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Analysis and Comparison of Three Phase VSI Fed Induction Motor Drive by Using Various Pulse Width Modulation Techniques

Pooja Singh

M. Tech. Scholar, NRI Institute of Technology, Bhopal, Madhya Pradesh, India

Dr. Amita Mahor

Associate Professor, Head of the Department (Ex), NRI Institute of Technology, Bhopal, Madhya Pradesh, India

Abstract:

Switching techniques of pulse width modulation (PWM) have been popular in the area of power electronics and drive systems. PWM is commonly used in applications like motor speed control, converters audio amplifiers etc. PWM is used to adjust voltage applied to the motor. There is no single PWM method which can suite for all applications. As per the advanced technology in solid state power electronic devices and microprocessors, various pulse-width modulation (PWM) techniques have been developed for different industrial applications. For the above reasons, the PWM techniques have been the subject of intensive research since 1970s. The main objective of the PWM is to control the inverter output voltage and to reduce the harmonic content in the output voltage. The pulse width modulation (PWM) techniques are mainly used for voltage control. These techniques are most efficient and they control the drives of the switching devices. The different PWM techniques are Single pulse width modulation, Multiple pulse width modulation, Phase displacement control, Sinusoidal pulse width modulation, Harmonic Injection modulation, Space Vector pulse width modulation, Hysteresis (Delta) pulse width modulation, Selective Harmonic Elimination and Current Controlled pulse width modulation. Hysteresis controller is used for Current source inverter and all the remaining PWM techniques are used for Voltage source inverter. Sinusoidal and Space Vector PWM techniques are most widely used. They control the output voltage as well as reduce the harmonic.

Keywords: PWM technique, multilevel inverters, reduced components, summer, Ac power generation

1. Introduction

1.1. Induction Motor

Three phase induction motor is the most popular types of A.C. motor. It is very commonly used for industrial application drive since it is cheap, robust, efficient and reliable. It has good speed regulation and high starting torque. It requires little maintenance. It has a reasonable overload capacity. Power inverters are devices which can convert electrical energy of DC form into that of AC. Inverters can be broadly classified into two types based on their operation:

1. Voltage Source Inverters (VSI)
2. Current Source Inverters (CSI) three phase VSI are superior when we compare with others by virtue of their medium to high power applications. In fig.1

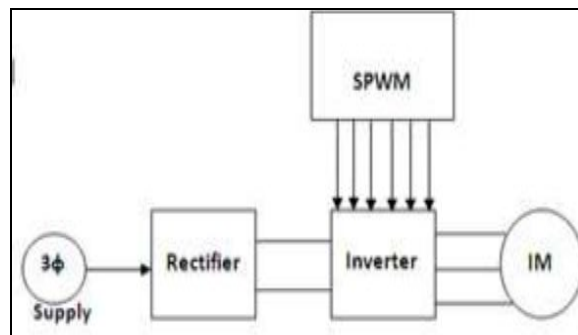


Figure 1: block diagram of VSI fed induction motor

1.2. PWM Techniques

PWM signal is applied to the gate of a power transistor; it causes the turn on and turns off intervals of the transistor to change from one PWM period to another PWM period according to the same modulating signal. The frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency, such that the energy delivered to the motor and its load depends mostly on the modulating signal.

1.2.1. Used PWM Techniques

- SPWM Techniques
- Third Harmonics Injection
- Trapezoidal PWM Techniques
- Square PWM Techniques

I) SPWM

A square wave waveform results, if turned on several times in a cycle an improved harmonic profile may be achieved. In the most straightforward implementation, generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular ‘carrier’ wave as depicted schematically in Fig.2. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output.

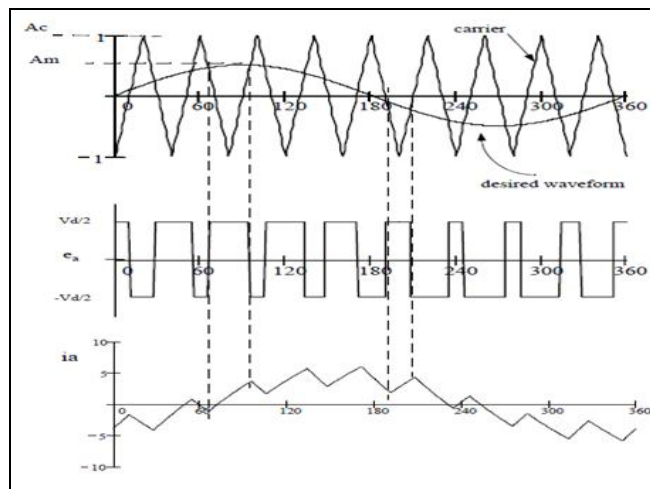


Figure 2: Principal of Pulse Width Modulation

II) Third Harmonics Injection Method

The output pulses of the fig are passed through Dead band circuit and the driver circuit before applying to the inverter. The general block diagram for generation of the gating signal. The Dead band circuit is used to introduce a dead time in the pulses to avoid short circuit of the switches of the same leg of the inverter, and the opto coupler circuit is to provide isolation between control circuit and the power circuit.

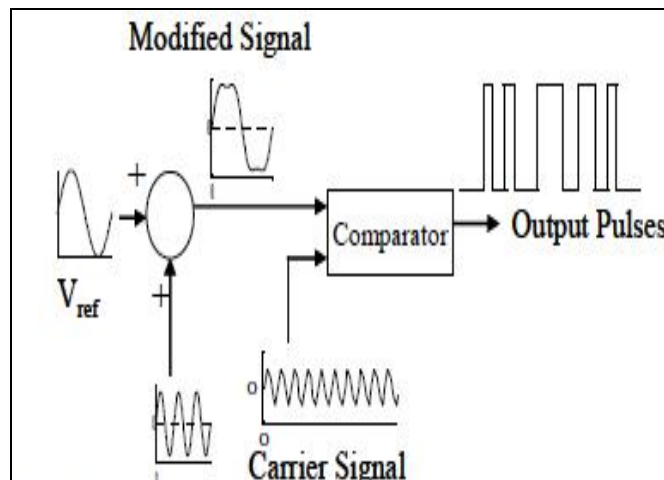


Figure 3: Third harmonics injection techniques

III) Trepezoidal PWM Technique

The gating signals are generated by comparing a triangular carrier wave with a modulating trapezoidal wave as shown in the figure below in fig.2.

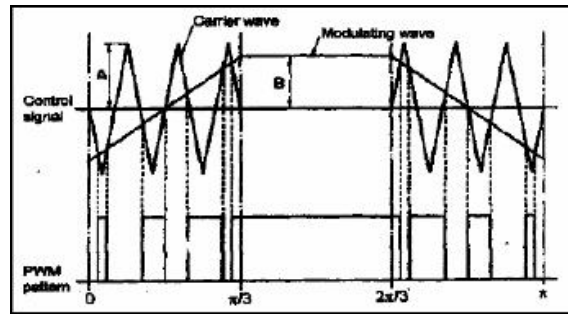


Figure 4: Trepezoidal PWM Techniques

The trapezoidal wave can be obtained from a triangular wave by limiting its magnitude to $+A_r$ which is related to the peak value $A_r(\max)$ by: $nA_r = \sigma A_r(\max)$ where σ is the triangular, limit switching losses it is necessary to control the device switching frequency, irrespective of the fundamental frequency of the current waveform. This can be achieved by making the parameter M , the pulse number in half cycle of the inverter operation, constant in many segments of the fundamental frequency (see next slide for switching frequency $\gg 1\text{kHz}$).

IV) Square PWM Techniques

Similarly the gating signals are generated by comparing a triangular carrier wave with a square wave. The harmonic content can thus be reduced by using several pulses in half cycle of the output voltage. Harmonics are defined as the sum of all components generated as a percentage of the fundamental waveform. Non-linear loads generate current harmonics, Harmonic currents flow largely through capacitors.

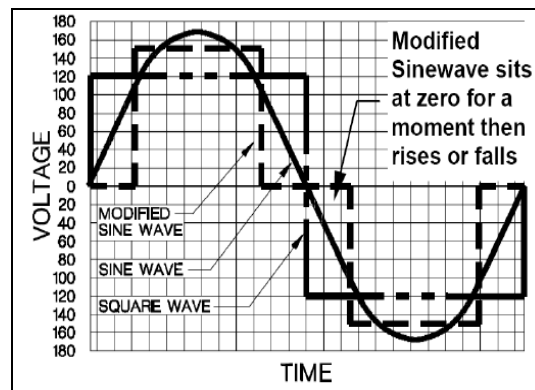


Figure 5: Square wave PWM techniques

2. Literature Review

- Xiaming Yuan Iro Barb et al. [1] in year 2007, He is proposed topology reduces the number of filter and reduces the number of components highly which does not use more number of capacitors and use less number of chargeable capacitors. As the name suggests that this is a five level inverter, but the output obtained is sinusoidal this is because of summer added in PWM technique.
- Simulation and analysis, et al. [2] in year 2009, proposed the clamping diodes to clamp the voltage to a particular value, but the proposed topology does not use any diodes to clamp the voltage. The control signals used here are easy for analysis, which requires the analysis of less number of switching states.
- Nikola Celanovic, et al. [17] in year 2007 deals with the problems of multi-star induction motors fed by voltage source inverters and describes the modes of operation with sinusoidal PWM and square wave mode with fundamental switching frequency and shows how the pulse patterns can be optimized, in order to get the lowest possible current harmonics at a given inverter switching frequency and a given fundamental frequency. Nikola Celanovic,
- Yahya Shakweh et al. [18] in year 2009 is proposed in this literature the fundamental limitations of neutral-point voltage balancing problem for different loading conditions of three level voltage source inverters. A new model in DQ coordinate frame utilizing current switching functions is developed, as a means to investigate theoretical limitations.

- Manfred GrBtzbach *et al.* [19] in year 2006 is reviews various PWM Voltage Source Inverter (VSI) topologies in the power range (3-8MW) also examine and compares practical VSI stack topologies used by VSI manufacturers to achieve a high power Medium Voltage (MV) converter design.
- Yu Meng *et al.* [20] in year 2008 suggested that the power supply of the inverter consists of a diode rectifier feeding a large dc link capacitor. Thus very high line current harmonics occur if no inductance is provided for current smoothing. Thus presents diagrams in order to predetermine easily the harmonic distortions of the line current.

Biswa B., Das S, Et.al [3] in year 2009, An MCSA technique is adopted for harmonic analysis under various fault conditions of Variable Frequency Drive (VFD) systems.

3. Methodology

- Firstly, having idea from many papers and then I have selected base paper for proposed work.
- Using MATLAB tools for modelling.
- Then generate some values for modeling components.
- Again select an induction motor and fed by VSI 120 degree mode.
- Applying different-different PWM techniques in VSI mode, generate pulse by comparing signals.
- After Applying these kinds of signal we observe the speed and induced harmonics of induction motor.
- The final analysis, comparison between speed and harmonics done.

4. Objective

Analysis and comparison of three phase vsi fed induction motor drive by using various pulse width modulation techniques.

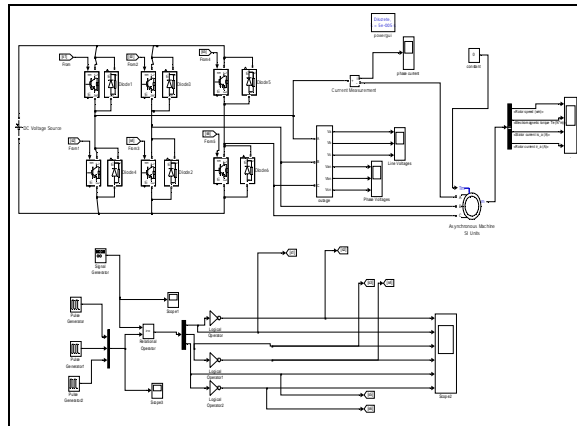


Figure 6: Simulation and modeling of VSI fed inverter

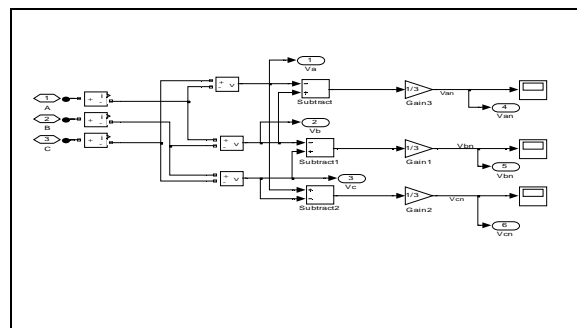


Figure 7: Line and phase voltage subsystem

5. Experimental- Setting

- MATLAB- Varsion 7.10.0.499 (R210a)
- 400 volt DC supply
- 120 degree VSI mode inverter
- Induction motor of 15:5.4 HP (4KW), 400V, 50HZ, 1430 RPM.

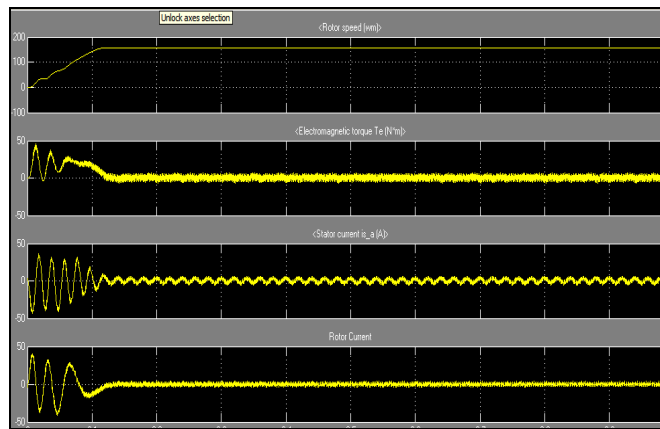


Figure 8: Speed analysis of sine wave

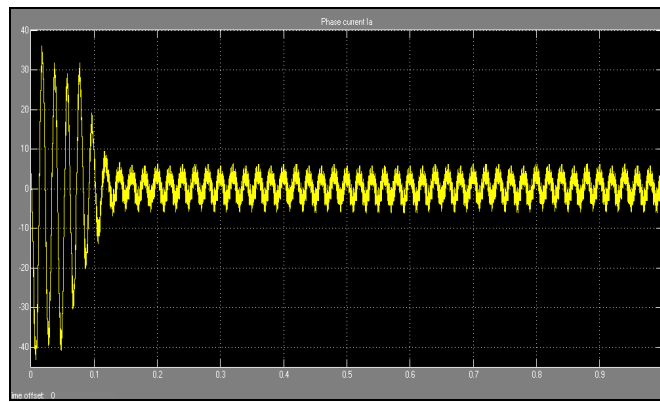


Figure 9: Phase voltage of SVPWM

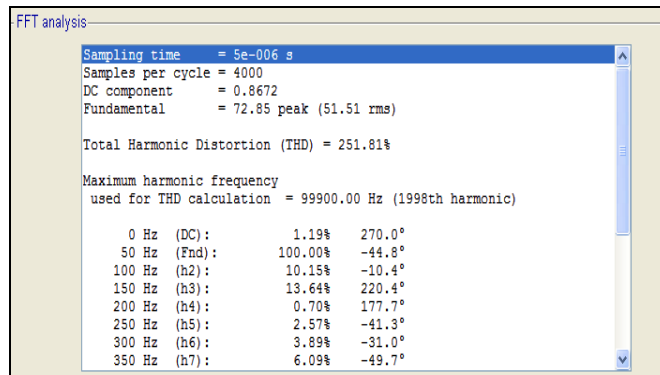


Figure 10: harmonics analysis of T.H.I method wave

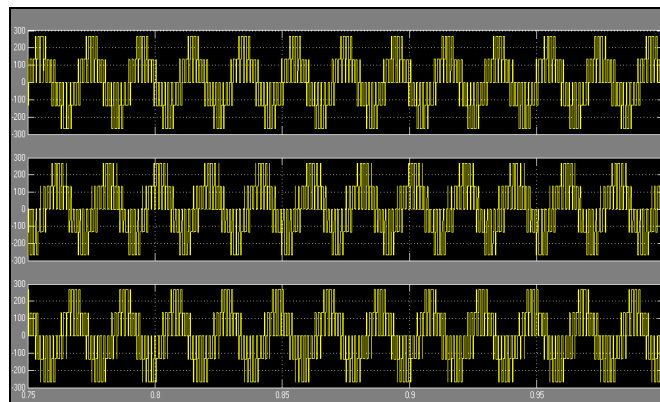


Figure 11: line voltage of SVPWM

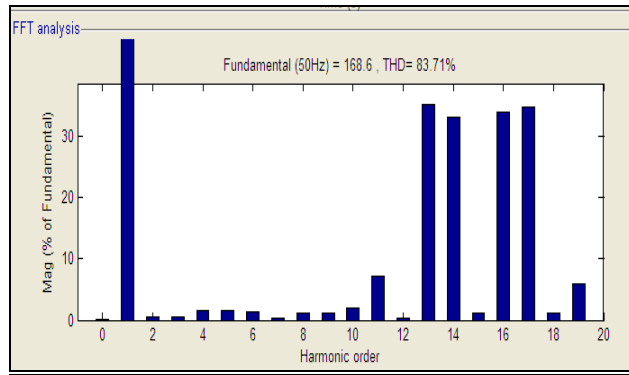


Figure 12: Total harmonics of SVPWM

S.NO	TECHNIQUES USED	SPEED ANALYSIS	TRANSIEN TIME PERIOD	3 RD HARMINICS ANALYSIS
1	SPWMN TEHNIQUES	1497 RPM	0.1	1.15%
2	THIRED HARMONICS INJECTION	1490 RPM	0.12	15.67%
3	TRIEZOIDAL PULSE TECHNIQUES	1490 RPM	2	13.69%
4	SQURE WAVE TWCHNIQUES	1117 RPM	30	1.85%

Table 1

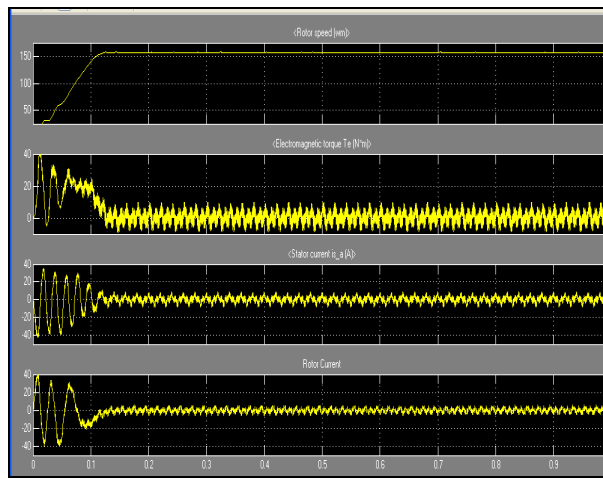


Figure 13: Speed analysis of T.H.I method wave

6. Results & Comparison

After comparing all techniques result we have a compare table and it shows in fig.13.

7. Future Scope

Further work can be carried out in the following areas:

- ▶ Research work can be carried by another signal like space vector Fig.13 comparison and analysis of PWM techniques PWM in the multilevel VSI.
- ▶ Further work can be done by another modulation index $m > 1$ by using third harmonics injection PWM.
- ▶ Further work can improve the efficiency of Induction Motor drive by using SVPWM by improving Total harmonics Distortion.

8. Conclusion

This work presents the investigations regarding the faulty behavior of a three-phase VSI fed induction motor drive & induction motor drive system when supplied by a reconfigured three-phase voltage source inverter with fault tolerant capabilities. Output waveforms are obtained and THD values are tabulated. From simulation, it is seen that the current harmonics gets increased due to the introduction of faults in the inverter module. The current gets reversed on introducing IGBT blown off fault and current value reduces to zero on introducing open leg fault. Frequency responses with FFT under four different fault conditions are distinctly different from the simulation studies, it is seen that the current harmonics are lower & the current.

Fig.13 comparison and analysis of PWM techniques value is higher than the normal VSI fed induction motor drive during an open leg fault in fault tolerant VSI fed induction motor drive.

9. References

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