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SVPWM & SPWM CONTROLLER BASED PERFORMANCE EVALUATION OF THREE PHASE INDUCTION MOTOR

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ABSTRACT

This paper presents the performance analysis of three phase induction motor using sinusoidal pulse width modulation(SPWM) and space-vector modulation(SVPWM). The main objective of this paper is to evaluate the power factor, efficiency and THD of three phase induction motor and compare the results using SPWM and SVPWM method. Space vector pulse width modulation (SVPWM) technique has emerged as a most used modulation strategy for the voltage source inverter (VSI) fed AC motor drives. This paper describes comparison of SVPWM and SPWM modulating techniques with induction motor as load. Switching strategies for the inverter based on space vector PWM (SVPWM) and sinusoidal PWM (SPWM) is used in this paper.

KEYWORDS: SPWM, SVPWM, Three phase Inverter, Three phase Induction Motor, THD

I. INTRODUCTION

Induction Machines is the most widely used motor in industry and also in residential application. It is used in various applications because the motor have low cost, high efficiency, wide speed range and robustness. In the present time, in the most of the applications, AC machines are useful than DC machines due to their simple and most robust construction without any mechanical commutators [1], [2]. Three phase voltage source inverter converts DC into AC based on PWM controller and with the help of these controllers three phase induction motor performance is evaluated.

Pulse-width modulation (PWM) inverters reduce harmonics in the output current and/or voltage by increasing the switching frequency and control the inverter output voltage as well as frequency by changing modulating wave. PWM inverters are more appropriate for speed control of induction motor (IM) instead of other techniques. [3]. Pulse width modulation refers to a method of carrying information on train of pulses and the information be encoded in the width of pulses. The AC voltage is dependent on two parameters i.e. amplitude and frequency. It is essential to control these two parameters. The most efficient to control these parameters are by using Pulse Width Modulation techniques. In order to generate the gating signals using Pulse Width Modulation Techniques we compare the reference signal amplitude (Ar) with carrier signal amplitude (Ac). The fundamental frequency of output voltage is determined using the reference signal frequency. The ratio of Ar to Ac is called Modulation index. The Pulse width can be varied from 0 to180 (degrees) by varying Ar from 0 to Ac [4].

Speed control techniques of induction motors can be broadly classified into two types –scalar control and vector control. Scalar control involves controlling the magnitude of voltage or frequency of the induction motor. Three phase induction motors are reliable, robust, and highly durable and of course need less maintenance. [5]

II. SPWM (SINUSOIDAL PULSE WIDTH MODULATION)

Three phase sine-wave is compared with a triangular wave to obtain gate pulses. The sinusoidal PWM technique is very popular for industrial converters. High switching frequency leads to better controlled sinusoidal output waveform. The fundamental frequency component in the inverter output voltage can be controlled by amplitude modulation index [6].

$$m_a = \frac{V_m}{V_{cr}} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where Vm and Vcr are the peak values of the modulating and carrier wave respectively.

The amplitude modulation index ma is usually adjusted by varying Vm while keeping Vcr fixed. The frequency modulation index is defined by,

$m_f = \frac{f_{cr}}{f_m}$……………….(2)

where fcr and fm are the frequencies of the carrier and modulating waves.

III. SVPWM (SPACE VECTOR PULSE WIDTH MODULATION)

Space Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters. It is a more advanced technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics [7].

The space-vector PWM technique is used to produce the switching control signals to be applied to the three-phase inverter. The SVPWM inverter is used to offer 15% increase in the dc link voltage utilization and low output harmonic distortions compared with the conventional sinusoidal PWM inverter. The control strategy of the SVPWM inverter is the voltage/frequency control method which is based on the space-vector modulation technique. [8]

The fundamental difference between SVPWM and SPWM is the existence of two additional zero voltage states V0 (000), and V7 (111). In addition to the six possible voltage vectors associated with the VSI, there are two zero voltage states associated with having all three of the positive pole switches on or all three of the negative pole switches on. This fact allows more output voltage since the third harmonic component exists. Thus, SVPWM is often considered as an eight state operation. [9]

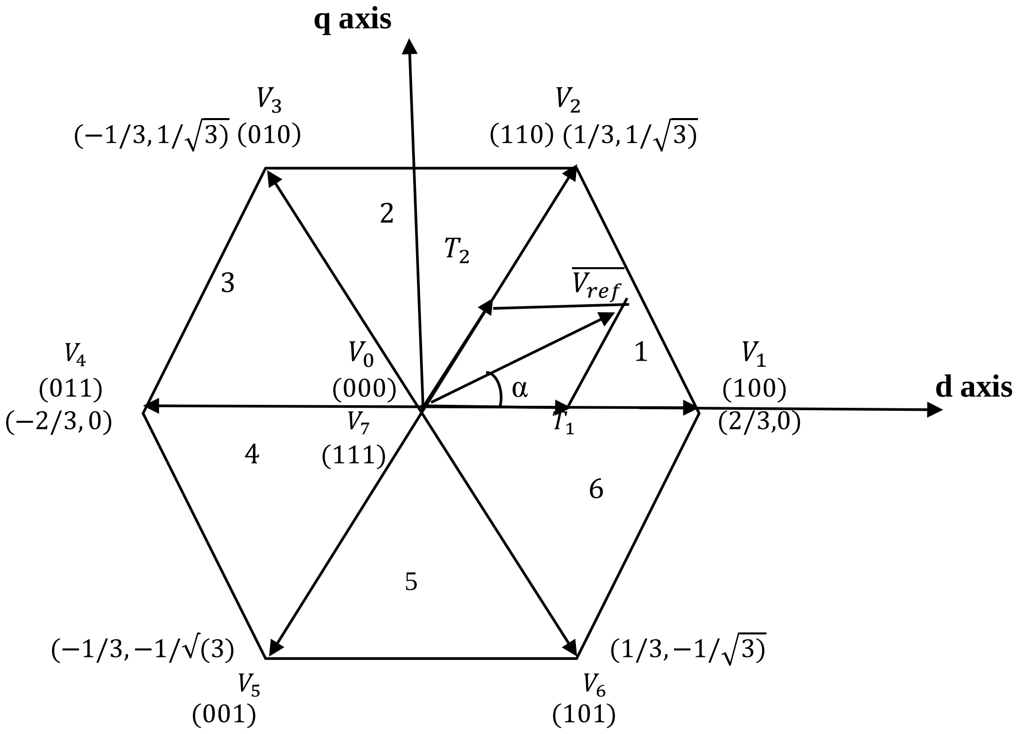

Fig-1: Space Vector Diagram

Locus comparison of maximum linear control voltage in sine PWM and SVPWM is shown in fig. 3. The SVPWM generates less harmonics distortion in the output voltages or currents in comparison with SPWM.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \text{……………....(3)}$$

$$|V_{ref}| = \sqrt{V_d^2 + V_q^2} \text{…………………………….(4)}$$

$$\alpha = \tan^{-1}\left(\frac{V_q}{V_d}\right) \text{……………………………….(5)}$$

IV. THREE PHASE DRIVE SYSTEM

Three phase induction motors are more common employed in adjustable speed drives than three phase synchronous motor. When a three phase supply is connected to three phase stator winding, the speed of this rotating field, called synchronous speed is given by

$$N_S = \frac{120 * f}{P} \quad \text{rpm......... (6)}$$

Where Ns = Synchronous Speed in rpm.
f = Supply Frequency in Hz.
P = No. of stator poles.

Rotor cannot attain synchronous speed. It must run at a speed Nr less than Ns, Where

$$N_r = N_s(1\text{-}s) \text{ .... (7)}$$

$$\omega_m = \omega_s(1\text{-}s) \text{ ....(8)}$$

Where Nr =Rotor Speed in rpm
ω_m= Rotor speed in rad/s

$$s = \text{slip} = \frac{N_S - N_r}{N_S} = \frac{\omega_s - \omega_r}{\omega_s} \text{..................(9)}$$

Three Phase Induction Motors are admirably suited to fulfill the demand of loads requiring substantially a constant speed. Several applications however, need adjustable speeds for their efficient operation [10].

In this paper three phase squirrel-cage induction motor with open loop voltage fed inverter is modelled in MATLAB/SIMULINK software. The tested motor has the following characteristics:

Table- 1: AC Motor Parameters.

Motor Parameters	**Value**
Horse Power	20 HP (15KW)
D.C. motor input voltage	400 V
Rated speed	1460 rpm or 152.8rps
Frequency	50 Hz
Slip	0.0267
Stator resistance Rs	0.2147 Ω
Stator Inductance Ls	0.000991 H
Moment of inertia J	0.102 kg–m^2
Load Torque(TL)	98.1 N-m

V. TOTAL HARMONIC DISTORTION

Total Harmonic distortion is the important method to calculate the order of harmonics present in the voltage or current waveform. It is also useful in analyzing the quality of ac output voltage or current. Non sinusoidal wave quality can also be observed through Total harmonic distortion (THD). The total harmonic distortion is a measurement of the harmonic distortion and is described as the ratio of rms value of all harmonic components to the rms value of fundamental component. Total Harmonic distortion is defined as summation of all the harmonic content of current with respect to fundamental component of current [10].

$$\text{THD}_V\% = \frac{\sqrt{\sum_{n=2}^{\infty}(\text{V}_{\text{oh rms}})^2}}{\text{V}_{\text{or rms}}} \quad \text{..................... (10)}$$

$$\text{THD} = \frac{\text{V}_{\text{oh}}}{\text{V}_{\text{or}}} \quad \text{(Voltage THD) ...... (11)}$$

Voh= rms value of all harmonic components present in the
Output voltage of inverter.
Vor = rms value of fundamental component of o/p voltage.

$$\text{THD}_\text{I}\% = \frac{\sqrt{\sum_{n=2}^{\infty}(\text{I}_{\text{oh rms}})^2}}{\text{I}_{\text{or rms}}} \quad \text{................... (12)}$$

$$\text{THD} = \frac{\text{I}_{\text{oh}}}{\text{I}_{\text{sr}}} \quad \text{(Current THD) .... (13)}$$

Ioh = rms value of all the harmonic components.
Isr = rms value of fundamental component of supply current.
The higher the percentage, the more distortion that is present on the mains signal.

VI. MATLAB SIMULATION OF VSI FED INDUCTION MOTOR

The Simulink model of IGBT based three phase PWM inverter controlling both the frequency and the magnitude is design in MATLAB software and is shown in Fig. 2. In this model SPWM are ON in pair and for 180-degree conduction.

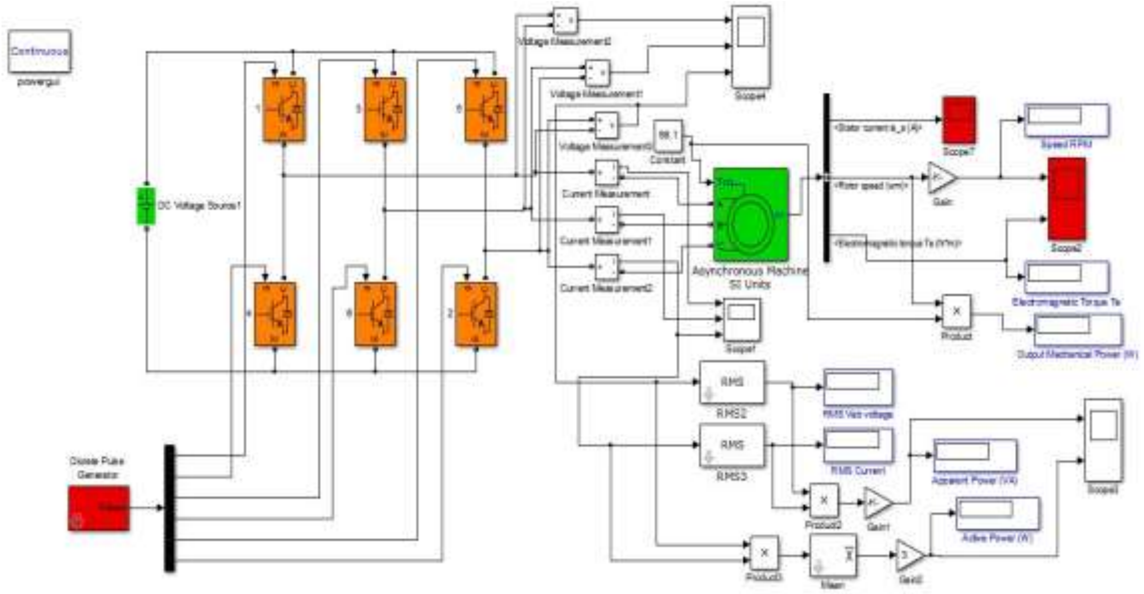

Fig-2: Simulink Model with SPWM Inverter

The design model of SVPWM inverter which is driving three phase induction motor is shown in Fig.3. The design proposed here are used to have a comparison between SPWM and SVPWM based three phase inverter fed induction motor drive.

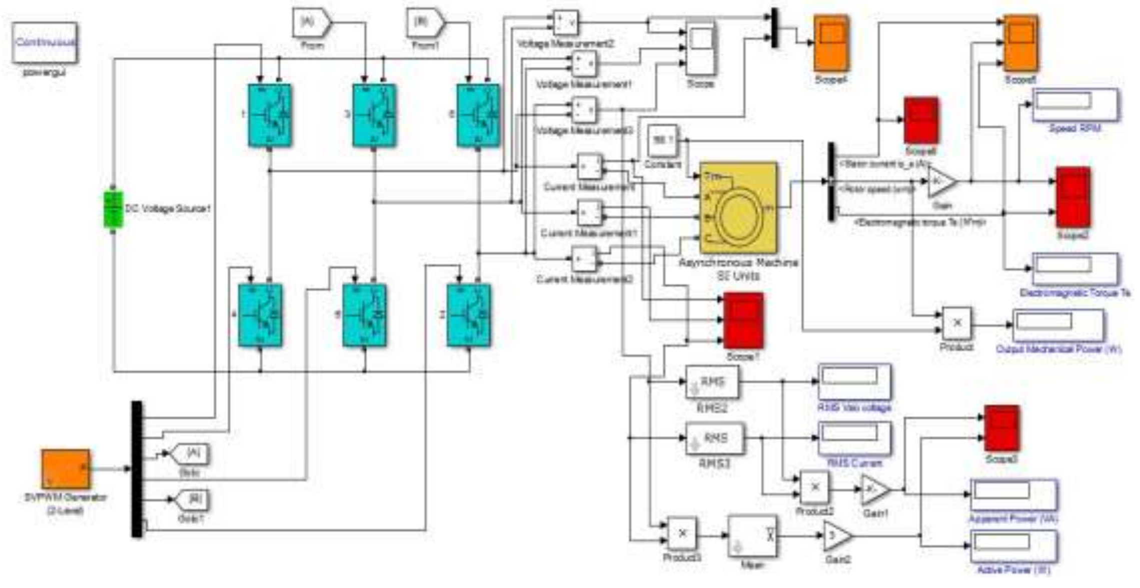

Fig -3: Simulink Model with SVPWM Inverter

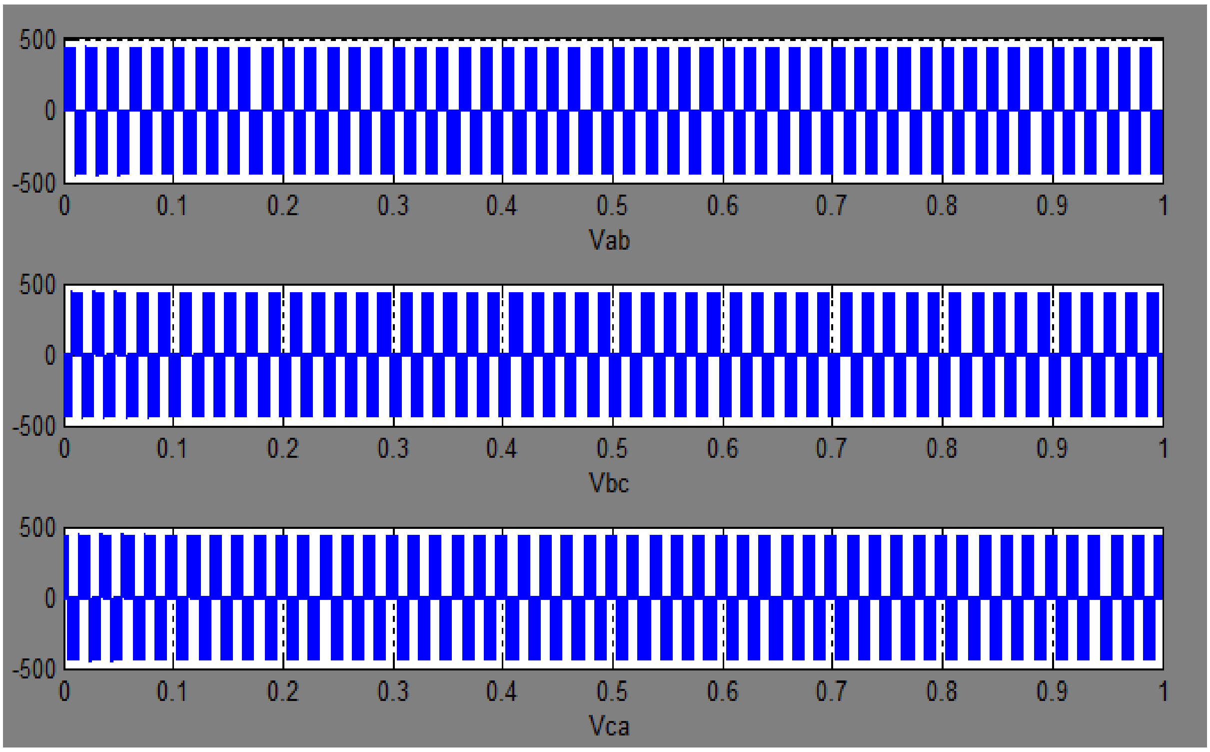

Fig-4 Three Phase Inverter Line Voltage

Case Study I: Simulation Results Using SPWM Control Strategy having Modulation Index 0.8

In this case study, results are obtained when drive is running at full load and response of stator current, speed and electromagnetic torque are shown in Fig.5 and Fig.6.

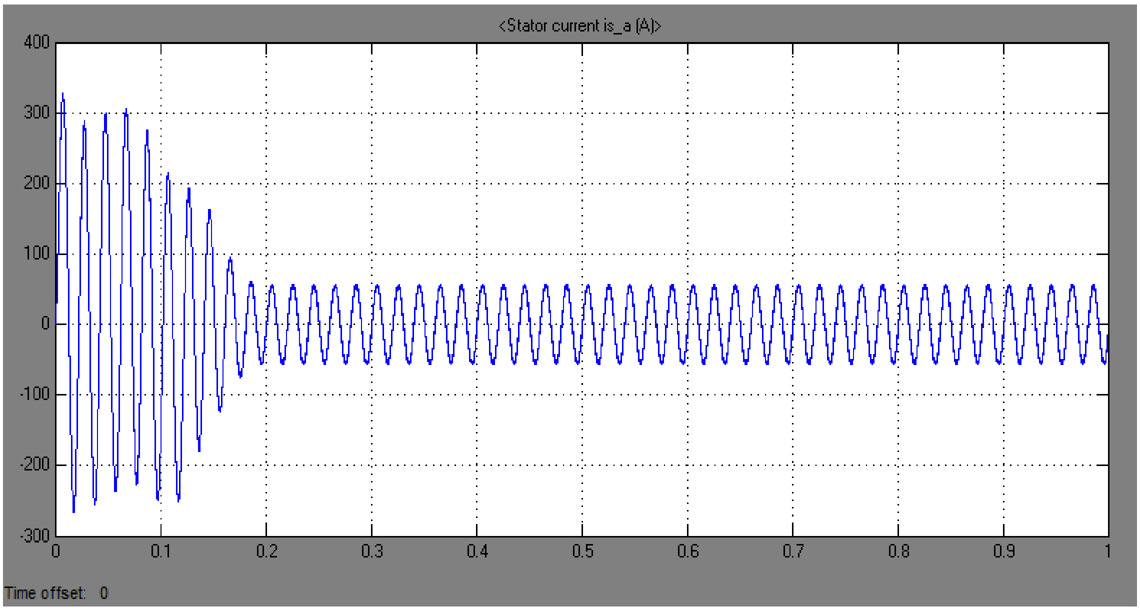

Fig-5: Stator Current at 0.8 modulation index

Above figure shows the stator current waveform for induction motor with SPWM based three phase inverter.

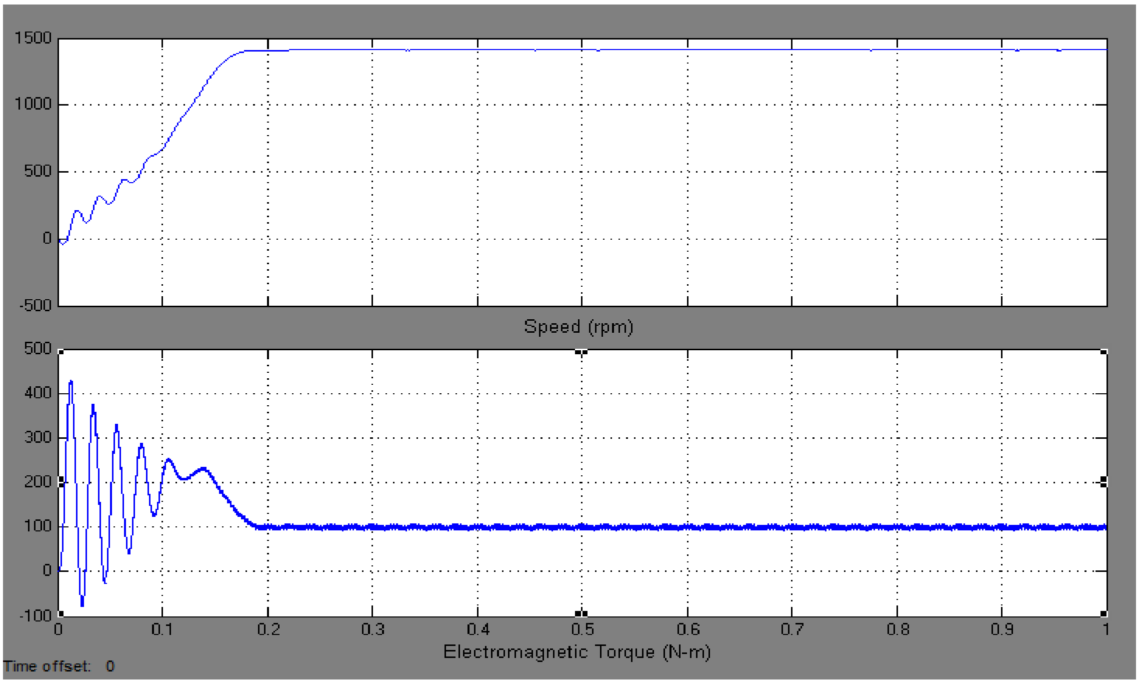

Fig-6: Speed and Electromagnetic Torque at 0.8 modulation index

Above figure shows the speed and electromagnetic torque waveform of three phase induction motor. It is observed that at rated torque, the speed is 1410 rpm and settling time of the drive is merely 0.245 sec.

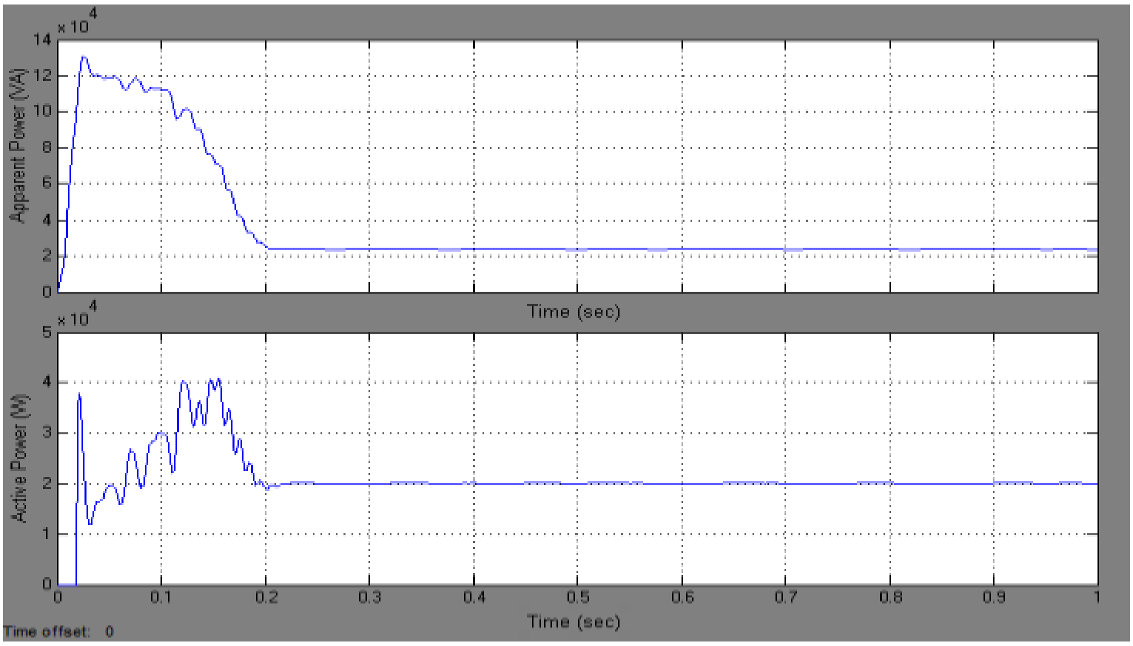

Fig-7: Apparent Power and Active Power at 0.8 modulation index

Fig.7 shows the apparent power and active power of three phase induction motor at 0.8 modulation index.

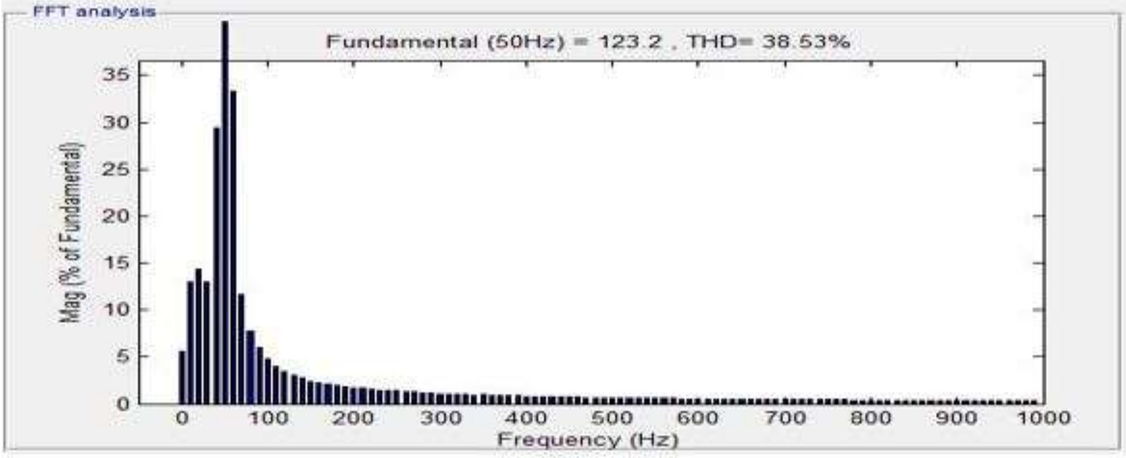

Fig-8: Harmonic profile of output current at 0.8 modulation index employing SPWM Technique

Case Study II: Simulation Results Using SPWM Control Strategy having Modulation Index 0.9

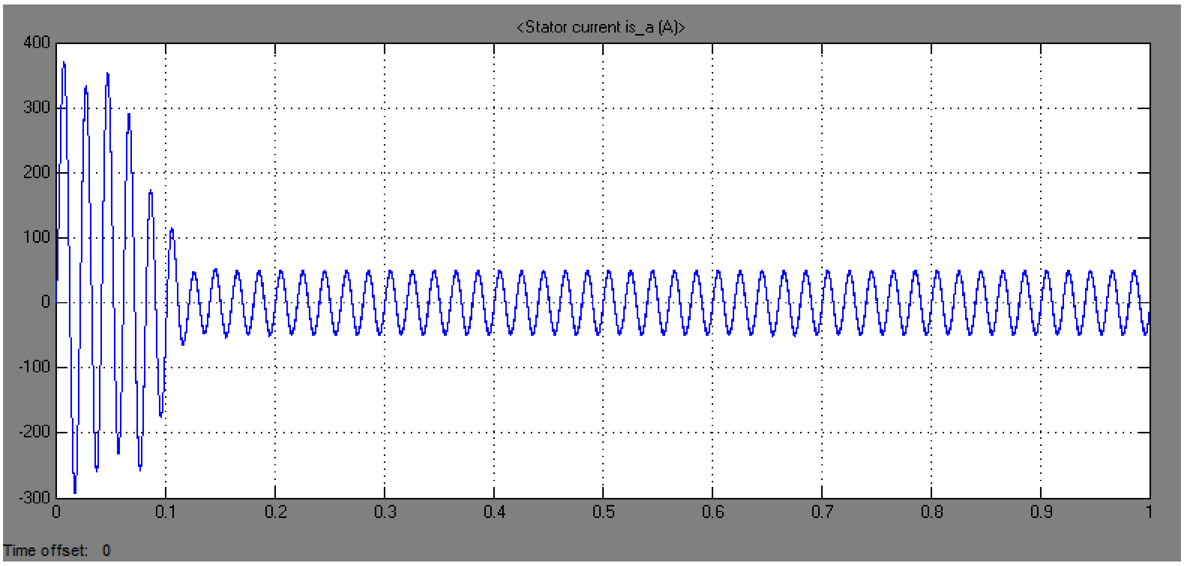

Fig-9: Stator Current at 0.9 modulation index

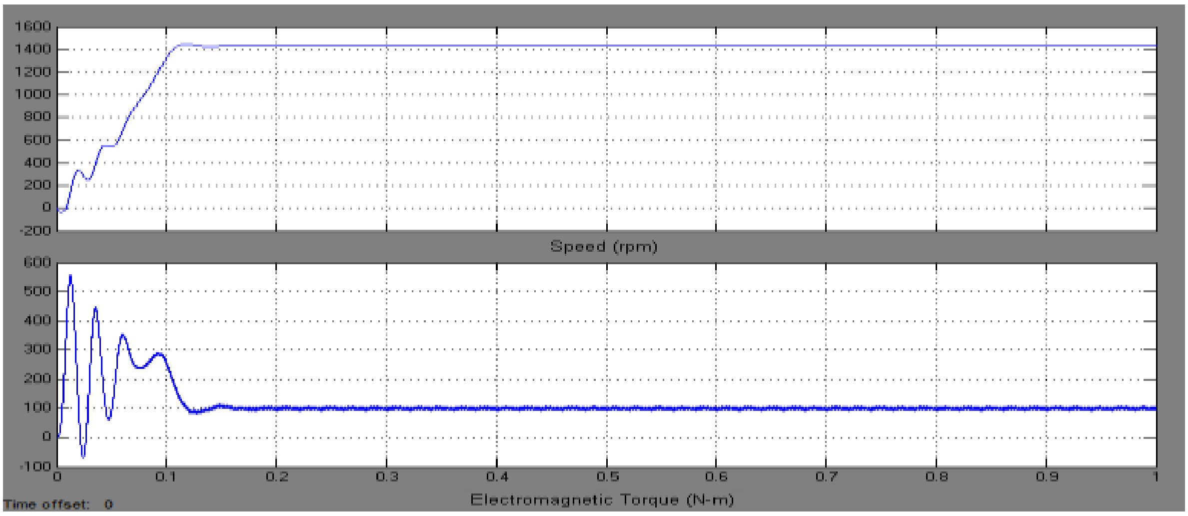

Fig-10: Speed and Electromagnetic Torque at 0.9 modulation index

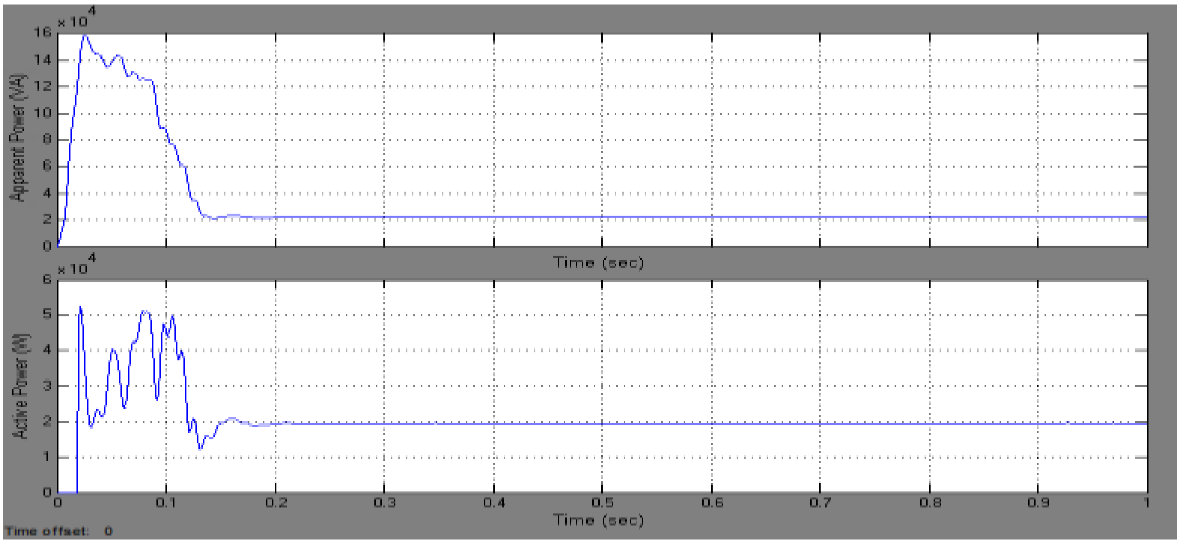

Fig-11: Apparent Power and Active Power at 0.9 modulation index

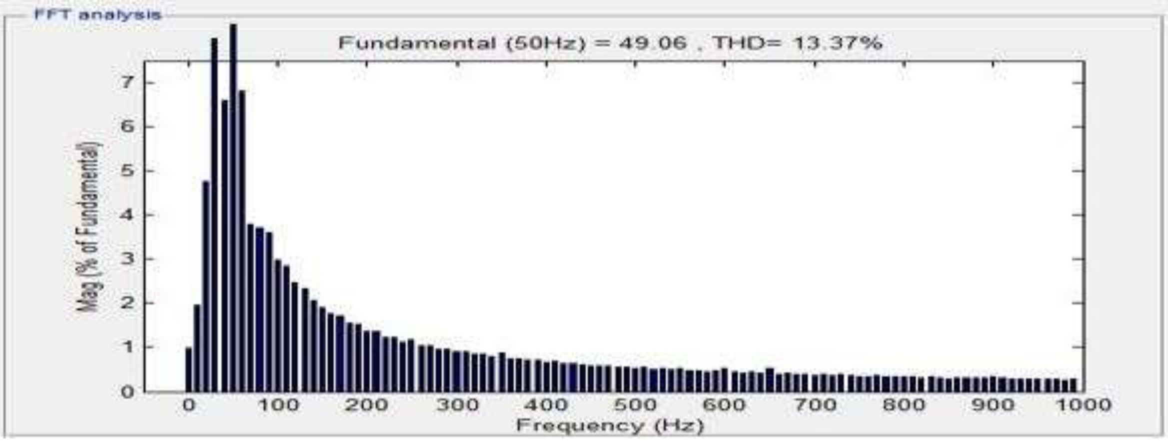

Fig-12: Harmonic profile of output current at 0.9 modulation index employing SPWM Technique

Case Study III: Simulation Results Using SPWM Control Strategy having Modulation Index 1

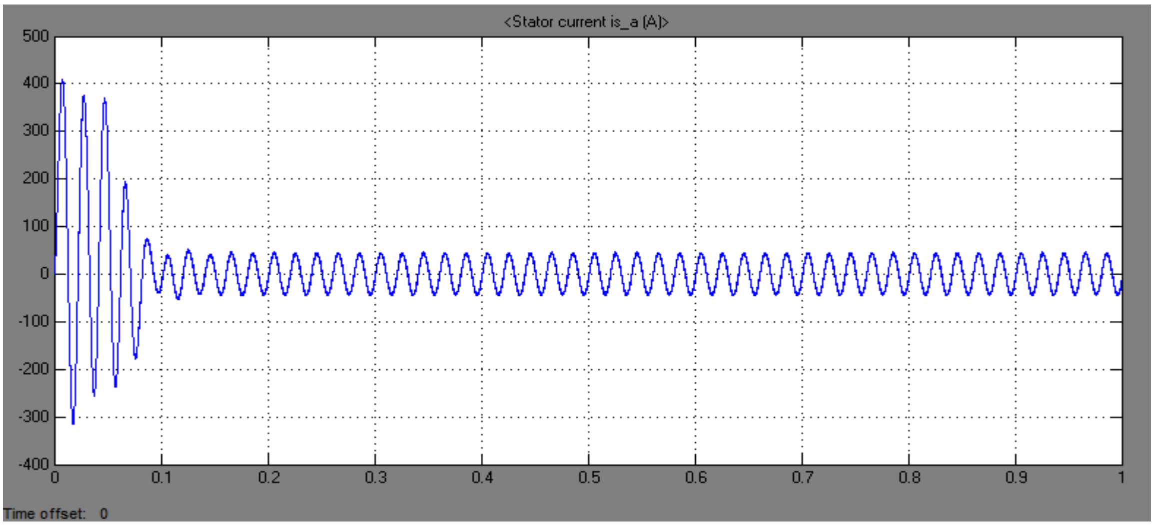

Fig-13: Stator Current at modulation index m=1

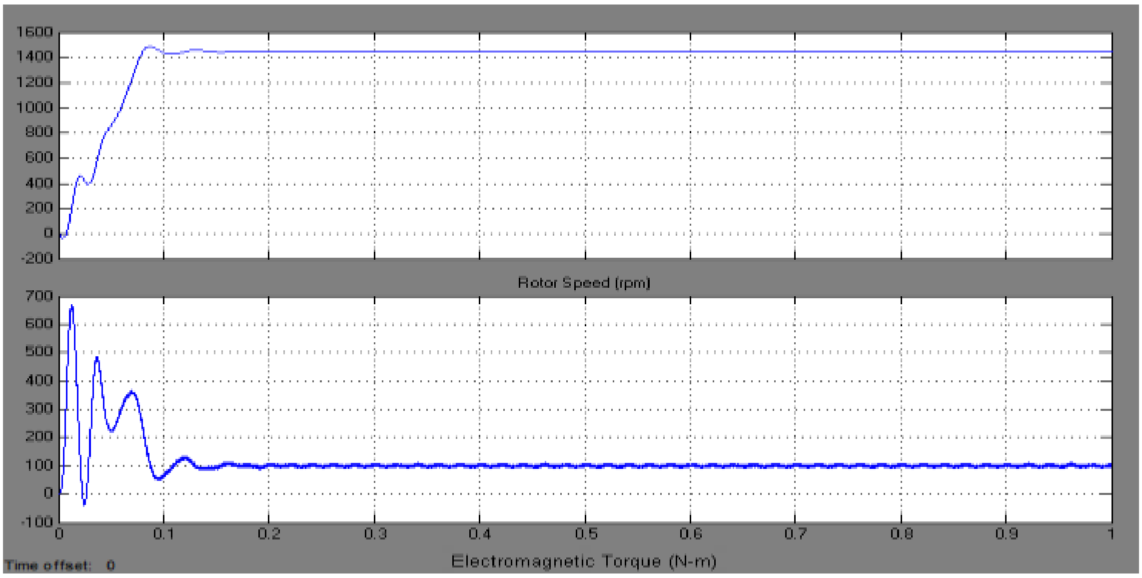

Fig-14: Speed and Electromagnetic Torque at modulation index m=1

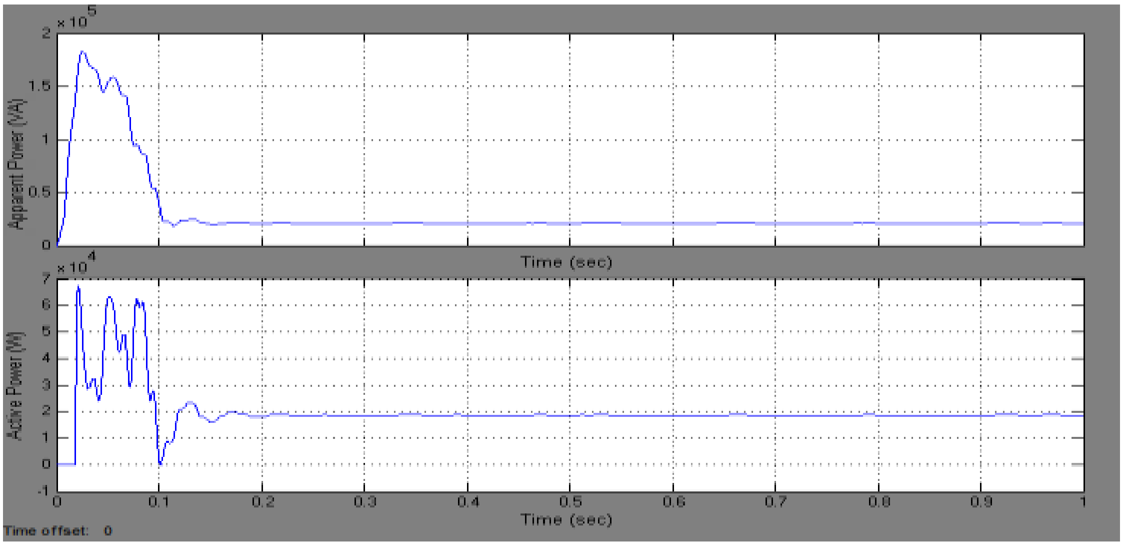

Fig-15: Apparent Power and Active Power at modulation index at m=1

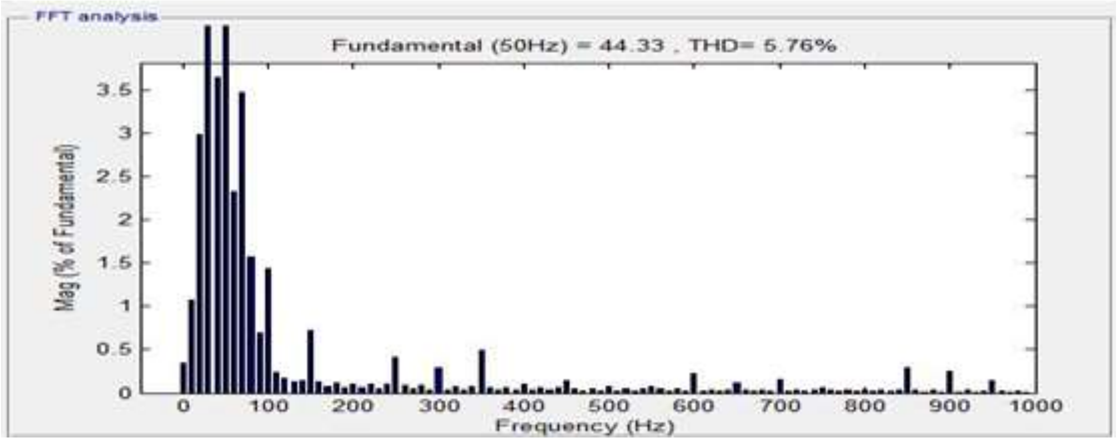

Fig-16: Harmonic profile of output current employing SPWM Technique at modulation index =1

Case Study IV: Simulation Results Using SVPWM Control Strategy having Modulation Index 0.8

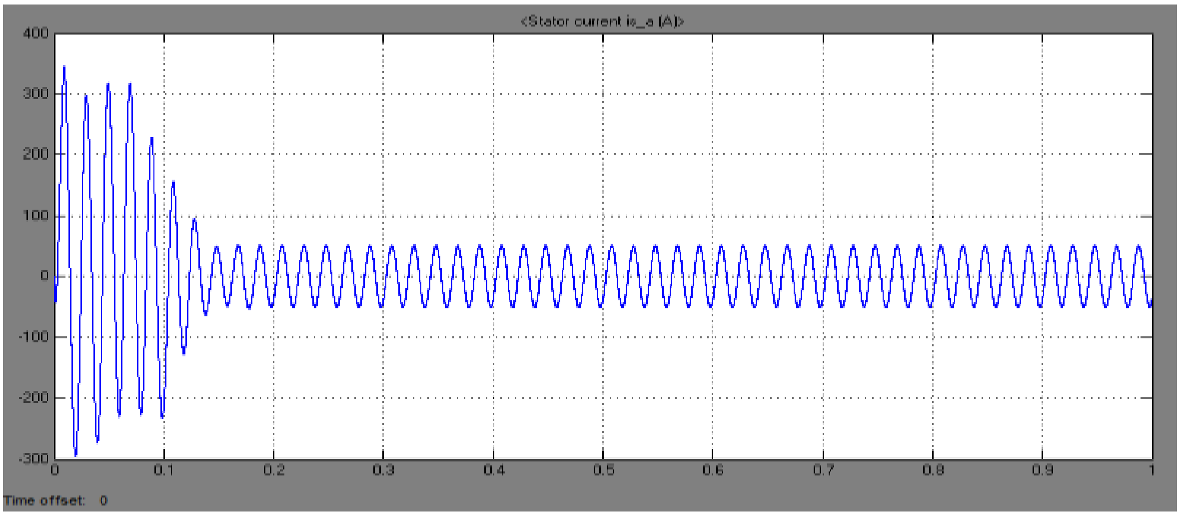

Fig-17: Stator Current at 0.8 modulation index

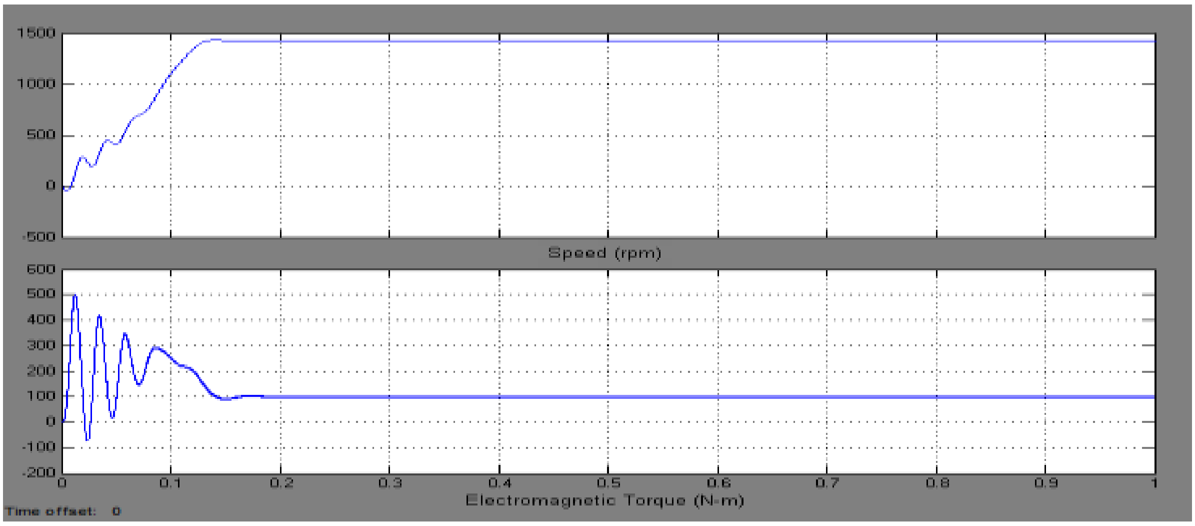

Fig-18: Speed and Electromagnetic Torque at 0.8 modulation index

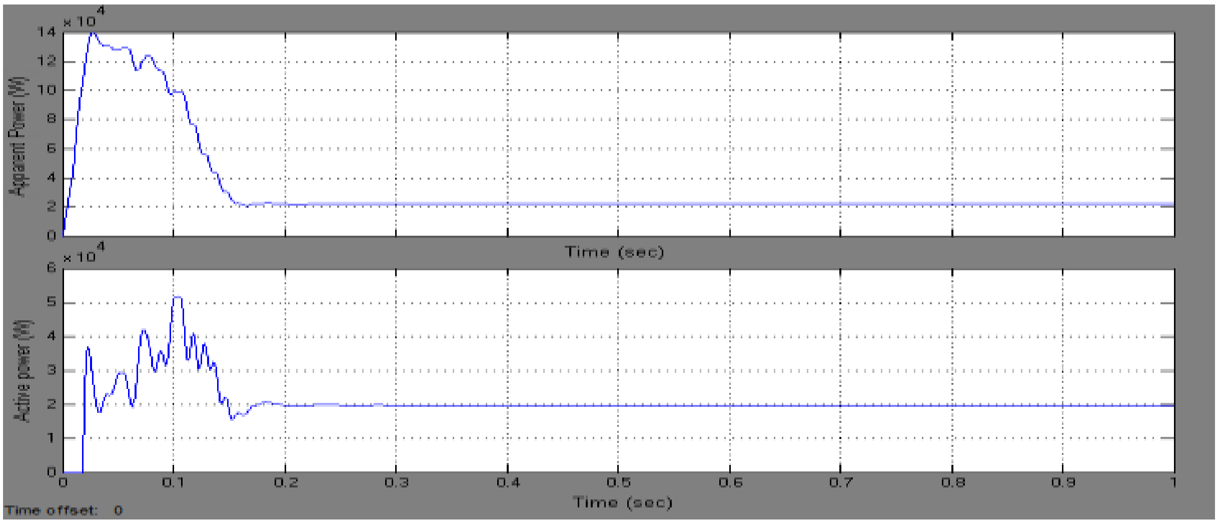

Fig-19: Apparent Power and Active Power at 0.8 modulation index

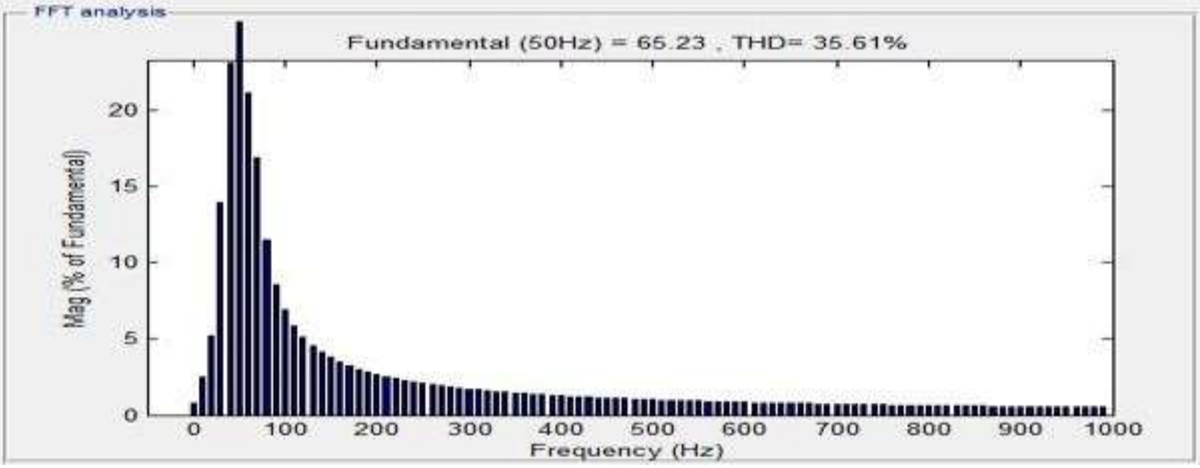

Fig-20: Harmonic profile of Output Current at 0.8 modulation index employing SVPWM Technique

Case Study V: Simulation Results Using SVPWM Control Strategy having Modulation Index 0.9

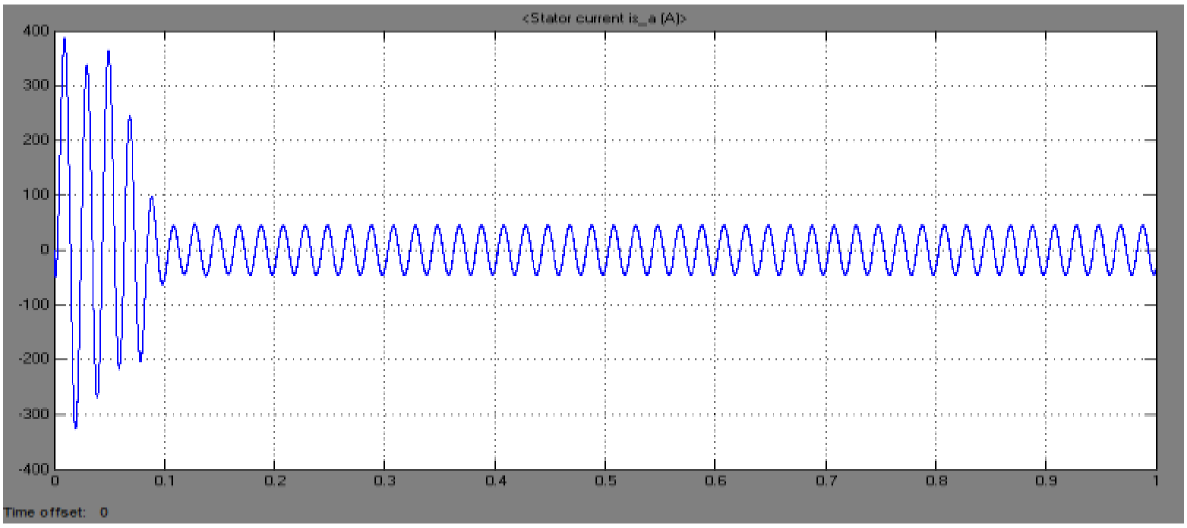

Fig-21: Stator Current at 0.9 modulation index

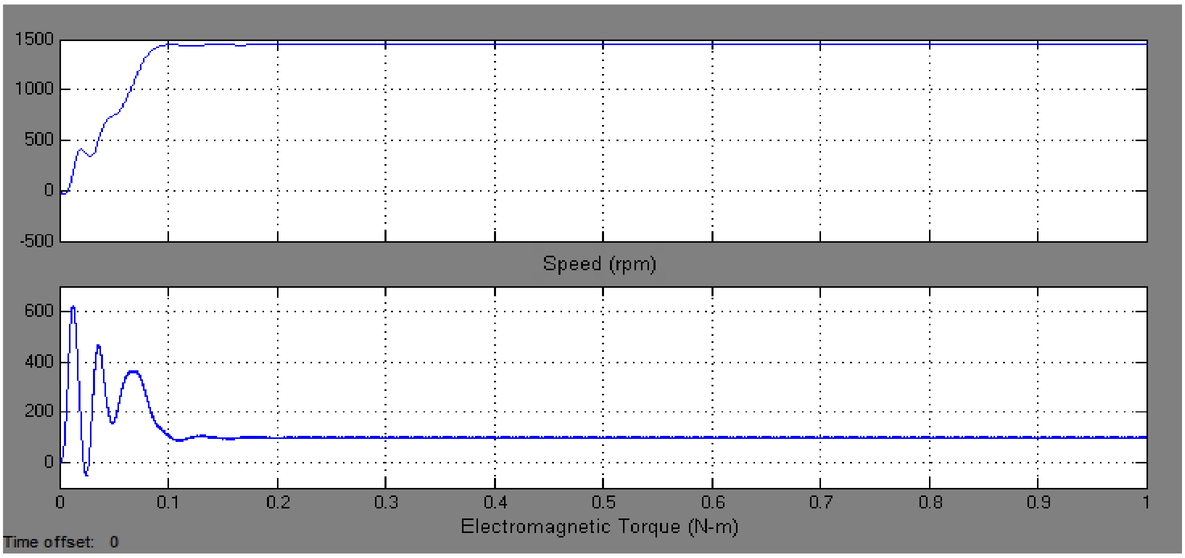

Fig-22: Speed and Electromagnetic Torque at 0.9 modulation index

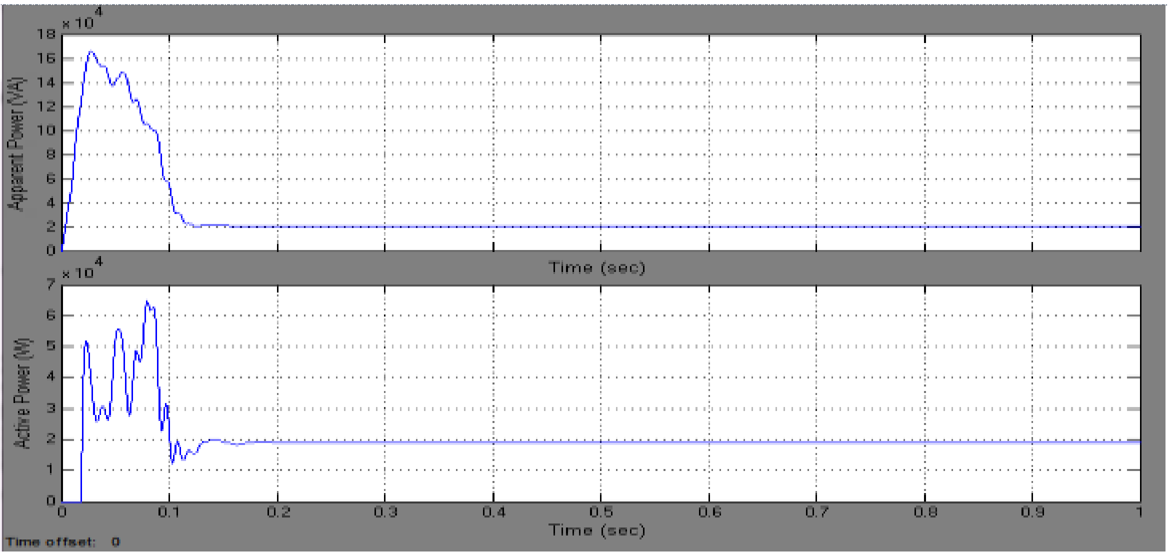

Fig-23: Apparent Power and Active Power at 0.9 modulation index

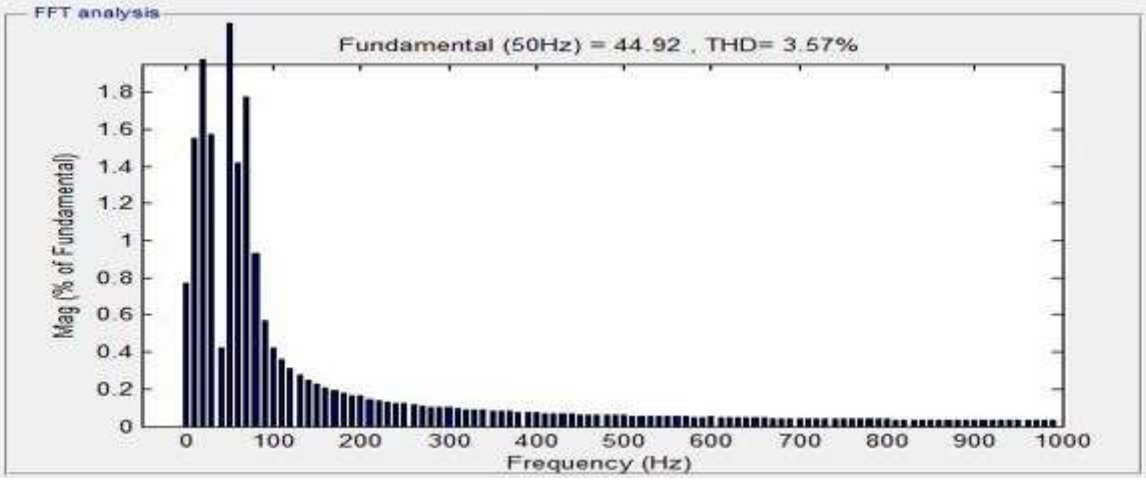

Fig-24: Harmonic profile of Output Current at 0.9 modulation index employing SVPWM Technique

Case Study VI: Simulation Results Using SVPWM Control Strategy having Modulation Index 1

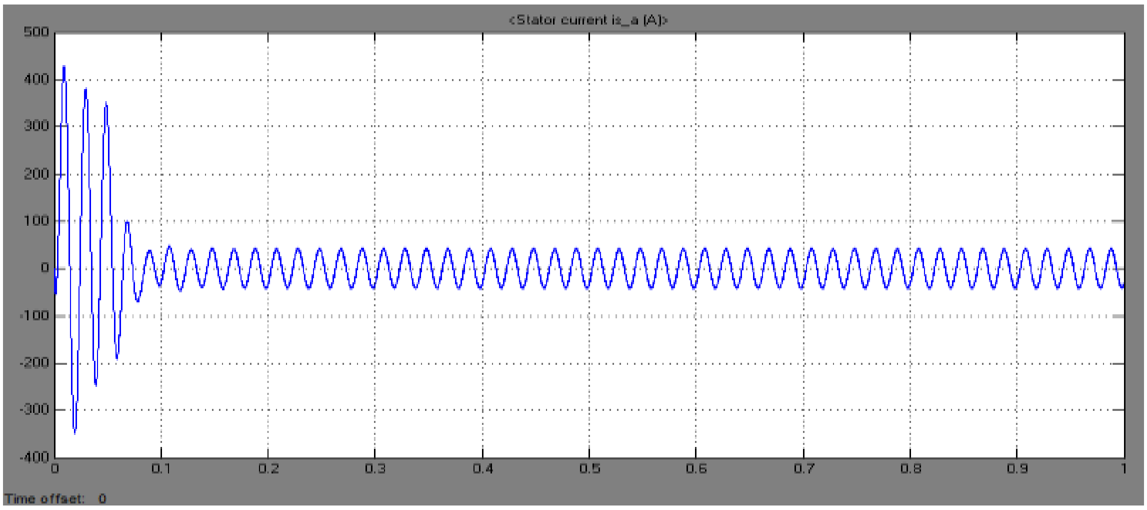

Fig-25: Stator Current at modulation index =1

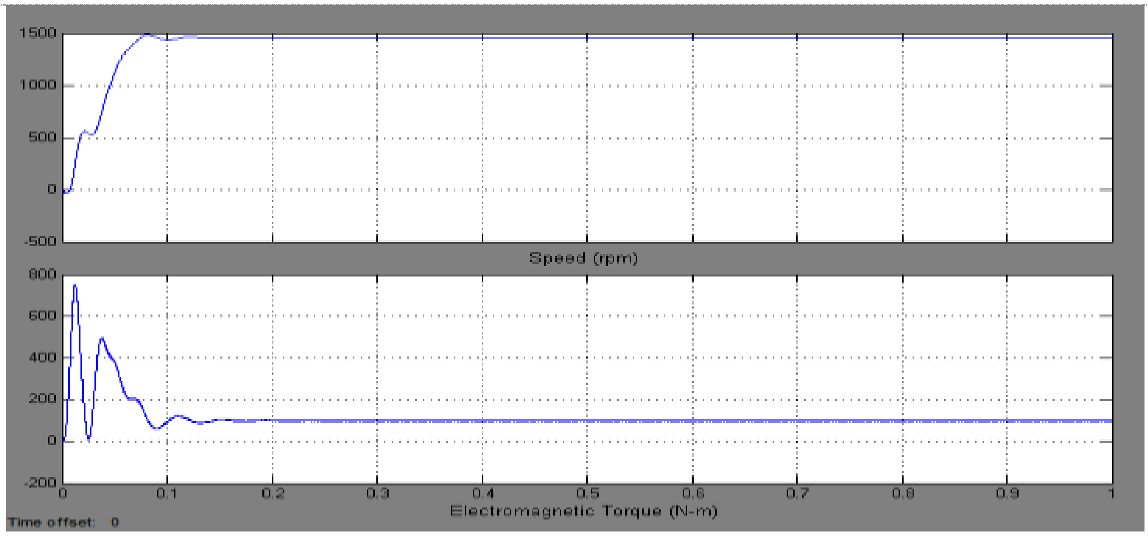

Fig-26: Speed and Electromagnetic Torque at modulation index =1

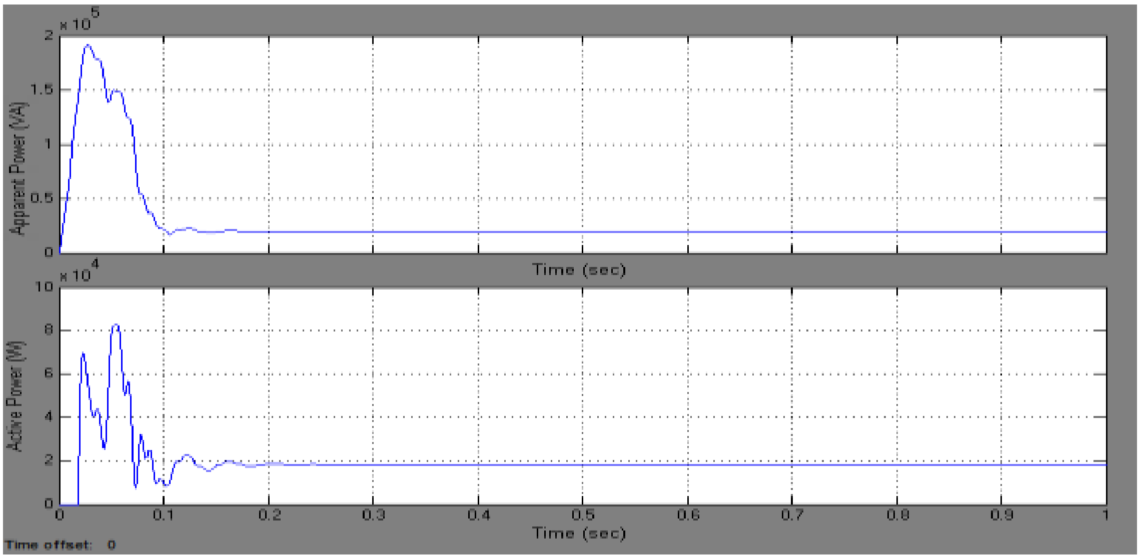

Fig-27: Apparent Power and Active Power at modulation index =1

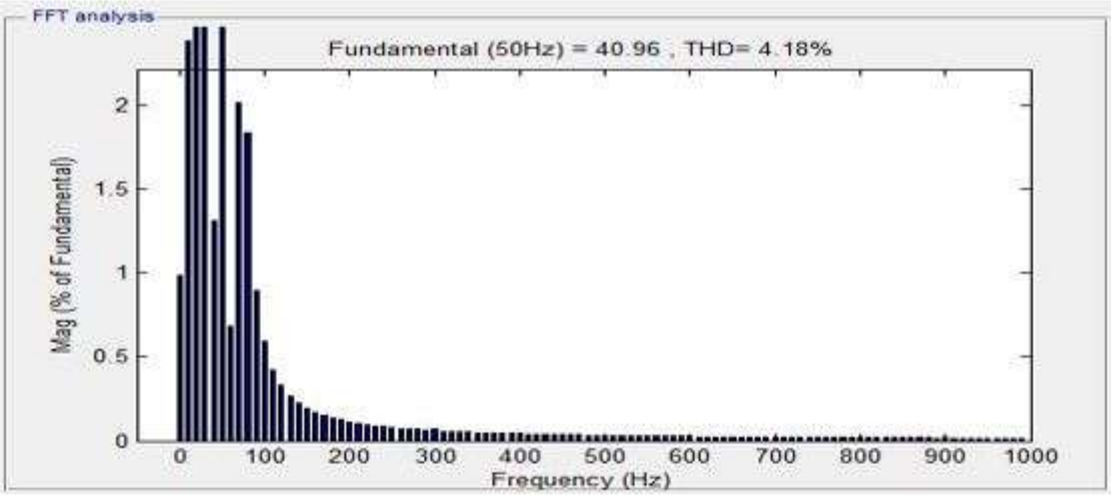

Fig-28: Harmonic profile of Output Current employing SVPWM Technique at modulation index =1

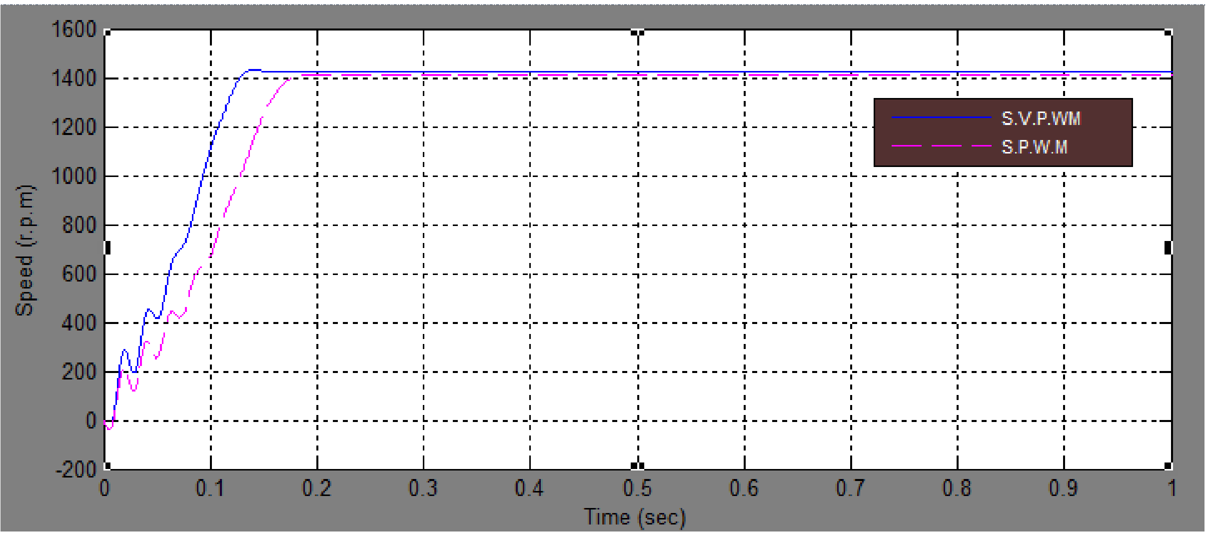

Fig-29: Speed Comparison of Three Phase Induction Motor at 0.8 modulation index using SPWM and SVPWM

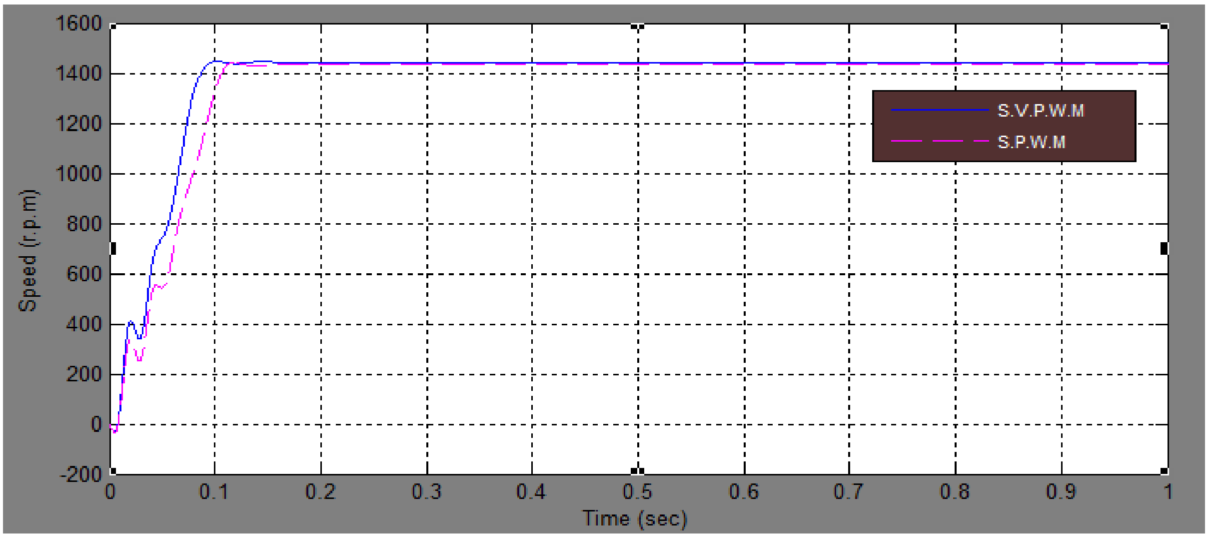

Fig-30: Speed comparison of Three Phase Induction Motor at 0.9 modulation index using SPWM and SVPWM

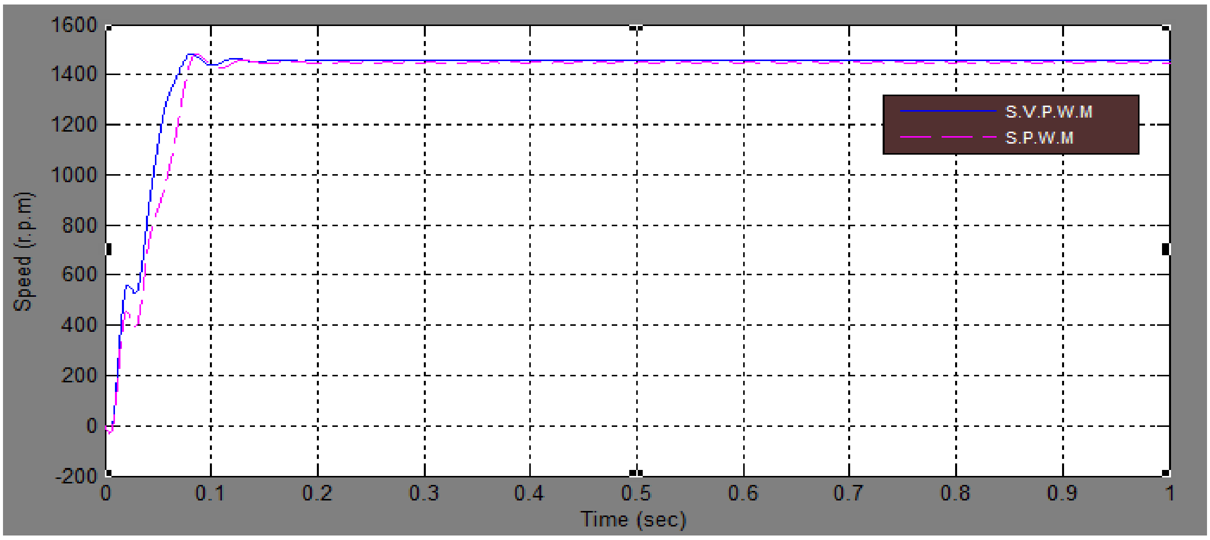

Fig-31: Speed comparison of Three Phase Induction Motor at modulation index=1 using SPWM and SVPWM

The comparison results for speed from simulation of models having SPWM and SVPWM with 0.8 modulation index are shown in Fig.29. Fig. 30 shows the comparison of speed using SPWM and SVPWM control strategy with 0.9 modulation index. Fig. 31 shows the speed response comparison of SPWM and SVPWM operated induction motor drive with modulation index 1.

VII. RESULTS AND DISCUSSION

Table 2. Comparison table for SPWM

S.No.	Modulation Index	Speed (r.p.m)	Output Mechanical power(kW)	Active Power (kW)	Apparent Power(kVA)	% Efficiency	Power factor	Settling Time(sec)	% Overshoot	% THD
1.	0.8	1410	14.48	20.06	23.9	72.18	0.8393	0.245	0.07	38.53
2.	0.9	1434	14.73	19.33	22.13	76.2	0.8734	0.222	0.139	13.37
3.	1	1447	14.86	18.6	21.13	79.89	0.8802	0.245	2.42	5.76

Table 3. Comparison table for SVPWM

S.No.	Modulation Index	Speed (r.p.m)	Output Mechanical power(kW)	Active Power (kW)	Apparent Power(kVA)	% Efficiency	Power factor	Settling Time(sec)	% Overshoot	% THD
1.	0.8	1426	14.65	19.69	22	74.4	0.895	0.211	0.418	35.61
2.	0.9	1443	14.83	18.97	20.77	78.17	0.9133	0.211	0.207	3.57
3.	1	1455	14.95	18.09	19.95	82.64	0.9234	0.23	1.821	4.18

- Table 2 shows the parameters of three phase induction motor at different modulation index and it is observed that optimum value for SPWM is obtained at modulation index 1 with good efficiency and improved power factor. The results obtained by SPWM fed induction motor drive system shows poor settling time and less efficiency as compared to SVPWM fed induction motor.
- From table 2 it is observed that improved result is obtained for SPWM fed induction motor drive at modulation index=1, with good efficiency, better power factor and a little improve in settling time as compared to other modulation index of SPWM. But it is observed that overshoot is increased. In order to reduce overshoot, we design a new control strategy in which SVPWM control strategies are used.
- From table 3, it is observed that, optimum value is achieved by using SVPWM at modulation index=1 with much improve in settling time, good power factor and better efficiency. It is observed that overshoot is reduced to a great extent keeping settling time to merely 0.23 sec. Since THD in current is reduced, so the losses are also reduced upto a great extent by using SVPWM control strategy. Hence SVPWM control strategy gives good dynamic response and efficient control of three phase induction motor drive.
- From the table it is clear that excellent results are obtained by using SVPWM as compared to SPWM for the induction motor drive system. The performance is evaluated at different modulation index and it is found that optimum performance is achieved at modulation index 1 for SVPWM control strategy.

VIII. CONCLUSION

In this paper, SPWM and SVPWM techniques are used and these techniques are applied on a 3-phase voltage source inverter (VSI) and their results are compared. It is observed that SVPWM control technique can minimize the settling time and shows better response as compared to SPWM control technique. With SVPWM control technique, a significant improvement is achieved in view of power factor, settling time, total harmonic distortion along with better drive efficiency.

IX. REFERENCES

[1] Shilpa V. Kailaswar, Prof. R.A. Keswani/International journal of Engineering Research and application (IJERA), pp. 1732-1736. "Speed Control of Three Induction Motor by V/F method for batching motion system", ISSN: 2248-9622, Vol. 3, Issue 2, March-April 2013, pp.1732-1736

[2] Prof. Harsha P. Pawar, Miss. Neha S. Chavan., Miss. Ashwini B. Shinde and Miss. Yugandhara S. Chavan, International Journal of Engineering Research & Technology (IJERT) "Speed Control of Induction Motor using PWM Technique" ISSN: 2278-0181, Vol. 4 Issue 04, April-2015, pp.174-177

[3] Aparna Sharma, Asst. Prof. Abhijeet Singh, Prof. P. Yadav, "Analysis of 3 Level SVPWM based Open Loop and Closed Loop V/F Control of Induction Motor" in International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 04, April-2015 ISSN: 2278-0181, pp. 1362-1365

[4] Aashitosh Todkar, Shubham Dange, Ashwini Palkhe, Reshma Sargar, Rajendra Madake, "Simulation based V/F speed control of three phase induction motor", International Journal of Scientific Development and Research (IJSDR), | Volume 2, Issue 1, January 2017 IJSDR, ISSN: 2455-2631, pp. 80-87

[5] Priya Janak , Ranvir Kaur, " Speed Control and THD for Three Phase Induction Motor Using Simulink", INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY,(IJESRT), June, 2014, ISSN: 2277-9655,pp.754-762

[6] Runzun Saxena, Mrs.S.C Rangari, "Comparison of three phase two-level inverter operation with SPWM and SVPWM" International Journal on Recent and Innovation Trends in Computing and Communication, Volume: 3, Issue: 2, ISSN: 2321-8169 pp.57-62

[7] K. Vinoth Kumar, Prawin Angel Michael, Joseph P. John and Dr. S. Suresh Kumar "Simulation and Comparison of SPWM and SVPWM Control for Three Phase Inverter", ARPN Journal of Engineering and Applied Sciences VOL. 5, NO. 7, JULY 2010, Publisher

[8] A Maamoun, A.M. Soliman, A.M. Khelreldin, "Space Vector PWM inverter Feeding a small Induction Motor", IEEE Proceeding of International Conference on Mechatronics, Kumamoto Japan, 8-10 May 2007

[9] S. Manivannan, S. Veerakumar, P. Karuppusamy, A. Nandhakumar, "Performance Analysis of Three Phase Voltage Source Inverter Fed Induction Motor Drive with Possible Switching Sequence Execution in SVPWM", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 6, June 2014, ISSN (Print): 2320 –3765, pp.10081-10104

[10] Niraj Kumar Shukla, Rajeev Srivastava, "Performance Evaluation of Three Phase Induction Motor Using MOSFET & IGBT Based Voltage Source Inverter" International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06 | June -2017, ISSN: 2395 -0056

[11] Bin. Wu. High-Power Converters and AC Drives. IEEE Press, John Wiley and Sons, Inc.(Book)

[12] P.S.Bhimbra," Power Electronics", Khanna Publication.

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