SVPWM Based Step-Up Inverter

Jonnalagadda K Sri Ganesh
Electrical Electronics Engineering
K L University

K. Bhargav Ram Uday
Electrical Electronics Engineering
K L University

B. Kiran Babu
Asst. Professor, EEE
K L University

Abstract

In a normal inverter the output voltage is boosted by means of a transformer so as to meet the load voltage. In the present topology an inverter has been designed which increments the voltage at the input itself, so the use of transformer is eliminated at output. To reduce the level of harmonic content Space Vector Pulse Width Modulation (SVPWM) is used. To describe the operating principle and control the paper focuses on running a 3-phase induction motor fed from the output of the inverter.

Keywords: *Switched Capacitor Step-up Converter, Space Vector Pulse Width Modulation, Fast Fourier transform.*

1. Introduction

A conventional square wave inverter has the disadvantage of getting lower order harmonics at a high level. To counter this disadvantage a number of pulse width modulation techniques like bipolar sinusoidal pulse width modulation, unipolar sinusoidal pulse width modulation, selective harmonic elimination and harmonic injection were implemented since decades, but the harmonic content is not reduced completely. To minimize the harmonic content approximately to zero Space Vector Pulse Width Modulation technique has been developed. The proposed inverter uses SVPWM technique.

In a normal H-Bridge inverter, for an applied dc voltage of a certain magnitude we get the ac voltage of same magnitude at the output of inverter. A step-up transformer is needed to boost the voltage to the level that is required by load. This increases the cost and size of the inverter. To rout out this disadvantage switched capacitor topology has been used that raises the voltage at the input of inverter. Hence ac voltage that is greater than the applied dc voltage is obtained without the use of transformer.

The first section of this paper gives introduction to the topic followed by the section describing about the switched capacitor step-up converter. The third section is about SVPWM technique, fourth section deals with the design of inverter using the above technologies to drive a 3-phase induction motor. Fifth section contains the simulation results and final conclusion in the sixth section.

2. Switched Capacitor Step-up Converter (SCSC):

A switched capacitor step up converter uses the capacitor switching to boost the output voltage to required value. This is done by charging capacitors in parallel and discharging them in series. The circuit of SCSC is shown in figure 1.

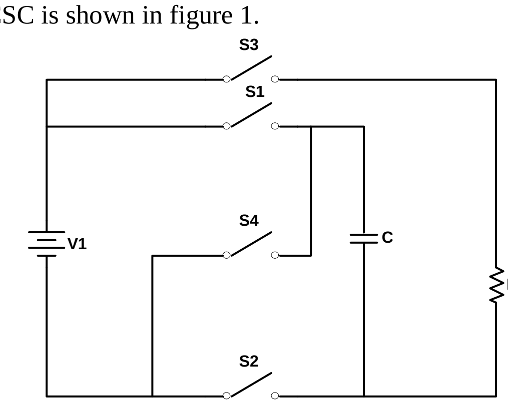

Figure 1: Step up converter

When the switches S_1, S_2 are closed the capacitor is charged to a voltage of $V_{d,}$ for a time t_1.

$$V_c = V_d \quad (1)$$

During this time S_3, S_4 are open .When the switches S_3, S_4 are closed the voltage across the load is $V_d + V_c$ for a time t_2 as shown in figure 2.

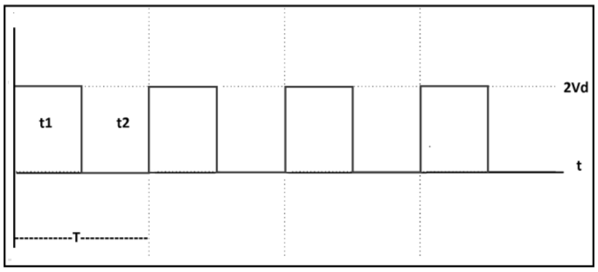

Figure 2: Output of Step up converter

$$V_L = V_c + V_d \tag{2}$$

$$V_L = V_d + V_d = 2V_d \tag{3}$$

Thus the voltage is boosted. Here we observe that as the number of capacitors increase, the output voltage also increases.

3. Space Vector Pulse Width Modulation (SVPWM)

By using SVPWM technique harmonics are eliminated in the output wave form, another advantage of this SVPWM technique is dc bus utilization can be increased up to 15%. Thus it proves itself to be more reliable over sinusoidal pulse width modulation.

3.1 Algorithm for SVPWM:

1) The sector in which the tip of the reference sector is situated is to be determined from the instantaneous phase references (V_a, V_b and V_c) as shown in figure 3.

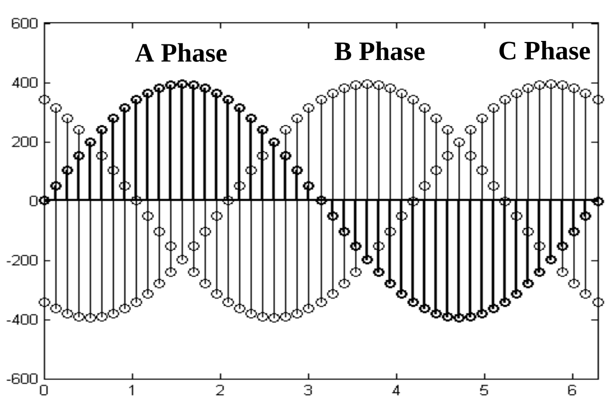

Figure 3: Three Phase reference voltages

a) V_a, V_b, V_c are converted to V_α, V_β.

b) Reference voltage magnitude and its angle with respect to α axis are calculated as below.

$$V_{ref} = \sqrt{(V_\alpha^2 + V_\beta^2)} \tag{4}$$

$$\theta = Tan^{-1}(V_\beta / V_\alpha) \tag{5}$$

c) Reference angle in a particular sector is calculated as

$$\alpha = \theta - k\,(60^0);\ \text{k such that } \alpha < 60^0 \tag{6}$$

d) Sector number = $k + 1$

2) Computation of T_1, T_2 and T_0 using

$$T_1 = \frac{3}{2}(T_s)(V_{ref})(V_{dc})\frac{\sin(\pi/3 - \alpha)}{\sin(\pi/3)} \tag{7}$$

$$T_2 = \frac{3}{2}(T_s)(V_{ref})(V_{dc})\frac{\sin(\alpha)}{\sin(\pi/3)} \tag{8}$$

$$T_0 = T_s - (T_1 + T_2) \tag{9}$$

3) Based on the time calculations given in step 2 firing pulses should be given to switches S_1 to S_6 as shown in figure (4-9).

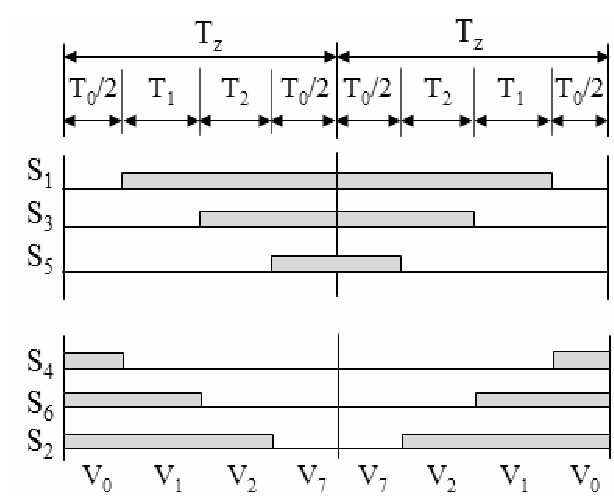

Figure 4: Switching sequence of sector 1

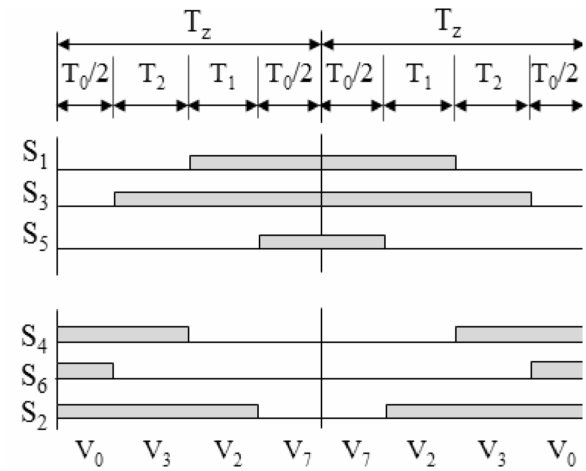

Figure 5: Switching sequence of sector 2

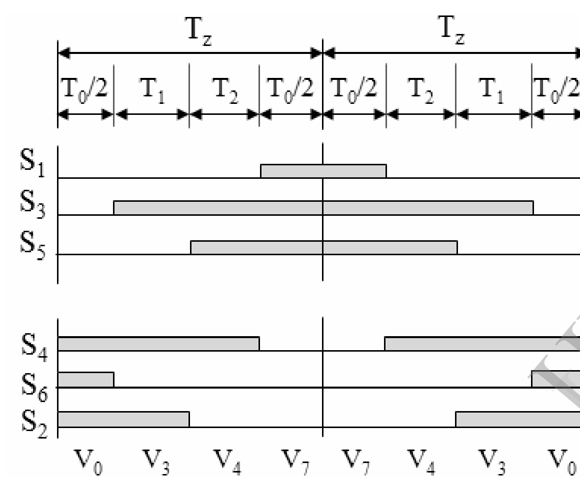

Figure 6: Switching sequence of sector 3

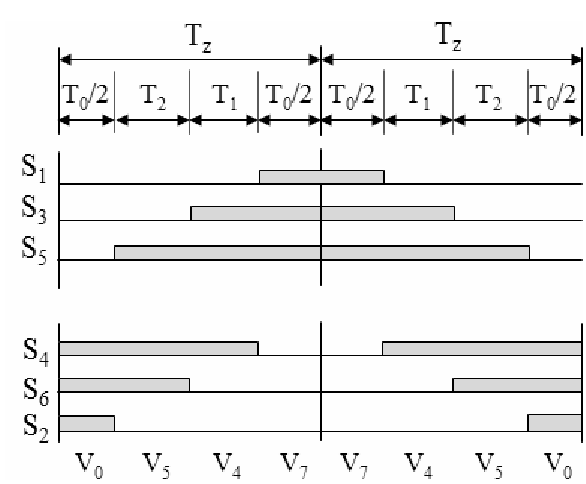

Figure 7: Switching sequence of sector 4

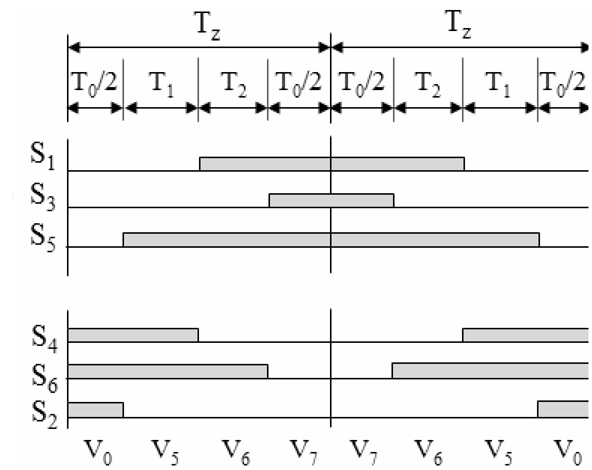

Figure 8: Switching sequence of sector 5

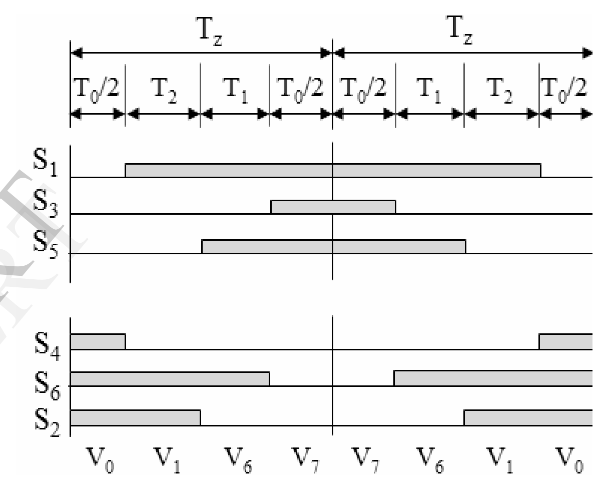

Figure 9: Switching sequence of sector 6

4. Design of proposed Inverter:

The novel inverter is a blended version of switched capacitor step-up converter and SVPWM inverter as shown in figure 10.

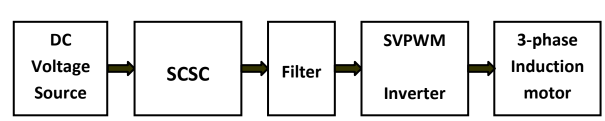

Figure 10: Block diagram of proposed system

The switched capacitor step-up converter which is connected to the input of inverter consists of two capacitors connected as shown in figure 11, using MOSFET's as input devices.

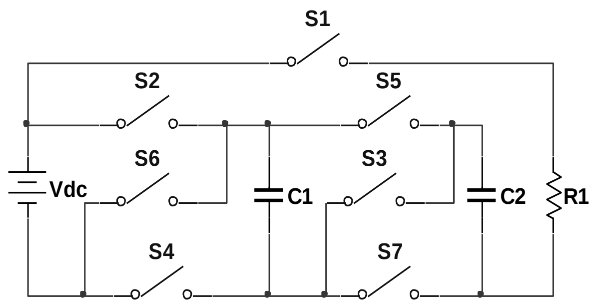

Figure 11: Switched Capacitor Step-Up Converter

The switching sequences of SCSC for feeding a normal two level inverter are:

1) Switches S_2, S_4, S_5 and S_7 are in closed condition and S_1, S_3 and S_6 are in open condition for 10 milliseconds to charge the capacitors C_1, C_2 in parallel.
2) Switches S_1, S_3 and S_6 are in closed condition and S_2, S_4, S_5 and S_7 are in open condition for next 10milliseconds to discharge the capacitors C_1, C_2 in series.

In this way the output voltage of SCSC is boosted to thrice the input. The obtained voltage consists of ripples which are suppressed by the use of filter shown in figure 12.

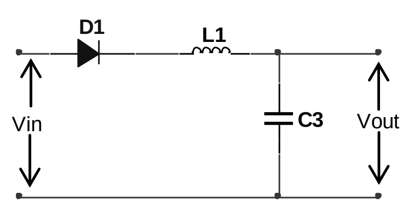

Figure 12: Filter Circuit

The diode D_1 is used to obstruct the negative peak from the inverter side such that the SCSC converter is protected. LC circuit acts as normal filter and gives pure dc voltage across the capacitor C_3.

The obtained dc voltage is applied to a three-phase inverter which is triggered by a SVPWM control circuit. Thus we get a three-phase ac voltage with V_{dc} as peak, across the inverter. The obtained ac voltage is given as input to an induction motor whose rated voltage is greater than or equal to the obtained ac voltage at the inverter output. The performance of inverter and motor are explained in the next section.

5. Simulation of the proposed system:

Simulation has been done using MATLAB (Simulink) for the proposed inverter feeding an induction motor with the following specifications:
Line voltage: 400V
VA Rating: 4000
Frequency: 50Hz
RPM: 1430
The complete Simulink model developed is given in Figure 13.

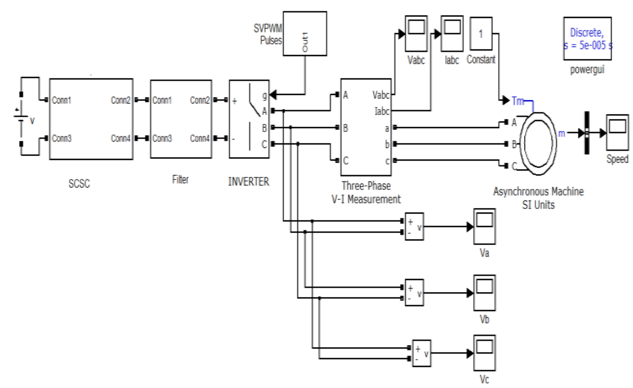

Figure 13: Simulink Model

5.1 Results and Discussion:

The proposed model has been simulated using MATLAB /Simulink toolbox. The variation of rotor speed with respect to time obtained from simulation is shown in figure 14.

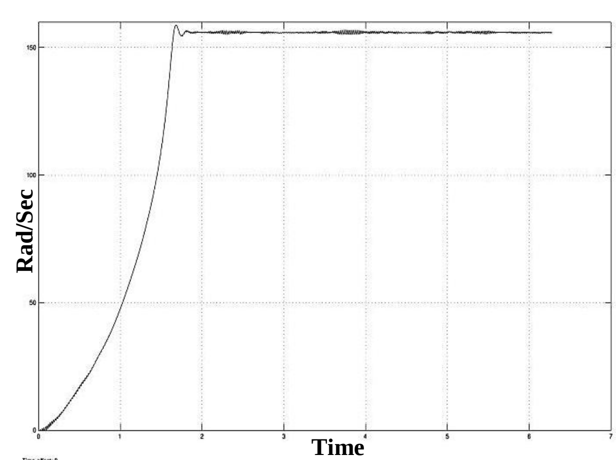

Figure 14: Variation of rotor speed w.r.t time

It is observed that speed became constant at 158 rad/sec i.e. 1508 rpm approximately.

The input voltage given to SCSC is 133.33 volts which is boosted to 400 volts (i.e. thrice the input). The waveforms of voltages V_a, V_b, V_c obtained from the SVPWM inverter are shown in figure (15-17).

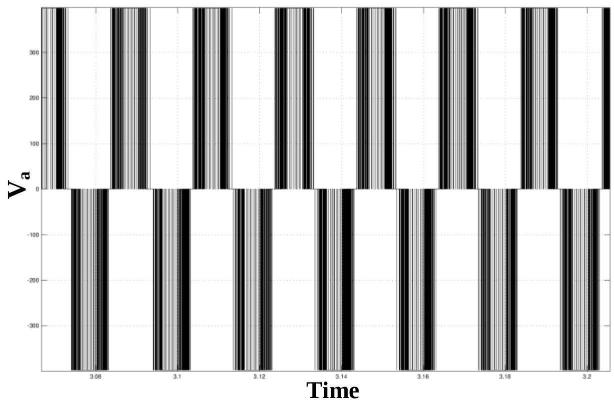

Figure 15: Phase 'A' Voltage (V_a)

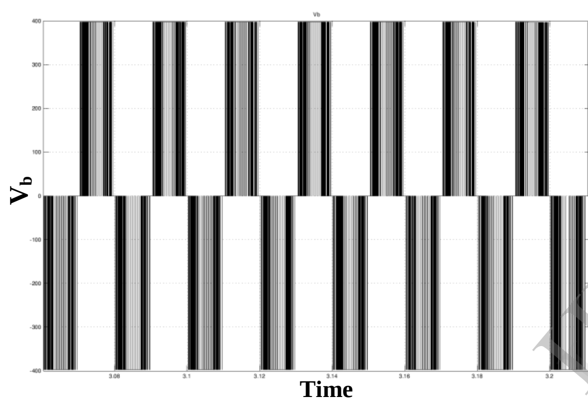

Figure 16: Phase 'B' Voltage (V_b)

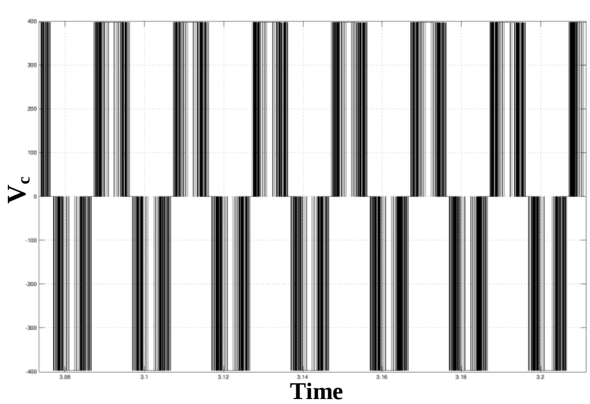

Figure 17: Phase 'C' Voltage (V_c)

The waveform of three-phase current drawn by three-phase induction motor measured at the output of the SVPWM inverter is shown in figure 18.

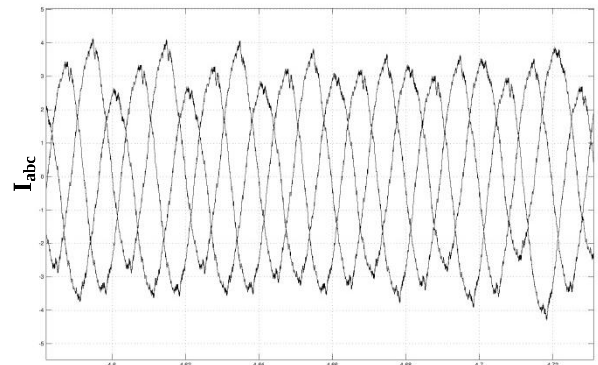

Figure 18: Three-Phase Currents

The reduction of harmonic content in Three-phase voltage is observed by doing Fast Fourier transform (FFT) analysis. The frequency Vs magnitude plot is shown in figure 19.

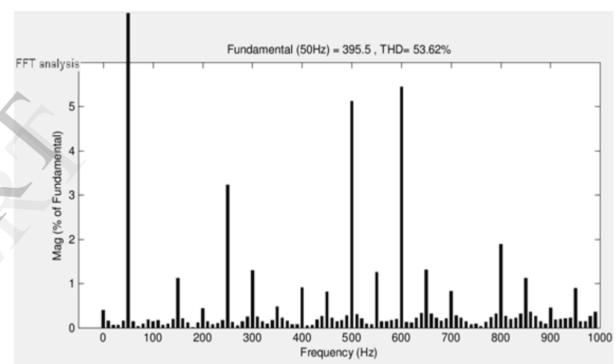

Figure 19: Frequency Vs magnitude plot

Total Harmonic Distortion: 53.62%
Third Harmonic: 0.11%
Fifth Harmonic: 0.25%
Seventh Harmonic: 0.08%
Eleventh Harmonic: 0.20%

6. Conclusion:

The combined performance of the switched capacitor step up converter and SVPWM inverter is presented in this paper. The harmonic content of the output voltage is greatly reduced by employing SVPWM technique and the voltage at the output of inverter is boosted by using switched capacitor technique. The analysis provides the information for effective use of proposed system.

7. References:

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