Available online at www.sciencedirect.com
SCIENCE DIRECT®
Mathematics and Computers in Simulation 71 (2006) 333–344
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Design and optimization of a torque controller for a switched reluctance motor drive for electric vehicles by simulation

David Cajander*, Hoang Le-Huy

Department of Electrical and Computer Engineering, Université Laval, Que., Canada

Abstract

This paper presents a study on an optimized controller for a switched reluctance motor drive intended for electric vehicle and hybrid electric vehicle applications. The proposed optimization approach using simulation is described. Simulation results obtained with an 8/6 switched reluctance motor drive are presented and exploited in the optimization process. The performance of the optimized controller is evaluated and validated by simulation.

Keywords: Switched reluctance motor; Torque control; Optimization

1. Introduction

In a relatively near future, we will have to replace the classic internal combustion engine (ICE) by electric motors in vehicle applications. This is necessary not only to limit gas emission, but also because of the rarefaction of the fossil resources. This transition will be done by an intermediate phase, i.e. by the development of the electric vehicles (EV) and hybrid electric vehicles (HEV). Typical electric motors used in EV and HEV nowadays are induction and permanent-magnet synchronous motors. Recently, the switched reluctance motor (SRM), a member of the AC motor family, has given rise to much interest for electric vehicle propulsion [4,5,7]. EV and HEV designers have discovered several features of the SRM that may be very beneficial to the application, in particular the robust construction and fault-tolerant operation. However, the SRM suffers from a major drawback which is related to the torque ripple it develops. In order to obtain good drive performance for a SRM drive in traction, a high performance controller is required which minimizes the torque ripple and maximizes the average torque over a wide speed range.

The purpose of this paper is to present a study on an optimized controller for a SRM drive intended for electric and hybrid electric vehicles. First, the basic characteristics of the SRM are studied to show out the main features required by propulsion systems. The main aspects that influence the drive performance in particular the machine structure and design, the converter configuration, and the control schemes are examined in order to point out the optimization directions. A specific SRM drive including the motor and converter configuration is then selected for the optimization study. A Simulink nonlinear model of the drive is used to predict the performance in terms of average torque and torque ripple as functions of turn-on and turn-off angles and rotor speed. The simulation results obtained are compiled in several multidimensional tables representing the controller performance.

* Corresponding author.
E-mail addresses: cajander@gel.ulaval.ca (D. Cajander), lehuy@gel.ulaval.ca (H. Le-Huy).

0378-4754/$32.00 © 2006 Published by Elsevier B.V. on behalf of IMACS.
doi:10.1016/j.matcom.2006.02.025

Superposition of the generated tables provides a general selection tool for optimizing torque performance over the speed range. The performance of the optimized controller is evaluated and simulation results are presented and discussed.

2. Description of an 8/6 SRM drive

After studying different existing designs of SRM and considering the configurations of unipolar converters for SRM supply we chose an 8/6 SRM, which produces less torque ripple because of its geometry, and a classical asymmetrical converter. The machine structure and the associated converter configuration that we consider are shown in Fig. 1 [2].

A very attractive alternative was to use a total current-controlled converter with a dc chopper that automatically regulates the total current in the machine. Obviously this configuration uses less power electronics switches and should be able to reduce significantly the torque ripple [6]. The simulation of this SRM drive configuration using a linear model of the SRM has provided encouraging results. However, in a real nonlinear SRM, the currents in motor phases must be separately controlled and overlapping between on-going phase and off-going phase must be permitted to produce smooth torque. That is the reason why the converter shown in Fig. 1b was chosen. Because the currents in

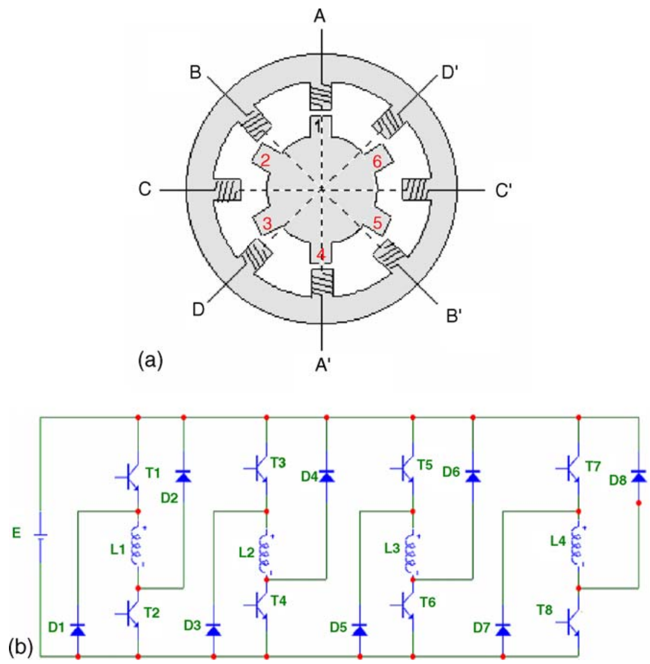

Fig. 1. An 8/6 switched reluctance motor drive. (a) Machine structure; (b) four-phase asymmetrical converter.

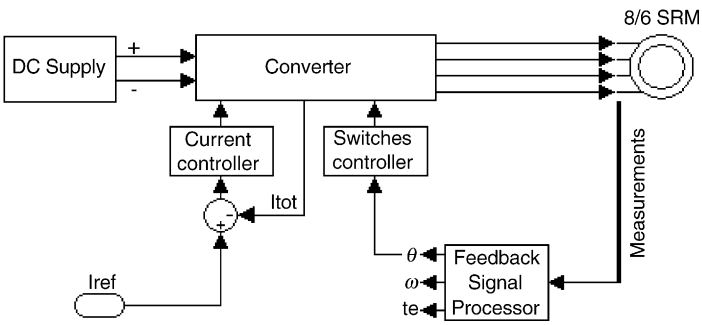

Fig. 2. Switched reluctance motor drive control configuration.