

Power Factor Enhancement Using Active Power Factor Correction Methods.

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Abstract: Single-phase switch mode ac-dc converters are being used as front-end rectifiers for a variety of applications due to the advantages of high efficiency and power density. The mains current in an ac/dc converter contains periodic current pulses due to the action of rectifier and output filter capacitor. The main focus of this study is to review various existing wave shaping methods in terms of their efficiency and power factor. Among the various wave shaping techniques, the improved active current wave shaping methods are analyzed and are simulated in PSIM software. The active method using a boost converter topology where MOSFET switch driven by the rectangular pulses of continuously varying duty cycle over a period of supply voltage is analyzed in this paper.

Key Word: MOSFET switch, Single-phase switch mode ac-dc converters

I. Introduction

Improvements in power factor and total harmonic distortion can be achieved by modifying the input stage of the diode rectifier filter capacitor circuit. Passive solutions can be used to achieve this objective for low power applications. With a filter inductor connected in series with the input circuit, the current conduction angle of the single-phase full-wave rectifier is increased leading to a higher power factor and lower input current distortion. With smaller values of inductance, these achievements are degraded.

However, the large size and weight of these elements, in addition to their inability to achieve unity power factor or lower current distortion significantly, make passive power factor correction more suitable at lower power levels. The power factor correction (PFC) technique has been gaining increasing attention in power electronics field in recent years. For the conventional single-phase diode rectifier, a large electrolytic capacitor filter is used to reduce dc voltage ripple. This capacitor draws pulsating current only when the input ac voltage is greater than the capacitor voltage, thus the THD is high and the power factor is poor. To reduce THD and improve power factor, passive filtering methods and active wave-shaping techniques have been explored. Reducing the input current harmonics to meet the agency standards implies improvement of power factor as well. Several techniques for power factor correction and harmonic reduction have been reported and a few of them have gained greater acceptance over the others. Commercial IC manufacturers have introduced control ICs in the market for the more popular techniques. In this paper, the developments in the field of single-phase PFC are reviewed. In this paper the hysteresis control method and average current control method is analysed and simulated using PSIM software and results are obtained near unity power factor.

II. Single Phase Boost Converter Topology

Design of input filters for power factor improvement in buck converters is therefore complex and provides only limited improvement in input current quality. On the other hand the boost type converter generate dc voltage, which is higher than the input ac voltage. However, the input current in these converters flows through the inductor and therefore can easily be actively wave-shaped with appropriate current mode control. Moreover, boost converters provide regulated dc output voltage at unity input power factor and reduced THD of input ac current. These converters have found widespread use in various applications due to the advantages of high efficiency, high power density and inherent power quality improvement at ac input and dc output.

The preferred power circuit configuration of single-phase boost converter is the most popular and economical PFC converter consisting of diode bridge rectifier with step-up chopper. The single phase boost converter with uni-directional power flow shown in Figure 1 is realized by cascading single-phase diode bridge rectifier with boost chopper topology.

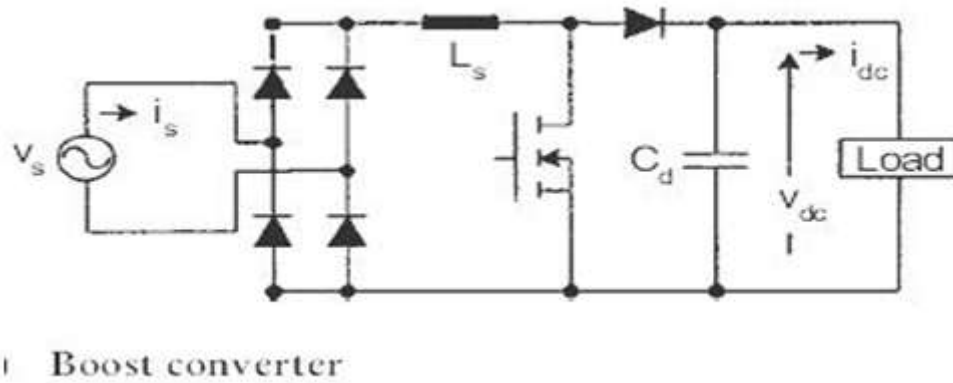


Figure 1

III. Power Factor Correction Techniques

In recent years, single-phase switch-mode AC/DC power converters have been increasingly used in the industrial, commercial, residential, aerospace, and military environment due to advantages of high efficiency, smaller size and weight. However, the proliferation of the power converters draw pulsating input current from the utility line, this not only reduce the input power factor of the converters but also injects a significant amount of harmonic current into the utility line. To improve the power quality, various PFC schemes have been proposed. There are harmonic norms such as IEC 1000-3-2 introduced for improving power quality. By the introduction of harmonic norms now power supply manufacturers have to follow these norms strictly for the remedy of signal interference problem.

The various methods of power factor correction can be classified as:

- (1) Passive power factor correction techniques
- (2) Active power factor correction techniques

In passive power factor correction techniques, an LC filter is inserted between the AC mains line and the input port of the diode rectifier of AC/DC converter as shown in Figure 1. This technique is simple and rugged but it has bulky size and heavy weight and the power factor cannot be very high [1]. Therefore it is now not applicable for the current trends of harmonic norms. Basically it is applicable for power rating of lower than 25W. For higher power rating it will be bulky.

In active power factor correction techniques approach, switched mode power supply (SMPS) technique is used to shape the input current in phase with the input voltage. Thus, the power factor can reach up to unity. Figure 2 shows the circuit diagram of basic active power correction technique. By the introduction of regulation norms IEC 1000-3-2 active power factor correction technique is used now a day.

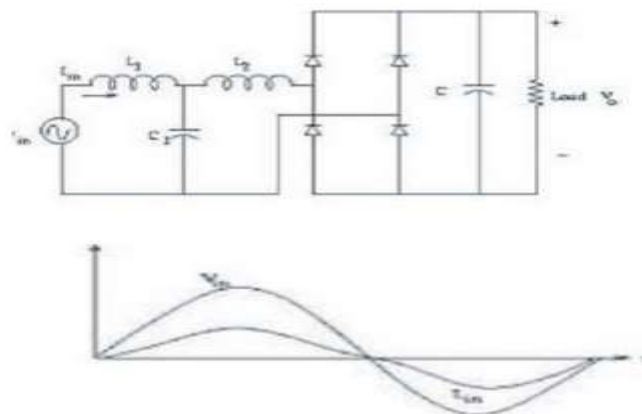


Figure 1: Passive PFC technique.

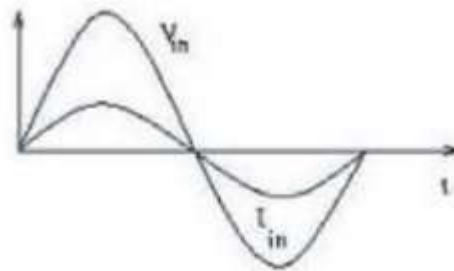
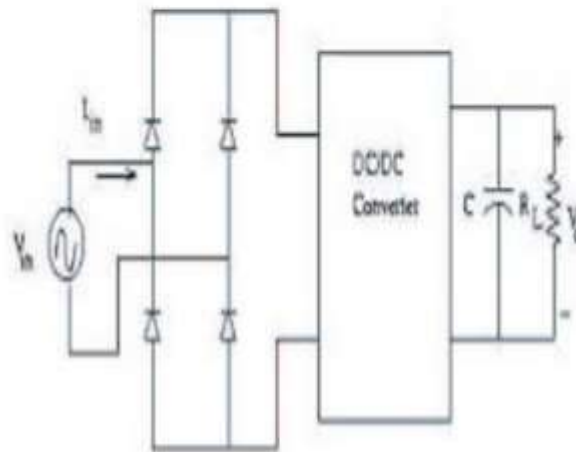


Figure 2: Active PFC technique.



The active PFC techniques can be classified as: (1) PWM power factor correction techniques; (2) Resonant power factor correction techniques; (3) Soft switching power factor correction techniques

In PWM power factor correction approach, the power switching device operates at pulse-width-modulation mode. Basically in this technique switching frequency of active power switch is constant, but turn-on and turnoff mode is variable. Different topologies of PWM techniques are as follows: (1) Buck type (2) Flyback type (3) Boost type (4) Cuk' type

IV. Different Control Techniques

There are various types of control schemes present for improvement of power factor with tight output voltage regulation .viz. (a) Peak current control method (b) Average current control method (c) Borderline current control method (d) Discontinuous current PWM control method (e) Hysteresis control method

Peak Current Control Method

Switch is turned on at constant frequency by a clock signal, and is turned off when the sum of the positive ramp of the inductor current (i.e. the switch current) and an external ramp (compensating ramp) reach the sinusoidal current reference. This reference is usually obtained by multiplying a scaled replica of the rectified line voltage v_g times the output of the voltage error amplifier, which sets the current reference amplitude. In this way, there reference signal is naturally synchronized and always proportional to the line voltage, which is the condition to obtain unity power factor .

Average Current Control Method

Here the inductor current is sensed and filtered by a current error amplifier whose output drives a PWM modulator. In this way the inner current loop tends to minimize the error between the average input current and its reference. This latter is obtained in the same way as in the peak current control. The converter works in CICM, so the same consideration done with regard to the peak current control can be applied.

Boderline Control Method

In this control approach the switch on-time is held constant during the line cycle and the switch is turned on when the inductor current falls to zero, so that the converter operates at the boundary between Continuous and Discontinuous Inductor Current Mode (CICM-DICM).

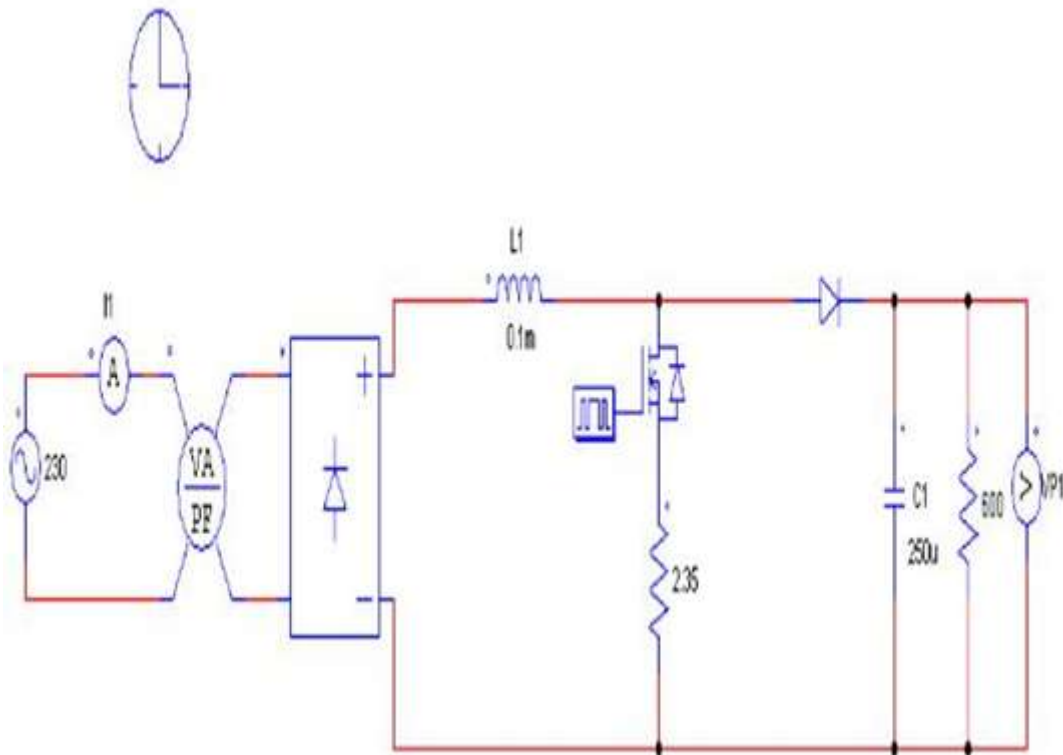
Discontinuous Current PWM Control Method

With this approach, the internal current loop is completely eliminated, so that the switch is operated at constant on-time and frequency. With the converter working in discontinuous conduction mode (DCM), this control technique allows unity power factor when used with converter topologies like fly back, Cuk and Sepic. Instead, with the boost PFC this technique causes some harmonic distortion in the line current.

Hysteresis Control Method

Two sinusoidal current references $I_{P,ref}$, $I_{V,ref}$ are generated, one for the peak and the other for the valley of the inductor current. According to this control technique, the switch is turned on when the inductor current goes below the lower reference $I_{V,ref}$ and is turned off when the inductor current goes above the upper reference $I_{P,ref}$, giving rise to a variable frequency control. Also with this control technique the converter works in CICM. In this paper the hysteresis control method and average current control method is analysed and simulated using PSIM software and results are obtained near unity power factor.

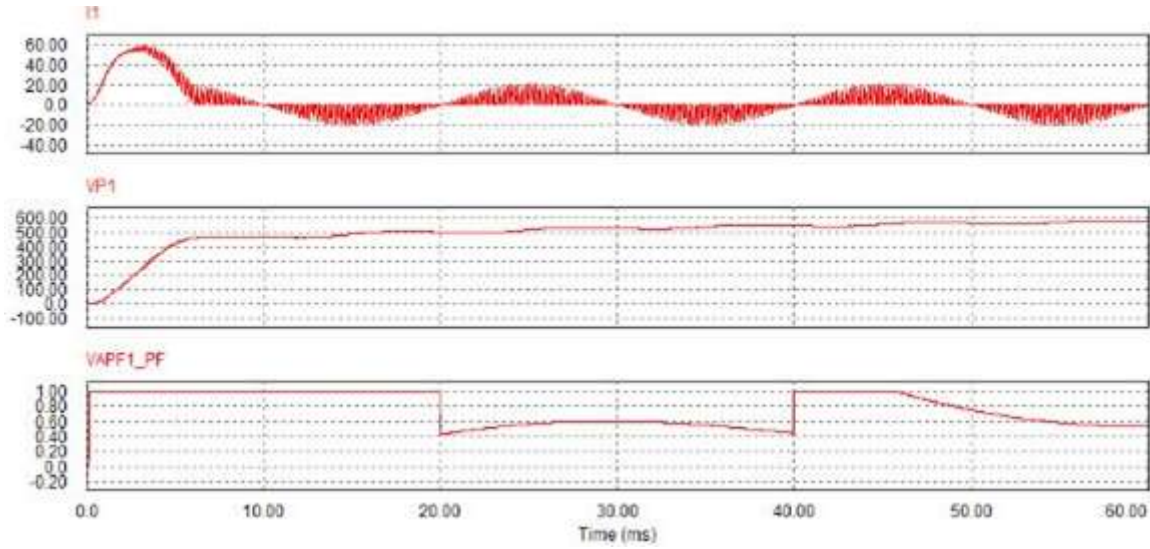
V.Simulation Results



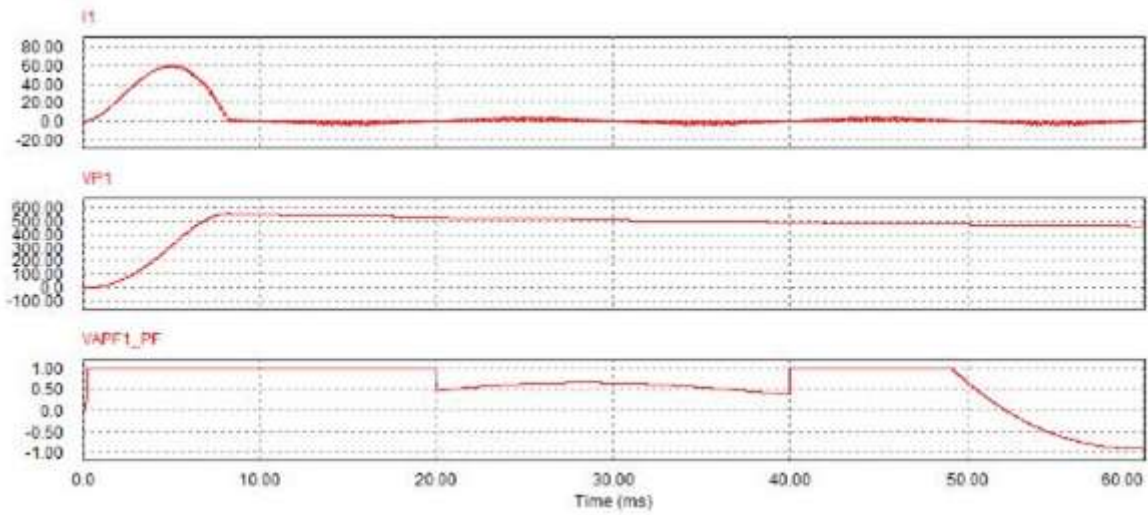
Effect of various parameters present in the circuit on the output voltage regulation & input power factor without control circuit.

Effect of inductor: (capacitor=250uF &resistance=600ohm)

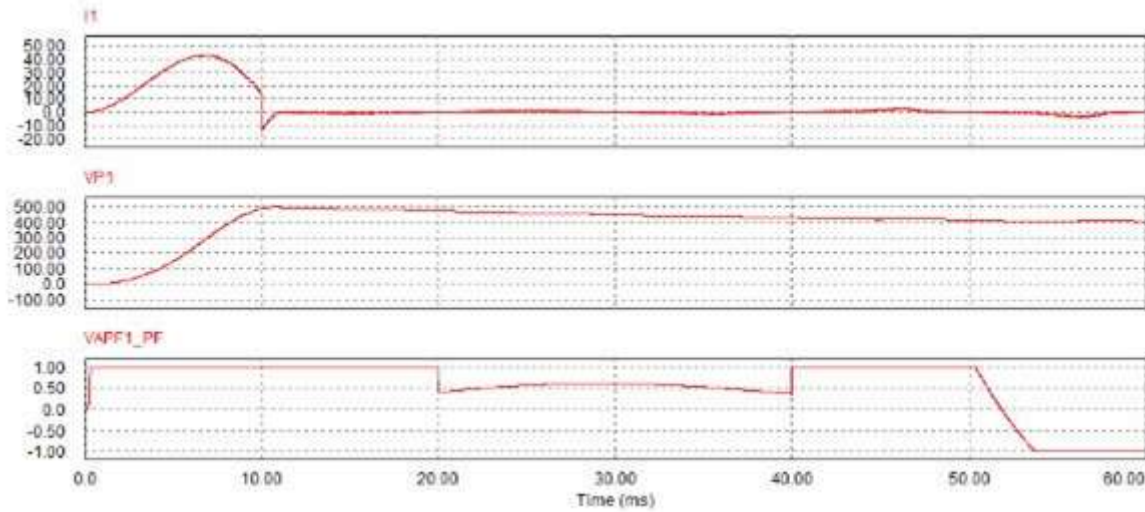
1.L=1m H p.f=.768



vout=501v
2. L=5mH p.f.=.613 &vout=468.5v

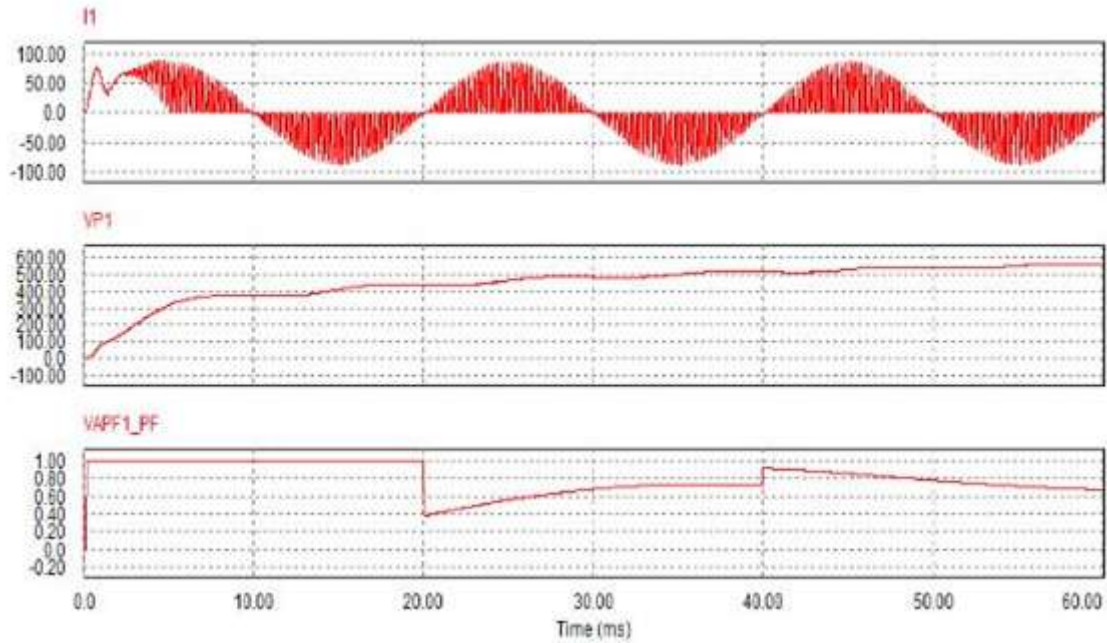


2. L=5mH p.f.=.613 &vout=468.5v



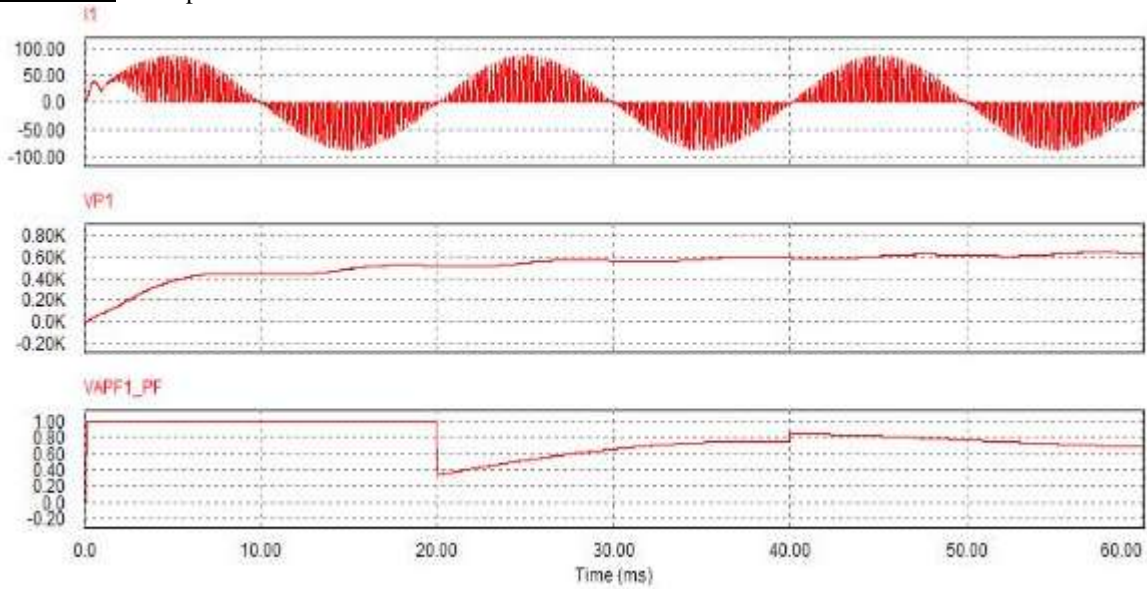
From the above it is concluded with increase in inductor pf & avg output voltage reduces.

1.C=500uF

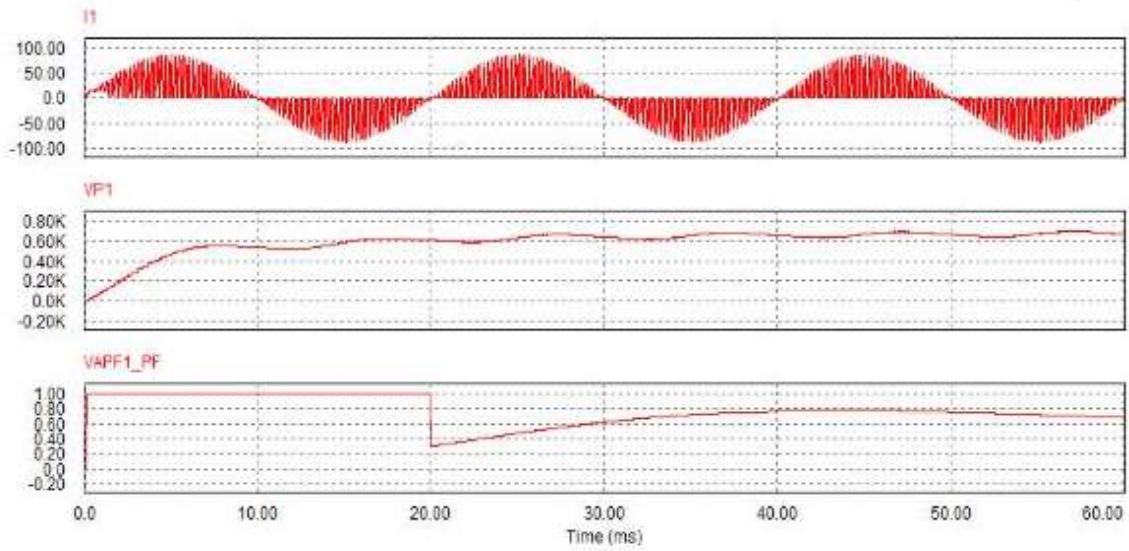


p.f=.81 &vout=454V

2.C=250uF p.f=.792 &vout=523V

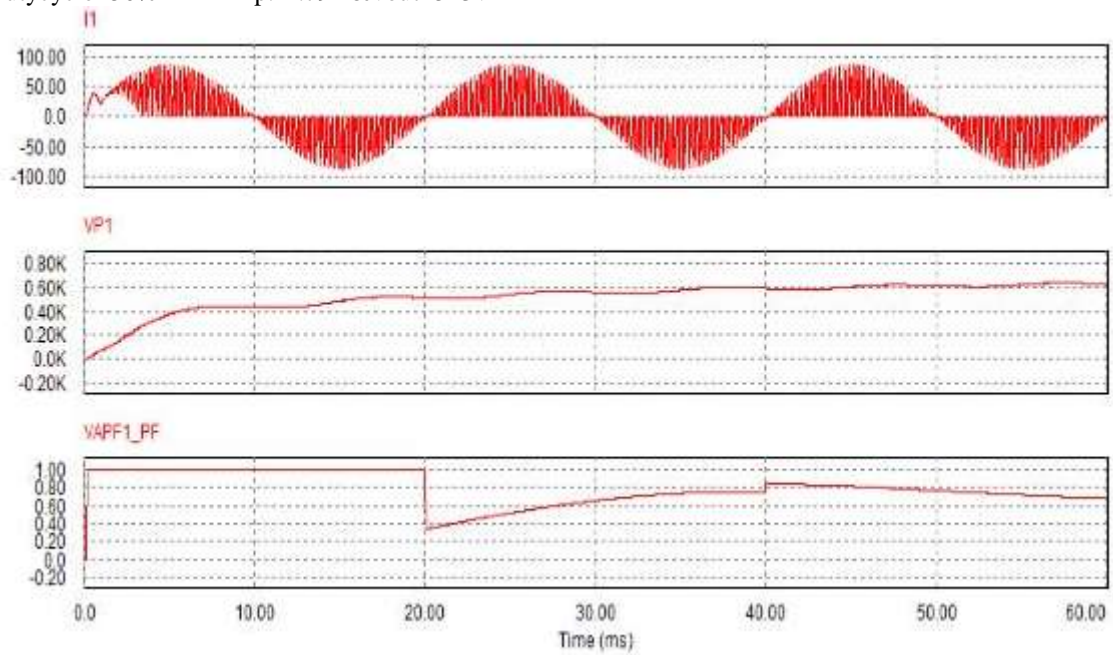


3.c=100uF p.f=.76 &vout=607V

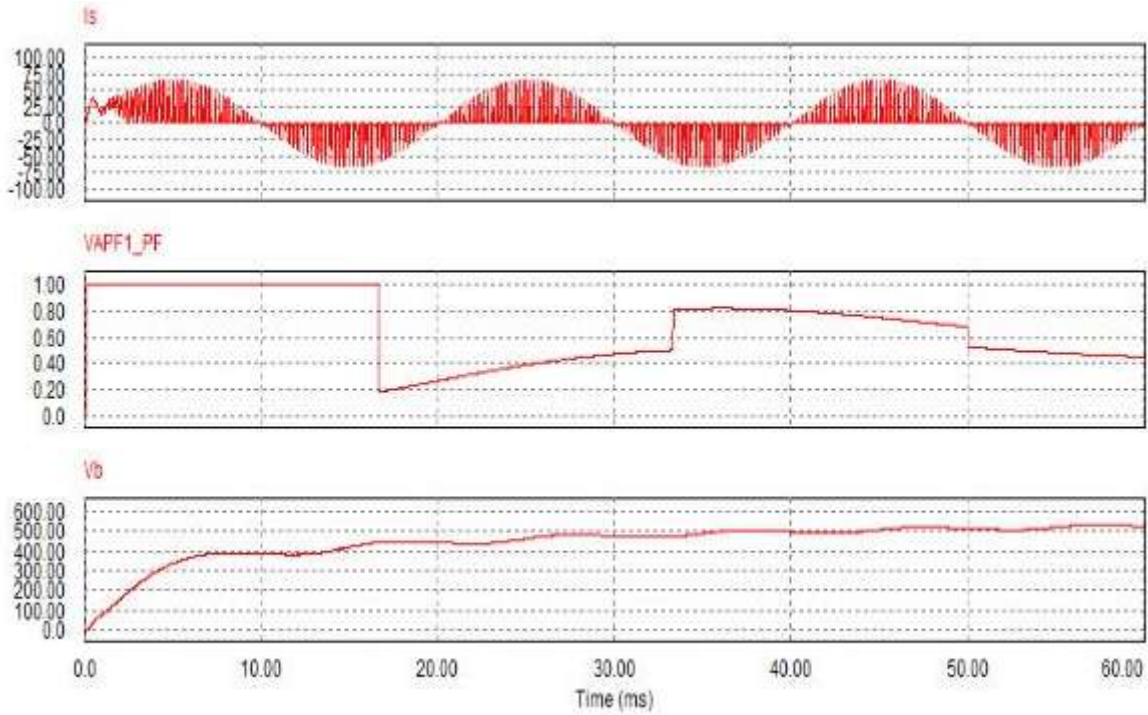


Effect of duty cycle:($L=1\text{m}$, $c=250\mu$ & $R=600\text{ohm}$)

1.Duty cycle=50% p.f=.792 & $v_{out}=523\text{v}$

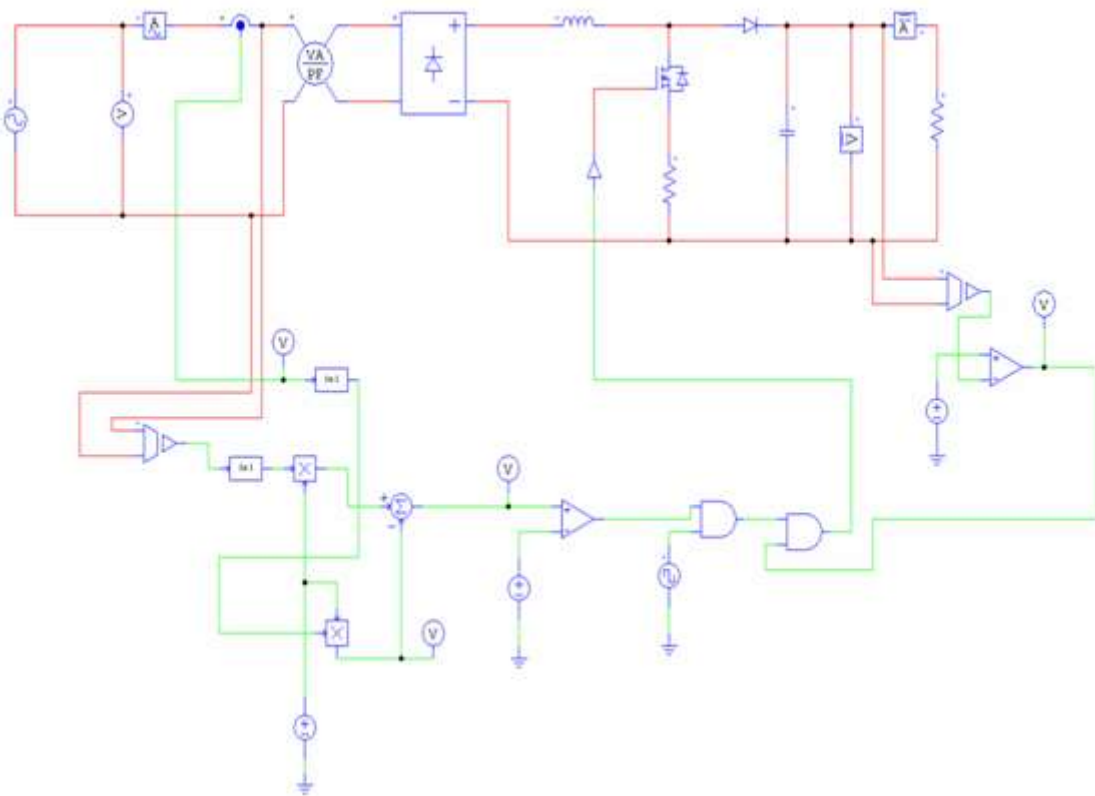


2. Duty cycle=25% p.f=.68 &vout=441V



From above it can be concluded that with rise in duty cycle p.f increases &vout rises

Average Current Control Method



POWER FACTOR IS FOUND TO BE UNITY

V. Conclusion

Most electronic equipment is supplied by 50 Hz utility power, and in almost all of them power is processed through some kind of power converter. Usually, power converters use a diode rectifier followed by a bulk capacitor to convert AC voltage to DC voltage. Unless some correction circuit is used, the input rectifier with a capacitive filter circuit will draw pulsating currents from the utility grid resulting in poor power quality and high harmonic contents that adversely affect other users. Active PFC solutions are a more suitable option for achieving near unity power factor and sinusoidal input current waveform with extremely low harmonic distortion. In these active solutions, a converter with switching frequencies higher than the AC line frequency is placed in between the output of the diode bridge rectifier and the bulk capacitor. The reactive elements of this converter are small, because their size depends on the converter switching frequency rather than the AC line frequency. The function of this converter is to make the load behave as an ideal resistive load and thus eliminate the generation of line current harmonics.

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