Improving the Steady-State and Transient-State Performances of PMSM Through an Advanced Deadbeat Direct Torque and Flux Control System

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***Abstract*—In this paper, a new advanced deadbeat direct torque and flux control (A-DB-DTFC) system is proposed that improves the steady-state and transient-state performances of the permanent-magnet synchronous motor by adopting two improved deadbeat methods. Whenever the error between the torque and its reference value is low, an improved deadbeat method is adopted by the A-DB-DTFC system, in which the phase and time duration of the voltage vector applied to the motor are adjusted in a manner that the stator flux and torque reach their reference values after just one control cycle. Whenever the torque error is high, another deadbeat method is adopted by the A-DB-DTFC system, where the voltage vector phase is adjusted such that the fastest torque response is achieved. In order to assess the effectiveness of the proposed A-DB-DTFC system, the steady-state and transient-state performances of the motor are tested in MATLAB software and in practice, where the simulation and experimental results confirm that the proposed control system reduces the torque and stator flux ripples and achieves the fastest dynamic response. The comparative assessment with the recent DB-DTFC method indicates that the proposed A-DB-DTFC system yields lower torque and flux ripples and a faster dynamic response with the advantage of a lower computation complexity.**

***Index Terms*—Deadbeat direct torque and flux control, permanent-magnet synchronous motor (PMSM) drives, space vector modulation (SVM), stator flux control, torque control.**

I. INTRODUCTION

DIRECT torque control (DTC) and field-oriented control (FOC) are the two most popular methods for high performance permanent-magnet synchronous motor (PMSM) drives. Lack of inner current controllers, rotary coordinate transformation, and pulse width modulation in DTC yields a faster dynamic response and a simpler structure in comparison with the FOC method [1]. Although DTC method has the aforementioned advantages, it has some drawbacks [1]–[3] among which the high torque and stator flux ripples are the most important, followed by variable switching frequency with respect to the motor speed and the load.

In the conventional switching table-based DTC (STDTC), only six active voltage vectors and two zero voltage vectors are accessible in controlling the motor; therefore, the torque and stator flux are not controlled moderately. To overcome this drawback, in some studies [4]–[7], space vector modulation (SVM) is adopted to increase the number of the accessible voltage vectors. In DTC-SVM methods, the voltage vector applied to the motor is selected through inner controllers such as proportional-integral controllers. These controllers with the rotary coordinate transformation blocks, often necessary to calculate the reference voltage vector in the DTC-SVM methods, degrade the dynamic response of the motor.

In some studies [8]–[11], a new hardware such as matrix converter is introduced to generate more voltage vectors and improve the performance of the DTC method. However, using a new hardware causes an increase in the size, volume, and cost of the control system.

In the STDTC method, only the sign of the torque and stator flux errors are considered in selecting the voltage vector without any calculation in finding the optimal voltage vector. In recent decade, various deadbeat and predictive control methods are proposed to overcome this drawback [12]–[24]; e.g., in [12], a stator flux FOC method is proposed in which the voltage vector applied to the motor is selected such that the torque and stator flux of an induction motor are controlled in a deadbeat manner. In this method, the duty cycle is calculated based on the torque and flux errors, transient reactance of the motor, and estimated voltage behind the transient reactance. In [14], a system of two equations is incorporated in the rotor reference frame with the objective of deadbeat control of the torque and stator flux. By solving this system, the reference voltage vector components are obtained and then transformed to the stationary reference frame. Although this method has an acceptable performance, its equations are in the rotor reference frame; hence, the complexity of this method is high.

A predictive control method is proposed in [23] where the parameters of the voltage vector applied to the motor are adjusted in a manner that the steady-state and transient-state performances of the motor are improved. In this method, in the steady state, in order to simplify the control algorithm and reduce the computation complexity, the torque and stator flux are controlled in a cascade manner independently. Moreover, in the transient state, a different predictive controller is adopted to improve the torque dynamic response and a hysteresis controller is adopted to control the stator flux.

In the STDTC method, the selected voltage vector is applied to the motor in the whole control cycle; hence, high torque and stator flux ripples are generated. In some studies [25]–[31],

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