ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Multi Level Inverter Based Active Power Filter for Harmonic Reduction

K Siva Gopi Raju
Department of Electrical and Electronics Engineering,
Andhra University,
Visakhapatnam, Andhra Pradesh 530003, India.

K Padma
Department of Electrical and Electronics Engineering,
Andhra University,
Visakhapatnam, Andhra Pradesh 530003, India.

Abstract

A shunt active power filter reduces the harmonic content due to non linear loads to a percentage below 5. But due to inverter configuration of filter the harmonic reduction is limited to some value. In this project the harmonic content is further reduced by modifying the inverter configuration. Multi level inverter provides sine wave by increasing the level at the output. The general configuration is 3 level which is modified to 5 level inverter. The results will be analyzed by using matlab simulink software.

Index Terms— multi level inverter, active power filter, total harmonic distortion.

I. Introduction

With the advent of power semiconductor switching devices like SCRs, GTO's, IGBT's (Insulated Gate Bipolar Transistors) and many more devices, control of electric power has become a reality. Such power electronic controllers are widely used to feed electric power to electrical loads, such as adjustable speed drives (ASD's), furnaces, computer power supplies, HVDC systems etc [1].

The power electronic devices due to their inherent non-linearity draw harmonic and reactive power from the supply. In three phase systems, they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor [2-4].

In addition to this, the power system is subjected to various transients like voltage sags, swells, flickers etc. These transients would affect the voltage at distribution levels. Excessive reactive power of loads would increase the generating capacity of generating stations and increase the transmission losses in lines. Hence supply of reactive power at the load ends becomes essential.

Power Quality (PQ) has become an important issue since many loads at various distribution ends like adjustable speed drives, process Industries, Printers, domestic Utilities, computers, microprocessor based equipments etc. have become intolerant to voltage fluctuations, harmonic content and interruptions [3].

Power Quality (PQ) mainly deals with issues like maintaining a fixed voltage at the Point of Common Coupling (PCC) for various distribution voltage levels irrespective of voltage fluctuations, maintaining near unity power factor power drawn from the supply, blocking of voltage and current unbalance from passing upwards from various distribution levels, reduction of voltage and current harmonics in the system and suppression of excessive supply neutral current [4].

Conventionally, passive LC filters and fixed compensating devices with some degree of variation like SCR switched capacitors, SCR switched reactors were employed to improve the power factor of ac loads. Such

Cite this article as: K Siva Gopi Raju & K Padma, "Multi Level Inverter Based Active Power Filter for Harmonic Reduction", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 5 Issue 9, 2018, Page 102-108.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

devices have the demerits of fixed compensation, large size, ageing and resonance. Nowadays equipments using power semiconductor devices, generally known as active power filters (APF's), Active Power Line Conditioners (APLC's) etc. are used for the power quality issues due to their dynamic and adjustable solutions. Flexible AC Transmission Systems (FACTS) and Custom Power products like STATCOM (Static synchronous compensator), DVR (Dynamic Voltage Restorer), etc, [5] deal with the issues related to power quality using similar control strategies and concepts. Basically, they are different only in the location in a power system where they are deployed and the objectives for which they are deployed z.

II. ACTIVE POWER FILTERS

Current Source Inverter (CSI) Active Power Filter [Fig 2.1.1(a)] and Voltage Source Inverter (VSI) Active Power Filter [Fig 2.1.1(b)] are two classifications in this category. Current Source Inverter behaves as a non-sinusoidal current source to meet the harmonic current requirement of the nonlinear loads. A diode is used in series with the self-commutating device (IGBT) for reverse voltage blocking. However, GTO-based configurations do not need the series diode, but they have restricted frequency of switching. They are considered sufficiently reliable, but have higher losses and require higher values of parallel ac power capacitors. Moreover, they cannot be used in multilevel or multistep modes to improve performance in higher ratings.

The other converter used as an AF is a voltage-fed PWM inverter structure, as shown in Fig 2.1.1(b).It has a self-supporting dc voltage bus with a large dc capacitor. It has become more dominant, since it is lighter, cheaper, and expandable to multilevel and multistep versions, to enhance the performance with lower switching frequencies. It is more popular in UPS-based applications, because in the presence of mains, the same Inverter Bridge can be used as an AF to eliminate harmonics of critical nonlinear loads [6].

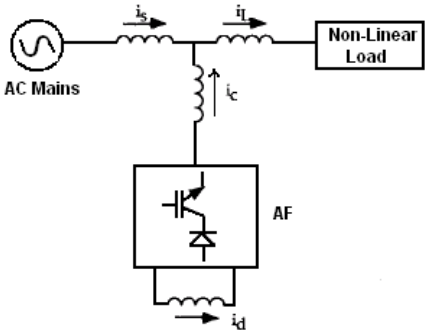


Fig 2.1.1(a) Current fed type AF

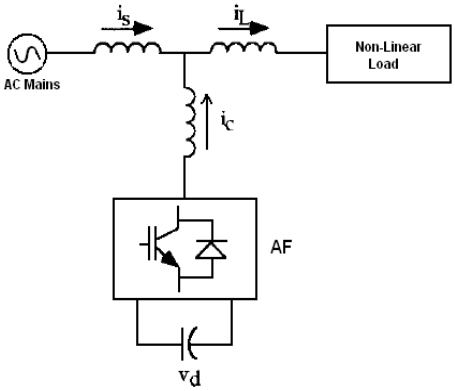


Fig 2.1.1(b) Voltage fed type AF

3 DSTATCOM compensating AC and DC loads:

Due to the simplicity, the absence of the unbalance in the dc link voltage and independent current tracking with respect to other phases, a three phase H-Bridge VSI topology is chosen. The following figure 3.3: shows a three phase-four-wire-compensated system using H-bridge VSI topology-based DSTATCOM compensating unbalanced and nonlinear ac load.

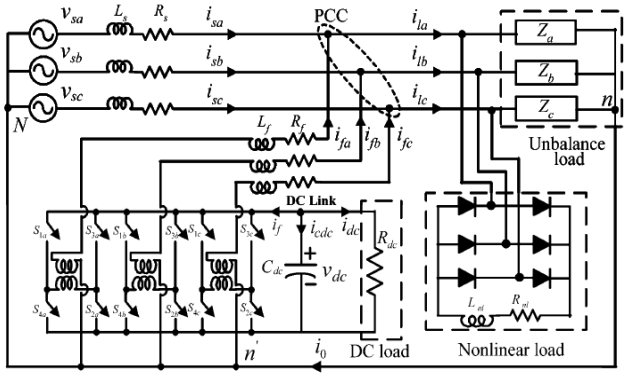


Figure 3.3: showing a three phase-four wire compensated system using the H-bridge VSI topology-based DSTATCOM

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A dc load (R_{dc}) is connected across the dc link. The DSTATCOM consists of 12 insulated-gate bipolar transistor(IGBT) switches each with an antiparallel diode, dc strorage capacitor, three isolation transformers and three interface conductors.The statr point of the isolation transformers($n^{'}$) is connected to the neutral of load(n) and source (N). The H-bridge VSIs are connected to the PCC through interface inductors. The isolation transformers prevent a short circuit of the dc capacitor for various combinations of switching states of the VSI. The inductance and resistance of the isolation transformers are also included in L_f and R_f. The source voltages are assumed to be balanced and sinusoidal. With this supply being considered as a stiff source, the feeder impedance(L_s-R_s) shown in the above figure.1: is negligible and hence it is not accounted in state-space modelling. To track the desired compensator currents, the VSIs operate under the hysterisis band current control mode due to their simplicity, fast response, and being independent of the load parameters. The DSTATCOM injects currents in to the PCC in such a way as to cancel unbalance and harmonics in the load currents. The VSI operation is supported by the dc storage capacitor C_{dc} with voltage V_{dc} across it. The dc bus voltage has two functions, that is, to support the compensator operationand to supply dc load. While compensating, the DSTATCOM mantains the balanced sinusoidal source currents with unity power factor and supplies the dc load through its dc bus.

IV MULTI LEVEL INVERTERS

The multilevel inverters have drawn tremendous interest in the power industry. They present a new set of features hat are well suited for use in reactive power compensation. It may be easier to produce a high-power, high-voltage inverter with the multilevel structure because of the way in which device stresses are controlled in the structure. Increasing the umber of voltage levels in the inverter without requiring higher ratings on individual devices can increase the power rating. The unique structure of multilevel voltage source inverters allows them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized-switching devices. As the number of voltage levels increases, the harmonic content of the output voltage waveform decreases significantly.

5.1. Types of multilevel inverter

The general structure of the multilevel converter is to synthesize a near sinusoidal voltage sources. As the number of level increases, the synthesized output waveform has more steps, which produce a staircase wave that approaches a desired waveform. Also, as more steps are added to the waveform, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases. As the number of levels increases, the voltage that can be spanned by summing multiple voltage levels also increases. The output voltage during the positive half-cycle can be found from

$Vao = \sum_{n=1}^{m} EnSFn$ .....(5.1.)

Where SFn is the switching or control function of nth node and it takes a value of 0 or 1.

The multilevel inverters can be classified into three types.

1. Diode-clamped multilevel inverter;
2. Flying-capacitors multilevel inverter;
3. Cascaded multilevel inverter.

5.1.1 Diode-Clamped Multilevel Inverter

Diode-clamped multilevel (m-level) inverter typically consists of (m-1) capacitors on the dc bus and produces m levels on the phase voltage. An m-level inverter leg 2(m-1)

Switching devices and (m-1) (m-2) clamping diodes.
The major advantages of the diode-clamped inverter can be summarized as follows:

1. When the number of level is high enough, the harmonic content is low enough to avoid the need for filters.
2. Inverter efficiency is high because all devices are switched at the fundamental frequency.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The major disadvantages of the diode-clamped inverter can be summarized as follows:

1. Excessive clamping diodes are require when the number of levels is high.
2. It is difficult to control the real power flow of the individual converter in multi-converter systems.

5.1.2 Flying-Capacitors Multilevel Inverter

The dc bus needs (m-1) capacitors for an m-level converter. The number of capacitors required for each phase is

$$Nc = \sum_{j=1}^{m}(m-j) \quad \text{.....(5.2.)}$$

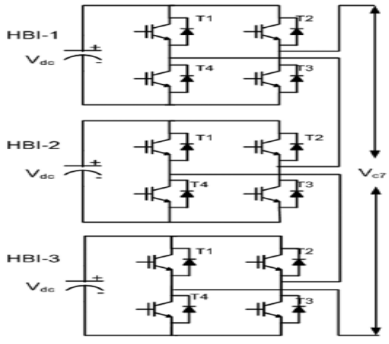
Thus for m=5, Nc=10.

The major advantages of the Flying-Capacitors Multilevel inverter can be summarized as follows:

1. Phase redundancies are available for balancing the voltage levels of the capacitors.
2. Real and reactive power flow can be controlled.
3. The large number of capacitors enables the inverter to ride through short duration outages and deep voltage sags.

The major disadvantages of the Flying-Capacitors Multilevel inverter can be summarized as follows:

Control is complicated to track the voltage levels for all of the capacitors. Also, recharging all of the capacitors to the same voltage level and startup are complex. Switching utilization and efficiency are poor for real power transmission. The large numbers of capacitors are both more expensive and bulky than clamping diodes in multilevel diode-clamped converters. Packaging is also more difficult in inverters with a high number of levels.



CASCADED H BRIDGE INVERTER

VOLTAGE SOURCE CONVERTER (VSC)

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. It also converts the DC voltage across storage devices into a set of three phase AC output voltages. It is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, is said to be in capacitive mode. So, it will compensate the reactive power through AC system. The type of power switch used is an IGBT in anti-parallel with a diode. The three phase four leg VSI is modeled in Simulink by using IGBT.

Voltage source converters are preferred over current source converter because it is higher in efficiency and lower initial cost than the current source converters. They can be readily expanded in parallel to increase their combined rating and their switching rate can be increased if they are carefully controlled so that their individual switching times do not coincide. Therefore, higher-order harmonics can be eliminated by using converters without increasing individual converter switching rates.

5.3 CONTROL TECHNIQUE USED FOR INTERFACING INVERTER TO ACT AS SHUNT APF

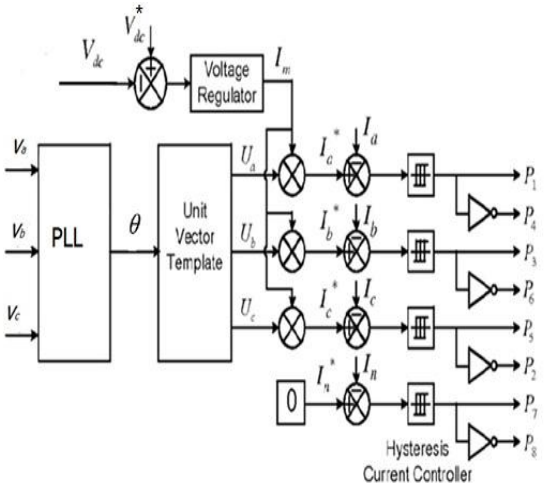


Fig 4.3: Control scheme

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The turn on and turn off instants of inverter switches should be such that the load and the connected RES could appear as balanced load to the system. The dc link voltage, Vdc is sensed at a regular interval and is compared with its reference counterpart Vdc*. The error signal is processed in a PI-controller. The output of the pi controller is denoted as Im.

The reference current templates (Ia*, Ib*, and Ic*) are obtained by multiplying this peak value (Im) by the three-unit sine vectors (Ua, Ub and Uc) in phase with the three source voltages. These unit sine vectors are obtained from the three sensed line to neutral voltages. The reference grid neutral current (In*) is set to zero, being the instantaneous sum of balanced grid currents. Multiplication of magnitude Im with phases (Ua, Ub, and Uc) results in the three phase reference supply currents (Ia*, Ib*, and Ic*).

The grid synchronizing angle (Θ) obtained from phase locked loop (PLL) is used to generate unity vector template as

$$U_a = \sin\theta \quad \{4.1\}$$

$$U_b = \sin\left(\theta - \frac{2\pi}{3}\right) \quad \{4.2\}$$

$$U_c = \sin(\theta + \frac{2\pi}{3}) \quad \{4.3\}$$

The instantaneous values of reference three phase grid currents are compute as

$$I_a^* = I_m * U_a \quad \{4.4\}$$

$$I_b^* = I_m * U_b \quad \{4.5\}$$

$$I_c^* = I_m * U_c \quad \{4.6\}$$

The neutral current is considered as

$$I_n^* = 0 \quad \{4.7\}$$

The reference grid currents(I_a*, I_b^*, I_c^* and I_n^*) are compared with actual grid currents(I_a, I_b, I_c and I_n) to compute the current errors as

$$I_{aerr} = I_a^* - I_a \quad \{4.8\}$$

$$I_{berr} = I_b^* - I_b \quad \{4.9\}$$

$$I_{cerr} = I_c^* - I_c \quad \{4.10\}$$

$$I_{nerr} = I_n^* - I_n \quad \{4.11\}$$

These errors are given to hysteresis current controller then generate the switching pulses for six IGBTs of the grid interfacing inverter.

5.4 MATLAB /SIMULINK MODEL OF PI CONTROL

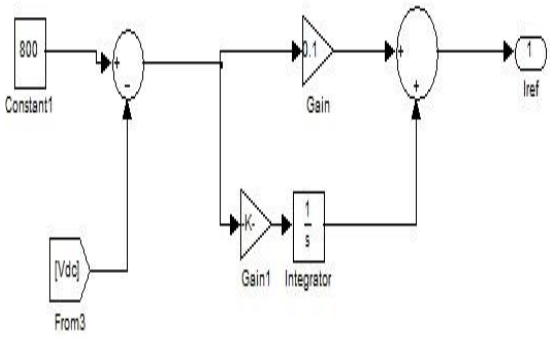


Fig.4.6: MATLAB Simulink model of PI control

5.5 NON LINEAR LOAD: A three phase four leg diode rectifier feeding an RL load is considered as a non-linear load. The load is modeled in Simulink by using diodes.

5.6 MATLAB/SIMULINK MODEL OF THE PROPOSED SYSTEM

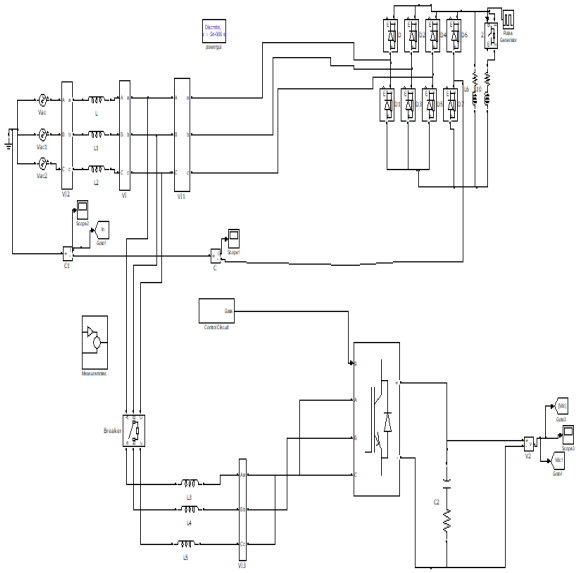


Fig .4.7: MATLAB Simulink model of the proposed system

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

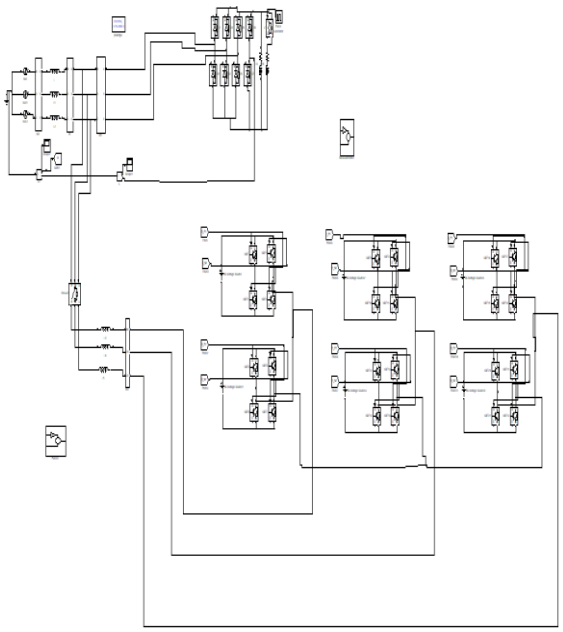


Fig .4.7: MATLAB Simulink model of the Using multi level inverter

THD ANALYSIS FOR NON LINEAR LOAD

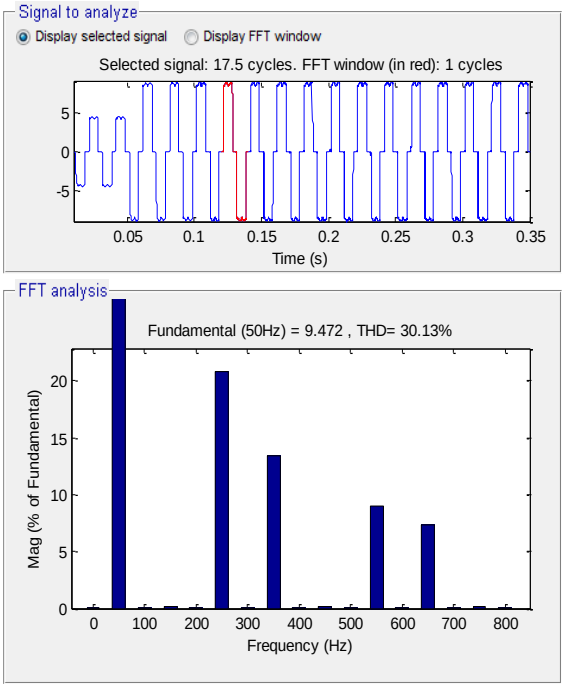


Fig.5.2: THD of Source Current before Compensation

Total Harmonic Distortion of Source Current before Compensation = 30.13%

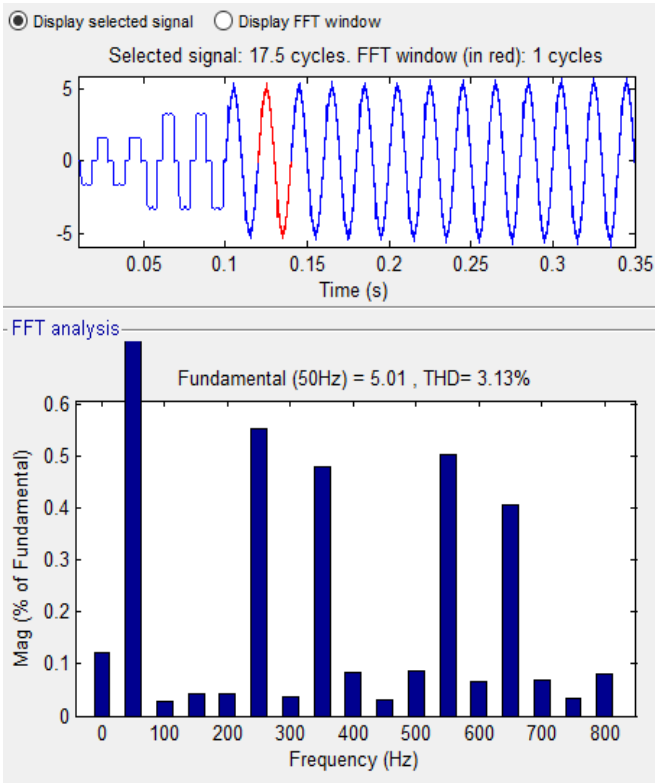
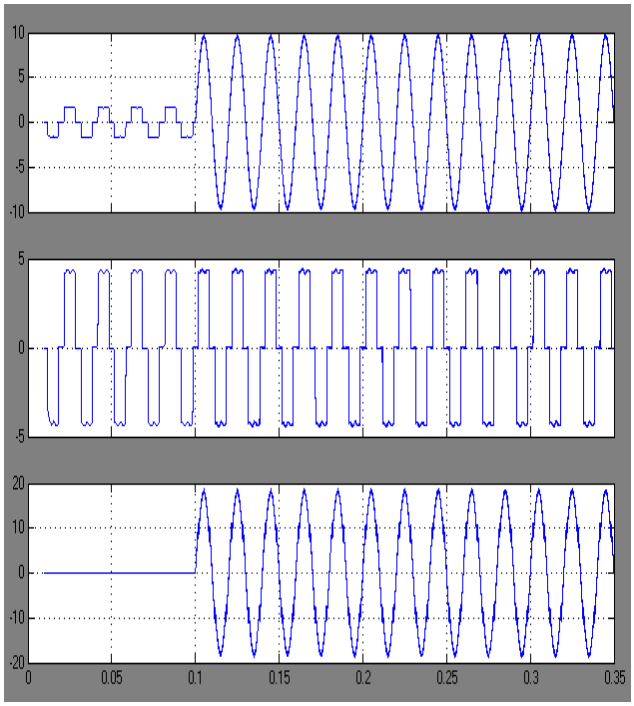


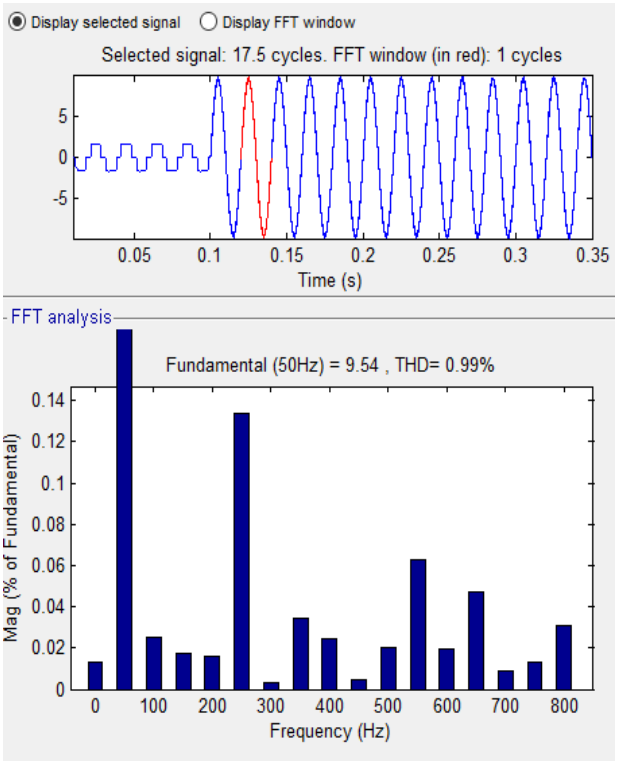
Fig.5.3: THD of Source Current after Compensation

Total Harmonic Distortion of Source Current after Compensation = 3.13%



Source current using multi level inverter

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



Source current THD using multi level inverter

vii. conclusions

Multi level inverter based active harmonic filter is developed in which the total harmonic distortion is less when the controller is based on inverter configuration. A 5 level inverter based inverter is developed in which the pulse number is increased in which the harmonic content will be reduced. By using 3 level inverter the THD is 3.13 percentage. And by using 5 level inverter the THD is 0.99 percentage. The results are analyzed using matlab simulink software.

viii. References

[1] J. M. Guerrero, L. G. de Vicuna, J. Matas, M. Castilla, and J. Miret,"A wireless controller to enhance dynamic performance of parallel invertersin distributed generation systems," IEEE Trans. Power Electron.,vol. 19, no. 5, pp. 1205–1213, Sep. 2004.

[2] J. H. R. Enslin and P. J. M. Heskes, "Harmonic interaction betweena large number of distributed power inverters and the distribution network,"IEEE Trans. Power Electron., vol. 19, no. 6, pp. 1586–1593,Nov. 2004

[3] Singh.B, Chandra.A, Al-Haddad.K, "A review of active filters for power quality improvement," IEEE Trans. Industrial Electronics, Vol. 46, pp. 960-971, Oct. 1999 .

[4] L Dinesh. M Divakar J uday venkatesh." DC Voltage Feedback Control to Active Power Filter for Harmonic Reduction". Journal of Energy Technologies and Policy. Iiste.

[5] L. Gyugi and E. C. Strycula, "Active AC Power Filters", IEEE-IAS Annual Meeting Record, 1976, pp. 529-535

[6] L. Dinesh, H. Sesham, and V. Manoj, "Simulation of D-Statcom with Hysteresis Current Controller for Harmonic Reduction," International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM), Chennai, pp. 104-108, 2012.