Standalone Photovoltaic System with Maximum Power Point Tracking: Modeling and Simulation

Hanane Yatimi, Abdelmalek Essaadi University, Tetouan, Morocco
Elhassan Aroudam, Abdelmalek Essaadi University, Tetouan, Morocco

ABSTRACT

In this article, on the basis of studying the mathematical model of a PV system, a maximum power point tracking (MPPT) technique with variable weather conditions is proposed. The main objective is to make a full utilization of the output power of a PV solar cell operating at the maximum power point (MPP). To achieve this goal, the incremental conductance (IC) MPPT technique is applied to an off-grid PV system under varying climatic conditions, in particular, solar irradiance and temperature that are locally measured in Northern Morocco. The output power behavior and the performance of the system using this technique have been analyzed through computer simulations to illustrate the validity of the designed method under the effect of real working conditions.

KEYWORDS

DC/DC Boost Converter, Incremental Conductance (IC), I-V Curves, MPPT, Photovoltaic Energy, P-V Curves, PV Storage System

1. INTRODUCTION

In the world of today, the continuous provide of electric power plays an important role in reaching economic and social rapid development in countries (Arezou et al., 2017), which causes energy and environment crisis. This requires the reduction of the dependence on traditional energy and the improvement of the level of the development and the utilization of the renewable energy sources gradually. The Renewable energy has an advance all over the world in the environment protection, thanks to the features of non-polluting and large reserve etc. (Yatimi & Aroudam, 2016a), in particular photovoltaic solar energy. PV systems have been widely utilized in various applications, such as battery charging, water pumping (Hamrouni et al., 2009), home power supply etc., to convert the solar energy to electrical energy through the semiconductor devices called photovoltaic cells based on photovoltaic effect (Yatimi & Aroudam, 2015). The PV system is a non-linear system, and like many other systems requires a continuous control to work performantly. In this context, many control systems are designed in the literature (Lazaros et al., 2017) in order to operate under strict specifications, to satisfy certain aims, like safety regulations in the industry, optimal production of PV panels, level control in chemical processes and many more. On the other hand, the output characteristic of PV module is nonlinear and changes with temperature and solar irradiance. Therefore, its maximum power point is not constant. Under each condition PV cell has a point at which it can produce its MPP. Hence, the use of MPPT techniques to uphold the PV module operating at its MPP and then to increase the PV system efficiency is crucial.
In recent years, a variety of techniques have been proposed for tracking the MPP of PV systems. MPPT (see meaning in Box 1) techniques are varying between them in many aspects, including simplicity, convergence speed, hardware implementation, sensors required and cost. For example, the Perturb and Observe (P&O) method (Prabaharan & Palanisamy, 2016), which is the most widely used algorithm due to the simplicity of structure and the ease of implementation, but has limitations, it can work well when the solar irradiance and the temperature do not vary quickly with time and the output power is oscillating around the MPP. The Incremental Conductance (IC) method (Rania et al., 2017; Kashif et al. 2014), which has better performance than the P&O method. The main advantage of IC method is that it can offer good performance under rapidly changing atmospheric conditions in addition to its ability to achieve lower oscillation around MPP.

Kashif et al. (2012) proposed the Particle Swarm Optimization (PSO) which is highly potential due to its simple structure, easy implementation, and fast computation capability. Since PSO is based on search optimization, in principle, it should be able to locate the MPP for any type of P-V curve regardless of environmental variations. Knowing these benefits, several researchers have employed this technique in many other systems such as for inverted pendulum system (Mousa et al., 2015).

Artificial intelligence (AI) based MPPT techniques include Fuzzy Logic and Neural Network. The Fuzzy Logic Controller (FLC) method (Chaouachi et al., 2010) doesn’t need a mathematical model that’s why it can handle non-linearity. It is used very successfully not only in the implementation for MPPT searching of the PV modules in PV area, but also in many other areas such as in the enhancement of people ‘life, for instance, in (Rabie & Ahmed, 2017), FLC is used for the disease spreading prediction problem. Anil et al. (2011) proposed an Artificial Neural Network (ANN) based MPPT technique, this controller has an advantage of low computation requirement and fast-tracking speed irrespective of the PV module used. Kharb et al. (2014) proposed Adaptive Neuro-Fuzzy Inference System (ANFIS) based MPPT which is a hybrid between neural networks and fuzzy logic. Temperature and Irradiance levels are taken as inputs to train the ANFIS. It is shown that the ANFIS works well under varying temperature and irradiance levels. To be robust, the AI based MPPT techniques require a massive database which needs long computation time and large memory size. The advantages of the two techniques are combined, which makes it the most powerful artificial intelligence technique. It can also be used efficiently in system disturbances, namely system faults diagnosis and a sudden application of a large system load as in (Hussein et al., 2017; Abdel Aziz et al., 2017).

Nonlinear controllers have attracted considerable attention. Among nonlinear controllers, Sliding Mode Control (SMC) has attracted a lot of interest due to the simple implementation, large signal stability, robustness to model uncertainty and disturbances (Yatimi & Aroudam, 2017). Sliding mode control is a nonlinear control strategy based on the variable structure theory. In a variable structure control system, the structure of the controller changes from one form to another (Utkin, 2013). Naghmash et al. (2018) proposed a nonlinear Backstepping controller (BSC) to extract the maximum power from the PV system. Reference voltages for the controller are generated by a regression plane and the stability of the system is verified through Lyapunov function.
Enabling the Interoperability of the Modelica DSL and Matlab Simulink towards the Development of Self-Adaptive Dynamic Systems