A Global Stability of Linearizing Control of Induction Motor for PV Water Pumping Application

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ABSTRACT

This article describes how a field oriented control can provide the same performance as it is achieved by a DC motor. However, this technique requires a mechanic sensor and is very sensitive to the variation of motor parameters which results in an undesirable coupling between the flux and the torque. To solve these problems, this paper proposes a global stability and robust nonlinear controller, applied to induction motor (IM), in order to achieve an exact decoupling between speed and flux for all motor operating conditions. The induction motor is coupled with a centrifugal hydraulic pump, powered by a photovoltaic array system. The proposed system is designed for usage in rural areas or remote electricity needs in absence of the grid network. A nonlinear controller adjusts the motor speed reference to attain the maximum power point (MPPT). In presence of rotor and stator resistances and irradiation disturbance the results obtained by simulations confirms the effectiveness of the proposed method.

KEYWORDS

1. INTRODUCTION

For over fifty years, Direct Current (DC) motors have been widely used in variable speed drives applications principally due to their fast torque response, high precision of regulation and the possibility to use these motors in whichever mode of operation (Cruz & Rivas, 2000). However, DC motors with drawbacks of spark, corrosion and necessity of maintenance, have been replaced by AC induction motors (IMs) (Wai & Lin, 2005). Since its discovery, induction motor is considered as actuator privileged in the in all industries with a reported 90% utilization in electrical motor applications, since it has many advantages such as low cost, high efficiency, good self-starting, simplicity of design, absence of the collector brooms system and a small inertia (Hussein et al., 2017; Cruz & Rivas 2000; Archana et al., 2012). The invention of power electronics and advances in computing have made a radical revolution in developing control strategies for induction motors. Many control strategies have been developed and used for IM drives namely Scalar Control Technique, Direct Torque Control (DTC) and Field-Oriented Control (FOC), (Muchande et al, 2013). FOC schemes, proposed by F.
Blaschke in 1972 (Blaschke, 1972), can provide at least the same performance, for an inverter-driven induction motor, as it is available for a DC motor (Wade et al., 1997), by decoupling the stator flux and electromagnetic torque. However, this technique is very sensitive to the deviation of motor parameters, particularly the rotor time-constant (Wai & Lin, 2005) and it requires a mechanic sensor to correctly determine the orientation of the rotor flux vector (Cruz & Rivas, 2000). This mechanic sensor increases the cost of the drive equipment and makes the driving system much larger and unstable (Casadei et al., 2002).

Trying to reduce the complexity of the algorithms involved in a FOC, researchers presented new techniques used for estimation of the motor speed and fluxes without a need of speed and flux sensors that can reduce the cost and having the features of precision, rejection of disturbance and fast torque response (Zhu et al., 2013). One of the most popular control methods is the feedback linearization which is based on the transformation of the nonlinear model into a linear one which makes the linear feedback control easy to be applied in respect to trajectory reference (Zhu et al.; Enev, 2007). The feedback linearization based on differential geometry control theory is used to uncouple and linearize the model, put it under canonical form and then make control using linear control techniques (Enev, 2007; Raumer et al., 1993). The advantage of the Input-Output Linearization Control (IOLC) over the FOC is the fact that by applying the linearization transformation, system stability and a complete decoupling of the torque and flux in a stator fixed reference frame is achieved, which enables the optimization of motor performances without degrading the mechanical output regularization (Raumer et al., 1993).

To improve the Field Oriented Control, many control strategies have been proposed (Wade et al., 1997). Several feedback linearization based solutions were proposed. It is, by now, well known that the induction motor model with a linear magnetic circuit is not feedback linearizable by static feedback (Ismail, 2012). In (Enev, 2007) the authors have proposed a controller designed to track torque and rotor flux references, in (Marino et al., 1993) have developed an input-output decoupling controller which decouples the regulation of the rotor flux and the rotor speed. To solve the influence of large dependencies on the parameters variation and need accurate cancellation the dynamic when using exact linearization method to nonlinear system. The authors in (Meng et al., 2011; Rashed et al., 2006) introduced Nonlinear decoupling control of induction motor based on parameter adaptive identification to observe the load torque changes. In (Enev, 2007) the author proposed an input-output linearizing control for induction motor, along with a simple scheme enabling the calculation of the rotor resistance and the load torque using steady-state speed and stator current information. In (Moutchou,2014) a structure on input-output linearization based Model reference adaptive system (MRAS), allowing simultaneous observation of stator resistance and rotor speed, in order to estimate rotor flux using a sliding mode observer has been proposed. Water supply, livestock and domestic needs are principal problems in the development of isolated regions and rural remote. Generally, the grid network is not present and the extension of the conventional electric network to the remote areas remains very hard to do (Chikh & Chandra, 2009; Meziane, 2009). Therefore, it is necessary to look for other energy resources to fulfill their energy requirements. A recently proposed solution to this problem is the usage of autonomous systems using inexhaustible resources (Camocardi et al., 2008).

These sources include wind energy, geothermal energy, bio energy and solar energy. PV is renewable and clean energy source because it has no contaminated waste, noise, disturbing effects, radiation, does not even need to the fuel and is converted directly to direct current (Mohamed et al.,2017; Biji, 2012; Ramya, 2012).

Recently, the application of a directly coupled photovoltaic panel to the electromechanical system for water pumping has received increasing devotion because of the expected cost reduction in PV array (Kolhe et al, 2004). Generally, a stand-alone PV pumping system consists of a PV array, a storage element, control/power processing components and a motor coupled to a hydraulic pump (Chikh & Chandra, 2009).
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