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Modified Perturb and Observe (P&O) with checking algorithm under various solar irradiation

Rozana Alik *, Awang Jusoh

Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Malaysia

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ABSTRACT

This paper proposes a modified maximum power point tracking (MPPT) technique for photovoltaic (PV) system using an improved Perturb and Observe (P&O) with a checking algorithm. The main advantage of this method is its simplicity and accuracy of the algorithm such that it can even be computed accurately using a low cost microcontroller. The basic idea of this modified P&O is adding a checking algorithm into a modified P&O MPPT. This checking algorithm functions to determine the global maximum power by comparing all existed peak points first, before the modified P&O algorithm takes place to identify the voltage at MPP (V_{MPP}), which is needed to calculate the duty cycle for the boost converter. A simulation using MATLAB/Simulink under partial shading condition has been done to test the effectiveness of the algorithm. The simulation results are satisfactory and show that the improved technique is able to track the PV maximum power during partial shading condition with 100% of tracking efficiency and produce zero ripple at the load side.

1. Introduction

Photovoltaic power generation is one of the most important green energy sources nowadays. Electric current is produced when solar energy strikes the solar cell. Nevertheless, the conversion of solar energy into electricity is highly dependent on the sun irradiation levels and associated temperature changes (Dolan et al., 2010; Vasisht et al., 2016). Most energy is produced during a hot sunny day as the sun irradiation is at the maximum level, approximately or more than 1000 W/m^2. However, the average output power of a typical 220 W of solar panel is only about 22 W, which means solar panel has only 10% of efficiency (Zhou et al., 2014).

An effective control method to extract and maintain the maximum available power from the solar PV is by using Maximum Power Point Tracking (MPPT) technique (Chu and Chen, 2009; Houssamo et al., 2010; Tseng and Wang, 2013). Reference (Pallavee Bhatnagar and Nema, 2013) provides a full analysis on almost 30 distinct MPPT algorithms. These techniques differ in some aspects such as complexity, cost, efficiency, sensor used and accuracy of tracking when the temperature or irradiation varies. Among all of the methods used, the simplest methods are Fractional Short Circuit Current (SCC) (Noguchi et al., 2002) that predicts optimal current by the short circuit current and Fractional Open Circuit Voltage (OCV) (Masoum et al., 2002) that predicts optimal voltage by open circuit voltage. However, a reference (Morales, 2010) clarified that these approaches incapable to track the precise MPP because an estimation is used to identify the linear relationship of PV curve.

Other techniques are also available, such as Perturb and Observe (P&O) and Hill Climbing (HC). It is widely known that both of these methods are the most popular ways to track the real maximum power point (MPP) (Femia et al., 2005) due to its simplicity of implementation and independence of PV array parameters (Aashoor and Robinson, 2012; Alqarni and Darwish, 2012; Femia et al., 2005; Killi and Samanta, 2015; Nanshikar and Desai, 2016; Piegari and Rizzo, 2010; Rezk and Eltamaly, 2015). In some references, P&O method also been called as an HC method since both of the methods use the similar concept in perturbing the MPP (Jusoh et al., 2014). The main difference of these methods is P&O yields reference voltage as the output control variable while HC gives duty cycle. Even so, the transient response of P&O is better than HC (Liu et al., 2008). However, these two methods are having with two major problems: oscillation steady state around the MPP and unable to track the real MPP during varying weather condition.

Abbreviations: MPP, maximum power point; GMPP, global maximum power point; MPPT, maximum power point tracking; PSC, partial shading condition; PV, photovoltaic; SCC, short circuit current; OCV, open circuit voltage; P&O, Perturb and Observe.

* Corresponding author.
E-mail address: rozana26@live.utm.my (R. Alik).

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Nomenclature

I_{MPP}	current of solar PV at MPP
I_{PV}	current of solar PV
I_{SC}	short circuit current of solar PV
V_{MPP}	voltage of solar PV at MPP
V_{OC}	open circuit voltage of solar PV array
V_{PV}	voltage of solar PV
P_{MPP}	power of solar PV at MPP

Incremental Conductance (IncCond) is an upgrade version of HC which able to track the MPP during rapid variation of sun irradiance as well as during partial shading condition (Esram and Chapman, 2007; Tey and Mekhilef, 2014). Yet, in order to obtain a constant MPP in practice is quiet challenging since additional sensors such as current and voltage sensor is compulsory, eventually it increases the cost and complexity of the system (Lee et al., 2010).

In addition, soft computing methods such as Artificial Neural Network (ANN) (Kaliamoorthy et al., 2010; Karamirad et al., 2013; Rai et al., 2011), Fuzzy Logic Control (FLC) (Chen et al., 2016) and Particle Swarm Optimization (PSO) (Miyatake et al., 2011), also have become increasingly popular among the researchers nowadays. Most of these methods, especially the soft computing methods, are capable to assure a good performance and can perform well in various atmospheric conditions, but the effectiveness of these methods depends on the user's knowledge. The users must have background knowledge about PV arrays study to effectively utilize the optimization, especially on the PSO method.

In a nutshell, the conventional MPPTs are relatively simple, but usually provide poor efficiency. In contrast, the soft computing techniques give higher efficiency, yet more complex than conventional methods (Tajuddin et al., 2015). Hence, this study proposes a modified P&O MPPT with a checking algorithm is introduced. This checking algorithm determines the global maximum power point (GMPP) by comparing all existed peak points first, before the modified P&O algorithm takes place to identify the voltage at MPP

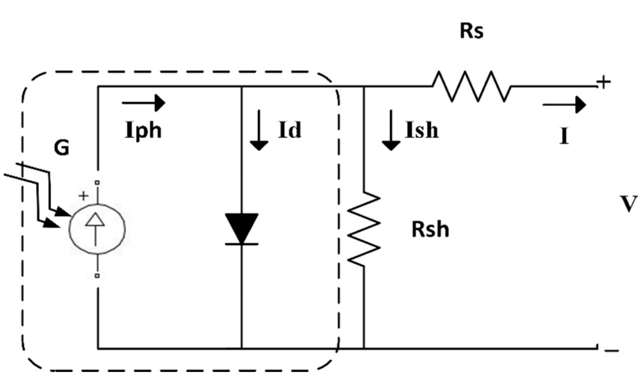

Fig. 1. Theoretical circuit for solar cell.

Table 1
Solar module PLM-80/12 specifications.

Parameter	Value
STC power rating Pmax	80 W
Open circuit voltage Voc	21 V
Short circuit current Isc	5.07 A
Voltage at maximum power V_{MPP}	17.5 V
Current at maximum power I_{MPP}	4.56 A
Number of cells	36

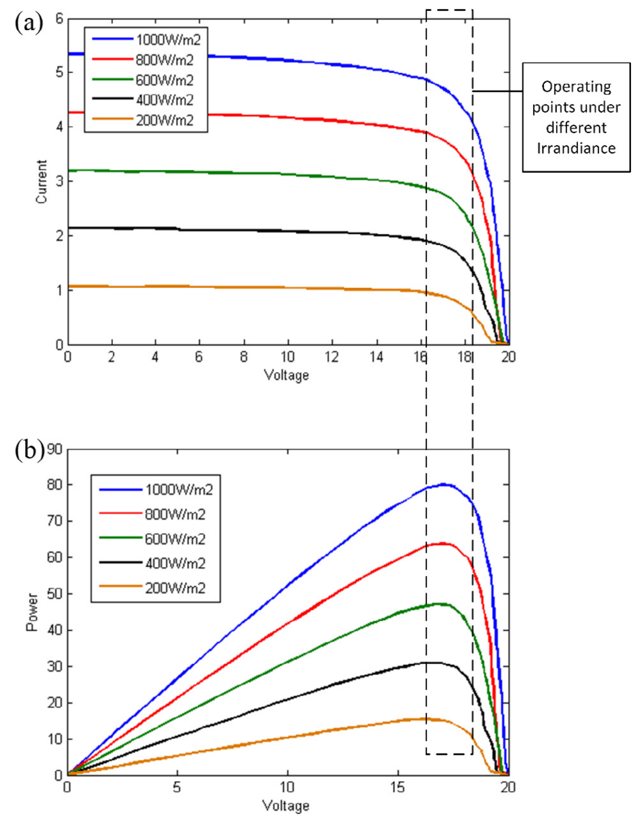

Fig. 2. Characteristic curves under several irradiations: (a) I-V curve and (b) P-V curve.

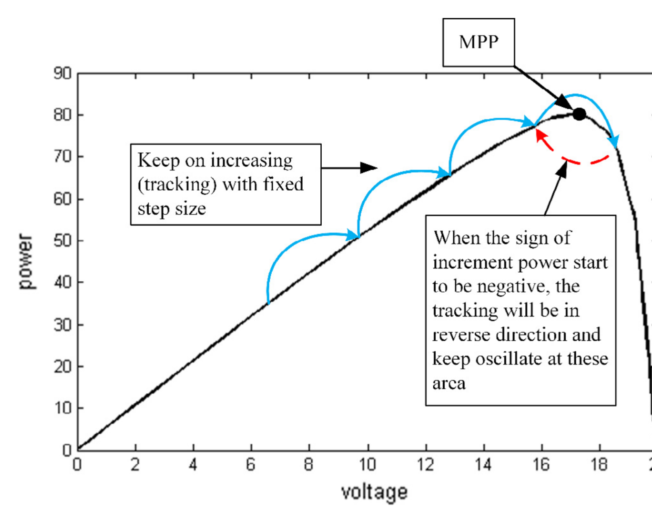

Fig. 3. Operation of conventional Perturb and Observe (P&O) Algorithm under normal P-V curve with Standard Test Condition (Irradiance 1000 W/m^2 and Temperature 25 °C).