ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Fault Analysis of VSI Fed Induction Motor Drive Using SPWM

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ABSTRACT*:* This paper focused on the development of Voltage Source Inverter fed Induction Motor Drive using Sinusoidal Pulse Width Modulation. Sinusoidal Pulse Width Modulation technique is used for improving the performance of voltage source inverter fed Induction Motor Drive. The proposed method has been simulated for healthy circuit, open circuit fault and short circuit fault condition using MATLAB. The line current, voltage and harmonics for various conditions were observed and the selected pattern has been exposed to give superior performance.

KEYWORDS- PWM, SPWM, VSI, IM Drives, FFT

I. INTRODUCTION

The three-phase AC induction motor has a squirrel cage rotor in which aluminium conductors or bars are shorted together at both ends of the rotor by cast aluminium end rings. When three currents flow through the three symmetrically placed windings, a sinusoidal distributed air gap flux generating the rotor current is produced. The interaction of the sinusoidal distributed air gap flux and induced rotor currents produces a torque on the rotor. The mechanical angular velocity of the rotor is lower than the angular velocity of the flux wave by so called slip velocity. In adjustable speed applications, AC motors are powered by inverters. The inverter converts DC power to AC power at the required frequency and amplitude. The inverter consists of three half-bridge units where the upper and lower switches are controlled complimentarily. As the power device's turn-off time is longer than its turn-on time, some dead-time must be inserted between the turn-off of one transistor of the half-bridge and turn-on of its complementary device. The output voltage is mostly created by a pulse width modulation (PWM) technique. The three-phase voltage waves are shifted 120° to one another and thus a three-phase motor can be supplied. These motors are mostly used for industrial drives. For small applications single phase motors are used. The speed of this motor is determined by the frequency of the supply current, so these machines are mostly used for constant-speed applications, and variable speed versions, using variable frequency drives. .The main cause of three phase induction motor is related to the bearing damage and stator fault particularly in the stator breakdown. Although three phase voltage-fed inverter induction motor drives exhibit excellent control characteristics a common fear that they are not adequately reliable is preventing their wide spread application. A three phase voltage-fed inverter can develop various faults of which open base drive and shoot through are most common. Open base drive fault may occur due to insufficient base drive which has to be deliberately suppressed in order to prevent the main switches. Sinusoidal pulse width modulation is a method of pulse width modulation used in inverters. An inverter produces an AC output voltage from a DC input by using switching circuits to simulate a sine wave by producing one or more square pulses of voltage per half cycle. If the widths of the pulses are adjusted as a means of regulating the output voltage, the output is said to be pulse width modulated. With sinusoidal or sine weighted pulse width modulation, near the edges of the half cycle are always narrower than the pulses near the centre of the half cycle such that the pulse widths are proportional to the corresponding amplitude of a sine wave at that portion of the cycle. To change the effective output voltage, the widths of all pulses are increased or decreased while maintaining the sinusoidal proportionality. Several pulses are produced per half cycle.

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A. SINUSOIDAL PULSE WIDTH MODULATION

Instead of, maintaining the width of all pulses of same as in case of multiple pulse width modulation, the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The distortion factor and lower order harmonics are reduced significantly [1]. The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave of frequency Fc. The frequency of reference signal Fr determines the inverter output frequency and its peak amplitude Ar, controls the modulation index M and Vrms output voltage VO [2]. The number of pulses per half cycle depends on carrier frequency Inverters that use PWM switching techniques have a DC input voltage that is usually constant in magnitude. The inverters job is to take this input voltage and output ac where the magnitude and frequency can be controlled. There are many different ways that pulse-width modulation can be implemented to shape the output to be AC power. A common technique called sinusoidal- PWM will be explained. In order to output a sinusoidal waveform at a specific frequency a sinusoidal control signal at the specific frequency is compared with a triangular waveform (See Fig. 1). The inverter then uses the frequency of the triangle wave as the switching frequency [3]. This is usually kept constant. The triangle waveform is at switching frequency fs; this frequency controls the speed at which the inverter switches are turned off and on. The control signal**,** $\mathbf{V_{control}}$**,** is used to modulate the switch duty ratio and has a frequency f1. This is the fundamental frequency of the inverter voltage output. Since the output of the inverter is affected by the switching frequency it will contain harmonics at the switching frequency [4]. The duty cycle of the one of the inverter switches is called the amplitude modulation ratio, ma.

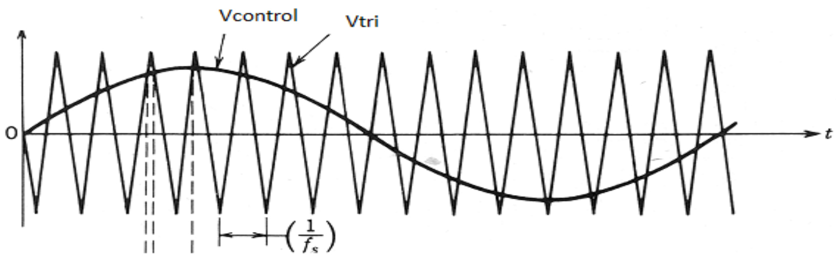

Fig 1. Desired frequency is compared with a triangular waveform

II. SIMULATION OF VSI FED IM DRIVE USING SPWM

A. HEALTHY VSI FED DRIVE

This is the Basic Simulink Model of Healthy VSI-Fed Drive using SPWM technique for three phase induction motor is simulated by using MATLAB. The simulation circuit is shown in Fig 2.The 415V AC voltage is applied to the induction motor [6].

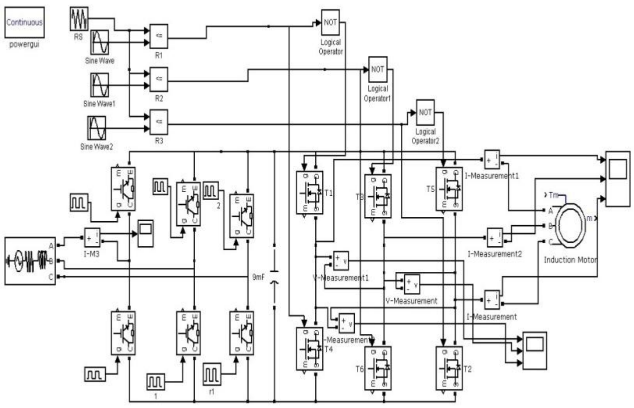

Fig 2. Simulation circuit for VSI-fed drive

Voltage waveform for the three phases A, B & C at the inverter side under healthy condition are shown in Fig 3. It is observed that under healthy condition all the line current and voltage waveforms are displaced w.r.t each other [5].

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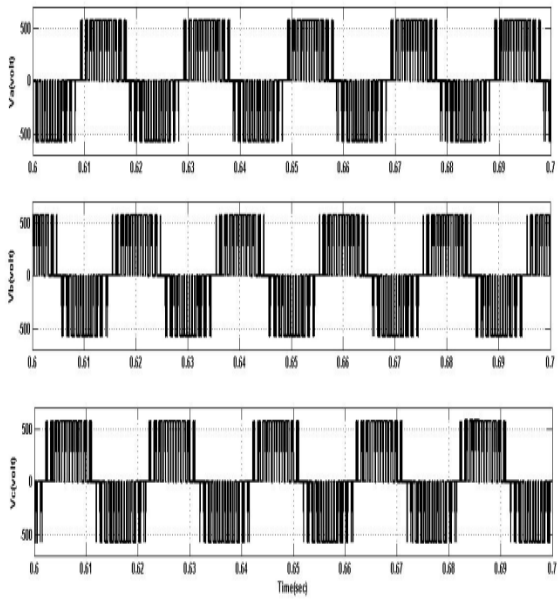

Fig 3. Voltage Waveforms (Healthy)

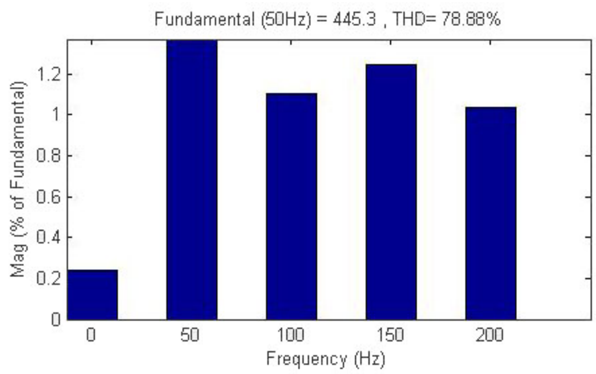

Fig 4. Voltage spectrum of phase A

It is noted that the output line current waveforms get distorted on the application of faults. The Voltage Total Harmonic distortion (THD) 78.88%.

B. OPEN CIRCUITING UPPER LEG MOSFET IN PHASE A

To simulate open circuit fault with upper MOSFET in the phase A has been replaced by a high resistance [7]. Introduction of the high resistance with one of the six MOSFETs is equivalent to the open circuiting of one of the six MOSFETs. The simulation circuit is shown in Fig 5. Here the upper leg MOSFET in Phase A is replaced by resistance of 1Mohms.

10.15662/ijareeie.2014.0312131

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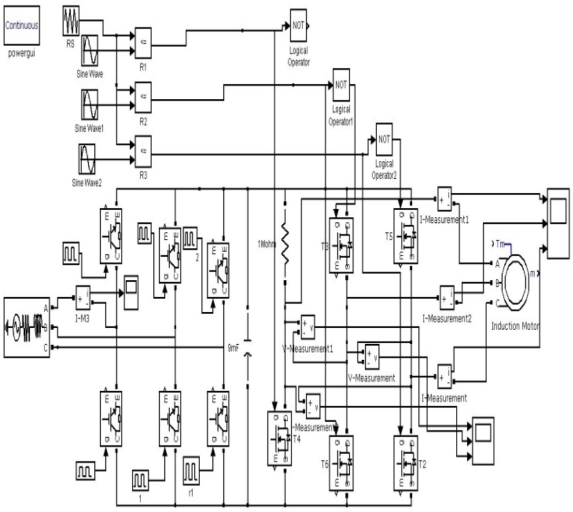

Fig 5. Simulation Circuit for Open Circuiting Upper leg MOSFET in inverter

Current waveform of the three phases A, B & C respectively under the fault conditions are shown in Fig 6. On introducing the fault line current and voltage waveforms are distorted. The line volt in phase A is reduced to 140 V [8].

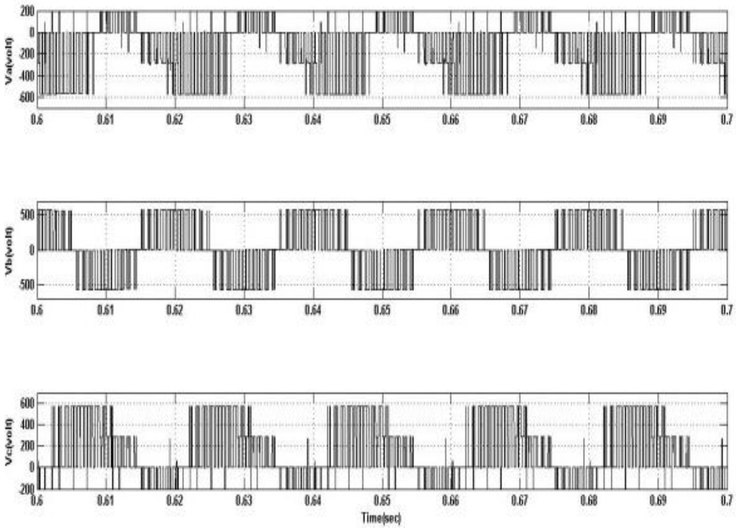

Fig 8. Voltage Waveform (Open circuit fault in upper leg)

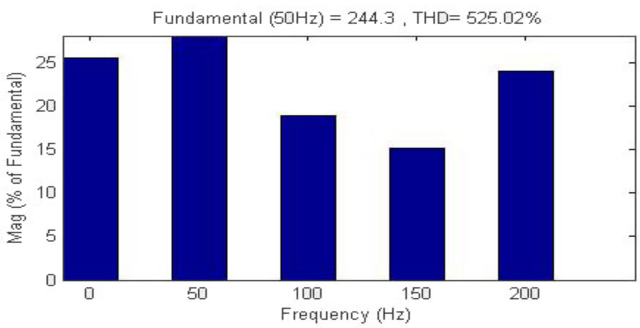

Fig 9. Voltage Spectrum of Phase A

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ISSN (Online): 2278 – 8875

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Vol. 3, Issue 12, December 2014

C. SHORT CIRCUIT FAULT IN UPPER LEG OF PHASE A

To simulate short circuit fault with upper MosFET in the phase A being replaced by a low resistance of 1µohm [9]. Replacing of the MosFET with low value of resistance is equivalent to the short circuiting upper leg of phase A. The simulation circuit is shown in Fig 10.

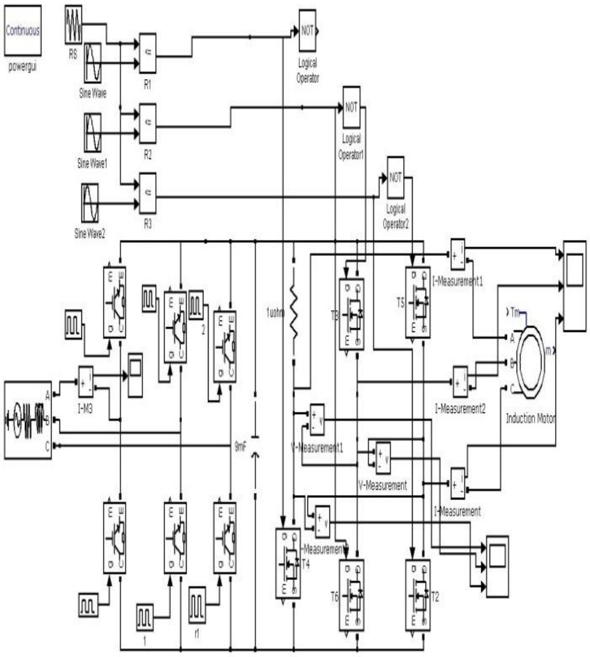

Fig 10 Simulation Circuit for Short Circuiting Upper leg MosFET in Phase A

The waveform of Line Voltage of the three phases A, B & C respectively due to Short Circuiting Upper leg of Phase A fault conditions are shown in Figure 11. On introducing the fault the line voltage is nearly 10.3V in phase A [12].

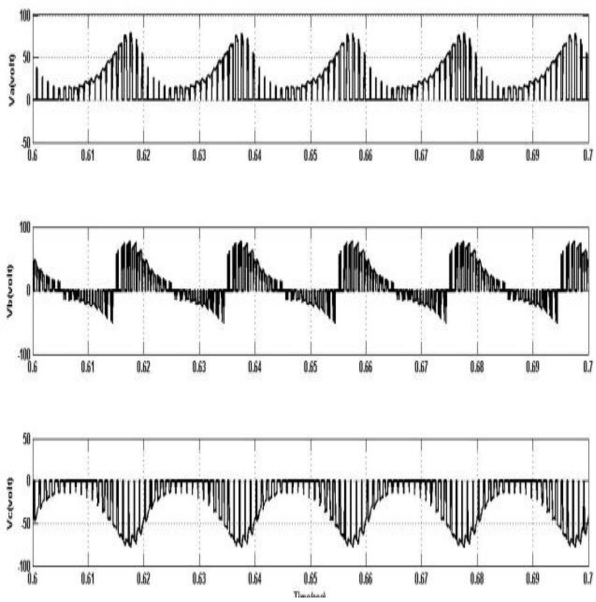

Fig 11. Voltage Waveform (short circuiting upper leg in phase A)

10.15662/ijareeie.2014.0312131

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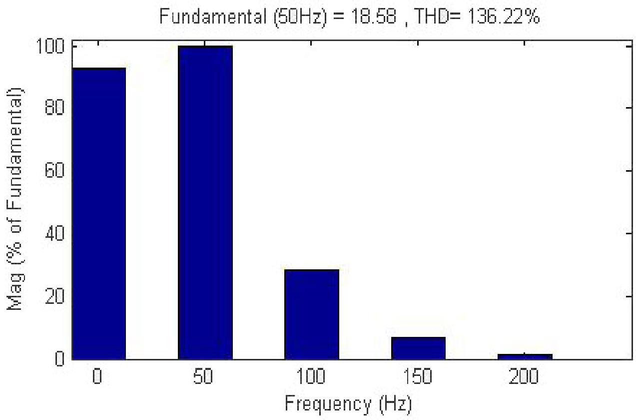

Fig 12 Voltage Spectrum of Phase A

The FFT spectrum under the faulty condition is shown in Fig 12. It is noted that the output line voltage waveforms get distorted on the application of faults [10]. The voltage Spectrum in Phase A is 136.22%

D. COMPLETE SHORT CIRCUIT FAULT IN PHASE A

To simulate complete short circuit fault with upper and lower MosFETs in the phase A being replaced by a low resistance of 1µohm. Replacing of the MosFETs with low value of resistance is equivalent to complete short circuiting of phase A [11]. The simulation circuit is shown in Figure 13.

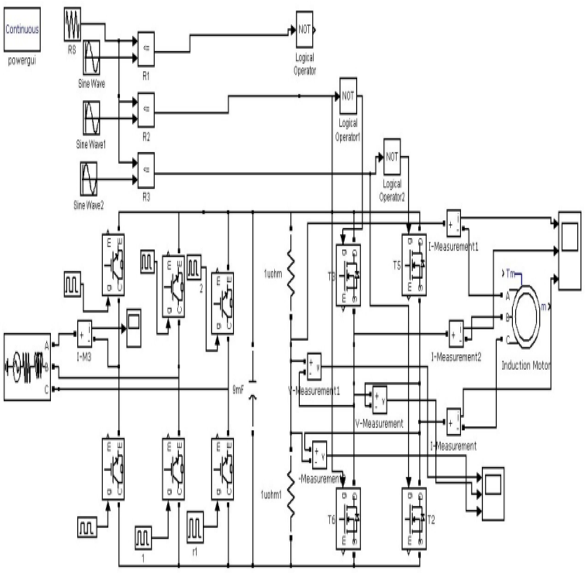

Fig 13. Simulation Circuit for Complete Short Circuit Fault

The waveforms of Line voltage of the three phases A, B & C respectively under the fault conditions are shown in Fig 14. On introducing the fault in the phase A, voltage becomes zero [13].

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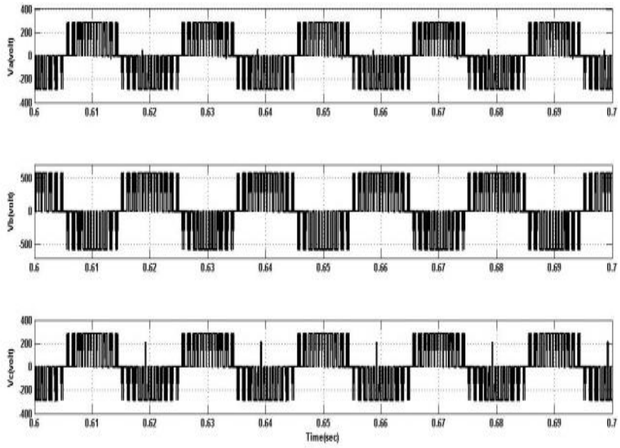

Fig 14 Voltage Waveform

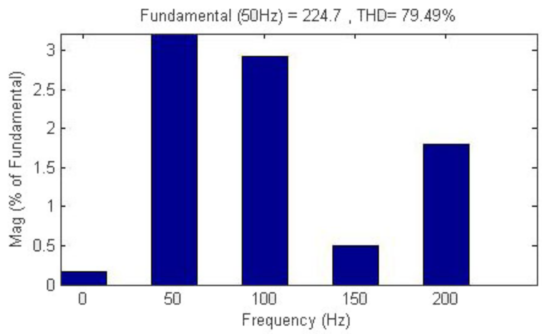

Fig 15. Voltage Spectrum of Phase A

The FFT spectrum under the faulty condition is shown in Fig 15. It is noted that the output line current waveforms get distorted on the application of faults. Thevoltage Spectrum in Phase A is 79.49% [15].

III. SUMMARY OF FFT ANALYSIS OF VSI-FED DRIVE USING SPWM

Total Harmonic Distortion for healthy and faulty conditions were observed and the observation is tabulated in Table 4.1**.** From the tabulated data we can make out the effect of fault on the introduction of fault for all the three phases [14].

Conditions	Parameters	VSI					
		Phase A		Phase B		Phase C	
Healthy Circuit	Voltage THD (%)	257.10		258.11		257.10	
	Line Voltage (A)	78.88		79.77		78.89	
Inverter Module		VSI (open)			VSI(short)		
Short/Open circuiting of MOSFET in upper leg of Phase A	Voltage THD (%)	141.04	257.49	137.98	10.72	15.87	17.85
	Line Voltage (A)	525.02	79.76	531.37	136.22	103.82	75.80
Complete open/short circuit in Phase A	Voltage THD (%)	129.73	258.65	129.09	6.876	11.96	6.86
	Line Voltage (A)	79.49	79.76	80.51	120.78	80.01	121.21

Table 4.1 VSI fed IM Drive using SPWM.

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IV. CONCLUSION

This paper presents the VSI fed IM Drive using SPWM technique. The output line current waveform, voltage waveform and Total Harmonic Distortion of VSI fed IM Drive using SPWM was simulated using MATLAB. From simulation result, it is observed that harmonics have increased on the introduction of faults in the inverter module of VSI fed IM Drive using SPWM. When compared to VSI fed drive using PWM, the harmonics in current is less under healthy conditions but harmonics in voltage is high. On the introduction of faults the harmonics in current increases and harmonics in voltage is very high. To reduce the harmonics in faulty conditions various fault tolerant method can be applied.

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