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Simulation Study of Two Torque Optimization Methods for Direct Torque-Controlled Induction Motors

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Abstract: The simplicity and excellent dynamic performance of Direct Torque Control (DTC) make Induction Motor (IM) drives attractive for many applications that require precise torque control. The traditional version of DTC uses hysteresis controllers. Unfortunately, the nature of these controllers prevents the optimization of the inverter voltage vectors inside the flux hysteresis band. The inverter voltage vector optimization can produce fast torque response of the IM drive. This research proposes two torque optimization methods for IM systems utilizing DTC. Analysis and Matlab simulations for the proposed optimization methods prove that the torque and, consequently, the speed responses, are greatly improved. The performances of the drive system controlled by the proposed optimization methods and the traditional DTC are compared. Conversely, the effects of the parameters on the proposed optimization methods are introduced. The proposed methods greatly improve the torque and speed dynamic performances against the traditional DTC technique. However, one of the proposed optimization methods is more sensitive to IM parameter variations than the other.

Keywords: induction motor (IM); direct torque control (DTC); voltage vector; optimization

1. Introduction

There are many applications that require high-performance Induction Motor (IM) drives such as electric vehicles, mine winders, high-speed elevators, machine tools, and other more sophisticated machines. These applications usually need speed–accuracy ≤0.5%, no less than 20:1 of wide-range speed control, and a speed transient response ≥50 rad/s [1–4]. Fast, transient response and accurate torque control are key to achieving a high-performance drive.

Three decades ago, direct torque control (DTC) was deemed the simplest, most accurate, and fastest torque control method for IM drives [5]. Additionally, the DTC algorithm does not depend on motor parameter variations [6,7]. Nevertheless, conventional DTC has the main disadvantage of having a wide band of inverter switching frequency, despite constant torque and flux [8]. The nature of hysteresis controllers has caused this wide inverter switching frequency to occur when being used for flux and torque. The introduction of techniques using constant sampling helped to lead to the advancement of the DTC concept. Therefore, these techniques have replaced conventional analog hysteresis controllers. Accordingly, the inverter upper switching frequency is restricted. Different additions and changes to the concept and theory of DTC regarding constant sampling frequency have been proposed by many authors [9–13]. The fast torque response was not considered by these researchers Kumar and Zaid [14,15].