Power Quality Comparison of Three Phase Bridge Inverter Based Induction Motor

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Abstract

The field of power electronics so important today due to latest development of solid state devices. These devices are significantly saving the energy when used for conversion and control of power electronic based energy systems such as photo voltaic systems, fuel cells, wind farms, active harmonic filters and energy efficient motor drives. The penetration of inverters in these applications is tremendously increased during the last decade. This paper presents three phase inverter topology used to control the speed of induction motor. The Simulink modelled based 3-phase six switch inverter fed to IM drive using MATLAB/Simulink software. The harmonics of three Phase bridge inverter with induction motor is analysed at 120^0, 180^0 and 150^0 mode of operations. It is concluded from simulation results of inverter controlled induction motor that 150o mode of operation has less Total Harmonic Distortion as compared to other mode of operations.

Keywords: *Power Quality, Voltage Source Inverter, Induction Motor, Conduction modes, Total Harmonic Distortion.*

1. Introduction

The generation of an electricity from nonconventional natural resources like wind and sun etc. are commonly employed for modern requirement of power demand consumption [1-2]. The future power demand and enhance quality pollution free supply and environmental friendly obtained from solar and wind energy are connected to the grid or specific consumer applications [1-4]. The utilization of an electrical energy from natural resources is not easy and cannot directly use power into load [5]. Hence the power electronic converters are used for power conversion in a system and make useful for connection of renewable power resources with load [6-8]. These power converters are needed to be design optimally in order to provide system efficiency, safety and reliability of the overall renewable energy system [9-11]. Nowadays 50% of total load is motor load and one third of this is Induction Motor (IM) load [12]. AC motor is preferred choice on account of its simplicity construction, robustness and low cost for industrial application. Hence IM ac drive considered in this paper. This paper focus on the addition of three phase bridge type VSI with an induction motor [13].
A power electronics inverter is a device which universally used as D.C to A.C converter at desired frequency and voltage [14]. These inverters are widely used in many applications like VFD, UPS, power generation system, grids, renewable resources such as photo voltaic systems, fuel cells, wind farms, active power filters and speed control of motor [14-16]. It is known that due to usage of inverter lead to harmonics added in the system which are more harmful

to the system [17]. So the improvement in the output voltage and reduction in harmonic distortion is very important factor to be considered [18-19]. This will be done by varying the gain of the inverter, which normally obtained by using improved control techniques and pulse modulation techniques are used to control and eliminate the harmonics of the inverter [20]. The variable output voltage and reduction in harmonics from the output of three phase VSI can be obtained by comparison of different conduction modes of operation such as 120,180,150 [21]. The proposed three phase bridge is compared with conventional modes like 120 and 180. Through literature review THD of these modes is 31% has been analyzed with resistive load [22]. In this paper the THD of proposed nonconventional conduction mode inverter based Induction motor analyzed found to be very less and cut down harmonics up to 50%. This will mainly focus on reduction harmonics at the out of inverter to drive an Induction motor. The simulation model is done on the proposed inverter topology using MATLAB/Simulink and the results are verified.

2. Three Phase VSI

The power circuit topology of three phase six switch bridge inverter is designed using six switch devices show in fig 1. The leg of inverter composed by two back to back electronic switches such as MOSFET, IGBT and GTO depend upon application [17-18]. Here we discuss simple square wave inverter operation. They are normally used for high power applications. A Conventional and Nonconventional conduction mode such as 180, 120 and 150 is considered. The output of inverter is a three phase balanced output. The three phase output may be obtained by connected three single phase inverters in parallel. The control signal as shown in fig 1 applying through gate terminals should be advanced in order to obtain three phase balanced voltage. Three phase voltage source inverter used DC power as an input and converts it into AC power by using control signal given to gate terminal.

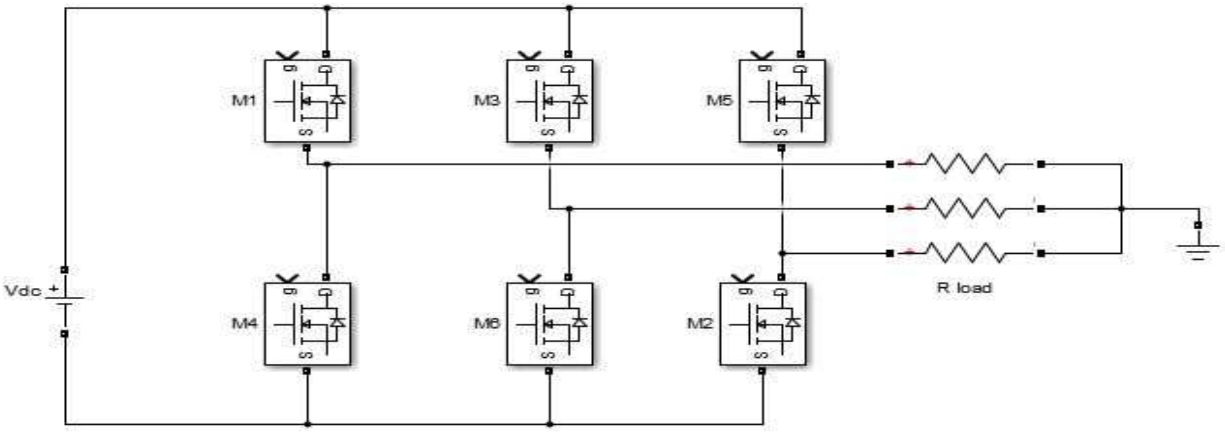


Fig.1. Three Phase VSI

3. Simulation of Three Phase inverter based Induction Motor at different Conduction Modes

The three six switch bridge inverter has three types of modes namely 180^0,120^0 and 150^0 mode of operation.

3.1 180^0 Conduction Mode

The simulation model of three phase 180^0 conduction mode bridge type based Induction Motor is shown in fig 2. The model consist of six MOSFET switches, DC input supply, balanced Induction motor load, six pulse generator and measurement block. This mode is also known as conventional conduction mode of inverter and most widely used in many industries as in square wave controlled three phase VSI. The simulation model of 180^0 mode uses six MOSFET electronic pairs in each leg i.e. M1 and M4, M3 and M6, M5 and M2, in which each switch conducts for 180^0 which implies that switches M1 and M4 conducts for 180^0 and so on for balance of output voltage and the turn on interval between the switches is straggled by 60 degree. It means pulse width is 50%, as result, only three switches conduct at any instant in a complementary manner. It exist that two switch conduct from upper side, while one from lower side of switches and vice versa. In this way the upper side of switches is connected to positive dc bus. For reverse output phase sequence pattern of switching may be reversed. But here in this 180 mode there is no time delay between the turn ON and turn OFF of upper and lower switch of same leg. So this can be producing short circuit of DC supply

through upper and lower switches.

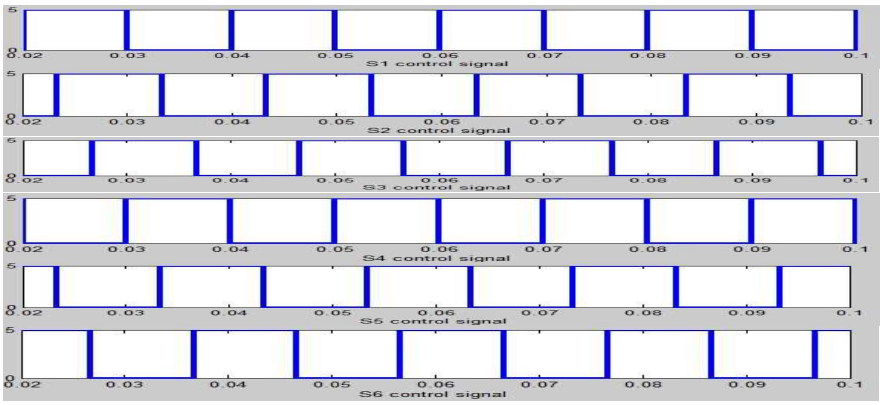


Fig 2. Control Switching pattern for full cycle

Table 1 Shows the control switching pattern for full cycle of 180^0 mode inverter is provided and fig 2 show the simulation of gating pulse at time 0.02s to 0.1s for all six switches. In this mode, each combination of switch conduct for 60^0 in the sequence to produce ac output voltage in phase sequence A,B,C.

Table 1: control Switching pattern for full cycle.

Interval	Duration	Conducting switch
i)	0 to 180/3	S_5on, S_6on S_1on,
ii)	π/3 to 2*180/3	S_6on, S_1on, S_2on
iii)	2*180/3 to π	S_3on S_1on, S_2on,
iv)	Π to 4*180/3	S_3on, S_2on, S_4on
v)	4*180/3 to 5*180/3	S_3on, S_4on, S_5on
vi)	5*180 /3 to 2*180	S_4on, S_5on S_6on

The simulation model has been made for 180 conduction mode which is shown in fig 3.

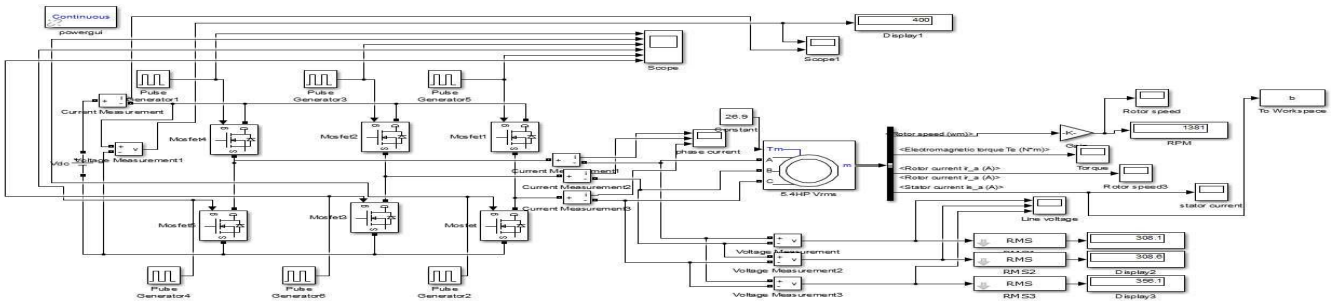


Fig.3. 3-phase VSI of 180 Mode with IM

The integration of an output of three phase bridge inverter at 180 mode is connected to 3-Φ Induction motor is shown in Fig. 3. The use of an inductive load in blocking the greater order harmonic current. Load current contain harmonics. These harmonic produced unwanted noise, vibration, losses and pulsating toque. Thus Electromagnetic torque of an inverter fed IM drive produced amount of ripple. The output of an inverter is nonsinusodial and contain some amount of harmonics. For large and medium type applications three phase bridge type inverters is preferred. Due to the availability of high speed and low cost power electronic devices, the harmonics contents at output voltage can be minimized by control techniques. The output of inverter change according to control pattern. In this simulation model, input voltage dc is V_{dc}=450 applied to inverter.

3.2 120 Conduction Mode

In this paper, a 3-Φ Induction motor is also fed using a three-phase bridge inverter operating at 120 conduction mode. The inverter circuit topology of 120^0 mode of a thee phase bridge VSI shown in simulation fig 5. In this type of mode assumed same bridge inverter can be controlled with each switch leg operate for 120^0 time period. At the instant of time two switches will operate for one cycle simultaneously, in which the upper switch remain on in the first half cycle and lower switch is On for next other half cycle. It is observed from that one conducting switches changes the state after an interval of $60^{0.}$ Further simulation is observed that no possibility of short circuit operation of switch, output RMS and utilization of switch is less as compared to 180^0 mode of operation.

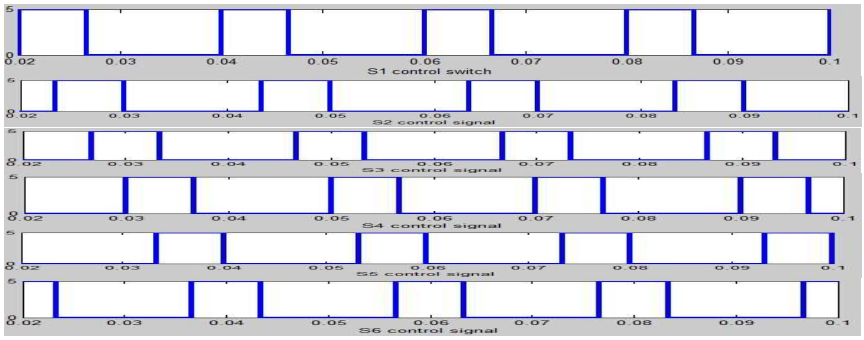


Fig.4. Control Switching pattern for full cycle

Table 2 shows available six conduction of control switching pattern for full cycle of 120 mode inverter is provided and simulation of fig 4 show the gating pulse at time 0.02s to 0.1s for all six switches at 120 mode of operation. This conduction made for 60^0 in the sequences for output ac voltage in phase sequence like A, B, C.

Table 2. Control switching pattern for full cycle

Interval	Duration	Conducting switch
i)	0 to 180/3	S_{5on}, $S_{1on,}$
ii)	π/3 to 2*180/3	S_{1on}, S_{2on}
iii)	2*180/3 to π	S_{3on}, S_{2on},
iv)	Π to 4*180/3	S_{3on}, S_{4on}
v)	4*180/3 to 5*180/3	S_{4on}, S_{5on}
vi)	5*180 /3 to 2*180	S_{5on} S_{6on}

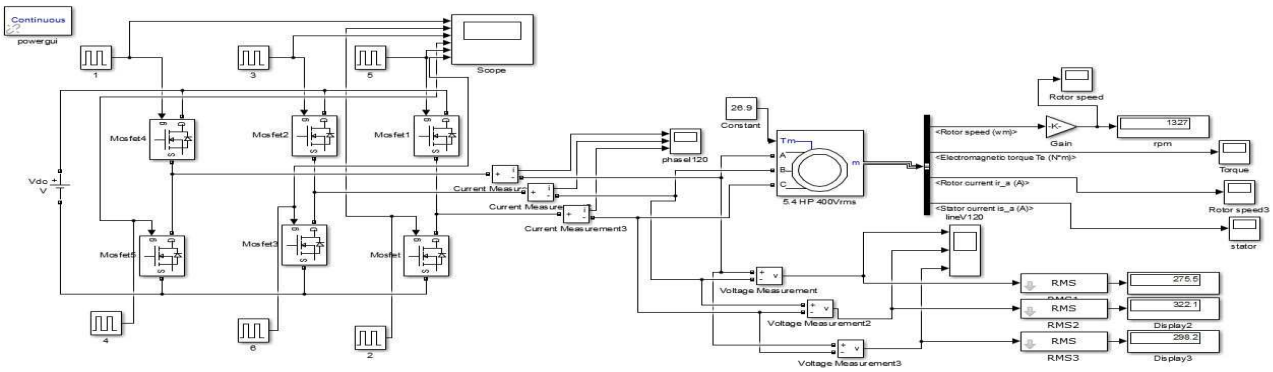


Fig.5. 3-phase VSI of 120 Mode with IM

In this mode there is existence of a 60^0 dead time between conducting switches, it provide a safety margin against the continuous conduction of two series switches across dc supply.

3.3 150^0 Conduction Mode

The Simulation model of 150 mode VSI is shown in fig.7 In this model six MOSFET switches are used, input DC supply fed to inverter and connected with Induction motor drive load. This power circuit model is same as 120 and 180 mode of inverter, but conduction modes operation for controlling are different. Here we used six pulse generator and measurement block is shown in simulation model. In this mode each switch conducts for 150^0, the duty cycle is 41.66% and each switch turn on for 5/12 period. It is very easy to design and implement and hence does not require any advance controller. This mode has divided a cycle in to 12 step and each have 30^0 duration for complete one cycle of the output ac voltage. By use of suitable pulses to MOSFET the output an inverter is square wave. The MOSFET pair are shown such as M1 and M4, M3 and M6, M5 and M2.

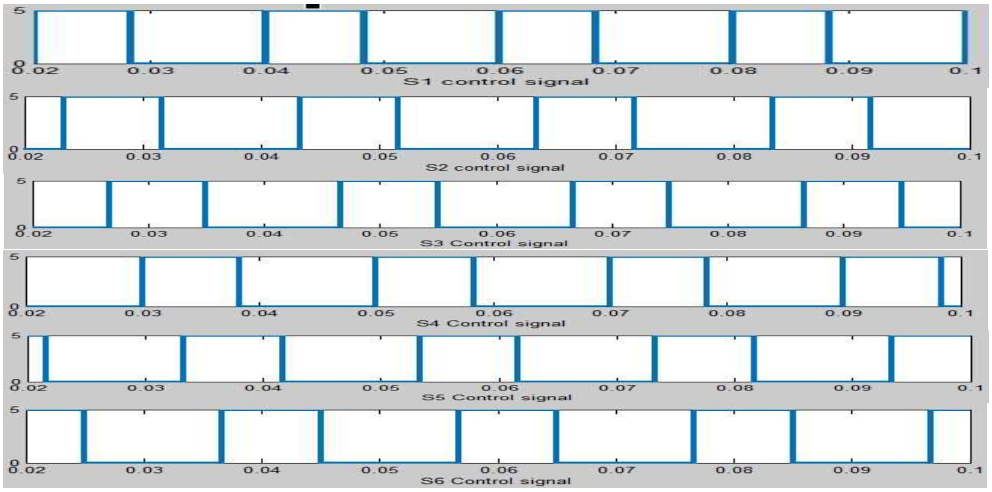


Fig.6. Control Switching pattern for full cycle.

Table 3 illustrates the control Switching pattern for full cycle of 150 mode inverter is provided and fig.6 shows simulated gating pulse at time 0.02s to 0.1s for all six switches of 150 mode of operation. The control switching pattern is make in such a manner that three switch are turn on in one interval followed by two switch conduct in next interval.

Table.3 Control Switching pattern for full cycle

Interval	Duration	Conducting switch
i)	0 to π/6	S_5on, S_6on S_1on,
ii)	π/6 to π/3	S_6on, S_1on
iii)	π/3 to π/2	S_6on, S_1on S2on
iv)	π/2 to 2π/3	S_1on, S_2on
v)	2π/3 to 5π/6	S_1on, S_2on, S_3on
vi)	5π/6 to π	S_2on S_3on
vii)	Π to 7π/6	S_2on S_3on S_4on,
viii)	7π/6 to 4π/3	S_3on, S_4on
ix)	4π/3 to 9π/6	S_3on, S_4on, S_5on
x)	9π/6 to 5π/3	S_4on, S_5on
xi)	5π/3 to 11π/6	S_4on, S_5on, S_6on
xii)	11π/6 to 2 π	S_5on, S_6on

The Simulation model is done on the proposed inverter topology using MATLAB/Simulink to determine the behaviour of IM drive system of fig 7.

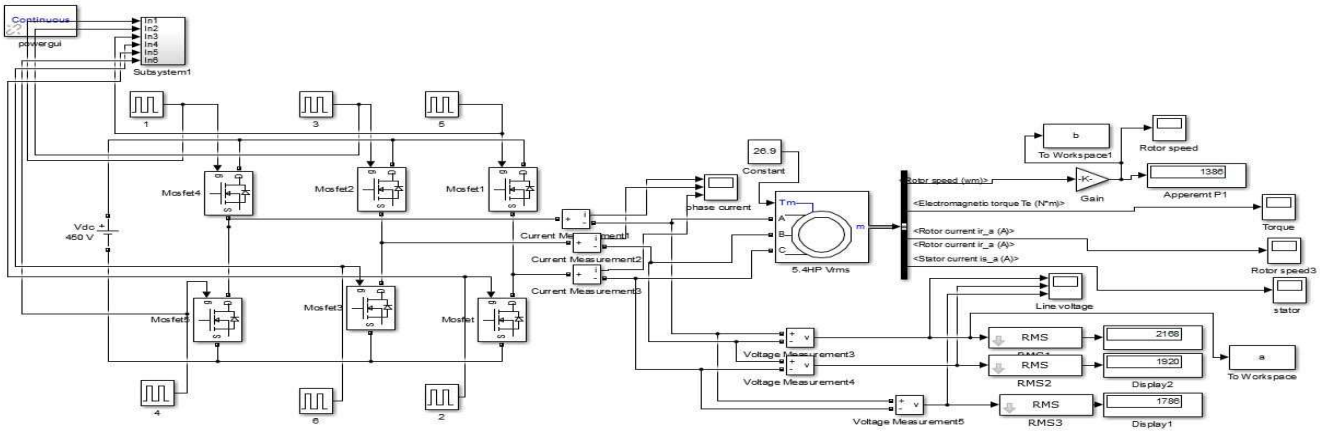


Fig7. 3-phase VSI of 150 Mode with IM

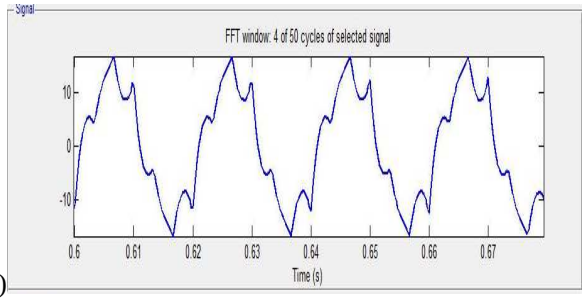
The output of inverter is fed to ac induction motor load. The ac motor load is inductive in nature with inherent harmonic currents in motor. This harmonic current results unwanted torque pulsation, resonance in system and copper losses in the motor. The motor speed hardly changes in response to these pulsations. The availability of high speed power switching devices, the harmonics order at the output can be significantly minimized by control switching technique. With the use of 150 mode the harmonics contents at output voltage can be minimized

4. Harmonics Analysis of Induction Motor at Different Conduction Modes

In this work, the harmonics of induction motor at 180, 120 and 150 conduction modes of VSI are analyzed. The comparison of harmonic analysis for all conduction modes is showed. The FFT analysis of the phase current is done. The magnitude of harmonic order present in the output. The output waveform of these modes of inverter show there is no dc component and less magnitude of even harmonics.

Thus paper compares the performance of three phase bridge VSI drive IM load using 180, 120 and 150 control conduction mode. Simulation results has been made using balanced three phase IM to evaluate performance drive system operating in three modes.

(a)



(b)

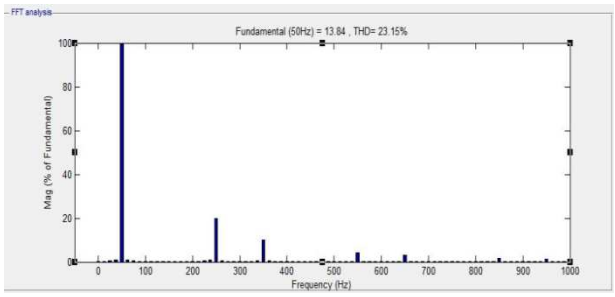
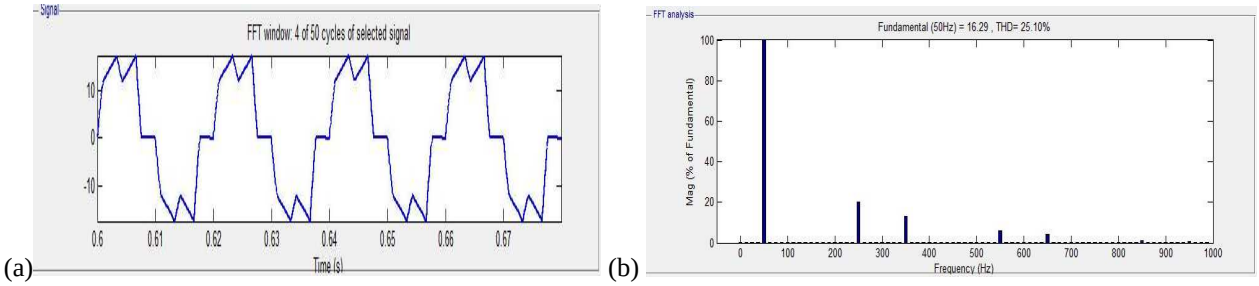


Fig.8. (a) Phase current waveform (b) FFT

Fig.8 Show the performance of induction motor at 180^0 conduction mode of VSI. The input current waveform is shown in fig 9(a) and Harmonic spectrum of is illustrated in fig 9(b).

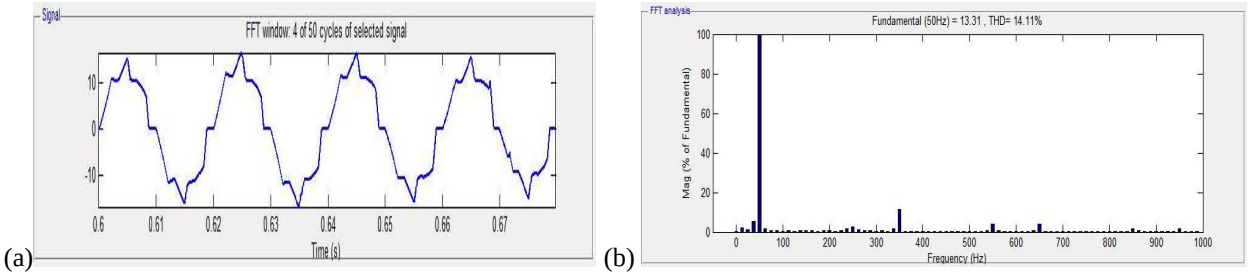
The comparison of harmonic analysis of 180 mode inverter and the phase current show in fig 8(a). So the fundamental value at the output is 13.84 and THD is formed equal to 23.15% with maximum lower harmonics contents as 5^{th} and 7^{th}.



(a) (b)

Fig.09. (a) phase current waveform (b) FFT

For 120^0 mode inverter, the Total Harmonic Distortion approximately remains same. Fig.9 Show the harmonic spectrum for 120^0 conduction mode of VSI. The waveform and Harmonic spectrum of 120 mode inverter is illustrated in fig.9 (a) and fig.9 (b) respectively. The fundamental value at the output is 16.29 and THD is formed equal to 25.10% with maximum lower harmonics contents as 5^{th} and 7^{th}.



(a) (b)

Fig.10. (a) Phase current waveform (b) FFT

The behaviour of induction motor at 150^0 mode is shown in fig.10. The phase voltage becomes seven level and twelve step waveform. So the THD for 150 modes reduces to 14.11% and the fundamental value is 13.31. Harmonics of 150 mode are less as compare to 23.11% and 25.10 % in 180 and 120 mode respectively. From FFT analysis it can be shown that the harmonic distortion is reduced by using the 150 conduction mode. It reduces up to 50% of 180 and 120 conduction modes.

5. Conclusion

Research works presents a simulation model and harmonic analysis of 3-Φ Induction motor fed by three phase voltage source inverter operated at 180^0, 120^0 and 150^0 conduction mode. It is clear from results, reduction in THD of the output phase current at 150 mode of operation. Analysis of simulation results verified that the THD is minimized by 50% when inverter operates at 150^0 mode as compared to 180^0 and 120^0 modes respectively.

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