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Study of AC Side Switched Active Filter Based High Performance Three Phase Buck Rectifier and a Three Phase Highly Efficient Pure Sine Wave Inverter

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This study proposes a new circuit consisting of a AC side switched active filter based high performance three phase Buck rectifier and a three phase pure sine wave inverter. The input switching makes input current switched at high frequency and then filtered by small filter along with small low pass filter to get low THD input current at near unity power factor. A low ripple and almost 97% efficient three phase pure sine wave inverter has been implemented which has a total harmonic distortion (THD) of less than 0.6%. So, overall the new technique revealed that the power factor has been improved above 0.9 providing high efficiency above 97%, low switching loss, reduced harmonic distortion, low cost, small size and simple control. The simulation work of this circuit has been done using PSIM

Field of Research: Power electronics.

1. Introduction

The input current shaping of rectifiers is important for reducing line losses and improving the power factor. There are different methods of improving input power factor [1-4].The buck converter at the output of the rectifier is one of the methods of switch mode regulated rectifiers [5-6]. The input filter required is smaller than the conventional rectifiers using passive filters. Moreover, input power factor improves and the output voltage can be bucked and controlled via the duty cycle control. So an AC side switched active filter based high performance three phase Buck rectifier is efficient to increase the input power factor.[7] It is also important to improve output power factor. The output current of different converters contain harmonics and harmonics have a negative effect in the operation of the electrical system and therefore, an increasing attention is paid to their generation and control [8-9]. A Pure Sine Wave Inverter provides low harmonics, low cost, high efficiency and simple control [10]. When an improved input power factor as well as the output power factor is achieved then high efficiency is gained. In our study an AC side switched active filter based high performance three phase Buck rectifier and a three phase pure sine wave inverter are used to ensure improved power factor in both the input side and the output side with low switching loss, reduced harmonic distortion, low cost, small size and simple control.

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2. An AC Side Switched Active Filter based High Performance Three Phase Buck Rectifier

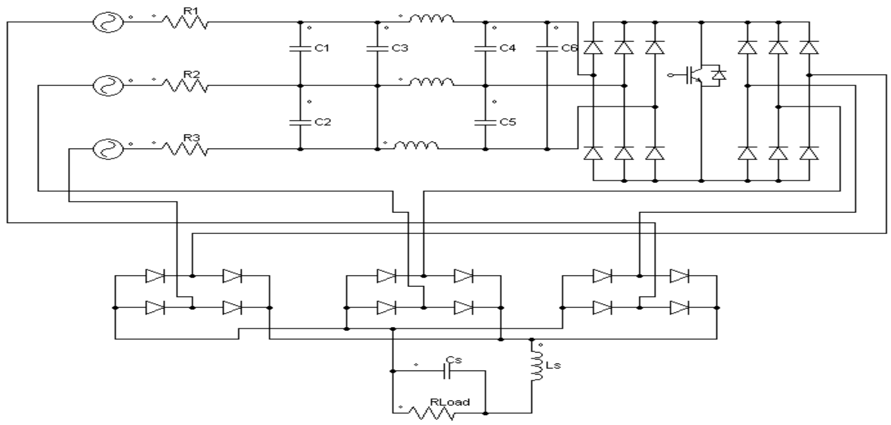

Figure 1: Three Phase Buck

In the circuit shown in Fig.1 Ls is used as buck inductor and L1, L2 and L3 are used as input filter inductors.C4, C5 and C7 are the input filter capacitors. Resistance R1, R2 and R3 and capacitor C1, C2 and C3 are used to design the additional low pass filter that is required due to the comparative high THD value of buck operation. Capacitor Cs is used to reduce ripple of the output dc voltage.The operation principle of a three phase rectifier switched at the input by a bi-directional switch is similar to the single phase circuit [7].

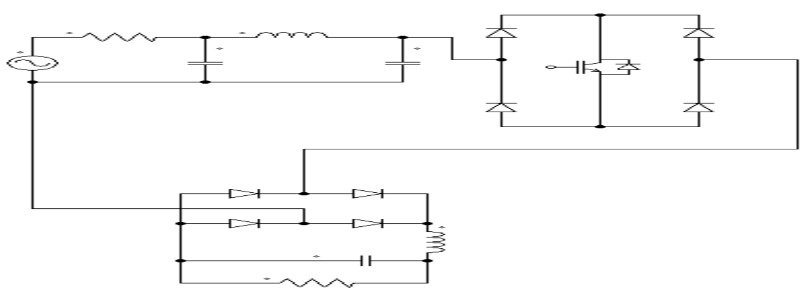

Figure 2: Single Phase Buck Rectifier

Fig.2 shows a single phase buck rectifier with resistive load switched by a bi-directional switch at the input. [7] The inductor at the output side of the circuit acts as the buck inductor. The bridge rectifier connected to load acts as buck diode in the overall circuit. In the input side the resistor, inductor and capacitor work as input filter to shape the current. In the positive supply cycle, when the switch is turned ON, inductor gets charged via two diodes of the rectifier enclosing the unidirectional switch. When the switch turns off during positive supply cycle, supply voltage and the inductor voltage is applied together across the load via two diodes of the rectifier connected to the load. When the switch is off, source current becomes zero (which is the main reason for high THD in buck operation); current pass through the filter to maintain its sinusoidal form.

3. Pure Sine Wave Inverter

In the Inverter design Sinusoidal Pulse Width Modulation (SPWM) is used to generate sine wave output from DC input. SPWM technique is implemented by constant amplitude pulse with varying duty cycle for each period. To generate SPWM signals a high frequency triangular wave is used as carrier signal (*V*c), which is compared with sinusoidal wave that is called reference signal (*V*r) [11-12]. The most important parameter of designing the switching strategy is amplitude modulation (*M*A) that will influence the performance of the inverter. *M*A is defined as the ratio between sine waveform also termed as reference signal and the triangular waveform also termed as carrier signal. The amplitude modulation is determined by the following equation:

$$M_A = \frac{Vr}{Vc} \qquad (1)$$

MA plays a crucial role to determine the output voltage of the inverter. However, theoretically if MA value increases, the AC output voltage of the inverter will be increased. Based on the equation (1), MA value should be less than 1, in order to achieve a high voltage gain with fewer harmonics. So filter designing is getting easier if the MA value choose between 0.8 and 0.9. The harmonics at MA greater than 1 will also increase. This condition is known as over modulation [10].

4. System Model

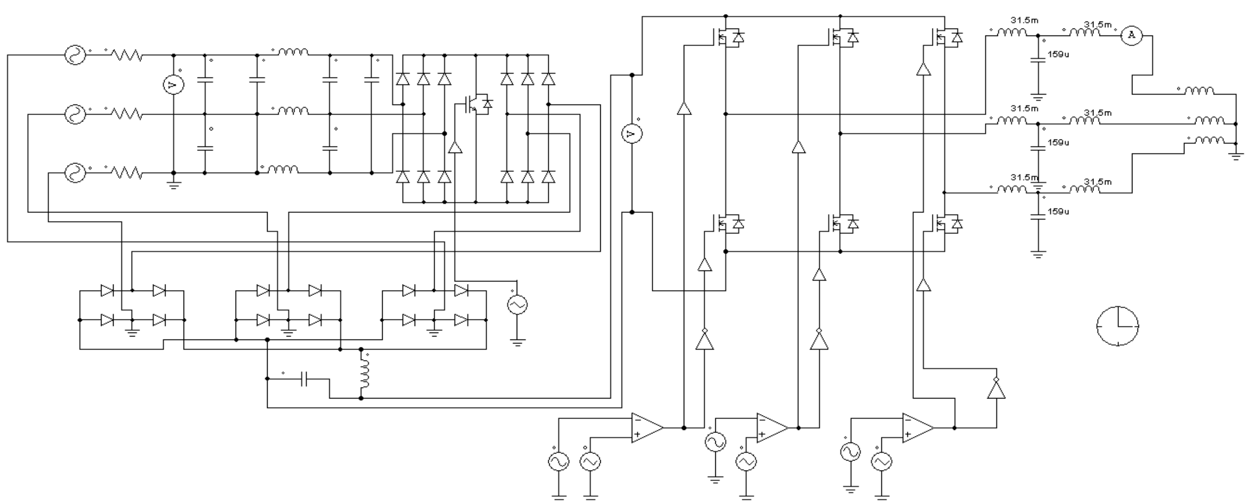

Figure 3: Schematic Diagram of Proposed Combined Circuit of Three Phase Buck Rectifier and a Pure Sine Wave Inverter

Fig.3 represents the model of a R-L load using three phase Buck rectifier and a three phase highly efficient pure sine wave inverter. The Buck Rectifier in which the input ac voltage is rectified dc voltage. The MOSFET is triggered using a triangular pulse wave. The three phase two pure sine wave inverter, where the MOSFETs are triggered using a triangular pulse of 12V. We also use a L-C filter to minimize the distortion. The last part of this circuit is the R-L load. Input power factor improves and the output voltage can be bucked and controlled via the duty cycle control. Duty cycle is

$$D=\frac{t_{on}}{T}\times 100\% \quad (2)$$

where D is the duty cycle, t_{on} is the time the signal is active, and T is the total period of the signal.

5. Simulation Result

Fig.4 shows the input voltage. Fig.5 exposes the input current before filtering. Fig.6 shows the filtered input current which contains low THD than the unfiltered one.Fig.7shows output current of the inverter. It contains ripple. To minimize this distortion we use a L-C filter. Then we get a almost ripple free current curve of the inverter in Fig.8. Same scenery has been achieved in the case of voltage. Fig.9 reveals a distorted voltage of the inverter before using filter while almost pure sinusoidal voltage curve is achieved in Fig.10 after using the L-C filter. L-C filter is available in market at low cost. So, it is cost effective. L-C filter can be handled easily. So, it also provides simple control of the circuit.

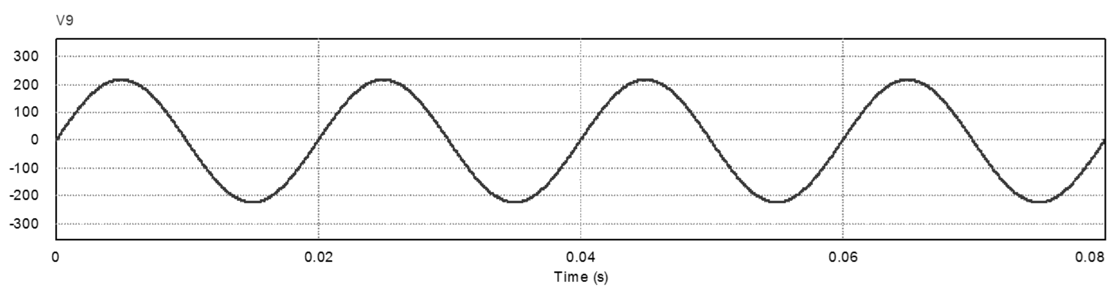

Figure 4: Input Voltage

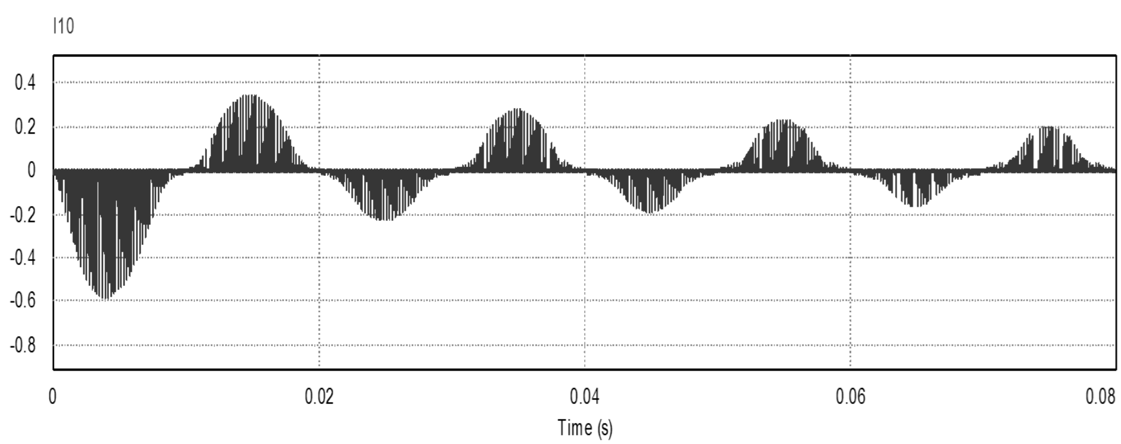

Figure 5: Input Current before Filtering

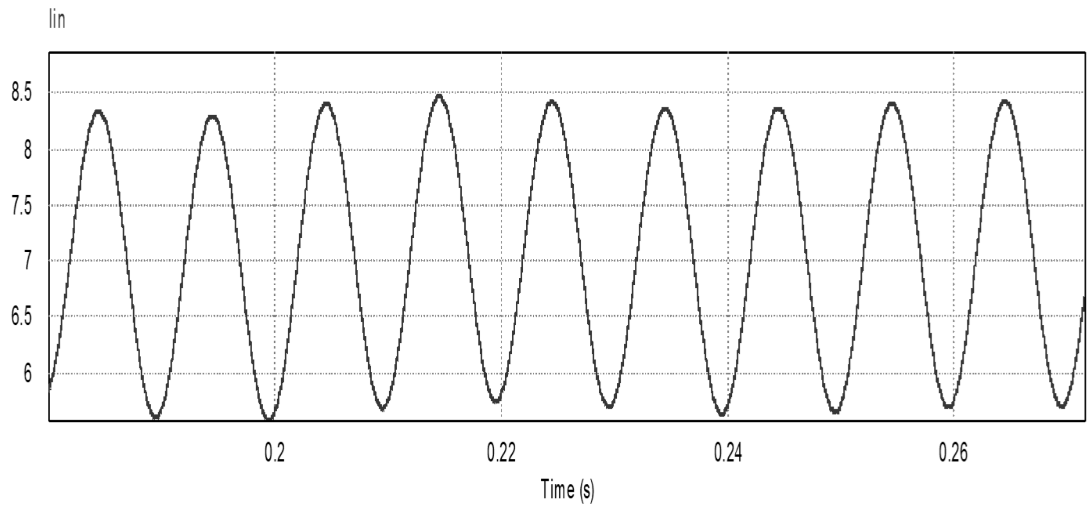

Figure 6: Input Current after Filtering

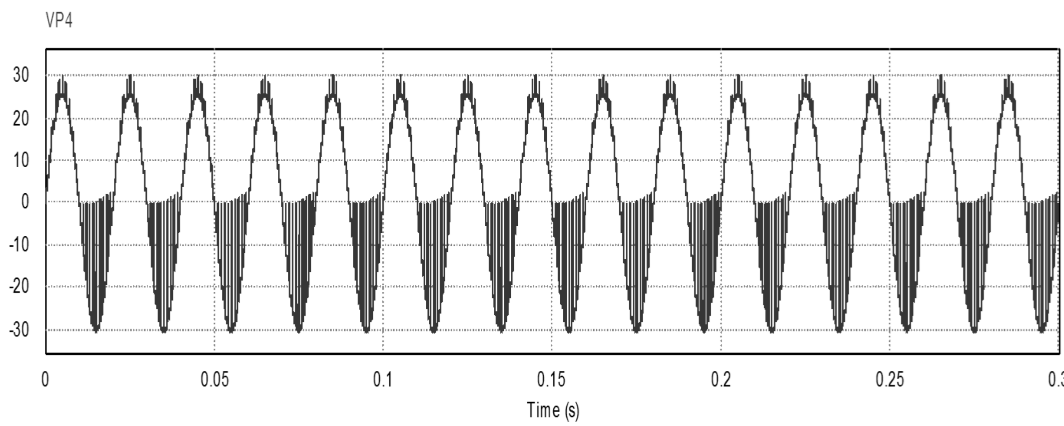

Figure 7: Output Voltage of the Pure Sine Wave Inverter before Using Filter

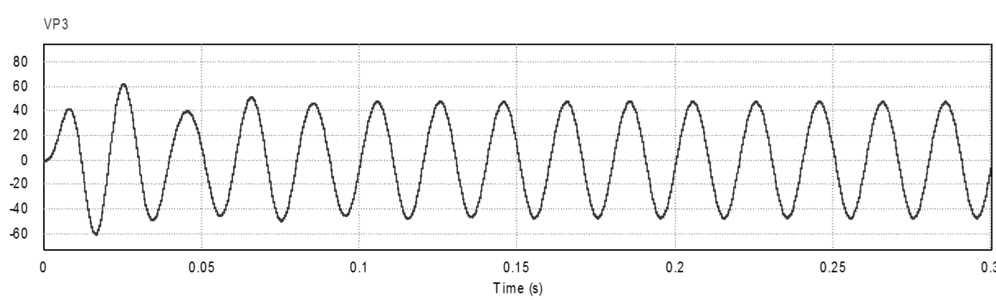

Figure 8: Output Voltage of Highly Efficient Pure Sine Wave Inverter after Filtering

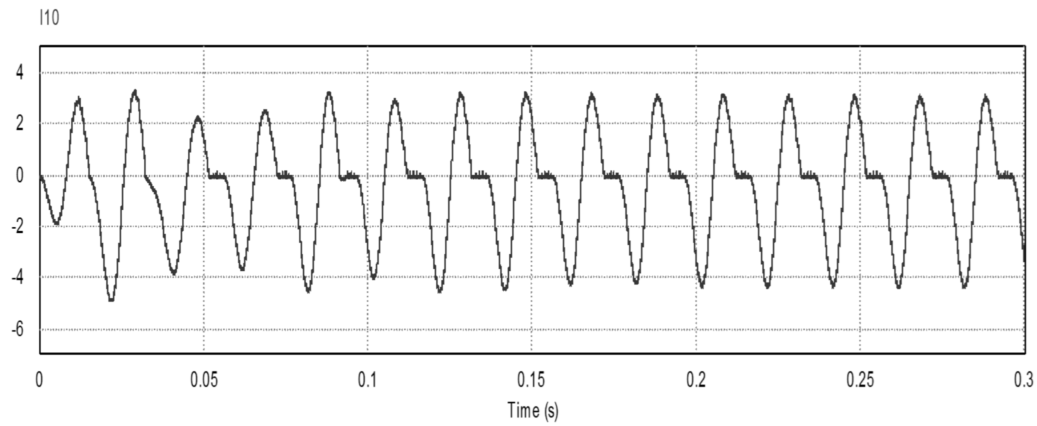

Figure 9: Output Current of Pure Sine Wave Inverter before Using Filter

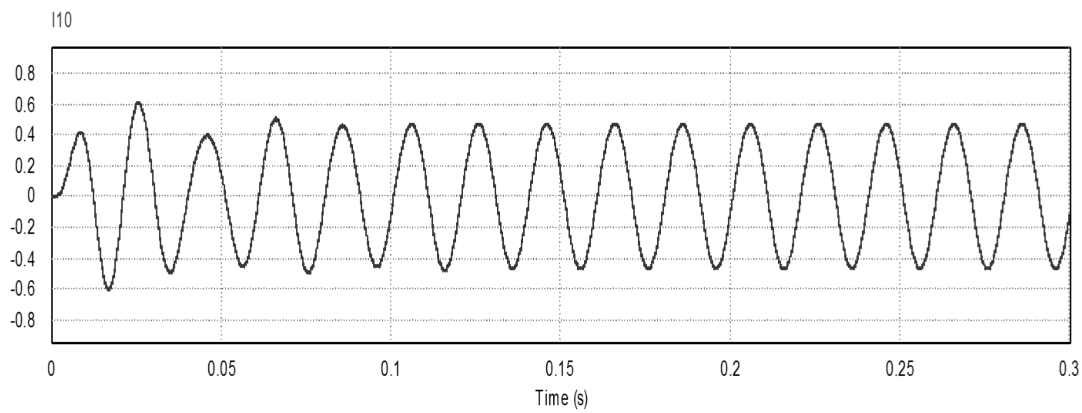

Figure 10: Output Current of Highly Efficient Pure Sine Wave Inverter after Filtering

6. Performance Analysis

In the rectifier circuit if we increase duty cycle input power facto increases but THD also increases and in turn efficiency decreases. Again the efficiency of the rectifier circuit increases if we use smaller filter inductor and capacitor. In this paper we have done the same. Small sized capacitor and inductor are used to design the filter. The output current and voltage of the pure sine wave inverter have been pure sinusoidal after using L-C filter. Before that there was ripple. An improved power factor of 0.91 has been achieved at the output side also. Fig. 11 shows the power factor vs duty cycle when applied the MOSFET's triggering pulses of the highly efficient pure sine wave inverter. It is further revealed that the power factor is improved up to above 0.9 after using the MOSFET's triggering pulses of the highly efficient pure sine wave inverter.

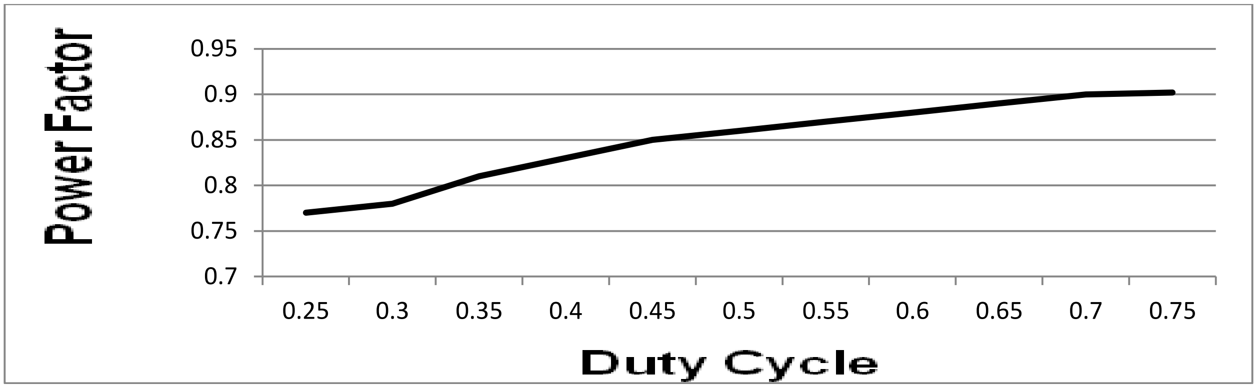

Figure 11: Power Factor Vs Duty Cycle for Pure Sine Wave Inverter's Gate Pulse When The Rectifier's Duty Cycle is Fixed At 0.25.

So, it is seen that this new circuit provides power factor improvement with low harmonic distortion.

7. Conclusion

The Three Phase Buck rectifier chops the input current at the AC side in contrast to the conventional schemes which chops the rectified output. The main advantage of this circuit is smaller input filter. It provides low input THD and high input power factor. Again the simulation result shows that the three phase pure sine wave inverter produces a high quality ripple free sinusoidal AC curve with a voltage THD below 0.1% which is very much lower than IEEE 519 standard. However, the power factor improved above 0.9 when we use a combined three phase buck rectifier and a highly efficient pure sine wave inverter. The significance of this new circuit is to provide higher power factor, high efficiency, low switching loss, reduced harmonic distortion, low cost, small size and simple control that may be the application of modern power electronic systems.

8. Limitations and Further Research:

This circuit has not been implemented in hardware. So, Experimental Implementation may be the further research.

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