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A comprehensive comparison of different MPPT techniques for photovoltaic systems

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Abstract

This paper aimed to study the behavior of different maximum power point tracking (MPPT) techniques applied to PV systems. In this work, techniques such as hill climbing (HC), incremental conductance (INC), perturb-and-observe (P&O), and fuzzy logic controller (FLC) are assessed. A model of PV module and DC/DC boost converter with the different techniques of MPPTs was simulated using PSIM and Simulink software. Co-simulation between PSIM and Simulink software packages is used to establish FLC MPPT technique. The co-simulation is done to take advantage of each program to handle certain part of the system. The response of the different MPPT techniques is evaluated in rapidly changing weather conditions. The results indicate that, FLC performed best among compared MPPT techniques followed by P&O, INC, and, HC MPPT techniques in both dynamic response and steady-state in most of the normal operating range.

Keywords: Maximum power point trackers; Incremental conductance; Perturb-and-observe; Hill climbing; Fuzzy logic; MPPT

1. Introduction

Renewable energy sources such as photovoltaic (PV) power play a crucial role in electric power generation, and become essential these days due to shortage and environmental impacts of conventional fuels. In the future, PV energy will gain more importance due to the shortage of fossil fuels and their environmental effects. More than 45% of necessary energy in the world will be generated by PV arrays (Faranda et al., 2008). Unfortunately, PV generation systems have two major problems: the conversion efficiency of electric power generation is low, and the amount of electric power generated by solar arrays changes continuously with weather conditions (Berrera et al., 2009; Sreekanth and Raglend, 2012). Moreover, because of nonlinear *I–V* and *P–V* characteristics of PV systems, their output power is always changing with weather conditions, i.e., solar radiation, atmospheric temperature and also nature of load connected (Fangrui et al., 2008; Emad and Masahito, 2010). Maximum power point tracking (MPPT) is essential as there is a probable mismatch between the load characteristics and the maximum power points (MPPs) of the PV module in order to ensure optimal utilization of solar cells (Xiao and Dunford, 2004; Ashish et al., 2007). Using of MPPT leads to reduce the cost of energy generated by PV panels (Hohm and Ropp, 2000). In recent

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years, a large number of techniques have been proposed for tracking the MPP of PV systems. There are many techniques available in the literature such as fractional open-circuit voltage and short-circuit current (Fangrui et al., 2008), the Artificial Neural Network (ANN) technique (El Sayed, 2013), and the fuzzy logic control (Eltamaly, 2010; Eltamaly et al., 2010). Also, it was demonstrated in Ibrahim and Houssiny (1999) technique to track the maximum power using look-up table in the microcomputer. Another common approach is to use the array power as the feedback. The popular tracking methods based on this approach are widely adopted in PV power systems (Faranda et al., 2008) which include but not limited to, perturb and observe method (P&O) (Koutroulis et al., 2001; Ioan and Marcel, 2013), the incremental conductance method (INC) (Xiao and Dunford, 2004; Esram and Chapman, 2007) and the hill climbing method (HC). These techniques are widely applied in the MPPT controllers due to their simplicity and easy implementation. Several different MPPT methods have been proposed, but there has been no comprehensive comparison between different techniques and their tracking efficiencies under varying weather conditions. The objective of this work was to bridge this gap. In this work, the attention will be focused on simulation comparison study between these widely applied MPPT techniques, considering solar radiation variation in order to understand which technique has the best performance in fast changing weather conditions.

This paper is organized as follows; section II descries the PV system modeling, illustrates basic operation principles for HC, INC, P&O and FLC techniques respectively. Simulation results, analysis and discussion are illustrated in Section 3. Finally, conclusions are given in Section 4.

2. PV system modeling

The solar PV generation system consists of a PV module, DC/DC boost converter and a battery as shown in Fig. 1. Radiation (R) is incident on the PV module. It generates a voltage (V) and current (I). The temperature of the module is measured at T. The negative terminal of the battery and the module are connected and are also connected to ground. The simulation of the PV system has been carried out using MPPT based on different techniques; HC, INC, P&O and, FLC. The system submodels are explained in the following sections:

2.1. PV solar module

The PV module used in this study consists of 36 poly-crystalline silicon solar cells electrically configured as two series strings of 18 cells each. Its main electrical specifications are shown in Table 1. The equivalent circuit model for a PV module is addressed in Khaehintung et al. (2006), Abouobaida and Cherkaoui (2012), Emad and Masahito (2011), Christy et al. (2014), Gokmen et al. (2013).

2.2. DC/DC boost converter

According to maximum power transfer theory, maximum power is being transferred from source to load when source impedance is equal to the load impedance (load matching). The load matching can be done by adjusting the duty cycle of the DC/DC converter. The duty cycle is the ratio between the switching on time of switch to the switching period. In order to track MPP the converter must be operated with duty cycle corresponding to it. With varying atmospheric conditions the duty cycle of the DC/DC converter has to be adjusted to extract maximum power from PV module (RezaReisi et al., 2013). There are several architectures of DC/DC conversion circuits which can be used for this purpose. In the present work the boost configuration is chosen due to its wide spread use and high reliability with respect to other more complex configurations (Berrera et al., 2009). The complete power device scheme is shown in Fig. 1. The diode D_1 is provided to protect the PV module against negative current which could damage it. C_1 placed at boost input to limit the high frequency harmonic components (Berrera et al., 2009).

2.3. MPPT techniques

In this work, four MPPT techniques have been selected for the purpose of comparison; hill climbing (HC), incre-

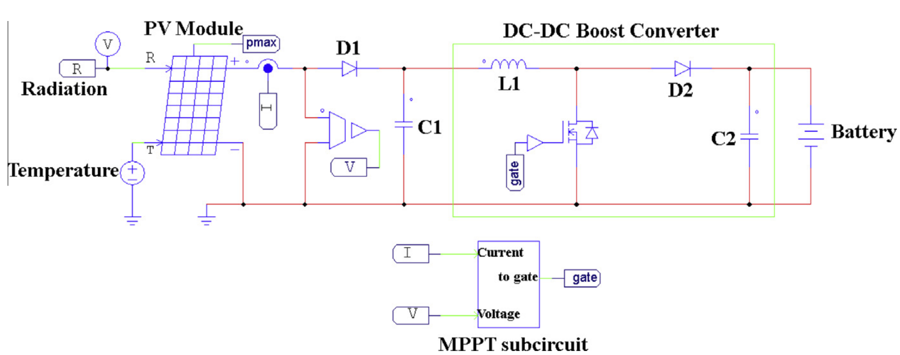

Fig. 1. Block diagram of a general PV system.