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Dynamic Hysteresis Torque Band for Improving the Performance of Lookup-Table-Based DTC of Induction Machines

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Abstract-- **The magnitude of hysteresis torque band has a considerable effect on the performance of two-level Direct Torque Control (DTC) of induction machines. The conventional DTC fails at low speed due to the poor flux regulation. In this paper, two dynamic hysteresis torque band (DHTB) strategies for the conventional DTC are proposed to solve this problem by dynamically altering the amplitude of hysteresis torque band based on a flux error range. In this way, the simplicity of DTC algorithm is retained since it only requires a minor modification on its structure. The paper also presents further analysis on flux degradation, particularly the droop in between the flux sectors. In addition, the switching frequency effect of reverse voltage vectors for both DHTB schemes is investigated on the performance of the speed-sensorless DTC drive. The effectiveness of the proposed schemes is confirmed by simulation and experimental validation. Results show a significant enhancement in the flux regulation and dynamic torque response from zero motor speed.**

Index Terms-- **Dynamic hysteresis torque band; direct torque control, flux regulation, induction motor, sensoless control.**

I. Introduction

THE interest in the research on direct torque control (DTC) of induction motors (IMs) has dramatically increased in the past decades due to the growing demand of high performance and high efficient drives for industrial applications. Excellent torque response, simple control structure, and robustness against parameter variations are some of the features that lead to its popularity. However, original DTC suffers from major drawbacks namely high sampling requirements for digital implementation, high torque ripple [1], and low speed problem due to flux magnitude droops [2]. Since its first introduction in 1980's [3], two main groups of DTC variations have emerged to partially or fully solve these problems which can be classified as: 1) Non-Lookup table based DTC (NLT-DTC) and 2) Lookup table based DTC (LT-DTC).

For the NLT-DTC scheme, two approaches are employed mainly to reduce the torque ripple and switching frequency. The first one, which is one of the popular variations of DTC [4-6], is based on space vector modulation (SVM) denoted as DTC-SVM. As apposed to the LT-DTC whereby the voltage vectors are obtained from the look-up table, in NLT-DTC, the reference voltage vectors are generated from the control algorithm. The reference voltage vectors are then synthesized using a space vector modulator. One major drawback of this scheme is the increased complexity of its control structure and implementation. Fast processors are required to ensure small sampling period hence obtaining good control bandwidth. The second approach to the NLT-DTC is known as predictive torque control (PTC) which has gained considerable amount of attention recently [7-10]. Several implementations of PTC still exploit the hysteresis comparators of flux and torque as in the classical DTC, but the selection of voltage vectors is obtained through a predefined cost function rather than a lookup table. In general, PTC strategies suffer from total harmonic distortion and high computation burden [10]. For proper operation of NLT-DTC, appropriate control bandwidth must be ensured; this translates for the requirement of high performance processor. Furthermore, stable operation at very low speed and zero is not guaranteed in NLT-DTC, particularly under no loading conditions.

In the second group of DTC variations, which is the LT-DTC, a lookup table is used to select the switching states of inverter depending on flux and torque requirements. In principle, the schemes under this category operate based on the originally proposed DTC [3] , but with some modifications either in its control structure or in the look-up table. Various techniques with larger lookup tables have been reported in the literature [11-13] with good torque performance but resulting in higher complexity and therefore higher computational requirement. An alternative approach is the variation of hysteresis bands for the torque controller based on different speed profiles [14, 15]. Despite the simplicity of this method, which is focused mainly on achieving constant switching frequency, other major problems of DTC, such as high torque ripple and problems at low speed operations still exist. Other

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