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Infinite Level Inverterbased Single Phase Active Power Filter

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***Abstract*– This paper proposes a new infinite level inverter (ILI) based single phase active power filter (APF). It is based on a dc-dc buck converter in the front end followed by H-bridge. This topology has many number of voltage levels depending on the carrier frequency used, and has numerous advantages over traditional voltage source inverter based (VSI) APF. PQ Theory is used for fundamental reactive power compensation and harmonic filtering.It is simulated using MATLAB/Simulink, and experimental prototype is developed for the single phase infinite level inverter and the control circuit is implemented using the Simulink desktop Real Time Windows Target (RTW). The control signals are obtained through RTW environment using National Instruments PCI card NI-PCIe 6351.**

***Index Terms*—Infinite level inverter, PWM inverter, multi-level inverter, DC link utilization, three phase active power filter, Power quality, *cascaded Buck-H Bridge* .**

I INTRODUCTION

In recent years many power electronic converters utilizing switching devices have been widely used in industrial as well as in domestic segments. It desires to draw purely sinusoidal currents from the distribution network, but this is no longer the case with this new generation of receivers that take advantage of all the recent advances and improvements in power electronics. These power electronic equipmentsdraw much distorted currents [1] thereby creating power quality problems [2-4].Classically, shunt passive filters consisting of tuned LC filters [5-6] and/or high-pass filters were used to suppress the harmonics, and power capacitors are employed to improve the Power Factor (PF) of the utility/mains[7-8]. But they have the limitations of fixed compensation and large size and can also excite resonance conditions.The objective of the active filtering is to solve these problems by combining the advantages of regulated systems with a reduced rating of the necessary passive components. Various topologies of the active power filter have been developed so far. The shunt active power filter based on the current-controlled voltage source-type PWM converter has proved to be effective even when the load is highly nonlinear [9].

Several topologies including full-bridge VSI and full-bridge current source inverter based Active power filters for single phase operation are presented in [10-11], but a very high capacitor voltage is required for its working [12-15], resulting high voltage stress across the active switches of the inverter.Even though multilevel inverter requires increased number of active and passive devices and complex control circuitry, it lowers voltage stress and harmonic component.

This paper proposes a new VSI topology, single phaseinfinite level inverter (ILI) based active power filter, which results fine sine wave compared to other converter topologies, and is superior to the traditional VSI. It has an infinite number of voltage levels depending on the carrier frequency, hence the name infinite level inverter (ILI). It has the advantages of lower voltage stress across the active components, quick response and reduced THD. Christo Ananth et al.[5] presented a brief outline on Electronic Devices and Circuits which forms the basis of the Clampers and Diodes.

In recent works, various inner control algorithmsare proposed. However, synchronous reference theory, instantaneous PQ theory, synchronous detection algorithm,and dc-bus voltage algorithm[16] are the extensively used APF algorithms.

Figure1 shows the block diagram representation of the proposed system.Comparison of Figure 1 (a) and (b) shows the compensation principle of a shunt active power filter. APF injects a current equal in magnitude but in phase opposition to harmonic current. Figure 4.5 shows the block diagram of a three-phase APF system. The heart of the APF system is the IGBT based Voltage Source Inverter (VSI).

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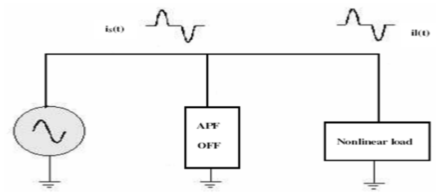


Fig 1 (a) Block diagram of a simple power system with APF off.

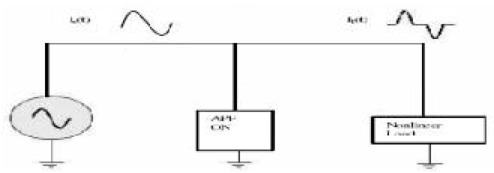


Fig 1 (b) Block diagram of a simple power system with APF on.

II. OPERATION OFINFINITE LEVEL INVERTER (ILI)

Figure 2 shows the single phase infinite level inverter (ILI) based APF. It has abuck converter in front end followed by an H-bridge.

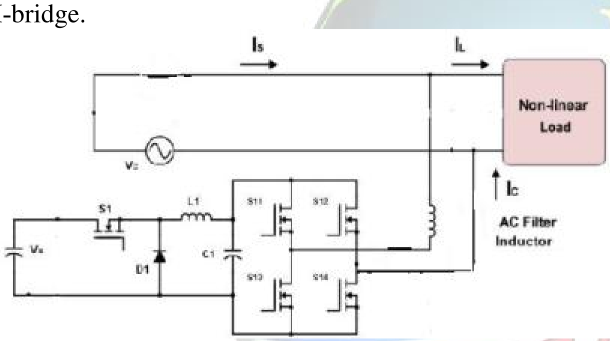
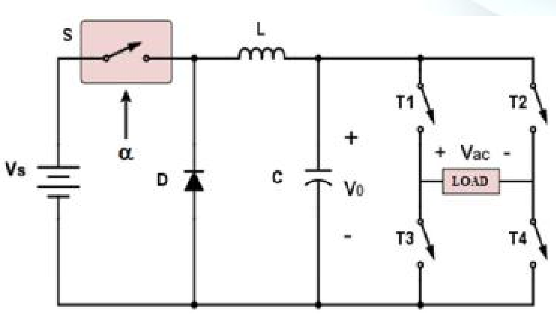


Fig.2. The proposed single phase infinite level inverter based APF

Figure 3 shows a single phase circuit of ILI and its output waveform. The buck inductor and capacitor filter out all the high frequency components in the output.



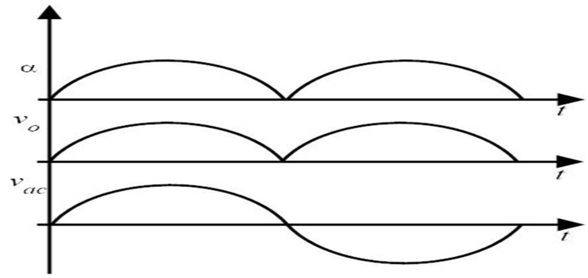


Fig.3. (a) Single phase switched mode dc-ac inverter (b) Duty ratio wave form and voltage wave forms

The steady state output voltage V_O of buck converter is given by

$$V_O = \alpha V_S \quad (1)$$

where Vs is the input dc voltage and α is the duty ratio. A sinusoidal pulse width modulated signal is used to trigger buck converter.

$$\alpha \equiv m * |\sin \omega t| \quad (2)$$

where 'm' is the modulation index ratio. Now

$$V_O = m V_S|\sin \omega t| \quad (3)$$

Varying α slowly relative to the switching frequency, a rectified sine wave is obtained across the capacitor. The H-bridge,following the buck converter is synchronized with thefully rectified reference sine wave. It is switched at thefundamental frequency to unfold the rectified sine wave into a
sinusoidal waveform as seen in Fig. 3(b).The output voltage, now has infinite levels depending on the switching frequency. The output phase voltage of a single phase inverter with peak amplitude of dc source Vs is given by

$$V_{ac} = m V_S|\sin \omega t| (4)$$

This voltage output is a quality sinusoid with low harmonic content compared with the classical voltage source inverter .

III. INFINITE LEVEL INVERTER AS ACTIVE POWE FILTER (APF)

The single phase infinite level inverter is tested for variouspower quality compensations such as reactive powercompensation, harmonic filtering and unity power factor for rectifier load.The parameters of buck converter are L=1mH and C=100μF and value of AC inductor is 1mH. Instantaneous reactive power theory (IRPT) or PQ control technique is used to extract the information of load current& voltage and necessary calculations are made to supply therequired reactive power.

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In order to obtain a steady output voltage for any changes in input supply or output load, closed loop control is employed. Here, hysteresis current control (HCC) as shown in Fig. 4, is used to obtain a dynamic response for any changes in the parameters.

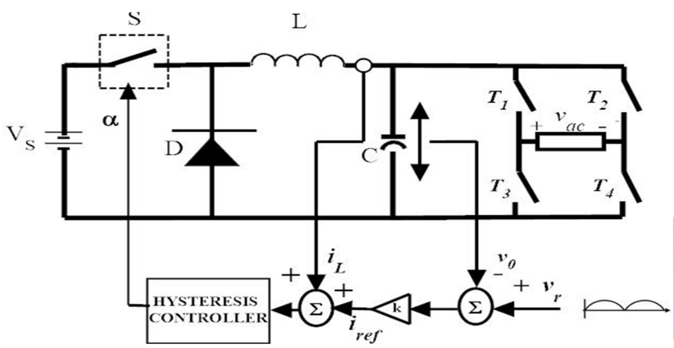


Fig. 4. Hysteresis current control in single phase inverter

VI SIMULATION AND SIMULATION RESULTS

In order to verify the feasibility of novel APF and validity of the control strategy, simulations using the "SIMULINK" software package of the "MATLAB" are taken.The single phase Infinite Level Inverter was simulated first which consists of a buckconverter cascaded by an H-bridge. The open loop control of the inverter is done by giving a rectified sine pwm pulse to the buck switch.Input DC voltage =150 V; Switching frequency,f_{sw}= 10 kHz ; Buck inductance =10mH and buck capacitance = 0.4µf.

ILI based APF is connected to the grid at 0.04s. From the results shown in figure 5, it is evident that the overall currenttaken from the grid is reduced after switching the infinite level inverter and the lagging currents are became in phase.

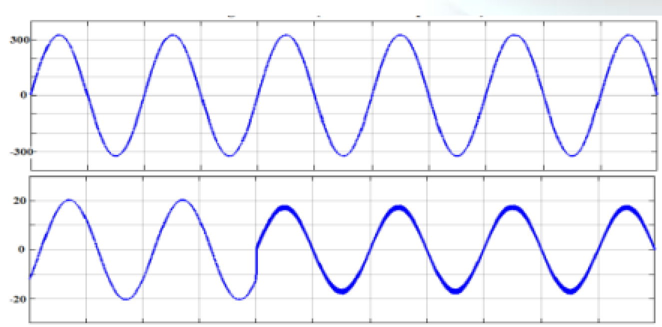


Fig. 5 Grid voltage and current before and after compensation

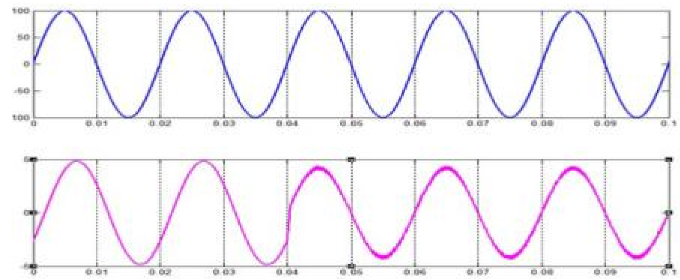


Fig 6.grid voltage and source current waveforms

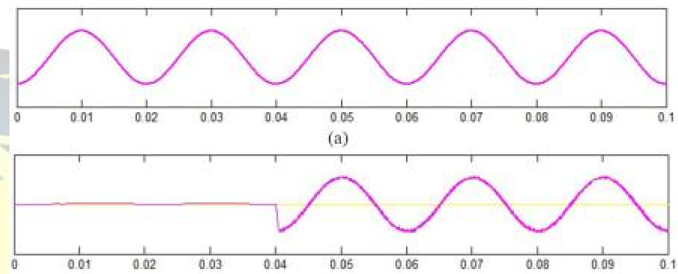


Fig. 7 (a) reference current and (b) converter current

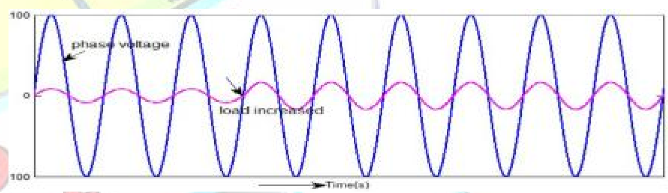
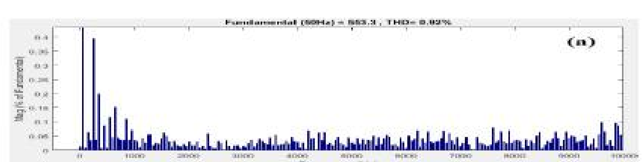


Fig 8 Grid voltage and phase current for sudden increase in the load

Fig. 9 Grid voltage and APF current for changes in reactive power demand.

From the figures 8 and 9, the ability of this new APF for dynamic changes are shown.



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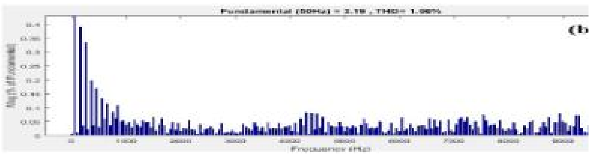


Fig. 10 THD using FFT of (a) voltage 0.92% (b) current 1.06%

As per IEEE-519 standards, harmonic limit on voltage is 5% for total harmonic distortion (THD) and 3% of the fundamental voltage for any single orderharmonic. Total harmonic distortion (THD) of the voltage and current are foundusing the Fast Fourier transform tool (FFT) in the MATLAB/Simulink. In the Fig. 10,it is seen that the voltage THD is 1 % and the highest singleorder harmonic is less than 0.4%. This shows that the quality of output voltage waveformvery high resembles a pure sinusoid.

V. EXPERIMENTAL SET UP

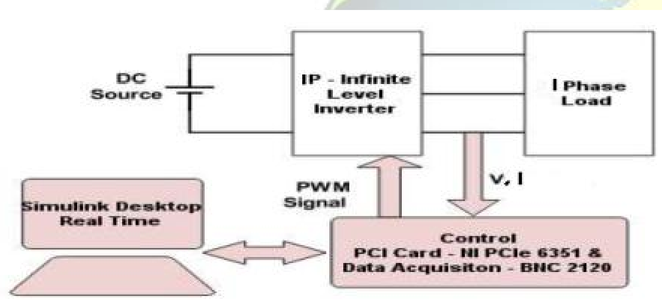
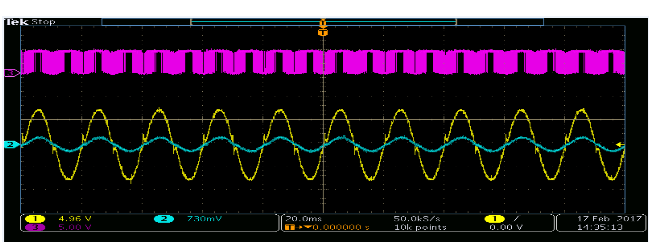


Fig. 11 shows the control scheme and experimental setup.

Experimental prototype is developed for the single phaseinfinite level inverter and the control circuit is implemented using the Simulink desktop Real Time Windows Target (RTW). Controlsignals are obtained through RTW environment using National Instruments PCI card NI-PCIe 6351. Fig. 11 shows the control scheme and experimental setup. The experimentalwaveforms of buck voltage,inverter voltage and current, and the voltage across the active switch are shown in figure 12.



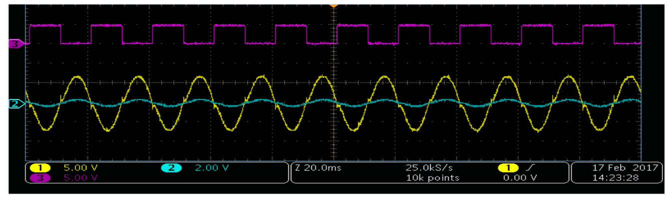


Fig. 12 The experimental waveforms of buck voltage, inverter voltage and current, and the voltage across the active switch

VICONCLUSION

In this paper, an ILI based, single phase APF is presented for power quality compensation. It has lower THD and minimized voltage stress resulting in better system reliability. In this filter the fundamental reactive power is supplied by the infinite level inverter based APF. Its steady state and dynamic performances outweigh other inverter topologies for the same application.

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