Simulation Modelling Practice and Theory 29 (2012) 1–17

Contents lists available at SciVerse ScienceDirect

Simulation Modelling Practice and Theory

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

A new approach for SVPWM of a three-level inverter-induction motor fed-neutral point balancing algorithm

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ARTICLE INFO

Article history:
Received 10 October 2011
Received in revised form 8 May 2012
Accepted 8 June 2012
Available online 3 September 2012

Keywords:
Three-level inverter
Space vector modulation
Neutral point balancing
Fuzzy logic controller
Induction motor

ABSTRACT

In this paper the performance of a neutral point clamped (NPC) three-level voltage source inverter is investigated. The inverter feeds an electric drive which is controlled by field oriented control (FOC). The improvement of the control scheme is achieved using Mamdani's fuzzy logic controller for both rotor speed and inverter current. The main issue of this work is neutral point (NP) balancing for a three-level NPC inverter combined with a new Space Vector Pulse Width Modulation (SVPWM) algorithm. The performance of the electric system is verified via Matlab/Simulink©. The operation of the electric system is investigated in steady state and transient responses in both cases whether using or not the NP balancing algorithm. Finally, the ability of the proposed switching pattern generation algorithm for NP balancing is established.

1. Introduction

Over the last years the utilization of multilevel converters for power electronic applications has gained increased recognition. Increasing the number of converter levels leads to achieving high quality output voltages at low switching frequencies. In addition, the decreasing cost of low voltage switches makes the multilevel converters more attractive. The diode-clamped converter (DCMC) is one of the most interesting multilevel topologies that has found applications in industry [23]. Many modulation techniques have been developed for DCMC. Space Vector Pulse Width Modulation (SVPWM) is the dominant method among them. New SVPWM algorithms have been proposed during the last years as well [2,6,7]. An important drawback in multilevel inverters is the NP balancing. The neutral point potential can be balanced using the modulation techniques [4,8,24] or external circuits [9,18,22]. The first has been achieved for the three-level inverter. In case of five-level inverter, the modulation technique balances the neutral point potential at a specific modulation index range [11]. On the other hand, using external circuits for NP balancing has excellent results for multilevel inverters but increases the cost of implementation. Another attractive issue is the control scheme used to control an electric drive system. Some of the control methods that are used, are field oriented control (FOC) [5,17] and direct torque control (DTC) [1,14]. Referring to FOC, research focuses on the optimization of the controllers used [20]. Fuzzy logic controllers have replaced conventional PI controllers in case of rotor speed and inverter current control [12,15].

In this paper an 'electric drive, three-level voltage source inverter' system is presented. The switching pattern is generated using the proposed SVPWM algorithm. As discussed in [10], this algorithm can be applied in any m-level converter and defines directly the two-level hexagon. The NP balancing is achieved combining the proposed SVPWM algorithm with a conventional NP balancing technique [8], and the results are presented in both cases, whether considering the NP balancing or not. The 'electric drive, three-level voltage source inverter' system is controlled using FOC. Mamdani's fuzzy logic controller

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1569-190X/$ - see front matter
http://dx.doi.org/10.1016/j.simpat.2012.06.001

(FLC) is used for both rotor speed and inverter current control, in contrast with most studies that use FLC to separately control the speed and current [14,20]. The FLC is used due to its advantages compared to the conventional PI controller in transient response of the system [13,19].

2. Control scheme

In this section the control scheme is analyzed. The control scheme consists of two parts. The first one is based on field oriented control applied to control the system "electric drive-inverter", in steady state and transient responses. The second one is referred to fuzzy logic control used for current and speed control.

2.1. Field oriented control

In Fig. 1 the block diagram of the electric drive system is shown. The control scheme is based on sensorless FOC. Each time moment currents i_a, i_b, i_c and voltages V_a, V_b, V_c are measured and then transformed in α–β reference frame. The transformations used in the control scheme are simple and efficient. Due to their simplicity, the computational time required is not important. Using these values, the flux of the rotor in α–β reference frame is calculated. The stator currents on d–q reference frame are calculated as well. The speed of the rotor is estimated. The estimation method used for the rotor speed is "direct synthesis from state equations" [3]. As a result rotor speed is expressed as:

$$w_r = \frac{1}{\hat{\Psi}_r^2}\left[\left(\Psi_{\alpha r}\frac{d}{dt}\Psi_{\beta r} - \Psi_{\beta r}\frac{d}{dt}\Psi_{\alpha r}\right) - \frac{1}{L_m}(\Psi_{\alpha r} i_{\beta s} - \Psi_{\beta r} i_{\alpha s})\right] \tag{1}$$

The rotor speed of the induction motor is regulated through a fuzzy logic controller. The actual value of rotor speed is compared with reference rotor speed and reference torque T_e^* results. Currents i_a, i_b, i_c are transformed in d-q reference frame using the angle of the rotor flux and i_{ds}, i_{qs} are calculated. Using the reference torque T_e^* and the absolute value of the rotor flux, reference current i_{qs}^* results. Keeping the rotor flux Ψ_r constant, reference current i_{ds}^* can be calculated. Comparing i_{qs} and i_{qs}^* through another FLC results V_{qs}^* and comparing i_{ds} and i_{ds}^* through a third FLC results V_{ds}^*. Then, values V_{ds}, V_{qs} using $\cos\theta_e$ and $\sin\theta_e$ are transformed in α-β reference frame.

The absolute value and the angle of the reference voltage vector are known using equations $|\vec{V}_{ref}| = \sqrt{V_\alpha^2 + V_\beta^2}$ and $\tan(\gamma) = \frac{V_\beta}{V_\alpha}$. As a result SVPWM can be applied in order to trigger the three-level inverter. The mathematical model used for field oriented control is analytically presented in [5].

2.2. Fuzzy logic control

In this subsection the fuzzy logic controller for rotor speed control and inverter current control will be analyzed. The structure of the fuzzy controller is based on the PI controller [13]. The conventional PI controller in the time domain is described in Eq. (2)

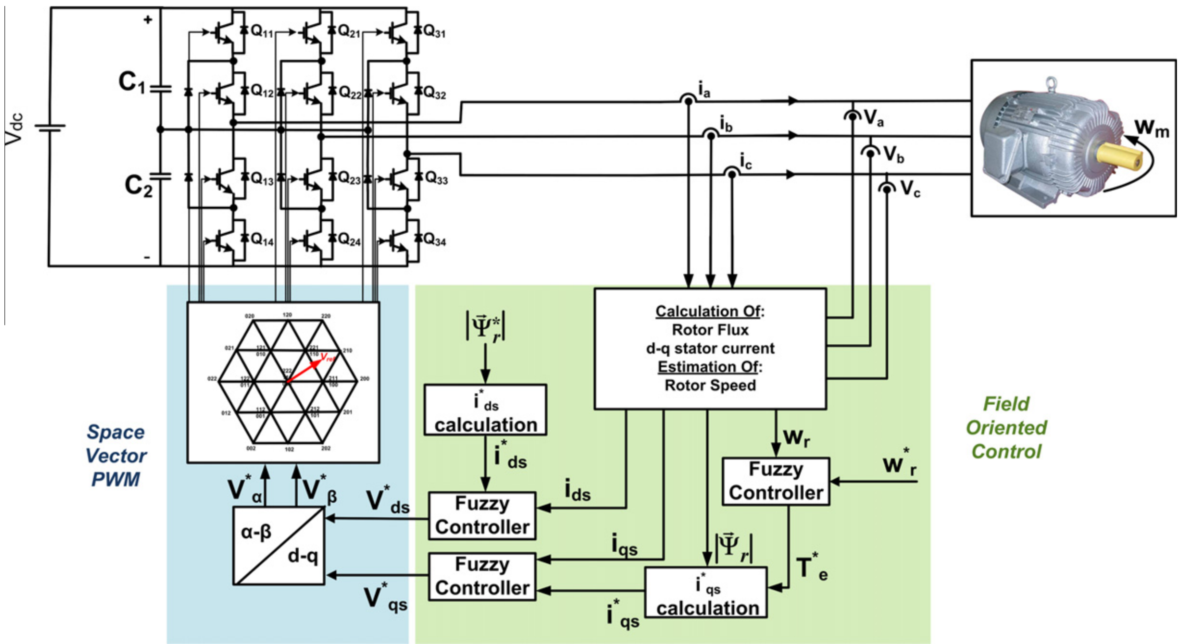

Fig. 1. Field oriented control.