REDUCTION OF HARMONICS BY POWER THEORY BASED MULTILEVEL SHUNT ACTIVE FILTER FOR POWER CONDITIONERS

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ABSTRACT

This paper presents synchronous reference frame (SRF) controlled cascaded multilevel inverter based shunt active filter to suppress the harmonics as well as improving the power quality in distribution systems. The SRF was developed by sensing the load currents only and is compensate the harmonics and reactive power under nonlinear conditions, due to nonlinear loads and also using of cascaded multilevel voltage source based shunt active filter. Here filter is a low pass type in conjunction with proportional integral (PI) controller which is used to estimate the peak reference current and maintain the DC bus capacitor voltage of the cascaded inverter nearly constant. Here we observed the simulation results of total harmonic distortion, reactive power and etc.

I. INTRODUCTION

Non-linear loads result in harmonic or distortion current and create reactive power problems .Traditionally passive filters have been used to compensate harmonics and reactive power; but passive filters are large in size, aging and tuning problems exist and can resonate with the supply impedance. Recently active power line conditioners (APLC) or active power filters (APF) are designed for compensating the current-harmonics and reactive power simultaneously.

In the proposed system the compensation process is based on sensing load currents only, which require current harmonics and reactive power elimination due to the loads. The cascaded H-bridge active filter has been applied for power quality applications due to increase the number of voltage levels, low switching losses and higher order of harmonic elimination. The main objective of the proposed system is to suppress the harmonics by using shunt active power filter designing based on SRF controller in electrical power system with non linear loads in order to improve the power quality in the distribution system.

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion and low power factor. Voltage sags is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occurs. It is often set only by two parameters, depth/magnitude and duration. The voltage sags magnitude is ranged from 10% to 90% of nominal voltage and with duration from half a cycle to 1 min.

A novel control algorithm that is efficient for controlling these cascaded active power filters is proposed. In the proposed algorithm, only one reference current calculation circuit and four current sensors are required for the three-phase three-wired applications. Simulations have been made to compare the performance of the proposed algorithm with other control algorithms. [1]. The harmonics induce malfunctions in sensitive equipment, overvoltage by resonance, increased heating in the conductors and harmonic voltage drop across the network impedance that effects power factor.[2]. An active power line conditioners (APLC) or active power filters (APF) are designed for compensating the current-harmonics and reactive power simultaneously. A new control scheme for a parallel 3-phase active filter to eliminate harmonics and to compensate the reactive power of the nonlinear loads. A 3-phase voltage source inverter bridge with a DC bus capacitor is used as an active filter (AF). A hysteresis based carrierless

PWM current control is employed to derive the switching signals to the AF. Source reference currents are derived using load currents, DC bus voltage and source voltage. The command currents of the AF are derived using source reference and load currents. A 3-phase diode rectifier with capacitive loading is employed as the nonlinear load. [3]

The harmonics induce malfunctions in sensitive equipment, overvoltage by resonance, increased heating in the conductors and harmonic voltage drop across the network impedance that effects power factor.[4]. In 1984, H.Akagi introduced instantaneous active and reactive power theory method that is quite efficient for balanced three-phase loads. The control strategy of active power filters using switching devices is proposed on the basis of the instantaneous reactive power theory. This aims at excellent compensation characteristics in transient states as well as steady states. The active power filter is developed, of which the power circuit consists of quadruple voltage-source PWM converters.[5].Being later worked by Watanabe and Aredes for three-phase four wires power systems.[6].zero-sequence currents was later proposed by F.Z.Peng. A generalized definition of instantaneous reactive power, which is valid for sinusoidal or nonsinusoidal, balanced or unbalanced, three-phase power systems with or without zero-sequence currents and/or voltages. The properties and physical meanings of the newly defined instantaneous reactive power are discussed in detail. A three-phase harmonic distorted power system with zero-sequence components [7].

In 1995, Bhattacharya proposed the calculation of the d-q components of the instantaneous three phase currents and this method creates a synchronous reference frame concept. A hybrid series active filter system has been designed, built and installed at Beverly Pump Station in New England Electric utility for 765 kVA adjustable speed drive load to meet IEEE 519 recommended harmonic standards. The series active filter is rated 35 kVA-4% of the load kVA, and is controlled by a synchronous reference frame based controller to act as a harmonic isolator between the supply and load. This paper discusses the basic synchronous reference frame controller structure and addresses its operation under nonunity controller loop gain conditions. Design trade-offs and implementation issues of the synchronous reference frame controller are discussed. Operation of the hybrid series active filter system under off-tuned passive filter conditions and its impact on the performance of the synchronous reference frame based controller is experimentally evaluated. Effectiveness of the series active filter to provide harmonic damping and the use of simpler and low cost power factor correction capacitors as passive filters, is demonstrated by laboratory experimental results. [8].

The SRF method is consists of a phase locked loop (PLL) circuit and abc-dqo transformation; it is a simple algorithm and good dynamic responses. The SRF is ability to compensate harmonics and reactive-power component from the distortion load currents. A parallel active filter system implementation for utility interface of an an adjustable speed drive air-conditioner chiller application to meet IEEE 519 recommended harmonic standards. Specifications of displacement power factor, efficiency, cost, size and packaging requirements with the rectifier front-end topology are used to determine the optimal active filter solution. Design issues and interaction of parallel active filter inverter switching ripple filter, rectifier front-end and supply are addressed. A synchronous reference frame based controller and a predictive charge error based current regulator and their hardware implementation has been developed for the parallel active filter [9][10].

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II.DESIGN OF SHUNT APLC SYSTEM

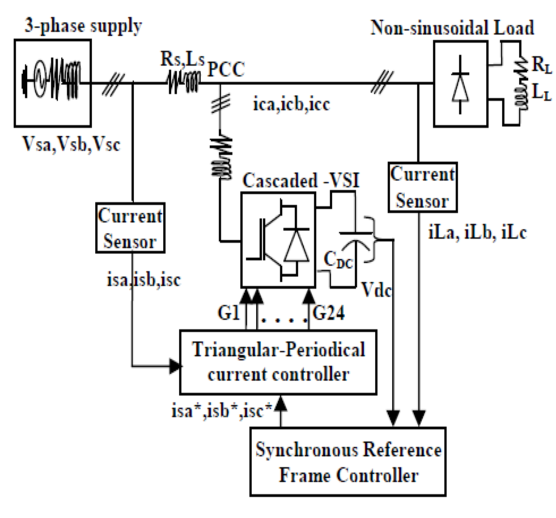


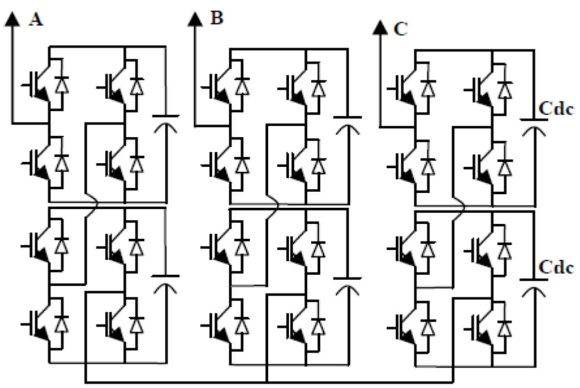
Fig. shunt active power line conditioners system

A cascaded active filter for power line conditioning system is connected in the distribution network at the PCC through filter inductances and operates in a closed loop.

Three phase active power filter comprises of 24-power transistors with freewheeling diodes; each phase consists of two-Hbridges in cascaded connection and every H-bridge having a dc capacitor.

The shunt APLC system contains a cascaded multilevel inverter, RL-filters, a compensation controller (synchronous reference frame controller) and switching signal generator (triangular-periodical current controller) as shown in the Fig

Cascaded voltage source inverter



The three-phase active filter comprises of 24-power transistors and each phase consists of two-H-bridges in cascaded method for 5-level output voltage.

Each H-bridge is connected a separate dc capacitor and it serves as an energy storage elements to supply a real power difference between load and source during the transient period. The capacitor voltage is maintained constant using PI-controller and the output voltage is V_{dc} .The 24- power transistors switching operations are performed using proposed triangular-periodical current controller and harmonics is achieved by injecting equal but opposite current harmonic components at point of common coupling (PCC).

Synchronous reference frame controller

There are several methods to extract the harmonic components from the detected three-phase waveforms. Among them, the so-called p - q theory based on time domain has been widely applied to the harmonic extraction circuit of active filters.The synchronous reference frame theory is developed in time-domain based reference current generation techniques.The SRF is performing the operation in steady-state or transient state as well as for generic voltage and current; it's capable of controlling the active power filters in real-time system. Another important characteristic of this theory is the simplicity of the calculations, which involves only algebraic calculation. The block diagram of the synchronous reference frame controller is shown in below fig

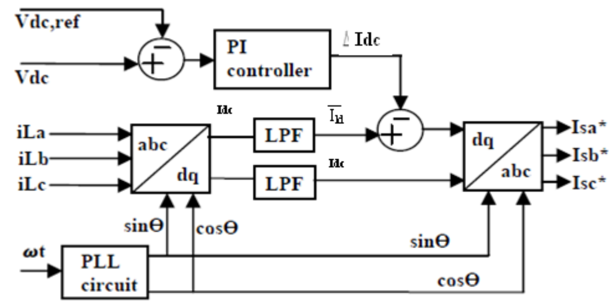


Fig Synchronous reference frame controller

The Shunt APLC block diagram is designed using synchronous reference frame theory where the sensitive load currents are I_{La}, I_{Lb}, and I_{Lc}. A three-phase stationary coordinate load current iLa, iLb, iLc are convert to id-iq rotating coordinate current, as follows

$$i_d = \frac{2}{3}\left[iLa\sin(\omega t) + iLb\sin\left(\omega t - \frac{2\pi}{3}\right) + iLc\sin\left(\omega t + \frac{2\pi}{3}\right)\right]$$

$$i_q = \frac{2}{3}\left[iLa\sin(\omega t) + iLb\sin\left(\omega t - \frac{2\pi}{3}\right) + iLc\sin\left(\omega t + \frac{2\pi}{3}\right)\right]$$

The measured currents of load are transferred into dq0 frame using sinusoidal functions through dq0 synchronous reference frame conversion. The sinusoidal functions are obtained through grid voltage using PLL. Here the currents are divided into AC and DC components.

$$i_{1d} = \overline{i_{1d}} + \tilde{i}_{1d}\,,\; i_{1q} = \overline{i_{1q}} + \tilde{i}_{1q}$$

The active part of current is i_d and i_q is the reactive one. AC and DC elements can be derived by a low pass filter. Controlling algorithm corrects the system's power factor and compensates the all current harmonic components by generating the reference current as Equation.

$$i_{fq}^{*} = i_{1q}\,\bar{i}$$

Here, system's currents are

$$i_{sd} = \overline{i_{1q}}, i_{sq} = 0$$

The desired reference current signals in d-q rotating frame is converted back into $a - b - c$ stationery frame. The inverse transformation from $d - q$ rotating frame to $a - b - c$ stationery frame is achieved by the following equations.

$$I_{sa}^{*} = i_d \sin(\omega t) + i_q \cos(wt)$$

$$I_{sb}^{*} = i_d \sin(\omega t - \frac{2\pi}{3}) + i_q \cos(wt - \frac{2\pi}{3})$$

$$I_{sb}^{*} = i_d \sin(\omega t + \frac{2\pi}{3}) + i_q \cos(wt + \frac{2\pi}{3})$$

The Resulted reference current $(i^{*}_{fa}, i^{*}_{fb}\ and\ i^{*}_{fc})$ are compared with the output current of shunt inverter $(i_{fa}, i_{fb}, and\ i_{fc})$ in periodical carrier current controller.

III Triangular carrier Current Controller (TCC)

The triangular carrier current controller is one of the familiar methods for active power filter applications to generate gate control switching pulses of the voltage source inverter. To determine the switching transitions by means the error current [desired reference current (ia*) compared with the actual source current (ia)] is multiplied with proportional gain (Kp). Theoutput signal of the proportional gain is compared with triangular carrier signal.

The four triangular signals are generated same frequency with different amplitude for cascaded multilevel inverter, because each phase in one converter does not overlap other phase shown in Figure 5.4. Thus the switching frequency of the power transistor is equal to the frequency of the triangular carrier signal.

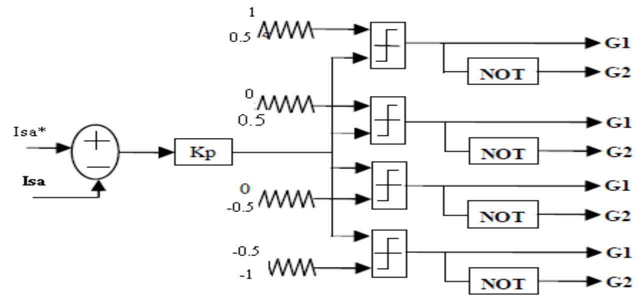


Figure .Triangular carrier current controller

DC Link Voltage Control

Figure 5.5 shows the block diagram of the proportional integral control scheme for the active power filter. The DC side capacitor voltage is sensed and compared with a desired reference voltage. The voltage error *e = V dc , ref - Vd c* at the *n th* sampling instant is used as an input for PI controller. The error signal passes through Butterworth Low Pass Filter (LPF). The LPF filter has cutoff frequency at 50 Hz that can suppress the higher order components and pass only fundamental components.

The PI controller estimates the magnitude of peak reference current *I* max and controls the dc side capacitor voltage of cascaded multilevel inverter. It transferred by the function which is represented as,

$H(s)=Kp+K_I/s$

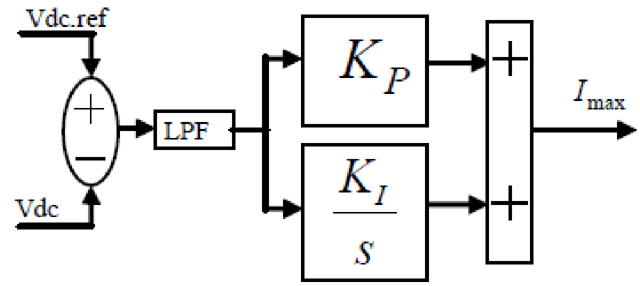


Figure. PI Controller block diagram

A PI controller is used to track the error exists between the measured and desired values of capacitor voltage in order to control the DC link voltage . This signal is applied to current control system in shunt voltage source inverter in a way that the DC capacitor voltage is stabilized by receiving the required active power from the grid. Correct regulation of proportional controller's parameter plays an important role in DC voltage control system's response.

IV. PROPOSED CONCEPT

Modern power systems are complex networks where hundreds of generating stations and thousands of load centers are interconnected through long power transmission and distribution networks. The main concern of consumers is the quality and reliability of power supplies at various load centers where they are located at .Even though the power generation in most well developed countries is fairly reliable. Power distribution systems ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the constant magnitude level and frequency. However in practice power systems especially the distribution systems have numerous nonlinear loads, which significantly affect the quality of power supplies.

As a result of the nonlinear loads, the purity of the waveform of supplies is lost. This ends up producing many power quality problems. Apart from nonlinear loads some system events both usual (e.g. capacitor switching, motor starting) and unusual (e.g. faults) could also inflict power quality problems. The consequence of power quality problems could range from a simple nuisance flicker in the electrical lamps to loss thousands of dollars due to production shutdown.

A power quality problem is defined as any manifested problem in voltage or current or leading to frequency deviations that result in failure or mis operation of customer equipment .Power quality problems are associated with an extensive number of electromagnetic phenomenon in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. Short duration variations are mainly caused by either fault condition or exercitation of large loads that require high starting currents. Depending on the electrical distance related to impedance, type of grounding and connection of trans formers between the faulted or load location.

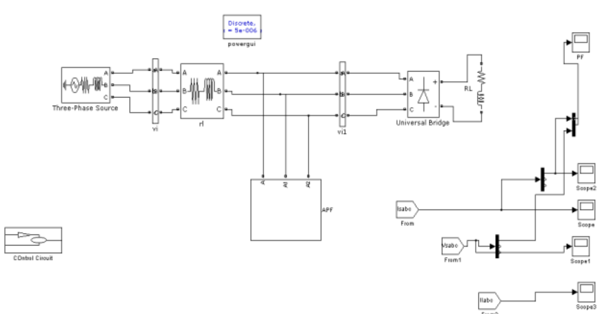


Fig4.1.proposed simulink model diagram

Fig shows the block diagram of SHUNT APLC system is simulated in MATLAB/SIMULINK. Three Phase Voltage source is connected to non linear load which is a RL Load which is connected through Diode Bridge. Cascaded active filter for power line conditioning system is connected in the distribution network at the PCC through filter inductances and operates in a closed loop .SHUNT APLC System consist of discrete virtual PLL, abc to dq0, dq0 to abc, PI controller and Periodical carrier current controller. The capacitor voltage is maintained constant using PI-controller and the output voltage is *Vdc* .

V. SIMULATION RESULTS

simulink model without SHUNT APLC, it consist of three phase AC source and Non-linear load. The source is directly connected to the load, observe the wave forms of three phase AC source input voltage and current , Non-linear load current and voltage, load power factor wave forms also observed.

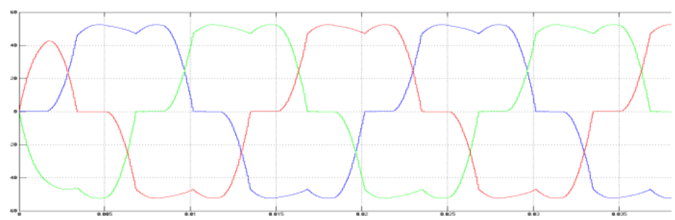


Fig Three phase input source current without SHUNT APLC

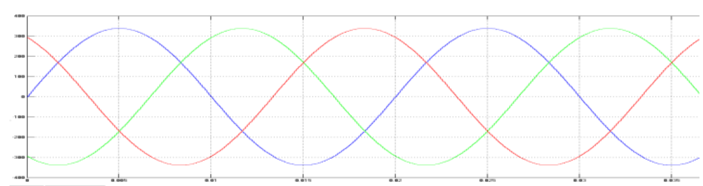


Fig shows Three phase input source voltage without SHUNT APLC

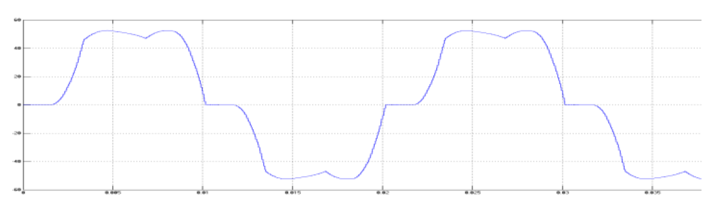


Fig shows Non- linear load current without SHUNT APLC

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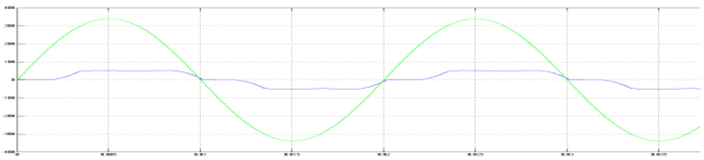
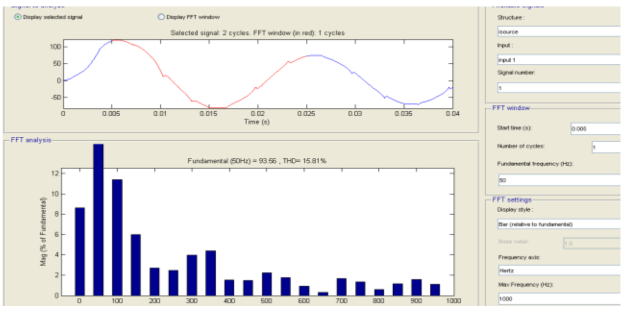


P.F OF the system without SHUNT APLC



THD Without SHUNT APLC

Simulation Results With SHUNT APLC

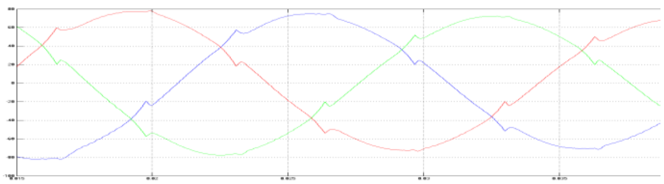


Fig shows Three phase source current with SHUNT APLC

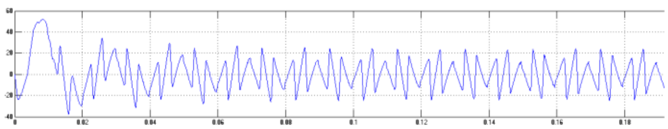
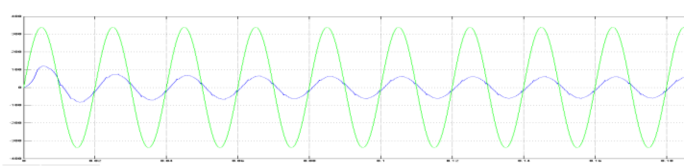
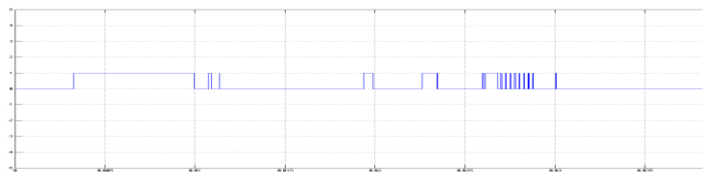


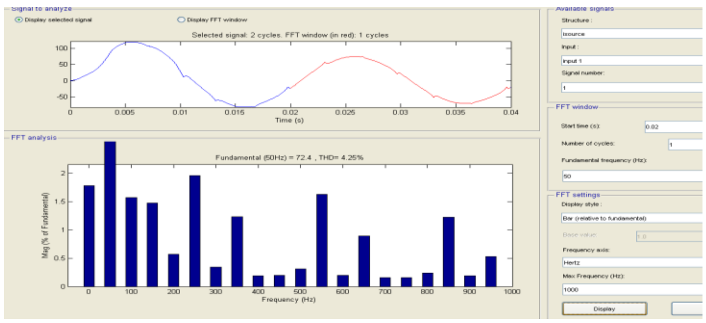
Fig shows Compensation current at the point of common coupling for PhaseA



Power factor of the system with SHUNT APLC



Gate pulses for Inverter in SHUNT APLC



THD With SHUNT APLC

The total harmonic distortion (THD) measured at the source(current) on the distribution system and the various parameters measured without APF and with APF are presented in Table

Parameter	Source Current(I_{sa}) without APF	Source Current(I_{sa}) with APF
Power factor	0.8793	0.9838
Real power	9.15KW	10.41KW
Reactive power	490VAR	315VAR
THD	28.94%	2.17%

Table Shows Measurement of various parameters for SRF based APF with and without compensation

VI. CONCLUSION

Power quality improvement in an isolated power system through series compensation has been investigated. It is observed that the power system contains significant proportion of fluctuating nonlinear load and high level of harmonic distortions. A method to control the injection of currents by the shunt compensators(SC)so that it can mitigate the effects of the harmonics has been proposed.

The cascaded inverter provides lower cost, higher performance and higher efficiency than the traditional PWM-inverter for power line conditioning applications. The cascaded inverter switching signals are derived from the proposed triangular-periodical current modulator that provides good dynamic performance under both transient and steady state operating conditions. Here a new controlling technique is applied i.e SRF is employed to extract the fundamental component from the nonlinear load currents. This controller is developed by sensing load currents only.

This approach is fairly simple to implement and is different from conventional methods. The extensive simulation results demonstrate the performance of the APF under different non-linear load conditions. Simulations have confirmed the effectiveness of the proposed method, as it is applied by the SRF based shunt APF to achieve improved quality of supply in the power system.

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BIOGRAPHIES

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