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An Improved Beta Method with Auto-scaling Factor for Photovoltaic system

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***Abstract*—Maximum power point tracking(MPPT) is essential to improve the energy yield of solar energy system. However, conventional MPPT algorithms show obvious problems such as the conflict of the steady-state oscillations and dynamic speed, and the clash of high computational burden and accuracy. Originated from the beta method, which shows the advantages of fast tracking speed in the transient stage, small oscillations in the steady-state and medium complexity of implementation, this paper proposed an improved beta method to further improve the overall performance especially for practical applications. Instead of manually tuning key parameters such as the range of β parameter and scaling factor N for different operating conditions, an auto-scaling factor is used, which make the method easier in practical implementation and suitable for wider conditions. The meteorological data of two distinct locations are used to verify that the β parameters derived from PV modules are valid for one whole year under different environmental conditions. A PV system with the proposed MPPT method was built in MatLab/Simulink and different indices such as the rise time, the setting time, and the tracking energy loss are used to evaluate the performance of various MPPT algorithms. Finally, two experimental tests were carried out, including the indoor test with solar array emulator and outdoor test with an actual PV module respectively, to show the effectiveness of the proposed MPPT algorithm.**

***Index Terms*—Maximum power point tracking (MPPT), photovoltaic (PV) energy, Beta method, fast tracking, power electronics.**

I. Introduction

Photovoltaic (PV) is now regarded as one of the most important sustainable energy sources world-widely. Compared with conventional energy sources such as gasoline and coal, solar energy is safe, reliable, clean, inexhaustible and free. However, how to extract the maximum possible power from the installed PV modules is still an challenging problem since the output power of PV modules shows strong nonlinear characteristics, which heavily depend on the environmental conditions such as irradiation and temperature. Therefore, maximum power point tracking(MPPT) is necessarily used for PV systems to improve the power yield.

Recently, many MPPT methods are proposed and evaluated [1–3], among them, the methods widely used in industry include the fractional open-circuit voltage [4], the fractional short-circuit current [5], Hill-Climbing (HC) [6], Perturb and Observe (P&O)[7–9], and Incremental Conductance (INC) method [10–12]. The fractional open-circuit voltage or short-circuit current method is a simple way to obtain the maximum power. However, the PV modules could not operate at the actual MPPs since the principle of two methods is the empirical relationship of the voltage or current at MPP with the open-circuit voltage or short-circuit current. Additional circuits are required, such as a series switch or a shunt switch for online measurement of open-circuit voltage or short-circuit current periodically [5]. Therefore, a periodical disconnection or short circuit of the PV panels is necessary, which will result in extra power loss, increased cost, and complexity of the PV system.

The P&O, HC, and INC method are widely used. However, obvious drawbacks are observed for these methods: fluctuation of the operating point around the maximum power point (MPP) in the steady state; and slow tracking speed for fast-changing irradiations. Besides, these methods are easily misjudged especially when the solar irradiation is quickly increased [12].

Modified HC, P&O and INC methods with variable step size have been proposed to address the conflict between the steady-state oscillations and dynamic speed. The basic idea of the these modified methods is to use a large step size in the transient stage, and a small step size in the steady state [13–21]. The step size can be automatically adjusted according to the derivative of the PV power with the voltage (dP/dV)[14] or converter duty cycle (dP/dD)[13, 15]. The variable step is expressed as:

$$\Delta V = N \times \frac{|P(k) - P(k-1)|}{|V(k) - V(k-1)|} \tag{1}$$

and

$$\Delta D = N \times \frac{|P(k) - P(k-1)|}{|D(k) - D(k-1)|} \tag{2}$$

where k and $k-1$ refer to the present and previous instants, and N is the scaling factor related to the step size. The step size derived from (1) and (2) is large when the operating point is far from the MPP. When the operating point is close to the MPP, the calculated step size becomes small in order to reduce the static oscillations. However, one difficulty is occurred for the implementation of the variable step methods, which is the selection of the scaling factor N. A large value of N is beneficial for the tracking speed, however it will result in large oscillations around the MPP [20]. On the contrast, a small value of N can cause the convergence process of the system towards the MPP becomes slow when the operating point is close to the peak of P–V curve and P–D curve. Parabolic prediction is recently used in the variable step-size MPPT methods considering that the P–V curve or P–D curve of PV modules is nearly parabolic shape [22–25]. However, multiplications are necessary for this algorithm in order to find the optimal point, which is difficulty to implement in a cheap