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PERFORMANCE IMPROVEMENT OF DISTRIBUTION SYSTEM BY USING SHUNT ACTIVE FILTER USING SPACE VECTOR PULSE WIDTH MODULATION

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ABSTRACT

This main objective of this project is to present a control method for hybrid active power filter using Space Vector Pulse Width Modulation (SVPWM). In this proposed control method, the Active Power Filter (APF) reference voltage vector is generated instead of the reference current and the desired APF output voltage is generated by SVPWM . A MATLAB code is developed to generate the SVPWM switching pulse fed to the two-level topology. The APF based on the proposed method can eliminate harmonics, compensate reactive power and balance load asymmetry. Simulation results show the feasibility of the APF with the proposed control method. From the comparison of SPWM Attention has been paid to active filters for power conditioning which provide the following multi functions: reactive power compensation, harmonic compensation, flicker balance compensation, and/or voltage regulation. Active filters intended for harmonic solutions are expanding their functions from harmonic compensation of nonlinear loads into harmonic isolation between utilities and consumers, and harmonic damping throughout power distribution systems

Keywords: *Space Vector Pulse Width Modulation; Active Power Filter; MATLAB Software*

I. INTRODUCTION

The growing use of non- linear and time varying loads has led to distortion of voltage and current waveforms and increased the reactive power demand. Harmonic distortion is source of several problems such as increased power losse s excessive heating in rotating machinery and harmonic resonances in utility. Traditionally LC passive filters have been used to absorb harmonic currents absorbed by non- linear load. Their main advantage is high reliability and low cost .However ,passive filters have several drawbacks, which may cause harmonic interaction with the utility problems with the utility system, in the presence of stiff utility sharp tuning of the L filter is required and may not meet the specified harmonic current limits . This provides the motivation for the investigation of an active filter topology, wh ich is practically viable ,cost effective and can meet the recommended standard for high power nonlinear loads .

Introduction to harmonics

General

Harmonics is the name given to distorting signals which are also sinusoidal in shape but in multiple of the fundamental. They are generated by non-linear "loads" or equipment. Industry has no alternative to non-linear equipment because it is a part of the western world's prescription for energy saving, therefore harmonic, one of several forms of electrical pollution, are exciting some alarm. Always present in electrical networks, they are now proliferating with new plant and replace must equipment to the proportion of epidemic Current harmonics, which may also be asymmetric, because voltage drops across the supply network impedance as well as other undesirable phenomena (e.g. shunt and series resonance, flicker) resulting in distorted supply voltages, and hence a reduction in the supply voltage quality.

Results Of Harmonic Distortions

The presence of harmonics in the power lines results in greater power losses in distribution, can cause noise problems in communication systems and, sometimes, cause failure of operation of electronic equipment's, which have higher sensitivity because of the inclusion of microelectronic control systems and these systems are low powered devices and thus a little noise can be significant. These are the reasons which make the power quality issue one of the most concerned issues as far the end user is concerned.

Total harmonic distortion
The presence of harmonics in the power lines results in greater power losses in distribution and cause problem by interfering in communication systems and, sometime cause operation failures of electronic equipment, which are more and more critical because it consists of microelectronic control systems, which work under very low energy levels. Because of these problems, the power quality issues delivered to the end consumers are of great concern.

Voltage THD:
It represents the Total Harmonic Distortion of the voltage waveform. It is the ratio of the root-sum-square value of the harmonic content of the voltage to the root-mean-square value of the fundamental voltage.

$$THD = \left(\frac{\sqrt{({V_2}^2 + {V_3}^2 + {V_4}^2 + \cdots + {V_n}^2)}}{V_1}\right) * 100$$

Current THD:
It represents the Total Harmonic Distortion of the current waveform. It is the ratio of the root-sum square value of the harmonic content of the current to the root-mean-square value of the fundamental current

$$THD_i = \frac{I_2^2 + I_3^2 + \ldots + I_\infty^2}{I^2} = \frac{\sum_{i=2} I_i}{I^2}$$

II. UNWANTED EFFECTS OF HARMONICS

A. Poor quality supply
As all power electronic converters generate harmonic currents which will be injected into the utility, causing distortion of the supply waveform. The output effects in addition to the voltage distortion (where source has source impedance) are listed as below.

B. Additional heating
As the current because of the additional harmonics in the line is the RMS value of the fundamental and the total harmonic that is the RMS current increases which results in an increase in the copper losses and thus heating.

C. Over voltage due to conditions
Due to the harmonics creeping up the voltage can shoot up at a frequency under the resonant condition, can cause severe problem to the loads connected.

D. Errors in metering
Due to the harmonics the motors experience Torque pulsation if connected to the supply. Most of the measuring equipment like the induction disc device or designed for works for the fundamental frequency. The pulsating Torque experienced by the disc, the meter shows improper reading.

III. HARMONICS MITIGATION TECHNIQUES

Passive Filter :
A passive filter is an arrangement of inductances, capacitances as well as resistances orderly in such a manner that it acts as a frequency discriminator, i.e., it provide low impedance path for harmonics component or we can say that it allows passing of several frequencies and discards others. It is possible to connect more than one passive filter in either shunt and/or series conFiguration.

Active Filter :

Passive filters have been used as a solution to solve harmonic current problems, but passive filters having many disadvantages, namely: they can filter only the frequencies they were previously tuned for; their operation cannot be limited to a certain load; resonances can occur because of the interaction between the passive filters and other loads, with unpredictable results. To come out of these disadvantages, recent efforts are concentrated in the development of active filters. Different control strategies for implementing active filters have been developed over the years. The main purpose of the APF installation by individual consumers is to compensate current harmonics or current imbalance of their own harmonic-producing loads. Besides that, the purpose of the APF installation by the utilities is to compensate for voltage imbalance or provide harmonic damping factor to the power distribution systems.

IV. ACTIVE POWER FILTER

Shunt Active Filter:

The shunt-connected active power filter, with a self -controlled dc bus, has a topology like that of a static compensator (STATCOM)[12] used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°.

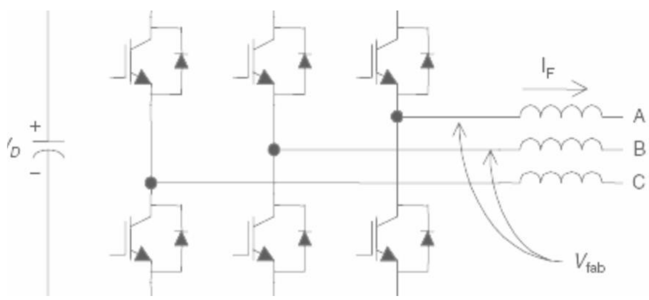

Fig 1: Voltage Source Converter Topology for Active Filters.

The switches in the voltage source inverter can be turned on and off as required[14]. In the simplest approach, the top switch is turned on If turned on and off only once in each cycle, a square wave waveform results. However, if turned on several times in a cycle an improved harmonic profile may be achieved

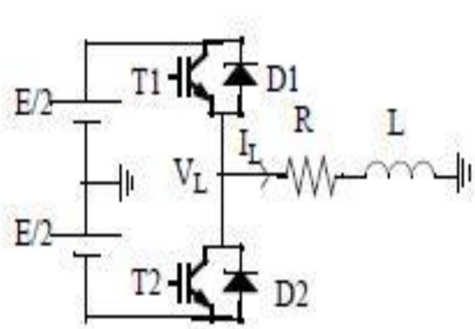

Fig 2 : Simple Voltage Sourced Inverter

In the most straightforward implementation, generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as depicted schematically in Fig.2. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output. Note that over the period of one triangle wave, the average voltage applied to the load is proportional to the amplitude of the signal (assumed constant) during this period. The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies of a close to the carrier frequency. Notice that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and hence the total harmonic distortion is not affected by the PWM process [14]. The harmonic components are merely shifted into the higher frequency range and are automatically filtered due to inductances in the ac system. When the modulating signal is a sinusoid of amplitude Am, and the amplitude of the triangular carrier is Ac, the ratio m=Am/Ac is known as the modulation index. Note that controlling the modulation index therefor controls the amplitude of the applied output voltage. With a sufficiently high carrier frequency (see Fig. 3 drawn for fc/FM = 21 and t = L/R = T/3; T = period of fundamental), the high frequency components do not propagate significantly in the ac network (or load) due the presence of the inductive elements. However, a higher carrier frequency does result in a larger number of switching's per cycle and hence in an increased power loss. Typically switching frequencies in the 2-15 kHz range are considered adequate for power systems applications. Also in three-phase systems it is advisable to use so that all three waveforms are symmetric.

Speed Control of BLDC Motor Using Fuzzy Logic Controller

Based on operation based on the nature of its excitation intrinsically suggest a low-cost way to take out rotor position information from motor-terminal voltages. In the excitation of a 3 phase Sensor Less Technique. Brushless DC motor drives have need of rotor position information for appropriate operation to execute phase commutation. Position sensors are generally used to provide the position information for the driver. So, this type of position sensors is not used in sensor less drives. The advantage of sensor less drives comprises of less hardware cost, increased system reliability, decreased system size and reduced feedback units. And, they are free from mechanical and environmental constraints. Various control methods arise for sensor less drive, in which a back-EMF is the most cost-effective method to obtain the commutation sequence in the star wound motors and current sensing provides enough information to estimate with sufficient rotor position to drive the motor with synchronous phase currents. BLDC motor drives that do not require position sensors but it contains electrical dimensions are called a sensor less drive. The BLDC motor provides sensor less BLDC motor, apart from the phase-commutation periods, two of the three phase windings are functioning at a time and no conducting phase carries in the back-EMF. Since back-EMF is zero at standstill and proportional to speed, the measured terminal voltage that has large signal-to-noise ratio cannot detect zero crossing at low speeds. That is the reason why in all back-EMF-based sensor less methods the low-speed performance is limited, and an open-loop starting strategy is required[10]. The proposed method is since rotor position can be detected by using a trapezoidal Back-EMF of BLDC motors. Since Back-EMF of the BLDC motor is not measured.

V. SPACE VECTOR PULSE WIDTH MODULATION TECHNIQUE (SVPWM)

Space vector pulse width modulation SVPWM [15] [16]is the best computational PWM technique for a three-phase voltage source inverter because of it provides less THD & better PF. A not worthy role is played by Pulse Width Modulation (PWM) inverters concerning power electronics. The most prevalent pulse width modulation scheme which is conceivably the most efficient one among all other PWM techniques is Space Vector Modulated PWM (SVPWM) since it manages to produce high voltages accompanied with less total harmonic distortion as well as toils splendidly field oriented structures to achieve motor control. Elimination of many small order harmonics by implementing an appropriate harmonic elimination methodology can lead to an excellent quality spectrum of output. SVPWM signifies an exceptional switching scheme of six semiconductor switches of a 3-phase converter. SVPWM has turned out to be a standard and prevalent PWM technique in some purposes like induction motor and synchronous motor control for 3-phase voltage-source inverters SVPWM is well known for its efficient modulation technique as compared to other methods as it causes reduced harmonic distortion in output voltage as well as current which is applied to the ac motor phases. This in turn makes the most efficient use of the supply voltage when compared to other modulation schemes. The switching frequency can be regulated with great ease in the case of SVPWM as it enables a steady unvarying switching frequency. Even though, SVPWM is more complex and intricate than other methods of harmonics elimination, it may be executed with great ease involving recent digital signal processing based control mechanism. For employing pulse width modulation (PWM) on three phase switching converters, space vector modulation (SVM) is an effective method to be applied. Operation of converter hardware for smooth working is increased with the help of SVM.

Two level svpwm inverter

The technique of SVPWM initially came into existence as a vector approach to Pulse Width Modulation (PWM) for 3-phase inverters. This technique is well-versed in generating sinusoidal waves that supplies higher voltages with less total harmonic distortion with sufficient sophistication. The classical prototype model of a characteristic three-phase two level voltage source PWM inverter has been indicated in Figure S1-S6: These are the six switches which are responsible for shaping the output, regulated by the switching variables a, a', b, b', c and c'. The corresponding lower transistor is switched or, we can say a', b' or c' become zero, when the upper transistor is switched on i.e. when a, b or c is 1. Hence, the output voltage can be determined by the on and off states of the transistors. SVPWM scheme involves 1800 conduction for the generation of gate signals. In case, two switches (one upper and one lower) conduct simultaneously in such a way that the output voltage is ± Vs, the switch state is 1. In case, the two switches are off simultaneously, the switch state is 0.

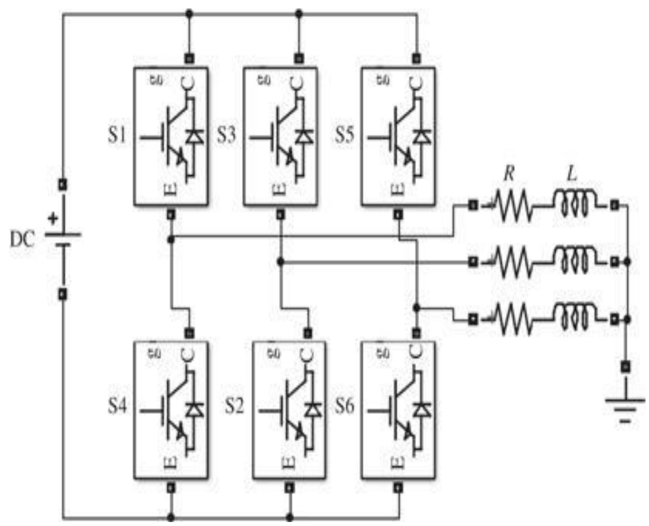

Fig 3:Phase Voltage Source Inverter (VSI)

The Figure shows the space vector diagram of a three-level inverter which can be thought of composed of six hexagons. The space vector diagram of a 3-level inverter which is centered on the six high points of the hexagon, is constituted by six hexagons. Two points need to be followed to get the simplified space vector diagram of a 3-level inverter: One hexagon needs to be chosen amongst the six hexagons from the position of a reference voltage. Then, the amount of the center voltage of the selected hexagon must be subtracted from the previous reference voltage. 5-level space vector plane gets transformed to the 3-level space vector plane with the above specified two steps. The space vector diagram of the 3-level inverter may be assumed to be composed of six small hexagons. These hexagons are focused at the center fn the six high-points or called the apexes of the inner hexagon as shown in Figure below. The twosteps discussed above should be employed again to get the space vector diagram of a 2-level inverter simplified.

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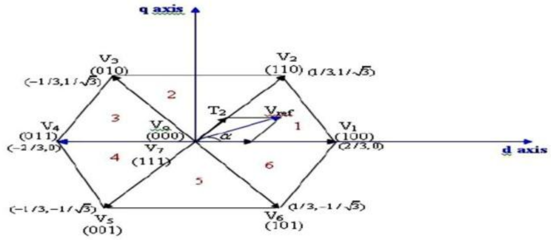

Fig 4:SWITCHING STATES

For 180° mode of operation, there exist six switching states and additionally two more states, which make all three switches of either upper arms or lower arms ON. To code these eight states in binary (one-zero representation), it is required to have three bits ($2^3 = 8$). And also, as always upper and lower switches are commutated in complementary fashion, it is enough to represent the status of either upper or lower arm switches. In the following discussion, status of the upper bridge switches will be represented and the lower switches will it's complementary. Let "1" denote the switch is ON and "0" denote the switch in OFF. Table-1 gives the details of different phase and line voltages for the eight states.

Voltage vectors	Switching vectors			Line to neutral voltage			Line to line voltage		
	A	B	C	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_0
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	2/3	-1/3	-1/3	1	0	-1
V_2	1	1	0	1/3	1/3	-2/3	0	1	-1
V_3	0	1	0	-1/3	2/3	-1/3	-1	1	0
V_4	0	1	1	-2/3	1/3	1/3	-1	0	1
V_5	0	0	1	-1/3	1/3	2/3	0	-1	1
V_6	1	0	1	1/3	-2/3	1/3	1	-1	0
V_7	1	1	1	0	0	0	0	0	0

Table 1: Different phase and line voltages for the eight

VI. ADVANTAGES OF SVPWM TECHNIQUES

Space Vector Modulation for a three phase inverter system can adapt the different switching behaviours such as: half load, full load, linear load, non-linear load, static load, pulsating load, etc.,Very low total harmonic distortions for the output voltage,Robust dynamic response.,The inverter efficiency can be optimized, for each load condition,Efficient use of the DC voltage.

Modelling and designing
By using Active Power Filters (APF) we generate Simulink for both linear and non-linear loads and the responses are taken by using some control techniques. Simulink models are generated for

- APF connected to linear loads with Space vector pulse width modulation (SVPWM).
- APF connected to linear loads without using SVPWM
- APF connected to nonlinear loads with SVPWM
- APF connected to nonlinear loads with sinusoidal pulse width modulation(SPWM)

VII. SYSTEM PARAMETERS FOR LINEAR AND NON LINEAR LOADS

Table 2: system parameters

System Parameters	Values
Source voltage(V_s)	415(peak)
System frequency(f)	50Hz
Resistance	100ohms,82ohms
Inductance	12H
Current	3.4amp,6.8amp
DC VOLTAGE SOURCE	1000V

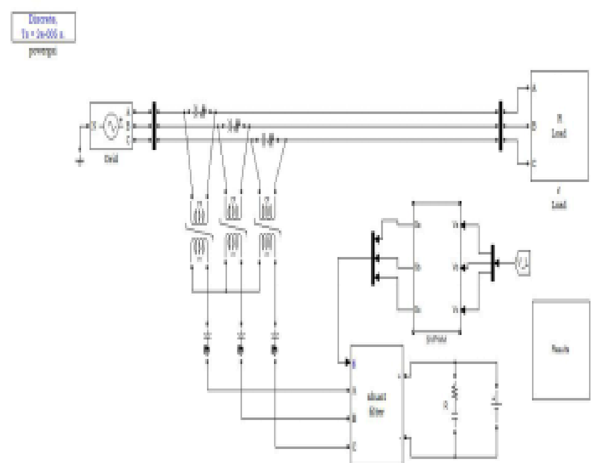

Fig 5 :Modelling for APF connected R-loads with using SVPWM

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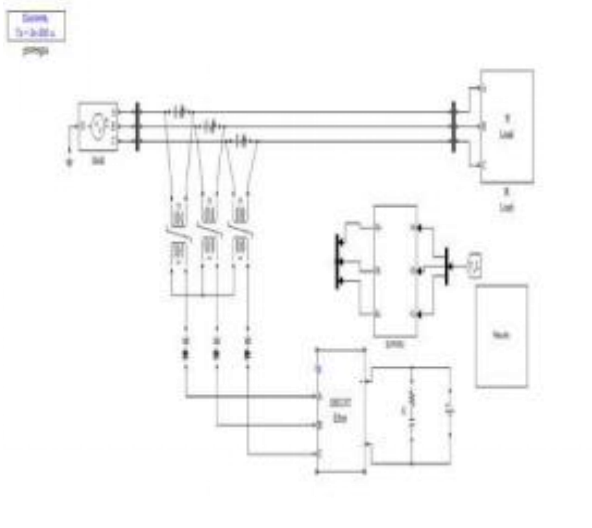

Fig 6: Modelling For APF Connected R-Load Without Using SVPWM

VIII. APF R-LOADS WITH SVPWM

Source wave forms for r-loads

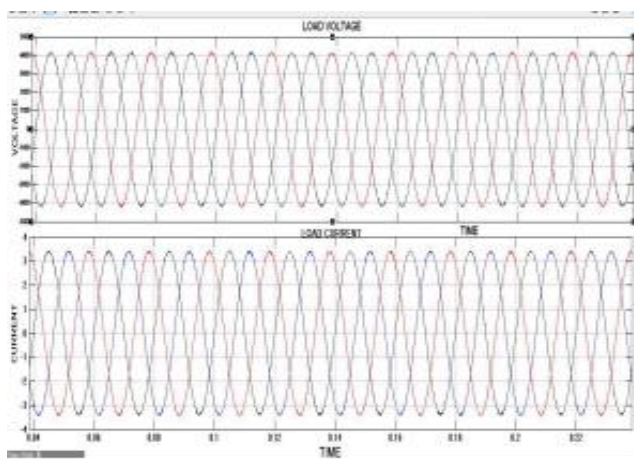

Fig 7 : load WAVE FORM FOR R LOADS

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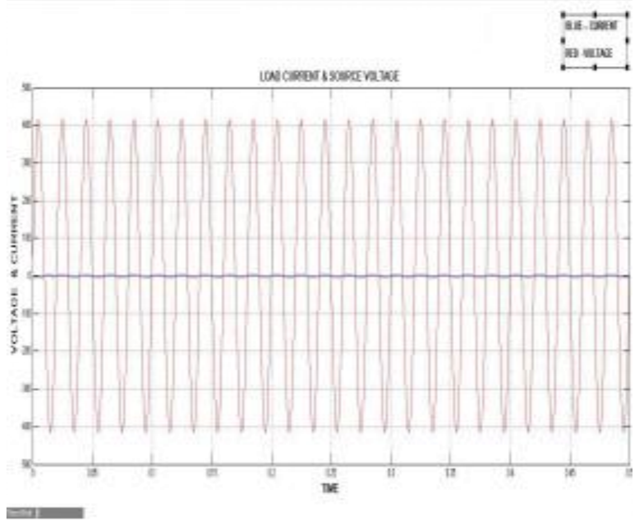

Fig 8 :load current and source voltage wave form

APF R-loads without SVPWM

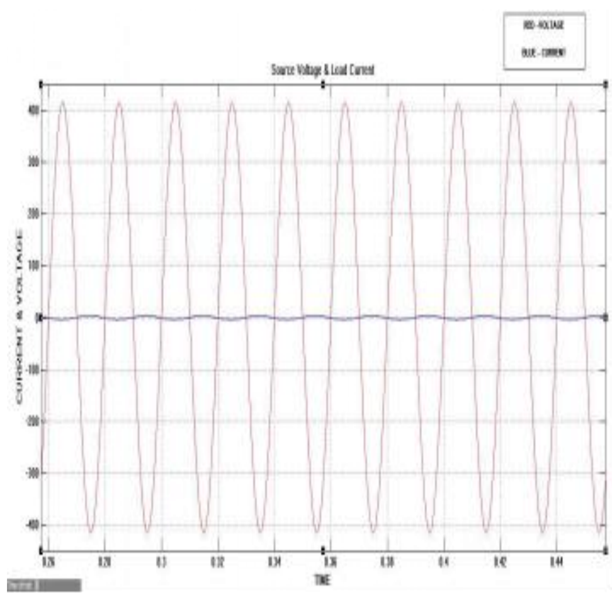

Fig 9 : load current and source voltage wave form

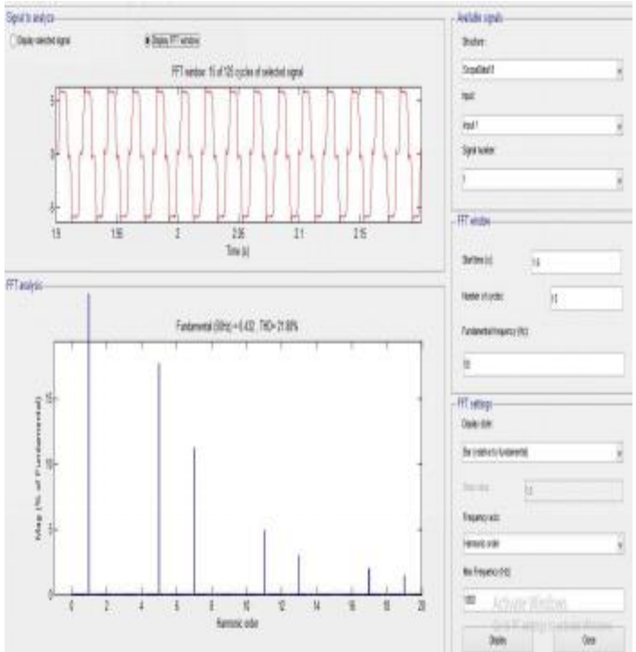

Fig 10 : total harmonic distortions in SPWM

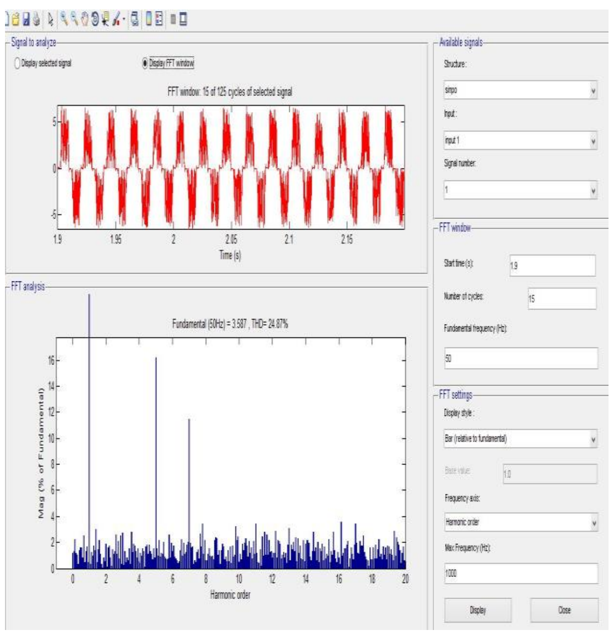

Fig 11: total harmonic distortions in SVPWM

IX. RESULT

In this project, we studied harmonics, its causes, its effects and influences on the power system. Then, we took an overview of the methods for harmonic reduction. The harmonics elimination techniques we adopted are

- Shunt Active Filter
- SVPWM

Then we underwent MATLAB simulation. First, we simulated voltage source inverter (VSI) without any filtration technique to estimate the actual harmonic content. Then, we simulated the VSI fed induction motor with harmonics reduction schemes and did FFT analysis to estimate %THD. The total harmonic distortion we got with shunt active filter is 21.89 % and 24.87 % with the implementation of SVPWM and SPWM. Here, we can see that % THD is less in case of SVPWM as compare to shunt active filter. Hence, we can easily conclude that Space Vector Pulse Width Modulation Technique is more efficient in eliminating harmonics.

X. CONCLUSION

The THD for SVPWM and SPWM is shown below

Table 3: THD for SVPWM and SPWM

TECHNIQUE	TOTAL HARMONIC DISTORTION
SVPWM	21.89%
SPWM	24.87%

From this we can conclude that space vector pulse modulation technique is more efficient in eliminating harmonics.

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