ARTICLE IN PRESS

Ain Shams Engineering Journal (2016) xxx, xxx–xxx

Ain Shams University

Ain Shams Engineering Journal

www.elsevier.com/locate/asej
www.sciencedirect.com

ELECTRICAL ENGINEERING

Matrix converters and three-phase inverters fed linear induction motor drives—Performance compare

Essam E.M. Mohamed *, **Mahmoud A. Sayed**

Electrical Engineering Department, Faculty of Engineering, South Valley University, Qena, Egypt

Received 23 March 2015; revised 19 January 2016; accepted 21 February 2016

KEYWORDS

Linear induction motors (LIM);
Three-phase inverter;
Matrix converters;
Space-vector PWM;
Indirect field oriented control (IFOC)

Abstract In this paper, the system of the Linear Induction Motor (LIM) driven by direct AC–AC matrix converter is presented and its dynamic performance is briefly compared with the conventional LIM drives based on AC–DC–AC converter. Space-vector pulse-width modulation (SVM) and indirect field oriented control (IFOC) are applied to control the two employed converters. For the sake of comparison, the PI controllers are applied to control the primary (mover) speed and current considering the same parameter settings. The objective of this paper was to compare theoretically the dynamic performance of linear induction motor (single-sided LIM) drives driven by three-phase voltage source inverters and the direct AC/AC matrix converters. The study compares the dynamic performance in addition to the harmonics content and THD of the input and output voltage and current for both converters. The simulation of each system has been implemented using the MATLAB/SIMULINK platform.

1. Introduction

Linear motors are special electrical machines, in which electrical energy is converted directly into linear mechanical movement without the need for rotary to linear conversion. There are many types of linear motors such as; DC motors, permanent magnet motors, synchronous motors, and stepping motors. Among these types, The Linear Induction Motor (LIM) is considered one of the most promising types of linear motors due to its high-starting thrust force, high-speed operation, simple mechanical construction, no need for a gear between motor and motion devices, reduction of mechanical losses and size of motion devices, silence operation, easy maintenance, no backlash, low friction, and suitability for both low and high speed applications [1]. Therefore, LIMs are now widely used in many industrial applications with satisfactory performance including transportation, conveyor systems, actuators, material handling, pumping of liquid metals, sliding door closers, robot base movers, office automation, drop towers, and elevators [2,3].

* Corresponding author. Tel.: +20 1060707573.
E-mail addresses: essam.mohamed@eng.svu.edu.eg (E.E.M. Mohamed), mahmoud_sayed@ieee.org (M.A. Sayed).

Peer review under responsibility of Ain Shams University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.asej.2016.02.002
2090-4479 © 2016 Faculty of Engineering, Ain Shams University. Production and hosting by Elsevier B.V.

Nomenclature

$\lambda_{dr}-\lambda_{qr}$	*d–q* secondary flux components	n_p	number of pole pairs
ϕ_i	phase angle of the input waveform	p	differential operator
ϕ_o	phase angle of the output waveform	R_r	secondary resistance per phase
$\lambda_{\alpha r}-\lambda_{\beta r}$	α–β secondary flux components	R_s	primary winding resistance per phase
θ	reference vector position	T_0	ON interval of zero vectors
σ	leakage coefficient	T_n	ON intervals of active vectors
D	viscous friction and iron-loss coefficient	T_r	secondary time constant
F_1	end-effect force disturbance	T_s	switching period
F_e	electromagnetic force	V_0: V_7	switching vectors
F_L	external force disturbance	V_{dc}	dc link voltage
h	pole pitch	V_{env}	instantaneous value of the rectified input voltage envelope
$i_{\alpha s}-i_{\beta s}$	α–β primary current components	V_s^*	reference vector
i_{sx}	supply input current, x denotes for r, s, or t	$V_{\alpha s}^*-V_{\beta s}^*$	α–β reference voltage components
i_{cx}	converter input current, x denotes for r, s, or t	$V_{\alpha s}-V_{\beta s}$	α–β primary voltage components
K_f	force constant	v	primary (mover) linear velocity
L_m	magnetizing inductance per phase	v_e	synchronous linear velocity
L_r	secondary inductance per phase	v_{sl}	slip velocity
L_s	primary inductance per phase		
M	total mass of the moving element		

In the past few decades, Indirect Field Oriented Control of linear induction machines has been tremendously applied through the literature to resemble the ideal performance of separately excited DC machines by decoupling the flux current component and the force current component to separate between secondary flux and motion dynamics. By doing so, the secondary flux-magnetizing current component is kept null and the secondary force producing current component is kept constant; hence, high dynamic performance is gained [4–7].

Voltage source inverters (VSIs) are extensively applied to study the performance of linear induction motor drives. The authors in [4,8–11] studied the performance of new vector control algorithms applying machine models that consider the end-effect. In [12] Hamedani and Shoulaie studied the LIM performance applying IFOC using five-level Cascaded H-bridge (CHB) inverter with multi-band hysteresis modulation. The Adaptive Fuzzy Sliding Mode Control of LIM has been examined experimentally using hysteresis current control (HCC) and IFOC by Chin et al. in [13]. In [14], Liu et al. studied the performance of Sliding Mode Current Control using VSI and IFOC. In [15–17], the performance of LIM is studied using voltage-source inverters incorporated with new direct thrust controller algorithms. Traditional voltage source inverters have some drawbacks: the two stage operation that reduces the reliability of the system, the bulky short life-time capacitor on the rectification stage, high power losses, and high input current THD [18].

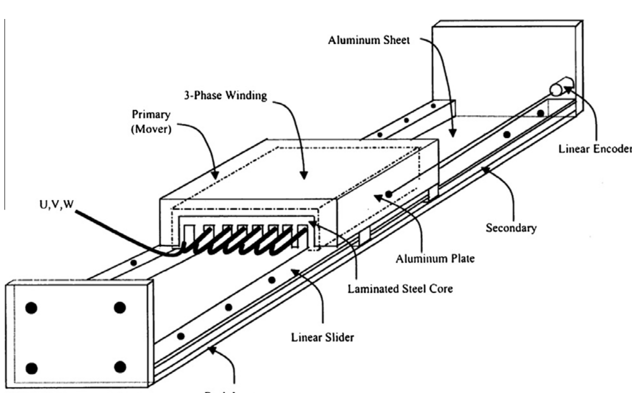

Figure 1 Structure of an experimental LIM [24].

On the other hand, direct AC/AC matrix converter overcomes the previous mentioned drawbacks of traditional VSI. The AC/AC matrix converters are applied to provide fully controllable output voltages in a single conversion stage. Features of matrix converters that make them an attractive solution for some applications include the following: bulky DC capacitors free, which improves the system reliability, bidirectional switches used in matrix converters which enable regenerative power process, unity input power factor which can be obtained at the input side, decreased THD of input and output currents in addition to the output voltage, and unlimited output frequency range [18]. At the same time, matrix converters have some drawbacks: the maximum ratio between the input and output is limited to 86.7%, as well as the complexity of the controller and converter structure [18]. In [19], the authors proposed the use of carrier based PWM matrix converters in controlling the LIM speed.

Space-vector pulse width modulation (SV-PWM), introduced in [20] based on the principles of space-vectors, is intended to approximate the demanded voltage based on the Volt. Second. The operation of space-vector PWM has been analyzed and detailed in [21]. The duty of SV-PWM is to generate the power converter controlling signals according to the reference *d–q* voltage components calculated by the speed and current control loops.

This paper presents a comparison of the linear induction motor drive performance fed by a conventional three-phase inverter and matrix converter drives. In both converters, the switching signals have been obtained based on SVM and the LIM speed is controlled based on IFOC. Section 1 provides an introduction to LIM drives and control. Section 2 presents

Please cite this article in press as: Mohamed EEM, Sayed MA, Matrix converters and three-phase inverters fed linear induction motor drives—Performance compare, Ain Shams Eng J (2016), http://dx.doi.org/10.1016/j.asej.2016.02.002