Review PI Control of Multi Level Inverter Based Shunt Active Power Filter for Harmonic Mitigation in Three Phase Systems

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Abstract - With the proliferation of nonlinear power electronics loads, the problem of harmonic is severity, which influences the quality of power grid. To mitigate current harmonics generated by non-linear loads Shunt APF is the best solution to eliminate harmonics drawn from nonlinear load especially for low power system, harmonics reduction and reactive power compensation simultaneously can be done by using a voltage source inverter connected in parallel with the system which acts as a shunt APF for reducing the distortions produced due to non-linear load in the load current. This active filter generates a compensating current which is of equal in magnitude as harmonic current and opposite in phase with it to reduce the harmonics present in the load current.APF is classified as series, shunt or combination both series and shunt but shunt APF is preferred here as the principle of the shunt APF is to produce compensating currents of equal in magnitude but opposite in phase to those harmonics that are present due to non-linear loads.

Keywords- Shunt active power filter, intelligent controller, Harmonic currents compensation, power quality improvement.

I. INTRODUCTION

In recent years both power engineers and consumers have been giving focus on the "electrical power quality" i.e. degradation of voltage and current due to harmonics, low power factor etc. Nearly two decades ago majority loads used by the consumers are passive and linear in nature, with a few non-linear loads thus having less impact on the power system. However, due to technical advancement in semiconductor devices and easy controllability of electrical power, non-linear loads such as SMPS, rectifier, chopper etc. are more used. The harmonic current pollute the power system causing problems such as transformer overheating, voltage quality degradation, rotary machine vibration, destruction of electric power components and malfunctioning of medical facilities etc. To provide clean power at the consumer-end active power filter (APF) is used. Fig. 1.1 shows a shunt active power filter connected to the power system at the point of common coupling (PCC). Due to use of non-linear loads, the load current is highly nonlinear in nature. The compensating current which is output of the APF is injected at PCC, so the harmonic cancellation takes place and the current between sources to PCC is sinusoidal in nature.

The active power filter (APF) is a popular approach for cancelling the harmonics in power system. The main component in the APF is the control unit. The control unit is mainly divided into two parts as follows. Harmonic extraction is the process in which, reference current is generated by using the distorted waveform. Many theories have been developed such as p-q theory (instantaneous reactive power theory), d-q theory, frieze controller, PLL with fuzzy logic controller, neural network etc.. Out of these theories, more than 60% research works consider using p-q theory and d-q theory due to their accuracy, robustness and easy calculation. Current modulator is mainly used to provide the gate pulse to the active power filter (Inverter). There are many techniques used for giving the gating signals to PWM VSI such as sinusoidal PWM, triangular PWM, hysteresis current controller, adaptive hysteresis current controller, space vector modulation and space vector with hysteresis current controller etc.

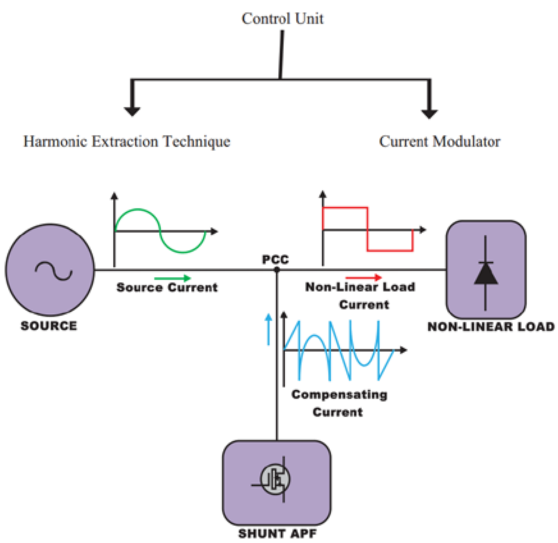

Figure 1.1 Shunt Active Power Filter.

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The above described two control techniques (harmonics extraction technique and current modulator technique) are main research foci of many researchers in the recent years. It may be noted that either harmonics extraction technique or the current modulator can be used individually or both at a time. Apart from these two techniques, most of the research works are directed also in dealing with multi-level inverter control problems.

To reduce the harmonics conventionally passive L-C filters were used and also capacitors were employed to improve the power factor of the ac loads. But the passive filters have several drawbacks like fixed compensation, large size and resonance problem. To mitigate the harmonics problem, many research work development are developed on the active power (APF) filters or active power line conditioners.

APLC's are basically categorized into two types, namely, single phase (two-wire connection), three-phase (three wire and four-wire connection)

Configurations to meet the requirements of the nonlinear loads in the distribution systems. Single-phase loads, such as domestic lights, TVs, air conditioners, and laser printers behave as nonlinear loads and cause harmonics in the power system. Many configurations, such as the active series filter, active shunt filter, and combination of shunt and series filter has been developed. The above mentioned APLC's either based on a current source inverter (CSI) with inductive energy storage or voltage source inverter (VSI) with capacitive energy storage devices.

II. SYSTEM MODEL

"Harmonics" means a component with a frequency that is an integer multiple (where n is the order of harmonic) of the fundamental frequency; the first harmonic is the fundamental frequency (50 or 60 Hz). The second harmonic is the component with frequency two times the fundamental (100 0r 120 Hz) and so on. As shown in Fig.2.1 harmonic distortion can be considered as a sort of pollution of the electric system which causes problems if the sum of the harmonic currents exceeds certain limits. The utilization of electrical power mainly depends up on supply of power with controllable frequencies and voltages, where as its generation and transmission takes place at nominally constant levels. So to convert nominal frequency to variable frequency power electronics circuitry (non-linear loads) is needed, which distorts the voltage and current waveforms. Therefore, the main source of harmonics in the power systems is the non linear loads.

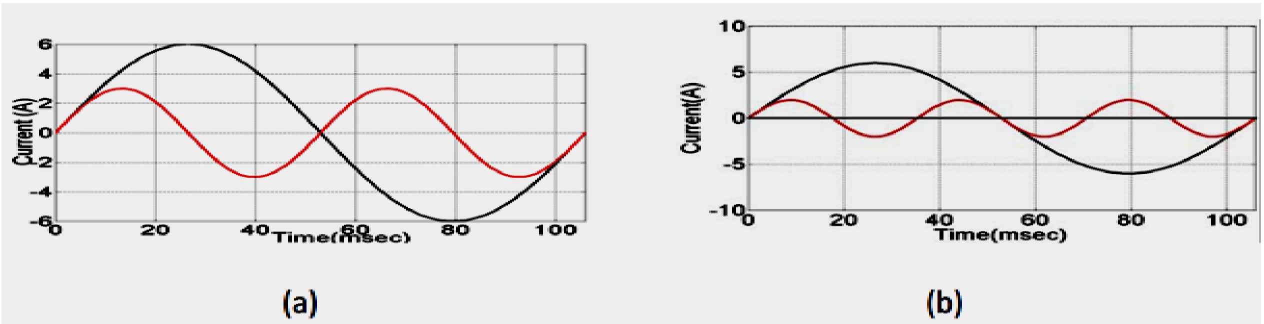

Figure 2.1 A sinusoidal waveform with fundamental frequency and its harmonic (a) 50Hz,(b) 100Hz.

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. One of the time domain control strategies is the instantaneous reactive power theory based (p-q theory) control strategy [2]. There's another control method termed instantaneous active and reactive current component (id-iq) method, based on synchronous rotating frame derived from the mains voltages without the use of phase-locked loop (PLL). And since the p-q theory is based on the time domain, this theory is valid both for steady-state and transient operation, as well as for generic voltage and current waveforms, allowing the control of APF in the real-time; another advantage of this theory is the simplicity of its calculations, since only algebraic operations are required.

Voltage source converters are used in the active power filter topologies, which have a DC capacitor voltage control as an energy storage device. Although a single pulse for each half cycle can be applied to synthesize an AC voltage, for most of the application which shows dynamic performance, pulse width modulation (PWM) is the most commonly used today. PWM techniques applied to a voltage source inverter consist of chopping the dc bus voltage to produce an ac voltage of an arbitrary waveform.

With PWM techniques, the ac output of the filter can be controlled as a current or voltage source device figure 2.2 Demonstrate the schematic of harmonic reduction in three phase using active shunt power filter.

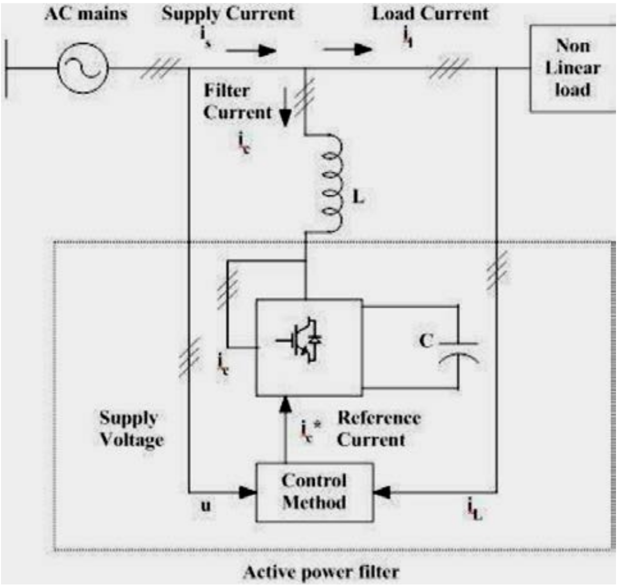

Figure 2.2 Schematic Diagram of shunt active power filter.

Voltage source converters are preferred over current source converter because it is higher in efficiency and lower initial cost than the current source converters [8]. 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.

III. PREVIOUS WORK

M. Hinduja, M. K. Rathi, S. T. J. Christa and N. R. Prabha,[1] Cascaded multilevel inverter is a power electronic device developed to synthesize a desired voltage or current waveforms from several levels of dc voltages making use of its reduced switching stress and modular structure. Such inverters have been recognized as very attractive topologies for implementing shunt active power filters in medium and high voltage applications. This research presents a five-level cascaded multilevel inverter based Shunt Active Power Filter (SAPF) to compensate reactive power and mitigate the harmonic currents generated by the non-linear loads. The functioning of the proposed system is improved by the inclusion of PI controller for dc-side voltage regulation of SAPF and triangular carrier current controller for the generation of switching pulses for the inverter switches. The control strategy of SAPF also incorporates Synchronous Reference Frame (SRF) theory to extract the harmonic components from distorted line currents which in turn are utilized in the production of required reference compensation currents. This research primarily focuses on the mitigation of the harmonics produced by the use of nonlinear loads with the aid of PI controller for dc voltage regulation. Extensive simulations are carried out to validate performance of the proposed SAPF system using MATLAB/ SIMULINK for diode bridge rectifier with RL load. The dynamic responses of the proposed SAPF system is verified under varying load conditions.

S. Po-Ngam,[2] n this research, the simplified control of three-phase four-leg shunt active power filter for harmonics mitigation, load balancing and reactive power compensation is proposed. In order to calculate the harmonics, current imbalance and reactive power, the load currents are detected and transformed to dq0 variables. By using the low-pass filter, the fundamental active power current can be separated from the d-axis current. Therefore, the commanded active power filter currents are consist of d-axis harmonic currents, q-axis and 0-axis currents. These components are regulated by the PI controller with feedforward utility voltage via the four-leg space vector inverter. Moreover, the design guidelines of space vector phase-locked loop (PLL), current controllers and DC-bus voltage controller are also presented. Validity of the proposed control schemes is confirmed by the simulation.

M. D. Solanki and S. K. Joshi,[3] The mathematical analysis and simulation of shunt active power filter, whose control is based on the “Instantaneous Reactive Power Theory” through PI controller having anti windup integral action has been presented in this work. Results achieved from simulation in PSIM, is verified by implementing the same algorithm into the prototype are presented.

L. A. Cleary-Balderas and A. Medina-Rios,[4] This research proposes a Shunt Active Power Filter (SAPF) for harmonic mitigation based a selective harmonic current mitigation (SHCM) method. The proposed SHCM method improves the filtering efficiency and solves many issues existing in highly contaminated loads. The Fast Fourier Transform (FFT) is applied to a specific harmonic current detection of a three-phase circuit. A simulation study of a three-phase compensated system is carried out using Matlab/Simulink® to validate the proposed method.

S. Mikkili and A. K. Panda,[5] The main objective of this research is to develop the Fuzzy controller with different membership functions (M.F's) to improve the power quality of shunt active filter by mitigating the harmonics. Issues related to harmonics are of a greater concern to engineers and building designers because they do more than just distort voltage waveforms, they can overheat the building wiring, cause nuisance tripping, overheat transformer units, and cause random end-user equipment failures. Thus power quality is becoming more and more serious with each passing day. As a result, active power filters have gained a lot of attention due to their excellent harmonic compensation. However, the performance of the active filters seems to have contradictions with different control techniques. To carry out this analysis, active and reactive power method (p-q) is considered. When the supply voltages are balanced and sinusoidal, all Fuzzy membership functions (Trapezoidal, Triangular and Gaussian) are converging to the same compensation characteristics. However, the supply voltages are distorted and/or un-balanced sinusoidal, the fuzzy logic controller result in different degrees of compensation in harmonics. Extensive simulations were carried out. The simulations were performed under balance, unbalanced and non sinusoidal conditions. The Fuzzy logic controller with Gaussian M.F gives dynamic performance than Fuzzy with other two M.F's.

S. Charles and C. Vivekanandan,[6] The most important part of the shunt active power filters is generating of gate signal for Voltage Source Inverters (VSI). In this research the proposed Space Vector Pulse Width Modulation (SVPWM) is implemented in a closed loop control system for a shunt active power filter. The reference harmonic components are extracted from the sensed nonlinear load currents by applying the Synchronous Reference Frame (SRF) theory, where a three-phase thyristor bridge rectifier with R-L load is taken as the nonlinear load. The switching control algorithms of the proposed SVPWM would be generating appropriate switching gates to the voltage source inverter. The shunt active power filter generates the actual compensating harmonic current based on the switching gates provided by the controller. For showing the performance of proposed method a typical system has been simulated by MATLAB/SIMULINK. The proposed active power filter is able to improve about 30.18% of the total harmonic distortion (THD) for the distorted line current caused by an uncontrolled rectifier as the nonlinear load and to meet IEEE 519 standard recommendations on harmonics level.

I. I. Abdalla, K. S. R. Rao and N. Perumal,[7] In this research a compensating system using four-leg shunt active power filter (SAPF) in a three-phase four-wire distribution network which will be able to mitigate harmonics, absorb or generate reactive power, and improve the power factor on supply side, is presented. Two control approaches based on p-q theory and load current detection using phase locked loop (PLL) are proposed. To validate the compensation performance of SAPF the distribution network with nonlinear loads is simulated using MATLAB/Simulink software. Simulation results have proved and validated the performance of SAPF minimizing the total harmonics distortion (THD) and neutral current.

IV. PROBLEM STATEMENT

Static power converters such as single-phase and three phase rectifiers, thyristor converters and a large number of low-power electronic-based appliances, are nonlinear loads that generate considerable disturbance in the ac mains. Current harmonics, which may also be asymmetric, cause 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. 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 equipments, 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.

V. CONCLUSION

In these review the harmonic component in power and its causes has analyzed harmonic is a major issue in AC supply it is occurred in circuit due the non linear loads like converters low power base appliances. Increased level of harmonic in current may cause the failure of the operation of the electronic devices and equipments shunt active power filter is the most effective solution for the mitigation of the harmonics in the power supply. Use of the filter is aimed at achieving the elimination of harmonics introduced by nonlinear loads. A control system that enables current harmonics to be generated and the dc voltage to be regulated is implemented in Park coordinates.

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