Design and Implementation of Single phase Active Harmonic filters for Harmonic elimination

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***Abstract:**With the widespread use of power electronics devices such as rectifier, inverter etc. in powersystem causes serious problem relating to power quality. One of such problem is generation ofcurrent and voltage harmonics causing distortion of load waveform, voltage fluctuation, voltagedip, heating of equipment etc. Also presence of non-linear loads such as UPS, SMPS, speed drivesetc. causes the generation of current harmonics in power system.The dc links of both inverters are connected in parallel,and the voltage of this dc link is maintained by the low-frequency inverter (LFI). The low-and high-frequency inverterseliminate lower and higher order harmonics respectively. In addition, it is possible to design the LFI such that it canalso compensate the reactive power of the load. The individual passive filter of the hybrid topology is designed to takecare of specific order of harmonics that are predominant in the load. In this paper a design for a three phase activepower filter use a reduced switch (B4) topology and one cycle control is presented. The B4 topology offers theadvantage of reduced cost and bridge losses at the expense of device stress and increased DC-side voltage. This designalso provides the advantages associated with one cycle control. The performances of the proposed topology and thecontroller are examined by MATLAB/SIMULINK-based simulation.*

***Keywords:** harmonics, passive filter, reduced switch topology*

I. INTRODUCTION

Proliferation of nonlinear loads has increased theproblems related to power quality (PQ) issues. Power qualityproblem is defined as voltage, current or frequency deviations.A growing power quality concern is harmonics distortion.Harmonics are caused by the non-linearity of customer loads. Inrecent years, active power filters has been developed tosuppress harmonics generated by static power converters. Aflexible and versatile solution to power quality is offered byactive power filters. Currently they are based on PWMconverters and connect to low and medium voltage distributionsystem in shunt or in series. Series active power filter alwaysoperates in conjunction with shunt passive filters in order tocompensate load current harmonics [2] - [4]. Since shunt activepower filters can be used for harmonic mitigation independentof passive filters is considered in this paper for analysis andimplementation.

With the increasing use of adjustable speed drives, arcfurnace, controlled and uncontrolled rectifiers, and othernonlinear loads, the power distribution system is pollutedwith harmonics. Such harmonics not only create morevoltage and current stress but also are responsible forelectromagnetic interference, more losses, capacitorfailure due to overloading, harmonic resonance, etc.Introduction of strict legislation such as IEEE519 limitsthe maximum amount of harmonics that a supply systemcan tolerate for a particular type of load. Therefore, use ofactive or passive type filters is essential. In addition, therecent thrust on extracting power from wind andphotovoltaic (PV) systems calls for extensive studies onpower filters to make the renewable energy green andclean (i.e., free from harmonics). Note that for any activepower filter (APF), the voltage source inverter (VSI) hasto feed the right nature of compensating current. Differentmethods to predict the compensating current have beenproposed. This includes the traditional d-q and p-q-rtheory-based approaches and more recently the softcomputing-based techniques.The controller design is equally important for animproved performance of an APF.A comparativeassessment for different type of controllers includingmultiple rotating integrators, stationary frame generalizedintegrators, proportional-sinusoidal integrators, and vectorproportional-integral controllers are reported. An outervoltage loop and an inner current loop are necessary forimplementation of such linear current control scheme. Anonlinear control technique utilizing two inner currentloops and an outer dc bus voltage loop is also proposed.The inner and outer loops are decoupled, and the systemtook about 1.5 cycles for the outer loop to converge.Passive filters have the advantages of low cost andlosses; however, they have the problems of harmonicresonance with the source and/or the load. Moreover, theyneed to be tuned properly to take care of a widerfrequency range. Active filter may completely replace thepassive counterpart. This requires higher voltage/currentswitches for medium/high power applications. Use ofhybrid filter, where a lower rating active filter is added inseries with the passive filter, has the merit of operating theactive filter at a convenient voltage and current. However,it required a transformer to couple the passive filter withthe active filter. Later, the transformer is eliminated and ahybrid combination for application with diode rectifier isdeveloped. The passive filter connected in series is tunedat seventh harmonics and the active filter is operated at amuch lower voltage (at 300 V for a 3.3-kV line). Laterresearchers developed a dual hybrid configuration wherethe series filters are tuned to eliminate fifth and seventhcurrent harmonics. Reduced switch topologies have theadvantages of more reliability and less cost andcomplexity. Reduced switch APF with one cycle controlis also proposed. The third leg of the inverter iseliminated, and the third phase is connected to themidpoint (derived by voltage splitting capacitors) of thedc bus. This topology has the problem of voltagebalancing across the dc link capacitors. This is laterimproved by connecting the where third phase to thenegative pole of the dc link.

II. BACKGROUND WORKS

Shunt Active Power Filter: As the name depicts the shunt active power filter (SAPF) are connected in parallel to the powersystem network wherever a source of harmonic is present. Its main function is to cancel out theharmonic or non-sinusoidal current produce as a result of presence of nonlinear load in the powersystem by generating a current equal to the harmonic current but off opposite phase i.e. with 180^{o}phase shift w.r.t to the harmonic current. Generally SAPF uses a current controlled voltage sourceinverter (IGBT inverter) which generates compensating current (ic) to compensate the harmoniccomponent of the load line current and to keep source current waveform sinusoidal. Basicarrangement of SAPF is shown in figure 1 through block model.

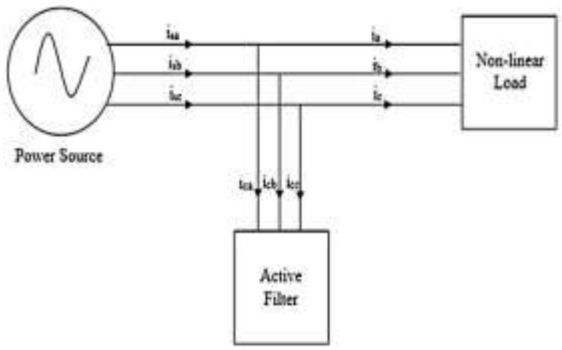

Figure.1 Shunt Active Power Filter

Compensating harmonic current in SAPF can be generated by using different currentcontrol strategy to increase the performance of the system by mitigating current harmonics presentin the load current. Various current control method [2]-[4] for SAPF are discussed below.
Instantaneous Real and Reactive Power Theory (p-q method)This theory takes into account the instantaneous reactive power arises from the oscillation ofpower between source and load and it is applicable for sinusoidal balanced/unbalanced voltagebut fails for non-sinusoidal voltage waveform. It basically 3 phase system as a single unit andperforms Clarke's transformation (a-b-c coordinates to the α-β-0 coordinates) over load currentand voltage to obtain a compensating current in the system by evaluating instantaneous activeand reactive power of the network system.The p-q method control strategy in block diagram form is shown in figure 2.

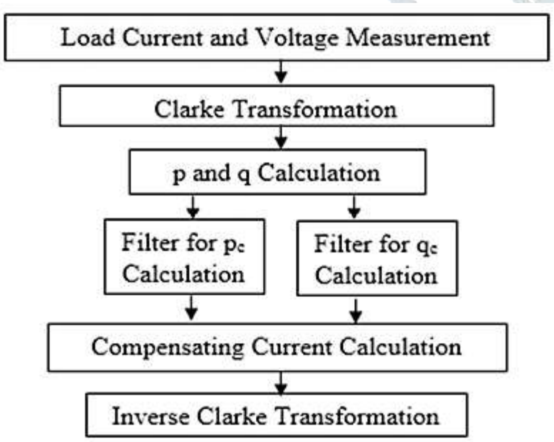

Figure.2 P-Q method control strategy

Instantaneous Real and Reactive Power Theory (p-q method): This theory works on dynamic principal as its instantaneously calculated power from theinstantaneous voltage and current in 3 phase circuits. Since the power detection taking placeinstantaneously so the harmonic elimination from the network take place without any time delayas compared to other detection method.

Although the method analysis the power instantaneously yet the harmonic suppression greatlydepends on the gating sequence of three phase IGBT inverter which is controlled by differentcurrent controller such as hysteresis controller, PWM controller, triangular carrier currentcontroller. But among these hysteresis current controlled method is widely used due to itsrobustness, better accuracy and performance which give stability to power system.

Hysteresis Current Controller: Hysteresis current control method is used to provide the accurate gating pulse and sequence to theIGBT inverter by comparing the current error signal with the given hysteresis band. As seen infigure 3 the error signal is fed to the hysteresis band comparator where it is compared withhysteresis band, the output signal of the comparator is then passed through the active power filterto generate the desired compensating current that follow the reference current waveform.

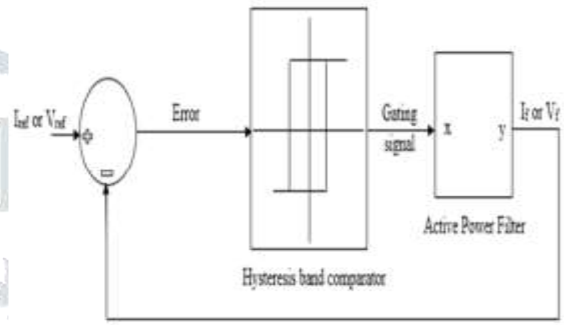

Figure.3 Hysteresis Controller control logic

Asynchronous control of inverter switches causes the current of inductor to vary between the givenhysteresis band, where it is continuously compare with the error signal, hence ramping action ofthe current takes place. This method is used because of its robustness, excellent dynamic actionwhich is not possible while using other type of comparators.There are two limits on the hysteresis band i.e. upper and lower band and current waveform istrapped between those two bands as seen from figure 4. When the current tends to exceed the upperband the upper switch of the inverter is turned off and lower switch is turned so that the currentagain tracks back to the hysteresis band. Similar mechanism is taking place when current tends tocross the lower band. Thus current lie within the hysteresis band and compensating current followthe reference current.

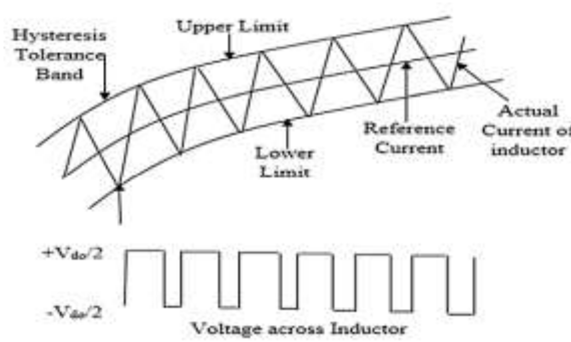

Figure.4 Hysteresis Band

Switching frequency can be easily determined by looking at the voltage waveform of the inductor.The voltage across inductor depends on gating sequence/gating pulse of IGBT inverter which isagain dependent on the current error signal of the hysteresis controller. Variable frequency can beobtained by adjusting the width of the hysteresis tolerance band.

Synchronous Reference Frame theory (d-q method): Another method to separate the harmonic components from the fundamental components is bygenerating reference frame current by using synchronous reference theory. In synchronousreference theory park transformation is carried out to transformed three load current intosynchronous reference current to eliminate the harmonics in source current. The main advantageof this method is that it take only load current under consideration for generating reference currentand hence independent on source current and voltage distortion. A separate PLL block it used formaintaining synchronism between reference and voltage for better performance of the system.Since instantaneous action is not taking place in this method so the method is little bit slow thanp-q method for detection and elimination of harmonics. Figure 5 illustrate the d-q method withsimple block diagram.

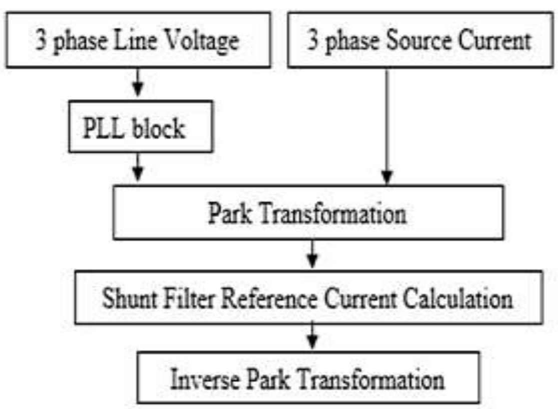

Figure.5 D-Q method control strategy

III. SYSTEM CONFIGURATION

The topology of the proposed APF is shown in Fig. 6.

This is the reduced switch version of the correspondingfull-bridge topology. A pair of switches (i.e., one leg) isremoved from each of the VSIs of the full-bridgeconfiguration. A diode bridge feeding a resistive load isconsidered as the nonlinear load for this study. Thesystem consists of a parallel connection of two units. Eachunit is a series connection of passive and APF. The twounits are optimized to take care of low- and highfrequency components of the load, respectively. The lowfrequency inverter (LFI) operates at 550 Hz and isconnected in series with the passive filter tuned toeliminate optimally the fifth and seventh harmonics. Notethat this inverter may also supply the reactive powerdemand of the load. In such case, the inverter may alsooperate under the selective harmonic elimination moderemoving fifth and seventh harmonics with minimumnumber of switching per half cycle. The second unit is thehigh frequency inverter (HFI) operates at 20 kHz andpassive filter of the second unit is tuned to optimallyeliminate the 11th and 13th harmonics, while the activefilter is operated to compensate for any harmonicsgenerated by the first unit and the rest of higher orderharmonics of the load that are not compensated by thefirst unit. Both the units are connected to the same dc linkthat is maintained by the first unit. The proposedconfiguration is optimal in the sense that it uses only twopassive filters to eliminate most of the lower orderharmonics, while the two active filters take care of theremaining distortion.

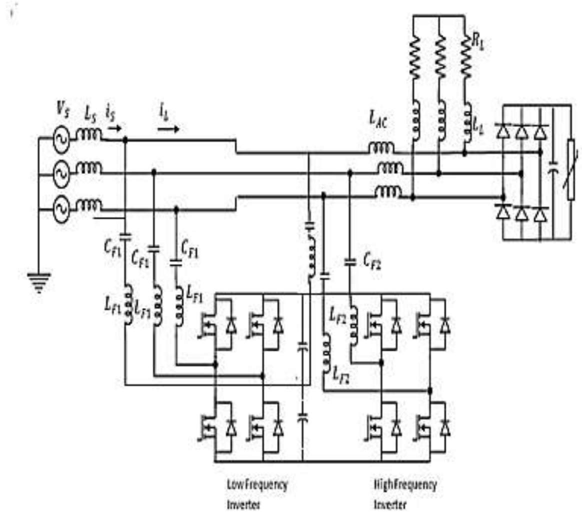

Figure.6 Reduced Switch Dual Parallel Topology

IV. SIMULATION RESULTS

Detailed simulation study has been carried outfor single phase active power filter. The abovediscussed control technique is used for usingMATLAB SIMULINK for proving the concept.Figure 7 shows the simulation block diagram.

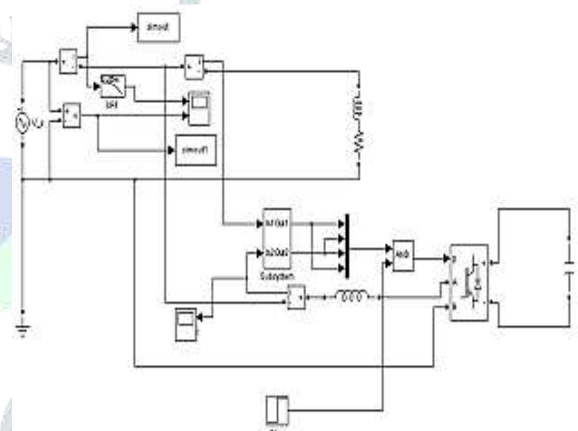

Figure.7. Simulation Block diagram of Singlephase shunt active filter

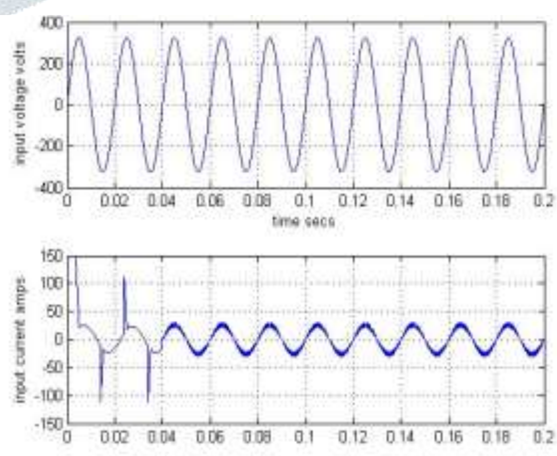

Figure.8 Source Voltage and current waveforms for harmonics loads

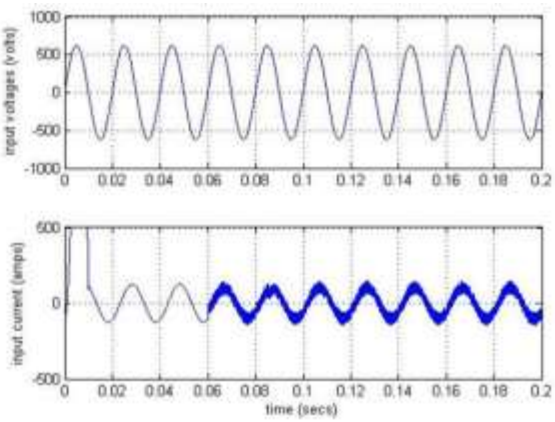

Figure.9 Source Voltage and current waveforms for lagging loads

V. CONCLUSION

Active power filters are efficient enough to removeharmonic content of non-linear loads, it was proven beyonddoubt by many researches in their footsteps, further extensionof filtering process is done using new topology of selectiveharmonic elimination. Eachinverter is connected in series with a passive filter. Thepassive filter forthe LFI is designed to optimally eliminatefifth- and seventh-order harmonics, whereas the passivefilter connected in series with the HFI is designed tooptimally eliminate 11th- and 13th-order harmonics. TheLFI operates typically around 550 Hz and takes care ofonly the lower order harmonics including reactive powerdemand of the system.

REFERENCES

[1] Grady, W. Mack, and Surya Santoso. "Understanding power system harmonics." IEEE Power EngineeringReview 21.11 (2001): 8-11.

[2] Morán, Luis A., et al. "Using active power filters to improve power quality." 5th Brazilian Power ElectronicsConference. 1999.

[3] Jou, H-L. "Performance comparison of the three-phase active-power-filter algorithms." IEE Proceedingsgeneration, Transmission and Distribution 142.6 (1995): 646-652.

[4] Chin Lin Chen; Chen E. Lin; Huang, C.L.; , "An active filter for unbalanced three-phase system usingsynchronous detection method," Power Electronics Specialists Conference, PESC '94 Record., 25th AnnualIEEE , vol., no., pp.1451-1455 vol.2, 20-25 Jun 1994

[5] B Singh, Ambrish Chandra, Kamal Al-Haddad, Bhim. "Computer-aided modeling and simulation of active powerfilters." Electric Machines &Power Systems27.11 (1999): 1227-1241

[6] Akagi. H, 1996. “New Trends in Active Filters for Power Conditioning”, IEEE Transaction on IndustrialApplications, vol. 32, No.6, Dec., pp 1312-1322

[7] Akagi. H, 2006. “Modern active filter and traditional passive filters”, Bulletin of the polish academy of sciencestechnical sciences vol.54.No.3

[8] H. Akagi, Y. Kanazawa and A. Nabae, “Analysis anddesign of an active power filter using quad seriesvoltage source PWM converters.”, IEEE Trans. Ind.Appli., vol. IA-26, pp.93-98.1990

[9] F.Z. Peng, H. Akagi, and A. Nabae, “A new approachto harmonic compensation in power system-Acombined system of shunt passive series activefilters.,” IEEE Trans. Ind. Appl., vol 26, p.983-990.1990.

[10] T. J. E. Miller “Reactive power control in electricsystems”, 1st edition 1982: A Wiley-InterScience Publication John Willey & Sons NewYork,