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Design and Implementation of Three-phase IPM Inverter based on SVPWM for AC Motor Applications using dsPIC30f4011

***Abstract**. Space Vector Pulse Width Modulation (SVPWM) algorithm has become important PWM and its widely used in the industry especially to drive a three phase IPM inverter with internal shunt resistor for AC motor applications due to it high efficiently and less harmonic distortion when compared with Sinusoidal PWM (SPWM) technique. In this paper we use a 16-bit Digital Signal Controller dspic30F4011 and IRAMY20UP60B intelligent power module inverter. In the proposed system three phase sinusoidal voltage is formed with six pulses signals generating using integrated PWM module. The experimental results are wisely studied to prove that our proposed approach and IPM inverter acquire a high performance.*

Streszczenie.** Algorytm modulacji szerokości impulsu przestrzennego (SVPWM) stał się ważnym PWM i jest szeroko stosowany w przemyśle, szczególnie do napędu z trójfazowym falownikiem IPM z wewnętrznym rezystorem bocznikowym w silnikach prądu przemiennego z powodu jego wysokiej wydajności i mniejszych zniekształceń harmonicznych w porównaniu z sinusoidalnym PWM (SPWM). W artykule przedstawiono zastosowanie 16-bitowego kontrolera cyfrowego dspic30F4011 i IRAMY20UP60B inteligentnego modułu mocy. W proponowanym układzie powstaje trójfazowe napięcie sinusoidalne z sześcioma sygnałami impulsów generowane za pomocą zintegrowanego modułu PWM. **Projekt i zastosowanie trójfazowego przekształtnika bazującego na modulacji SVPWM wykorzystującego kontroler DSPIC30f4011

Keywords: *Space vector pulse width modulation, three-phase inverter IPM, dsPIC30F4011, iramy20up60b*.
Słowa kluczowe: Modulacja szerokości impulsu wektorowego, trójfazowy inwerter, IPM, dsPIC30F4011, iramy20up60b.

Introduction

Inverters are largely used in several applications as industrial, electric traction, etc. In these systems, inverters are used as important devices to convert DC to AC power supply, under a given necessity of frequency and amplitude [1, 2], however, it contains several problems such as over-current and over-temperature protections. To overcome these problems many researchers proposed to replace them by Intelligent Power Module (IPM) inverters especially in AC motor drive applications systems. In Order to enhance the harmonic free environment and attain maximum performance, PWM control techniques must be used. The objective of PWM techniques was to fabricate a sinusoidal AC output whose magnitude and frequency could both be controlled [7] [8].

SVPWM is one of the best and most used PWM technique for variable frequency drive application. In this method, the voltage reference is provided using a revolving reference vector, magnitude and frequency are controlled and that gives high efficiently and generates less harmonic distortion [2, 4]. Many products of digital signal controllers and microcontrollers with integrated PWM module have been launched to the electronic market [1],[5].Microchip produces power conversion and motor control chip families (PIC18F dsPIC30F, and dsPIC33F) is one of the most popular company such a Motorola, Texas instrument, etc.

In this work, a three phase IRAMY20UP60B inverter and a Digital Signal Controller dsPIC30F4011 is used. This IPM module deliver a high level of protection such over-current, over-temperature protections and integrated under-voltage lockout function also it built with failsafe operation and along with short-circuits rated IGBTs [3]. This intelligent module is the best inverter for AC motor drive applications due to its excellent properties; the Digital Signal Controller is used to design the three-phase SVPWM signals. The hardware model is neatly studied to show that our proposed approach and IPM inverter obtain high performance [1, 4].
Finally, the experimental results and the conclusion are presented.

The principle and algorithm of three-phase IPM inverter based on SVPWM method

The principle and algorithm of three-phase IPM inverter is presented in figure 1

SVPWM principle

In SVPWM technique the above three phase voltages can be controlled based on rotate vector diagram as illustrated in Fig. 2 [2][4].

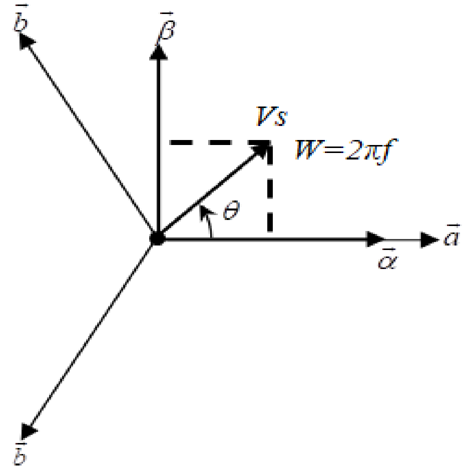

Fig.2. Relationship of the three-phase voltage on (α β) coordinates

We can deduce from the above figure that the three phase voltages are alternatively represented by a rotation vector Vs [9]. According to Concordia transformation, we can use only two vectors Vα and Vβ, in which the horizontal α is allocated in the same direction with phase A and β is the vertical axis as typical. Now, Vα and Vβ vector axes are equivalent to Vs [2] [4].

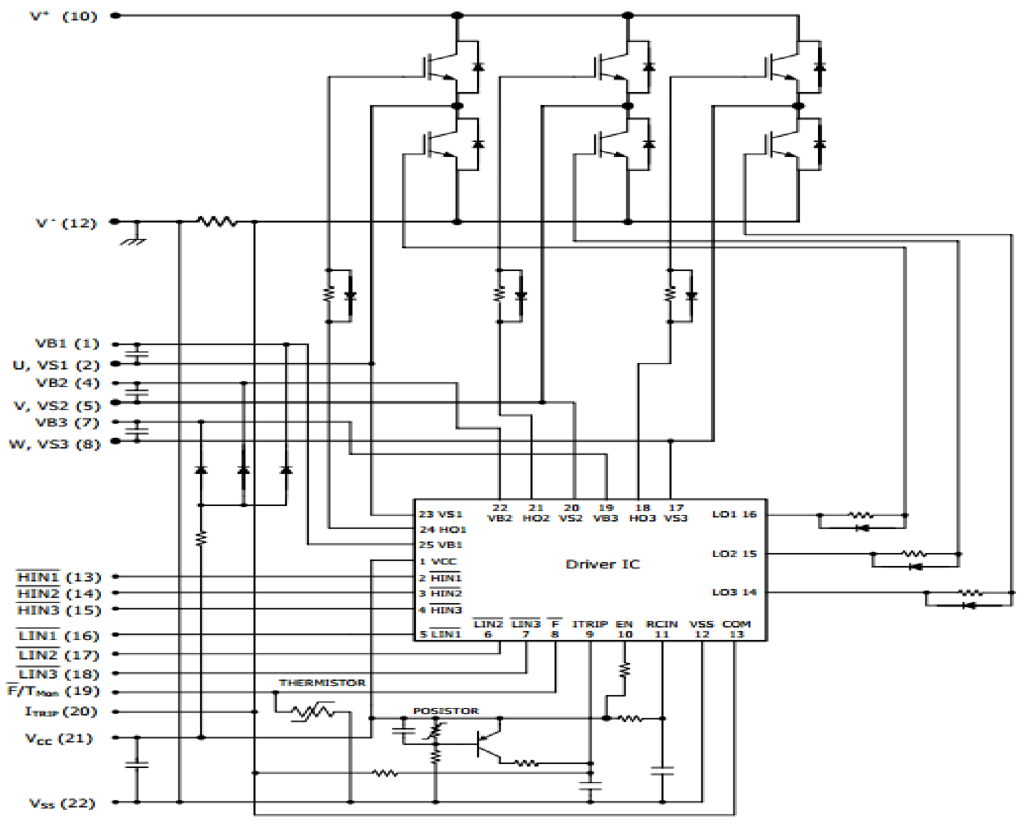

Fig.1. Circuit diagram of three-phase IPM inverter [3]

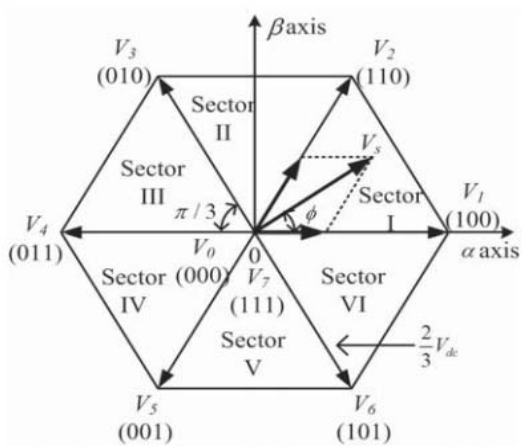

Fig.3. Basic Space vector and switches state. [4]

The new coordinate system, it is readily to observe that the three-phase voltage is completely controlled by voltage vectors (Vα Vβ) described using a set of formulas as below corresponding to the horizontal α and vertical β

(1) $$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} V_{AN} \\ V_{BN} \\ V_{CN} \end{bmatrix}$$

(2) $$V_s = \sqrt{V_\alpha^2 + V_\beta^2}$$

(3) $$\theta = \arctan\left(\frac{V_\alpha}{V_\beta}\right)$$

(4) $$\omega = 2\pi f_m$$

To control the three-phase voltage by Vα and Vβ. We have to convert these two vectors into a three bit logic control vector [a b c]. The combination of three-bit control vector forms eight basic vector voltages (V0, V1,...,V7) (see Table I and Fig.3). Among them, there are six active voltage vectors (V1,V2,..,V6) and two zero voltage vectors (V0,V7). The former set divides the modulation space into six sectors, each with angle 2π/3 (rad) and amplitude 2Vdc/3. If the voltage vector Vs is in an arbitrary sector, the corresponding two active vectors of this sector are used to modulate Vs representing the three-phase voltage [2] [9].

Table.1. The parameters of the sensor

Voltage vector	Control vector [a b c]	Output V_{AN}	Phase V_{BN}	voltage V_{CN}
V0.7	[0 0 0][1 1 1]	0	0	0
V1	[1 0 0]	$2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}/3$
V2	[1 1 0]	$V_{dc}/3$	$V_{dc}/3$	$-2V_{dc}/3$
V3	[0 1 0]	$-V_{dc}/3$	$2V_{dc}/3$	$-V_{dc}/3$
V4	[0 1 1]	$-2V_{dc}/3$	$V_{dc}/3$	$V_{dc}/3$
V5	[0 0 1]	$-V_{dc}/3$	$-V_{dc}/3$	$2V_{dc}/3$
V6	[1 0 1]	$V_{dc}/3$	$-2V_{dc}/3$	$V_{dc}/3$

SVPWM Algorithm

According to fig.4, we can modulate the two related vectors Vk and Vk+1 during two corresponding periods Tk and Tk+1 such that Tk+Tk+1≤T [1]–[2]. Then the sum of Tk and Tk+1 should be less than or equal to T. The inverter need to be in V7 or V0 state for the rest of the period [2] [10]. Mathematically, this can be given by:

(5) $$\int_{nT}^{(n+1)} V_s dt = T_k V_k + T_{k+1} V_{k+1} + T_0 V_0$$

Since Vs is constant, the equation becomes as follows

(6) $$TV_s = T_k V_k + T_{k+1} V_{k+1} + T_0 V_0$$

The carrier wave *generating using integrated PWM module* of dsPIC30F4011 is symmetric. From Fig. 5 we can note that in each period T, V0 and V7 occur in T0/2. However, V0 andV7 are equal to zero, this result leads to rewriting 5 as follows

(7) $$V_s = \frac{T_k}{T} V_k + \frac{T_{k+1}}{T} V_{k+1}$$

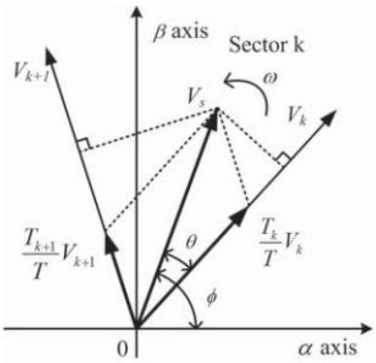

Fig. 4 Vs vector in the k-th Sector

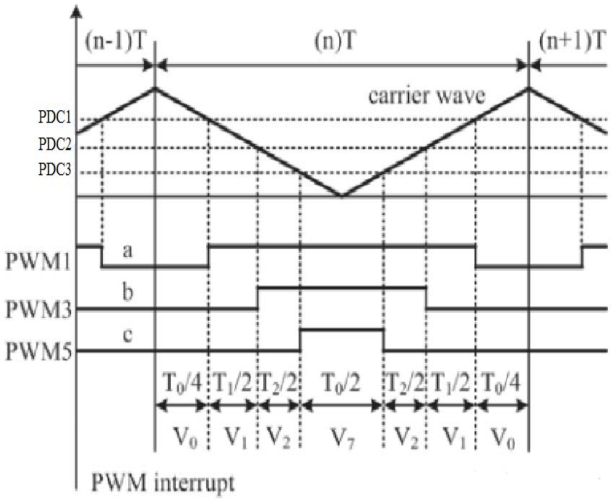

Fig.5 PWM wave form in sector 1 [4]

And

(8) $$T_0 = T - T_k - T_{k+1}$$

To obtain Vs, we need to find out the values of Tk and Tk+1. By using Fig. 4, we can deduce the following equations

(9) $$\theta = \phi - \frac{k-1}{3}\pi$$

(10) $$V_s \sin\left(\frac{\pi}{3} - \theta\right) = \frac{T_k}{T} V_k \sin\left(\frac{\pi}{3}\right)$$

(11) $$V_s \sin\left(\theta\right) = \frac{T_{k+1}}{T} V_{k+1} \sin\left(\frac{\pi}{3}\right)$$

By replacing Vk, Vk+1 with 2Vdc/3, and using (8), (9) and (10) we finely obtain

(12) $$T_k = \frac{\sqrt{3}TV_s}{V_{dc}} \sin\left(-\phi + \frac{k}{3}\pi\right)$$

(13) $$T_{k+1} = \frac{\sqrt{3}TV_s}{V_{dc}} \sin\left(-\phi + \frac{k-1}{3}\pi\right)$$

dsPIC30F4011 control board and SVPWM algorithm on microcontroller

In this paper, we implement our Space Vector PWM algorithm by using a high performance 16-bit Digital Signal Controller dsPIC30F4011, which is able to design the inverter in control our ACIM motor. As described in fig. 6 the microcontroller is set to operate at 20 (MIPS), supplied by a 5v source, to control the SVPWM inverter using integrated PWM module. During this process we changed the frequency of carrier wave by a potentiometer to control the motor speed since our DC power supply produces only 84 volts. The sine functions (11), (12) in the range from 0 to 2π/3 (rad) and the arctan function (3) are generated by using a lookup table in order to enhance the computational speed. The accuracy of lookup table is 3600 point per 2π (rad). At the beginning of a new cycle PWM interrupt occurs -fig.5 Tk, Tk+1, and T0 are calculated.

For this experiment we put 2μs of dead time between high and low side PWM to prevent short circuit across the bridge power during the phase switching [6].

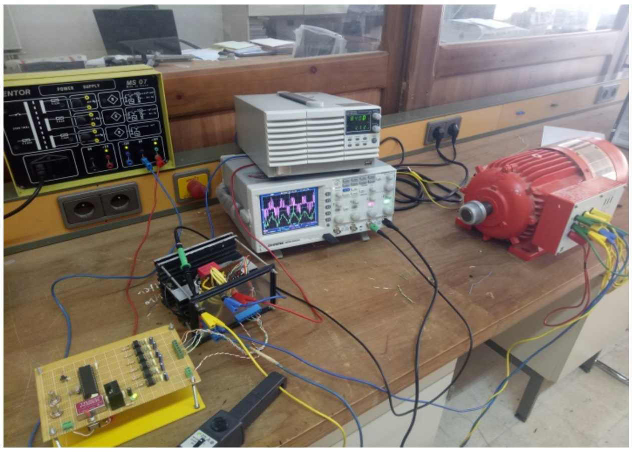

Fig.6. Hardware setup of three phase inverter fed to three phase induction motor

Power stage and isolation circuit

Power stage module of SVPWM inverter is an IPM IRAMY20UP60B supporting up to 20 (A), 600 (V). This IPM is built-in temperature monitor over-current and over-temperature protections, also deliver high level of protection The DC power supply is 84 (V) and 1.3 (A). The three-phase load is an induction motor. DsPIC30F4011 control board is isolated from power stage by a high time response using HCPL4504 as shown in Fig.7.

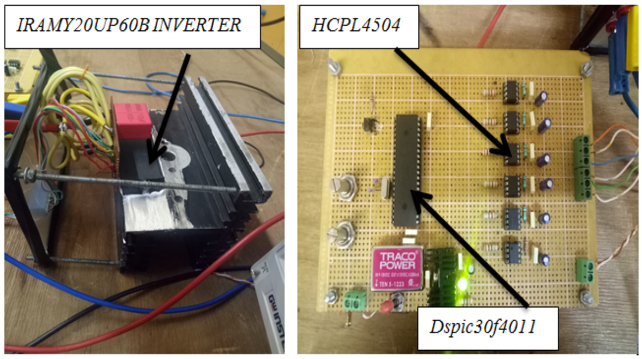

Fig.7. Power stage and isolation circuit

Experimental result

This prototype is powered by 84 (V) and 1.3 (A). Dead time of 2μs, PWM H PWM L is presented in fig.7 and fig.8 respectively. The result also shows the voltage and current output wave form feed to drive an induction motor in fig.9 and fig.10.

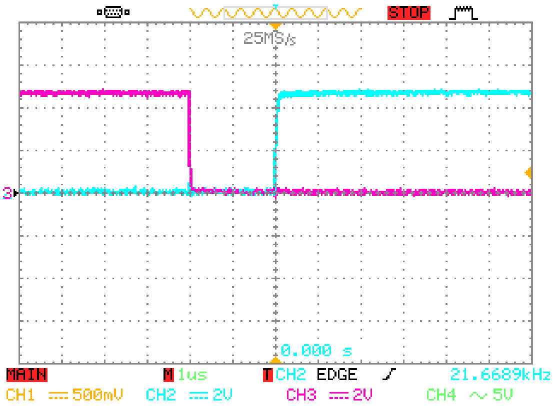

Fig.8. dead time between high and low pulse

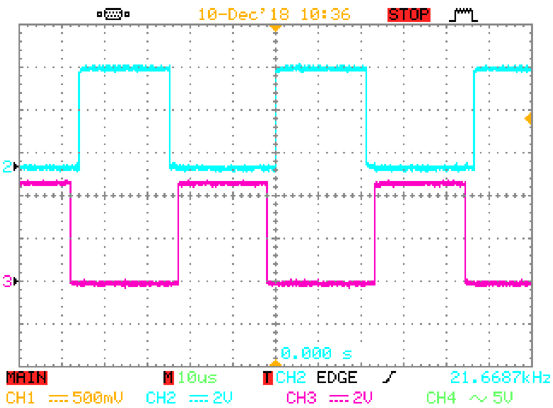

Fig.9. high and low svpwm pulse of one leg inverter

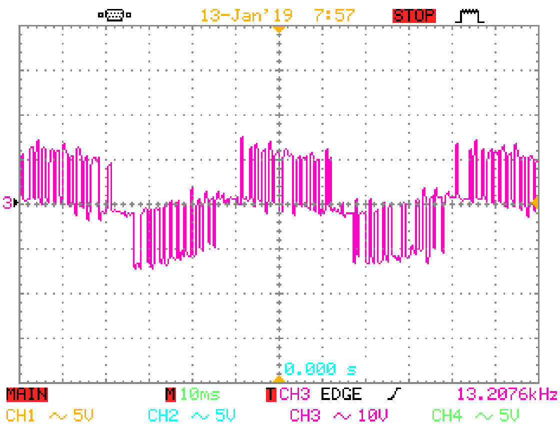

Fig.10. line voltage of the three phase inverter (without filter)

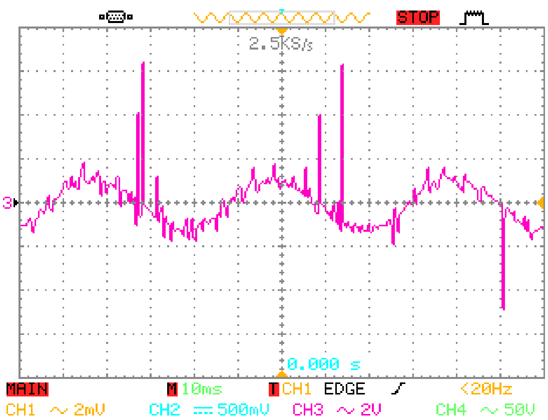

Fig.11. output current wave forme of the three phas inverter

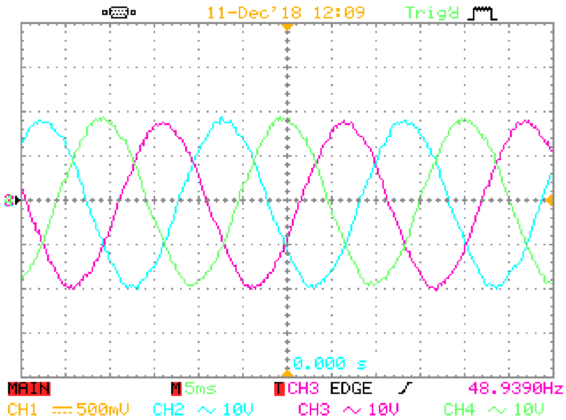

Fig.12 Output voltage of Three-phase SPWM Inverter (with LC-filter)

Conclusion

In Order to control motors, reduce harmonic and attain high performance, IPM inverter is used due to its good properties alongside with Space Vector Pulse Width Modulation (SVPWM) algorithm. The proposed controller shows that Space vector PWM provides an improved efficiently and generates less harmonic distortion with a great enhancement and stability of systems performance.

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