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Interval Type 2 Fuzzy-Logic-Based Solar Power MPPT Algorithm Connected to AC Grid

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ABSTRACT

In this article, an interval type-2 fuzzy logic controller (IT2FLC) is used as a Maximum Power Point Tracker (MPPT) to supply a large scale interconnected grid. The IT2FLC has the advantage of being able to regulate the MPP in case of severe variations of the weather conditions. A photovoltaic array is connected to AC grid via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC). The duty cycle of the boost converter is switched by the IT2FLC. A three phase VSC converts the V_{DC} link voltage to AC and keeps unity power factor. The VSC control system uses two control loops: an external control loop which regulates DC link voltage to alternative current and an internal control loop which regulates the active and the reactive grid currents. Vd and Vq voltage outputs of the current controller are converted to three modulating signals used by the PWM Generator.

KEYWORDS

Boost Converter, Grid-Connected Photovoltaic System, Interval Type 2 Fuzzy Logic Controller (IT2FLC), Maximum Power Point Tracker (MPPT), Photovoltaic (PV) Array

INTRODUCTION

In the last decade, due to several limitations of conventional sources of energy such as high cost of fossil fuels, the contributions towards pollution and environmental damage, and scarcity in resources, there is an urge for the utilization of renewable sources of energy.

As the sun is an inexhaustible source of energy and available in most parts of the world, the photovoltaic (PV) system has become one of the most important sources of renewable energy. The energy obtained being in direct current, it can be converted into alternative current by using converters and thus can be used to power loads or to connect to the AC distribution system. The use of photovoltaic energy has become increasingly common as demand for electricity in the world grows. When the PV system is connected to the power supply, it is necessary to meet certain criteria such as the stability of the power system and the quality of the energy supplied. As all photovoltaic systems are interfacing the utility grid through a voltage source inverter (Jiayi et al., 2008) and a boost

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converter, many control strategies and controller types (Ali et al., 2016; Liang et al., 2002; Mattavelli & Marfao, 2004) have been investigated.

The significant advantage of photovoltaic system is the use of abundant and free energy from the sun (Jiayi et al., 2008). Photovoltaic system has a major problem: the amount of electric power generated by solar arrays changes continuously according the weather conditions and day time (Kataria & Panday, 2010).

In order to increase the efficiency of photovoltaic systems (rising the power delivered from the PV system to the load), maximum power point tracking (MPPT) controllers are used. These controllers have become indispensable in PV systems. Several MPPT techniques have been designed, such as current and voltage feedback techniques, or improved power feedback techniques such as incremental conductance technique or perturbation and observation technique (Hohm & Ropp, 2003; Hussein et al., 1995).

Recently intelligent based controls MPPT such as fuzzy logic controller has been introduced (Hannan et al., 2015, Shiau et al., 2015). Fuzzy logic controller (FLC) has paid an increasing attention to researchers since it has been successfully applied to control complex or ill-defined processes whose mathematical models are difficult to obtain. The ability of converting linguistic descriptions into automatic control strategy has made it a practical and promising alternative to the classical control scheme for achieving control of complex nonlinear systems (Naguib & Lopes, 2010; Hang et al., 2011; Rashid et al., 2011; Singh & Chandra, 2011; Uddin & Rebeiro,2011; Alajmi et al., 2011, Faquir et al., 2015; Mohammadian, 2017). However, some limitations such as the expression of uncertainties and nonlinearities are presented by Type 1 Fuzzy Logic systems (T1FLS).

The concept of fuzzy logic system type 2 (T2FLS) was initially proposed by Zadeh, it is a generalization of ordinary fuzzy sets. The footprint of uncertainty (FOU) is the main characteristic of T2FLS, it allows to describe the uncertainties and the nonlinearity of the systems. Many studies have demonstrated that T2FLS are much more efficient in dealing with uncertainties and nonlinearities compared to T1FLS (El Khateb et al., 2013; Abbadi et al., 2013; Hagras, 2004; Suresh & Singh,2016; Mikkili & Panda,2013, Lazim & Liana, 2017, Paul & John, 2017). This gives that the type-2 fuzzy logic controller based on the T2-fuzzy sets can deal with both the linguistic and the numerical uncertainty effectively. Type-2 fuzzy logic controller can obviously outperform its T1 counterpart under the situation of high uncertainty.

In this article, an intelligent control technique using interval type 2 fuzzy logic control system is associated to an MPPT controller in order to improve energy conversion efficiency of a grid-connected PV system.

This article is organized as follows. In Section II, the 100-kW grid-connected PV system is described. The interval type 2 fuzzy logic controller design is presented in Section III. In section IV, the proposed control is validated by means of simulation and discussed. Finally, the conclusions are summarized in Section V.

POWER SYSTEM MODEL

Figure 1 shows the detailed model of a 100-kW Grid-connected PV Array. The 100-kW PV array is connected to a 25-kV grid (Figure 2 depicts the power system utility grid) via a DC-DC boost converter and a three-phase three-level Voltage Source Converter (VSC). Maximum Power Point Tracking (MPPT) is implemented in the boost converter by means of a Simulink model using the fuzzy logic controller.

The detailed model contains the following components:

- PV array delivering a maximum of 100 kW at Standard Test Conditions (1000 W/m^2 sun irradiance and 25° C temperature).

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