4)$$

where k ≈0.76 in this case.

The solar panels are always disconnected from the converter circuit for a short duration of time for V_{OC} measurement. The operating voltage of the MPP is then set to 76% of the measured V_{OC}. The major advantage of this method is that the MPP may be located very quickly. However at the same time this method suffers from low accuracy, because the V_{OC} is also affected by the temperature of the solar cells which may change the V_{OC}/V_{MPP} ratio significantly. Any small deviation of the V_{OC} after the sampling can cause large difference in tracking the MPP during that sampling period. Moreover, power is lost during the short sampling time, further reducing the efficiency of constant voltage method.

6. MATLAB-SIMULINK Environment

The model shown in Figure 7 represents a block diagram of a PV array connected to a resistive load through a dc/dc (buck or buck boost) converter with MPPT controller.

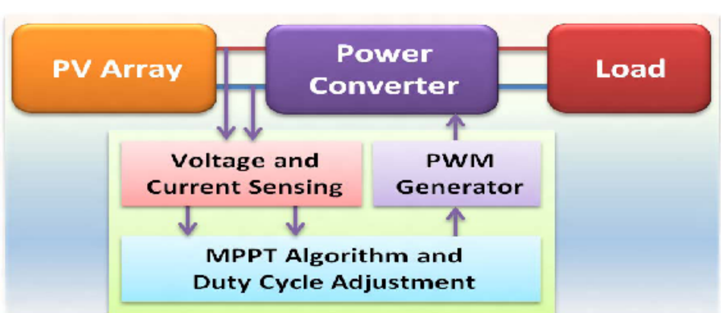

Figure 7. Block diagram of a PV array connected to the load

In Figure 8 the model of PV panel as a constant dc source created using the subsystem block from Simulink library browser, which included all functions of PV panel. The model has three inputs irradiance, temperature and voltage input that is coming as a feedback from the system and the output of the block gives the current. This model generates current and receives voltage back from the circuit.

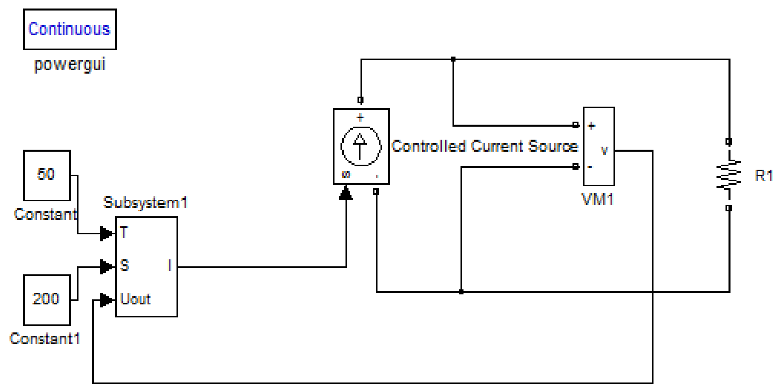

Figure 8. Block diagram of a PV panel connected to the load.

Figures 9 and 10 present a SIMULINK® diagram of a both buck and buck-boost converters. Figure 11 shows a SIMULINK® diagram of a Perturb and Observe maximum power point tracking Algorithm, while Figures 12 and 13 show a SIMULINK® of complete diagram of both buck and buck-boost converters plus P&O MPPT and PV module.

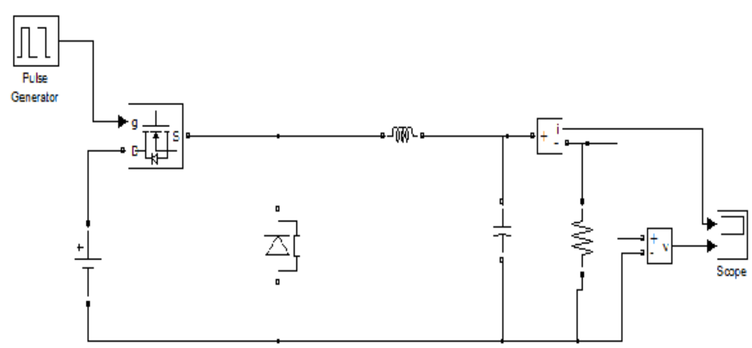

Figure 9. Simulink® model of buck converter

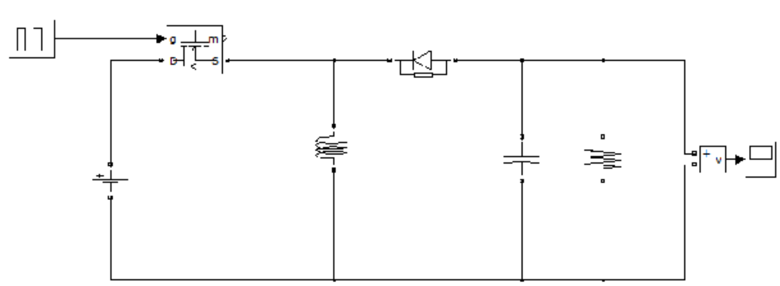

Figure 10. SIMULINK® model of buck-boost converter

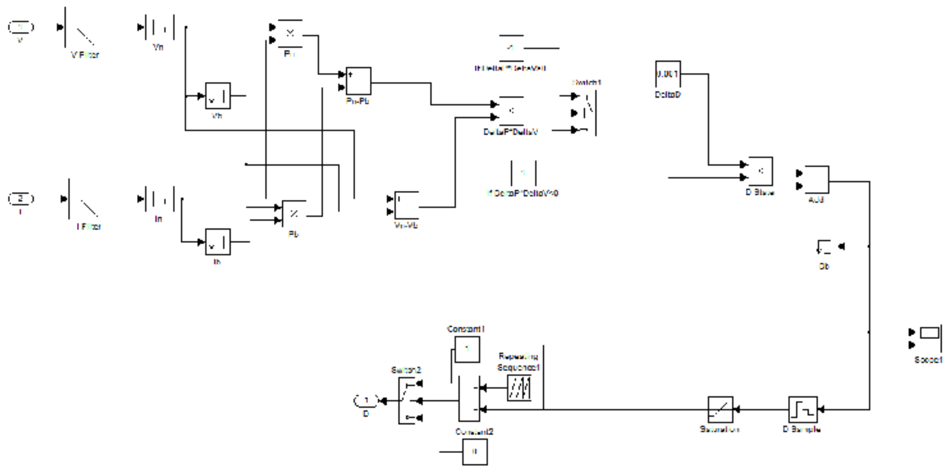

Figure11. SIMULINK® model of P&O Algorithm

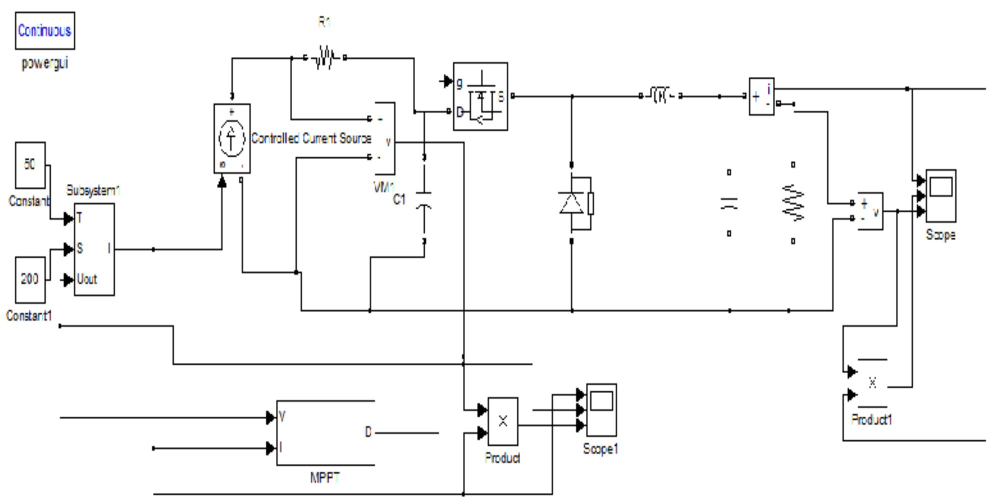

Figure 12. SIMULINK® model of buck converter and P&O MPPT

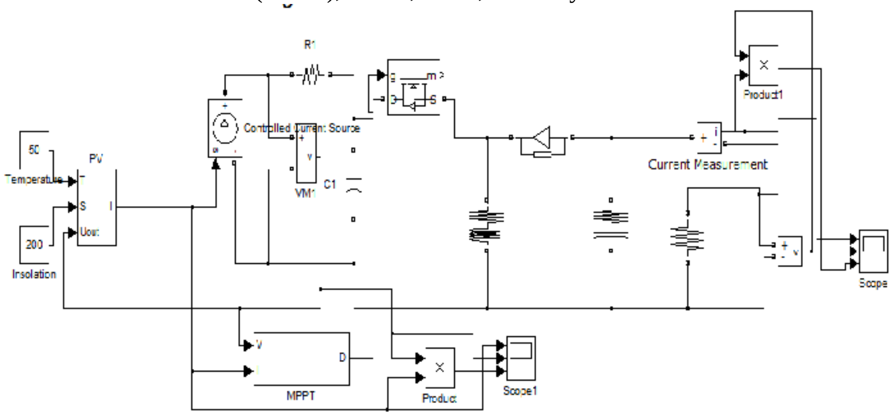

Figure 13. SIMULINK® model of buck-boost converter and P&O MPPT

7. Results and Simulation

The models shown in the above figures were simulated using MATLAB® / SIMULINK®. Simulation and results for buck and buck-boost converters have been recorded to make sure that comparison of the circuit can be obtained accurately. The voltage, current and output power is the main points of comparison to take into account. The complexity and simplicity of the circuit have been set based on the literature. Hardware required, convergence speed and range of effectiveness are as in [23].

7.1 Buck Converter Simulation With Perturb and Observe Controller

The simulation result at constant temperature (T=50 degree) with changes in the insolation (S=400 to 200 w/m²)

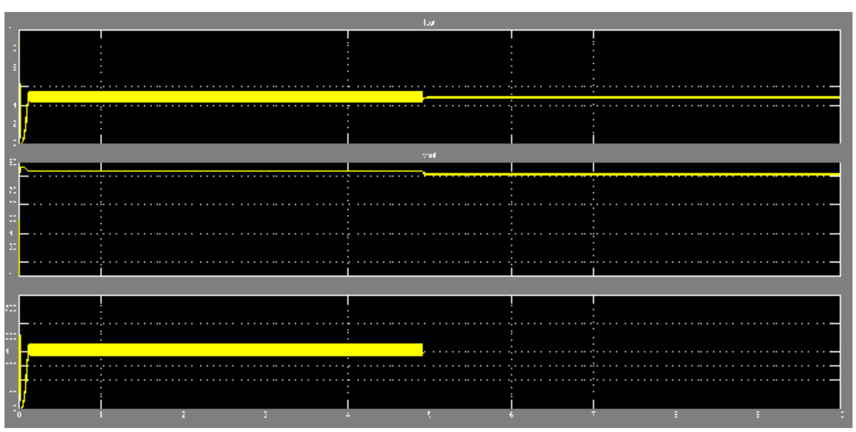

Figure 14. Output current, voltage and power of PV panel (insolation changed from 400 to 200 w/ m² at a time of 4.915 sec.)

From Figure 14, the results below including current, voltage and power:

At T=50 degree and S=400 w/ m²
I= 5.48 Ampere, V=84.1 volt and P=458 watt
At T=50 degree and S=200 w/ m²
I=4.85 Ampere, V=82.25 volt and P= 395 watt

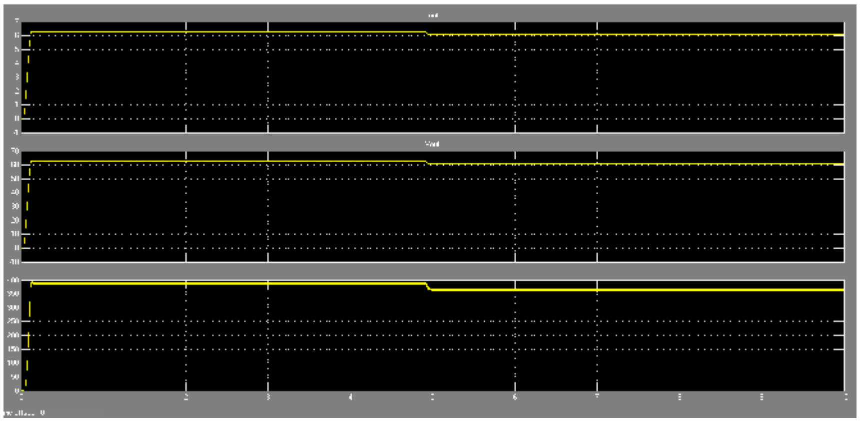

Figure 15. Output current, voltage and power of buck converter with P&O algorithm (Insolation changed from 400 to 200 w/ m² at a time of 4.915 sec.)

From Figure 15, the results below including current, voltage and power:

At T=50 degree and S=400 w/ m²
I= 6.26 Ampere, V=62.6 volt P=392 watt
At T=50 degree and S=200 w/ m²
I=6 Ampere, V=60.85 volt P= 370.5 watt

7.2 Buck-Boost Converter Simulation With Perturb and Observe Controller

The simulation result at constant temperature (T=50 degree) with changes in the isolation (S=400 to 200 w/m²)

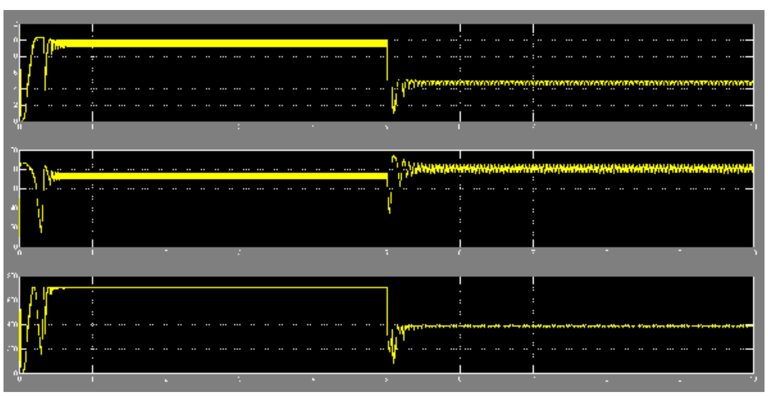

Figure 16. output current, voltage and power of PV panel (Insolation changed from 400 to 200 w/ m² at a time of 5.017 sec.)

It can be seen from Figures 14 and 16 that the output of the PV panels clearly changes due to the change of the used converter as that variation of the converter affect of the output of the PV panel.

From Figure 16, the results below including current, voltage and power:

At T=50 degree and S=400 w/ m²
I= 10Ampere, V=76.5 volt and P=712 watt
At T=50 degree and S=200 w/ m²
I=5.05 Ampere, V=86 volt and P= 395 watt

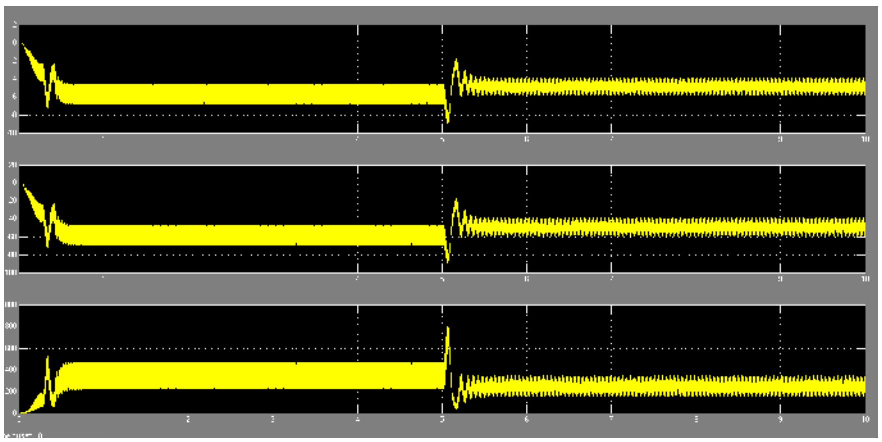

Figure 17. Output current, voltage and power of buck-boost converter with P&O algorithm
(Insolation changed from 400 to 200 w/ m² at a time of 5.017 sec.)

From the Figure 17, the results below including current, voltage and power:

At T=50 degree and S=400 w/ m²
I= -4.7 Ampere, V=-47 volt and P=470 watt
At T=50 degree and S=200 w/ m²
I=-3.8 Ampere, V=-38 volt and P= 350 watt

Comparing the results of Figures 15 and 17, it is clear that:

1- Perturb and Observe add oscillations to the output value, this is the main drawback of using this technique.

2- Buck converter suppresses the oscillations more efficiently than buck-boost converter.

Table 1. P&O MPPT algorithm with buck and buck-boost converters
(Insolation=400 w/ m² and temperature=50 degree)

DC-DC Converter	I in (A)	Vin (V)	Pin (watt)	Iout (A)	Vout (V)	Pout (watt)
Buck	5.48	84.1	458	6.26	62.6	392
Buck-Boost	10	76.5	712	-4.7	-47	470

Table 2. P&O MPPT algorithm with buck and buck-boost converters
(Insolation=200 w/ m² and temperature=50 degree)

DC-DC Converter	I in (A)	Vin (V)	Pin (watt)	Iout (A)	Vout (V)	Pout (watt)
Buck	4.85	82.25	395	6	60.85	370.5
Buck-Boost	5.05	86	395	-3.8	-38	350

From Tables 1&2, once the converters transfer the electrical power from the solar panel to the load and the controller start function, output value of the solar panel do not provide same input voltage value to controller (Vin). This is because the controller function that varies the value of duty cycle will change the input value that sense by the controller. The input voltages of this controller show a different each other. Input voltage of Buck that connected with P&O is 84.1 V (82.25V at 200 w/ m²) while input voltage of buck-boost that connected with P&O is 76.5V (86V at 200 w/ m²). The output value behaves as Buck and buck-boost converters behave. The buck voltage will drop from 84.1V to 62.6V (82.25V to 60.85V at 200 w/ m²), while the buck-boost voltage drop from 76.5V to -47V (86V to -38V at 200 w/ m²). This system show that perturb and observe controller will work better with buck controller than buck-boost.

8. CONCLUSION

P&O MPPT method is implemented with MATLAB-SIMULINK for simulation. The MPPT method simulated in this paper is able to improve the dynamic and steady state performance of the PV system simultaneously. Through simulation it is observed that the system completes the maximum power point tracking successfully despite of fluctuations. When the external environment changes suddenly the system can track the maximum power point quickly. Both buck and buck-boost converters have succeeded to track the MPP but, buck converter is much more effective specially in suppressing the oscillations produced due the use of P&O technique.

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