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A FPGA Based Multi Motor Variable Speed Drive

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Abstract: Induction motors are widely used in industries for obtaining motive power, as it has many practical advantages over other types of electrical motors. Induction motor characteristics are suited for Variable Speed Drive which is mostly preferred over Constant Speed Drive. This study implements speed control of two three-phase induction motors are controlled on the basis of FPGA drives. The SVPWM is criticized on a single FPGA chip to provide necessary switching pulses for inverter blocks .The adjustable speed is worked out bymanaging voltage and frequency using FPGA. The experimental setup is built with Xilinx Spartan-6 FPGA family. Experimental results are evidence for that FPGA-based solution for multi induction motor drives are operation flexibility, lower cost and good in performance.

Key words: Space Vector Pulse Width Modulation (SVPWM), multi drive, FPGA, experimental, induction, operation

INTRODUCTION

Because of their robust and rugged construction of Induction motors have been preferred for a variety of industrial applications. As per the specifications, the IM runs at rated speed. By varying the parameters, speed is varied for numerous applications like industrial drives, motion control; automotive control, etc. varying these parameters of IM is complexowing to its nonlinear characteristics. Whether there are various methodsfor speed control, V/f is themost universal methodof speed control used in low cost fairly constant load applications. Among the control systems like PID control used for the speed control, digital control of induction motors results in suitable operation of the motor, resulting in existence, lesser power dissipation.

The Sinusoidal Pulse Width Modulation (SPWM) (Ebersohn and Gitau, 2004; Cecati *et al*., 2004; Liu *et al*., 2005; Hava *et al*., 1998) is most popular and simple technique applicable for IM drives. In which Space Vector Pulse Width Modulation (SVPWM) provides greater control signal (Lopez *et al*., 2008). In today's industrial scenario induction motors are digitally controlled through microprocessors/icrocontrollers/Digital Signal Processing (DSP) units by PWM techniques, giving superior stability, expectable output and stronger anti-noise capability compared to analog controllers (Tamboli and Patil, 2014; Ramirez *et al*., 2014; Morcos and Lakshmikanth, 1999). The μp based regulator are quit cheap, but repeatedly facingcomplexity in dealing with control systems that desires high processing and input/output handling speeds. The option of implementing a controller on a variety of Programmable Logic Device (PLD), Field Programmable Gate Array (FPGA) for fast advances in digital technologies hasgiven. FPGA is right for swift implementation controller and can be programmed to do any type of digital functions (Mekhilef and Masaoud, 2006; Wang and Wu, 2006; Naouar *et al*., 2007). Implementing difficult algorithms becomes easier in FPGA over DSP or μP especially parallelism which is important for multi drive (Telba, 2014; Bossoufi *et al*., 2014). Since, different parts of FPGA can be configured to perform independent functions simultaneously. Diverse parts of FPGA can be constituted to perform autonomous functions simultaneously and better performance over DSP. The FPGA afford a low cost control for induction motor by many control strategy (Monmasson and Cirstea, 2007; Elangovan and Mohanty, 2015). FPGA with SVPWM provides controlled speed for induction motor (Lopez *et al*., 2008).

MATERIALS AND METHODS

SVPWM based speed control: An induction motor torque is controlled by induction current from the stator magnetic field (Ramirez *et al*., 2014). The speed control of an induction machine is very important for industry use which depends on few parameters mainly frequency, numbers of poles and load torque. Machine speed is more important in any kind of industry:

$$N = \frac{120f}{P}(1-s) \quad (1)$$

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Where:
N = Speed of the shaft in rpm
f = Supply frequency
S = Operating slip

Frequency is one of the important parameter to organize the speed of this induction motors as shown in the equation.

Constant V/f control: This method of speed control, the induction motor's speed is adjusted by modifying the magnitude of stator voltages and frequency and keeping that the air gap flux at the preferred value at the steady-state. Figure 1 shows the steady state equivalent. Assume the Zero stator resistance (R_s) and the stator leakage inductance (L_{1s}) is fixed into the (referred to stator) rotor leakage inductance (L_{lr}) and the amount of air gap flux represented by the magnetizing inductance:

$$L_l = L_{1s} + L_{lr} \quad (2)$$

The air gap flux is generated by the ratio of stator voltage and the frequency. Its steady-state analysis phasor equation can be seen as:

$$I_m = V_s / j\omega L_m \quad (3)$$

where, L_m is constant when the induction motor operating under linear region then:

$$I_m = V_s / 2\pi f L_m \quad (4)$$

From Eq. 4, air gapflux remains constant if the ratio V/f remains constant for any change in f, then the torque becomes independent of the supply frequency. With the intention of to stay the magnitude of stator flux constant, the ratio of V/f would also be constant for the different speed.

The stator voltages must be relatively increased in order to remain the ratio of V/f as constant.This is most commonly used than other techniques (Spataru *et al*., 2011). The realistic control limits is shown in Fig. 2.

Space Vector Pulse Width Modulation(SVPWM): As stated above, the handling of V/f ratio gives effective control. But, this leads to more complication in real time, this is possible by a particular technique which determines the proper switching progression for the converter switches (Lopez *et al*., 2008) of a 3 phase voltage source inverter and this technique provides with a reduction of harmonic distortion in the outcome voltage or current of the motor also the DC bus voltage is used more effectively.

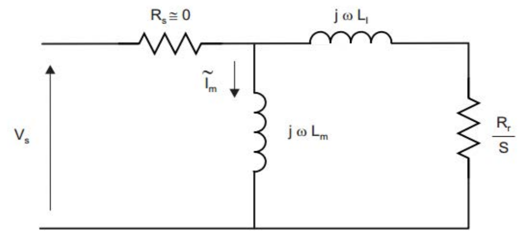

Fig. 1: Simplified steady-state equivalent circuit of IM

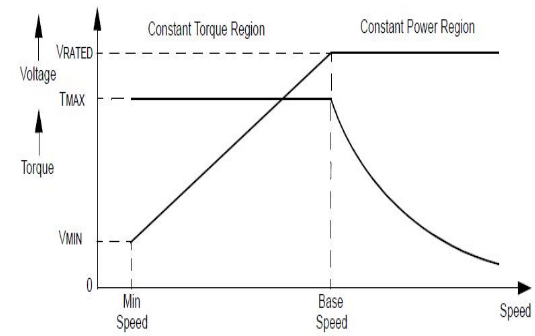

Fig. 2: Stator voltage versus speed under v/f control

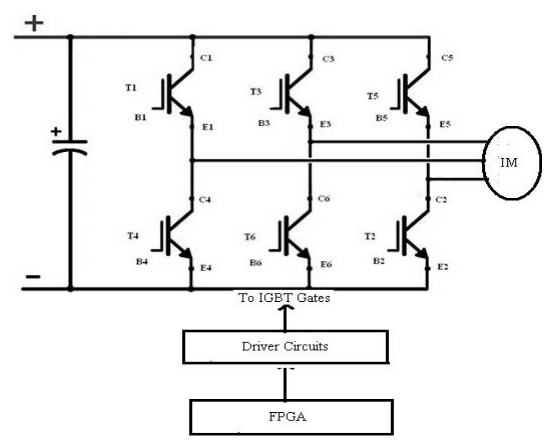

Fig. 3: VSI-power circuits

Figure 3 shows a three phase VSI. The V_a,V_b and V_c are given output voltages to the motor windings as shown. The six power switches T1-6 are the gate signals to control the output voltage for the motor windings. The most important point in this switching sequence is when an upper power switch is in 'on' the lower switch of the same leg switch should be in OFF to avoid dead short.

Table 1: Switching pattern

A	B	C	V_q	V_d	V_{dq}
0	0	0	0	0	$V_0 = 0$
0	0	1	$-1/3V_{dc}$	$1/\sqrt{3}\times V_{dc}$	$V_1 = 2/3V_{dc}$
0	1	0	$-1/3V_{dc}$	$-1/\sqrt{3}\times V_{dc}$	$V_2 = 2/3V_{dc}$
0	1	1	$-2/3V_{dc}$	0	$V_3 = 2/3V_{dc}$
1	0	0	$2/3V_{dc}$	0	$V_4 = 2/3V_{dc}$
1	0	1	$1/3V_{dc}$	$1/\sqrt{3}\times V_{dc}$	$V_5 = 2/3V_{dc}$
1	1	0	$1/3V_{dc}$	$-1/\sqrt{3}\times V_{dc}$	$V_6 = 2/3V_{dc}$
1	1	1	0	0	$V_7 = 0$

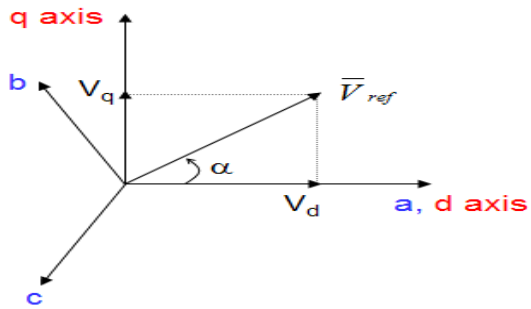

Fig. 4: Voltage Space Vector components in (d, q)

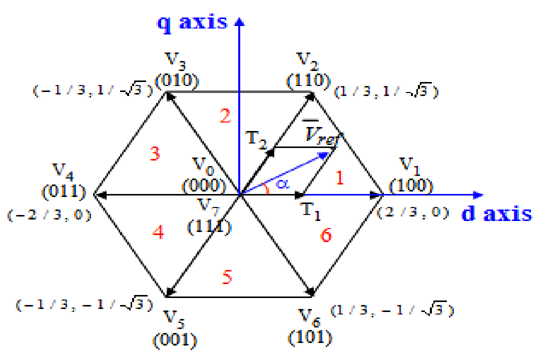

Fig. 5: Sectors and basic switching vectors

To get variable V/f ratio, the power switches are in need of proper sequence switching combinations. This is possible by Space Vectors Pulse Width Modulation which gives eight sequences from the bus voltage as shown in Table 1.

The switching sequences are: The three phase supply voltage Va, Vb, Vc are converted into two axis parameters as Vd, Vq by three phase transformation. From these two axis parameters (Cecati *et al*., 2004), the reference voltage can be obtained. The main work is to find the gate pulse for the device which is possible by identifying proper vectors. This sector identification is easy by found the angle of Vref (Fig. 4):

- Sin θ and Cos θ are used to find duty calculation
- From the duty calculation generation of PWM pulse is made to control the speed of induction motor

The particular sector is assigned according to the θ value. These sectors are used to declare the switching to turned ‘ON’. The switches 001 indicates that 1st and 2nd leg lower switches will be turned ON and the 3rd leg upper control is to be turn ON (Fig. 5).

RESULTS AND DISCUSSION

FPGA implementation over all block diagrams of the proposed system is shown in Fig. 6. The rectifier is a single-phase bridge rectifier with four diodes and capacitor to remove the ripples in the rectified signal. A VSI is used to translate the DC to the essentialsinusoidal voltages and frequency. The power part consists of power converter, filter and power inverter for each set of IM. AC outputs of this inverters feed to the two motors. Each inverter having 6 switches that are controlled by the SVPWM signals generated from the FPGA controlleras shown in Fig. 6. At a time, only three switches will be on, either top or bottom switches of power inverters of each set. To avoid dead short between phase and neutral. Between switching off the upper switch and switching on a dead time is given to avoid short.

The closed loop V/f controller was implemented for two 3 phase induction motors with FPGA. Single FPGA is used to control both the motors for different set speeds, thus making it suitable for multi-drives.

The proposed system is verified using Xilinx Spartan-6 FPGA. SVPWM is tested with the help of Xilinx ISE Design Suite 13.1. It can be observed that the switching sequence is varying for all six IGBTs of each set after an equal interval of time. Generated switchingpattern has been varied to test the variation in speed of drive. Figure 7 shows the 12 SVPWM pulses generated to control the speed of two different induction motors. The first six pulses are designed to control inductor motor IM1 and next six pulses are for controlling induction motor IM2.

The experimental set up is exposed in Fig. 8 and 9. This unit consists of FPGA unit and power circuit.The FPGA-Xilinx Spartan-6 XC6SLX25-FT256. FPGA is used to develop a full digital signal for the controllersoftwo IM drive.

From the Table 3, it is observed that tangible speed is about near to set speed with an error of <that 0.5%. The v/f ratio for different speed settings is also constant. The induction motors specifications are shown in the Table 2.

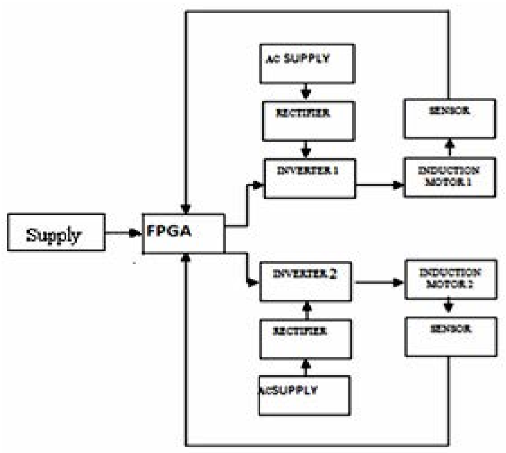

Fig. 6: Block diagram of the proposed system

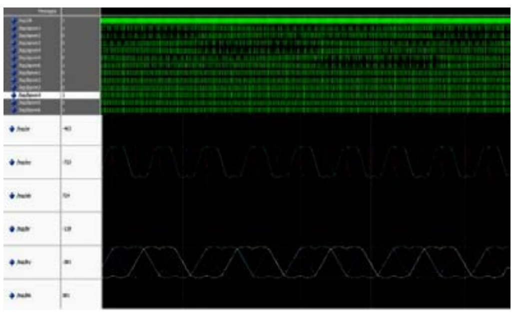

Fig. 7: Generated SVPWM pulses

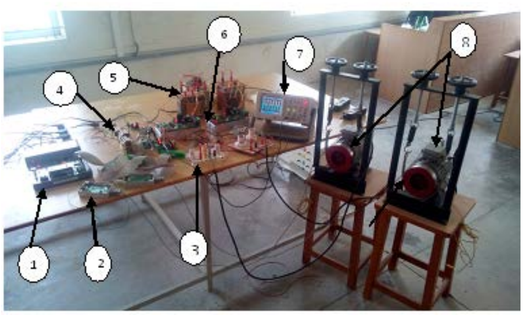

Fig. 8: Hardware setup; 1. FPGA 2; Sensor 3; Power supply 4; Rectifier 5; Isolation transformer 6; Inverter Units 7; DSO 8; Induction motors

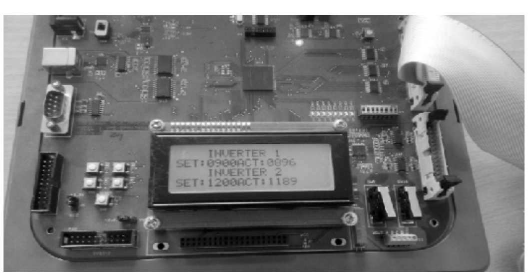

Fig. 9: Set Speed using FPGA

Table 2: Induction motor specifications

Variable	Values	Variable	Values
Hz	50	kW	0.75
V	415Y	A	1.8A
rpm	1415	pf	0.8

Table 3: Experimental results

Induction motor 1		Induction motor 2	
Set speed (rmp)	Actual speed (rmp)	Set speed (rmp)	Actual speed (rmp)
750	746	900	896
1225	1224	1200	1197
1360	1357	1350	1348

CONCLUSION

FPGA based control of two 3 phase induction motors has been implemented. The system has developed and tested for different set of speeds. Speed control of motor is achieved with anexactness of >99.5%. Thus, the FPGA-based control of induction motor drive is cheap, flexible also provides high-performance than the existing methods.

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