Electrical Power and Energy Systems 33 (2011) 1721–1727

Contents lists available at SciVerse ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Current control of brushless dc motor based on a common dc signal for space operated vehicles

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ARTICLE INFO

Article history:
Received 26 March 2011
Received in revised form 19 August 2011
Accepted 20 August 2011
Available online 17 October 2011

Keywords:
Inverter
PSIM
BLDC motor
Micro-controller

ABSTRACT

The objective of the paper is to build a simple current controlled modulation technique for brushless dc motors. In electric traction and most other applications, a wide range of speed and torque control of the electric motor is required. The dc machine fulfills these requirements, but it requires constant maintenance. In the brushless permanent magnet motors, they do not have brushes and so there will be lesser maintenance. Brushless dc motors are widely used in applications which require wide range of speed and torque control because of its low inertia, fast response, high reliability and less maintenance. This current controlled technique is based on the generation of quasi-square wave currents using only one controller for the three phases. The current control strategy uses a triangular carrier for the power transistors which is simpler and more accurate than any other options. The advantages of this technique are: (a) The stator currents are completely characterized by their maximum amplitude. (b) The three phases are controlled with the same dc component, and then the phase currents are kept at exactly the same magnitude I_{max}. (c) The dc link current measurement is not required. (d) Phase currents are kept balanced and phase over currents are eliminated.

1. Introduction

In electric traction, like in other applications, a wide range in speed and torque control for the electric motor is desired. The dc machine fulfils these requirements, but this machine needs periodic maintenance. The ac machines, like induction motors, and brushless permanent magnet motors do not have brushes, and their rotors are robust because commutator and/or rings do not exist. That means very low maintenance. This also increases the power-to-weight ratio and the efficiency. For induction motors, flux control has been developed, which offers a high dynamic performance for electric traction applications. However, this control type is complex and sophisticated. The development of brushless permanent magnet machines has permitted an important simplification in the hardware for electric traction control [1]. Today, two kinds of brushless permanent magnet machines for traction applications are the most popular: (1) permanent magnet synchronous motor (PMSM), which is fed with sinusoidal currents (2) brushless dc motor (BDCM), which is fed with quasi-square wave currents. These two designs eliminate the rotor copper losses, giving very high peak efficiency compared with a traditional induction motor (around 95% in Nd–Fe–B machines in the range 20–100 kW). Besides, the power-to-weight ratio of PMSM and BDCM is higher than equivalent squirrel cage induction machines. The aforementioned characteristics and a high reliability control make this type of machine a powerful traction system for electric vehicle applications [2]. The research introduced in this paper is guided to give a simple and efficient modulation control system, which allows having good current waveforms. In order to fulfill these objectives, a BDCM was used because of the following advantages: (1) the quasi-square wave armature currents are mainly characterized through their maximum amplitude values, which directly controls the machine torque; (2) the position sensor system for the shaft needs only to deliver six digital signals for commanding the transistors of the inverter; (3) the inverter performance is very much reliable, because there are natural dead times for each transistor. The first characteristic allows designing a circuit for controlling only a dc component, which represents the maximum amplitude value of the trapezoidal currents, I_{max}. The second and third characteristics allow reducing the complex circuitry required by other machines, and allows the self-synchronization process for the operation of the machine. The most popular way to control BDCM for traction applications is through voltage–source current-controlled inverters [3]. The inverter must supply a quasi square current waveform whose magnitude, I_{max}, is proportional to the machine shaft torque. Then, by controlling the phase-currents, torque and speed can be adjusted.

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doi:10.1016/j.ijepes.2011.08.014