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Boost chopper MPP assessment based on solar irradiance and predictive duty cycle applied to a PV system

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ABSTRACT

The aim of this paper is the implementation of a PV panel system operating at its optimal state. The investigation is divided into two parts. The first part focuses on the estimation of the position of the sun at each moment of the year. Thus an optimum fixed tilt of the panel is defined in order to get the best capture of the sun power for a year in a studied area. The second part of this investigation aims at maximizing the yield of the whole PV system. A maximum power point of the PV panel is reached thanks to a chopper for which a predictive duty cycle is considered and successfully tested. This proposed control involves less oscillations and fast response resulting in better accuracy compared to the Perturb and Observe technique.

Introduction

Total energy demand all over the world keeps on increasing proportionally to population growth, particularly for clean energy. Investment in renewable energy was higher in the poorer countries than in the richer ones for the first time in 2015 [1]. Climate change and sustainable development are of great importance in the development programs namely in Algeria. The Algerian government is committed to launch renewable energy sources (RES) and energy efficiency programs. Solar energy is considered as the most significant among the various possible alternative sources of energy for urban and rural areas [2], and the strategic choice of this program is motivated by the huge energy solar potential. By 2030, solar energy is expected to cover more than 37% of the country's electricity production [3].

To install photovoltaic panels, it is essential to know its geographical location, orientation, inclination, the sunshine level and the shaded areas [2]. Their optimization requires the search of the maximum power point (MPP). There are several approaches to track the maximum power point and the most used ones are the Perturb and Observe technique, the incremental method and the implementation of smart technology

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[4–6]. By an appropriate control of the duty cycle, the conversion system is brought to its maximum operating point. All these techniques have a common drawback, which is the compromise between convergence time and oscillations around the maximum power point [7,8].

In this study, the use of a chopper is investigated, allowing the panel to convert the maximum power from the solar irradiance (Fig. 1). The PV system consists of a photovoltaic panel for which power conversion is customized by a DC/DC converter and a chopper controlled by a circuit based on maximum power point tracking. The irradiance measurement is the mean parameter that imposes the MOSFET duty cycle via its driver. We wish to assign for each irradiation level the corresponding value of the optimum power. In order to do so, two ways are proposed, either an adjustment based on the voltage or another one on the current control. These control variables are put to use to define the chopper duty cycle so that the PV system reaches the maximum power point.

The first goal of our work is to optimize the inclination angle so that the solar panel can receive the maximum energy enabling the best performance of the installation to be set for both winter and summer [9,10]. The case of a photovoltaic array in the region of Annaba in Algeria is considered. This system is also dependent on the temporal variation of the irradiance, so an installation of a chopper is associated with the photovoltaic panel to allow its operating at maximum power point. Due to the non-linear nature of the panel, the efficiency of the energy extraction is also problematic. In many articles, several techniques are proposed, with the same antagonist constraints of convergence and accuracy of the maximum power point. Our investigation aims at overcoming these two conflicting parameters by going directly to the operating point corresponding to the MPP of the panel.

Modeling

Solar irradiance

When perpendicular to the sun, a solar panel has a maximum performance. The knowledge of the sun path in the sky allows the optimization of the position of a solar panel in order to make it heliotrope like a sunflower. Models based on semi-empirical methods are utilized to assess the solar irradiance at ground level. The parameters of the model depend on the region defined by its latitude, longitude and altitude, the time and the day of the year and also the albedo of the site. The set of Eq. (1) is divided into two parts. The first one enables to calculate the parameters which are independent of the inclination of the capture surface, such as direct and diffuse radiation on a horizontal plan and the sun zenithal angle. The second corresponds to the calculation of the incident irradiation on a tilted surface [11].

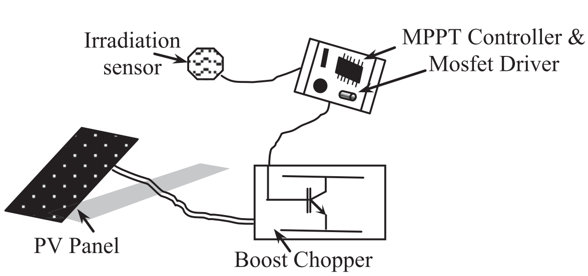

Fig. 1 – Photovoltaic system studied.

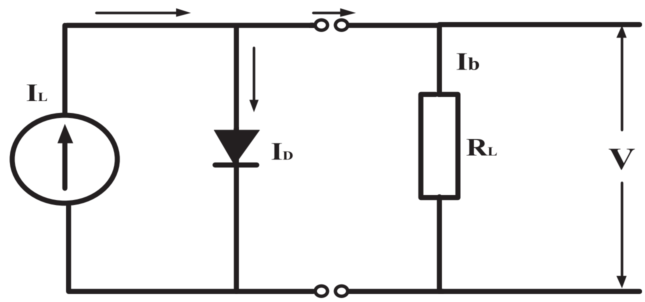

Fig. 2 – Photovoltaic cell model.

$$\left.\begin{aligned}
&\delta = 23.45 \sin\left[\frac{2\pi(Day-81)}{365}\right]\\
&\omega = -\text{acos}[-\tan L\cdot\tan\delta]\\
&RHA = B_0\left[1+\frac{(0.033\cdot\cos(2\pi\cdot Day))}{365}\right]\\
&\sin\alpha = \sin L\cdot\sin\delta\cdot\sin\omega+\cos L\cdot\cos\delta\\
&RHG = RHA\cdot\tau_d + RHA\cdot\tau_b\\
&\tau_b = a_0 + a_1\cdot\exp\left(\frac{-K}{\sin\alpha}\right)\\
&\tau_d = 0.2711 - 0.294\,\tau_b
\end{aligned}\right\} \quad (1)$$

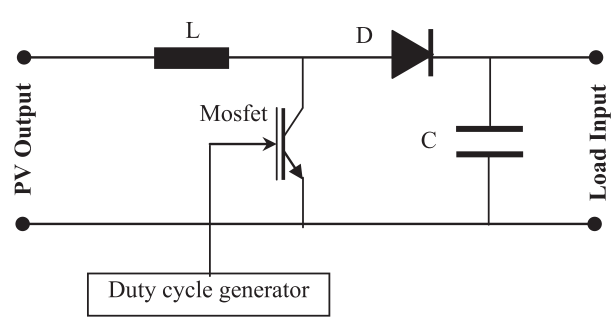

Fig. 3 – Boost chopper structure.

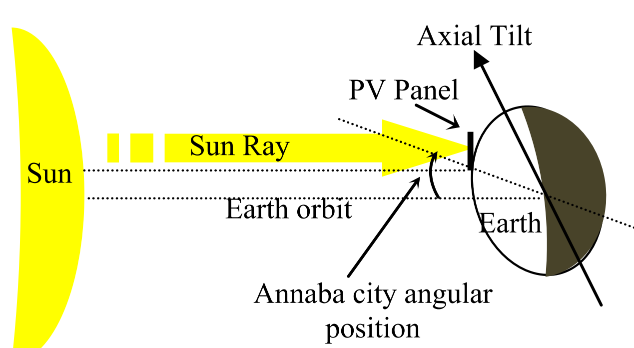

Fig. 4 – Earth orbiting position.