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A Novel Method For The Harmonic Analysis of A Three Phase System

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Abstract- A large amount of harmonics is produced by the increasing practice of electronic equipments in power systems. It is owing to the non- sinusoidal currents expended in nonlinear loads. Non-linear loads includes: diode-rectifiers, thyristor converters, variable speed drives, furnaces, computer energy supplies, UPS, etc. Even though such devices are cost-effective, adaptable and power efficient, these possess the disadvantage of worsening the quality of power by generating harmonic currents as well as exhausting unnecessary reactive power. This phenomenon may lead to a lot of tribulations: e.g. resonance, undue neutral currents, reduced power factor and much more. This harmonics can be reduced by using the shunt active filter. There are many control strategies to reduce harmonics. This project presents space vector PWM (SVPWM) control strategy for extracting reference currents of shunt active filters under non-linear load conditions. The three-phase, three-wire, and five level Diode Clamped multilevel inverter are used as a medium-voltage shunt active power filter. The effectiveness of the proposed control system is demonstrated by MATLAB/SIMULINK simulation and experimental results of a shunt active filter for a three-phase three wire distribution system with non-linear loads.

Index Terms— Shunt Active Power Filter (SAPF), Space Vector Pulse Width Modulation (SVPWM).

1.INTRODUCTION

One of the main points in the development of alternating current transmission and distribution power systems at the end of the 19th century was based on sinusoidal voltage at constant-frequency generation. Sinusoidal voltage with constant frequency has made easier the design of transmission line and transformers. If the voltage were not sinusoidal, complications would appear in the design of transformers, machines, and transmission lines. In recent days power electronic components were used in most of the industries. This is responsible for the generation of current harmonics in the system and it would lead to various problems, most probably power loss in form of heat. These equipments won't draw pure sine waveform as its input. Instead draws Non-Sinusoidal waves in it.

Normally Active Power Filter (APF) is connected in parallel (Shunt) to the power line. The name itself says that the components used in the filter will be Active components. Most probably devices from Thyristor family are used, because it can be controlled easily. Output from Filter will be injected into the line using Inductor, which filters the disturbances, if any. In this project MOSFET's were used as a controlled device in the Active power Filter.

The basic block diagram of the Shunt Active Filter is shown in Figure. 1.1.

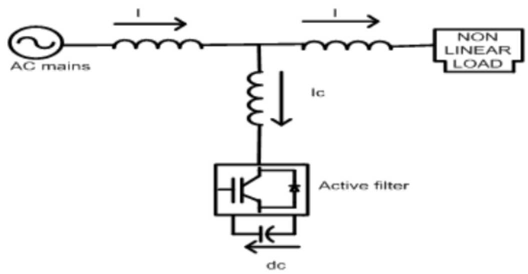

Figure 1.1 Block diagram of Line with SAPF

Thus this project deals with the creation of switching sequence for Shunt Active Power Filter (SAPF) using Space Vector Pulse Width Modulation (SVPWM). The proposed system is designed using MATLAB/SIMULINK software.

A. Existing technique

Several different solutions are proposed for harmonic mitigation. The right choice is always dependent on a variety of factors, such as the activity sector, the applicable standards, the power level. Several solutions are relative to Variable Speed Drives, as this type of electrical equipment represents a large part of the installed power in industrial installations and the most significant power harmonic current generators.

1.1 AC-Line or DC-link Chokes for Drives

They are commonly used up to about 500kW unit power or 1,000kW total drives power. Depending on the transformer size and cabling, the resulting THDv will be ~5%, which is usually well accepted in industrial networks.

1.2 Multi-pulse arrangement

This solution includes a dedicated transformer directly supplied from the MV network. Standard is the use of a 3-winding transformer providing a 12-pulse supply for one or multiple rectifiers or drives. This limits the power harmonic emission considerably and usually no further mitigation is necessary. Besides, multi-pulse solutions are the most efficient in terms of power losses. This is usually used for drives above 400 kW, but could also be reasonable for smaller power ratings.

1.3 Active Front End (AFE)

An Active Front End is a sophisticated electronic circuit connected on the supply side of a Variable Speed Drive. This is the best performing solution concerning harmonic mitigation, limiting the THDi below 5%. All the applicable standard requirements can be met. No detailed system evaluation is necessary, making this solution the easiest to implement.

1.4 Passive Filter

A passive filter consists of reactors and capacitors set up in a resonant circuit configuration, tuned to the frequency of the power harmonic order to be eliminated. A system may be composed of a number of filters to eliminate several harmonic orders.

1.5 Active Filter

An active filter is electronic equipment which injects, in opposite phase, the same harmonic current as drawn by the load, such that the line current remains sinusoidal.

1.6 Hybrid Filter

A hybrid filter is a combination of a passive filter and an active filter in a single unit. Among them, tuned filter is used to reduce harmonics in line current of nonlinear. It is illustrated in figure 12.It is necessary to consider between reliability and economic.

B.PROPOSED TECHNIQUE

- A noteworthy 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 a number of 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.
- On comparing with sinusoidal PWM, it is observed that SVM can accomplish a higher AC voltage level (15% more in magnitude).In this work, we have developed a SVM models in Matlab/Simulink, which is a most common and well known in the field of power system dynamic research. In order to illustrate the principles of SVM based sinusoidal waveform synthesis theory of space vector has been clearly explained.

The three unique inputs of this include:

(i) A saw tooth triangular waveform is used to produce repeating switching period for digital control

(ii) A method to incorporate blocks with different sampling rates is employed to generate SVM pulses

(iii) Matlab / Simulink model is developed.

The models that are developed are very useful to extend detailed SVM enabled power converters in the study of power system. The basic block diagram of the proposed system is shown in figure 1.2.

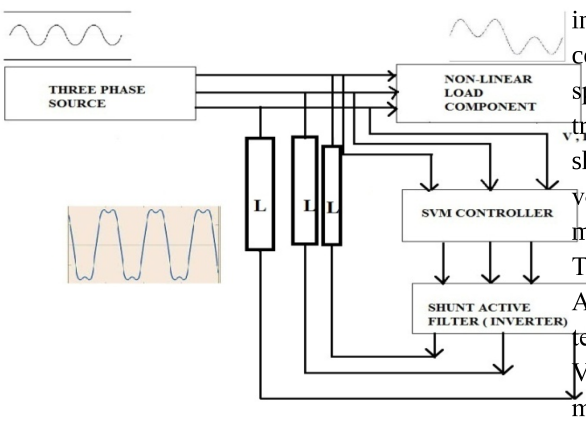

Figure 1.2 Block diagram of proposed system

2.SVPWM CONTROL ALGORITHM

Space vector pulse width modulation is applied to output voltage and input current control. This method is an advantage because of increased flexibility in the choice of switching vector for both input current and output voltage control. It can yield useful advantage under unbalanced conditions. The three phase variables are expressed in space vectors. For a sufficiently small time interval, the reference voltage vector can be approximated by a set of stationary vectors generated by a matrix converter. If this time interval is the sample time for converter control, then at the next sampling instant when the reference voltage vector rotates to a new angular position, it may correspond to a new set of stationary voltage vectors (Casadei et al 1993). Carrying this process onwards by sampling the entire waveform of the desired voltage vector being synthesized in sequence, the average output voltage would closely emulate the reference voltage. Meanwhile, the selected stationary vectors can also give the desirable phase shift between input voltage and current. The modulation process thus required consists of two main parts: selection of the switching vectors and computation of the vector time intervals. The above methods give the theoretical maximum voltage gain of 0.866, though they use different approaches. This is realized in Venturini Method.

Modulation of the line to line voltage naturally gives an extended output voltage capability. The computational procedure required by SVPWM method is less complex than that for Venturini method because of the reduced number of sine function computations (Kolar et al 1991). The number of switch commutations per switching cycle for SVPWM method is 20% less than that of Venturini method. Roots of vectorial representation of three-phase systems are presented in the research contributions of Park and Kron, but the decisive step on systematically using the Space Vectors was done by Kovacs and Racz (Park 1933). They provided both mathematical treatment and a physical description and understanding of the drive transients even in the cases when machines are fed through electronic converters (Maamoun et al 2010).SVPWM refers to a special switching sequence of the upper three power transistors of a three-phase power inverter. It has been shown to generate less harmonic distortion in the output voltages and or currents applied to the phases of an AC motor and to provide more efficient use of supply voltage. There are two possible vectors called zero vector and Active vector. The objective of space vector PWM technique is to approximate the reference voltage vector Vref using the eight switching patterns. One simple method of approximation is to generate the average output of the inverter in a small period, T to be the same as that of Vref in the same period. Therefore, space vector PWM can be implemented by the following steps:

Step 1: Determine Vd, Vq, Vref, and angle

Step 2: Determine time duration T1, T2, T0

Step 3: Determine the switching time of each transistor (S1 to S6)

All sectors in SVPWM are shown in Figure 2.1. It uses a set of vectors that are defined as instantaneous space vectors of the voltages and currents at the input and output of the inverter. These vectors are created by various switching states that the inverter is capable of generating.

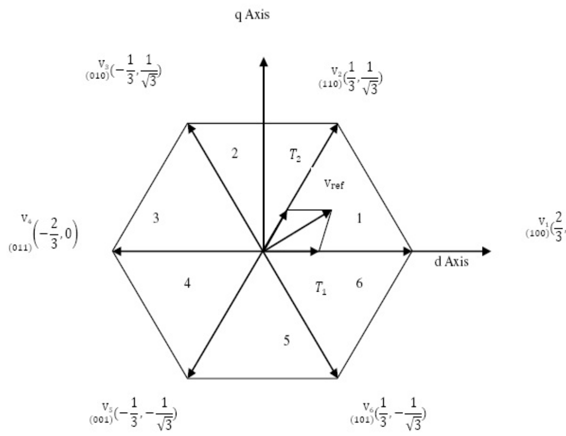

Figure 2.1 space Vector Diagram with Sectors

Figure 2.2 shows the maximum control voltages obtained using sine wave pulse widh modulation which is (1/2)Vdc and space vector pulse width modulation scheme which is (1/√3)Vdc.

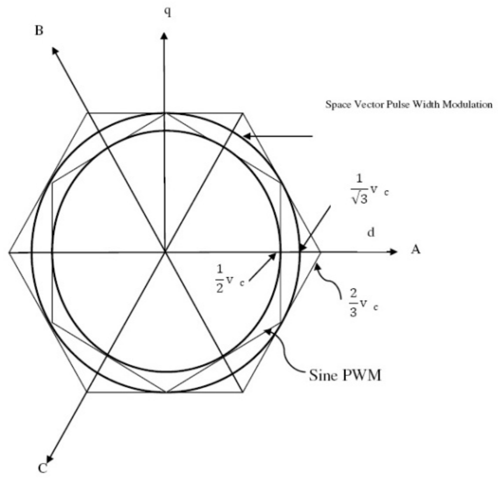

Figure 2.2 Maximum Voltage Transformation Ratio

To implement the space vector PWM, the voltage equations in the ABC reference frame can be transformed into the stationary dq reference frame. Relating the three phase voltages and currents in terms of „ωt‟ is difficult to handle directly. It can be transformed into two reference frames by using Park‟s transform (Bernard Adkins and Harley 1975) and their relationships are shown in Equation (4.20). That consists of the horizontal (d) and vertical (q) axes as shown in Figure 2.3.

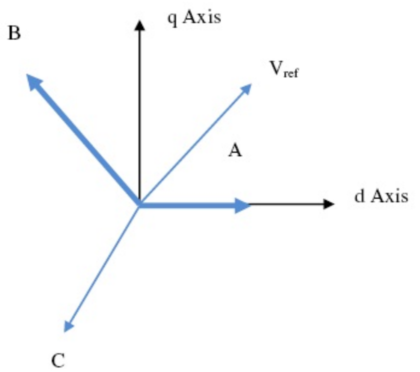

Figure 2.3 dq and ABC Reference Frame

$$f_{dqo} = K_s \, f_{abc}$$

$$_s = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/2 & 1/2 & 1/2 \end{bmatrix}$$

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In d_q reference frame, there are six sectors. Each sector is divided equally by sixty degrees. Basic Vectors are V1, V2, V3, V4, V5 and V6.

A. Calculation of time period for Sector I

At sector I, V1 and V2 are voltage vectors. Assume Vref makes „ ‟phase angle difference with V1. This Vref can be calculated using vector calculus by referring Figure 2.4.Tz„is switching time interval at which output voltage of inverter is constant. T1 and T2 are switching time duration of voltage space vectors V1 and V2.

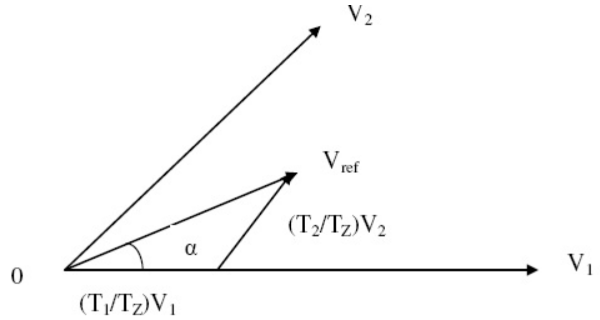

Figure 2.4 Reference Vector with respect to Sector I

$$\int_0^{T_z} V_{ref} = \int_0^{T_1} V_1 + \int_{T_1}^{T_1+T_2} V_2 + \int_{T_1+T_2}^{T_z} V_0$$

$$T_z . V_{ref} = (T_1 V_1 + T_2 V_2)$$

$$T_z . |V_{ref}| . \begin{bmatrix} \cos\alpha \\ \sin\alpha \end{bmatrix} = T_1 . \frac{2}{3} . V_c \begin{bmatrix} 1 \\ 0 \end{bmatrix} + T_2 . \frac{2}{3} . V_c \begin{bmatrix} \cos\left(\frac{\pi}{3}\right) \\ \sin\left(\frac{\pi}{3}\right) \end{bmatrix}$$

where, $0 \le \alpha \le 60°$

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$$T_z . |V_{ref}| . [\cos\alpha] = T_1 . \frac{2}{3} . V_c [1] + T_2 . \frac{2}{3} . V_c \left[\cos\left(\frac{\pi}{3}\right)\right]$$

$$T_z . |V_{ref}| . [\sin\alpha] = T_2 . \frac{2}{3} . V_c \left[\sin\left(\frac{\pi}{3}\right)\right]$$

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$$T_1 = T_z . A . \frac{si\ \left(\frac{\pi}{3} - \alpha\right)}{si\ \frac{\pi}{3}}$$

$$T_2 = T_z . A . \frac{si\ (\alpha)}{si\ \frac{\pi}{3}}$$

$$T_0 = T_z - (T_1 + T_2), \text{where}, T_z = \frac{1}{f_z} \text{ and } A = \frac{|V_{ref}|}{\frac{2}{3} V_{dc}}$$

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B. Switching Time at Any Duration (T1, T2, T0)

Switching time at any instant can be illustrated in following Equation. For „n‟ number of samples T1, T2 and T0 are,

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$$T_1 = \frac{\sqrt{3}\ \ T_z\ \ |V_{ref}|}{V_{dc}}\left(\sin\left(\frac{\pi}{3} - \alpha + \frac{-1}{3}\pi\right)\right)$$

$$= \frac{\sqrt{3}\ \ T_z\ \ |V_{ref}|}{V_{dc}}\left(\sin\left(\frac{\pi}{3} - \alpha\right)\right)$$

$$= \frac{\sqrt{3}\ \ T_z\ \ |V_{ref}|}{V_{dc}}\left(\sin\left(\frac{\pi}{3}\cos\alpha - \cos\frac{\pi}{3}\sin\alpha\right)\right)$$

$$T_2 = \frac{\sqrt{3}\ \ T_z\ \ |V_{ref}|}{V_{dc}}\left(\sin\left(\alpha - \frac{-1}{3}\pi\right)\right)$$

$$= \frac{\sqrt{3}\ \ T_z\ \ |V_{ref}|}{V_{dc}}\left(-\cos\alpha.\sin\left(\frac{-1}{3}\pi\right) + \sin\alpha.\cos\left(\frac{-1}{3}\pi\right)\right)$$

$$T_0 = T_z - (T_1 - T_2)$$

where, n=1 through 6 (that is sector 1 to 6), $0 \le \alpha \le 60°$

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Table 2.1 Switching Time Calculation of Each Section switch (VSI)

Sector	Upper switch	Lower switch
1	S_1=T_1+T_2+T_0/2 S_3= T_2+T_0/2 S_5= T_0/2	S_4=T_0/2 S_6= T_1+T_0/2 S_2= T_1+T_2+T_0/2
2	S_1= T_1+T0/2 S_3= T_1+T_2+T_0/2 S_5= T_0/2	S_4= T_2+T_0/2 S_6= T_0/2 S_2= T_1+T_2+T_0/2
3	S_1= T_0/2 S_3=T_1+T_2+T_0/2 S_5= T_2+T_0/2	S_4= T_1+T_2+T_0/2 S_6= T_0/2 S_2= T_1+T_0/2
4	S_1= T_0/2 S_3= T_1+T0/2 S_5= T_1+T_2+T_0/2	S_4= T_1+T_2+T_0/2 S_6= T_2+T_0/2 S_2=T_0/2
5	S_1= T_2+T_0/2 S_3= T_0/2 S_5=T_1+T_2+T_0/2	S_4= T_1+T_0/2 S_6= T_1+T_2+T_0/2 S_2=T_0/2
6	S_1=T_1+T_2+T_0/2 S_3= T_0/2 S_1= T_1+T_0/2	S_4=T_0/2 S_6= T_1+T_2+T_0/2 S_2= T_2+T_0/2

3. SIMULATION AND RESULTS

The overall simulation of the proposed system is shown in figure 3.1.

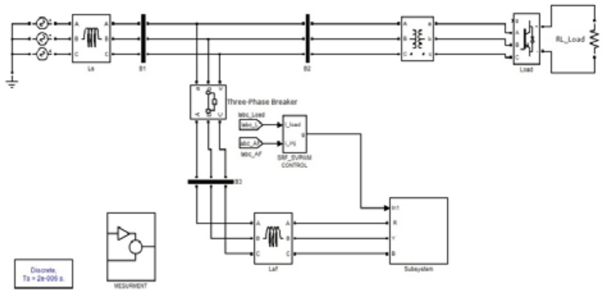

Figure 3.1 Simulation of non-linear load with SAPF

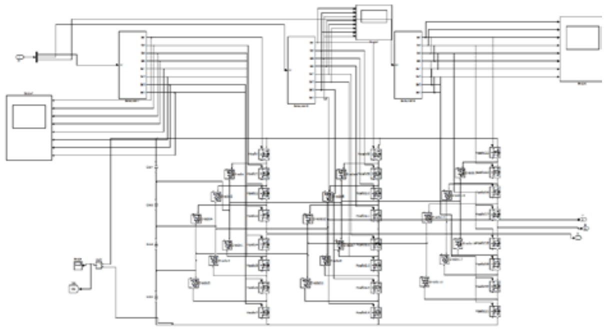

Figure 3.2 simulation of 5 level DCI

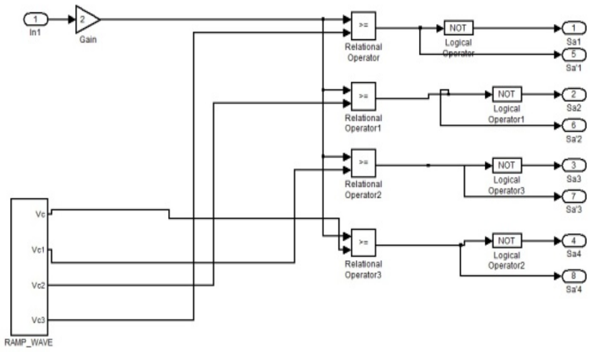

Figure 3.3 switching circuit

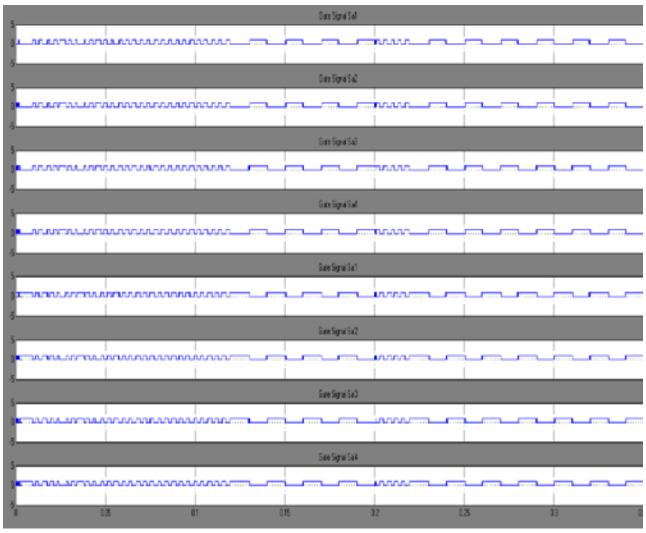

Figure 3.4 switching pulse of leg-1

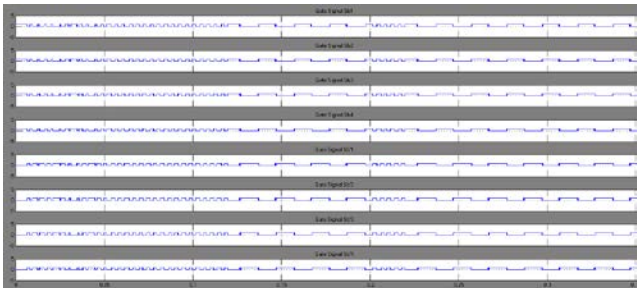

Figure 3.5 switching pulse of leg-2

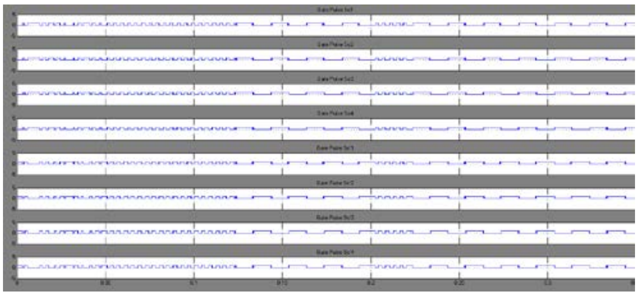

Figure 3.6 switching pulse of leg-3

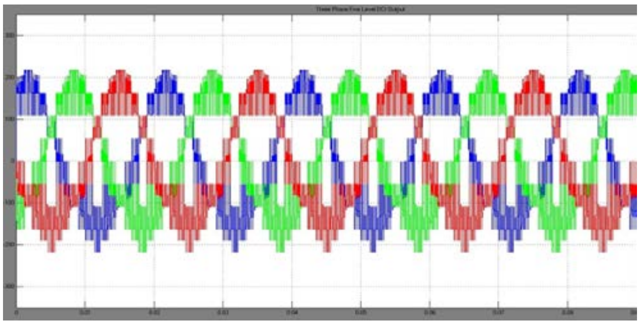

Figure 3.7 5 level DCI output

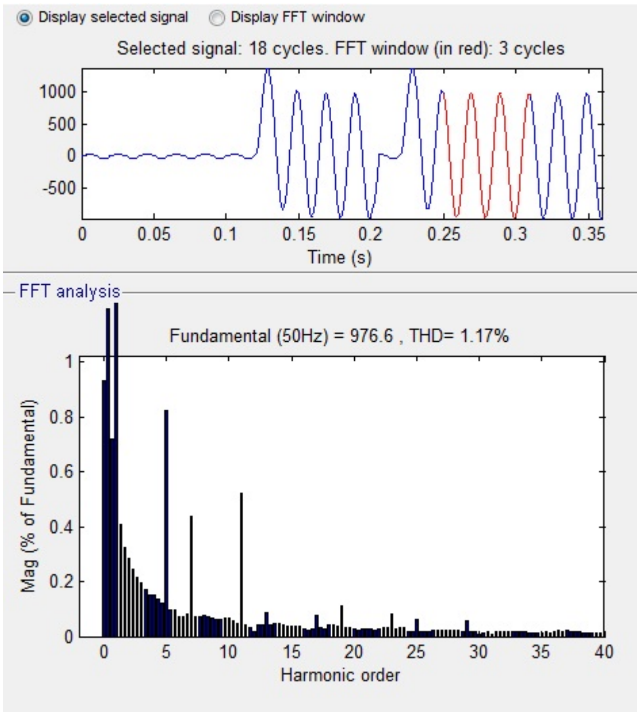

Figure 3.8 THD of the system with filter

4. CONCLUSION & FUTURE SCOPE

In the above discussed project we had presented the THD of non linear load, with Space Vector Pulse Width Modulation (SVPWM). And FFT Analysis is shown below IEEE Guideline (5%). We had used MOSFET as a switching device in the filter (five level DC Inverter). Also the features of MATLAB/Simulink are also explained.

In future the same Harmonic reduction Technology can be implemented to IGBT's and other advanced switching devices, by means of which THD may be brought down as much as possible.

5. REFERENCES

[1] Phuong Hue Tran, "MATLAB/SIMULINK Implementation And Analysis of Three Pulse-Width-Modulation (PWM) Techniques," *A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering Boise State University*, May 2012.

[2] Anne Ko , Wunna Swe and Aung Zeya ," Analysis of Harmonic Distortion in Non-linear Loads ", *The First International Conference on Interdisciplinary Research and Development*, 31 May - 1 June 2011, Thailand.

[3] 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

[4] R.Karthikeyan, Dr.S.Chenthur Pandian," An Efficient Multilevel Inverter System for Reducing THD with Space Vector Modulation", *International Journal of Computer Applications,Volume 23– No.2, June 2011*

[5] Phuong Hue Tran , "MATLAB/SIMULINK Implementation And Analysis Of Three Pulse-Width-Modulation (PWM)TechniqueS," *A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering Boise State University*, May 2012.

[6] T.Ohnishi and H.Okitsu, "A novel PWM technique for three-phase inverter/converter," *International power electronics conference*, 1983, pp.384-395.

[7] F.Baabjerg,J.K.Pederesen and P.Thoegersen, "Improved modulation technique for PWM-V SI drives," *IEEE Transactions on Industrial Electronics*, vol.44 , No.1, Febraury 1997.

[8] T.-P.Chen,Y.-S.Lai and C.-H.Liu," New space vector modulation technique for inverter control," *IEEE Power Electronics Specialties Conference*, vol.2,1999,pp.777-782.

[9] S.R.Bowes and G.S.Singh ,"Novel Space-Vector-based harmonic elimination inverter control," *IEEE Transactions on Industry Applications*, vol. 16,No.3,May 2001, pp. 351-359.

[10] C.Zhan, A.Arulampalam, V.K.Ramachandramurthy, C.Fitzer, M.Barnes and N.Jenkins," Novel voltage space vector PWM algorithm of 3-phase 4-wire power conditioner," *IEEE Power Engineering Society Winter Meeting*,2001, vol. 3,pp. 1045-1050.

[11] Muhammad H.Rasid, *Power Electronics Circuits, Devices and Applications* Pearson Third Edition 2011,pp. 271-278.

[12] D.Pradeep kumar, "Investigations on Shunt Active Powerfilter for Power Quality Improvement", *2007 National Institute of Technology, Rourkela.*

[13] D.Pradeep kumar, "Power Quality Improvement on Active Filter", *2007 National Institute of Technology, Rourkela.*

[14] Aneesh Mohamed A. S., Anish Gopinath, and M. R. Baiju, Member, IEEE "A Simple Space Vector PWM Generation Scheme for Any General n-Level Inverter ", *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS*, VOL. 56, NO. 5, MAY 2009.