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RESEARCH ARTICLE

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Observer design for induction motor: an approach based on the mean value theorem

Abstract In this paper, observer design for an induction motor has been investigated. The peculiarity of this paper is the synthesis of a mono-Luenberger observer for highly coupled system. To transform the nonlinear error dynamics for the induction motor into the linear parametric varying (LPV) system, the differential mean value theorem combined with the sector nonlinearity transformation has been used. Stability conditions based on the Lyapunov function lead to solvability of a set of linear matrix inequalities. The proposed observer guarantees the global exponential convergence to zero of the estimation error. Finally, the simulation results are given to show the performance of the observer design.

Keywords observer design, differential mean value theorem (DMVT), sector nonlinearity transformation, linear matrix inequalities (LMI), induction motor

1 Introduction

The induction motor (IM) is the most widely used motor in industrial driving system applications due to its performance characteristics. The IM is rugged, reliable, and low cost and has simple hardware structure. However, it is very difficult to achieve high performance with the IM, due to the intrinsic nonlinear coupling between the dynamics of the electrical and mechanical parts.

In the available literature, most of the works are based on linear models of the studied systems [1,2]. However, the use of nonlinear models seems very interesting and appropriate because it allows an accurate representation of the system on a wide operating range. But the disadvantage of the nonlinear approach is the lack of a unified and general solution for observer design. For this reason, the authors are oriented to specific classes of nonlinear systems, such as Lipschitz systems. Many approaches have been then elaborated, for example, using the immersion, Lie algebraic transformations, etc [3,4], and high gain observer, etc [5–7].

To achieve a more accurate and robust speed estimation performance of the induction motor, many strategies were proposed in literature such as adaptive methods, sliding-mode, extended Kalman filter, and extended Luenberger observer. A robust adaptive observer for sensorless IM was designed based on the linearized dynamic equation and linear matrix inequality method [8]. Sliding mode observers to estimate rotor flux were proposed [9,10]. An extended Kalman filter method was adapted to estimate the rotor flux of induction motor [11]. Nonlinear Luenberger observers were proposed for sensorless vector control of IM [12]. A nonlinear observer was used to estimate the IM flux which proved to be satisfactory [13]. An approach based on the nonlinear transformation of the original system into a linear was proposed [14,15], but it was very difficult to achieve this due to the strong conditions under which these transformations existed.

The Takagi-Sugeno (TS) fuzzy approach was extensively used to nonlinear systems [16–18]. The basic idea was to decompose the model of a nonlinear system into a set of linear subsystems with associated nonlinear weighting functions [19].

The class of Lipschitz nonlinear systems was also

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