iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VI **Month of publication:** June 2017

DOI:

Volume 5 Issue VI, June 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

SVPWM Controlled Three Phase VSI Based Induction Motor Drive

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Abstract: In modern days variable voltage and frequency for AC drives is obtained from Voltage Source Inverter. The most popular PWM techniques for VSI are carrier pulse PWM and Space vector pulse width modulation used to vary the voltage and frequency. The space vector pulse width modulation is preferred because of its easy digitalization and DC bus voltage utilization. In this paper a detailed implementation steps for space vector pulse width modulation is given and implemented by using MATLAB/SIMULINK.
Keywords— PWM, SVPWM, VSI, DC voltage utilization, AC Drives.

I. INTRODUCTION

In these days the generation of electricity mainly depends on the non-renewable energy sources. In future the generation of power depends upon the renewable energy sources like wind, water, solar etc. Majority of sources generates DC power only. So a converter is needed to convert the DC to AC called as inverter. By choosing appropriate modulation index and controlling of static switches of the inverter, the voltage and frequency levels at In order to vary the output voltage and frequency of the inverter most popular PWM techniques are carrier based PWM and Space Vector pulse Width modulation (SVPWM). There is an increase in trend of utilizing SVPWM because of its easy digital implementation and maximum utilization of DC bus voltage. The main focus of this paper is to implement simple MATLAB/SIMULINK model. The reason for choice of MATLAB/SIMULINK as a development tool is because it is the most important and widely used simulation software in Electrical Engineering courses. Firstly three phase inverter is presented on the basis of space vector representation. This is followed by the basic principle of SVPWM. Finally a MATLAB/SIMULINK model for the SVPWM controlled three phase inverter is presented for induction motor drive.

II. THREE PHASE VOLTAGE SOURCE INVERTER

Three phase inverters are normally used for high power applications. The advantages of a three phase inverter are: The frequency of the output voltage waveform depends on the switching rate of the switches and hence can be varied over a wide range. The direction of rotation of the motor can be reversed by changing the output phase sequence of the inverter. The ac output voltage can be controlled by varying the dc link voltage. The general configuration of a three phase DC-AC inverter is shown in Figure1. Two types of control signals can be applied to the switches:180^0 conduction mode and 120^0conduction mode

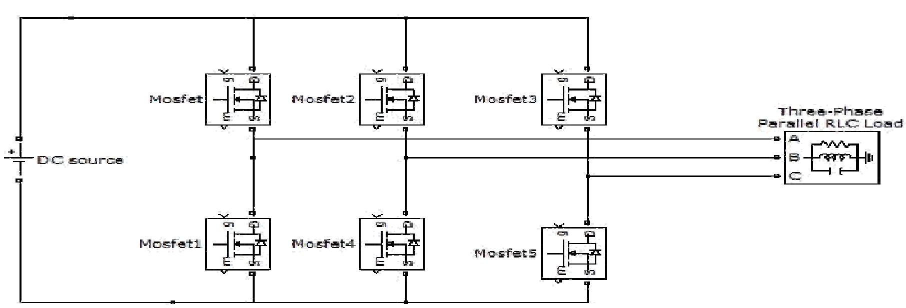

FIGURE-1:THREE PHASE VSI

A. *Svpwm Principle*

For easier study on PWM techniques, values on three phase (a-b-c) coordinate system are usually transferred to that on $\alpha\ \beta -$ plane. In the SVPWM technique, the referring voltage vector is V_{ref} that rotates in the space with an angular frequency of w is selected as the control instruction. When it arrives in one of the 6 sectors 1~6, two effective voltage space vectors nearest to V_{ref} as well as one of the two null vectors (V_0 or V_1) are selected to equal V_{ref} by means of different operating time of various vectors, and the power

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switches in the inverter are drove under the switch conditions corresponding to selected vectors, (000, 001,...or 111), “0” for off and “1” for on Reference [2]. The inverter outputs a cycle of sinusoidal voltage when V_{ref} has made one revolution in space.

B. Space Vector Implementation In Three Phase Inverter

The Circuit Model for a typical three phase voltage source PWM inverter is shown in figure2.Here, S1 to S6 are the six power switches that shape the output waveform. When an upper transistor is switched ON, the corresponding lower transistor is switched OFF. The ON – OFF states of the upper transistors S1, S3 & S5 determines the Voltage vector state.

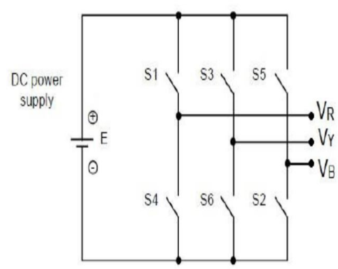

FIGURE 2

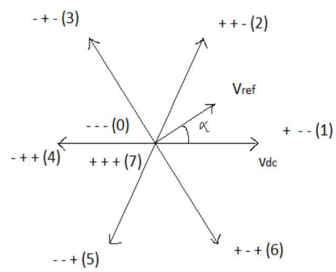

FIGURE 3

Figure 3 denotes the rotation as the switches are switched ON and OFF. Only the upper transistor switching is considered here. So „+ - -„denotes S1=ON, S3=OFF & S5=OFF and so on.As per the Figure 4.3 shows Vector space location of every state denoted along with their corresponding switching states of the upper switches of the circuit.

Main Sectors and Voltage Vector states

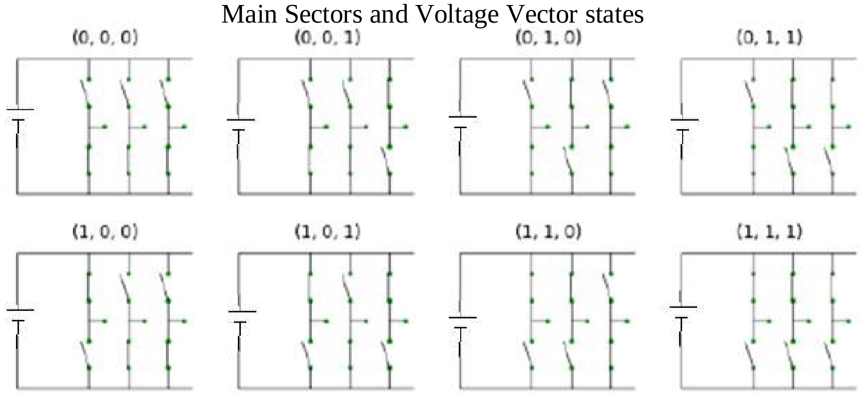

FIGURE 4 Equivalent switching pattern of space vectors

Voltage vectors created divides the cycle into 6 sectors as observed in figure 4.4. Here 6 vector states forms the six corners of a hexagon structure around which the reference voltage revolves. Other 2 states namely, (111) & (000) are null vectors as produce no effective output. The rotating takes the intermediate values between each sector using the adjacent space vector as d-q plane as shown in figure 5.

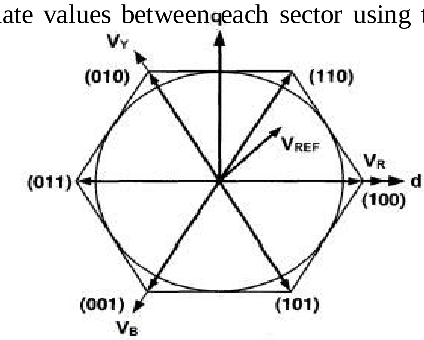

FIGURE 5 Space Vector diagram

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C. SVPWM Algorithm

Step 1: Determine V_d , V_q, V_{REF} and angle (α)

Here, V_{REF} and angle (α) are obtained through V_d & V_q which are calculated through the following matrix,

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} 3/2 & 0 & 0 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} VRN \\ VYN \\ VBN \end{bmatrix}$$

Where $\alpha=\tan^{-1}(V_d/V_q)$ and $|V_{REF}|=\sqrt{(V_d^2+V_q^2)}$

Step 2. Determine time duration T1, T2, T0

Switching time is calculated based on the Volt-Second integral i.e

$$V_{REF}.T_s=V_1.T_1+V_2.T_2+V_z.T_z$$

$$T_s=T_1+T_2+T_z$$

giving result as $T_1=(3/2).m[(T/\sqrt{3})\cos\alpha-(T/3)\sin\alpha]$

$$T_2=mT\sin\alpha$$

Where $m=V_{REF}/(V_d/\sqrt{3})$

Step 3. Determine the switching time of each transistor (S1 to S6)

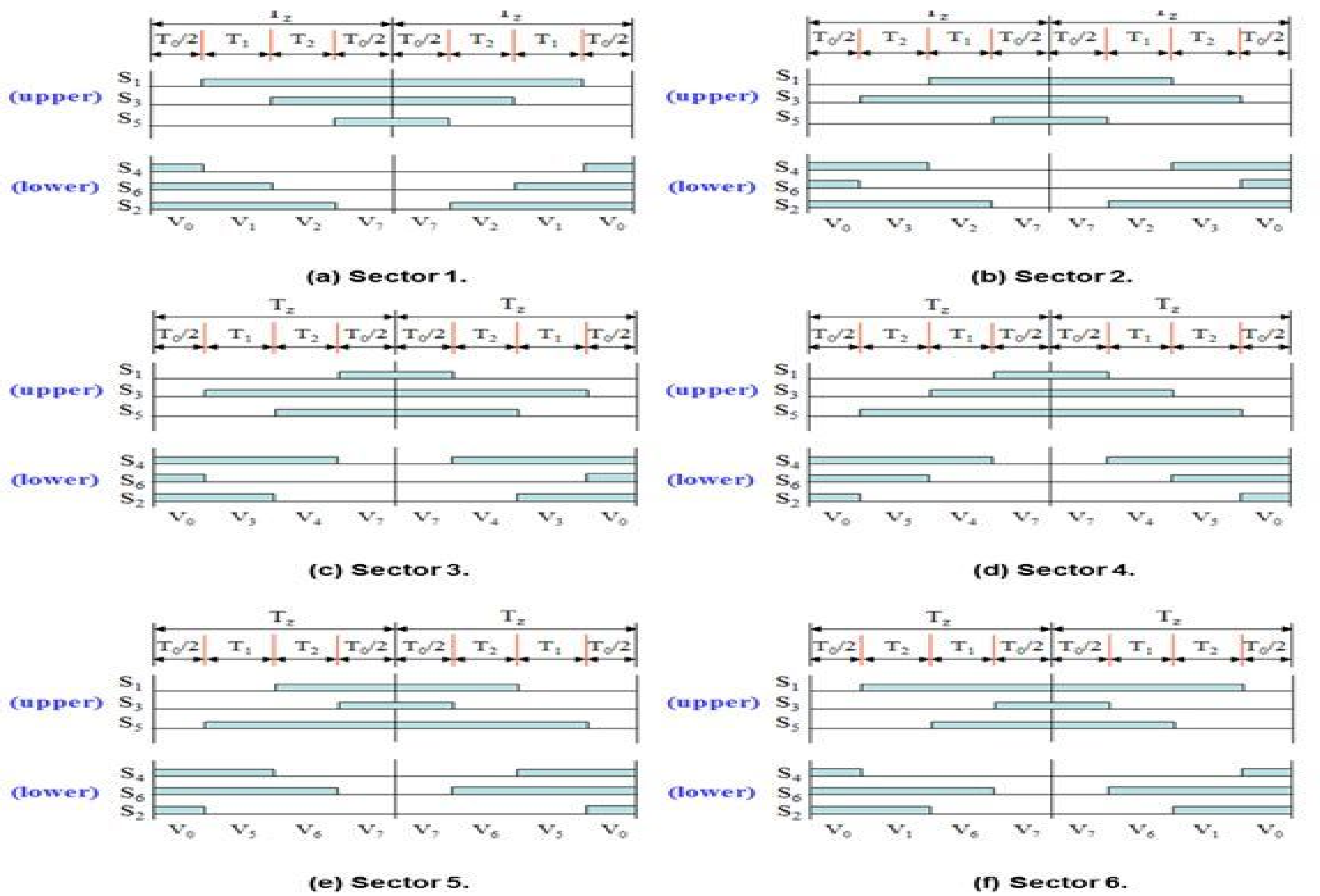

FIGURE 6: Sector switching pattern

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Switching time for every vector state (e.g. T1 or T2 for sector 1) is calculated and the corresponding switches which defined the state (e.g. state "+ - -" or „100" is defined as

S1, S6 & S2 as positive while S4, S3 & S5 as closed) are triggered for the calculated time. This is done for all the required switches and their respective operation is shown in figure 4.10. and respective switching time is shown in table 4.1,

Sector-wise switching pattern and Switching Timetable can be determined by +following graphical representation of the switching sequence during each sector. Their values are calculated dynamically as mentioned in the previous steps

Sector	Upper Switches (S_1, S_3, S_5)	Lower Switches (S_4, S_6, S_2)
1	$S_1 = T_1 + T_2 + T_0/2$ $S_3 = T_2 + T_0/2$ $S_6 = T_0/2$	$S_4 = T_0/2$ $S_6 = T_1 + T_0/2$ $S_2 = T_1 + T_2 + T_0/2$
2	$S_1 = T_1 + T_0/2$ $S_3 = T_1 + T_2 + T_0/2$ $S_5 = T_0/2$	$S_4 = T_2 + T_0/2$ $S_6 = T_0/2$ $S_2 = T_1 + T_2 + T_0/2$
3	$S_1 = T_0/2$ $S_3 = T_1 + T_2 + T_0/2$ $S_5 = T_2 + T_0/2$	$S_4 = T_1 + T_2 + T_0/2$ $S_6 = T_0/2$ $S_2 = T_1 + T_0/2$
4	$S_1 = T_0/2$ $S_3 = T_1 + T_0/2$ $S_5 = T_1 + T_2 + T_0/2$	$S_4 = T_1 + T_2 + T_0/2$ $S_6 = T_2 + T_0/2$ $S_2 = T_0/2$
5	$S_1 = T_2 + T_0/2$ $S_3 = T_0/2$ $S_5 = T_1 + T_2 + T_0/2$	$S_4 = T_1 + T_0/2$ $S_6 = T_1 + T_2 + T_0/2$ $S_2 = T_0/2$
6	$S_1 = T_1 + T_2 + T_0/2$ $S_3 = T_0/2$ $S_5 = T_1 + T_0/2$	$S_4 = T_0/2$ $S_6 = T_1 + T_2 + T_0/2$ $S_2 = T_2 + T_0/2$

Table 1 sector time calculation

C. Main Simulation Block Diagram

The below is the main simulation block diagram of a three phase VSI controlled by SVPWM technique. Here the VSI is fed by a 400V dc supply and a three phase load is connected to it. The gating pulses are generated in the SVM block and three reference pulses are taken with a phase shift of 120 degrees each. The SVM block generates the required pulses and also shows the sector in which the reference vector lies. A separate block named outage is used to show the line and phase voltage produced from the VSI. There are different scope block showing the load voltage and line current of load.

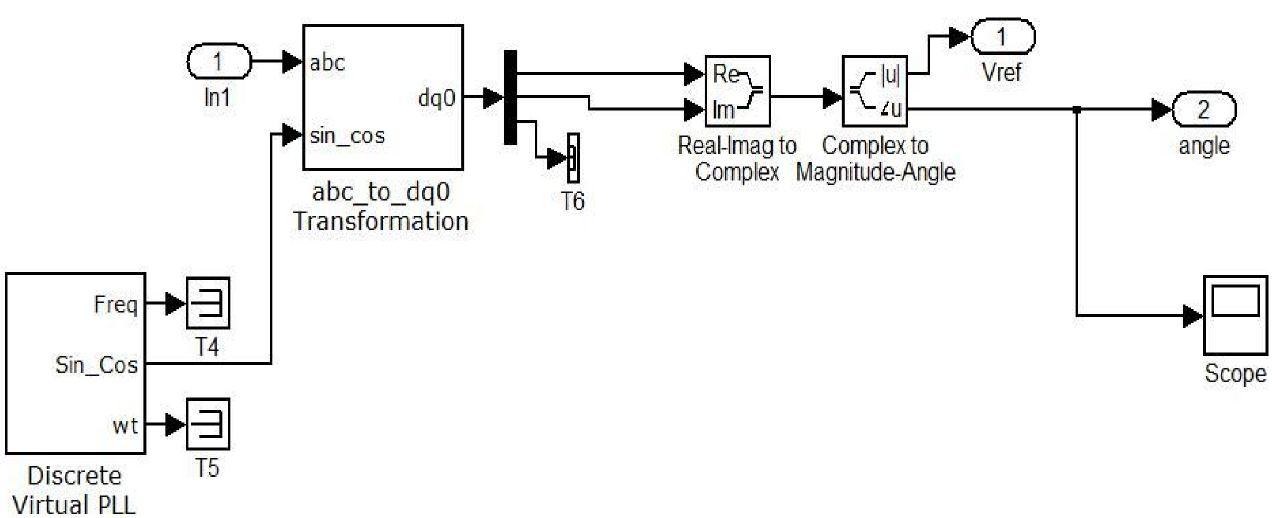

FIGURE 7: MAT LAB / SIMULINK Block digram of SVPWM based VSI

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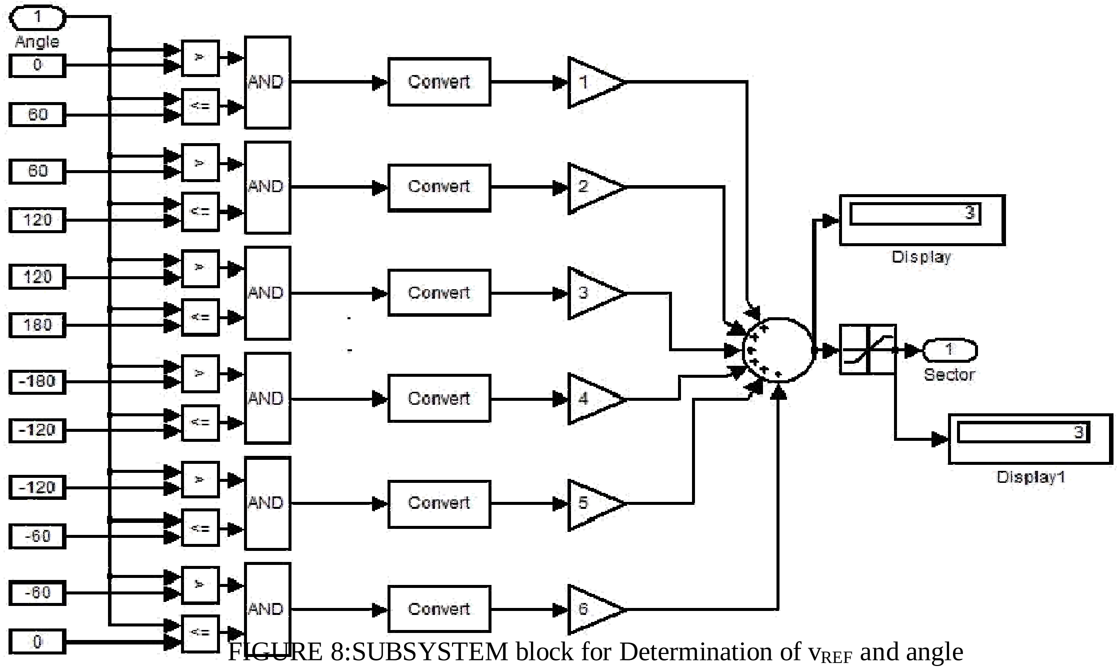

FIGURE 8:SUBSYSTEM block for Determination of v_{REF} and angle

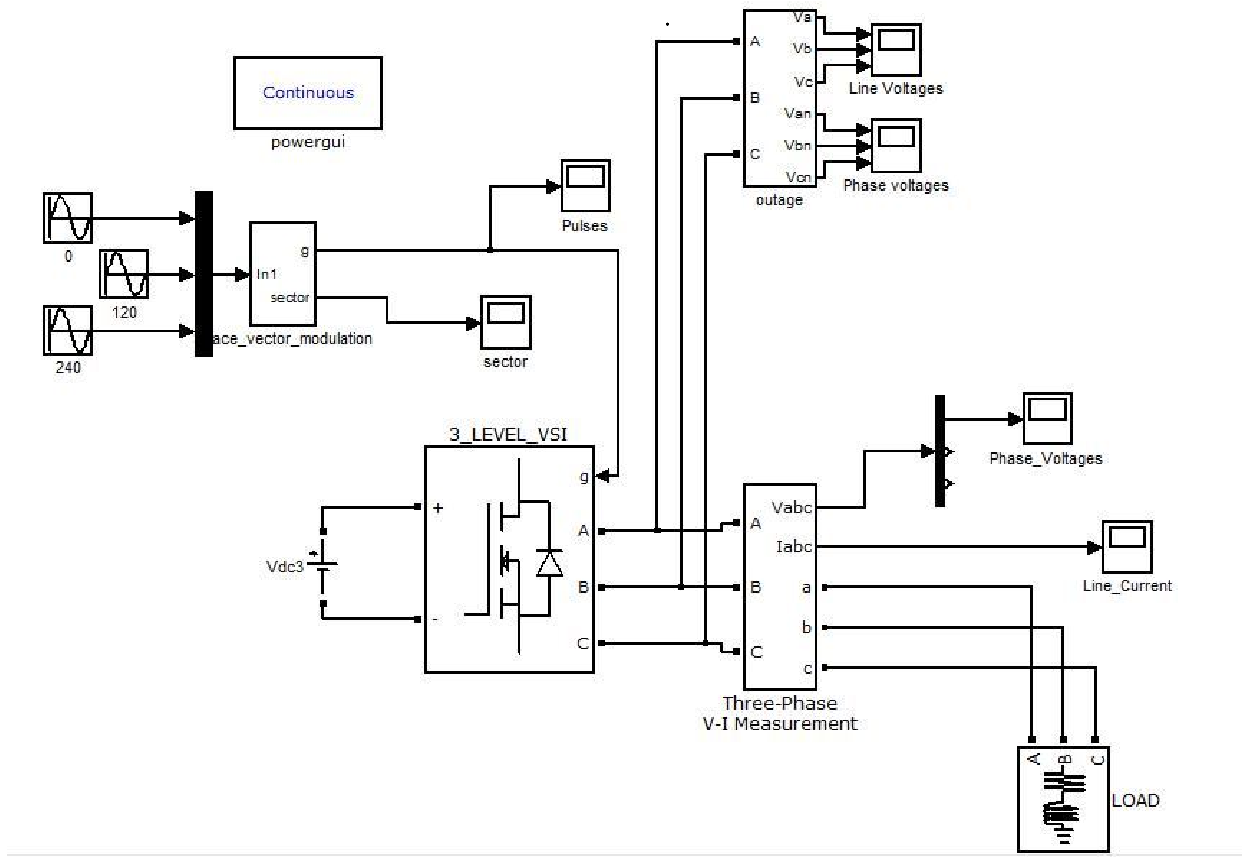

figure 9:sub block of mat lab / simulink svpwm model for sector calculations

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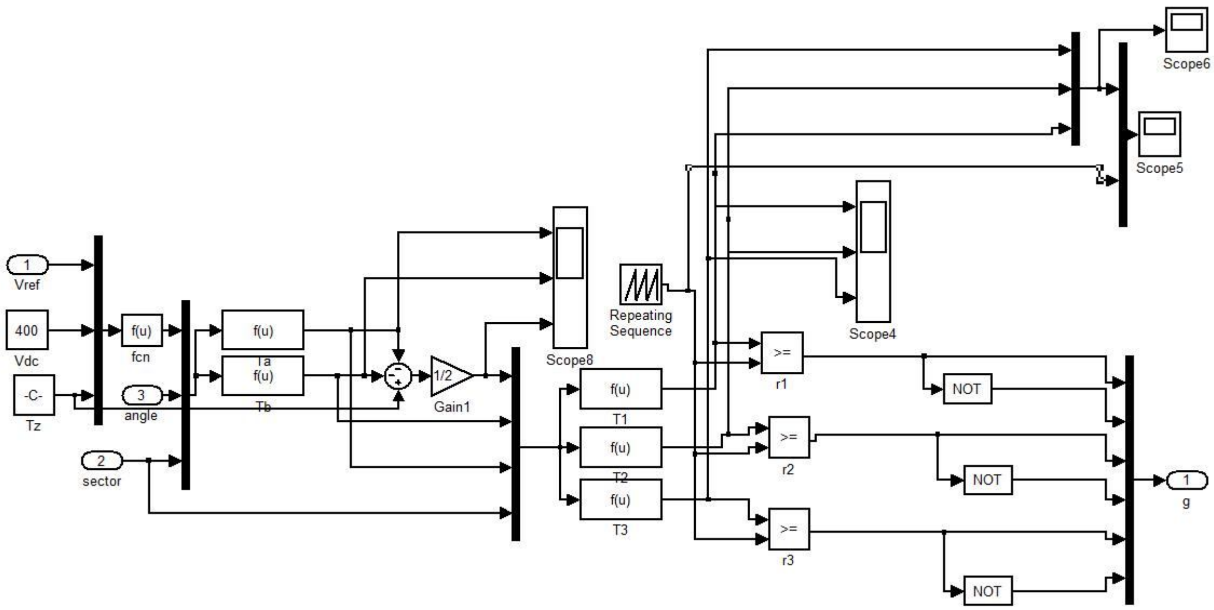

FIGURE 10:BLOCK for Gating pulses

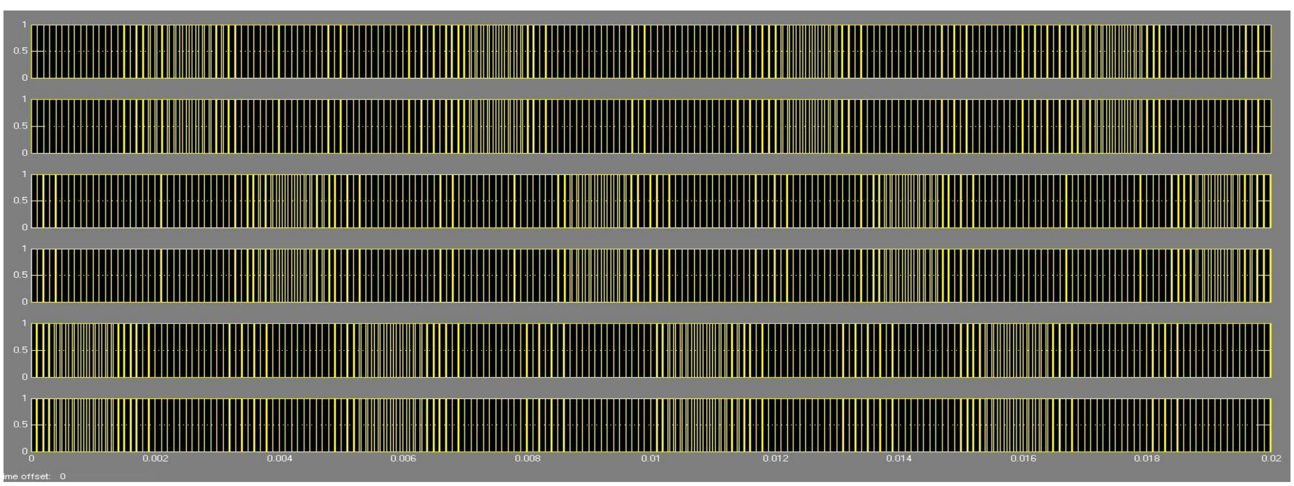

FIGURE 11:Switching pulses for each switch

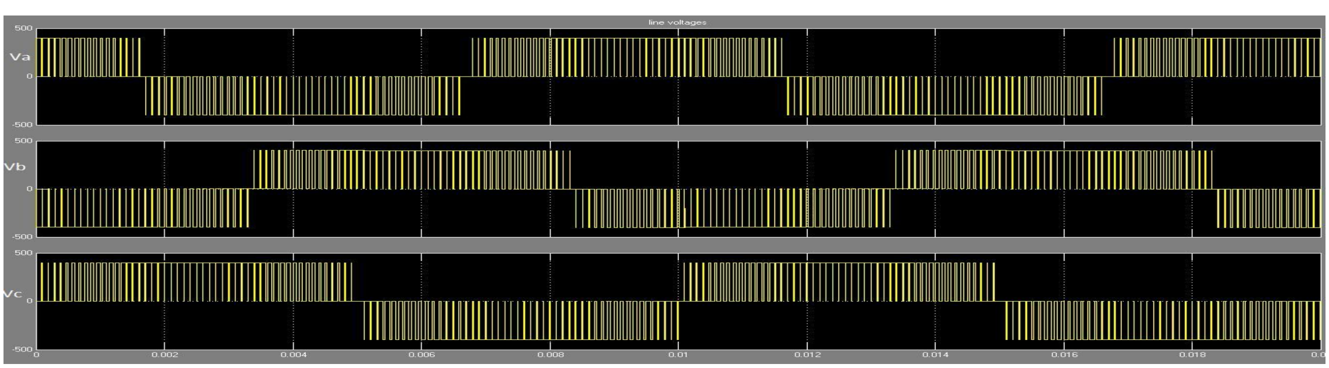

FIGURE 12: Output line Voltage of VSI

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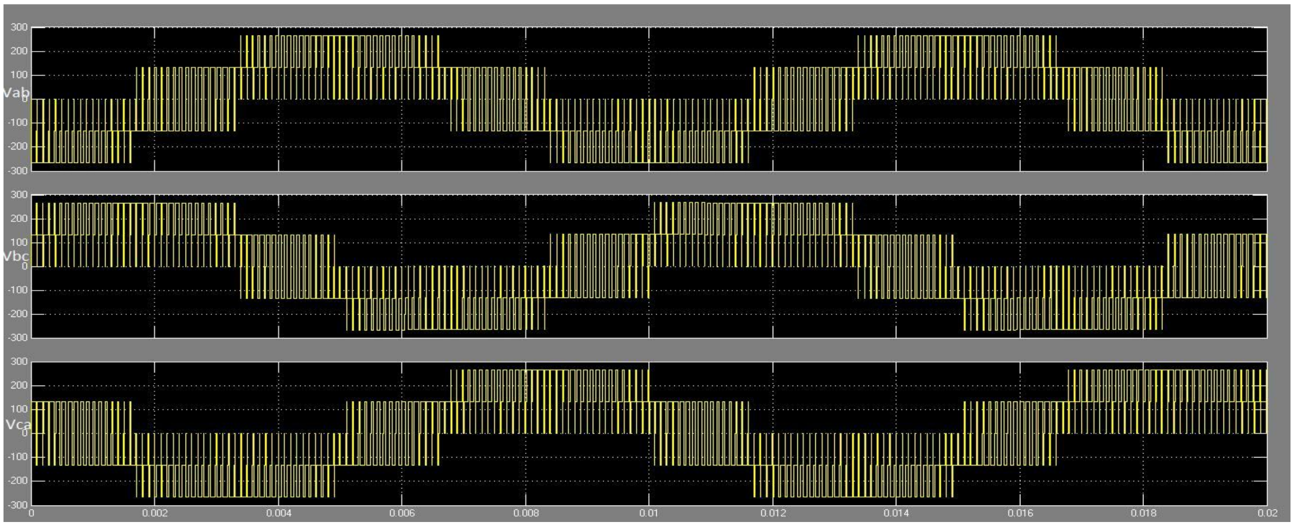

FIGURE 13: Output line Voltage of VSI

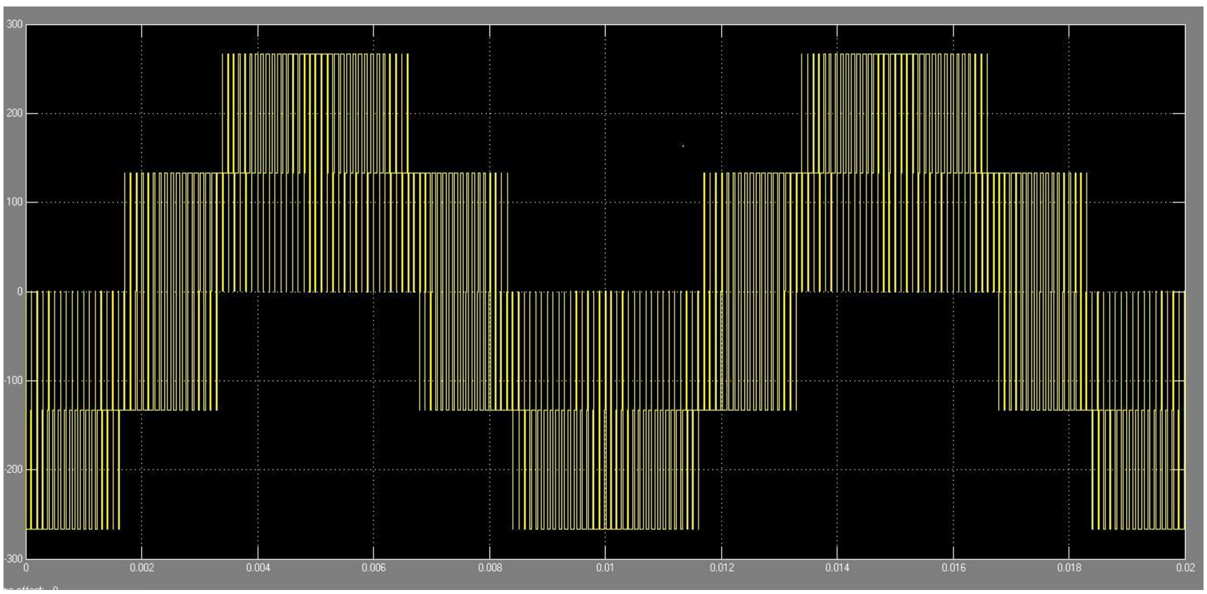

Figure14: Load phase voltage

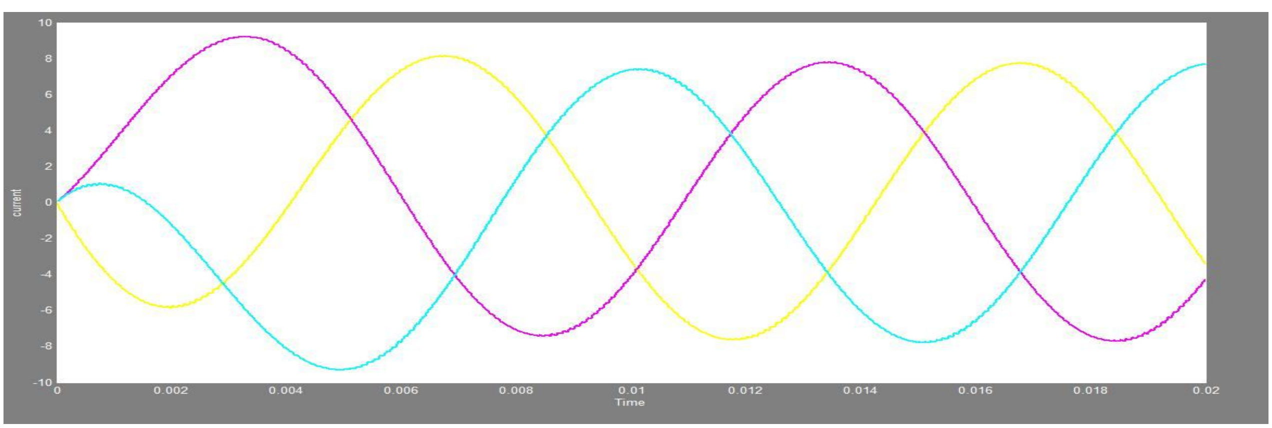

Figure15: Load current

III. CONCULSION

SVPWM is used for controlling the three phase inverter for providing more efficient supply voltage to the load. This method is a more sophisticated technique for generating a fundamental sine wave that provides a higher voltage to the motor and lower total harmonic distortion (THD).

A MATLAB/Simulink based model for implementation of SVPWM is presented. The step development is reported. The presented model gives an insight into SVPWM. The proposed three level VSI produces a line voltage of 400V AC supply for a DC input supply of 400V. The produced line voltage is a three level output voltage and the phase voltage is a five level voltage with amplitude of 270V.

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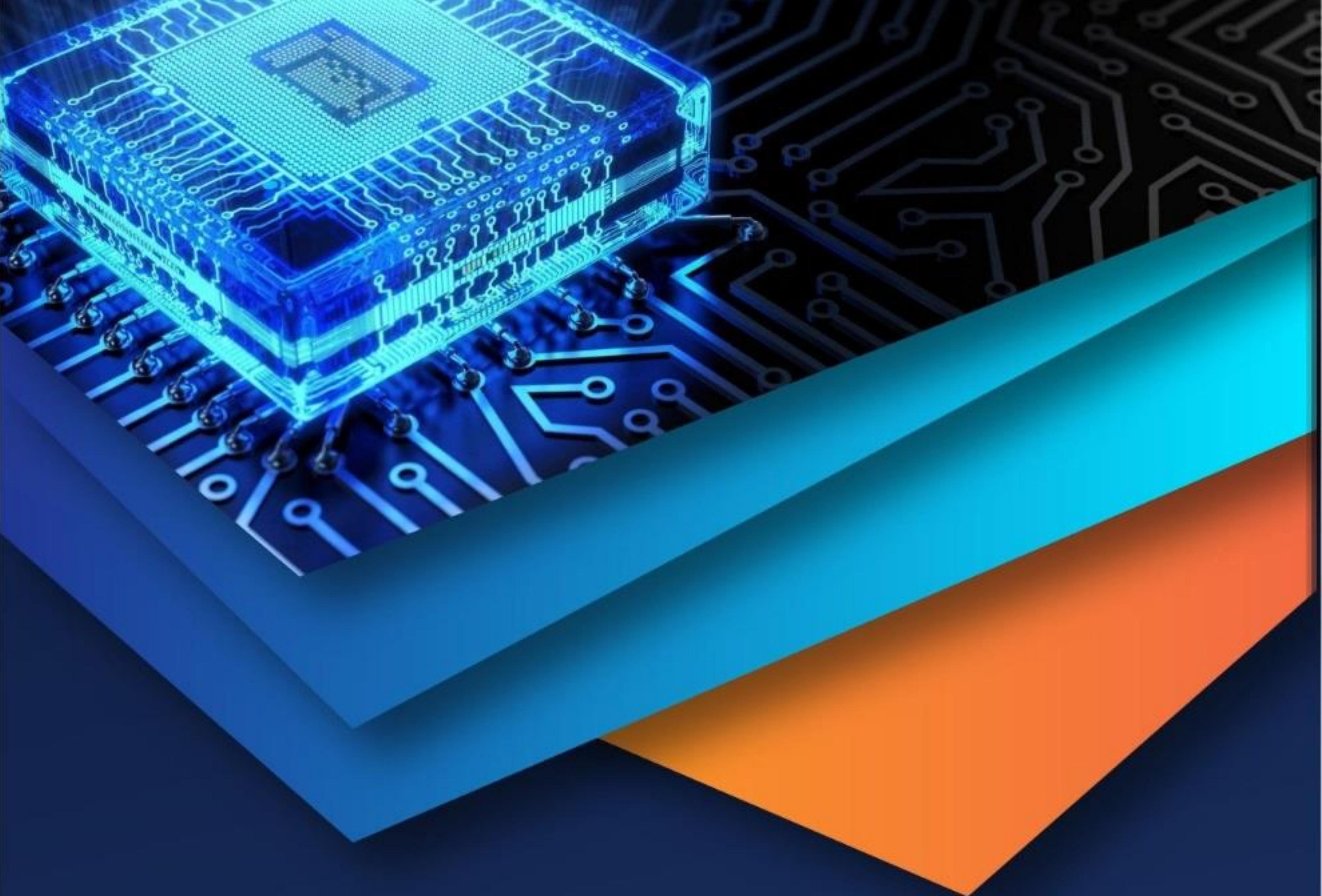

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