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Simulation of Power Factor Correction Boost Converter

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Abstract:

This project proposes a Power Factor Correction (PFC) Controller applicable for maintaining high input power factor of boost converter. The input current distortion occurs due to ripple in the output voltage feedback, input voltage feed forward path, distortion in the input voltage, non-linearity in the multiplier and poorly designed current regulator. These factors cause reduction in power factor. Thus two or more component factors are taken into account for power factor improvement by neglecting the input of other components. In this project ripple in output voltage feedback, input voltage feed forward path and an improved current regulator are considered. It requires micro controller, analog to digital converter and PWM generator. By using microcontroller, triggering pulses are generated. The boost converter is used to get increased voltage at the output end. If load is varied, the output voltage varies, which causes a change in the input power factor of the circuit. In a PFC, the controller works to improve the input side power factor by adjusting the duty cycle. Here the duty cycle is adjusted for power factor correction in addition to its variation for maintaining constant voltage at the output end. To improve the power factor, the input current is made to follow the input side voltage.

Keywords — **Power factor correction (PFC)**

I. Introduction

POWER factor correction (PFC) used to be synonymous with sinusoidal input current and extremely low total harmonic distortion (THD). F.C.Lee in[1] deals with single stage switch. Many PFC converters have been presented. They usually can be divided into two categories: i. Two Stage Approach. ii. Single Stage Approach. The two stage approach actually includes two power conversion processes. The first stage is a PFC stage is like a boost converter and the second stage is a dc/dc converter or dc/ac converter to tightly regulate the output voltage. The two stage approach has the disadvantage of increasing the cost because of increase device count. Therefore the single stage approach integrates the PFC stage with a dc/dc converter into one stage.

A.Fernandez in [2] deals with PFC topologies with two loop control system is the obvious solution for low and medium power levels. i.Inner Loop

Control, ii.Outer Loop Control. The Inner Loop control is a current loop. Outer Loop control is a voltage loop. Inner Loop control forces the input current to be sinusoidal. Outer loop control regulates the output voltage. Boost or fly back converters are used for this control. To achieve this, a PWM with an analog multiplier is used. Therefore a sinusoidal input current with a small distortion, a low pass filter with low corner frequency should be placed in feedback path of voltage loop to reduce the 1000Hz ripple and not to distort the input current.

R.B.Ridley in [3] deals with unity power factor. Full wave rectifier is the scheme currently proposed for dc loads like computers and other electronic instrumentation. Such a rectification scheme suffers from poor power factor and generates harmony currents which are particularly problematic for a high frequency ac bus. It can be seen that with a band pass filter of the series resonant type whose centre frequency is the same as the line frequency, has been inserted between the line and a conventional full wave rectifier. The quality factor as shown in the equation of the filter determines its bandwidth, BW = ωo / Q,which in turn determines the harmonic content of the line current. Hence a narrower bandwidth results in less harmonic currents which in turn result in operation closer to unity power factor.

A.Fernandez in [4] deals with the improved active current The input current waveform obtained with passive solutions is not sinusoidal since very bulky inductor should be used to obtain a perfect sinusoidal input current. On the other hand, active solutions with fast output voltage regulation are usually based on two switching conversion stages (input current wave shaping plus dc-to-dc conversion). In all these cases, the input current is sinusoidal [or quasi sinusoidal when using stages based on a boost converter]. On the other hand, active solutions with fast output voltage regulation are usually based on two switching conversion stages. This option is based on using standard dc-to-dc topologies with slight change at low a cost. In this case, the main objective, as in the case of using passive solutions, is not to obtain a sinusoidal (or almost sinusoidal) input current, but to obtain an input current with a less harmonic content.

L.H.Dixon [5] deals with the design of a high power factor active pre-regulator is optimized to achieve less than 3% harmonic distortion and power factor better than 0.995 without a sample/hold. Off-line switching power supplies have historically used full wave rectifier bridges with simple capacitor input filters to power the DC input bus. The line current waveform is a narrow pulse resulting in notoriously poor power factor (0.5-0.6) and harmonic distortion (>100% of the fundamental). In high power factor pre-regulator circuit input current distortion is mainly 3rd harmonic, arising from two sources: (i) Input current fails to track perfectly with the sine wave programming signal. (ii) The current programming signal is distorted by 2nd harmonics from the feedback output voltage. Discontinuous flyback circuits are simple to control. By fixing the duty cycle throughout each 60Hz half-period, the 100 kHz averaged current will track the 60 Hz voltage waveform (crudely).The technique called Average Current Mode Control overcomes these difficulties. PFC Pre-regulators used for both high and medium power levels.

II. General Description

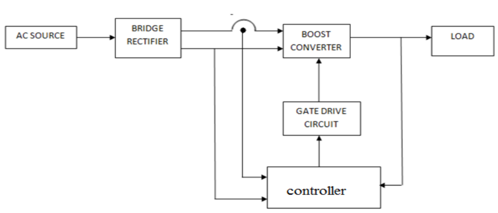

Fig.1 Block Diagram

The block diagram of the PFC system is shown in Fig. 1. The commercial AC source is given to the bridge rectifier to convert it into DC, followed by the boost converter to boost up the voltage. The output of the converter is given to the resistive load. In order to correct the power factor on the source side the input voltage, input current and output voltage sensed and given to the controller for triggering the switch in the boost converter.

1) *Modes of operations*

The average output voltage is greater than the input voltage then it is called as boost converter. It is equivalent to the step up chopper operation. Fig shows boost converter by using power transistor.
The modes of operation of the boost converter are shown in Fig. 3 and Fig. 4.

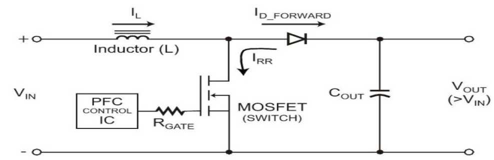

Fig. 2 Boost converter

MODE 1 OPERATION:

The switch (MOSFET) S is turned on by applying gate signal. At t=0, s comes to ON state. At that time, diode D is reversed biased. Due to this, load is isolated from the input. The input supplies energy to inductor (L). Now, the inductor current increases from I1 to I2. Fig shows the equivalent circuit of mode 1 operation. The inductor voltage is equal to the supply voltage.

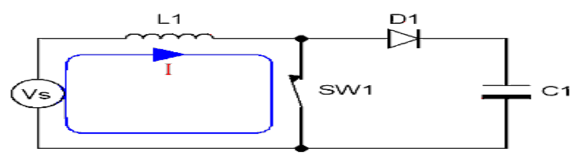

Fig. 3 Current flow path in mode 1

MODE 2 OPERATION:

At t=t1, the gate signal of switch (MOSFET) is removed, and then switch S comes to the off state. During the off time period (T_{off}) diode D comes to conduction and current flow through inductor, diode capacitor (C) and load. The energy stored in inductor L is transferred to the load. The inductor current decreases from I2 to I1.mThe voltage across the inductor L is (V_s-V_o). Here the output voltage is greater than input voltage. Fig shows the equivalent circuit of mode 2 operation.

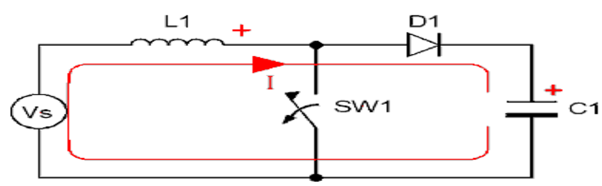

Fig. 4 Current flow path in mode 2

III. Design of Boost Converter

1) *Design of boost converter:*

To design of Boost Converter by assuming the following parameters:
Load power (P_O) =500W
Input voltage (V_{in}) =230V
Output voltage (V_0) =400V
Output voltage ripple (ΔV) < 1%
Switching frequency = 100 KHz

2) *To find the input power (P_{in}) of the converter:*
The output power equation (P_0)= V_0I_0 (1)
By assuming the converter efficiency at about 90%
P_{out} =0.9*input power (P_{in}) (2)

3) *To find input current (I_{in}) of the converter:*
$P_{in}=V_{in}*I_{in}$ (3)

4) *To find the ripple current (ΔI_p):*
For designing the inductor (L) the ripple current (ΔI_p) is assume to be 25% of the input current.

$$\Delta I_p=0.25I_i \qquad (4)$$

5) *To find Inductor Peak Current:*
Inductor current (I_{il})= I_{in} =2.41A (5)

$$\text{Inductor Peak Current } (I_{pl})=I_{in}+\frac{\Delta Ip}{2} \qquad (6)$$

6) *To find the Duty Cycle (D):*

$$D=1-\frac{Vin}{Vo} \qquad (7)$$

7) *To find the switch ON time (Δt):*

$$\Delta t=D*T \qquad (8)$$

8) *Design of Boost Inductor (L):*

$$V=L*\frac{\Delta Ip}{\Delta t} \qquad (9)$$

9) *Design of output capacitor (c_{out})*

By assuming the ripple voltage (ΔV)= 50μV

$$C_{out}= I_0*\frac{\Delta t}{\Delta V} \qquad (10)$$

10) *Design of load (R):*

$$P_0=I^2 *R \qquad (11)$$

IV. Design of Closed Loop Controller

1) *DC voltage controller:*

A proportional integral (PI) voltage controller is selected for zero steady-state error in DC voltage regulation. The DC voltage V_{dc} is sensed and compared with the set reference voltage V_{dc}*. The resulting voltage error $V_{e(u)}$ at the nth sampling instant is:

$$V_{e(n)}=V_{dc}^*-V_{dc(n)}$$

The output of the PI voltage regulator $V_{o(n)}$ at the nth sampling instant of the PI controller will be:

$$V_{o(n)}=V_{o(n-1)}+K_p\{V_{e(n)}-V_{e(n-1)}\}+K_iV_{e(n)}$$

Here K_p and K_i are the proportional and integral gain constants, respectively.

$V_{e(n-1)}$ is the error at the (n-1)th sampling instant. The output of the controller $V_{o(n)}$ after limiting to a safe permissible value is taken as the amplitude of the input current reference A.

2) *Reference supply current generation:*

The input voltage template u(t) obtained from the sensed supply voltage is multiplied by the amplitude of the input current reference A to generate a reference current. The instantaneous value of the reference current is given as:

$$I_L^*=AB/C^2$$

Where B is the input voltage template u (t) and C is the input voltage feed forward component obtained by the sensed input voltage signal.

V. Result and Discussions

1) Open loop response

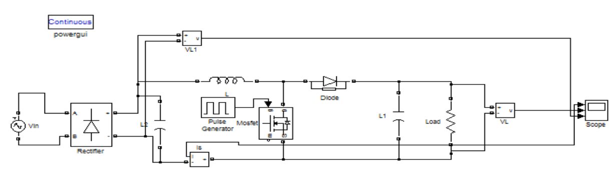

Fig. 5 PFC Boost converter

Fig. 5 shows the MATLAB model for the open loop of the PFC boost converter. An external pulse is given for MOSFET using pulse generator. The inductance L and capacitance is designed for 3mH and 100μF respectively to have a output voltage 400V for the input voltage 230V.

Fig. 11 shows the output voltage of boost converter for an open loop circuit, where the output voltage is around 380V which is an unregulated voltage since the pre-regulator is not included. Fig. 8 shows the output current of rectifier, where the current is about 38A, which is high compared to closed loop since the pre-regulator part is not presenting the open loop circuit. Fig. 9 shows the output voltage of rectifier i.e. the input voltage is 230V.The pulse generated is at a frequency of 100 KHz is shown in the Fig. 8.

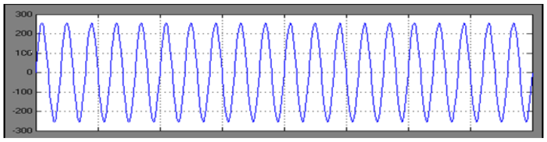

Fig. 6 open loop source voltage before PFC

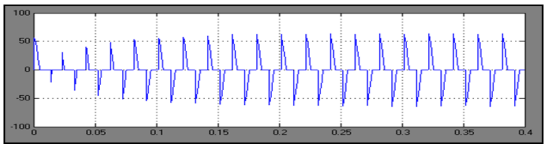

Fig. 7 open loop source current before PFC

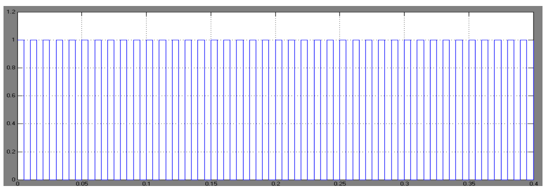

Fig. 8 Pulse for MOSFET

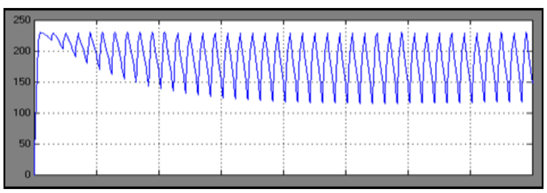

Fig. 9 open loop rectified output voltage waveform

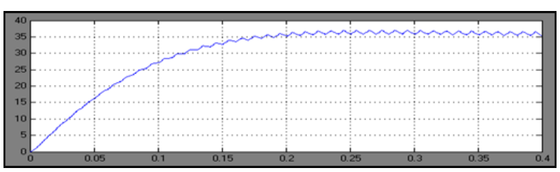

Fig. 10 open loop rectified output current waveform

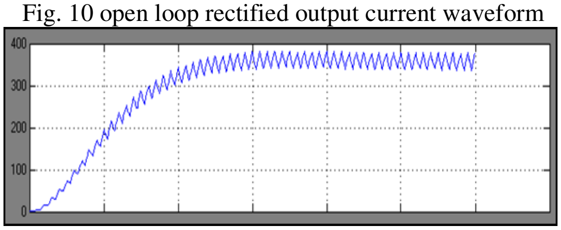

Fig. 11 open loop output voltage waveform

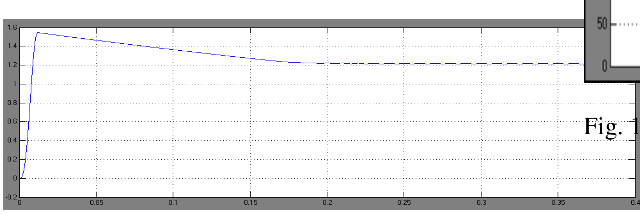

Fig. 12 open loop output current waveform

2) Closed loop response

Fig. 13 shows the MATLAB models for the closed loop PFC boost converter with a pre-regulator for the same specifications of open loop. The pulse for the MOSFET is generated using three control parameters like boost converter output voltage V_L, rectifier output voltage V_{L1}, rectifier output current I_S. A pre-regulator circuit is used to regulate the output voltage of the boost converter.

The output voltage of boost converter is shown in the Fig. 18. The output voltage is 400V when the input voltage is 230V, where the output voltage is regulated because of the pre-regulator part is presented in the closed loop circuit. The output current of the rectifier is around 1.25A which is less compared to open loop circuit. The rectifier input voltage 230V is shown in the Fig. 16.

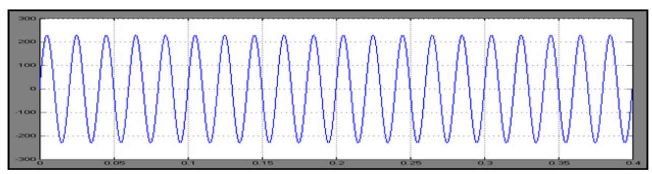

Fig. 13 closed loop source voltage after PFC

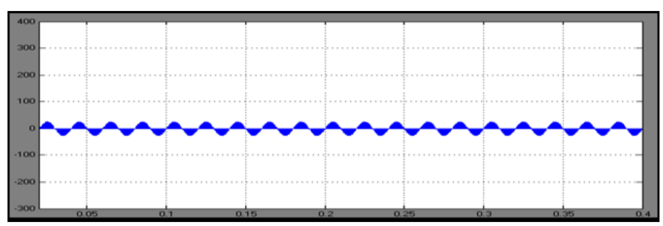

Fig. 14 closed loop source current after PFC

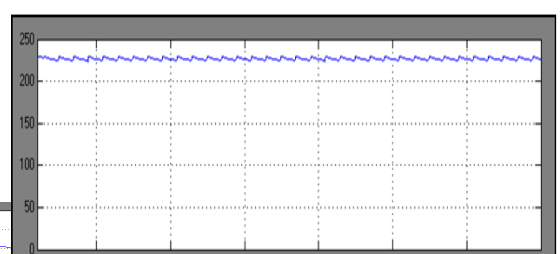

Fig. 15 closed loop rectified output voltage waveform

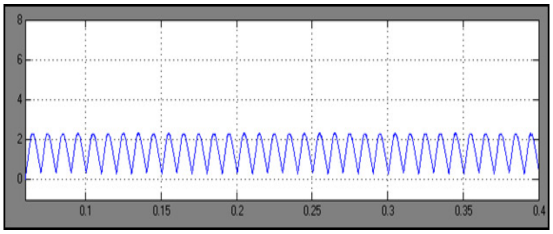

Fig. 16 closed loop rectified output current waveform

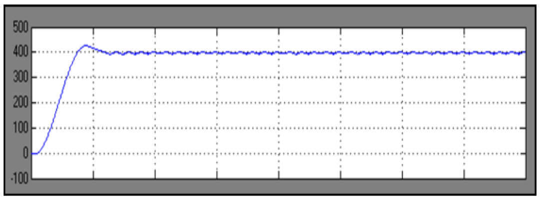

Fig. 17 closed loop output voltage waveform

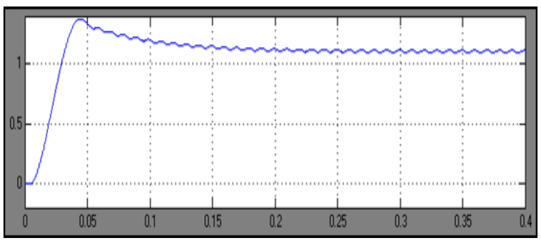

Fig. 18 closed loop output current waveform

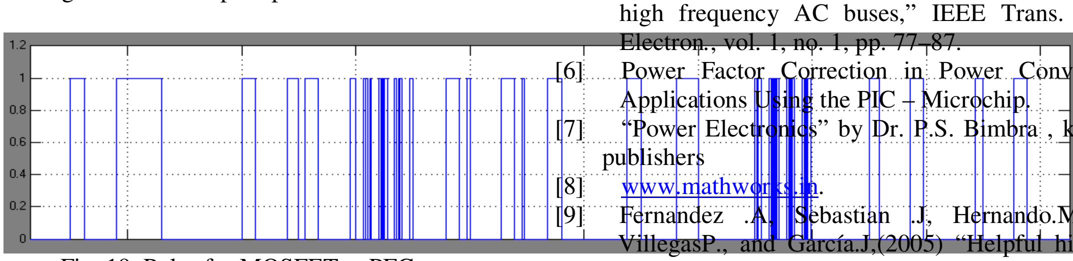

Fig. 19 Pulse for MOSFET at PFC

The input current waveform is shown in Fig. 15. It is clear from the graph that the current is in phase with the voltage such that the source side power factor is almost unity. The corresponding pulses are listed in Fig. 20.

VI. Conclusion

The power factor correction boost converter is a single stage approach with a fast dynamic response. The converter is simulated using MATLAB/SIMULINK. The regulator output voltage of 400V when the input voltage is 230V which is same as desired value. The drawback of the double stage approach is increased cost because of the bulky capacitor used in between the PFC AC/DC conversion stage and boost regulator/converter. This drawback can be overcome by a single stage approach, where the PFC AC/DC stage and the boost regulator stage are integrated into one stage and the capacitor is replaced and shared by a common switch.

References

[1] DixonL.H,(2012) "High power factor pre-regulators for off-line power supplies," presented at the Unitrode Switching Regulator Power Supply Design Seminar (SEM 700).

[2] Fernandez .A, Sebastian .J, Hernando.M. M, VillegasP., and García.J,(2013) "Helpful hints to select a power-factor-correction solution for low- and medium-power single-phase power supplies,"IEEE Trans. Ind. Electron., vol. 52, no. 1, pp. 46–55.Meksarik, V.; Masri, S.; Taib, S.; Hadzer, C.M, "**Development of high efficiency boost converter for photovoltaic application",** Power and Energy Conference, 2009. PECon 2004.pp. 153 - 157 , Nov.2004 .

[3] Fernandez.A, Sebastian.J, VillegasP. J., HernandoM. M., and LoperaJ. M,(2011) "Improved active input current shapers for converters with symmetrically driven transformer," IEEE Trans. Ind. Appl., vol. 37, no. 2, pp. 592–600. Shen Weixiang; Choo Fook

[4] LeeF. C, QianJ,and ZhaoQ,(2011) "Single-stage single-switch power factor- correction ac–dc converters with dc-bus voltage feedback for universal line applications," IEEE Trans. Power Electron., vol. 13, no. 6, pp. 1079–1088..

[5] RidleyR.B., and Vorperian.V (2010) "A simple scheme for unity power factor rectification for high frequency AC buses," IEEE Trans. Ower Electron., vol. 1, no. 1, pp. 77–87.

[6] Power Factor Correction in Power Conversion Applications Using the PIC – Microchip.

[7] "Power Electronics" by Dr. P.S. Bimbra , khanna publishers

[8] www.mathworks.in.

[9] Fernandez .A, Sebastian .J, Hernando.M. M, VillegasP., and García.J,(2005) "Helpful hints to select a power-factor-correction solution for low- and medium-power single-phase power supplies,"IEEE Trans. Ind. Electron., vol. 52, no. 1, pp. 46–55.Meksarik, V.; Masri, S.; Taib, S.; Hadzer, C.M, "**Development of high efficiency boost converter",** Power and Energy Conference, 2004. PECon 2004.pp. 153 - 157 , Nov.2011 .

[10] LeeF. C, QianJ,and ZhaoQ,(2013) "Single-stage single-switch power factor-," IEEE Trans. Power Electron., vol. 13, no. 6, pp. 1079–1088..

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