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Design of a Low-Cost Controller for Sun-Tracking to Maximize the Output of Photovoltaic Panels

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ABSTRACT

The electrical energy is considered as the main resource for the development of countries. As there are several sources of renewable energy, the solar energy is one of the green energies, which is imperishable. A lot of researchers have been working on the improvement of the efficiency of solar photovoltaic panels in order to generate more electrical power. Tracking the sun position is a solution to increase the power produced by photovoltaic panels. Referring to some measurements, the parallel orientation of the photovoltaic panels with the sun raises the produced power by more than 40%. This article aims first to control their position to track the sun during the day. The control system is based on an induction motor controlled by the Direct Toque Control (DTC) approach. To overcome the conventional DTC drawbacks, a robust DTC-SVM based on sliding mode controllers is the second contribution in this article. The simulation results demonstrate that the robust DTC-SVM with sliding mode controllers offers the best results in terms of ripples compared to conventional DTC approaches.

KEYWORDS

DTC-SVM, FPGA, Position Control, Ripples, Sliding Mode Control

1. INTRODUCTION

The sun-tracking system is an important part in the development of solar applications that convert the solar energy into an electrical one (Mousazadeh, Keyhani, Javadi, Mobli, Abrinia, & Sharifi, 2009.), (Yeh, Yen, Yen, Wu, Liu, Wu, & Peng, 2011). The solar tracker is a device that keeps the photovoltaic panels in an optimal position perpendicular to the solar radiation during the days, so as to increase the collected energy (Mousazadeh, Keyhani, Javadi, Mobli, Abrinia, & Sharifi, 2009). The sun tracker is utilized to reduce the incidence angle between the incoming light and the photovoltaic panel, which consequently increases the produced energy by about 40%. Recently, it has been estimated that solar trackers are found in at least 85% of new Photovoltaic (PV) installations, where production is greater than 1 MW (Rhif, 2011). Three categories of solar trackers have been developed and

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evaluated, which are multi-axis, two-axis and one-axis sun-tracking systems (Rhif, 2011), (Abu-Khader, Badran, & Abdallah, 2008), (Neville, 1978). The single axis trackers have one free-degree movement that allows the rotation of the mechanism around one axis and the track of the sun position during the day from the north to the south or from the east to the west (Sefa, Demirtas, & Çolak, 2009), (Huang B, Huang Y, Chen, Hsu, & Li, 2013). For a two axis sun-tracking system, the tracker follows the sun position from the east to the west daily and from the north to the south annually. There is a lot of research work that has been developed in the literature to track the sun. In (Tomson, 2008), the author presented the daily performance of PV modules with two positions, in the morning and in the afternoon. The obtained results indicated that the seasonal energy yield was increased by 10 to 20% over the yield from one position. In (Bakos, 2006), the writers described the effect of the operation under two-axis tracking on the collected solar energy. The measured energy was compared with that collected by a fixed surface tilted at 41° towards the south. The obtained results demonstrated that the collected solar energy on the moving surface was considerably larger (up to 46.46%) compared with that obtained by the fixed surface. In (Abdallah, 2004), the authors presented four sun-tracking systems: two axes, one axis (vertical), one axis (east-west), and one axis (north–south), which were constructed in order to study the effect of tracking on the electrical power with the different loads. The obtained results indicated that the increases in the electrical power gained up to 43.87% for the two-axis tracking system, 37.53% for the east-west, 34.43% for the vertical, and 15.69% for the north-south, compared with the electrical power obtained by the fixed system. In this paper a one-axe control system is presented, which aims to improve the performances of the control system (the motor drive, the digital devices and the control law). However, in the position control applications the DC motors, and the Permanent-Magnet Synchronous Motor (PMSM) are utilized (Rhif, 2011), (Vittek, Bris, Štulrajter, Makyš, Comnac, & Cernat, 2008), (Shin, Choi, Youm, Lee, & Won, 2012), (Vittek, Stulrajter, Makys, Vavrus, Dodds, & Perryman, 2005). These motors are very expensive relative to the Induction Motor (IM) and require an important rate of maintenance. To overcome the DC and the PMSM motors problems, the IM is proposed in this paper to control the PV position. The IMs controlled with the Field Oriented Control (FOC) approach has found an important acceptance in several industrial applications (Bose, 1997). Nevertheless, the FOC approach is based on a complex coordinate transformation, two control loops of the current and several motor parameters (Casadei, Profum, Serra, Tani, 2002). The Conventional Direct Torque Control (CDTC) provides fast speed and torque responses and it is featured by a simple structure (Depenbrock, 1988), (Habetler, & Divan, 1991). It does not require a coordinate transformation, current regulators and a Pulse Width Modulation (PWM), and it is less sensitive to motor parameter variations. By way of contrast, the CDTC has some problems like the high-torque and flux ripples, the high-current distortions and the variation of the frequency of the inverter during the sampling period. Moreover, when the IM operates with an important load torque at a very low speed, the stator current distortion will increase due to the drop of the stator flux. This reduces the system efficiency (Wong, & Holliday, 2004), and results variations in the rotor speed, mechanical vibrations and acoustic noises (Vaez-Zadeh, & Mazarei, 2000), hence raising the rate and maintenance cost and shortening the service life of the IM. To overcome these disadvantages, various control techniques have been developed in the literature, such as the combination between the DTC and the artificial intelligence. In (Krim, Gdaim, Mtibaa, & Mimouni, 2015), (Liu, Wang, Chen, & Li, 2010), there was a combination between the fuzzy logic control and the DTC. The fuzzy logic was used to select the optimal voltage vectors. This method offered good performances in terms of ripples, but the switching frequency remained variable and the torque ripples did not enormously go down. In (Riad, Hocine, & Salima, 2010), a DTC based on an adaptive neural fuzzy inference system was developed. The model of the system had to be known and the system stability would be affected by the parameter variation. The other solution consists in combining between the DTC and the SVM to guarantee an operation with a constant switching frequency (Taib, Rekioua, & François, 2010), (Jidin, Idris, Yatim, Elbuluk, & Sutikno, 2012). The DTC-SVM can be classified in three types. The first method was developed in (Zhang, Yang, & Li,