Energy Balance Power Factor Correction with Boost Regulator

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Abstract: **The rapid placement of power electronic system in residential, commercial and industrial sides has energized the longing of an improved power factor to reduce the loss and cost. In this paper, a boost regulator based three phase rectifier for unity power factor is analyzed and described. Pulse Width Modulation (PWM) technique is used to control of the boost regulator. We also used current control loop inside feedback which is far flexible than voltage control mode. Running behind the improvement, we achieved the PF limit from 0.9706 to 0.9937, which is a great achievement on practical basis. This paper also shows that when harmonics filter is attached with input LC filter then input current becomes sinusoidal input current and power factor improves notably.**

Keywords: **Three Phase Rectifier Input Current, Boost Pre-regulator, Harmonics Filter**

Introduction

Most of the industrial and domestic loads are inductive and operate at a low lagging power factor. A low power factor at the load means higher line losses in the system [1]. Low power factor leads high reactive power requirement and reduces voltage at the load [2-3]. As a result line and equipment losses increase. In addition to eliminating utility company penalties, correcting low power factor by installing power capacitors can add capacity back into the power distribution system [4]. Load on transformers can be reduced by the installation of power capacitors because raising the power factor on a kW load reduces kVA. By adding capacitors, you can add additional kW load to the power distribution system without altering the kVA [5].

Again the power factor improvement is important to minimize the cost of production [6]. Due to correct it we have find out the preliminary sources behind its poverty. Various power factor correctors are described before as a way to eliminate the poverty [7-9]. In this paper a Boost regulator has been analyzed with a 1-φ diode bridge rectifier for the purpose of power factor correction, because at present it is one of the most important research topics in power electronics [10]. The rectifier is best suitable in industrial and commercial application which can provides pure sinusoidal input current with unity power factor. Running behind the improvement we achieve the PF limit from 0.9706 to 0.9937, which is a great achievement as practical basis. Finally we believe that by such design the cost will be deducted in a way which will be blissful for both the producers and customers

Problems of Power Factor in Single Phase Line Commuted Rectifiers

Classical line commutated rectifiers suffer from the following disadvantages:

1) They produce a lagging displacement factor w.r.t. the voltage of the utility [11].
2) They generate a considerable amount of input current harmonics.

These aspects negatively influence both power factor and power quality. The massive use of single-phase power converters has increased the problems of power quality in electrical systems.

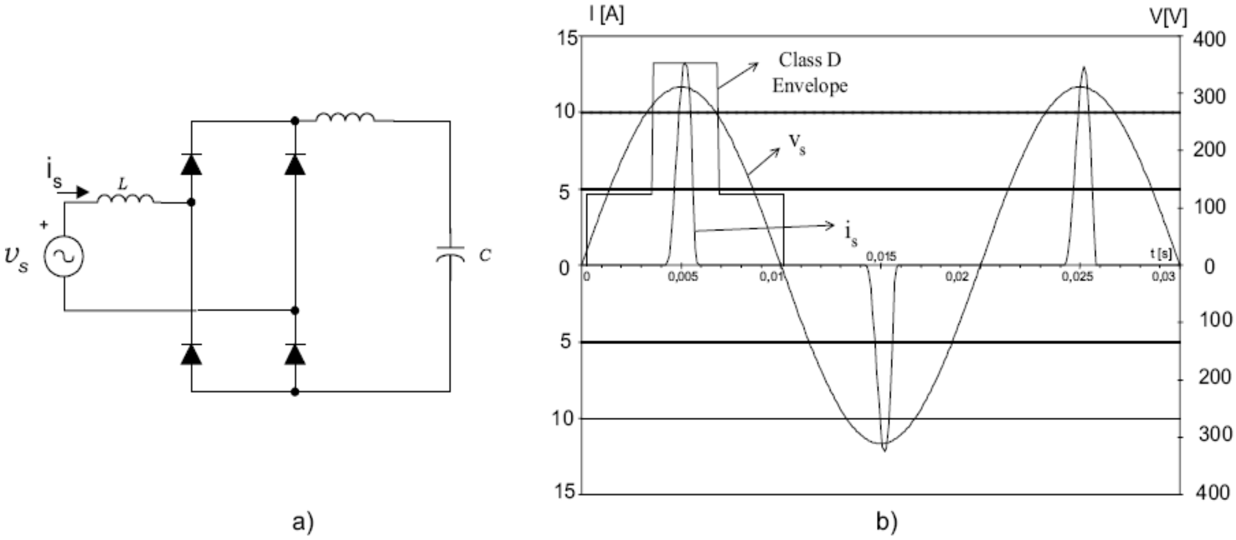

Fig. 1: Single Phase Rectifier (a) Circuit (b) Waveforms of Input Voltage and Current

Energy Balance in Power Factor Correction (PFC) Circuit

Let $v_l(t)$ and $i_l(t)$ be the line voltage and line current respectively. For an ideal PFC unit (PF = 1), we assume

$v_l(t) = V_{lm}\sin \omega_l t$ (1)
$i_l(t) = I_{lm}\sin \omega_l t_t$ (2)

where V_{lm} and I_{lm} are the amplitudes of line voltage and line current respectively. The instantaneous input power contains the real power (average power) component and an alternative component with frequency 2ωl.The working principle of a PFC circuit is to process the input power in such a way that it stores the excessive input energy when instantaneous power Pin is greater than the power demanded Po . The excessive input energy, $w_{ex}(t)$ is given by

$w_{ex}(t) = Po/2\omega_l\ (1-\sin 2\ \omega_l t)$ (3)

The excessive input energy is stored in the dynamic components (inductor and capacitor) of the PFC circuit. They require large value high current inductors which are expensive and bulky. A passive PFC circuit requires only a few components to increase efficiency, but they are large due to operating at the line power frequency.

Contribution of DC-DC Converters

Power electronic converters are essentially required when we need to convert electricity from one form to other. They form an interface between the source and load side. In the last several years, the massive use of single phase power converters has increased the problems of power quality in electrical systems. High-frequency active PFC circuit are preferred for power factor correction. Any DC-DC converters can be used for this purpose, if a suitable control method is used to shape its input current or if it has inherent PFC properties. The DC-DC converters can operate in Continuous Inductor Current Mode – CICM, where the inductor current never reaches zero during one switching cycle or Discontinuous Inductor Current Mode - DICM, where the inductor current is zero during intervals of the switching cycle. In CICM, different control techniques are used to control the inductor current. Some of them are (1) peak current control (2) average current control (3) Hysteresis control (4) borderline control. The average mode control technique is specifically developed for PFC boost converters and is analyzed here.

Principle of a Boost Regulator

The input current $i_s(t)$ is controlled by changing the conduction state of transistor. By switching the transistor with appropriate firing pulse sequence, the waveform of the input current can be controlled to follow a sinusoidal reference, as can be observed in the positive half wave in Fig.3(a,b). This figure shows the reference inductor current i_{Lref} , the inductor current i_L, and the gate drive signal x for transistor. Transistor is ON when x = 1 and it is OFF when x =0. The ON and OFF state of the transistor produces an increase and decrease in the inductor current i_L.

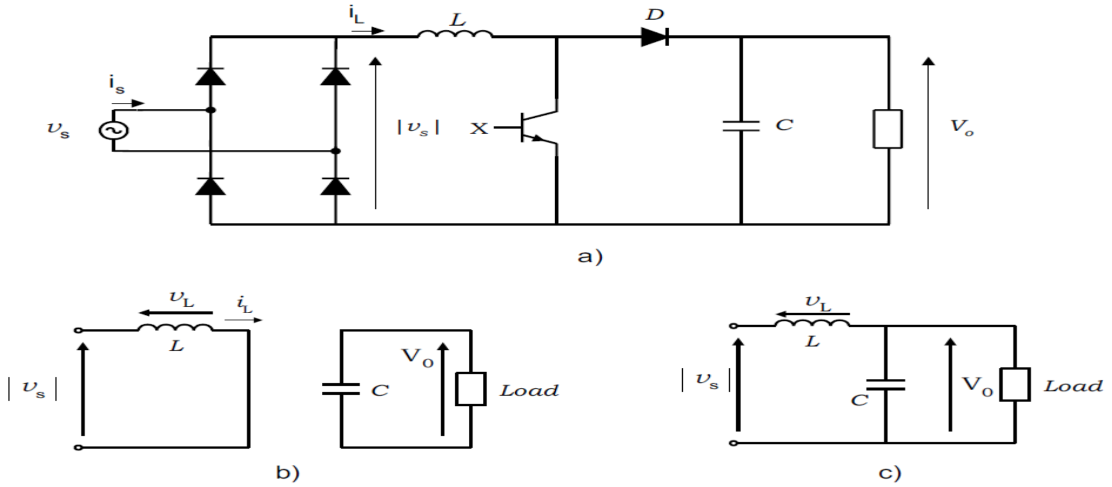

Fig. 2: The On and Off Stage of Boost Rectifiers

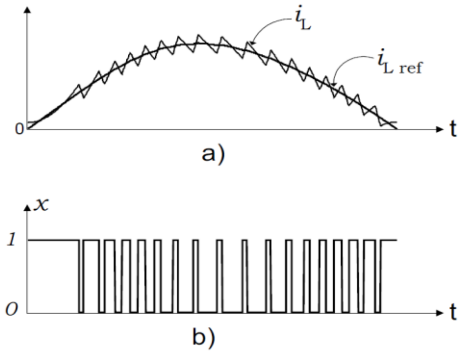

Fig. 3: Behavior of inductive current - (a) Waveforms (b) Transistor T gate drive signal x. The PFC properties of a boost converter can be estimated from the given plots.

Circuitry and Simulation Diagrams of a PFC Circuit without Any Feedback

The classical boost regulated PFC circuit is implemented here. IRF 540 power mosfet used as switch. No feed back part attached with. That’s why the full control over the circuit is absent here.

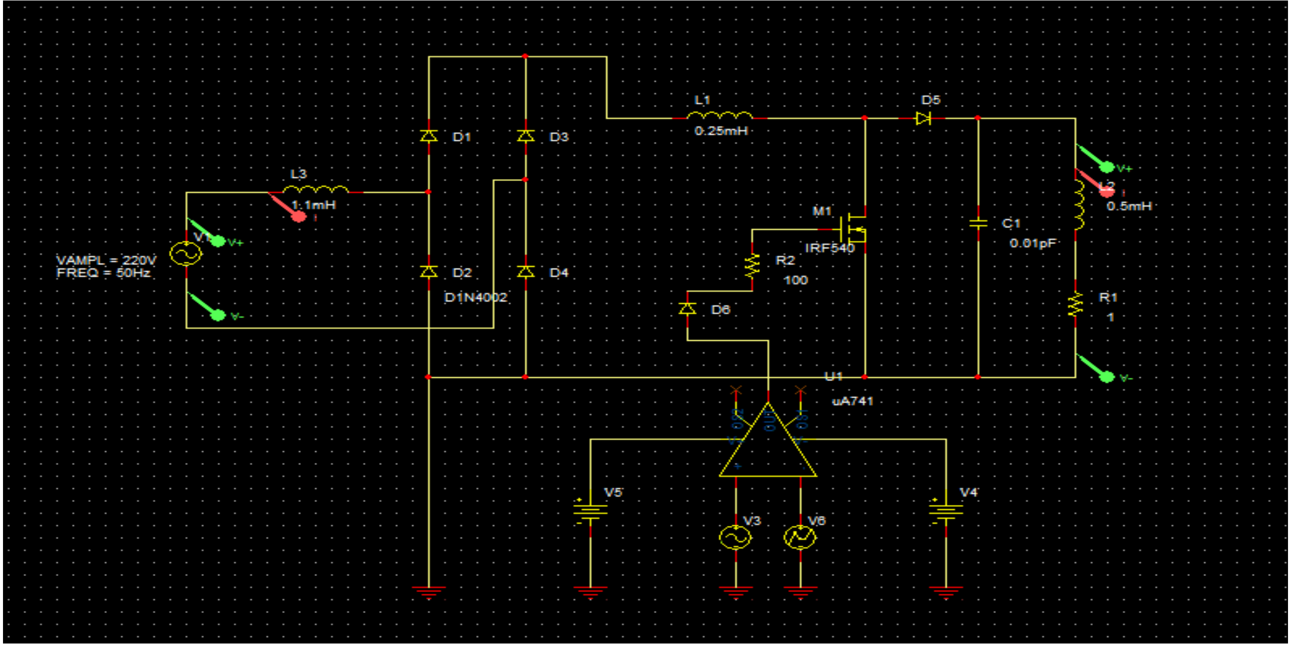

Fig. 4: PFC Circuit without Feedback

The RMS wave contributes to calculate the power factor.

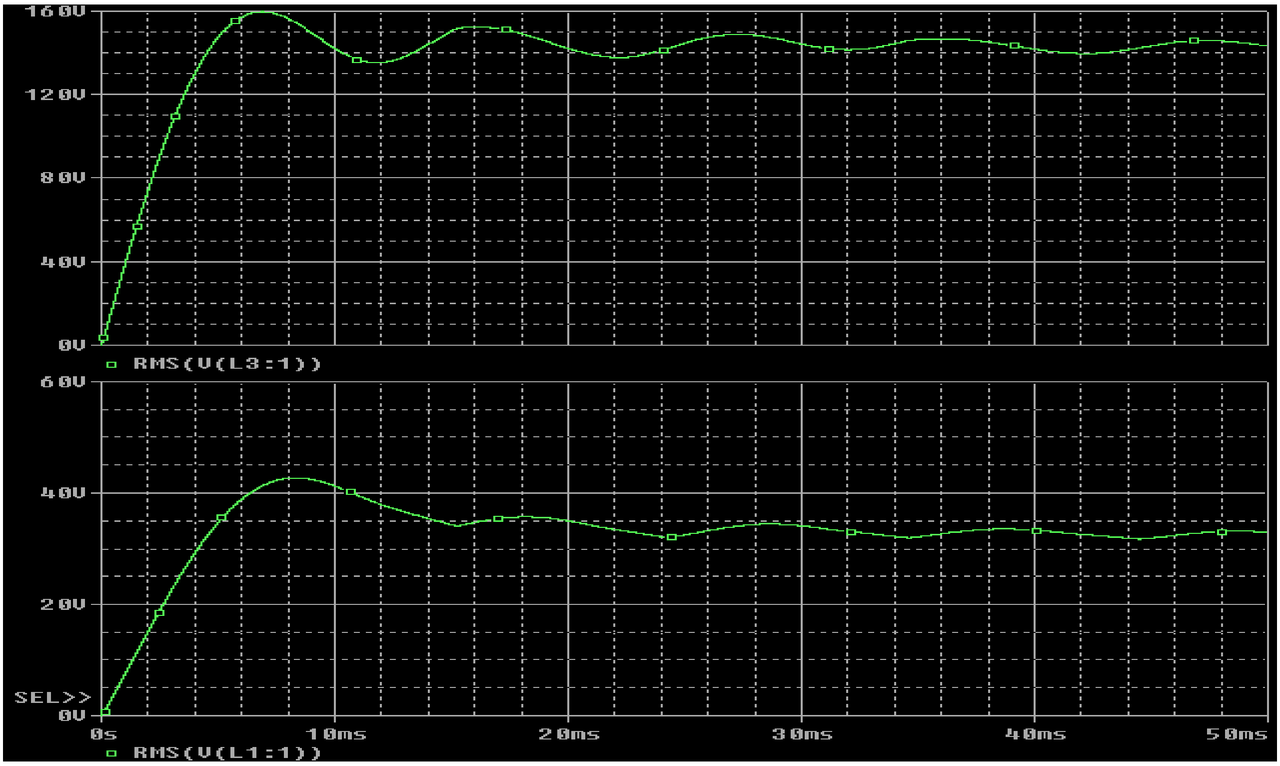

Fig. 5: RMS Wave of Input and Output Voltage

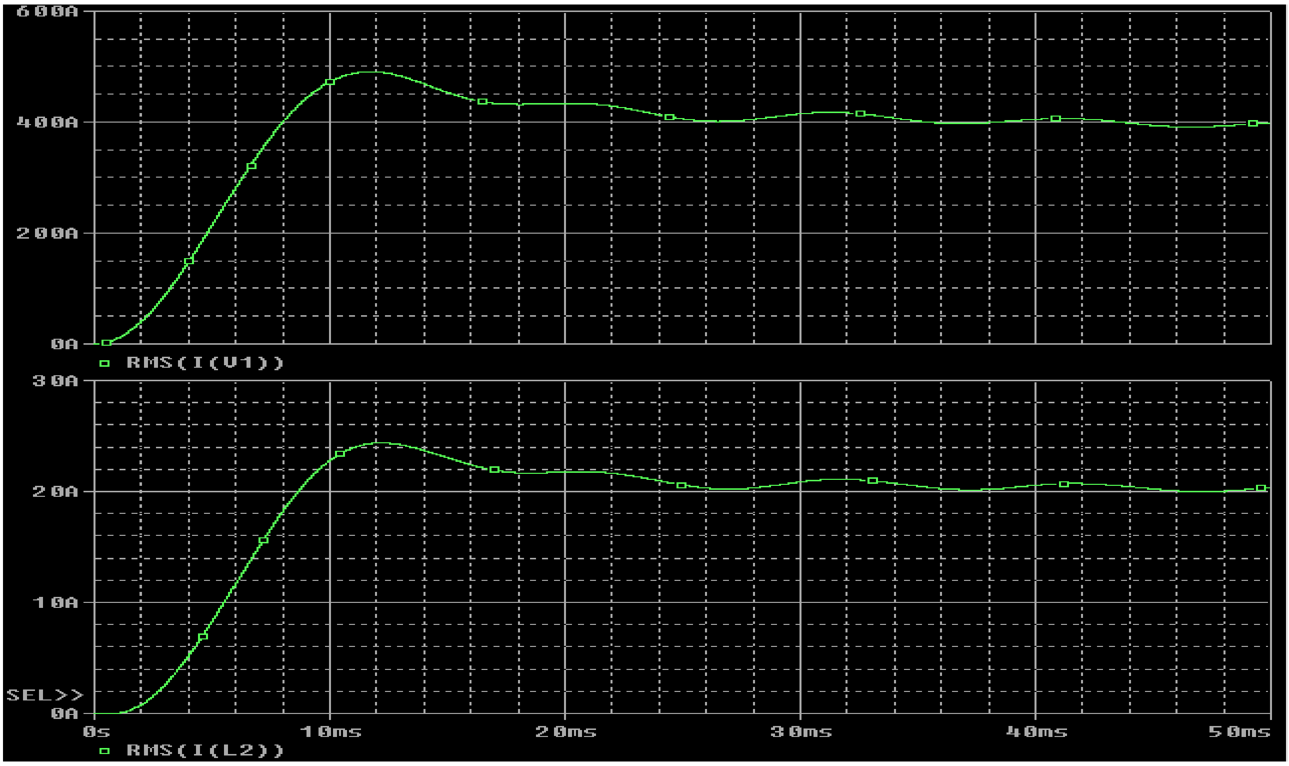

Fig. 6: RMS wave of Input and Output Current

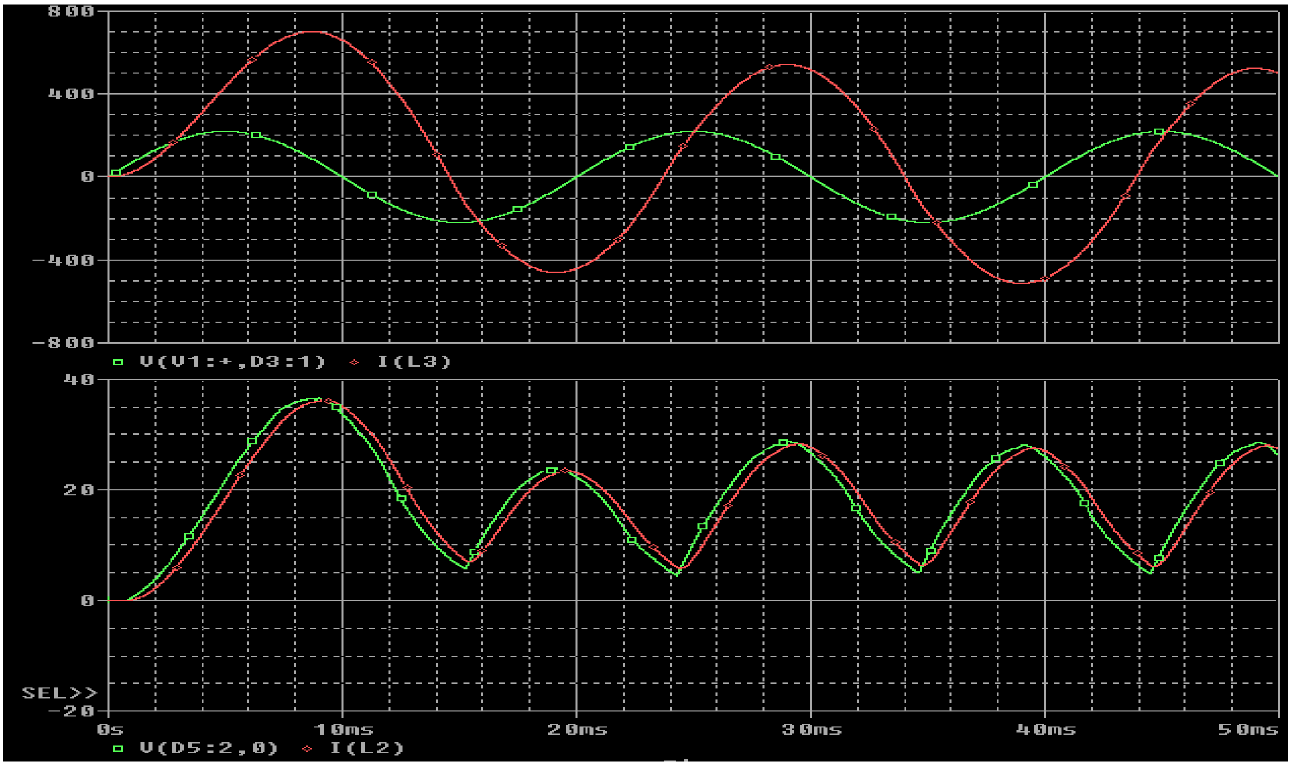

Fig. 7: Input and Output Curves PFC Circuit using Boost Converter without Feedback

From the figures it is clear that for inductive load current lags. Because of comparative better power factor, the lags a little. This least situation is also be removed within next circuit design.

Proposed Circuitry and Simulation Diagram of a PFC Circuit having Parallel Boost Converter with Feedback

This is our final effort-boost controlled PFC circuitry with feedback system. The key which make the difference, is the usage of two different type of power mosfet. P-type and N-type. Which specify the specified boost regulator loop at separate time. The PWM creates a square wave by comparing the saw-tooth with the sinusoidal wave which came from CEA. The output of CEA varies with the variation of load. Agate drive IC should have to be implemented which was given at ACM control mode design but is absent here. Cause the accurate gate drive IC model IR2771C was not available in our library and the IR2771 model is obsolete. We used a resistance and diode instead. Some times in practical, the mosfet supplies back some of the current that which is harmful for the system. To avoid this, a diode is used as reverse for that backing current. MOSFET needs 1-2A current flow to its gate to work as a switch.

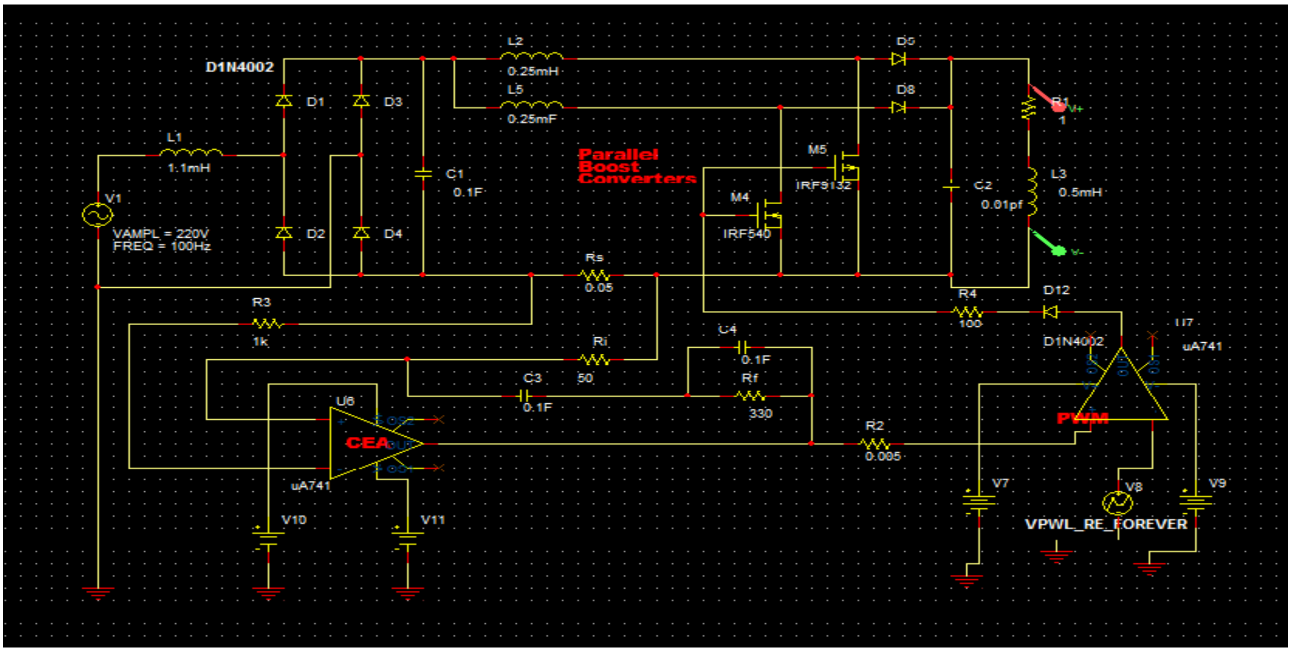

Fig. 8: PFC Circuit with Parallel Boost Converter with Feedback

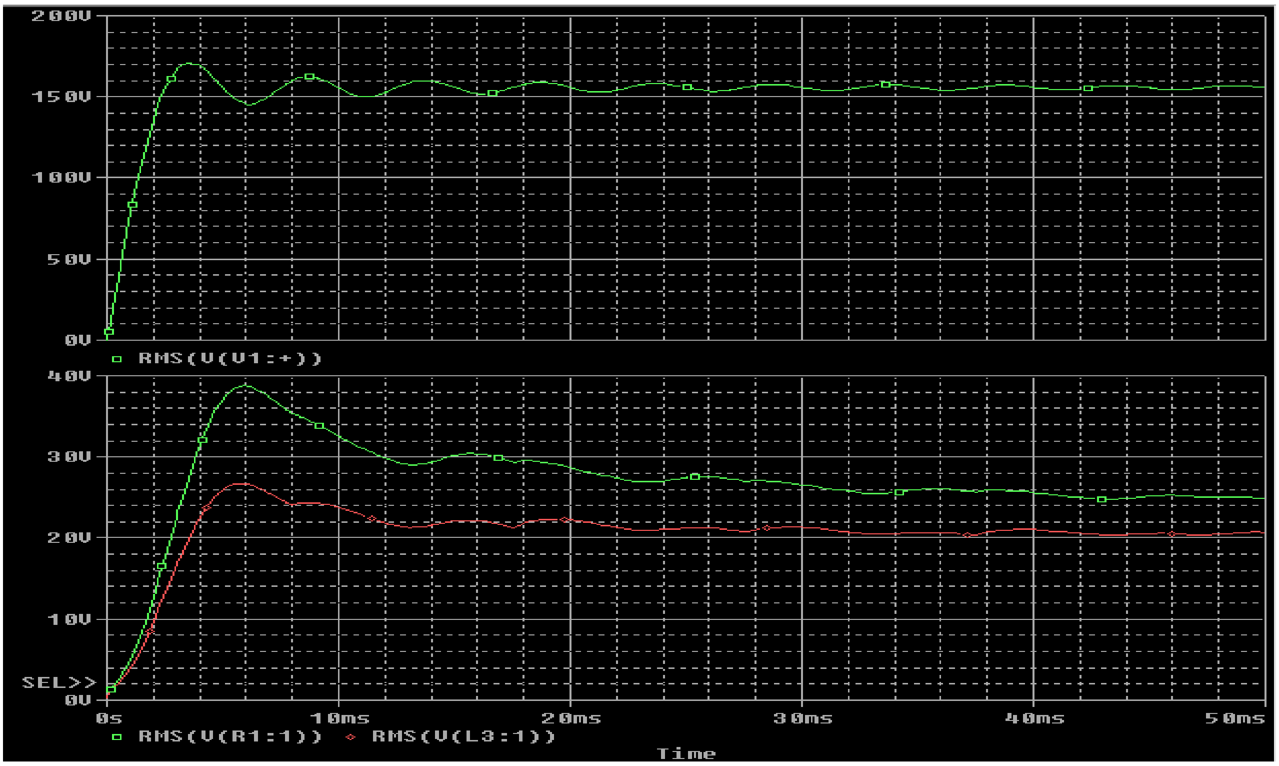

Fig. 9: RMS Wave of Input and Output Voltage

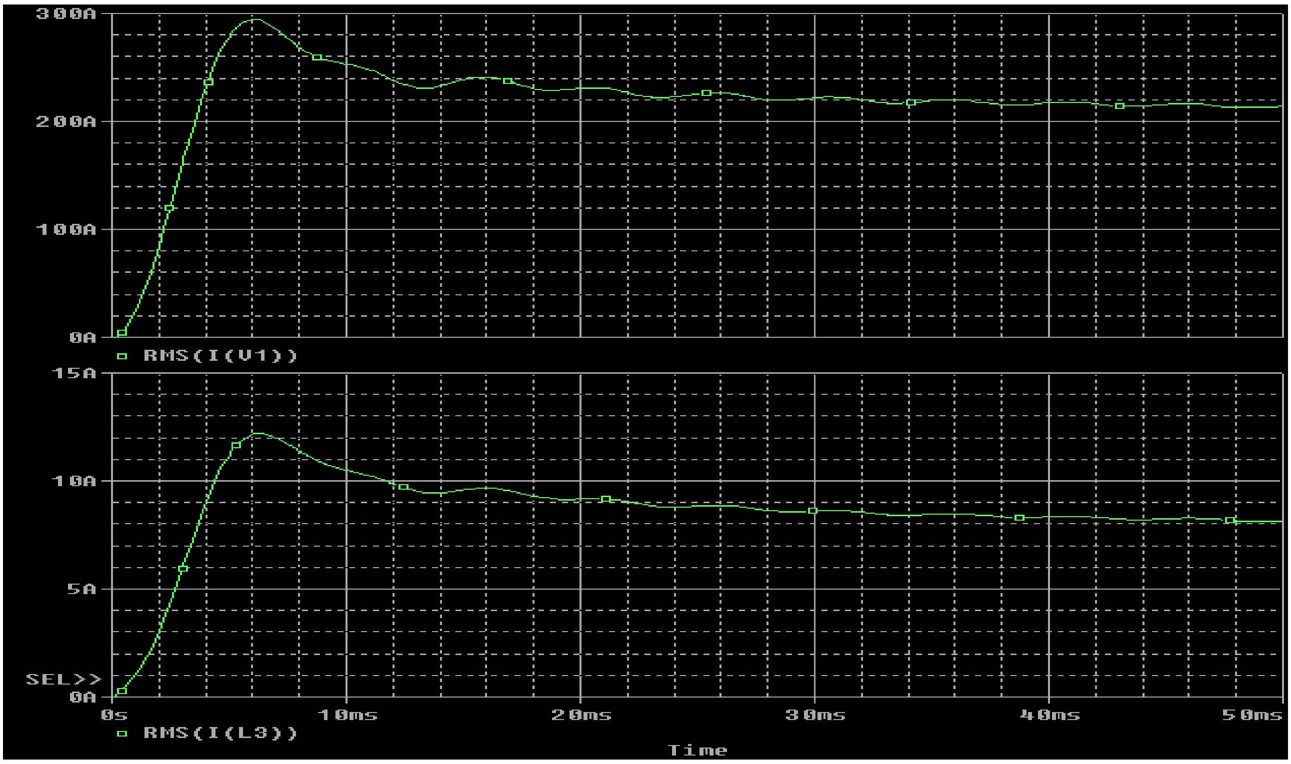

Fig. 10: RMS Wave of Input and Output Current

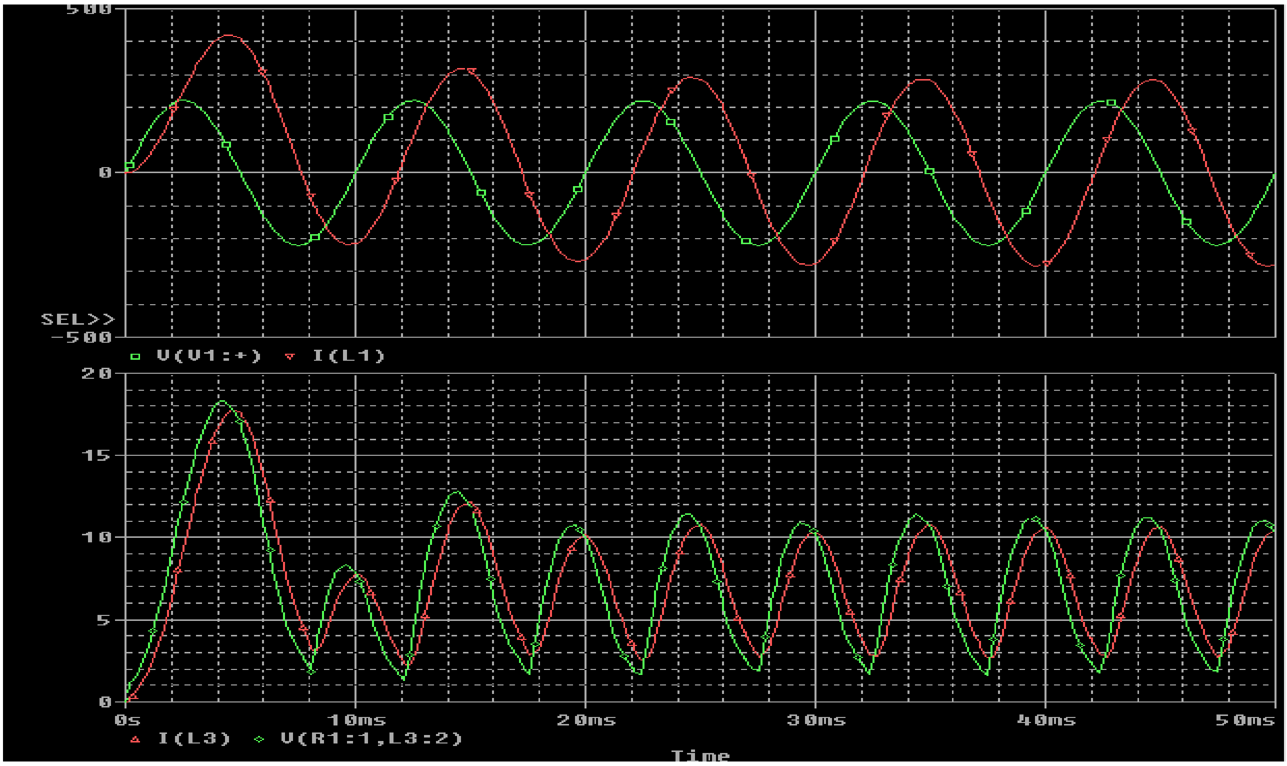

Fig. 11: Input V-I Wave Shape and Output V-I Wave Shape

Here we have found our longed curve which represents a very successful power factor as practical. On the previous circuit, the power factor could be recommended as better and this could be the best.

Comparison between the Output Wave Shapes of Last Two Circuitry

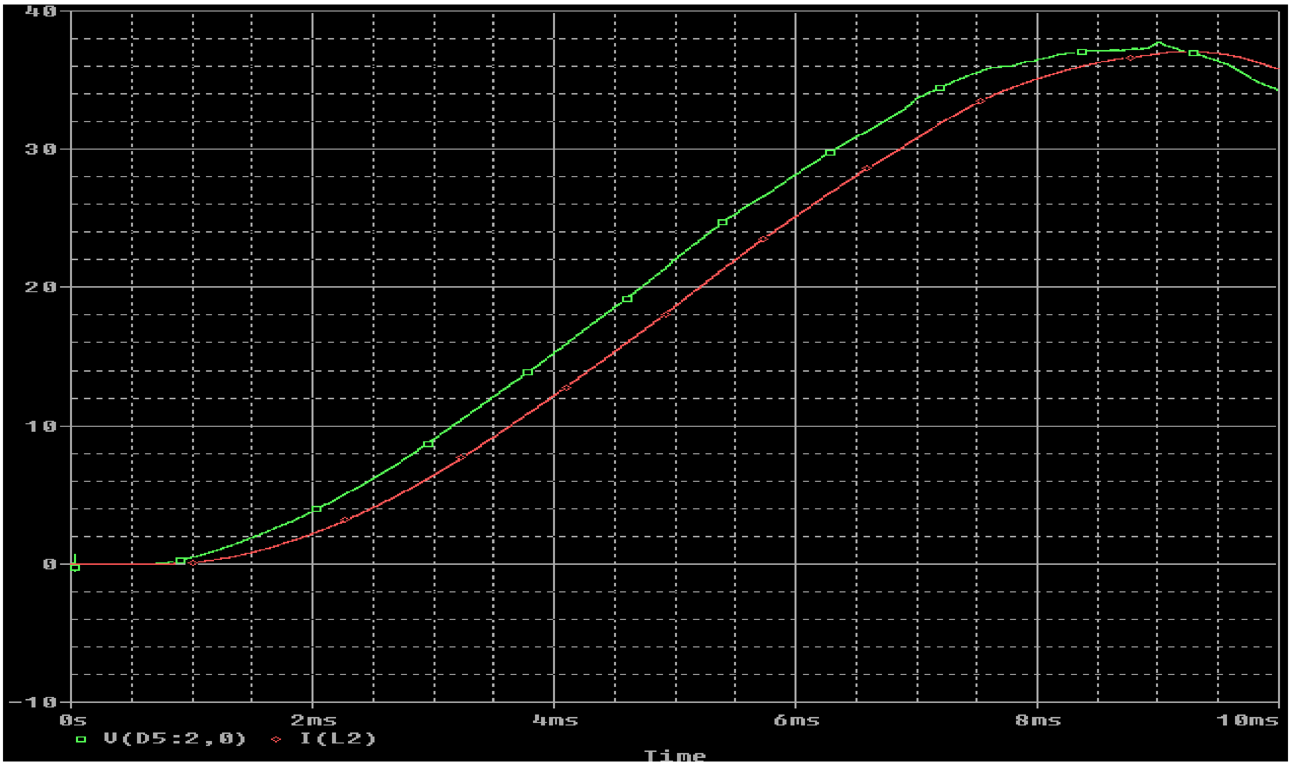

Fig. 12: PFC Circuit using Boost Converter **without** Feedback

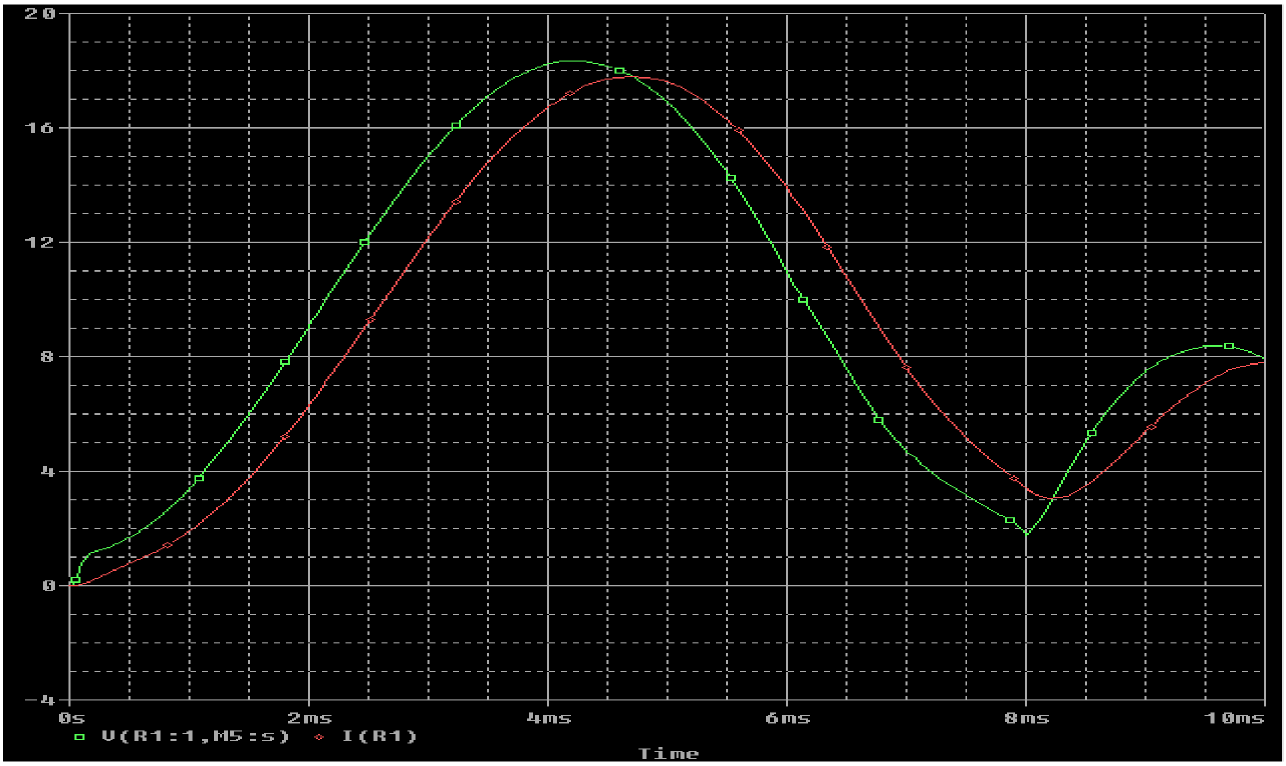

Fig. 13: PFC Circuit using Parallel Boost Converter **with** Feedback

Here, in the 1st figure we see that without using the feedback circuit the V-I curve starts at approximately 1millisec,which represents that pf is not that improved. But if we add a feedback circuit this phenomena is been removed.

Future Expectancy

What we implement here is could be the most recent innovation which brought the power factor much nearer to unity. One of our assumptions, so far the gain of current control loop go accurate and synchronous, the improvement of power factor could go far as well. And adding of a more perfect capacity load can give more better power factor by offsetting the inductive load. Here we used 0.01pF capacitor in parallel to the R-L load and found the power factor much better.

Conclusion

On the continuation of the analysis, we found the causes behind the poverty of power factor first We eliminate the effects of harmonics so far. We used parallel topology of boost converter, where one boost converter improves and another filters the power factor. It also mentioned the further expectancy in this sect. We hope, this paper will be a most innovative and important handbook to improve the power factor for non-linear loads.

Acknowledgements

The authors would like to acknowledge with gratitude the support provides by the Dept. of EEE, Manarat International University, Dhaka, Bangladesh and Dept. of EEE, Ahsanullah University of Science and Technology, Dhaka, Bangladesh.

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