

Design PFC Circuit for AC/DC Converter Using Dynamic Programming MATLAB/SIMULINK

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ABSTRACT

In this paper a simple power factor correction PFC circuit was designed, simulated and tested for AC/DC converter which generates input current harmonics due to its non-linear characteristics. PFC was achieved through current harmonics mitigation by using PWM boost regulator. The circuit utilizes the charging and discharge increments of boost inductor current to shape a sinusoidal input current. Inductor current was controlled by means of PWM controller. The controller accepts two feedback signals, the first is the inductor current and the other is the output voltage of the AC/DC converter. The simulation results of fast Fourier transform FFT show a great reduction in current harmonic which in turn tends to a great improvement in power factor. Key words : the AC/DC converter – fast Fourier transform FFT - PFC circuit was designed.

I. INTRODUCTION

Currently, the electrical power industry has grown rapidly and loads are changing from simple, non-electronic loads such as tungsten lamps, motors, relays and resistive heaters to electronic ones such as fluorescent lamps, motors with solid-state drivers and industrial drives. These electronic loads (also known as non-linear loads which draw a non-sinusoidal current even when the supply voltage is perfectly sinusoidal) [1] are the major sources of excessive current harmonics

which leads to power quality PQ pollution introduced in electrical grids. The current harmonics has a significant effect on customer loads in a form of heating, distortion or operation malfunction. Harmonic disturbances are the most researched part of all power quality disturbances, especially over the past two decades.

These filters have no switches and hence no electromagnetic interference emissions EMI. Beside that it is very simple, robust and has low cost of implementation. However, their performance lower when compared to active circuits, they are heavy bulky specially when designed for low harmonics mitigations. Passive filters are employed either to shunt the harmonic currents off the line or to block their flow between parts of the system by tuning the elements to create a resonance at a selected harmonic frequency [2]. The second technology use switching circuits controlled actively. Some of active technologies based on harmonics-injection techniques and called active filters. The active filter senses the harmonics distortion, and injects currents that are 180 degrees out of phase with the harmonic frequencies that exist in the system. They have the distinct advantage that they do not resonate with the system. They can be used in very difficult circumstances where passive filters cannot lie. They can also address more than one harmonic at a time and combat other power quality problems such as flicker [3].

II. THE PROPOSED PFC CIRCUIT

The proposed PFC circuit is designed for AC-DC converter and it considered as nonlinear load. The PFC circuit is essentially based on current wave shaping technique. Boost DC-DC regulator with high frequency PWM controller are utilized, the controller gets the two control signals and generate the PWM switching pulses accordingly as shown in figure 1. This result in minimum conducted electromagnetic interference (EMI) at the line when the circuit operates in continuous conduction mode (CCM) [5].

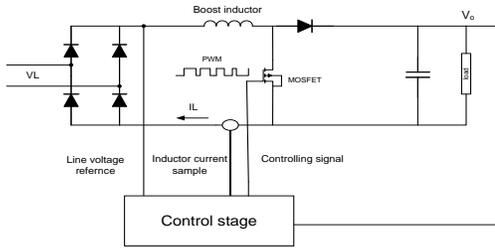


Figure 1: Boost DC-DC Switching Converter Filter

When the boost switch is turned ON, the inductor current tends to rise due to charging of boost inductor, and when the switch turned OFF, the inductor current will decay down by discharging through boost capacitor. The rise increment is given by equation.1 [6]. These increments up and down of boost inductor current are the key of current shaping.

$$\Delta i_L = \frac{\sqrt{2}V(t)D}{LF_s} \quad (1)$$

where

- Δi_L Increment in inductor current
- $V(t)$ Instantaneous phase voltage
- D Duty cycle of boost switch
- L Boost inductor
- F_s Switching frequency of boost converter

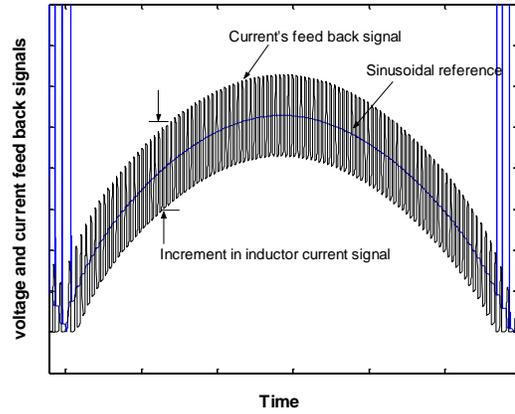


Figure.2 Simulation Shows How the Boost Inductors Ripples Follow the Sinusoidal Reference.

III. PWM CONTROLLER DESIGN

PWM controller responsible of generating switching pulses for boost regulator to perform two functions; sinusoidal current shaping and maintaining constant and stable output voltage. For this reasons the controller is designed with two feedback signal, one from output voltage of the converter and the other from input line current which is equivalent to boost inductor current as shown in figure (3).

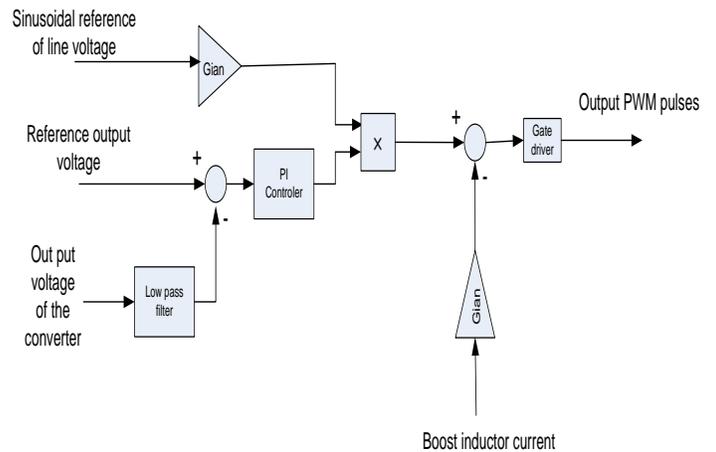


Figure 3: PWM Controller with Two Feed Back Loops

Low pass filter is used to control the out put ripple voltage of the converter and the reference voltage is used to select the required level of output voltage. Sinusoidal reference is taken as pattern over which the line current is shaped. Gains are used to modify the signal to next controlling stage. The error signal that used as an input for gate driver is generated from comparing the boost current with modified sinusoidal reference after the product. Gate driver generate positive pulse when the error is positive and zero voltage when the error is negative and it works as PWM modulator.

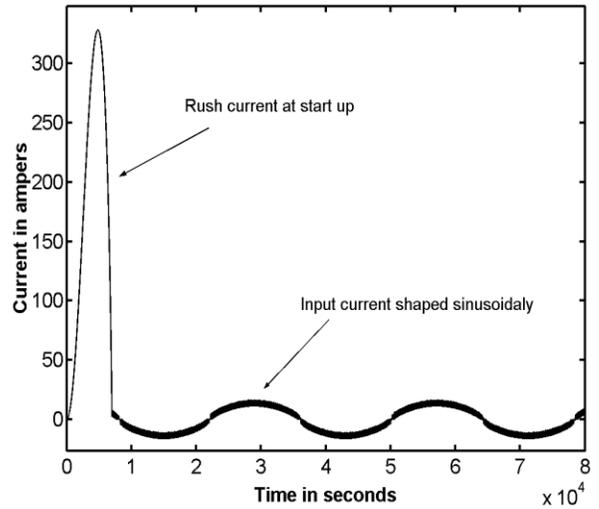


Figure 4: Shows the Input Line Current after PFC

IV. SIMULATION RESULTS

CCM boost converter was simulation by Matlab, the effect of duty cycle on inductor current saw tooth and output voltage are monitored and calculate. Simulink model was used to simulate a PFC circuit for single phase AC/DC converter; the converter can also work as Adjustable Speed Drive ASD by adjusting the output voltage reference in PWM controller. The fast Fourier Transform FFT analysis was applied to the input current of ASD to calculate the harmonic content of the input current which used to calculate the power factor of the ASD circuit before and after PFC. Figure 4 shows the input line current after PFC, it is clear that the current tends to rush up at the beginning of operation for a part of half cycle. This is because the output capacitor is empty of charge and works as short circuit at that point. This problem can be solved by using a soft starting circuit which is out of our scope. In figure 5, the inductor current (input current) appears as saw tooth due to charging and discharging phases of boost inductance. The conduction point between charging and discharging is kept at none zero value which indicates that the converter works in CCM.

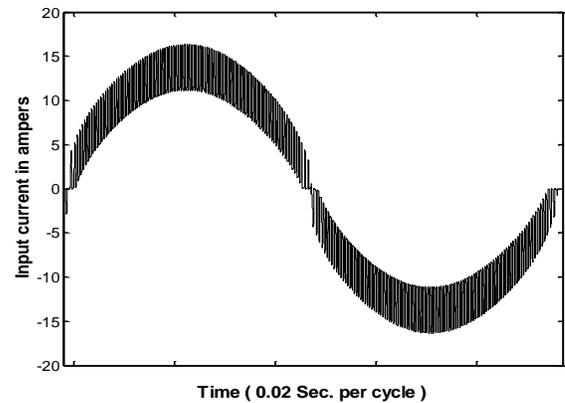


Figure 5: Inductor Current Made of Charging and Discharging Phases

Figure 6 shows the input current plotted over the line voltage. PFC achieve unity displacement factor that can be noted from zero phase difference between current and voltage. Also PFC achieve near unity distortion factor due to small harmonics contents of input current and this can be noted visually from a sinusoidal shape of the current and numerically for the result of FFT analyser.

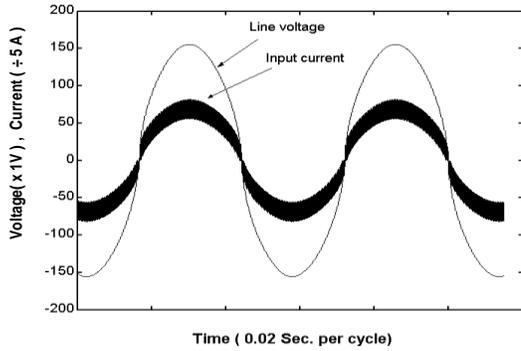


Figure 6: Shows The Input Current Plotted Over The Line Voltage.

The FFT analysis was applied to the input line current generated by the Matlab simulation model. The ASD model is designed to work at a maximum DC output voltage of 300 V, and load of 80 Ω. All measurements were taken at this operating point. Analysis was performed before and after PFC. The harmonics plot prior to the mitigation is shown in Figure 7. It shows a significant 3rd, 17th and 19th harmonics of 4.85 V, 4.85 V and 9.26 V respectively. Exact odd harmonic levels are listed in Table 1. Different RMS values of phase current are given in Table 2.

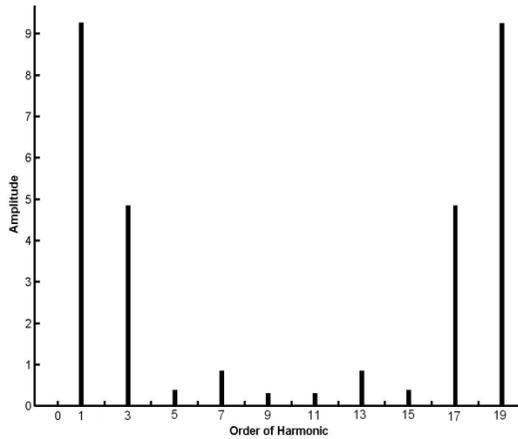


Figure 7: Odd Harmonics Plot Prior to the Mitigation

Table 1.: Odd Harmonics Levels Prior to the PFC

Harmonic Order	DC	1 st	3 rd	7 th	13 th	17 th	19 th
Harmonic Amplitude in A	0.00	9.26	4.85	0.86	0.86	4.85	9.26

Table 2: RMS Values of Phase Current before PFC

Total RMS Current	DC Current	Fundamental RMS Current	Harmonics RMS Current
10.5 A	0.00 A	6.55 A	8 A

Harmonics mitigation are achieved by using inherent boost DC-DC switching regulator in which harmonics levels were significantly reduced. Figure 8. shows the odd harmonics plot after mitigation. Exact odd harmonic levels are listed in Table 3. Different RMS values of input phase current are given in Table 4.

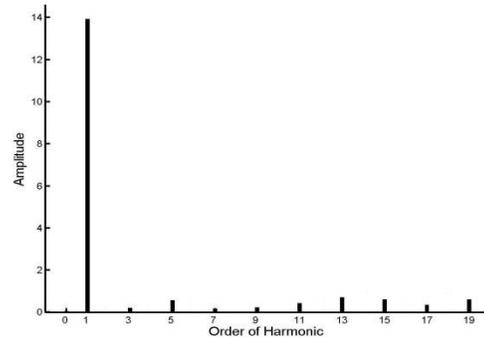


Figure 8: Odd Harmonics After Mitigation

Table 3: Odd Harmonics Levels after PFC

Harmonic Order	DC	1 st	3 rd	5 th	7 th	9 th	19 th
Harmonic Amplitude in A	0.6	13.97	0.56	0.48	0.34	0.13	0.76

Table 4: RMS Values of Phase Current after PFC

Total RMS Current	DC Current	Fundamental RMS Current	Harmonics RMS Current
9.99 A	0.11 A	9.88 A	1.48 A

The presence of a significant 19th harmonic before PFC is due to switching frequency of DC-DC boost regulator. The 19th harmonic amplitude was mitigated from 9.26 A to 0.76 A, 3rd and 17th are also significantly mitigated. Harmonics mitigation results in a huge improvement in power factor improved from 62.3 % to 98.8 %.

V. CONCLUSION

A single phase power factor correction PFC circuit using pulse width modulated PWM boost regulator has been proposed for AC/DC converter. The design circuit has achieved both output voltage regulation and PFC with two feed back signal from output voltage and input current. Simulation was performed and shows good result in harmonic mitigation and output voltage regulation. Harmonics mitigation results in a huge improvement in power factor improved from 62.3 % to 98.8 %.

VI. REFERENCES

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