A Review Article on PWM Inverter and Z-Source Inverter for Induction Motor

Hempushpa Bharti and B. M. Prasad

Abstract This paper presents the study and analysis of the development of an inverter specifically PWM-based voltage source inverter and Z-source inverter that supplies variable frequency and variable voltage and is used for speed control in an induction motor. In this paper, the review work of the already presented paper has been done. The sinusoidal PWM method and space vector PWM method used in VSI fed induction motor are studied, and also, the comparison between them is studied and analyzed. These methods have advantages in terms of harmonic reduction. The space vector PWM method reduces current and voltage harmonics more than the sinusoidal PWM method. Also, using a Z-source inverter increases the efficiency which has also been described and studied in this paper. Utilizing this method with a maximum boost control switching method results in a faster rate of achieving a steady speed.

Keywords Induction motor · MBS-ZSI · SPWM · SVPWM · VSI

1 Introduction

Induction motor (IM) has been playing an important role in running of industry since a long time due to its robustness, high efficiency, low cost and less maintenance. As the frequency voltage supply was not available, the induction motors were mainly for constant speed applications. With the progress of power electronics, the frequency of the voltage supplies can be varied, and thus, the induction motor can also be utilized in variable speed drive applications [1–3]. The drive units are being designed with voltage source inverters together with induction motors in various fields [4–6]. Variable speed AC motor drives are also being designed using high-speed power semiconductor technology utilizing the three-phase inverters. Although the basic circuit for an inverter may seem simple, but these devices incur lots of challenges during switching [7–10]. Three-phase VSI will supply Variable frequency and

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variable voltage for adjustable speed drives (ASD). To control the speed of the load, the required AC signal for the load is obtained from converting the DC currents to AC through different converter topology. For these converters, the switching pulses can be obtained from different PWM techniques. Hence, different advanced PWM techniques have been developed to generate the switching pulse [11–13]. Due to the low power losses in the switching devices, this method gives higher efficiency which is a major advantage. PWM switching strategy also has the advantages like less total harmonic distortion, effective dc bus utilization and also takes care of problems like electromagnetic interference (EMI) reduction, better distribution of harmonics over spectrum [14, 15].

Many research works are being done towards the development of the efficient control algorithms for high-performance variable speed induction motor (IM) drives. While constructing IM drives, six switches three-phase inverters (SSTP) have been normally used [16]. But, it results in the increased losses and increased complexity of the control algorithms and interface circuits. The disadvantage of using the six switches three stage inverter is that the harmonic content is high. Researchers focused on the improvement of new control calculations to deal with this issue. The main objective of the research work was to design a simple, cost-effective and efficient high-performance IM drive. There is no single PWM method that suits to all our requirements as far as the optimal performance of induction motor is concerned. The two popular approaches for the implementation of PWM algorithms are sinusoidal PWM (SPWM) and space vector PWM (SVPWM) [17–26]. SPWM is used for harmonic reduction and better performance at output of induction motor. It is simple method to implement and hence is widely used. But SVPWM gives better output voltage and is more capable of reducing the harmonics. Space vector PWM (SVPWM) is a complex method as regarding the switching time of individual switching devices, it comprises minute calculations. SVPWM gives more output voltage as compared to other techniques and has fewer ripples in output waveforms that give smooth torque characteristics in industrial appliances such as induction motors [27]. Also, to enhance the efficiency and increase DC output voltage from the battery, a dual stage boost voltage source inverter (VSI) has been proposed, but it has low efficiency because of high switching losses, and gate drivers must be specifically designed so that the effect of shoot through zero state on VSI topology does not damage the switching component. Thus, a maximum boost control Z-source inverter (MBC-ZSI) topology method is developed which increases voltage with single stage or only one circuit topology. This topology can increase the efficiency of the inverter for induction motor drives [28–31].

This paper presents the review of the work done towards the development of SPWM and SVPWM techniques used for the VSI fed induction motor. The comparison among both is studied. A Z-source inverter has also been studied and analyzed in this paper for improvement in terms of efficiency.

2 Voltage Source Inverter

At the desired voltage and frequency output, to translate power in DC form to AC form, an inverter is used. Voltage source inverter (VSI) accepts the DC input from a voltage source. Whereas when the current source provides input to the circuit, then it is known as a current source inverter (CSI) [31–33]. The VSI circuit directly controls AC output voltage, whereas the CSI is capable of controlling AC output current. Output voltage waveforms of an ideal VSI should be independent of load connected at the output. According to a number of phases, inverters are classified into two types: Single-phase voltage source inverter and three-phase voltage source inverter. Single-phase VSI can deal with only low power applications. With controlled magnitude, phase and frequency of voltages, three-phase VSI are favoured to provide three-phase voltage source for high power applications.

Figure 1 shows a typical structure of a three-phase power inverter, where Vdc is the continuous inverter input voltage, and a, b and c are the voltage output points that are supplied to the star connected motor windings. Power electronic devices such as IGBT, GTO and power BJT can be used as switches. The order of making the devices ON and OFF must follow certain conditions: out of six, three switches must always be ON, keeping the other three always OFF, and also, two complementary pulsed signals drive the upper and the lower switches of the same leg. Thus, in this way, the overlap in the power switch transitions is avoided while making no vertical conduction possible.

2.1 Sinusoidal PWM-VSI

Whenever any waveform controls the duty ratio of any pulsating waveform, the technique is called as pulse width modulation (PWM). The sinusoidal wave is compared

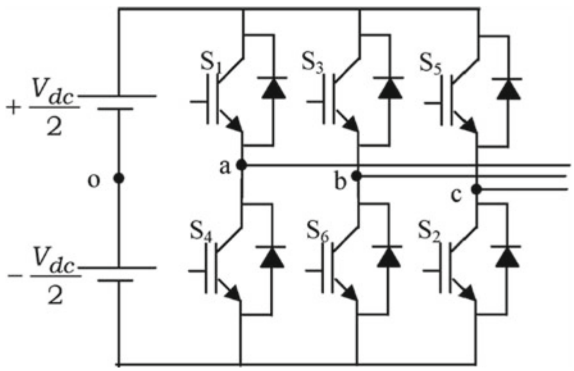

Fig. 1 Voltage source inverter

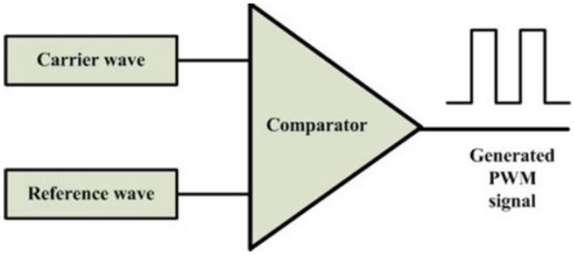

Fig. 2 Sinusoidal pulse width modulation [18, p.1]

with the triangular wave in SPWM method. Whenever the magnitude of the sinusoidal wave is more than triangular wave, then the trigger pulse is generated which is fed to the VSI.

In SPWM, the triangular signal is imposed upon the sinusoidal reference wave. A comparison is done between the two waves, and a gate pulse is generated where the sinusoidal wave amplitude is more than the triangular carrier wave as shown in Fig. 2. Three sinusoidal reference waves are there to obtain three-phase system which results in gate pulses of three types that will be fed to VSI using suitable logic.

2.2 Space Vector PWM-VSI

In SVPWM method, the reference voltage obtained from the rotating reference vector is used to generate the triggering pulse. This strategy uses the DC link voltage more efficiently, and the harmonic content that is present in the three-phase VSI output voltage is very low. In SVPWM, based on the discrete voltage vectors of eight switching states in three-phase VSI system, the vector position is traced and shown in Fig. 3. The two adjacent basic vectors are having binary representations that differ

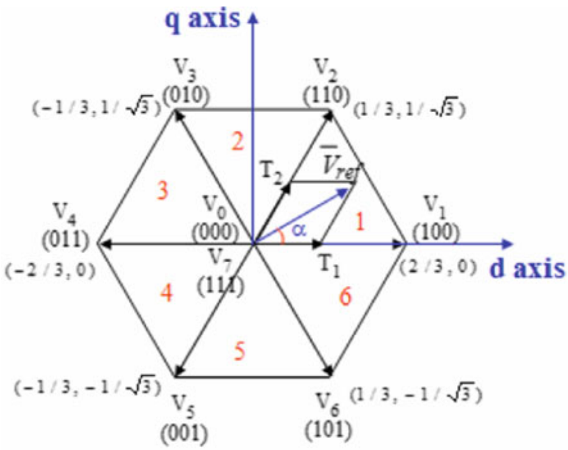

Fig. 3. Switching vectors and sectors [18, p.2]

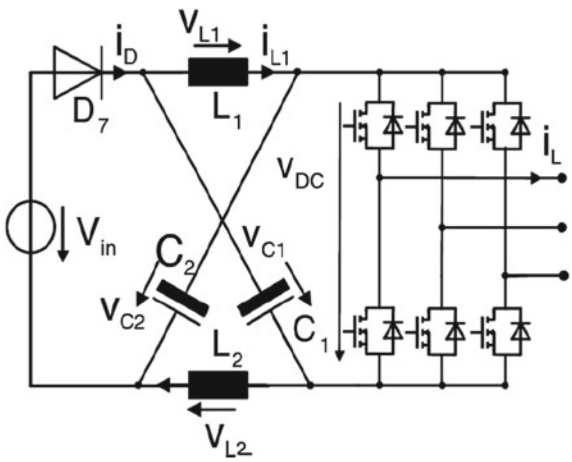

Fig. 4 Three-phase Z-source inverter [29, p. 381]

in only one bit. Therefore, when the movement of switching pattern is from one vector to the adjacent one, only one of the upper transistors switches.

2.3 Z-Source Inverter

The Z-source inverter is an impedance network operating in two modes, buck mode and boost mode and which consist of two inductors and two capacitors. It can also fulfil the purpose of a second order filter to decrease voltage ripple and reduce harmonics. The Z-source inverter can be connected to a voltage source in the form of ia photovoltaic or battery. The Z-source inverter can be seen in Fig. 4. One of the switching methods of Z-source inverter is maximum boost control. This method is an amendment of sinusoidal PWM (SPWM) where there are extra conditions for shoot through zero state. When the carrier wave is larger than the sine wave in maximum boost control Z-source inverter (MBC-ZSI), the condition of the shoot through zero state occurs as the switch at the gate gets activated. Whereas when the carrier wave is smaller than the sine wave, a normal PWM wave is produced [34].

3 Results and Discussion

A simulink block model is designed in MATLAB for the SPWM VSI fed to induction motor shown in Fig. 5. MATLAB simulation for SPWM VSI fed to induction motor is done, and Fig. 6 shows the corresponding results. Stator current for all three phases, electrical torque, angular frequency and line voltage is plotted. To calculate the harmonic content in voltage and current, FFT analysis is done. MATLAB simulink

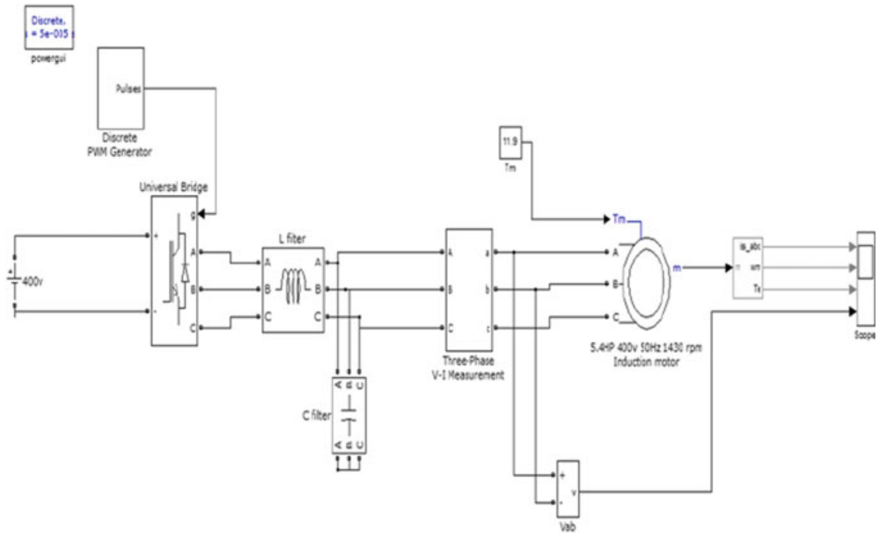

Fig. 5. Modelling of SPWM [18, p.2]

model is developed for SVPWM method as shown in Fig. 7. MATLAB simulation results for SVPWM VSI fed to induction motor are shown in Fig. 8.

From the FFT analysis, the THD for current and voltage for sinusoidal PWM and SVPWM is measured. Based on the MATLAB simulation, it can be inferred that THD for voltage is 33.08%, and THD for current in SPWM is 19.25%. Meanwhile, in SVPWM, the THD for voltage is 14.15%, and THD for current in sinusoidal PWM is 16.65% [18]. This concludes that the harmonic reduction in SVPWM technique is better done than sinusoidal PWM. i

The MBC-ZSI system's performance is tested by simulation. Modelling of the MBC-ZSI system can be seen in Figure 9. Testing has been carried out with different loads for induction motor. With a load of 1 Nm, the MBC-ZSI system can achieve steady speeds of 0.2 s faster than SPWM VSI. Then, at 4 Nm load, MBC-ZSI also has a faster time of 0.27 s. Then, at 8 Nm load, the time needed is 0.33 s faster. So that the average time needed to achieve steady speeds on the MBC-ZSI system is 0.26 s faster than SPWM VSI [29].

4 Conclusion

Thus, from the above discussion, it can be concluded that SPWM and SVPWM methods for VSI fed induction motor have several advantages which can be utilized in the application of induction motor. Also, comparatively, the SVPWM method results in lesser harmonics for current and voltage. A Z-source inverter also increases the efficiency of the induction motor. Based on the results of testing that has been

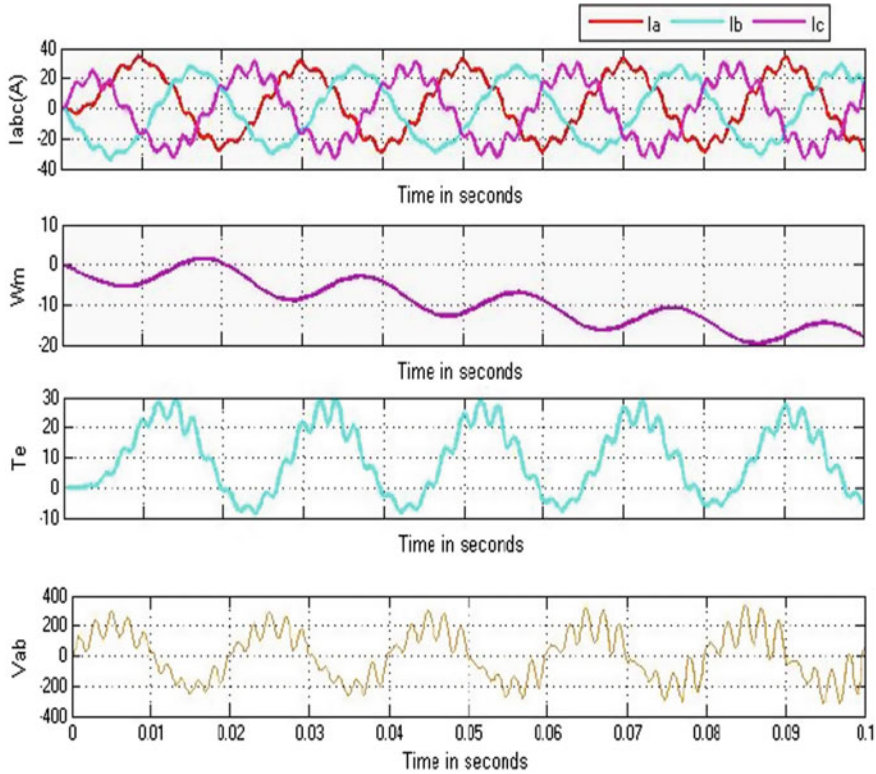

Fig. 6. Waveforms for SPWM [18, p.3]

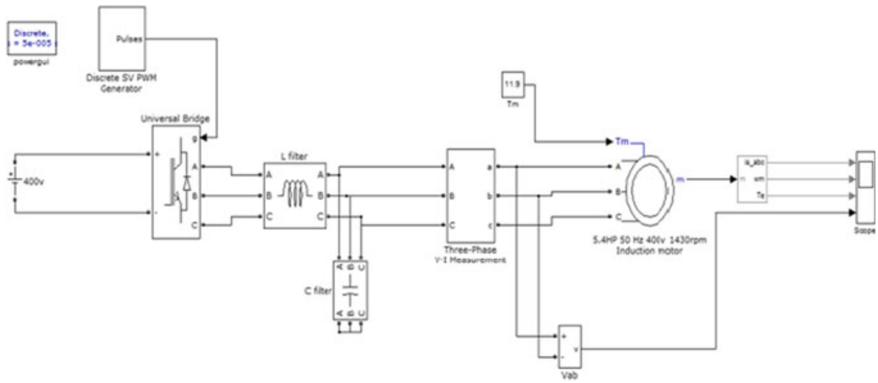

Fig. 7 Modelling of SVPWM [18, p.3]

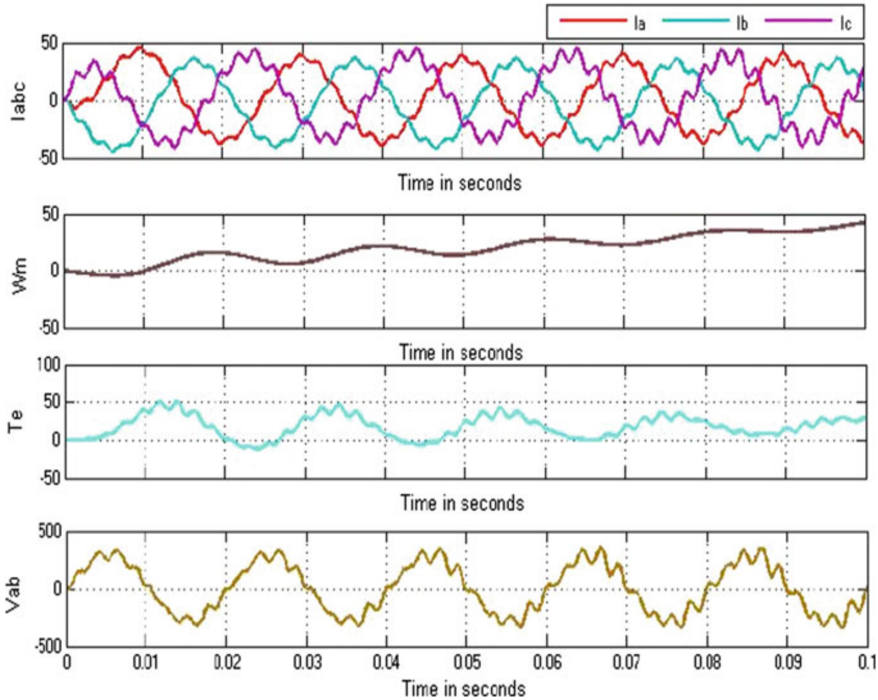

Fig. 8. Waveforms for SVPWM [18, p.3]

done, in achieving a steady speed, the MBC-ZSI system gave a better response. As future scope of work, utilizing the ZSI along with the aforementioned PWM methods can give better performance. Also, the closed loop system can be developed using a controller-like fuzzy controller.

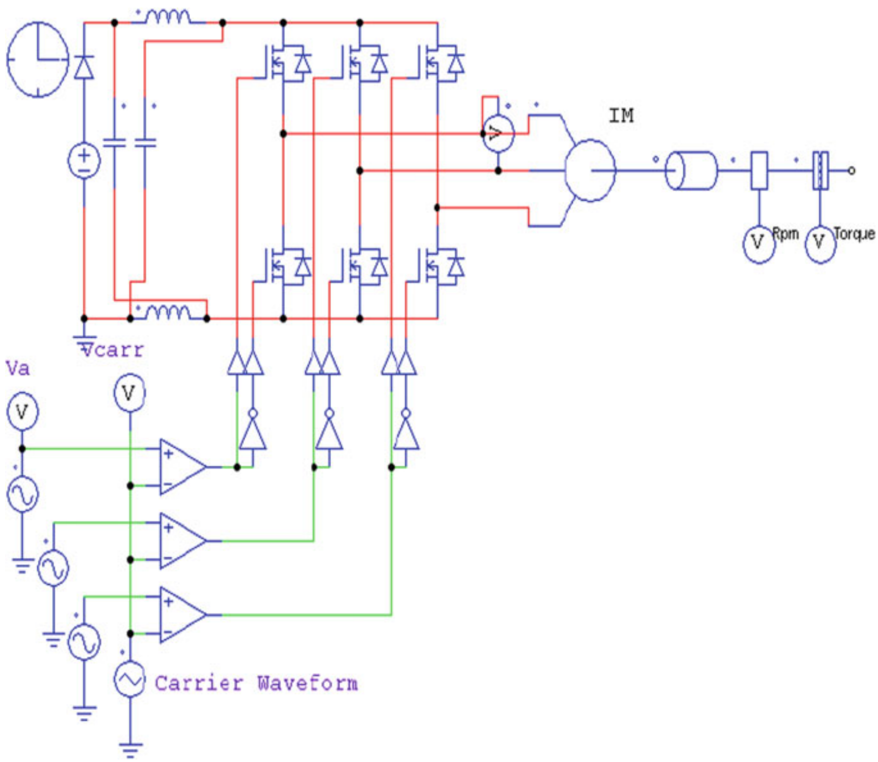

Fig. 9 . Modelling of MBC-ZSI [29, p. 382]

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