Inverter Fed Technique To Control The Speed of Three Phase Induction Motor And Harmonic Reduction Using Passive Filter

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Abstract- *Harmonics is the distortion in waves when high voltages and switching takes place in an electrical system. There is no method to completely remove it from the system as we know that in this world nothing is ideal. But we can reduce is upto 5% but not below that, this work is basically done to reduce harmonics upto 5% with the help of passive filters.*

In this work the concept of PWM is widely used and all the work is done on MATLAB and its variations are analyzed in simulink. As we have used inverter first to change DC to AC and then fed from high frequency pulse is imposed via PWM generator. The output parameters are once analyzed without using filters and then using filters. The final results are then analyzed and compared with ideal values.

Keywords- MATLAB, Simulink, Inverter, Pulse Width Modulation, Passive filters(LC)

I. INTRODUCTION

An inverter is a power electronic device, used to change the power from one form to other like DC to AC at the necessary frequency & voltage output. The classification of this can be done based on the source of supply as well as related topology in the power circuit. So these are classified into two types - VSI (voltage source inverter) and CSI (current source inverter). The VSI type inverter has a DC voltage source with less impedance at the input terminals of an inverter. The CSI type inverter has a DC current source with high impedance. [2]

Here in the work presented we have controlled the three phase Induction motor using PWM technique in VSI inverter.

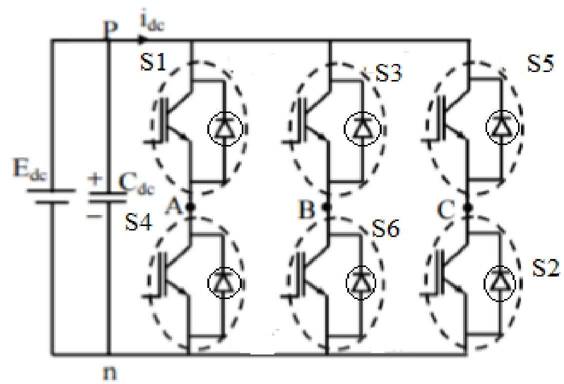

Figure 1: Inverter Circuit Diagram

II. LITERATURE SURVEY

A. What is Induction Motor?

An induction motor or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor. An induction motor's rotor can be either wound type or squirrel-cage type.

Three-phase squirrel-cage induction motors are widely used as industrial drives because they are self-starting, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFD) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel-cage induction motors are very widely used in both fixed-speed and variable-frequency drive applications.

B. Three Phase Inverter Circuit Diagram

The circuit diagram of a three-phase inverter is shown Fig-1. The main function of this kind of inverter is to change the input of DC to the output of three-phase AC. A basic 3 phase inverter includes 3 single phase inverter switches where each switch can be connected to one of the 3 load terminals.Generally, the three arms of this inverter will be delayed with 120 degrees angle to generate a 3-Phase supply.The switches used in the inverter have 50% ofratio and switching can be occurred after every 60 degrees angle. The switches like S1, S2, S3, S4, S5, and S6 will complement each other. In this, three inverters with single-phase are placed across a similar DC source. The pole voltages within the three-phase inverter are equivalent to the pole voltages within the half-bridge inverter with a single phase.

The two types of inverters like the single-phase and three-phase include two conduction modes like 180 degrees conduction mode and 120 degrees conduction mode. In the work presented employs 180 degree conduction mode.

C. Pulse Width Modulation

Pulse-width modulation (PWM), is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage and current fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.[4]

D. Harmonics

Harmonics are produced by rapid rise of current, either in positive or negative direction. This results to non-sinusoidal nature of the waveform of the output of an inerter voltage source. Square waves and pulse wave produce a rapid and abrupt rise in this type of waveform. Harmonics currents are the results of non-linear loads demanding a current waveform different from the shape of applied voltage wave. The non-linear load devices includes solid state power switching devices such as diodes, thyristors, SCRs or transistors that converts dc power by drawing the current in pulses.[5]

Harmonic elimination by Pulse width modulation switching strategies have been used for sometime in voltage fed inverters and this in more recent times are applied to current fed inverters drives.

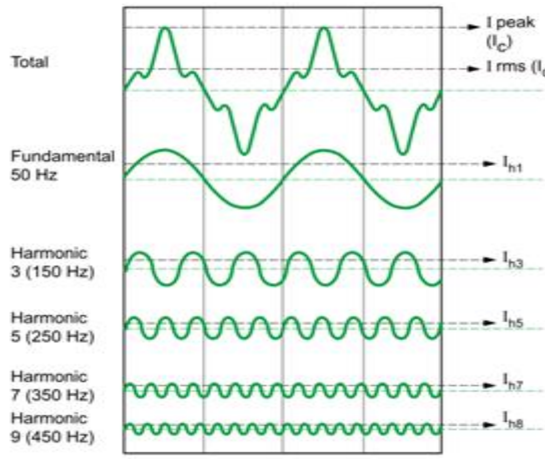

Figure: 2 Odd Harmonics

E. Papers Studied

The following papers were studied and analyzed in detail and hence summarized in the table below:

Table 1: Papers Reviewed

Topic of Paper	Concept Analyzed	Tools Used
Induction Motor Analysis by Time Stepping Techniques[1]	Variation of Speed by stepping of waves.	Hardware Implementation
Comparing capacitive and LC compensators for power factor correction and voltage harmonic reduction[2]	Value of L & C used in Simulink model.	MATLAB
Harmonics Reduction by use of sinusoidal pulse width modulation[3]	Concept of PWM with its carrier frequency.	MATLAB
Eliminating Harmonics from the Power System.[4]	Reduction of harmonics in power system.	Hardware Implementation
Harmonics and Suppression for Electrical system supplying power converter and other non linear loads[5]	Reduction of Harmonics in electrical system.	Hardware Applications

III. DESIGN METHODOLOGY AND IMPLEMENTATION

A. Objective

- Our main objective is to study the various parameters i.e current, speed, torque variation on changing the V/f ratio. And from there we would analyze the total harmonic distortion in the waves.
- After this we have to apply one LC filter in the supply system and this will reduce the harmonic contents from the system.

B. Problem Statement

- The use of semiconductor devices will introduce a large harmonic distortion in the system. But the basic thing is to remove it from the system. Harmonics should be completely removed from the system to nearly zero, but it cannot be possible.
- It can be reduced upto 5% by using the passive filters or low pass filter. In this project our main aim is to lower down the harmonics upto 85%, such that losses in the machine would be less and maximum output from the system can be achieved.
- But the choice of the values of L & C in low pass filters is the major concern for the completion of project. In this project the values of filter parameter are taken by hit and trial method.

C. Block Diagram

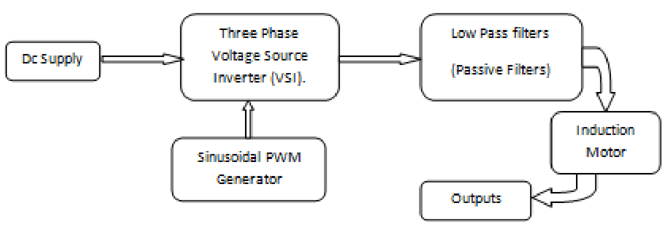

Figure 3: Block diagram for harmonic elimination form Three Phase VSI.

- As we can see first of all we will give dc supply to Voltage Source Inverter and after that high frequency PWM generator such that output would be uniform. After applying PWM we should pass it through Low pass filters and then the output voltage of Inverter is fed to the Indution Motor to drive the load.

D. Matlab Simulation of PWM Inverter in Simulink

Simulink is a graphical extension to MATLAB for modeling and simulation of systems. One of the main advantages of Simulink is the ability to model a nonlinear system, which a transfer function is unable to do. Another advantage of Simulink is the ability to take on initial conditions. When a transfer function is built, the initial conditions are assumed to be zero.

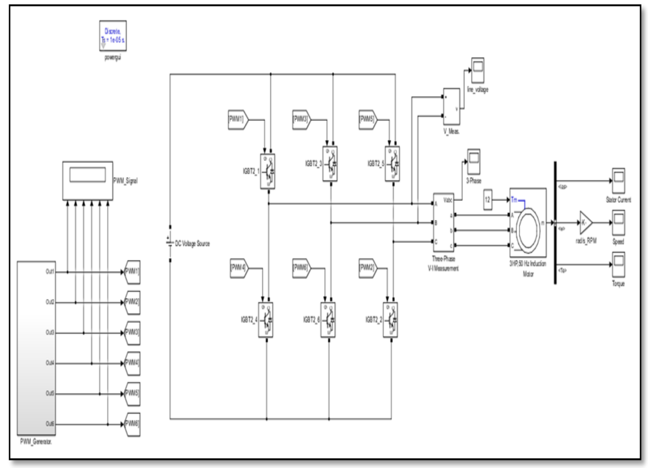

Figure 4: Simulink Model

In Simulink, systems are drawn on screen as block diagrams shown in Fig 4 . Many elements of block diagrams are available, such as transfer functions, summing junctions, etc., as well as virtual input and output devices such as function generators and oscilloscopes.

As shown in Fig 4, we don't use filters because first we have to take the readings of harmonics in either Input or in Output. In this part we have taken only two parameters in our consideration, first is rotor torque and other is stator current and its line voltage.

IV. RESULT AND DISCUSSION.

We have connected Passive low pass filters to the Simulink model to check the variations and THD (Total Harmonic Distortion) in the system present. We have the scope at every point so we can see each and every waveform clearly

The output of inverter is connected to three phase Induction Motor with low pass filter as shown in Fig 5. The busbar at end is use to get the output of the system. PWM is fed in six IGBTs to provide the required wave pulse so that DC supply easily converted into AC and that distortionless wave when fed to the Induction Motor will give the output with very less total harmonic distortion in stator current and torque.

Lesser harmonic content is basically means that the uneven waveform must be removed from the system and LC filter in this system perfectly do it as we can see in the output waveform of torque at 50Hz,220V supply.

As we can see in Fig 6, the output stator current has more uneven variation in its waveform.

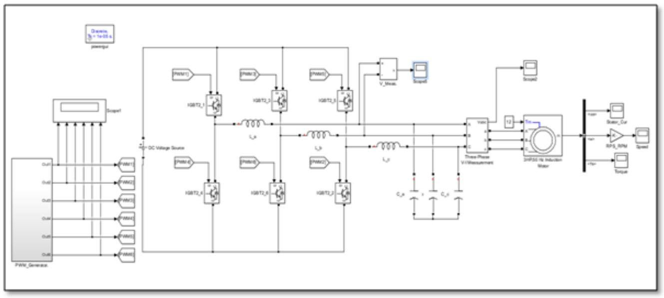

Figure 5: Simulink model with Passive Filters.

For knowing the value of harmonics we can see FFT window in Fig 7,shows 62.19% THD, while after application of filters in simulink model as shown in Fig 5, we lower down the value of THD to 7.76 % which means filter alone lower it by nearly 54.43%. Table 4

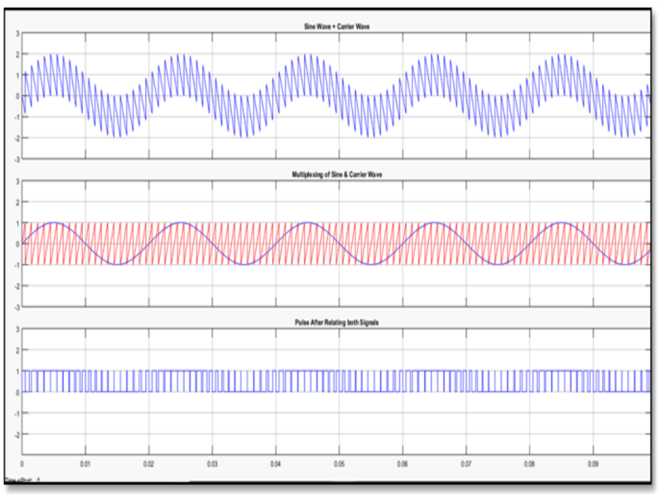

Figure6:Waveform of Subsystem.

In the Fig 6 Waveform we can see that there is a combination of two signals, first one is sine wave and other is carrier wave, whose frequency is very high. This type of signal is applied to the Three phase Inverter circuit

In PWM generator we have to compare two waves and which one is greater then the signal would be high and low when first wave is less than other wave. Once we get this wave then in simulink model we have to give supply to the system so that we can go for the next step for the output waveforms

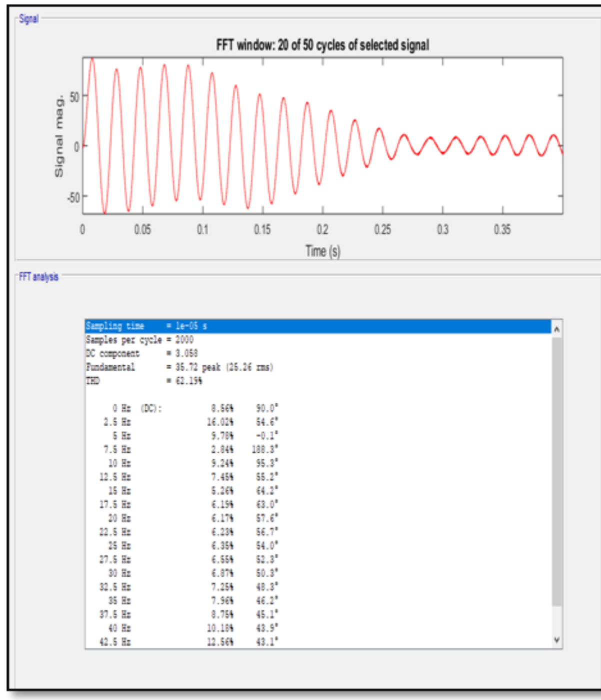

Figure 7: Total Harmonic Distortion in stator current before and after the application of filters respectively.

Table 2. THD in Stator Current & Line Voltage without Filters.

S.No	Voltage (V)	Frequency (Hz)	Speed (RPM)	THD_Stator Current (Without Filter)	THD_Line Voltage (Without Filter)
1.	220	50	1490	62.19%	68.59%
2.	210	47.72	1415	72.19%	68.67%
3.	200	45.45	1270	82.09%	68.68%
4.	170	38.63	1195	101.88%	68.70%

Now when we use passive filters with the VSI shown in Fig 5 and then give supply to Simulink window, then we get the output waveform same as that of without filters.But when we take close view from scopes we will get the waveform as shown in Fig 6.

Table 2 is the result of stator current and line voltage without filter and Table 3 is the result of stator current and line voltage with filter. In table 4, total reduction of values are written by which we can conclude that harmonics has been reduced by nearly 70.82% (average) from Stator Current & 50% (average) from Line Voltage.

Table 3. THD in Stator Current & Line Voltage with Filters.

S.No	Voltage (V)	Frequency (Hz)	Speed (RPM)	THD_Stator Current (With Filter)	THD_Line voltage (With_Filter)
1.	220	50	1490	7.76%	15.54%
2.	210	47.72	1415	8.88%	16.53%
3.	200	45.45	1270	8.89%	14.78%
4.	170	38.63	1195	9.52%	24.26%

Table 4. Table showing reduction of THD Stator Current & Line Voltage.

S.No	Voltage (V)	Frequency (Hz)	Speed (RPM)	Reduction of THD in Stator Current.	Reduction of THD in Line Voltage.
1.	220	50	1490	54.43%	53.05%
2.	210	47.72	1415	63.31%	52.14%
3.	200	45.45	1270	73.21%	49.91%
4.	170	38.63	1195	92.36%	44.45%

When we open FFT window for torque we get the result that net harmonics in system would have reduced to 31.93%, as shown in Fig 7 which has been reduced from 95% (without filter) to 31.93% (with filter) i.e total reduction of 63.07%.

Similiary when we check stator current FFT window we will come to know that it has been reduced by 54.43%as shown in Table 4.

As one result is not sufficient we have reduced the speed of Induction Motor by keeping V/f ratio constant, such that their would be no magnetic saturation in core keeping magnetic flux of core constant.

Table 2 is the result of stator current and line voltage without filter and Table 3 is the result of stator current and line voltage with filter. In table 4, total reduction of values are writtenby which we can conclude that harmonics has been reduced by nearly 70.82% (average) from Stator Current & 50% (average) from Line Voltage.

VII. CONCLUSIONS

- The paper presents harmonic elimination technique for three phase voltage source inverter with Induction motor as load. Analysis and result of total harmonic distortion for sinusoidal PWM technique has been done.

From the observation it is evident that the total harmonic distortion (THD) is reduced upto 88% in stator current and 74% in starting torque (Table 4). The use of closed loop PID controller can further reduce the total harmonic distortion.

- Harmonics is the generalised term used to describe the distortion of a sinusoidal waveform by waveforms of different frequencies.
- The work done presents harmonic elimination technique for three phase voltage source inverter with Induction motor as load. Analysis and result of total harmonic distortion for sinusoidal PWM technique has been done. From the observation it is evident that the total harmonic distortion (THD) is reduced upto 71% in stator current and 50% in line voltage (Table 4).
- Use of semiconductor devices like rectifiers, SCRs, power converters & switching circuits etc produces large harmonics in the system.
- PWM technique uses high carrier wave but it provide smooth input to the system so that uneven ups and down gets completely removed.

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