Simulation Modelling of 1-Ø I.M with AC-AC Chopper Using ANN Controller

Sharad Chandra, Vivek Patel

Abstract - A neural network controller based PWM AC to AC chopper operated single phase induction motor's Simulink model is proposed in this paper. Single phase AC to AC converter with pulse width modulation (PWM) is presented to control the voltage of stator of the single phase induction motor. The PWM AC to AC chopper consist four IGBT switches to control the stator voltage, either of four switches only two switches operate at a time. So the proposed PWM AC to AC chopper improves the input power factor and also minimizes the harmonics effect of stator/rotor voltage/current waveforms.In the industrial sector an induction motor play a very important role especially in field of drive and control. In a specific application it is almost terrible to achieve the preferredaction without proper controlling of speed, therefore the induction motor speed control is very important action in an industrial process. Closed loop speed control mechanism is generally provided to maintain the speed of the constant speed driven appliances like pump, fan etc. A neural network controller is used to make the closed loop system. The ANN controller proposed for the system to maintaining the motor speed to be constant while the load is varies. The neural network is trained to estimate the required voltage for different load conditions and also trained for the speed of the drive tracks the reference speed. At the different load conditions, different duty ratio will obtained and this signal is used to train the neural network. MATLAB/SIMULINK software is used to develop a single phase induction motor model. It is found that with the use of the ANN controller the performance and dynamics of the induction motor are enhanced.

Keywords - AC-AC Chopper, SIMULINK, ANN Controller.

I. INTRODUCTION

Simple construction, lightness, low maintenance, and robustness features of single phase induction machine are make it wide use in industry. There is leading demand of motor drives in industries, therefore alternately an increasingdemand of improvements of the power quality and reliability of the drive system. The Phase control (inverse parallel connected pair of thyrister) are generally employed for solid state ac power control applications, like heater control, illumination control etc. But there are several limitations of phase control, it suffer from lagging power factor at the input even if load is purely resistive. The voltage across a load contains a harmonics at multiple of main supply voltage and harmonic current flowing through the load produce a considerable amount of heat, as a result produce a pulsating torque on the motor.

Now line commutated phase control ac controller can be replaced by the force commutated PWM AC to AC chopper to overcome the above problems and improve the overall performance of the system. Constant speed operation is required by the most of the drive system,by changing the firing angle of the chopper the stator voltage as well as speed of the motor is maintain to constant. The closed loop system is implemented by using neural network controllers. This neural network controller is a three layers (input layer, an output layer, and a hidden layer) neural network. The accuracy of a specific application is regulates by the number of neurons in the hidden layer. Neural networks are gaining potential as controllers due to the fact that they represent better properties than the conventional controllers.

II. SIMULINK MODEL OF SINGLE PHASE INDUCTION MOTOR

The designed Simulink model of the single phase induction motor is shown in Fig. 2.1. For the very small value of slip *s*, $\frac{r_2'}{2s}$ is taken higher than $\frac{r_2'}{2s}/[2 \cdot (2 - s)]$. Generally, the magnitude of V_0 is 92% to 94% of the supplied voltage. At this small value of V_0 the value of backward field is minimum, therefore it neglected.

The stator current can be expressed as

$$I = \frac{V - V_0}{r_1 - jx_1} \tag{1}$$

If the rotor current I_2 referred to the stator is taken as I_2', no-load current can be expressed as

$$I_0 = I_1 - I_2' \tag{2}$$

The expression for output voltage can be expressed as

$$V_0 = I_0 \frac{jr_0 x_0}{\left[4\left(\frac{r_0}{2} + \frac{jx_0}{2}\right)\right]} \tag{3}$$

It expression can be rewritten as:

$$V_0 = I_0\left[\frac{r_0}{2} - \left\{\frac{\left(\frac{r_0}{2}\right)^2}{\left(\left(\frac{r_0}{2} + \frac{jx_0}{2}\right)\right)}\right\}\right] \quad (4)$$

The voltage across the inductor $\frac{jx_2'}{2}$ is expressed as:

$$V_0 - I_2'\left(\frac{r_2'}{s}\right) \quad (5)$$

The expression of torque developed by the motor is given as:

$$T = (I_2')^2 \frac{\left(\frac{r_2'}{2s}\right)}{2\pi n_s} \quad (6)$$

The equation balance load is given by:

$$T = j\frac{d\omega}{dt} + B\omega + T_L \quad (7)$$

By using the above described equations, the Simulink model for the single phase induction motor is obtained.

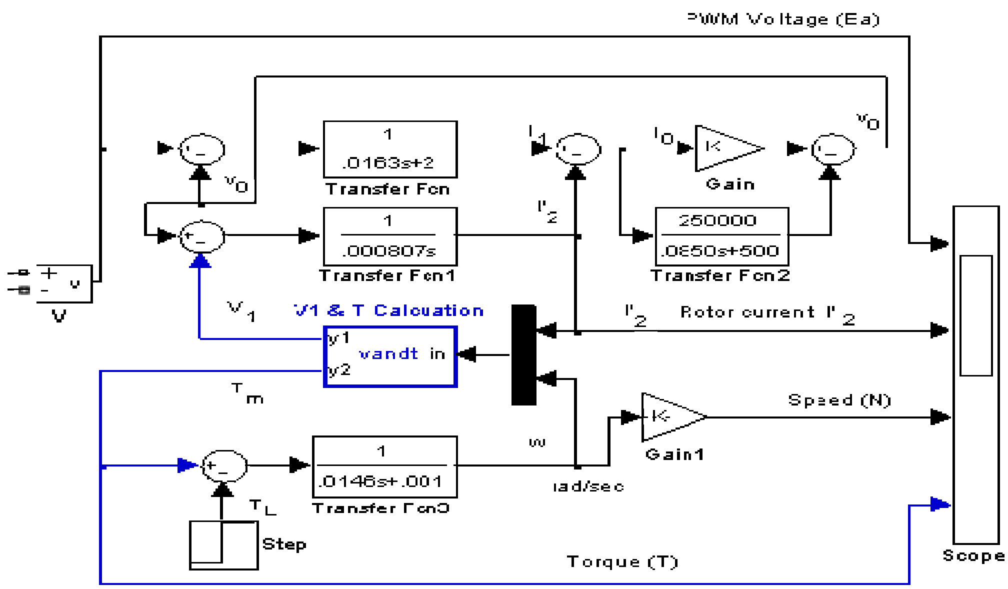

Figure 2.1 Simulink model of single phase induction motor.

III. PWM AC-AC CHOPPER FED INDUCTION MOTOR

A block diagrammatic representation of AC-AC fed single phase induction motor with neural network feedback controller is depicted in fig.3.1. The circuit input parameters voltage and current are directly supplied from a single phase line. The voltage across each IGBT switch is limited by the line voltage. The various parameters, namely, stator pulse modulated voltage (E_a), stator current (I_1), rotor speed (N) and error generated in speed (ΔN) are sensed and forward to the neural network. Neural network generated pulse given to the IGBT switch through pulse generator in order to control the firing angle and maintain the speed of motor at reference speed. The proposed neural network act as a feed back is used for speed regulation. During each running stage, the weight and biases of neural network are updated. The back propagation algorithm is used to generate the error between the desired output and the actual output of the neural network which is less than the predefine reference value. The input layer design to receives four input (Ea, I_1, N and ΔN), hidden layer has three neurons and output layer has single neuron, therefore it say that neural network controller has a 4-3-1 type structure. This proposed neural network controller generates the results in the many repeated trials.

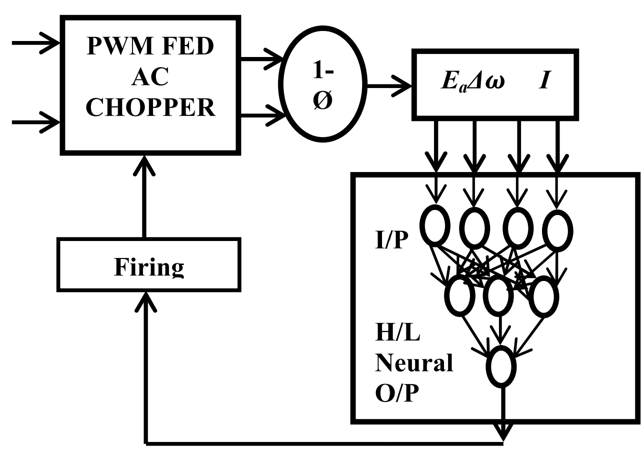

Figure: 3.1 PWM AC-ACChopper fed Single Phase Induction Motor.

IV. NEURAL NETWORK CLOSED LOOP STATOR VOLTAGE CONTROLLED SINGLE PHASE INDUCTION MOTOR

A simulation model of AC to AC chopper fed, neural network controlled single phase induction motor is depicted in Fig.4.1. Here, stator voltage is obtained from the output of the PWM AC to AC chopper. The variation in stator voltage varies the speed of the single phase induction motor. A speed sensor is introduced to sense the speed of the motor. These sensed speed is compared with the predefine reference speed. If an error is generate then transferred to firing circuit through the neural network controller. As this way by controlling the firing pulse, a number of training pattern are obtained at the stator of the motor. These pattern may be obtain by the four parameters (stator voltage E_a, stator current I_1, speed of the machine N, and error in speed ΔN). By these obtained patterns the neural network controller is trained, and by using the back propagation algorithm, the simulation of neural network is performed.

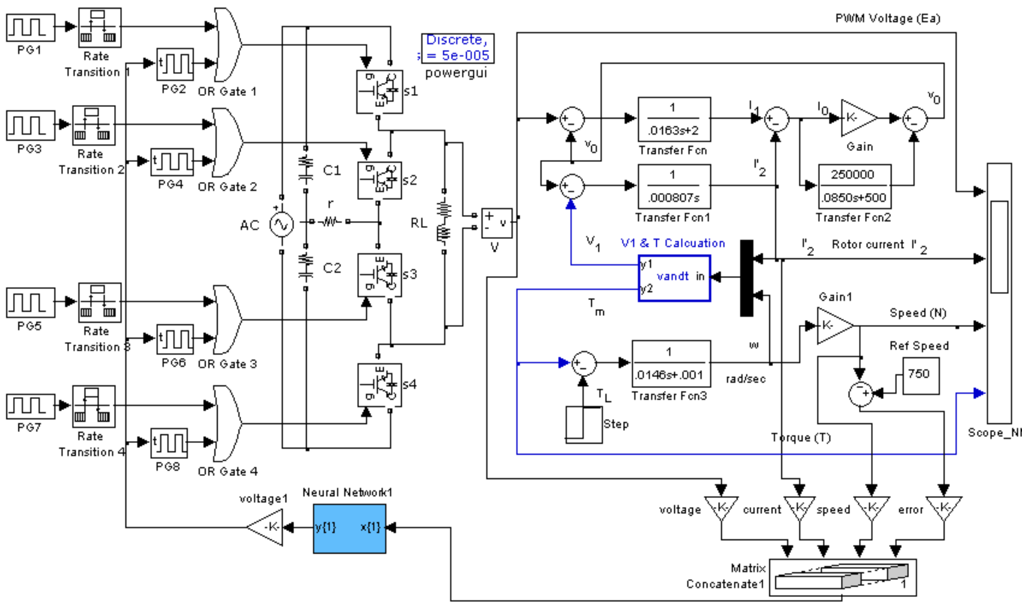

Figure: 4.1 Simulink model of closed loop single phase induction motor.

V. RESULT ANALYSIS

5.1 WAVE FORM OUTPUT

5.1.1 AC Chopper:

In the figure 5.1the firing pulse for four GTOs are shown, which are working in proper switching sequence.

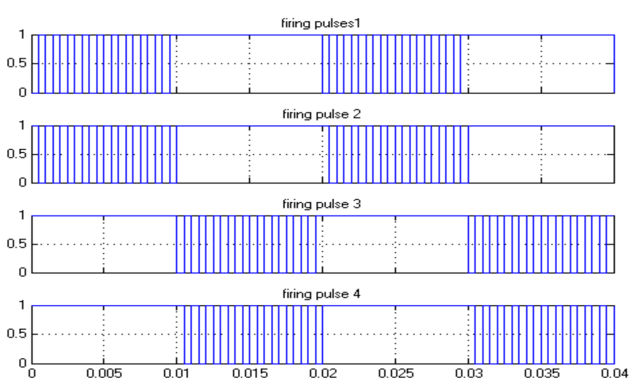

Figure: 5.1 PWM AC-AC choppers firing pulses

The PWM ac-ac chopper is working according to the proper sequence of switching and this is responsible for the rotor current.

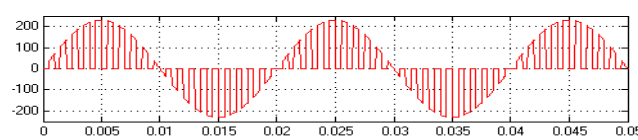

Figure: 5.2 PWM AC-AC chopper waveform

5.1.2 WAVEFORMS OF 1-Ø I.M WITH PWM AC-AC CHOPPER

Fig. 5.3 represents the waveform of the PWM AC-AC chopper fed 1-Ø induction motor's voltage and current. In this system by the use of PWM AC-AC chopper means the use of power electronics device (non-linear load), therefore wave shape of such a system's voltage and current is not the proper sinusoidal but a quite distorted waveform.

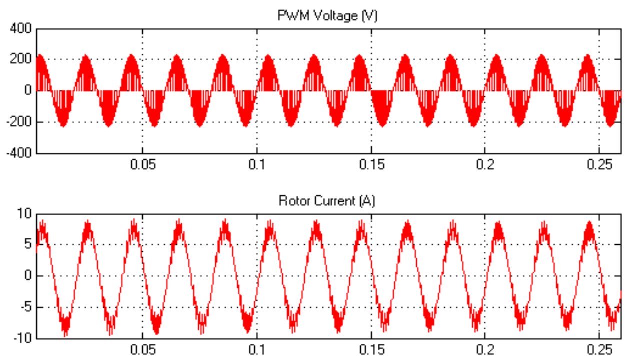

Figure: 5.3 Waveform of voltage and current of 1-Ø I.M with PWM AC-AC chopper

The fig. 5.4 shows the waveform of speed and torque of single phase induction motor. It's clear from the waveform that the speed took the large time to reach the reference speed i.e 750 rpm in this case.

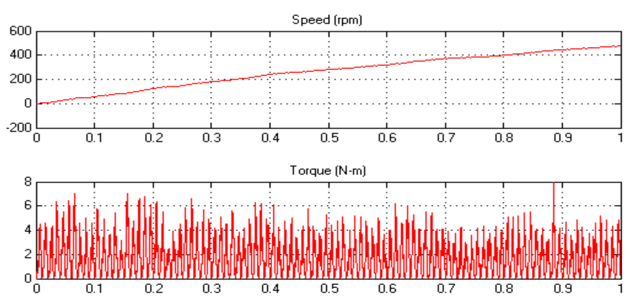

Figure: 5.4 Speed & Torque Waveform of 1-Ø I.M with PWM AC-AC chopper

In the torque waveform it is seen that the harmonic distortion is quiet less due to the PWM AC-AC chopper. Since chopper is fast acting switch therefore at the little change in the firing pulse the stator voltage as well as torque is controlled.

5.1.3 WAVEFORMS OF ANN BASED CLOSED LOOP STATOR VOLTAGE CONTROLLED SINGLE PHASE INDUCTION MOTOR

Fig. 5.5(a) and fig. 5.5(b) shows the waveform of the PWM AC-AC chopper fed 1-Ø induction motor's voltage and current. In this system we also use the neural network as a feed back; the system becomes the closed loop systems therefore the wave shape found to be less distorted.

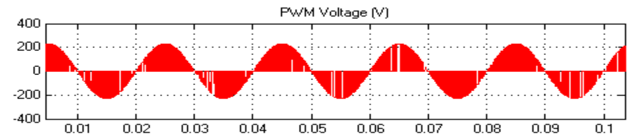

Figure: 5.5 (a) ANN based Waveform of voltage of PWM AC-AC chopper fed 1-Ø I.M

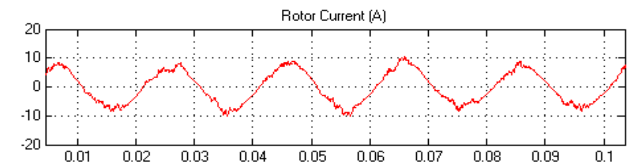

Figure: 5.5(b) ANN based Waveform of voltage and current of PWM AC-AC chopper fed 1-Ø I.M

The fig. 5.6 shows the waveform of speed. It's clear from the waveform that the speed variation is smooth and fast than PWM AC-AC chopper fed open loop system. In this case the reference speed is taken as 750 rpm. Neural network regulate speed smoothly and provide automatic speed control.

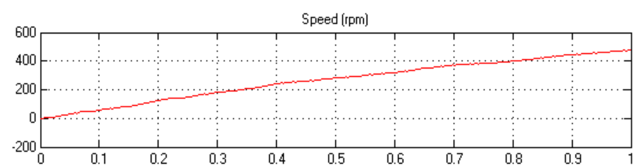

Figure: 5.6 Waveform of speed of PWM AC-AC chopper fed 1-Ø I.M with ANN feed back close loop system

In the torque waveform represented in fig. 5.7 it is seen that the harmonic distortion in torque waveform is quiet less due to the PWM AC-AC chopper. The ANN controller responds fast at the little variation in the single phase induction motor connected load.

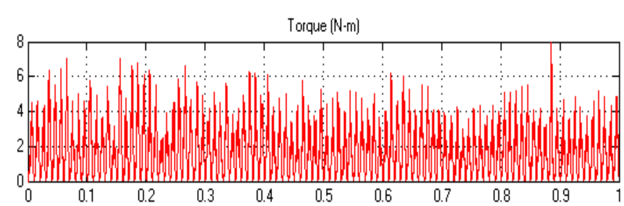

Figure: 5.7 Waveform of torque of PWM AC-AC chopper fed 1-Ø I.M with ANN feedback close loop system

5.2.1 FFT ANALYSIS OF PWM AC-AC CHOPPER FED 1-Ø I.M

Figure 5.8 shows the FFT analysis of PWM AC-AC chopper fed single phase induction motor. The total harmonic distortion is 12.12 % at the fundamental frequency. The peak to peak voltage is 85.9 V. Due to the non-linear power electronic devices the harmonic contents is increase therefore the total harmonic distortion is increased than without introduction of non-linear power electronic devices.

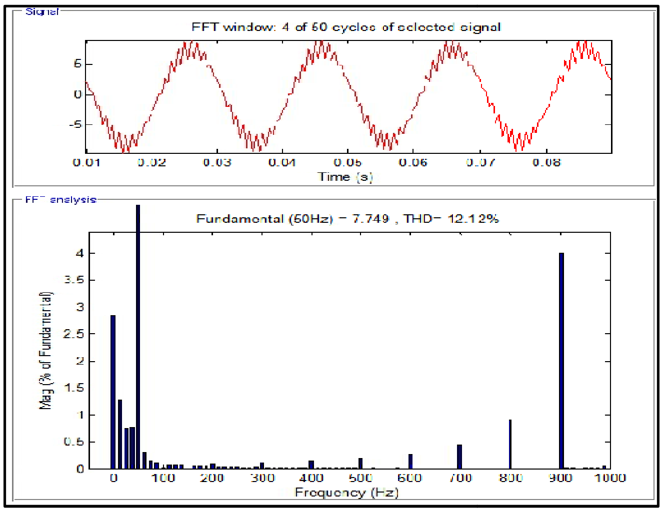

Figure 5.8 FFT analysis of PWM AC-AC chopper fed 1-Ø I.M Rotor Current

5.2.2 FFT ANALYSIS OF 1-Ø I.M WITH PWM AC-AC CHOPPER BY USING ANN AS A FEEDBACK CLOSE LOOP SYSTEM

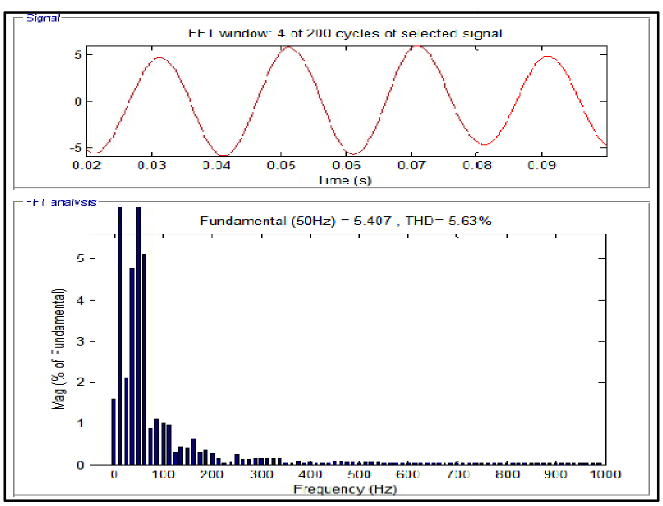

Figure 5.9 Neural Network Based FFT analysis of PWM AC-AC chopper fed 1-Ø I.M Rotor Current

Figure 5.9 represents the FFT variation of single phase induction motor with PWM AC-AC chopper fed, neural network controller close loop system. The total harmonic distortion is 12.12 % at fundamental frequency. The stator peak voltage is 113.9 V. Due to the introduction of neural network close loop system the total harmonic distortion is going to be reduced the PWM AC-AC chopper fed open loop system.

The FFT results are summaries as below

1-Ø I.M stator voltage with PWM AC-AC chopper THD= 12.12%

1-Ø I.M stator voltage with ANN feedback close loop THD= 5.63%

Table: 4.1 Result analysis of open loop and closed loop system

Open Loop FFT Analysis	Close Loop FFT Analysis
Sampling time = 1.30691e-005 s	Sampling time = 4.42538e-006 s
Samples per cycle = 1530.33	Samples per cycle = 4519.39
DC component = 0.4199	DC component = 0.3585
Fundamental Voltage = 85.9 peak (60.74 rms)	Fundamental Voltage = 113.9 peak (80.54 rms)
Total Harmonic Distortion (THD) = 12.12%	Total Harmonic Distortion (THD) = 5.59%
Maximum harmonic frequency used for THD calculation = 38200.00 Hz (764th harmonic)	Maximum harmonic frequency used for THD calculation = 112900.00 Hz (2258th harmonic)

Table: 4.2 Comparison of harmonic content in open loop and closed loop PWM AC-AC chopper

Frequency (Hz)	THD (%)	
	Open loop	Close loop
50 Hz(fundamental)	100.00%	100.00%
150 Hz (h3):	0.33%	0.41%
250 Hz (h5):	0.44%	0.27%
350 Hz (h7):	1.47%	0.04%
450 Hz (h9):	0.20%	0.09%
550 Hz (h11):	0.12%	0.05%
650 Hz (h13):	0.27%	0.05%
750 Hz (h15):	0.40%	0.05%
850 Hz (h17):	0.39%	0.04%
950 Hz (h19):	0.56%	0.03%

5.2.3 VARIATION OF THD OF OPEN LOOP AND CLOSED LOOP SYSTEM

Figure 5.10 shows the graphical representation of total harmonic distortion (in percent) of PWM AC-AC chopper fed open loop and artificial neural network controller fed close loop system. The horizontal axis shows the harmonic frequency (Hz) and vertical axis shows the total harmonic distortion of both the open loop and closed loop system. The red line shows the variation of THD of closed loop system and blue line shows the variation of THD of open loop system.

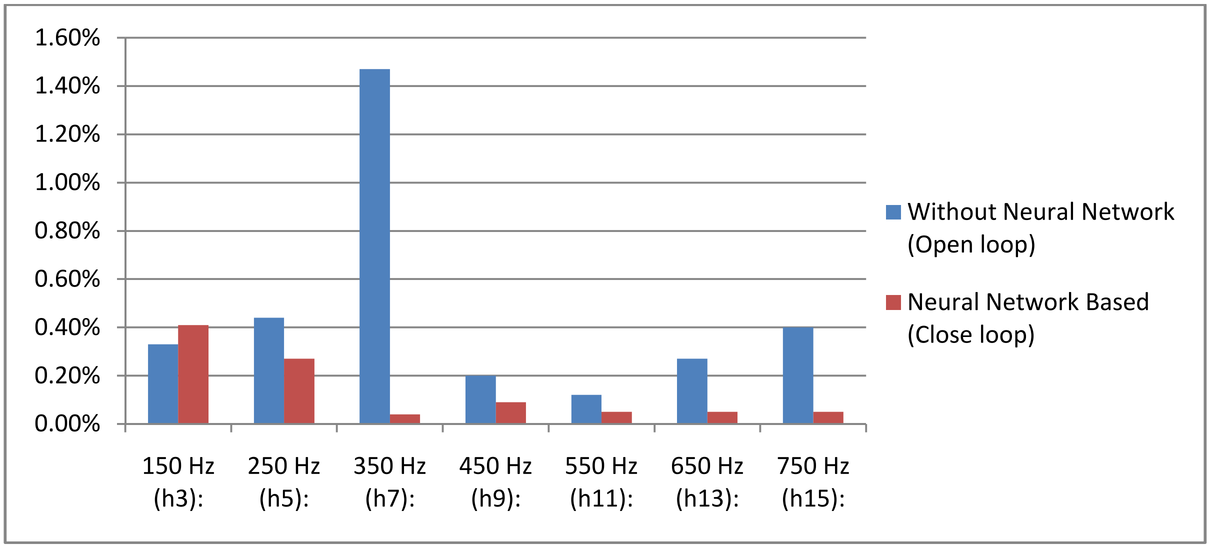

Figure 5.10 graphical variation of open loop, close loop THD with several harmonic frequency

VI. CONCLUSION

This paper deals with applications of the PWM AC-AC chopper and ANN controller. The detailed models of the PWM AC-AC chopper and ANN controller were implemented and tested in MATLAB/Simulink environment. The models are applicable for stator voltage control of single phase induction motor, and cover broader range of speed control.

The effects of PWM AC-AC chopper and ANN controller in the speed control of single phase induction motor are analysed in this paper, and the conclusions are as follow:

(1) The PWM AC –AC chopper is considered in this paper work. The main purpose of the PWM AC –AC chopper is to eliminate the harmonics (mainly lower order) by generating appropriate switching pulses for the operation of switches (IGBT).

(2) The Simulink model was developed for open loop and ANN fed closed loop PWM AC chopper. As per the simulation results it can be seen that the performance of the PWM AC-AC chopper has improved in its ANN closed loop mode of operation which is manifest with the THD reducing to 5.63%. The objective of selecting the closed loop operation of PWM AC-AC chopper is to reducing the total harmonic distortion under permissible limit.

(3) The ANN fed closed loop PWM AC-AC chopper give superior performance than open loop PWM AC-AC chopper.

(4) As has been discussed above (1)-(3) it has been observed that the stator voltage is improved by introducing the PWM AC-AC chopper, the best performance of single phase induction motor has been obtained by introducing ANN fed closed loop PWM AC-AC chopper.

VII. FUTURE WORK

The future work should include introduction of the developed PWM AC-AC chopper, ANN fed closed loop model for power factor correction and harmonics elimination at the stator input of the motor. The artificial neural network controller that introduce in this paper is provide the feed back path between the load and the PWM AC-AC chopper. This controller fed back the any variation of four parameter speed, torque, stator voltage and current and pulse width is accordingly changed to maintain the constant operation of the machine. The performance of the ANN controller may enhance by adjusting the hidden layer and biasing of the neural network. The models should be further used in wide range of speed control of the single phase motor. The dynamic performance of the three phase motors and synchronous motor also can be studied.

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