International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-6, September 2015
ISSN: 2395-3470
www.ijseas.com

The Shunt Active Power Filter to Compensate Reactive Power and Harmonics Under Unbalanced Non-Linear Load Conditions

Visvanathan Kalaiah (Research Scholar)

Balaji Veerasamy (Research Scholar)

***Abstract*— This paper proposes the novel control strategy of Shunt Active Power Filter for power quality control. The shunt active power filters expand their performance day by day in power quality aspects especially harmonics suppression and reactive power compensation in effective load injection. The improved form of multilevel inverter topology is presented and it is includes a performance of multilevel inverter over power quality improvement in the form of Sag compensation, reactive power control, real power control and harmonics elimination. The current type and voltage source type of inverter have faces difficulties in harmonics suppression. So is to avoid demerits over classical approach, a simplified multilevel inverter is used to reduce or regret the power quality control under fault condition of load. The aggressive power flow is obtained even if distorted load and source power. The Proposed converter provided pure sinusoidal and reduced harmonics on main line by simplified multilevel inverter is presented. A modified phase opposition and disposition (MPOD) carrier scheme is introduces for present multilevel inverter based active power converter circuit. The MATLAB/Simulink software used to verify this approach.**

Keywords— Shunt Active Power Filter, Multilevel Inverter (MLI), Power Quality, Pulse Width Modulation (PWM), Modified Phase Opposition & Disposition (MPOD), unbalancing Non-linear load.

I. INTRODUCTION

Recently, the shunt active filter provided a prominent results and effective absorption of reactive power over FACTS devices. The coordinative voltage control method of STATCOM is used to keep or control the voltage of power system in an allowable range of steady-state and securing method of momentary reactive power compensation. The voltage deviation of load bus can be minimized by adjusting reference voltage within the margin of reactive power backlog. Furthermore, there is a need to minimize the number of switching of the mechanical shunt device such as switched-shunt for maintenance cost. The power quality problems depends on the presence of harmonics in the power lines results in greater power losses in distribution, interference problems in communication systems and also sometimes the operation failures of electronic equipment's with very low energy levels [1].

The voltage source inverter and current source inverter provided a simple arrangement in conventional scheme. But it has required more passive filter components. So multilevel inverter is the option to reduce or regret the power quality issues especially harmonics suppression in effective load injection. Basically it required less number of passive filters over the injection and low range of inductive and capacitive elements if we required or present. The concept of power inversion in multilevel inverters is based on a series connection of switching components with several lower DC voltage sources to synthesize staircase voltage waveform. An appraisal of three different types of control techniques based on multicarrier level shifted PWM such as S-IPD, S-POD and S-APOD applied to a single phase full bridge five level diode clamped inverter for power quality improvement. The multilevel inverter structure is simulated for various functions with the required harmonic components for voltage Active Filter applications. The analysis results are revealed that among the methods under study, the S-IPD method results in a better output voltage quality than the other two techniques S-POD & S-APOD in terms of THD and Harmonic spectrum [2]-[3]. The performance of the APF is mended importantly compared to the traditional control scheme from effective compensation techniques. The APF must be generating the harmonic currents to compensate harmonics produced by the nonlinear load and also to make the supply currents sinusoidal. So that in order to improve the performance with nonlinear RL and RLC loads as well as good dynamic response against load variations. The supply current is nearly perfect sinusoidal and in-phase with the supply voltage even under the distorted voltage condition [4].

The unified power quality conditioner (UPQC) based control on three levels (NPC) inverter capable to extenuate source current harmonics and compensate all voltage disturbances perturbations such as voltage sags, swells, unbalances and harmonics. The advantages of NPC voltage source converters to UPQC is making up the unbalance DC link Voltages due to the transient operating condition. A shunt active power filters based novel synchronous reference frame (SRF) method can be used to extract the reference compensating current for fast transient response. The possible to improve the quality of the power cell input currents whenever the input/output frequencies are different in the cascade multilevel converter. So better results would be obtained if the leakage inductance of Multi-pulse transformer were increased, ensuring the absence of sub and inter-harmonics caused by the power cells. This can be achieved by means of magnetic couplings among the dc-links of the power cells that feed different output phases, when keeping the high power quality on the load side [5]-[7].

The Performance comparison of composite filter and passive filter can be improving the power quality at point of common coupling. The composite filter is lying of a shunt LC passive filter connected with a lower rated voltage source PWM converter based series active power filter. The analyzed scheme of composite filter performs gives to better than the passive filter alone for harmonic compensation, voltage flicker mitigation and clearing voltage unbalance. The possible to separate harmonic and fundamental components of the line voltage and current a highly selective filter (HSF) has been used. Calculating on the power errors and line voltage vector position, a switching table produces the appropriate control vectors leading to the active and reactive power variation required to reach the zero power references, even under grid voltage unbalanced and distorted conditions. Also, the novel current control strategy in three-phase parallel active filter with the Instantaneous Power Theory used to improve power quality through compensating harmonics and reactive power required by a nonlinear load. The advantages of this method based on measured load current and supply voltage can’t need to know the harmonics and reactive power required by load [8]-[10].

The Selective Harmonic Distortion is provides total elimination for low order harmonics as well as a reduction of the characteristic harmonics amplitude reducing the total distortion. The Shunt active power filter is effectively used to reduce the power system harmonics when will improve the quality of the power. The strength of APF with linear current control scheme is used to prove by measuring the Total Harmonic Distortion (THD). The shunt active power filter depicts a strong in eliminating harmonics and reactive power when has received extensive pertain in power electronic filed. This implementation of system is used to eliminate current harmonics generated by a nonlinear load [11]-[13]. In this proposal work will showing about performance of shunt active filter topology using novel multilevel converter scheme for power quality control aspects. So in order to harmonic suppression can be achieved by easily through MLI type APF for medium to high voltage applications.

II. POWER QUALITY CONSEQUENCE

The late survey of Power Quality experts indicates that 50% of all Power Quality problems are related to rounding, ground bonds and neutral to ground voltages, ground loops, ground current or other ground associated issues. The Power quality refers to the stability and consistency of the electricity supply and the most critical issues in ensuring reliability are monitoring power system performance. The usually can be used terms those describe the parameters of electrical power that describe or measure power quality are Voltage sags, Voltage variations, Interruptions Swells, Brownouts, Blackouts, Voltage imbalance, Distortion, Harmonics, Harmonic resonance, Inter-harmonics, Notching, Noise, Impulse, Spikes (Voltage), Ground noise, Common mode noise, Critical load, Crest factor, Electromagnetic compatibility, Dropout, Fault, Flicker, Ground, Raw power, Clean ground, Ground loops, Voltage fluctuations, Transient, Dirty power, Momentary interruption, Over voltage, Under voltage, Nonlinear load, THD, Voltage dip, Voltage regulation, Blink, Oscillatory transient etc., [IEEE 100 Authoritative Dictionary of IEEE Standard].

A. *Major Characteristic of power quality*

The Power quality problems are generally characterized in terms of the effect upon the supply voltage and can be broken down into the following major categories such as,

a) The main effect of power quality such as RMS voltage variations, short or long duration, sags, swells and interruptions. Sags the most common type of PQ disturbance, usually last from 4-10 cycles and are generated within the facility, not by the utility.

b) The Voltage transients also known as impulses are rapid, short-term voltage increases that are categorized as either impulsive.

c) In Waveform distortion contains the Harmonics, inter-harmonics and sub-harmonics are mainly caused by phase angle controlled rectifiers and inverters and other static power conversion equipment found in variable frequency drives, PCs, PLCs and other devices employing switching power supplies.

d) The Voltage imbalances of three-phase systems consider as voltage imbalance occurs when the amplitude and/or phase angles of the three voltage or current waveforms are unequal. According to the DOE, imbalance is probably the leading power quality problem resulting in motor overheating and premature failure.

B. *Harmonics*

The wide use of FACT controllers to control the flow of power in transmission line has the ability of promoting the harmonic distortion levels due to the inherent non-linearity associated with these devices and the normal development of using non-linear and electronically switched loads at customer side will continue to increase affect of harmonics. In a relieved environment harmonic problems will be continue to increase because of the fact that the independent power producers IPP, when are using wind and solar energy to generate power. It will depend mainly on inverters to interface with the utility grid leading to the increase of the harmonic distortion.

The creation result of harmonic in power system contains as,

- Overheating of cables, transformers and motors
- Unstable circuit breakers and relays
- Extra power consumption

The Non-linear characteristics of devices and loads on the power system give rise to harmonic distortion. Harmonic distortion levels are depicted by the complete harmonic spectrum with magnitudes and phase angle of each harmonic component.

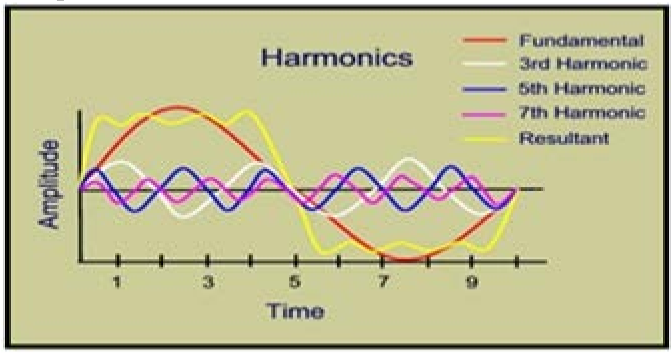


Fig 1. Different Harmonic Order

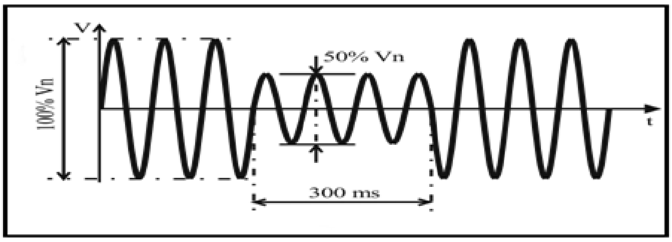


Fig 2. Limited Period of Voltage Sag

C. *Interruption*

The total interruption of electrical supply depends on the duration from few milliseconds to one or two seconds. It is mainly due to the opening and automatic enclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover. The number of interruptions of the supply can be also inclines to increase in deregulated environment like voltage sags and a suitable mitigation is essential. An interruption occurs the supply voltage decrease less than 10% from its original value up to a period of time not exceeding one minute.

D. *Voltage Sag*

The power system is field to disturbance, the voltage level dips. Some tender equipment such as electronic controlled motors, cooling equipment and high pressure lighting would be affected. A sudden reduction (between 10% and 90%) of the voltage magnitude at a point in the electric system and surviving from 0.5 cycles to few seconds is termed as Voltage sag (IEEE Standard 1159-1995).

A voltage dip can be also caused either by switching operations or any type of faults as well as fault clearing process. Switching like those associated with a temporary disconnection of the supply or flow of heavy currents associated with the starting of large motor loads is the most common. These events maybe originated at the utility side or at the customer site. The malfunction of information technology equipment namely such as microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage.

III. MULTIPLE INVERTER TOPOLOGY

The recent results survey a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. Because it is not only used to achieve high power ratings but also enables the use of renewable energy sources. The main list of renewable energy sources such as photovoltaic, wind and fuel cells can be easily interfaced to a multilevel converter system for a high power application. The multilevel inverter coating focus on the industrial medium-voltage motor drives, utility interface for renewable energy systems, flexible AC transmission system (FACTS) and traction drive systems. The harmonic components of the output voltage are found out by the carrier frequency and switching functions. To overtake this limitation, this paper presents a five-level PWM inverter whose output voltage can be constituted in the following five levels: zero, +1/2Vdc, Vdc, -1/2V dc and -Vdc. Since the number of output levels increases, the harmonic content can be reduced. This inverter topology uses two reference signals such as instead of one reference signal, to generate PWM signals for the switches.

The novel type of single phase H-bridge multilevel inverter is shown above in Figure. 3. It can be make the three level, five level, seven level, nine level and eleven level inverters without using any type of modulation technique and by using the same mathematical relation M=2N+1. In increase the several modulation and control strategies have been developed or adopted for multilevel inverters.

It’s also including the following multilevel sinusoidal (PWM) such as multilevel selective harmonic elimination and Space Vector modulation.

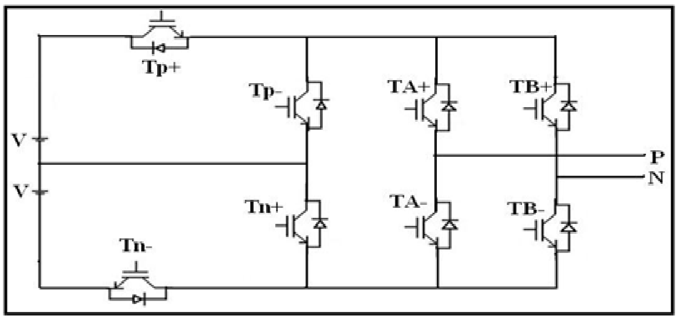


Fig 3. Single Phase Five Level Inverter

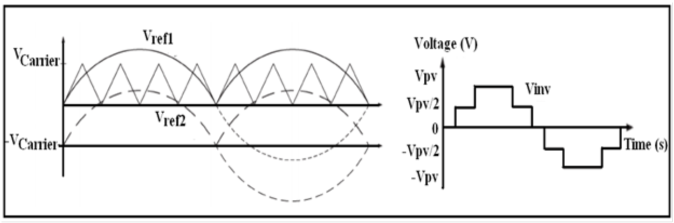


Fig 4. Comparison Signal and Output Voltage

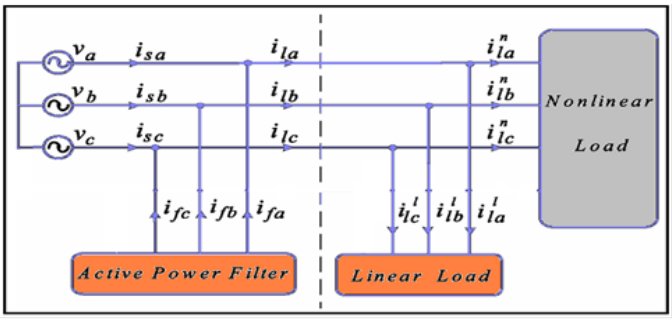


Fig 5. Schematic Diagram of Overall Configuration

In each separate D.C. source is associated with a single-phase full-bridge inverter. The ac terminal voltages of different level inverters are connected in series. Here, both the reference signals Vref1 and Vref2 are identical to each other, except for an offset value equivalent to the amplitude of the carrier signal $V_{carrier}$. The shunt active filter is employed to keep the output current sinusoidal and to have high dynamic performance under quickly changing atmospheric conditions and to maintain the power factor at near unity. The simulation results are demonstrated to validate the proposed inverter configuration.

IV. NOVEL CONTROL SCHEME

The novel control of single carrier and multi references of Modified Phase Opposition and Disposition (MPOD) scheme on Shunt Active Power filter configuration. The multilevel inverter is used for harmonic elimination and reactive power control. The function of shunt active power filters (APF) is used to eliminate harmonic currents and also to compensate reactive power for linear/nonlinear loads. The particularly main features of a shunt APF is designed without active energy source units such as batteries or in other forms in compensation mechanism. In early words, an ideal APF does not take any average real power provided by the source. To achieve this function, it requires an effective reference compensation strategy for both reactive power control and harmonic/neutral current compensation of the load. The rewards of the proposed approach are that no reference-frame transformation is required and simple APF using simplified multilevel inverter design can be obtained for required above power quality standard.

The schematic diagram of proposed configuration is shown in above fig 5. The active powers filters are implemented using a combination of passive and active components for require an outside power source. The principle of APF system is used to inject a current equal in magnitude but in phase opposition to harmonic current to achieve a purely sinusoidal current wave in phase with the supply voltage.

The reference current generation algorithm based SAPF are simplified block diagram is shown above in figure 6. The thinned current measurement control algorithm used to sensing only three-phase voltages and three source currents. Also, the DC-link voltage is adequate to compute reference currents of the three-phase SAPF. In this manner, the overall system design becomes easier to carry out and the total implementation cost is reduced. So in order to use as SAPF with reduced current measurement based control method can be compensating neutral, harmonic and reactive currents effectively in the unbalanced and distorted load conditions.

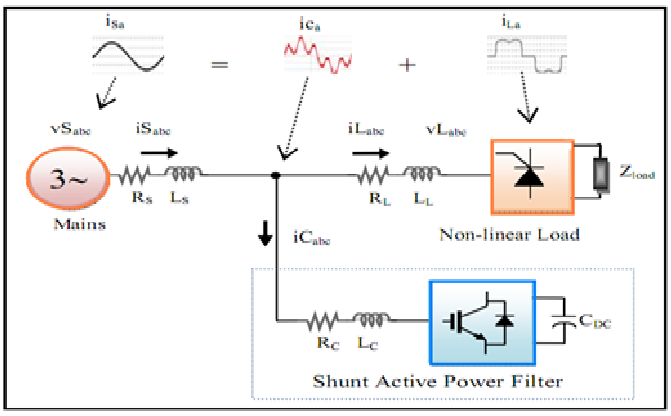


Fig 6. Block Diagram of SAPF

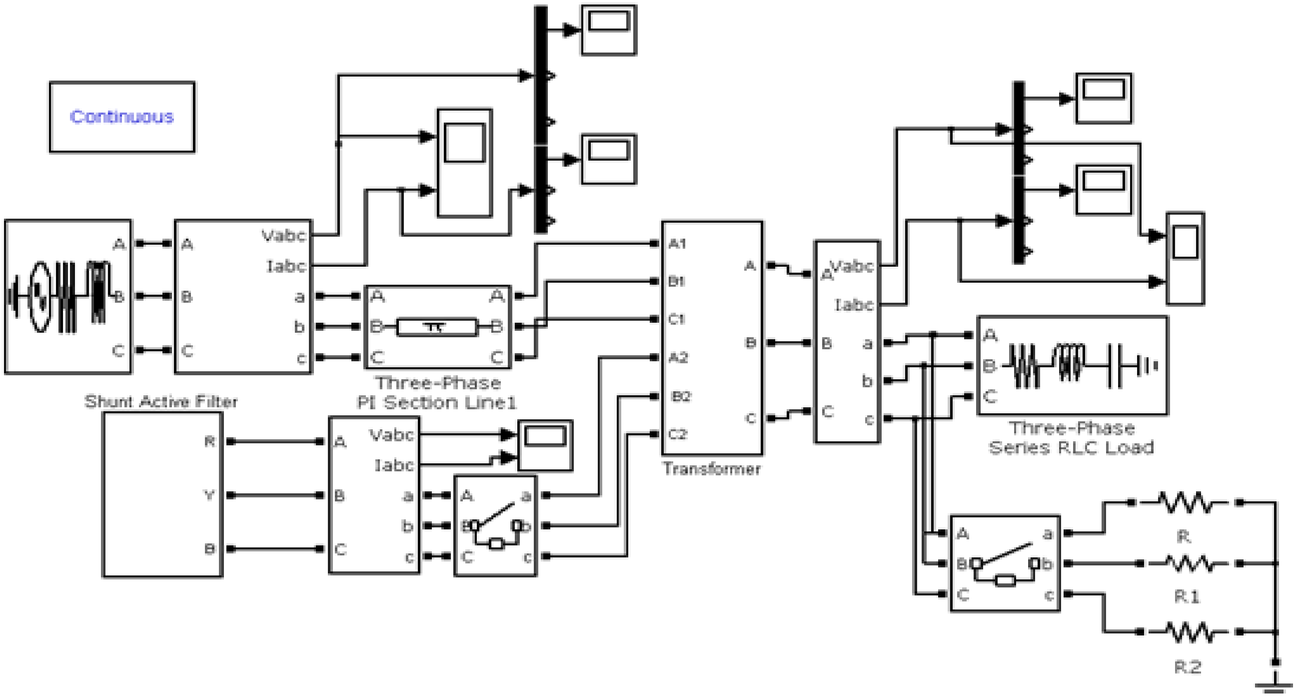
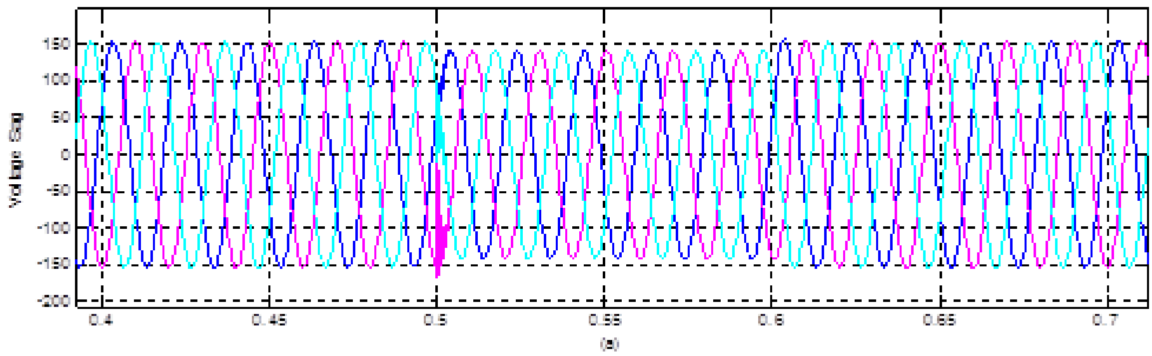


Fig 7. The simulation circuit implementation



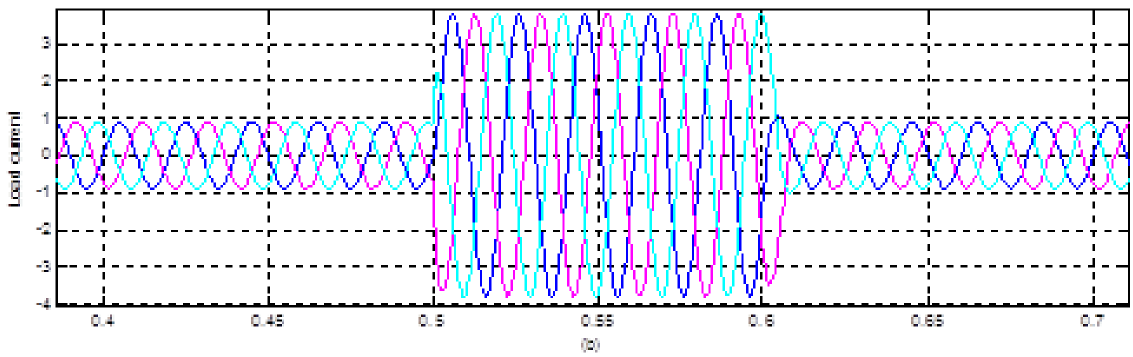


Fig 8. During Load Change Condition: (A) Voltage Sag (B) Current Swell

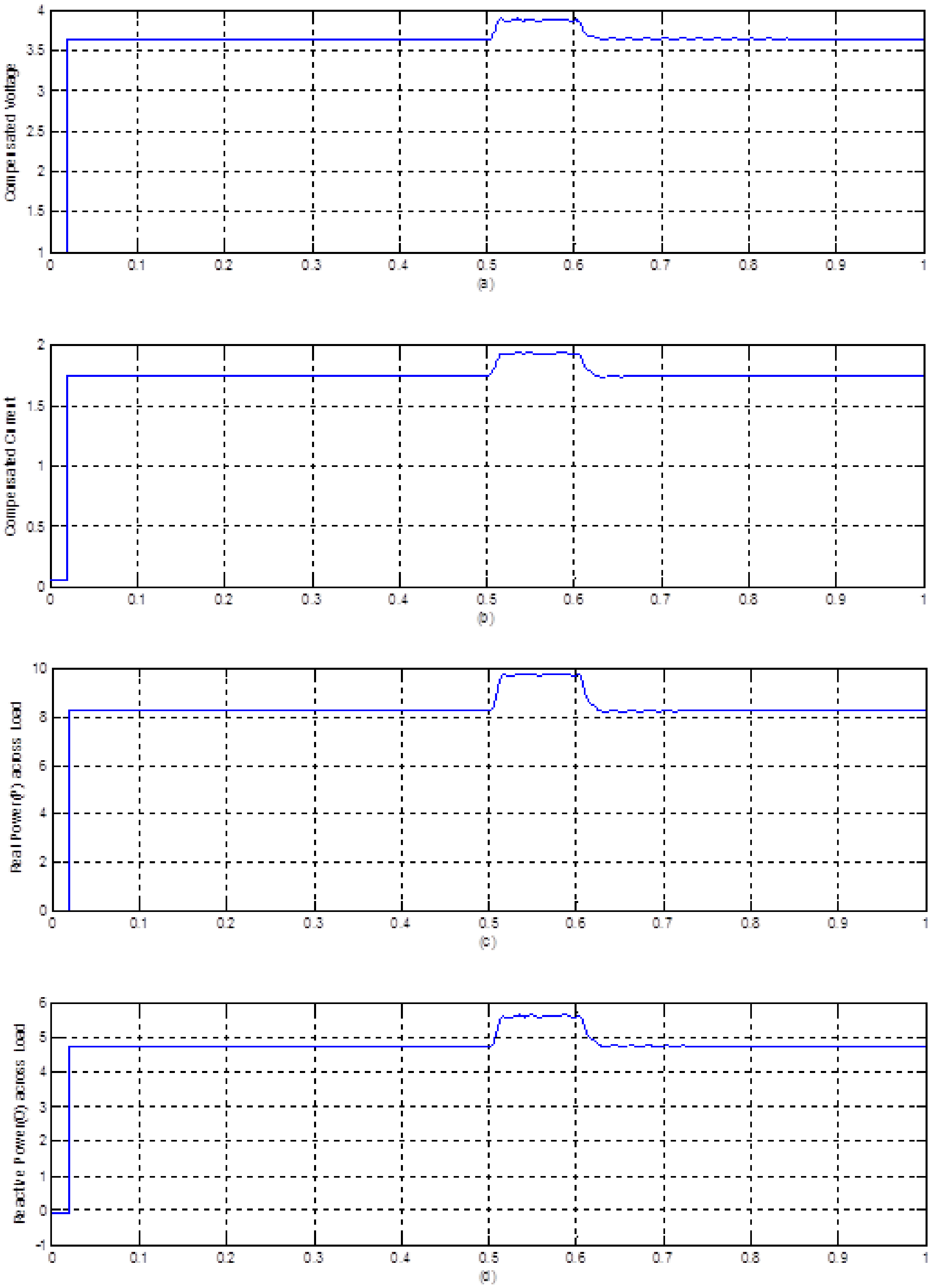


Fig. 9. Compensated and controlled performance by active filter injection: (a) load voltage. b) Load current. (c)Real Power. (d) Reactive Power.

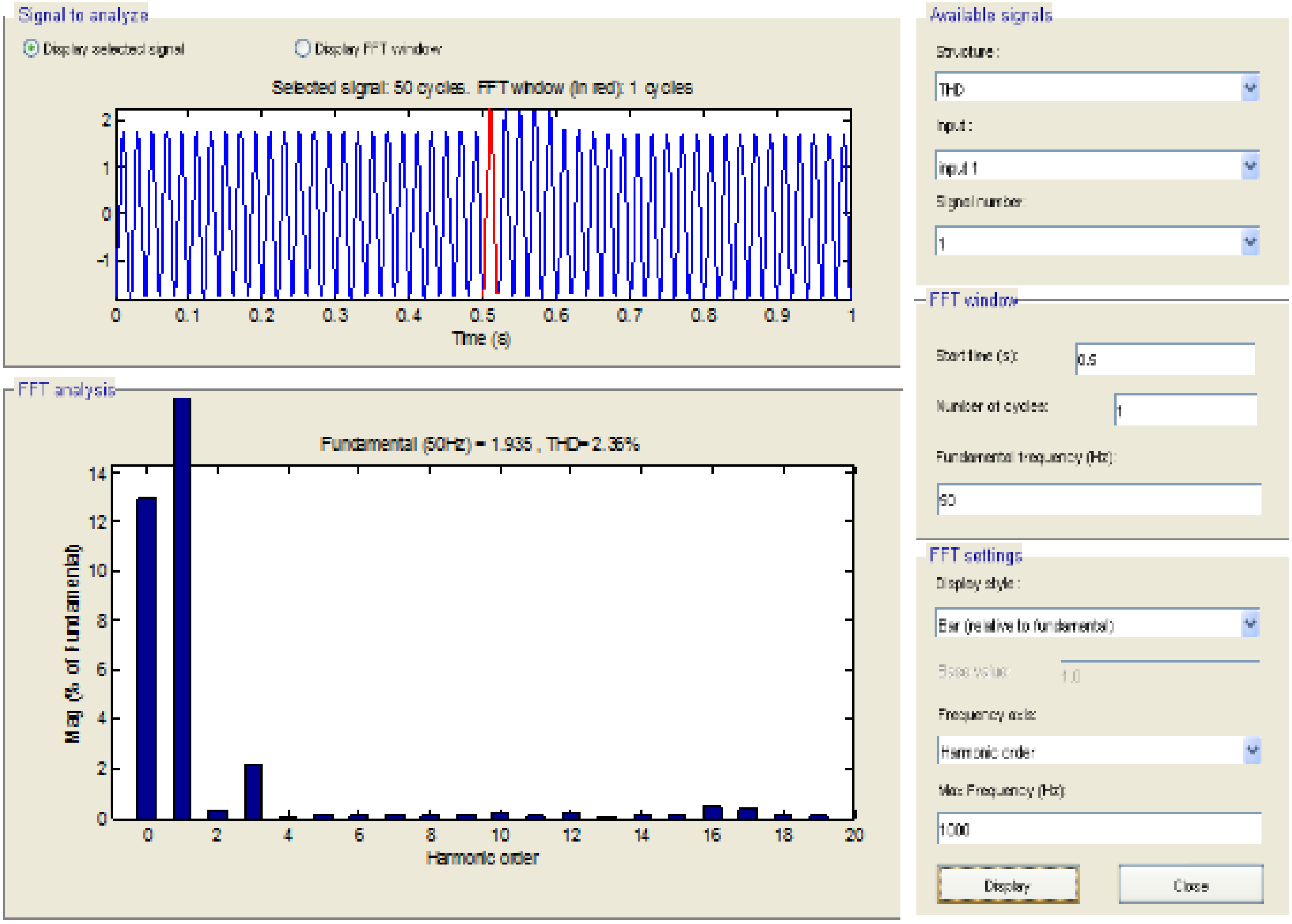


Fig. 10. Total harmonics distortion analysis using FFT (Fast Fourier Transform) under sag compensating condition (0.5sec to 0.7sec).

V. SIMULATION RESULTS

This paper proposes the novel control method of Shunt Active Power Filter (SAPF) for purpose of compensating reactive power and harmonics under unbalanced non-linear load condition. This proposed scheme is measured by using simulation results given in Mat lab /Simulink software. In simulation fields, the result are carried out of SAPF system is operated. Also, if the SAPF system can be operated means the load has been changed and dynamic response of the system was tested. The simulation circuit of enhancement scheme is shown in Figure.7 and ability of circuit is verified by various analysis is given bellow. Voltage is created by injecting unbalanced non-linear load is shown in Figure.8. The enhancement of presented simplified multilevel inverter based active filter was verified by injecting in main line during voltage sag conditions.

Voltage sag is created by 10% of normal conditions is shown in Figure.8. Modified Phase Opposition and Disposition (MPOD) based simplified multilevel based active filter is easily obtained better result. The compensated load voltage, current, Real Power and Reactive power was obtained easily by the enhancement of present scheme is sown in Figure.9. The topology is required least amount of passive elements and low range of device. The Total Harmonics Distortions (THD) is reached 2.36% under fault timing between 0.5sec to 0.7sec is shown in Fig. 10. The obtained harmonics is in desired limits as it is [14].

VI. CONCLUSION

This concept is presented to improve the performance of active filter topology via power quality control. The analysis of present multilevel inverter scheme is that capable of compensating sag voltage, reactive power compensation and harmonics elimination in IEEE standard range. The control performance is distinct factors in active filter for improving the performance across the load. This is effectively achieved by the modified phase opposition and disposition scheme. This approach is largely reduces harmonics even by least amount and range of passive elements. This is proved a prominent solution to reactance control and real power extraction during unbalancing Non-Linear Load Conditions. The simulation result was verified by MATLAB/Simulink.

REFERENCES

[1] Beser, Ersoy, et al. "Design and application of a single phase multilevel inverter suitable for using as a voltage harmonic source." Journal of Power Electronics 10.2 (2010): 138-145.

[2] Tamasas, Mohamed, et al. "Evaluation of modulation techniques for 5-level inverter based on multicarrier level shift PWM." Mediterranean Electrotechnical Conference (MELECON), 2014 17th IEEE. IEEE, 2014..

[3] Park, Ji-Ho, and Young-Sik Baek. "Coordination Control of Voltage Between STATCOM and Reactive Power Compensation Devices in Steady-State." Journal of Electrical Engineering & Technology 7.5 (2012): 689-697.

[4] Trinh, Quoc-Nam, and Hong-Hee Lee. "An advanced current control strategy for three-phase shunt active power filters." Industrial Electronics, IEEE Transactions on 60.12 (2013): 5400-5410.

[5] Salim, Chennai, and Benchouia Mohamed Toufik. "Simplified Control Scheme of Unified Power Quality Conditioner based on Three-phase Three-level (NPC) inverter to Mitigate Current Source Harmonics and Compensate All Voltage Disturbances." Journal of Electrical Engineering and Technology 8.3 (2013): 544-558.

[6] Monfared, Mohammad, Saeed Golestan, and Josep M. Guerrero. "A new synchronous reference frame-based method for single-phase shunt active power filters." Journal of Power Electronics 13.4 (2013): 692-700.

[7] Baier, Carlos R., et al. "Improving Power Quality in Cascade Multilevel Converters Based on Single-Phase Nonregenerative Power Cells." Industrial Electronics, IEEE Transactions on 61.9 (2014): 4498-4509.

[8] Bhonsle, D. C., and R. B. Kelkar. "Design and analysis of composite filter for power quality improvement of electric arc furnace." Electric Power and Energy Conversion Systems (EPECS), 2013 3rd International Conference on. IEEE, 2013.

[9] Djazia, Kamel, et al. "Active Power Filtering Using the ZDPC Method under Unbalanced and Distorted Grid Voltage Conditions." Energies 8.3 (2015): 1584-1605.

[10] Irannezhad, Faegheh, et al. "Using the Instantaneous Power Theory in order to control the current in the parallel active filter to compensate reactive power and reduction of harmonics." Power Electronics, Drives and Energy Systems (PEDES), 2012 IEEE International Conference on. IEEE, 2012.

[11] Guiñez, G. A., et al. "Improvements in harmonic mitigation for multilevel AC-Drives for high power applications." Industrial Electronics (ISIE), 2010 IEEE International Symposium on. IEEE, 2010.

[12] Rajalakshmi, R., and V. Rajasekaran. "Improvement of energy efficiency through power quality by the compensation of harmonics with shunt active power filter." Recent Advancements in Electrical, Electronics and Control Engineering (ICONRAEeCE), 2011 International Conference on. IEEE, 2011.

[13] Singh, Anand, and Prashant Baredar. "Power quality analysis of shunt active power filter based on renewable energy source." Advances in Engineering and Technology Research (ICAETR), 2014 International Conference on. IEEE, 2014.

[14] Duffey, Christopher K., and Ray P. Stratford. "Update of harmonic standard IEEE-519: IEEE recommended practices and requirements for harmonic control in electric power systems." Industry Applications, IEEE Transactions on 25.6 (1989): 1025-1034.