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Comparison of simple Maximum Power Point Tracking algoritms and simulation by PSIM for a standalone photovoltaic system

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ABSTRACT

Traditional fossil energy sources are increasingly exhausted, leading to the need for mankind to exploit alternative energy sources; and solar energy can be viewed as infinite. Solar photovoltaic and its applications are increasingly widely studied. However, due to its nonlinearity and unstable nature, high technology is required to achieve good conversion efficiency. One of the techniques to optimize solar cell efficiency is to use the Maximum Power Point Tracking algorithm (MPPT) and P&O is a relatively easy algorithm to implement. This article will present some problems about photovoltaic cells, power converters in solar power systems and using PSIM software to simulate an independent solar system with several harvesting solutions for solar power and compare the efficiency of them.

Keywords: *solar energy, PSIM, MPPT, P&O, DC/DC converter, power electronics*

1. Introduction

Today, electricity from solar photovoltaic (PV) is the most environmental type of energy to use. It has become one of the leading power generation for a future based on sustainable and pollution-free energy technology as a replacing old and costly (DOLARA et al., 2009). However, electricity generated by photovoltaic panels is an unstable energy source because it depends directly on several factors such as solar irradiation level and temperature, spectral characteristics of sunlight, dirt, shading and so on (Mohapatra et al., 2017). For independent load solar PV systems, the generating capacity of the PV system also depends on the impedance of the load. Without control, the load capacity obtained from the solar PV system is very low during dynamic operation. Therefore, it is essential to control the solar power conversion system so that the PV panels operate at maximum power point (MPP) to increase the efficiency of the system.

A PV solar system with DC load included: Photovoltaic panel (PV) convert solar energy to electric energy; DC/DC converter and battery system for storage. In which, the DC/DC converter has a very important ingredient of the system because it both keeps stability and improves the efficiency of the system (Tripathi & Kumar, 2019). There were many research about enhancement DC/DC converter efficient and some of them presented the simulation form or deploying in simple practical hardware (Jamil & Hamed, 2019; Pindado & Cubas, 2017; Sabry et al., 2017). In this paper, we will present the MPPT algorithm of DC/DC buck converter in simulation with PSIM. Beside, we also show the comparison between the P&O and other simple - cheap - method for there efficiency in the PV system to adapt with environment characteristics change for users to have a clear view of PV panel, converters and have the right choice according to specific needs.

2. PV panel model, buck converter and MPPT algorithm

2.1 PV panel

A solar cell, or photovoltaic cell, a solar cell is a device that converts light into electricity using the photoelectric effect. ... Solar energy is available in nature and is endless so it is not afraid to be depleted like other renewable energy sources. In recent years, with the support of foreign organizations and our state agencies, solar energy has been used more and more (Lakatos et al., 2011). In particular, the transformation of photovoltaic energy into direct energy, especially the design of the solar panel rotation system in the direction of sunlight, the method of detecting the maximum power point around the solar cell and the direction Method of power reserve charger for convenient use and storage (Rubio et al., 2007). In this paper, we will present the simulation of a PV system with a DC/DC buck converter that feeds independent loads and examine some simple control methods commonly used in practice and provide comparison results to have a clearer view of this issue.

PV solar cell or PV solar panel is depicted as a circuit in Figure 1 consisting of a current source, a diode and resistors. The PV panel is a nonlinear circuit element with a V-I characteristic curve shown in Figure 2. We can see from characteristic V-I that the conversion from solar radiation to electrical energy depends on the output voltage and current of solar panels and that only a pair of values of V, I will give output capacity is maximum which is called maximum power point (MPP) (Dabra et al., 2017).

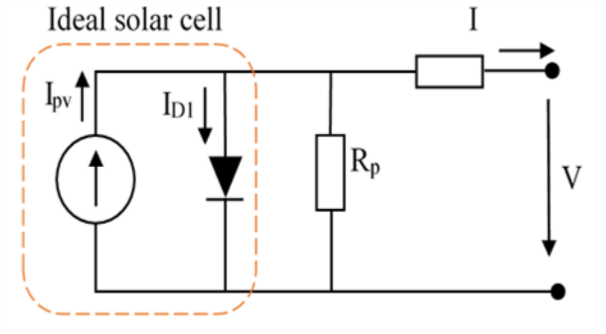

Figure 1. *Equivalent circuit model of solar cell/panel*

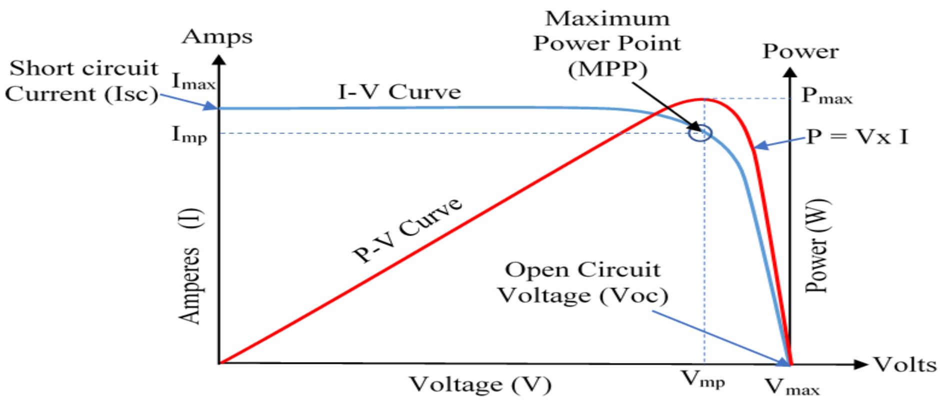

Figure 2. *Solar Cell I-V Characteristics Curve*

2.2 DC/DC buck converter

Solar photovoltaic produces in DC power. But, solar panel conversion efficiency is limited, typically around 16-22 percent depending on technology and fabrication techniques. Besides, the voltage output of PV panel (Wang & Lu, 2013). Therefore, a device to stabilize the output voltage is required. Furthermore, it is also necessary to have an appropriate control mechanism to extract the maximum energy of the PV system.

DC/DC converters were commonly used can be listed: Buck converter (output voltage is less than input voltage), Boost converter (output voltage is greater than input voltage), Fly - Back converter (arbitrary output voltage), Push - Pull converter (same as Fly - Back converter) ... (Zongo, 2021). In this article we will present a system using a buck converter to controlling output voltage in accordance with 12VDC load of solar PV panel with open-circuit voltage greater than 20VDC. This converter will receive a control signal to facilitate the solar panel connected at the input always operates at maximum power point (MPP) regardless of varying environmental conditions or output load at setting voltage.

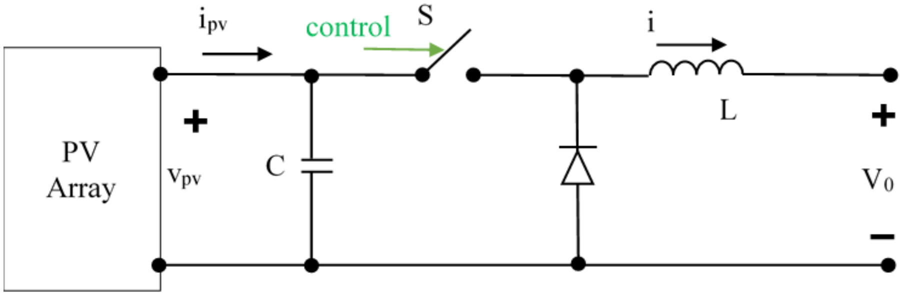

Figure 3. *DC/DC Buck converter with PV array variable input and control output value*

A DC/DC buck converter is shown in Figure 4a. It converts the input voltage into output voltage that is less than the input voltage. Its switch-on and switch-off equivalent circuits are shown in Figure 4b and 4c (Tan et al., 2005).

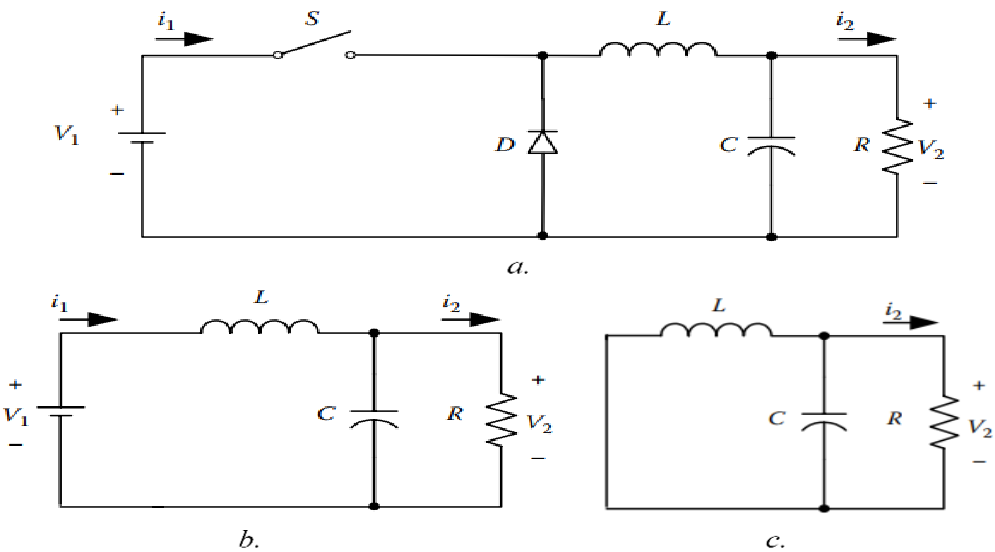

Figure 4. *A buck converter and its equivalent circuits: (a) buck converter, (b) switch-on, and (c) switch-off*

When the “switch” is on, the source is connected to the circuit, then the current flows through the inductor and the current in the inductor increases, at this time the capacitor is charged while providing current through the load as Figure 4a.

When the “switch” is off, the power is disconnected from the circuit. In the inductor, the magnetic field energy accumulates and the previously accumulated capacitor discharges through the load change and decrease (Tan et al., 2005).

The average voltage in continuous switching mode is:

$$V_{OUT} = V_{IN} \times D$$

D - Duty coefficient is determined by a relation:

$$D = T_{on} / (T_{on} + T_{off}) < 1$$

where T_{on}, T_{off} is the switch-on and switch-off time.

The frequency operation of the circuit is rather high around dozen kHz.

2.3 Maximum Power Point Tracking (MPPT)

To harvest maximum power from the PV panel a charge controller with MPPT capability is proposed in this paper. The two broad categories of MPPT techniques are the indirect techniques and direct techniques. Indirect techniques include the fixed voltage, open circuit voltage and short circuit current methods. In this kind of tracking, simple assumption and periodic estimation of the MPPT are made with easy measurements. For example, the fixed voltage technique only adjusts the operating voltage of the solar PV module at different seasons with the assumption of higher MPP voltages in winter and lower MPP voltages in summer at the same irradiation level. This method is not accurate because of the changing of irradiation and temperature level within the same season (DOLARA et al., 2009).

Another most common indirect MPPT technique is the open circuit voltage (OV) method. In this method, it is assumed that:

$$V_{MMP} = k \times V_{oc}$$

Where k is a constant and its value for crystalline silicon is usually to be around 0.7 to 0.8. This technique is simple and is easier to implement compared to other techniques. However the constant k is just an approximation leading to reduced efficiency, and each time the system needs to find the new open circuit voltage (Vout) when the illumination condition changes. To find the new open circuit voltage, each time the load connected to the PV module must be disconnected causing power loss. Direct MPPT methods measure the current and voltage or power and thus are more accurate and have faster response than the indirect methods. Perturb and observe (P&O) is one of the direct MPPT techniques, which is used here with some modifications (Koukouvaos et al., 2014).

2.4 Perturb and Observe Algroritm (P&O)

Typically, P&O method is used for tracking the MPP. In this technique, a minor perturbation is introduced to cause the power variation of the PV module. The PV output power is periodically measured and compared with the previous power. If the output power increases, the same process is continued otherwise perturbation is reversed. In this algorithm perturbation is provided to the PV module or the array voltage. The PV module voltage is increased or decreased to check whether the power is increased or decreased. When an increase in voltage leads to an increase in power, this means the operating point of the PV module is on the left of the MPP. Hence further perturbation is required towards the right to reach MPP. Conversely, if an increase in voltage leads to a decrease in power, this means the operating point of the PV module is on the right of the MPP and hence further perturbation towards the left is required to reach MPP. The flow chart of the adopted P&O algorithm for the converter is given in Figure 5 (Tripathi & Kumar, 2019).

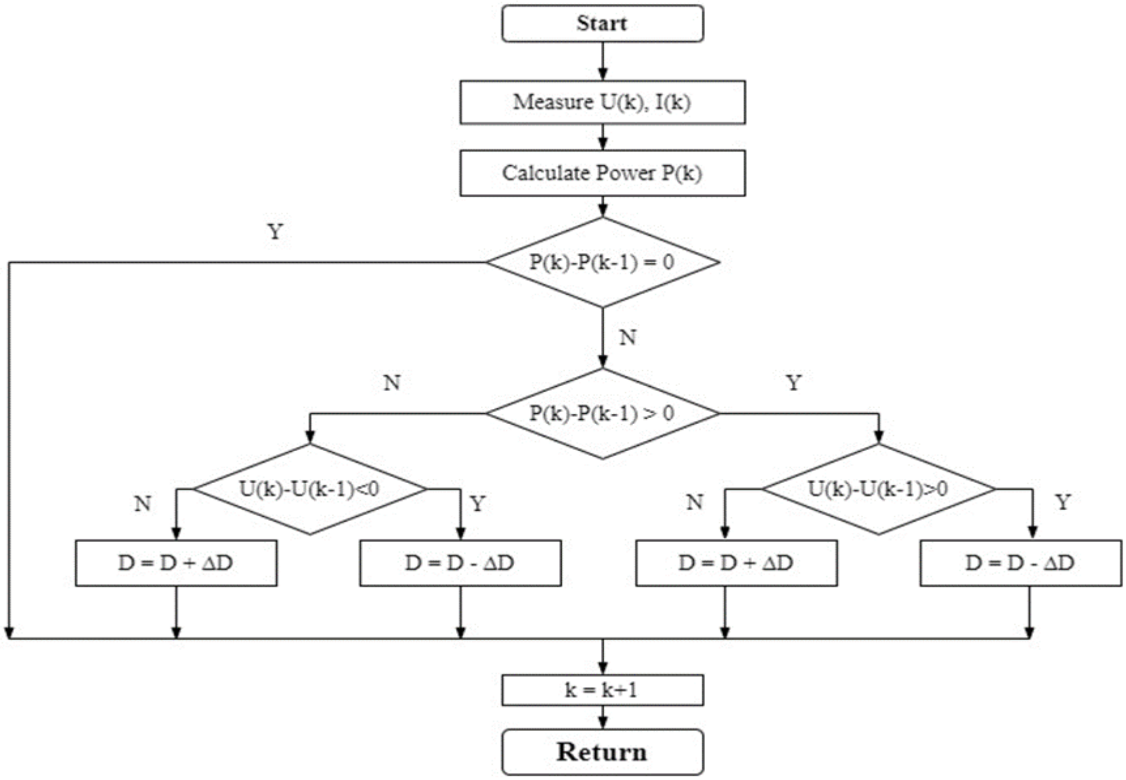

Figure 5. *P&O algorithm Flowchart*

4. Model and simulation PV system with PSIM

In this chapter, a model of standalone PV system as Figure 6 will be modeled in PSIM software as Figure 7 to survey and compare the efficiency between two MPPT techniques in difference conditions of environment.

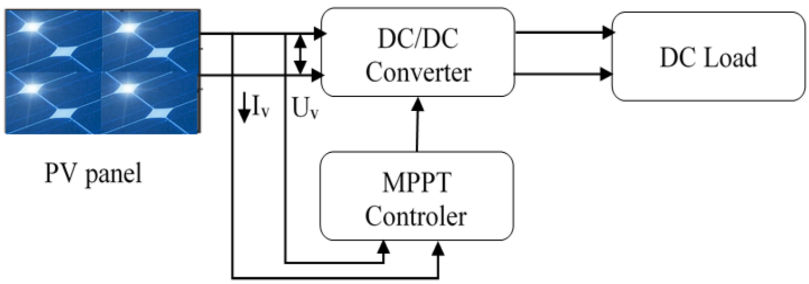

Figure 6. *Standalone PV system with DC load*

The following figure shows an independent solar cell system with varying conditions of input radiation conditions. We will present two methods of power converter circuit control described above. With method 1, the opening pulse width for the semiconductor valve is 75 ~ 80%. The results from Figure 8 show that the fluctuation of power on load and solar panel capacity depends entirely on the variation of radiation intensity and the change in load parameters. The output voltage on the load also fluctuates significantly. The system's efficiency in this case depends entirely on the characteristics of the system and the environment, completely uncontrollable so sometimes quite high but can also be very low (Dabra et al., 2017). In the case we are directly connected to the solar panel (equivalent to closing the circuit 100% of the time), the result is that the solar panel's efficiency is very low compared to its capacity (Psolar << Pmax) when solar radiation conditions change as shown in Figure 10.

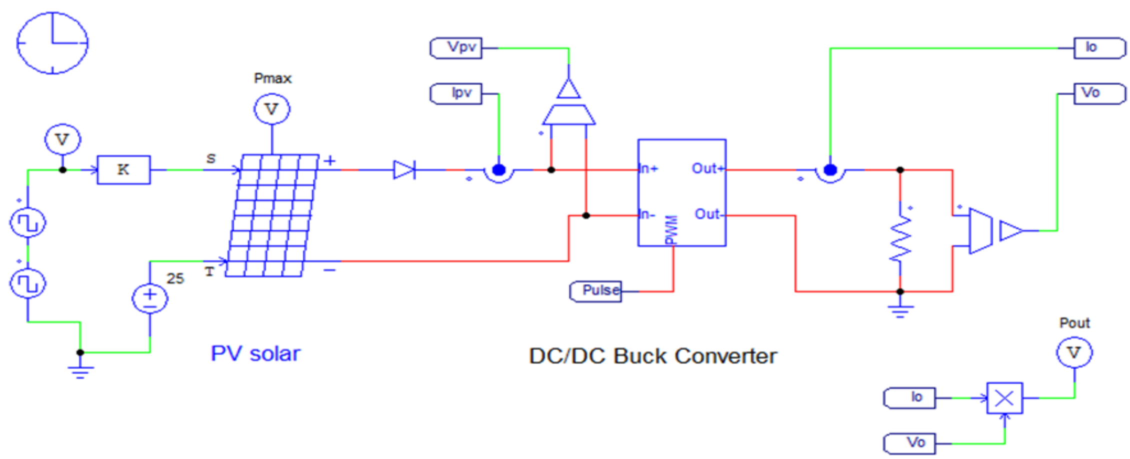

Figure 7. *PSIM simulation for surveyed system*

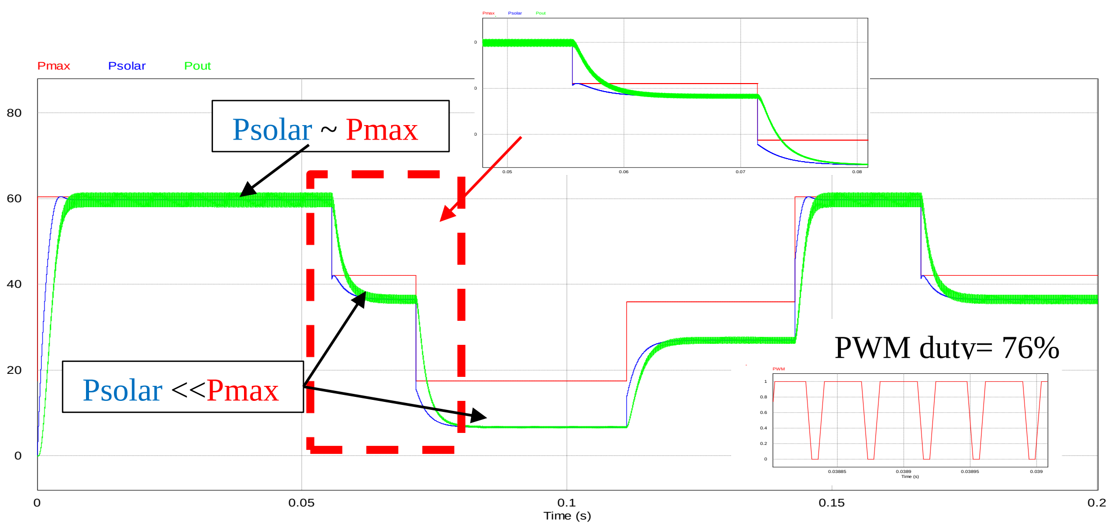

Figure 8. *PSIM simulation for surveyed system, PWM duty= 76%*

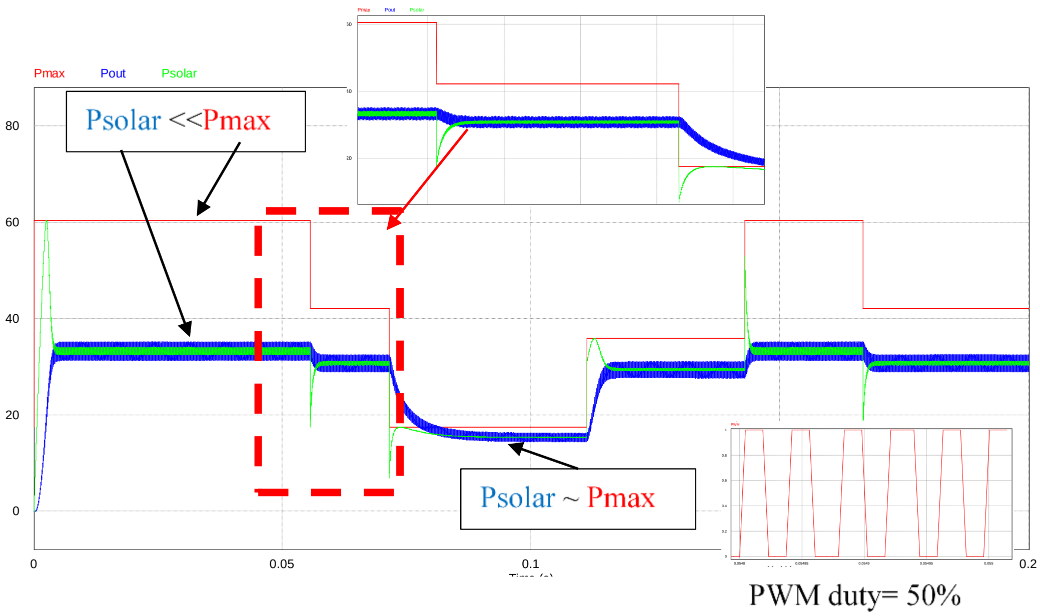

Figure 9. *PSIM simulation for surveyed system, PWM duty= 50%*

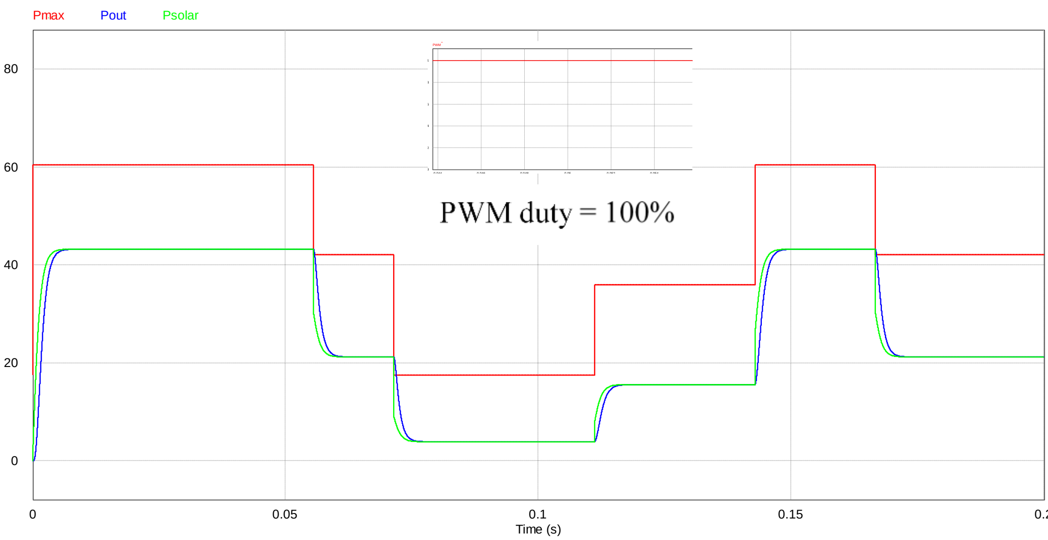

Figure 10. *PSIM simulation for surveyed system, PWM duty = 100%*

Therefore, the DC/DC converter needs to be ON/OFF with PWM duty so that the solar panel power (Psolar) always follows the maximum power point (Pmax), meaning the highest possible efficiency with all changes. Environmental changes as well as variable load parameters. In this case, we propose to use the P&O algorithm to find the appropriate PWM duty for the "switch" aperture as presented in the section 2 above and the test simulation results as shown in Figure 11.

In the Figure 11 below, we simulate the change in the medium, where the light intensity (W/m2) is influenced by a number of reasons such as cloud cover, timing, shade, etc. The simulation results show that PWM duty varies with different cases and the solar panel power at the converter input (Psolar) as well as the power on load (Po) follow the maximum power of the PV panel (Pmax) according to variable luminous intensity conditions.

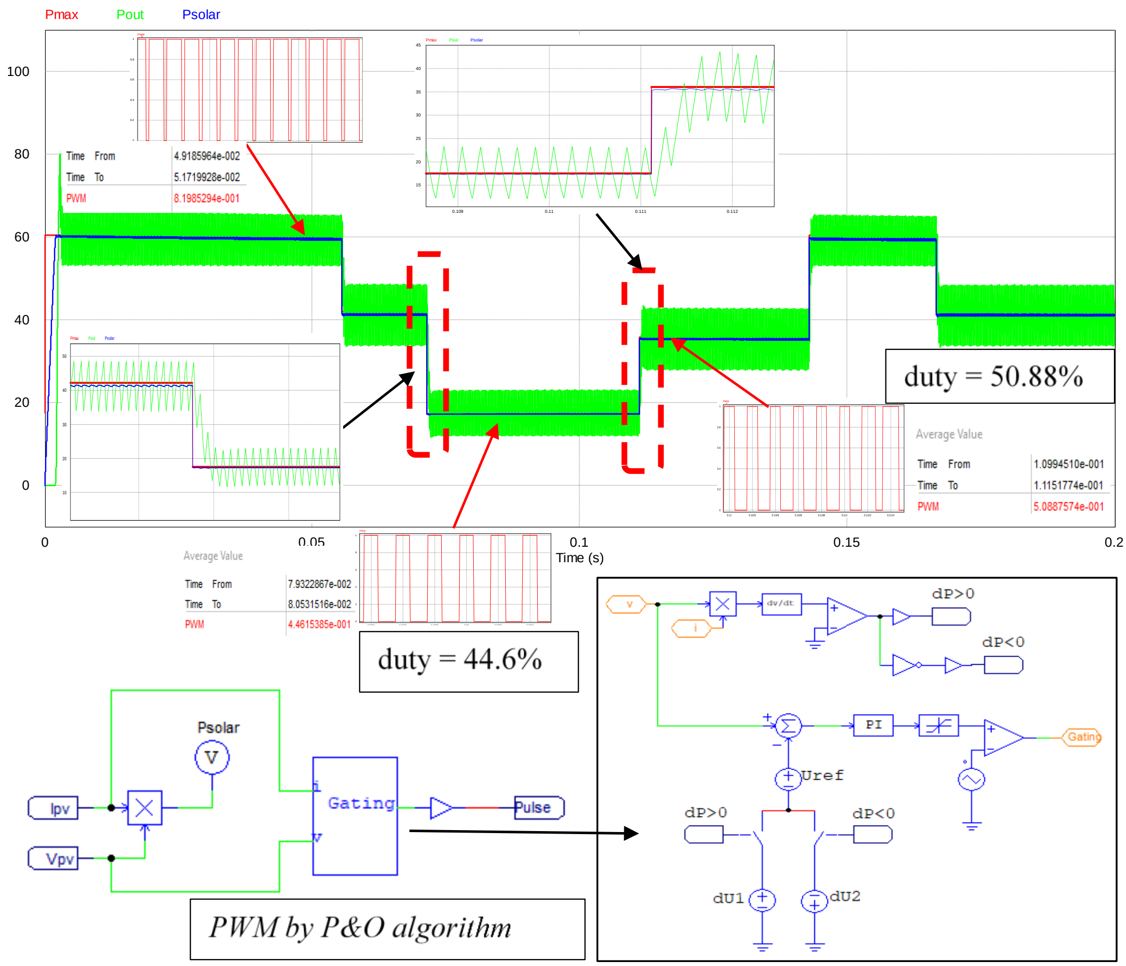

Figure 11. *PSIM simulation for surveyed system, PWM is Flexible by P&O algorithm*

5. Result and discussion

In this article, some solar energy issues; solar panels, equivalent electrical circuit of PV panel; a power electronics converter for harvesting solar power, the DC/DC Buck converter and some simple and popular control methods have been shown. Besides, a solar power system with independent loads was simulated with PSIM software and compares the resulting electrical energy at the output of the panel as well as the energy supplied to the load.

The simulation results in Figure 12 clearly presented the advantages of controlling the power converter for the solar energy system to follow the maximum power point compared with no control or control of the switching fixed ratio. However,, with the P&O control method we need to use 2 more sensors to measure voltage and current on the solar panel as well as need to add a microcontroller and program the computation more complicated than the other methods presented in this paper. The results also show a very large (%) difference between the solutions. In the case of a large system, the additional amount of electricity when using the P&O algorithm to control will also increase proportionally and using this method for PV panel is extremely useful.

Moreover, from the simulation results, we can also see that the PV panel's power in case the P&O algorithm always follows the MPP according to its parameters but does not immediately reach that point. This is also a limitation of P&O algorithm. The working point of solar panels and systems always fluctuates around the MPP, which also means that performance during constant radiation intensity is never immediately optimal. We will to present about the problems in the future research.

PSIM is one of powerful software has the intuitive interface, capable of simulating almost real systems and components, this is very useful in researching and testing the systems on the simulation before performing with hardware.

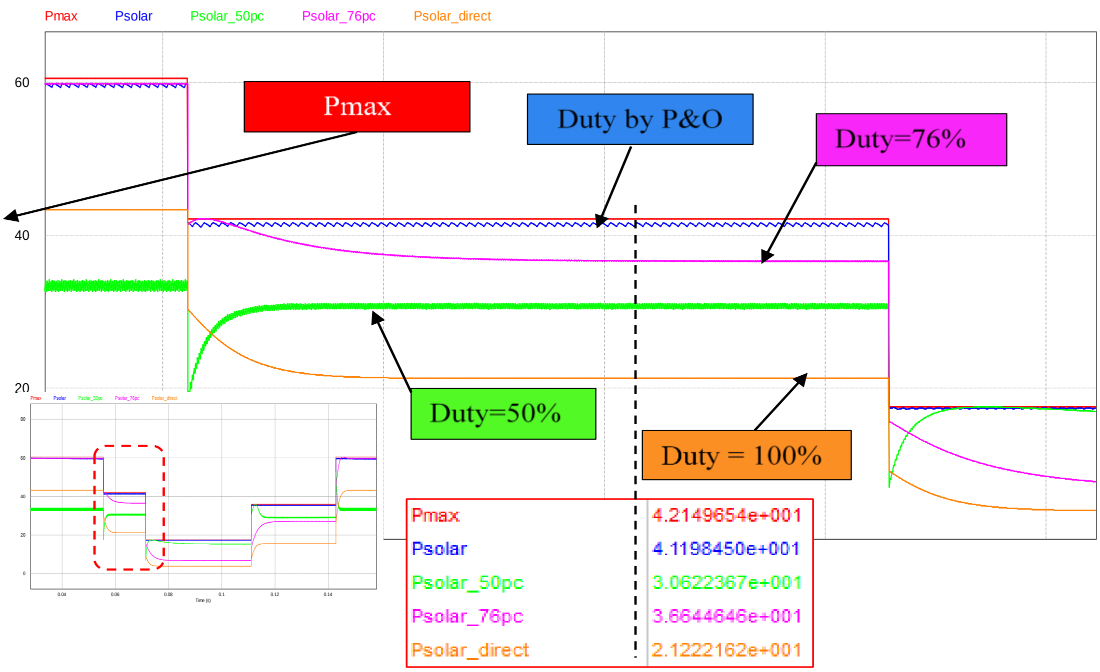

Figure 12. *PSIM simulation result with different control and comparison*

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