Design and Simulation of the Three Phase Z-source Inverter

Praveen Kumar M[1],
Assistant Professor, Dept. of EEE, ATME College of Engineering, Mysuru, Karnataka, India
Santhosh Kumar R[2],
Assistant Professor, Don Bosco Institute of Technology, Bengaluru, Karnataka, India
Vinod Kumar P[1]
Assistant Professor, Dept. of EEE, ATME College of Engineering, Mysuru, Karnataka, India

---***---

Abstract— *Inverter is basically an electrical device used extensively for various applications such as grid connected Wind Energy scheme or Photovoltaic scheme for a transition of dc to ac supply. Basically inverters are categorized as two current source inverter (CSI) and voltage source inverter (VSI). However, due to limitations of conventional inverter, the Z source inverter configuration is presented. The Z-source inverter design can also be used to dc-dc power conversion, ac-dc power conversion and also ac-ac power conversion. Z-source concept uses a distinctive impedance circuit for coupling source and power circuit. For better understanding of this concept, detailed design analysis and simulation for a simple Boost control technique is carried out.*

Keywords- *Inverter, three phase Z source, MATlab Simulink, voltage source inverter (VSI), simple Boost control, current source inverter (CSI).*

1. INTRODUCTION

The inverter are fundamentally a DC to AC converter mainly used in UPS, Induction motor drives etc. the conventional inverters are categorized into two types namely, i) Current source inverter ii) Voltage source Inverter. The Fig. 1 depicts the conventional three phase VSI. The main limitation of traditional inverter is that the VSI output voltage always less compared to the input supplied voltage and for many application higher voltages than the input is required. For getting higher voltage more the input voltage at the output, a boost converter is used. The Design, Simulation of Single phase Z-source Inverter are reported in [1]. The basic diagram of Z source inverter is described in [2][6]. Two control methods to get Highest voltage boost is described in [3]. The detailed working of Z-source inverter concept is reported in [4]. Z-source converter closed loop controller design using PWM technique is described in [5]. The design of LC filter to obtain pure sinusoidal voltage is described in [8]. [7] Presents the improved control of Z source inverter for speed control of induction motor.

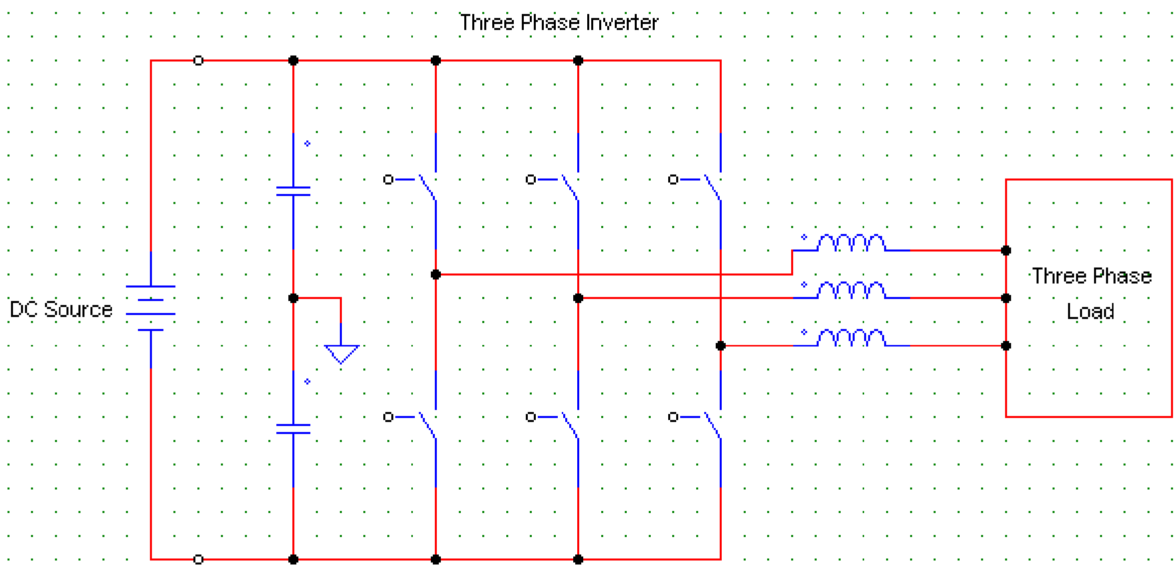


Fig. 1: Traditional three phase VSI

2. Three Phase Z-Source Inverter

Limitations of traditional inverter are overcome by the Z-source concept. The Figure 2 depicts three phase Z-source inverter configuration. It consists mainly of condenser and inductors, which is linked in X shape and this forms coupling medium between input DC source and converter

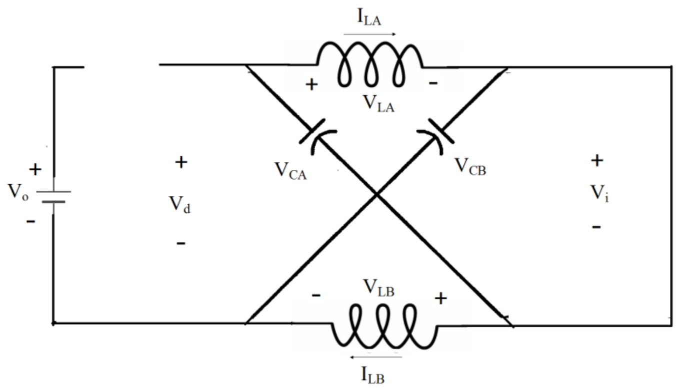


Fig. 2: Basic Three phase Z-source Inverter

This three phase Z-source inverter comprise of nine switching states, eight non-shoot-by active states and one Shoot-by zero state. *Z*-source inverter are less amplified by miss firing of devices due to EMI. The other benefits of the Z source concept is that the dead time can be eliminated which increases system reliability and waveform distortion

3. Modes of operation

The three-phase Z-source inverter consists of nine operating modes. Whereas the usual three-phase VSI has only eight modes. The three-phase Z-source inverter electrical circuit has an extra zero state when ends of the load are shorted by lower and upper switches of any phase leg or any two legs of phase, or on all three legs. This zero shoot-through mode is not present in the usual V-source inverter. The zero shoot-through state is possible by Z-source concept which provides the buck and boost operation of input DC voltage. The equivalent electrical circuit for the shoot through state and non shoot-through modes is depicted in Fig. 3 and Fig. 4.

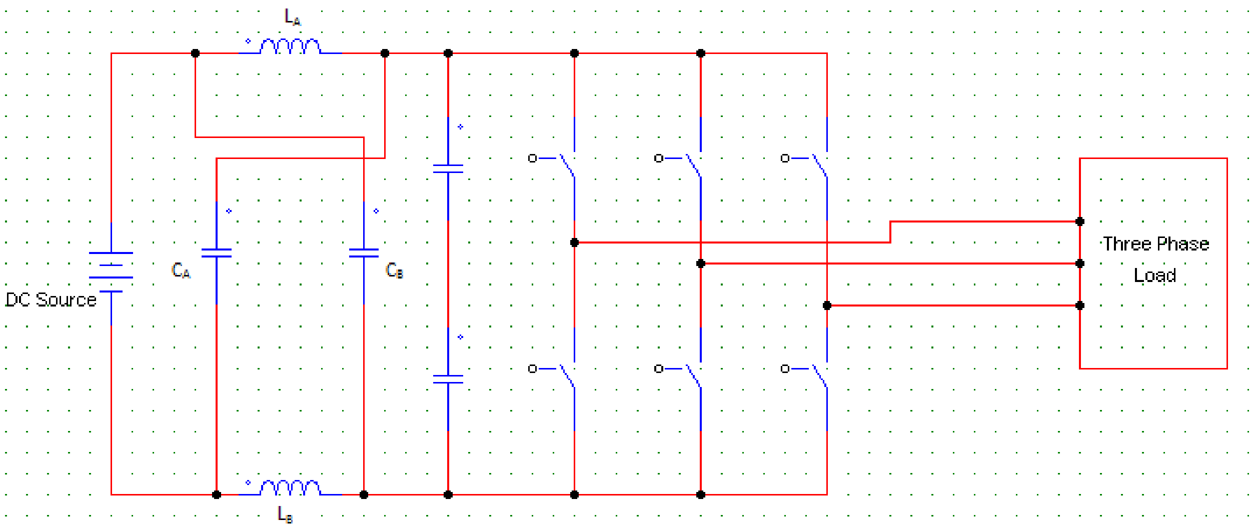
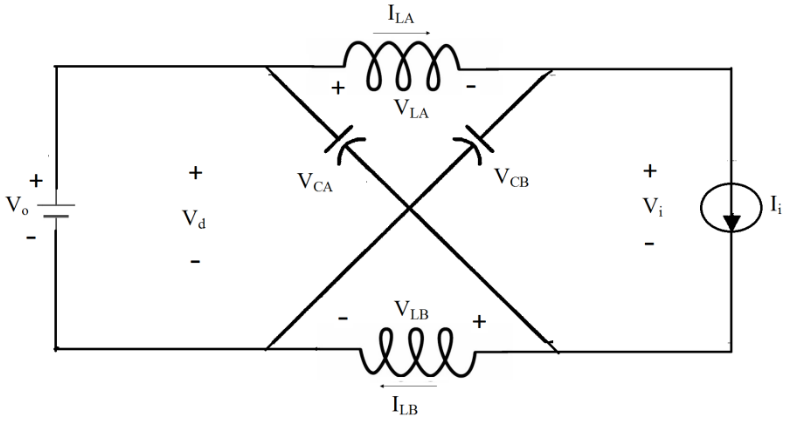


Fig. 3: zero shoot-through state



. Fig. 4: non shoot-through modes

4. Pulse Width Modulation technique

The PWM with carrier wave and reference wave to generate the required triggering pulse for the all the six switches of three phase Z source inverter is depicted in Fig. 5.

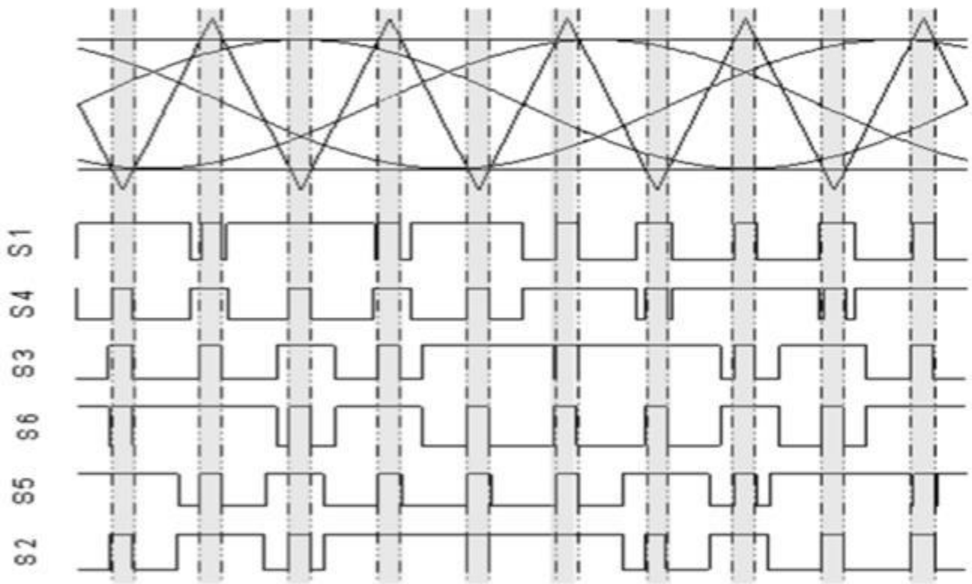


Fig. 5: Pulse sequence for IGBT switching

5. Design of Circuit Parameters

Assuming $V_{CA}=V_{CB}=V_C$

$V_{LA}=V_{LB}=V_L$

$V_C= V_D/2$

Let frequency of switching be 5KHz.

Therefore T = 1/f

$T = 2*10^{-4}$ sec

Let Duty cycle be 30%.

The peak current in inductor during shoot through.

$I_{L\,max} = I_L + I_L * 30\%$

$I_{L\,min} = I_L - I_L * 30$

$\Delta I_L = I_{Lmax} - I_{Lmin}$

$I_L = (Pin/Vin)$

$= (96*25.6)/(96)$

$= 25.6A$

$I_{Lmax} = 33.22$ A

$I_{Lmin} = 17.92$ A

Boost factor: $B = \dfrac{1}{1-2D}$

$= 2.5$

Output Voltage= 96*2.5=240V

Capacitance of Z –source network

$C = (I_L*T)\ (V_L*3\%)$

$C = (25.6*2*10^{-4})\ (65.2*0.03)$

$C = 1000\mu F$

Duty cycle of Shoot through is

$Ds = (B - 1)/2B = 0.3$

$Vc = (Vin+Vin_1)/2$

$= 410V$

$L = T * (Vc/\Delta I_L)*D$

$= 160\mu H$.

6. Three Phase Z-SOURCE Inverter Simulation

Simulations are done to realize proposed analysis using MATlab Simulink. The input Dc supply will be of 96V and the boosted output voltage is designed to obtain 240V rms or 340V peak and average current of around 25A.. The circuit is designed for a switching frequency of 5KHz and duty cycle of 30%.

The logic block for generation of triggering pulses for Switch S1 is shown below in Fig.6 similarly the triggering pulse is generated for remaining five switches according to requirement shown in Fig. 5

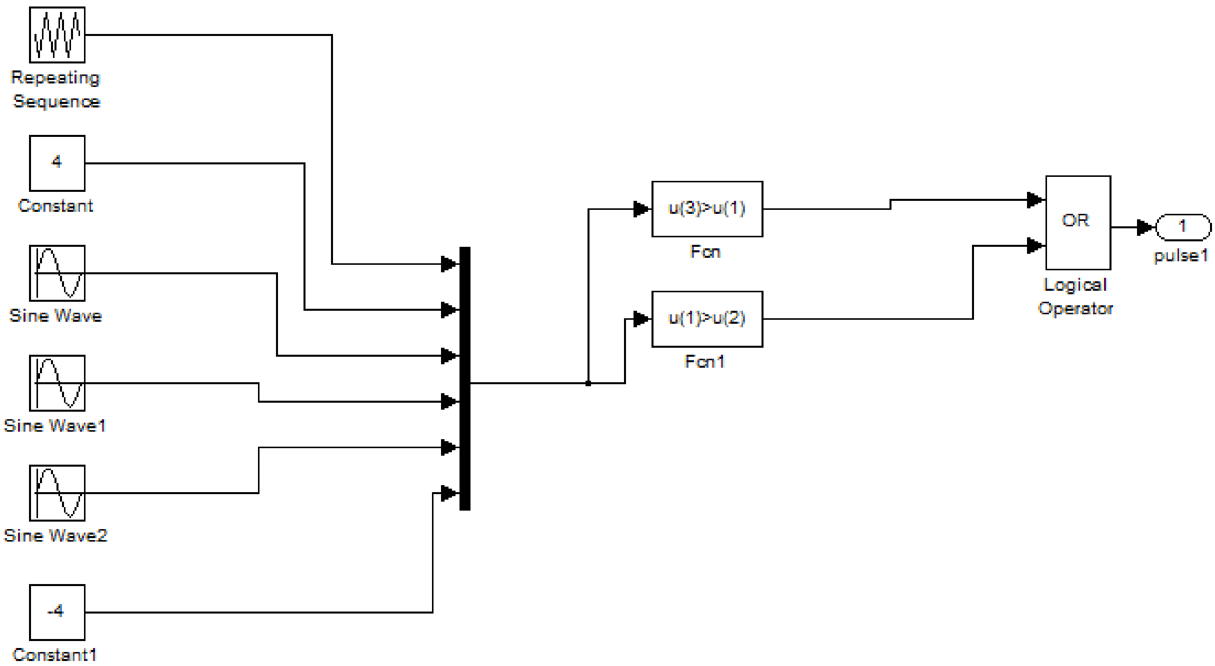


Fig. 6: The logic block for generation of triggering pulses for Switch S1

The simulated results of the triggering pulses for all the six switches is depicted in Fig. 7. This waveform of pulse obtained is same as the required pulses for all the six switches depicted in Fig. 5

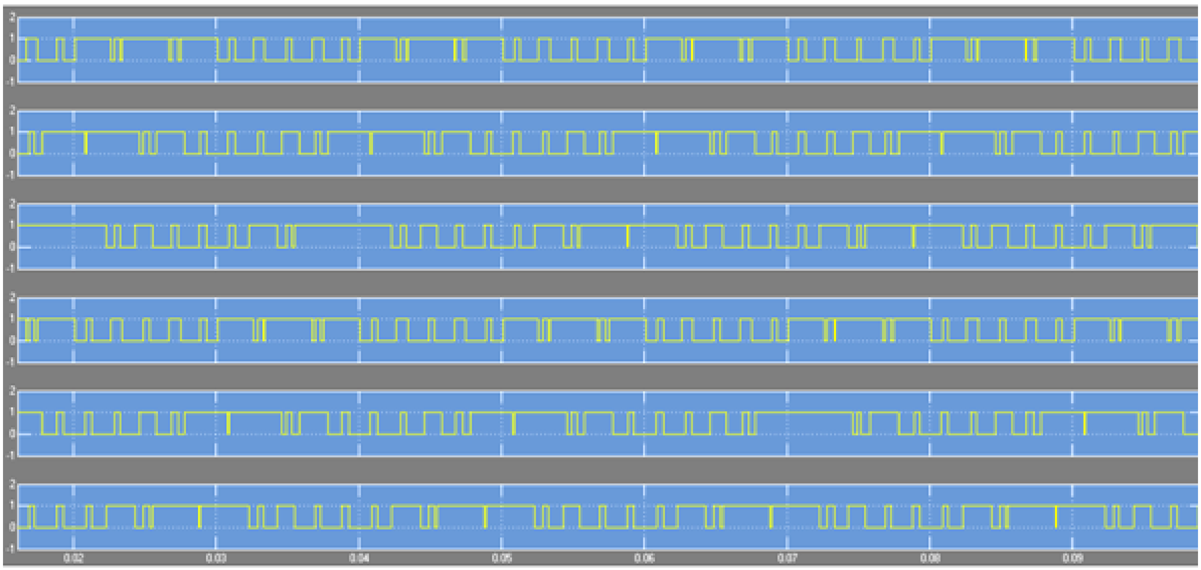


Fig. 7: Simulated result of Triggering pulses of all the six switches

The simulation of three phase Z-source inverter conducted using MATlab Simulink is shown in Fig. 8

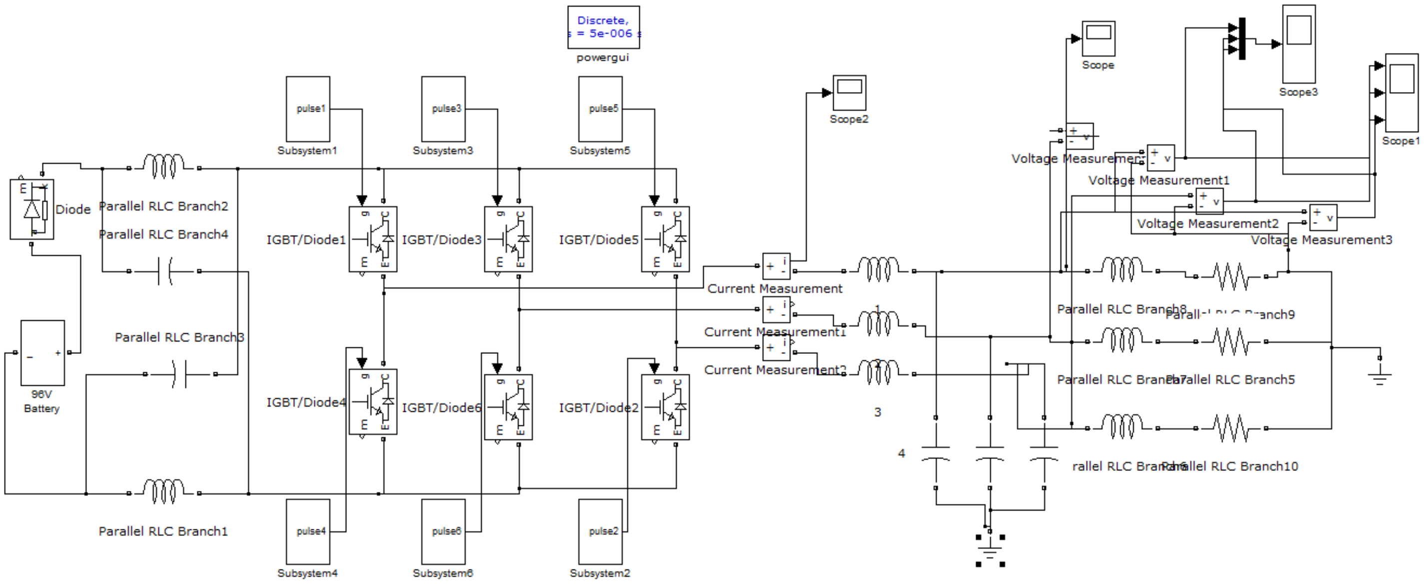


Fig. 8: Simulation of the three phase Z-source inverter

The waveform of line-line output voltage of three phase Z source inverter depicted in Fig. 9. The current waveforms of the circuit are depicted in Fig. 10

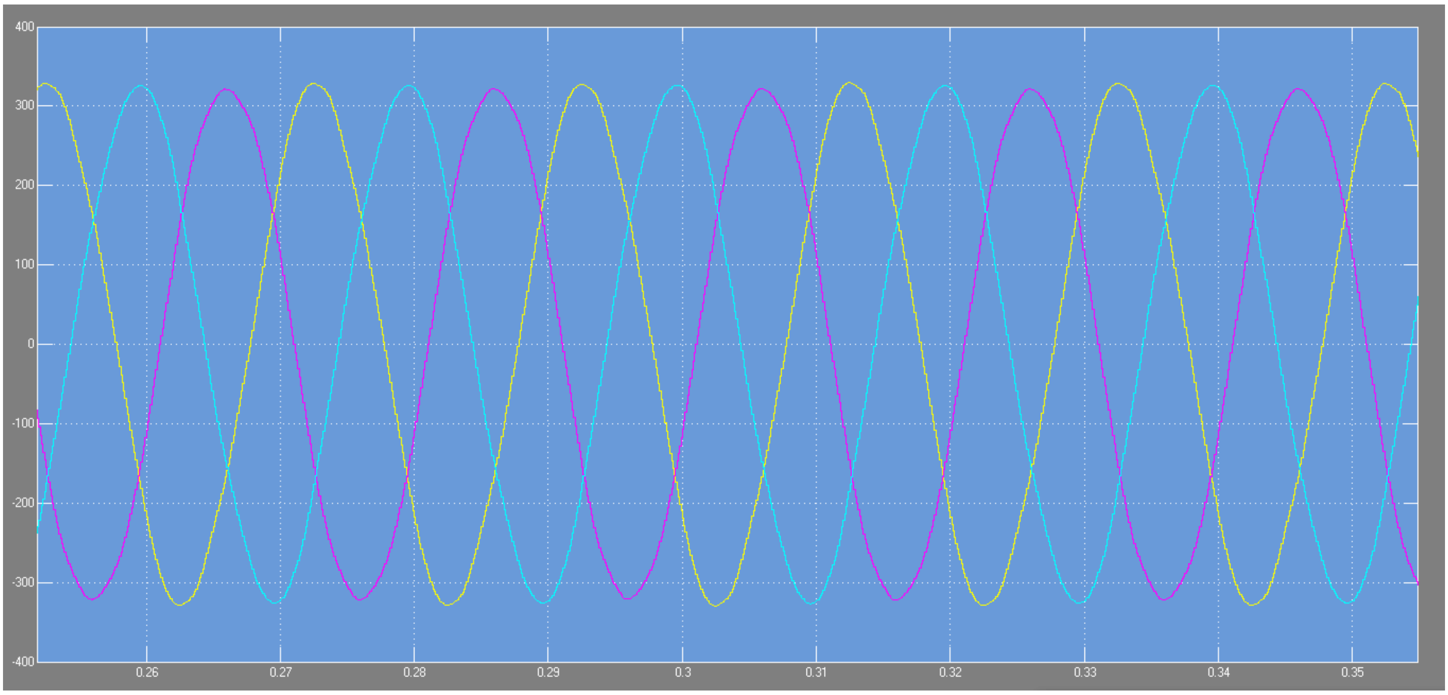


Fig. 9: Output line to line voltage waveform of Z source inverter

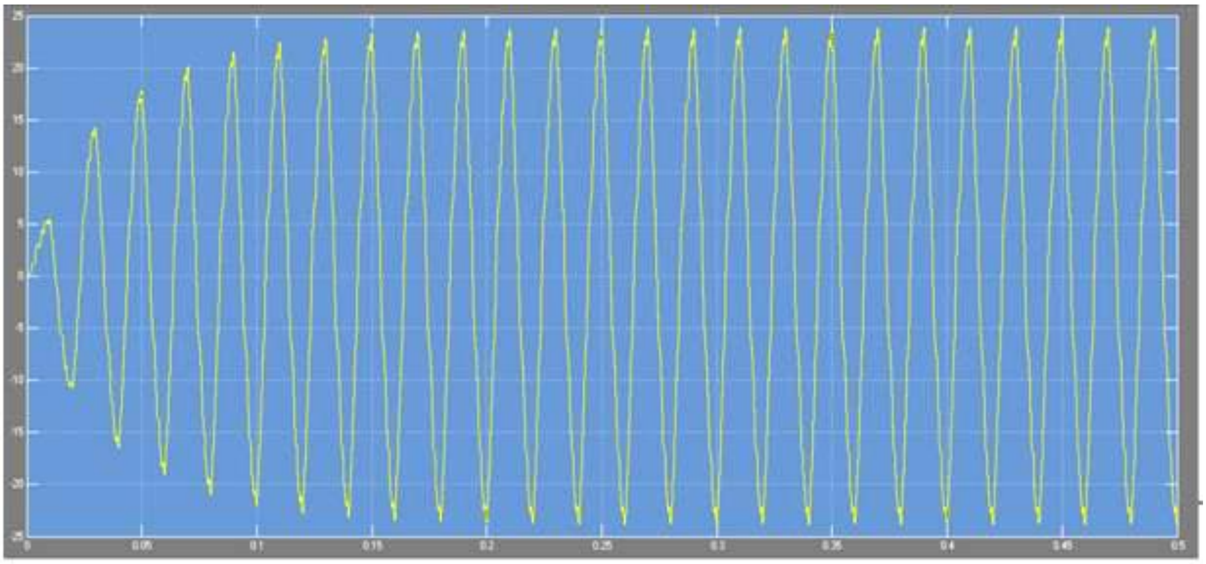


Fig. 10: Output current waveform of three phase Z source inverter

From the Fig. 9 and Fig. 10, we can see that simulated output voltage for the designed circuit is 340V peak and we have got the average output current of 25A.

7. Conclusion

In this paper, the generation of the triggering pulses for six switches of the three phase Z source inverter is proposed employing the MATlab Simulink. The design & simulation of the three phase Z-source inverter conducted and the results are shown. The results of Simulation shows the desired load sinusoidal voltage and sinusoidal current is obtained by Z-source inverter concept with filter which compared to the usual inverter.

8. Future work

This paper presents the Z-source concept for only DC to AC converter. But the concept can be extended for AC to DC, AC to AC and DC to DC power conversions also

9. REFERENCES

[1] "Design and Simulation of Single phase Z-source Inverter" by Mr.Santhosh Kumar R, Mrs. Maria Sushma and Mr. Praveen Kumar M in IJARIIT, April 2019
[2] "Z-source inverter," by F. Z. Peng, IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 504–510, 2003. M. Tolbert, and D. J. Adams, Conf. Rec. 2004 IEEE Ind. Appl. Conf. 2004. 39th IAS Annu.Meet., vol. 1, pp. 142–147, 2004.
[3] "Maximum constant boost control of the Z-source inverter" by Miaosen Shen, Jin Wang, Alan Joseph, Fang Z. Peng, Leon M. Tolbert. 2004 IEEE pg no. 142-147.
[4] "Design and Control of a Z-source Inverter for Photovoltaic Applications" by S. B. Kjær, vol. 3, no. January, p. 228, 2005 Institut for Energiteknik, Aalborg Universitet.
[5] "Control of a Fuel Cell Based Z-Source Converter,"by J.-W. Jung and A. Keyhani, IEEE Trans. Energy Converse, vol. 22, no. 2, pp. 467–476, 2007.
[6] "Modeling and Simulation of Z- Source Inverter," by S. Y. Own and N. Me, no. January, 2012 IEEE Transactions.
[7] "Improved Z Source Inverter for Speed Control of an Induction Motor" by D. Amudhavalli and L. Narendran, vol. 2, no. 4, pp. 1240–1247, ICICES,2013.
[8] "An LC filter design method for single-phase PWM inverters," by P. a. Dahono, a. Purwadi, and Q. Qamaruzzaman, Proc. 1995 Int. Conf. Power Electron. Drive Syst. PEDS 95, no. 95, pp. 571–576, 1995.
[9] "Design of passive filters," by M. Jayalakshmi, G. Asha, and K. Keerthana, vol. 10, pp. 44–48, IJETEE,2014.