

## Comparative Study and Design Analysis of Several Pulse Width Modulation Control Techniques

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**Abstract** – Various PWM techniques are used for controlling the different loads such as R, R L, and RLE. In the existing system the control technique like, TSPWM, Single pulse PWM and Multiple Pulse PWM is Used to control the load, which has Acoustic noise and harmonic distortion .The proposed system reveals the reduction of losses by comparing TSPWM, SVPWM and RPWM .The highest possible peak phase fundamental is higher for SVPWM than TSPWM, and the RPWM technique offers significant benefits over deterministic PWM when implementing motor drive system.

**Keywords:** Triangular-Sinusoidal pulse width modulation (TSPWM), Space vector pulse width modulation (SVPWM), Random pulse width modulation (RPWM), Acoustic noise

### 1. Introduction

Widely used inverters in recent years is used to control different kinds of loads, which has many losses and these losses can be mitigated by various PWM techniques, such as TSPWM and SVPWM, whereas losses are not reduced much. The proposed system in this paper implemented RPWM technique. Comparing SPWM and TSPWM, the RPWM technique has lower acoustic noise and harmonic distortion. To solve the problem, RPWM [1]-[2] has attracted attention from 1987 [3]. The remarkable features of an inverter adopting RPWM, its output harmonic spectra dispersed and continuously distributed. Hence the acoustic noise, mechanical vibration and harmonic spectra can be greatly reduced.

Pulse width modulation technique is the used most widely or controlling the modulation depth of inverter. The most common such Power inverter is the voltage source inverter, shown, the constructed of six power switching devices such as IGBTs or MOSFETs [4]. The switching device is chosen, based on the desired operating power level, required switching frequency and acceptable inverter power losses. Sine-triangle comparison method is the popular one [5].The sine-triangle method has excellent harmonic reduction in which higher amplitude harmonics are centered at the carrier frequency and its side band. In these methods different ratios of frequency modulation are used at different range of speed so as to control the switching Losses [6].

The phase voltages can therefore be expressed in terms of the state of the bottom phase leg switches. In particular, when the bottom switches are on, regardless of the direction of load current, the voltage across the switch is zero (ideal switch); when the switch is off, the

voltage across it is the dc input voltage,  $V_{dc}$ .  $V_{ag}$ ,  $V_{bg}$ , and  $V_{cg}$  are determined from the PWM control logic these voltages are then used to determine the phase voltages [7]. The phase voltages provide inputs to integrators that calculate the phase currents, which are then used to determine whether the diodes or transistors are conducting. Also, at low frequency

ratios, carrier wave synchronizing with the modulating wave is important in controlling the sub harmonics. With SVPWM method, the switches of the inverter are controlled based on the comparison of sinusoidal control signal with a triangular switching signal [8]. The sinusoidal control waveform represents the desired fundamental frequency of the inverter output, while the triangular waveform represents the switching frequency of the inverter.

## 2. SVPWM Based Three Phase Inverter

SVPWM techniques are increasingly becoming popular [1, 4, 6] as an alternate to sine-triangle PWM in various applications of drives. In 1980s, form of PWM called Space Vector Modulation (SVM) was proposed. Both Space vector PWM and SVPWM are very much similar and the difference is in the distribution of zero vector state during a sampling period. The SVPWM scheme has significant advantages over natural and regular sampled PWM with respect to their performance, easy implementation and ratio of maximum transfer.

SVPWM is explicit identification of pulse placement and the additional degree of freedom that can be exploited to achieve reduced harmonic performance. The SVPWM principle is that there is only eight possible switch combination for three phases (Two levels) inverter. Basic inverter and three phase inverter their switching states vector identifies the uses of ‘0’ as negative phase voltage level and ‘1’ to represent the Positive phase voltage.

The system can be defined by  $V_a(t)$ ,  $V_b(t)$  and  $V_c(t)$  is represented in rotating vector by,

$$V = V_a(t) + V_b(t)e^{j2\pi/3} + V_c(t)e^{-j2\pi/3} \quad (1)$$

$$\begin{aligned} V_a(t) &= V_m \sin \omega t \\ V_b(t) &= V_m \sin \left( \omega t + \frac{2\pi}{3} \right) \\ V_c(t) &= V_m \sin \left( \omega t + \frac{4\pi}{3} \right) \end{aligned} \quad (2)$$

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Here, the reference frame voltages for each inverter in SVPWM the switching states are mapped to the complex two phase  $\alpha$ - $\beta$  plane To implement space vector modulation a reference signal  $V_{ref}$  is sampled with a frequency  $f_s$  ( $T_s = 1/f_s$ ).

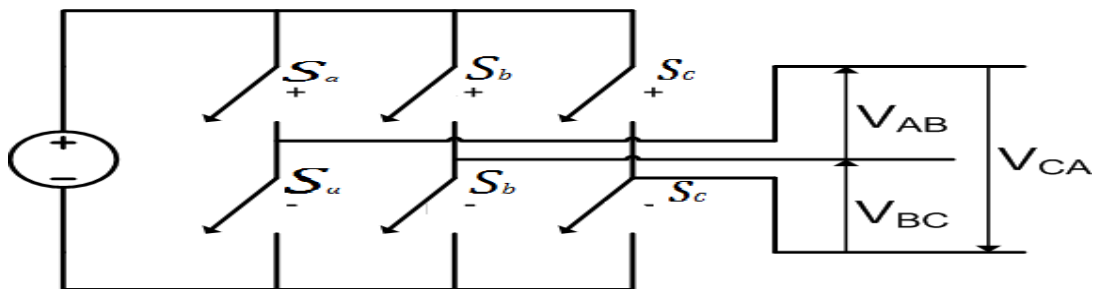


Fig.1.Circuit diagram for 3 phase inverter

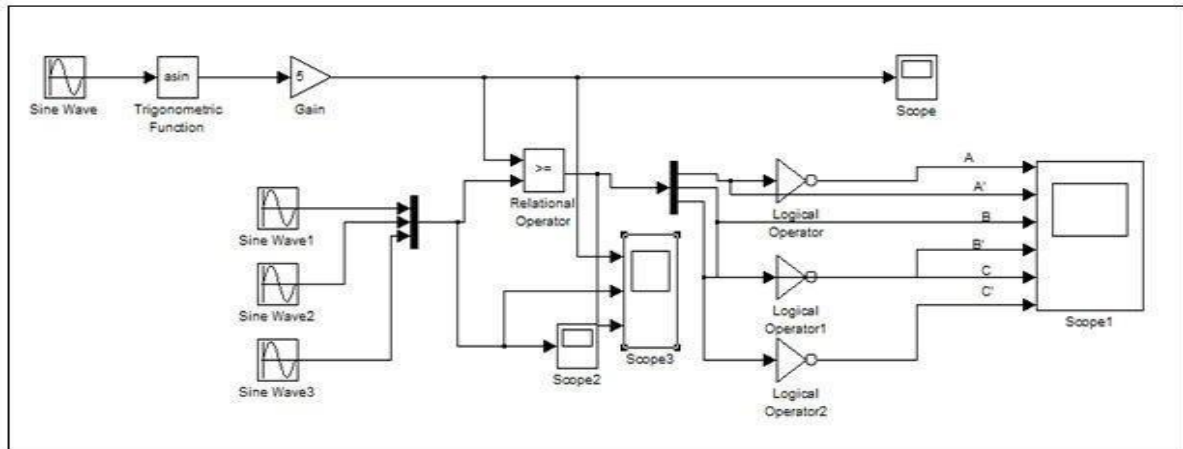


Fig 2. Matlab Simulink Diagram For SVPWM

TABLE I. SVPWM – Chart Diagram

Vector	$S_a^+$	$S_b^+$	$S_c^+$	$S_a^-$	$S_b^-$	$S_c^-$	$V_{AB}$	$V_{BC}$	$V_{CA}$	
$V_0 = \{000\}$	OFF	OFF	OFF	ON	ON	ON	0	0	0	zero vector
$V_1 = \{100\}$	ON	OFF	OFF	OFF	ON	ON	$+V_{dc}$	0	$-V_{dc}$	active vector
$V_2 = \{110\}$	ON	ON	OFF	OFF	OFF	ON	0	$+V_{dc}$	$-V_{dc}$	active vector
$V_3 = \{010\}$	OFF	ON	OFF	ON	OFF	ON	$-V_{dc}$	$+V_{dc}$	0	active vector
$V_4 = \{011\}$	OFF	ON	ON	ON	OFF	OFF	$-V_{dc}$	0	$+V_{dc}$	active vector
$V_5 = \{001\}$	OFF	OFF	ON	ON	ON	OFF	0	$-V_{dc}$	$+V_{dc}$	active vector
$V_6 = \{101\}$	ON	OFF	ON	OFF	ON	OFF	$+V_{dc}$	$-V_{dc}$	0	active vector
$V_7 = \{111\}$	ON	ON	ON	OFF	OFF	OFF	0	0	0	zero vector

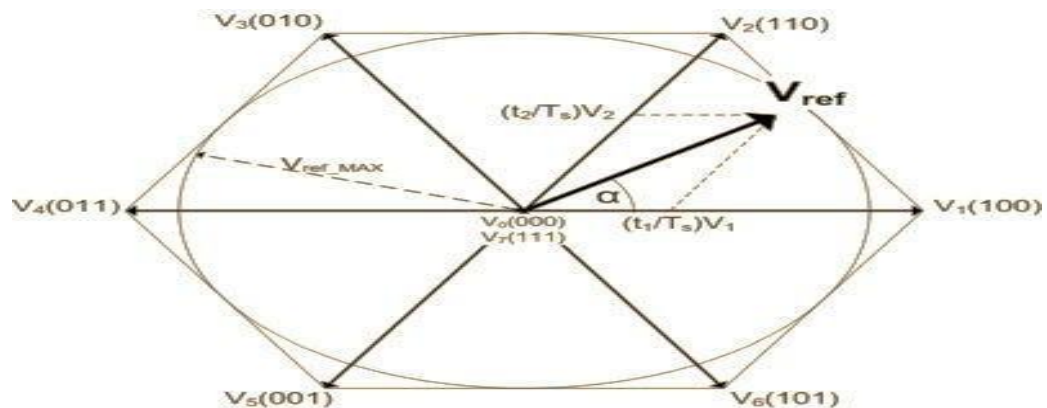


Fig.3.The Space Vector Representation

Three separate phase references using the  $\alpha\beta\gamma$  transform generates reference signal. The combination of the two adjacent active switching vectors and one or both of the zero vectors synthesize reference vector. Strategy selection will affect the harmonic content and the switching losses. This operation system has six non-zero vector (V1 and V6) which shapes the hexagonal axis and their angle for adjacent non-zero vector is  $60^\circ$ .

### 3. Triangle PWM Based Three Phase Inverter

In most of the instance the triangle wave magnitude is held fixed. The amplitude of the inverter output voltages is therefore controlled by the amplitude adjustment of the sinusoidal control voltages. The amplitude modulation ratio is the ratio of the amplitude of the sinusoidal waveforms to the amplitude of the triangle wave. In systems in which the inverter sources inductive loads, the inverter must source power in all four quadrants. The diodes in this provide the path for current when a transistor is on but does not conduct the polarity of the load current. For example, if the load current is negative at the instant the the upper transistor is on by giving the gate pulse, the diode in parallel with the upper transistor will conduct till the load current becomes positive at which time the upper transistor will begin to conduct.

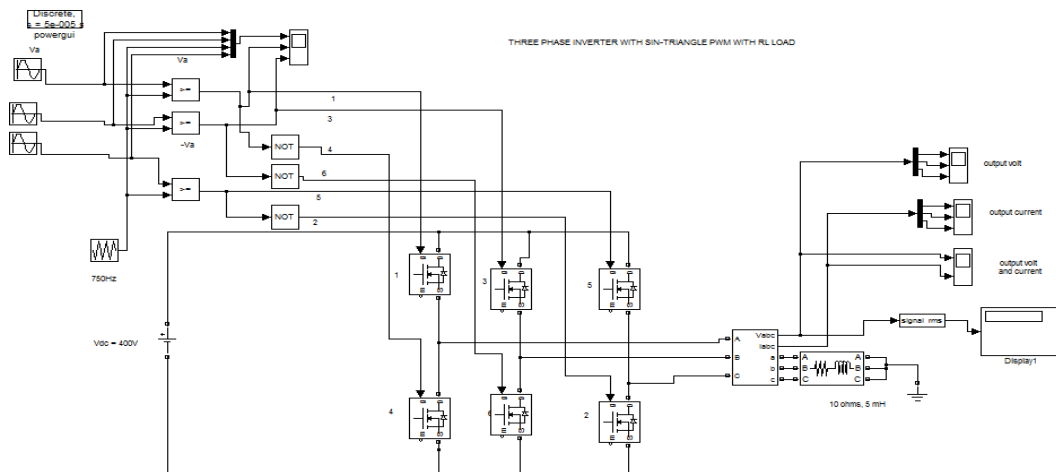


Fig.4. Matlab Simulink for Triangle Sine PWM

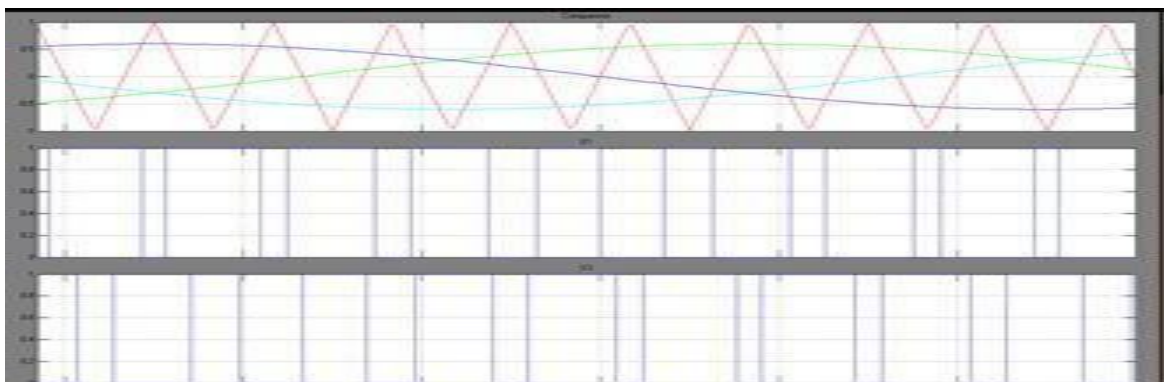


Fig.5. Triangular pulse Waveform

Figure 4 shows an expanded view of the PWM generation process for a single PWM switching cycle. The diagram illustrates the relationship between the assumed reference voltage waveform,  $v_{ref A}$ , and the resultant PWM signal, AH. In this application note, sinusoidal modulation is assumed so that the reference voltage is assumed to take on a sinusoidal time variation the desired fundamental frequency and voltage level. However, the computation of the required on-time of the PWM signal ON, A is independent of the particular modulating function used.

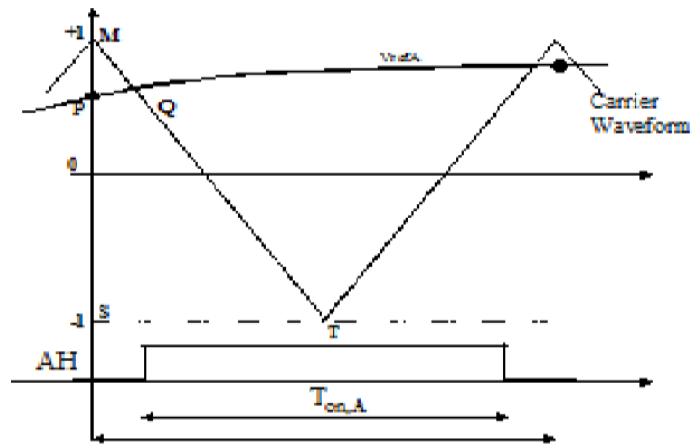


Fig.6.Expanded View for generation Of PWM Signal for one Switching period.

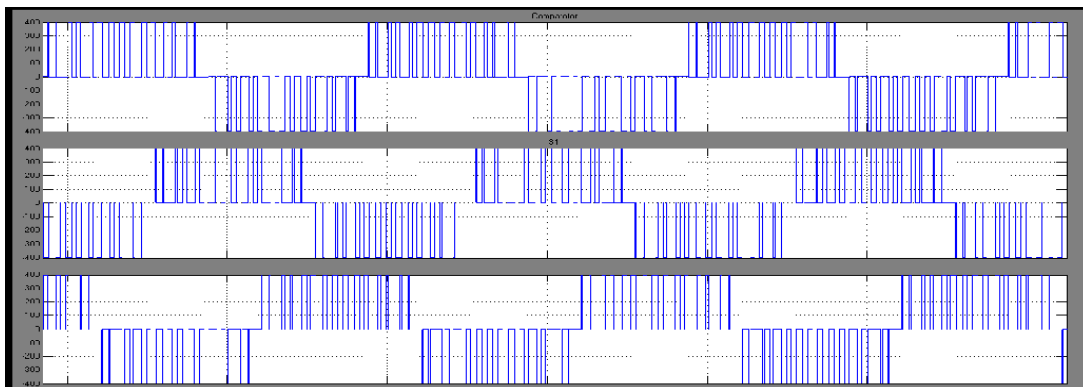


Fig.7.Output voltage waveform

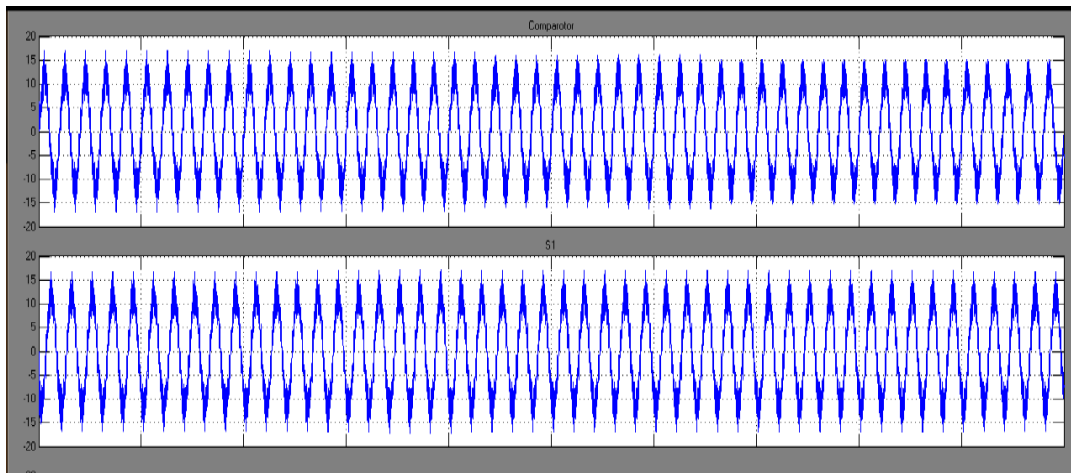


Fig.8.Output current waveform

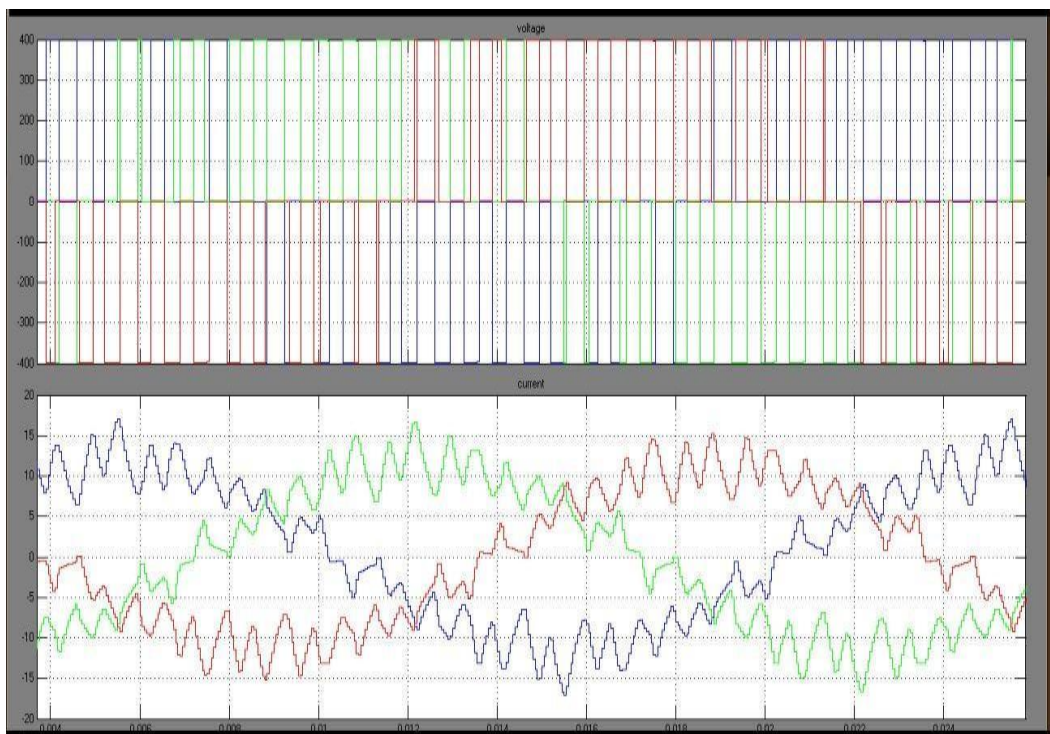


Fig.9.Output voltage and current waveform

A common triangular carrier to generate PWM pulses for the three phases. The carrier frequency signal is very high compared to the modulating signal. The magnitude and frequencies of the fundamental component in the line side are controlled by changing the modulating signal. It is simple and linear between 0% and 78.5% of six step voltage values, which results in poor voltage utilization. Voltage range has to be extended and harmonics has to be reduced.

#### 4. RPWM Based Three Phase Inverter

Pulse Width Modulation (PWM) waveforms are widely used in adjustable speed drives for

AC and DC motors. By varying the ratio between high and low states, known as the duty cycle, the user can vary the average voltage applied to the motor, and hence control its speed. The simplicity of this technique, coupled with the wide availability of PWM peripherals on microcontrollers, has made this the standard for implementing adjustable speed drives. However, there is a drawback in implementing drives in this manner. The switching frequency of the PWM will introduce a high harmonic content into the motor current, resulting in emission of both acoustic and electromagnetic noise. The harmonic structure of this noise, which is a series of tonal ‘combs’, is seen as a set of energy spikes at the fundamental switching frequency of the PWM, and it’s higher order harmonics.

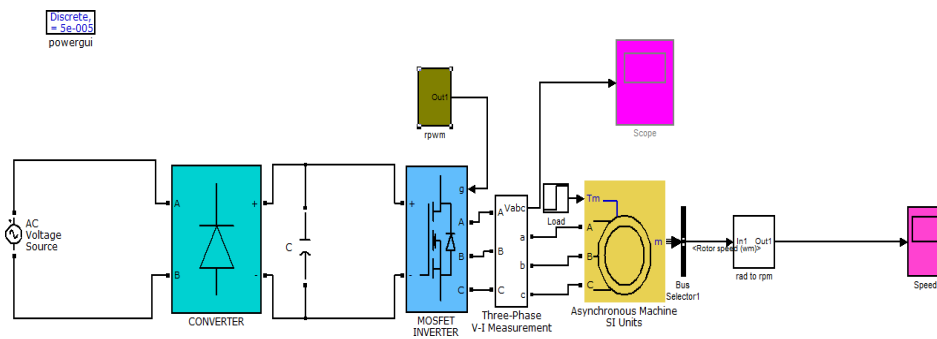


Fig.10. Matlab Simulink RPWM With Load

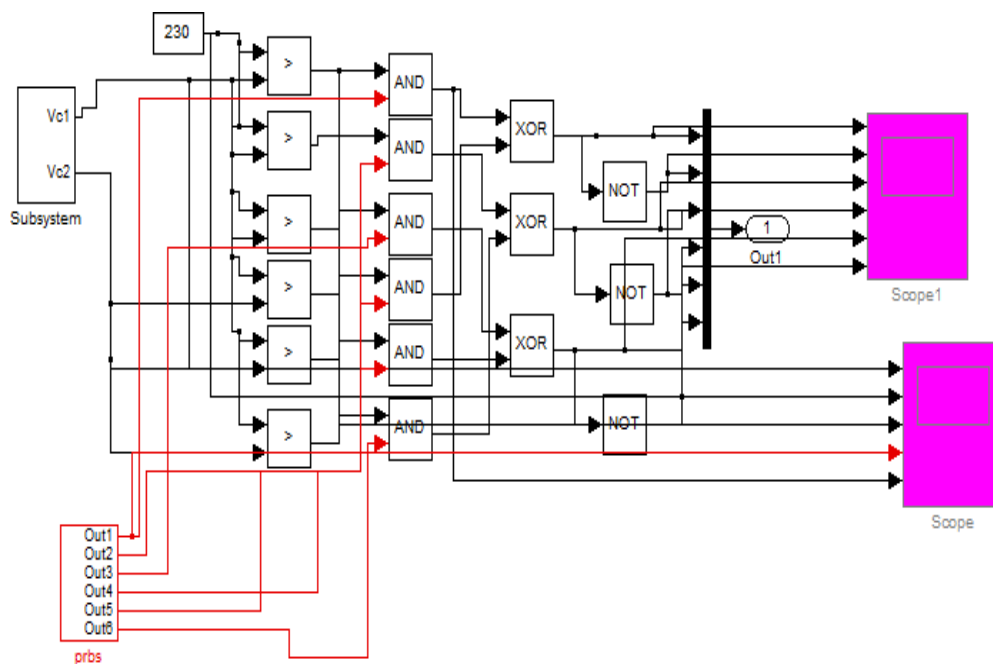


Fig.11. Matlab Simulink for RPWM Pulse



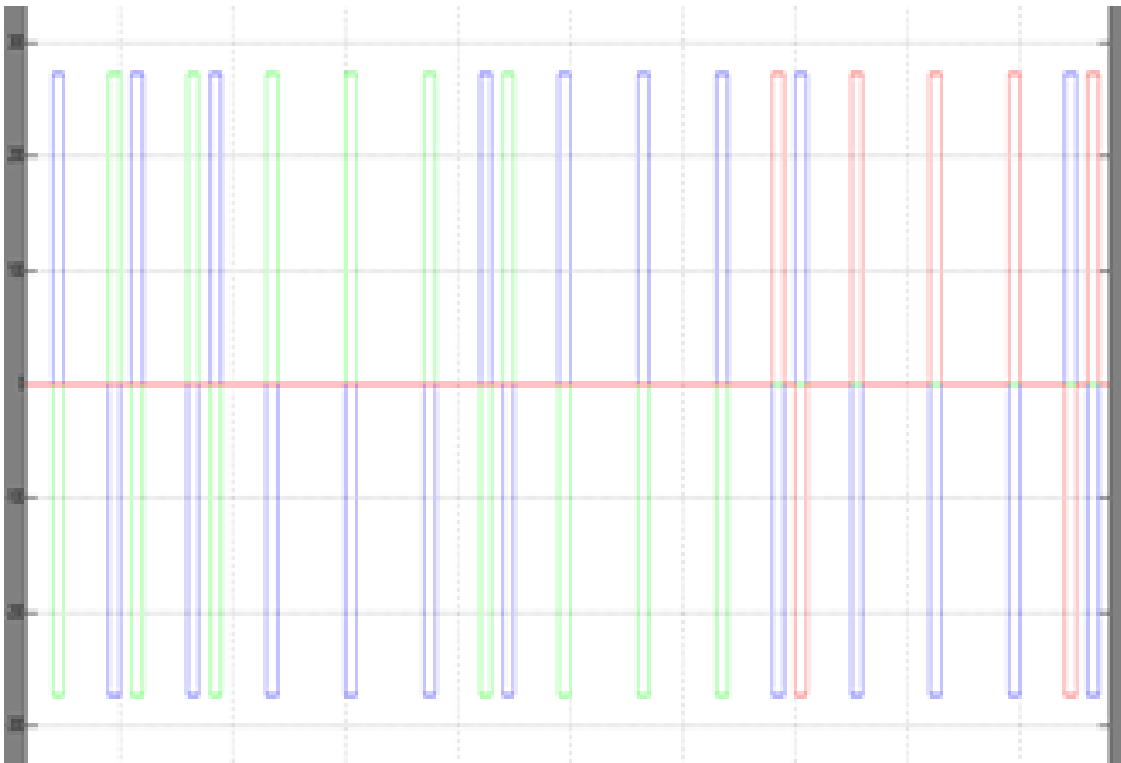


Fig.12.Output pulse (RPWM)

In order to achieve the random switching, both the high and low times are varied. Because this effect is derived by some deterministic technique, there will be a period in which the pattern of high and low times will repeat. If the ratio of this period relative to the shortest switching period is very high, this will spread any harmonics resulting from this period over a broad range of frequencies.

## 5. Simulation Results Parameter Discussion

### (i) Space Vector PWM

Input clock: 50MHz

Switching frequency: 10 kHz

PWM Output mode: Symmetrical PWM

Dead time: 1.2us

Filter inductance: 1.27mh

Filter capacitance: 0.25fu

### (ii) Triangle PWM Technique

Input voltage  $V_{dc} = 400$  V  $R = 10\text{ohm}$ , Inductance  $= 5 \times 10^{-3}$

Output voltage  $= 400$  V, output current  $= 15$  A.

### (iii) Random PWM

Time-domain waveforms are measured at  
5-V logic level

Fundamental frequency  $f = 50$  Hz,

Modulation index  $M = 0.8$

Triangular carrier  $f_c = 3 \pm 1 \text{ kHz}$ , PRBS=8bit and 2.5-A

## 6. Conclusion

Pulse width modulation techniques are used in variable speed motor drives of all types, and these techniques have many desirable characteristics with one undesirable characteristic. i.e. the primary switching frequency lead to losses, an effective low cost solution for this issue has been demonstrated in utilizing pseudorandom PWM technique. This technique which has continues pulse sequence lead a smooth control of load, and comparing to the previous two techniques this RPWM technique reduces the acoustic noise and harmonic distortion.

## References

1. M. Trzynadlowski, K. Borisov, Y. Li, and L. Qin, "A novel random PWM technique with low computational overhead and constant sampling frequency for high-volume, low-cost applications," *IEEE Trans. Power Electron.*, vol. 20, no. 1, pp. 116–122, Jan. 2005.
2. Ki-Seon Kim, Young-Gook Jung, and Young-Cheol Lim, Member, IEEE "A New Hybrid Random PWM Scheme" *IEEE TRANSACTIONS ON POWER ELECTRONICS*, VOL. 24, NO. 1, JANUARY 2009
3. J.-Y. Chai, Y.-H. Ho, Y.-C. Chang, and C.-M. Liaw, "On acoustic-noise reduction control using random switching technique for switch-mode rectifiers in PMSM drive," *IEEE Trans. Ind. Electron.*, vol. 55, no. 3, pp. 1295–1309, Mar. 2008.
4. G. D. Holmes and T. A. Lipo, *Pulse Width Modulation for Power Converters: Principles and Practice*. Hoboken, NJ: Wiley, 2003
5. Laslo Mathew, Member, IEEE, Florin Lungeanu, Dezso Sera member, IEEE, Peter Omand Rasmussen, Member, IEEE, and John K. Pedersen, Senior Member, IEEE "Spread Spectrum Modulation by Using Asymmetric-Carrier RANDOM PWM", *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS*, VOL59, NO.10, OCTOBER 2012
6. Yen-Shin Lai, Senior Member, IEEE, Ye-Then Chang, IEEE and Bo-Yuan Chen, Student Member, IEEE "Novel Random Switching Pwm Technique With Constant Sampling Frequency And Constant Inductor Average Current For Digital-Controlled Converter" *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS*, VOL29, NOV.10, 2012

7. Young-Cheol Lim, *Member, IEEE*, Seog-Oh Wi, Jong-Nam Kim, Gook Jung “A Pseudorandom Carrier Modulation Scheme” IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 25, NO. 4, 797 APRIL 2010.
8. Haifeng Lu, Wenlong Qu, Xiaomeng Cheng, Yang Fan, and Xing Zhang “A Novel PWM Technique With Two-Phase Modulation” IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 22, NO. 6, 2403 NOVEMBER 2007.