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Real time simulation of MPPT algorithms for PV energy system

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ABSTRACT

Solar panels have a nonlinear voltage-current characteristic, with a distinct maximum power point (MPP), which depends on the environmental factors, such as solar irradiance and ambient temperature. In order to increase the power extracted from the solar panel, it is necessary to operate the photovoltaic (PV) system at the maximum power point (MPP). In this paper a novel maximum-power-point tracking (MPPT) method based on current perturbation algorithm (CPA) with a variable perturbation step and fractional short circuit current algorithm (FSCC) to determine an optimum operating current. An experimental comparative study of these maximum power point tracking methods using dSPACE is presented in this article. The effectiveness of proposed algorithm in terms of dynamic performance and improved stability is validated by detailed simulation and experimental studies.

Introduction

Electricity production using non-conventional energy (oil, gas, ...) leads to the depletion of its reserves and intensifies the release of greenhouse gases and thus the pollution of the atmosphere resulting climate change. Faced with these alarming consequences, it was necessary to consider the development of alternative energy called renewable energy sources.

Solar energy is considered today as one of the most useful sources of renewable energy, because it is relatively less polluted and maintenance, an inexhaustible source, free and superabundant, looks very promising, available in every country and every day.

The disadvantage of the solar energy is that the sun doesn't shine 24 h a day, when the sun goes down or is heavily shaded, solar PV panels stop producing electricity. In addition, solar energy conversion efficiency into electrical energy is very low especially in low radiation areas.

Because of the non-linear relationship between the current and the voltage of the photovoltaic cell, it can be observed that there is a unique maximum power point (MPP) at a particular environment, and this peak power point keeps changing with solar irradiance and ambient temperature [1]. Therefore, monitoring of maximum power point tracking (MPPT) is an essential part of the photovoltaic (PV) system to ensure that the power converters operate at maximum power point (MPP) of the solar panel.

Many MPPT algorithms have been developed in [2,3]. These algorithms differ from each other in terms of number of the sensors used, complexity, and cost to implement the algorithm. The goal of all major MPPT algorithms is how to reach the maximum power quickly, with accuracy and especially reduce the disturbance around the MPP. Each algorithm can be categorized based on the type of the control variable it uses: (1) voltage; (2) current; or (3) duty cycle [4].

Among the more popular ones are perturb and observe (P&O) [5,6], incremental conductance (INC) [7], fractional open-circuit voltage (FOCV) [8] and fractional short-circuit current (FSCC) [9].

In the P&O method, a small perturbation (step size) is applying to control parameter and measures the PV array output power before and after the perturbation. If the power increases, the algorithm continues to perturb the system in the same direction; otherwise, the system is perturbed in the opposite direction.

In the INC method, operation point of module is determined which side of MPP by derivation of power to voltage and then, this point towards to MPP via tuning duty cycle. Both methods are working effectively under uniform irradiance because of only one MPP formed in this condition [10]. However, both P&O and INC methods always produce power loss oscillations around MPP in static weather and did not perform well during rapid changing of atmospheric conditions because of the MPP point vary with irradiance level and temperature.

Fast-changing solar irradiation level has a significant impact on the electrical characteristics than the temperature which usually changes quite slowly during the day, so that the temperature is often considered constant. Therefore, the effect of temperature on photovoltaic module performance is often neglected.

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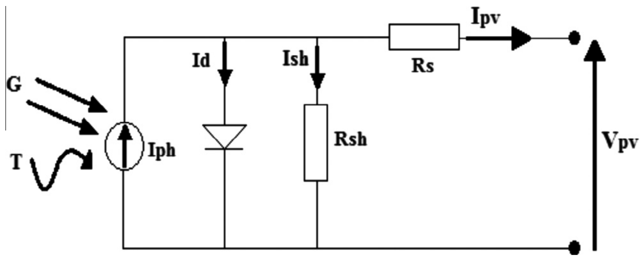

Fig. 1. Equivalent circuit of solar cell.

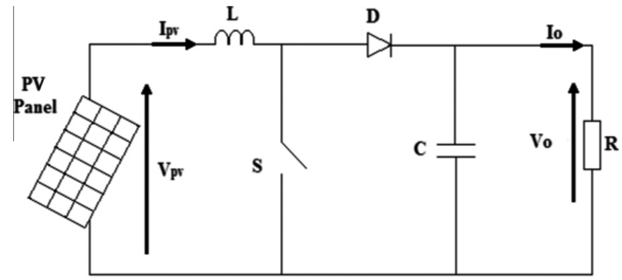

Fig. 3. Power stage schematic of boost converter.

Table 1
Parameter specification of STP080S-12/Bb PV panel.

Parameter	Variable	Value
Maximum power	P_m	80 W
Maximum voltage	V_m	17.5 V
Current at max power	I_m	4. 58 A
Open circuit voltage	V_{oc}	21.9 V
Short circuit current	I_{sc}	4.95 A

Table 2
Dynamics of perturbation size.

signΔP_{pv1}	signΔP_{pv0}	$I(k)$
1	1	$\Delta I(k-1)$
1	−1	$m_1 \Delta I(k-1)$
−1	1	$m_1 \Delta I(k-1)$
−1	−1	$\Delta I(k-1)$

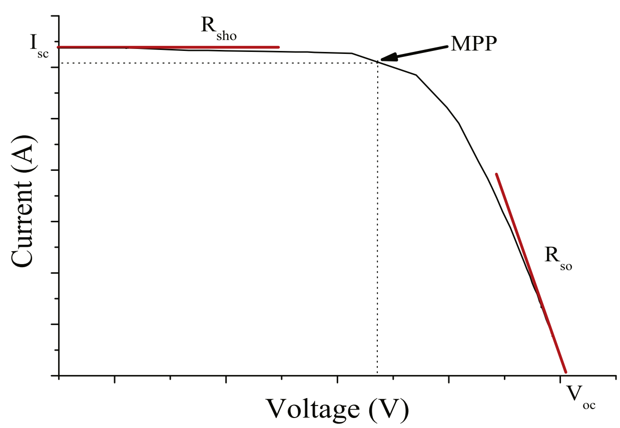

Fig. 2. Experimental Ipv(Vpv) characteristic for a given temperature and solar radiation data.

The accuracy of FOCV and FSCC methods is not guaranteed because they approximate a constant ratio of V_{oc} and V_{mpp} or I_{sc} and I_{mpp}.

To overcome the disadvantages mentioned above a fuzzy logic algorithm and neural network (NN) have been developed [11,12]. In general, the controllers by fuzzy logic can provide an order more effective than the traditional controllers for the nonlinear systems, because there is more flexibility [13]. The main disadvantage of the fuzzy logic controllers is their reliance on the designers knowledge of the system.

Because of this diversity of MPPT methods in the years presi- dent researchers and practitioners in PV systems have presented a comparative analysis of existences MPPT techniques [14,15].

In this paper a comparative study of current perturbation algorithm (CPA) and short circuit current (FSCC) MPPT algorithms is presented. To overcome the drawbacks in these two methods a novel MPPT algorithm is proposed.

The real time simulation using dSPACE is carried out in this paper for constant and variable irradiance considering the temperature was kept unchanged during a day.

This paper is organized as follows; Section "Mathematical modeling of PV solar module" descries the PV system modeling. Secti on "DC–DC boost converter" is devoted to the DC–DC boost converter. The MPPT techniques are explained in Section "MPPT techniques". In Section "Configuration and operation of proposed system" configuration and operation of proposed system is presented. Simulation results, analysis and discussion are illustrated in Section "Simulations". Section "Experimental results and discussions" presents the experimental results obtained. Finally conclusions end the paper.

Mathematical modeling of PV solar module

PV modules are made by combining a large number of elementary cells (series and/ or parallel). The equation for the model of the photovoltaic cell involves the relationship between the output voltage, V_{pv}, and the current, I_{pv}. The main equation for a cells output current can be modeled through the circuit shown in Fig. 1 [16].

$$I_{pv} = I_{ph} - I_s * \left[\exp\left\{q\frac{(V_{pv}+R_sI_{pv})}{AkT}\right\} - 1\right] - \frac{V_{pv}+R_sI_{pv}}{R_{sh}} \quad (1)$$

where V_{pv} and I_{pv} represent the output voltage and current of the solar cell, respectively; I_s is the total diffusion current through the PN junction; q is the electron charge ($1.6e^{-19}C$); A is an diode-ideality factor of the PN junction; K is the Boltzmann constant ($1.38e^{-23}J/K$); T is the temperature (K); R_s and R_{sh} is the series and parallel resistance of the cell, respectively.

For the simulation and the experimental setup, the Sun-Tech STP080S-12/Bb module was chosen. The electrical parameters are given in Table 1.

To determine the series, shunt resistance and the ideality factor we used the five parameters method, for a given temperature and solar radiation data according to the open voltage circuit V_{oc}, the short circuit current I_{sc}, the voltage V_m and current I_m to the maximum power point (MPP) and the slopes of the curves I–V near V_{oc} and I_{sc} [17].

Thus, determination of the parameters is given by Eqs. (2)–(6):

$$\left(\frac{dV_{pv}}{dI_{pv}}\right)_{V_{pv}=V_{oc}} = -R_{so} \quad (2)$$

$$\left(\frac{dV_{pv}}{dI_{pv}}\right)_{I_{pv}=I_{sc}} = -R_{sho} \quad (3)$$

$$A = \frac{V_m + (I_m * R_s) - V_{oc}}{V_t\left[ln\left(I_{sc} - \frac{V_m}{R_{sho}} - I_m\right) - ln\left(I_{sc} - \frac{V_{oc}}{R_{sho}}\right) + \frac{I_m}{I_{sc}-\frac{V_{oc}}{R_{sho}}}\right]} \quad (4)$$

$$R_s = R_{so} - \frac{AV_t}{I_s} exp\left(-\frac{V_{oc}}{A * V_t}\right) \quad (5)$$

$$R_{sh} = R_{sho} \quad (6)$$