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Full Length Article

Assessment of a proposed hybrid photovoltaic array maximum power point tracking method

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Abstract

Photovoltaic arrays have limited conversion efficiency and thus, a maximum power point tracking technique is essential. This makes the maximum power point tracking (MPPT) require prior prediction of the mentioned point in spite of the undeniable changes in the environment. In this manuscript an introduction and assessment of the different techniques of MPPT is presented. The categorization scheme of the MPPT techniques is according to either the predefinition of operating points without system data update (offline methods) or continuous sampling of system variables, to update the PV module measurements (online methods). Whereas hybrid method is a combination of both. A number of techniques from each class were simulated in MATLAB/Simulink environment in order to compare their performance. Moreover, the hybrid method was simulated in two successive steps without pre-assumption of the output of the offline method. The results demonstrated the relevance of the hybrid method when applied to a photovoltaic system due to its good performance, fast response and less fluctuations, when subjected to sudden climatic changes.

Keywords: PV systems; MPPT; Online methods; Offline methods; Hybrid methods

1. Introduction

Recently the use of solar energy has been emerging. The main advantages of photovoltaic (PV) systems are zero greenhouse gas emission, low maintenance costs, fewer limitations with regard to site of installation and absence of mechanical noise arising from moving parts (Reisi et al., 2013). The global PV market reached 173 GW in 2014. However, there are three major limitations in photovoltaic generation systems: the conversion efficiency to electric power is low (9–17%), the variability of electric power generated due to the weather conditions and sunlight hours at

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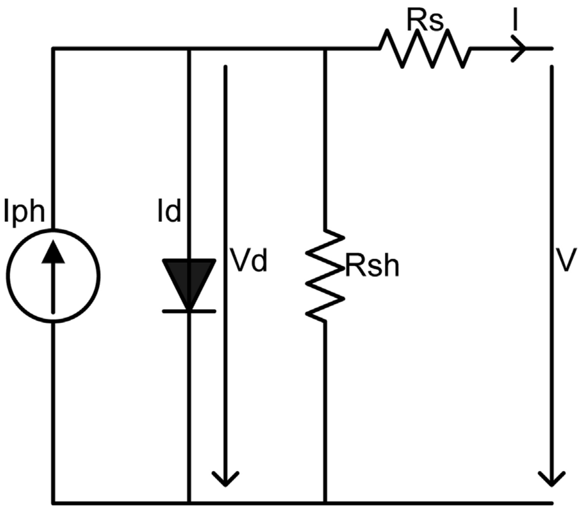

Fig. 1. Single diode equivalent circuit of a solar cell.

daytime (Xiao et al., 2006), and the relatively higher cost (12.5 ¢/kWh) as compared to that produced by conventional power generation (7.4 ¢/kWh for natural gas combined cycle) systems or even to other renewable sources such as hydro electrical energy (8.4 ¢/kWh) (Energy Innovation, 2015).

A solar cell (also called photovoltaic cell or photoelectric cell) is a solid state device that converts the energy of sunlight directly into electricity by the photovoltaic effect (Zhang et al., 2011). Assemblies of cells are used to make solar modules, also known as solar panels. Photovoltaic system uses various materials and technologies such as crystalline Silicon (c-Si), Cadmium telluride (CdTe), Gallium arsenide (GaAs), chalcopyrite films of Copper-Indium-Selenide ($CuInSe_2$).

Solar cells exhibit a non-linear current–voltage characteristics that depend on solar radiations and temperatures. There is a point on the characteristics curve where the output power from the array (a string of panels) has a maximum value. Solar cells are usually assessed by measuring the current voltage characteristics of the device under specific conditions of illumination and then determining a set of parameters. In order to ensure efficient operation of the solar array the maximum power point (MPP) of the array has to be tracked. MPPT, in addition to rising the power delivered from the PV module to the load, is considered as a PV system lifetime booster (Bahgat et al., 2005).

1.1. PV system

For simplicity in analyzing characteristics of solar cells, electrical equivalent circuits are used in representing them. Researchers used numerous equivalent circuits to help in predicting the behavior under various environmental conditions, and further in obtaining (I–V) and (P–V) characteristic curves. The most commonly used equivalent circuits are the single diode model (De Blas et al., 2002) (shown in Fig. 1), the double diode model (Cabestany and Castaner, 1983) and the three diode model (Khanna et al., 2015).

According to the above circuit the solar cell can be represented by: a current generator, a diode indicating the recombination losses, a shunt resistance symbolizing losses from currents that return across the junction and a series resistance denoting resistance losses. By applying a simple Kirchhoff's current law (KCL); the relation of the current I and the voltage V is given as:

$$I = I_{ph} - I_o\,(e^{\frac{q(V+IR_s)}{nkT}} - 1) - \frac{V + IR_s}{R_{sh}} \tag{1}$$

where I_{ph} is the photocurrent, I_o is the saturation current of the diode, R_s is the series resistance, R_{sh} is the shunt resistance, n is the diode ideality factor, k is Boltzmann's constant (1.4×10^{-23}), q is the electron charge (1.6×10^{-19}), T is the absolute temperature in Kelvin.