

Bridgeless High Power Factor Buck Converter with Controlled Boost Converter

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Abstract:- Power factor is an important performance parameter of a system. If the power factor of a system is low, it draws more current from the supply. So improving power factor is very much essential for better and economic performance of a system. This paper introduces a new power factor correction circuit which overcomes all the drawbacks of conventional power factor correction approaches. This proposed circuit will provide output voltage range of 257V, with input power factor 0.81 and input current THD of 40%. Here bridgeless buck rectifier output is given as input to the boost converter for maximising the output voltage level. Simulation has been carried out to study the performance of the proposed topology in MATLAB/SIMULINK environment.

Keywords:- Power factor correction (PFC), Bridgeless rectifier, Boost converter, voltage doubler, Total harmonic distortion (THD)

I. INTRODUCTION

The rise in the industrial, commercial and residential applications of electronic equipments has resulted in a huge variety of electronic devices requiring mains supply. These devices have rectification circuits, which is the prominent reason of harmonic distortion. These devices convert AC to DC power supply which causes current pulses to be drawn from the ac network during each half cycle of the supply waveform. This distorted current decreases the power factor of the system. If the power factor of a system at a given power requirement is poor, then large value of Volt- Amperes or large amount of current is required by the system which is drawn from the supply. So various measures are taken to improve the power factor of a system. Thus, in order to decrease the effect of this distortion, power factor correction circuits are added to the supply input side of equipments used in industries and domestic applications. The objective of power factor correction circuits is to make the input to a power supply behave like purely resistive or a resistor. When the ratio between the voltage and current is a constant, then the input will be resistive hence the power factor will be unity.

Power factor correction (PFC) can be classified into active power factor correction and passive power factor correction. In passive PFC [3] passive elements like inductors and capacitors are introduced to improve the nature of the line current. The idea of passive PFC is to filter out the harmonic currents by use of a low pass filter. For achieving better power factor we have to increase the size of the filter this makes the system bulky. An active PFC [3] is a power electronic device designed to control the amount of power drawn by a load and obtains a power factor as close as possible to unity. The active power factor correction (PFC) circuits are widely used to effectively draw the energy from the mains via an AC to DC converter. The active PFC circuits are normally consists of full bridge diode rectifier and DC-DC converter.

In the earlier stages, a bridge diode rectifier followed by a boost converter has been the most commonly used PFC circuit because of its simplicity and good PF performance. This conventional PFC [1] [2] scheme has lower efficiency due to significant losses in the diode bridge. The conventional PFC circuit exhibits 1-3% lower efficiency at 100-V line compared to that at 230-V line. This drop of efficiency draws more current that produces higher losses in semiconductors. Also it has relatively high output voltage, typically in the 380-400-V range. This high voltage leads to high switching losses and require high rated semiconductor devices. To avoid these drawbacks we can use a bridgeless buck converter for power factor correction. The major drawback of bridgeless buck rectifier is the limitation of output voltage level. If we increase the voltage to a higher level the power factor of the circuit get reduced. To avoid the drawbacks of conventional PFC circuits we can use a bridgeless buck converter with controlled boost converter. This bridgeless PFC rectifier allows the current to flow through a minimum number of semiconductor devices so losses are less. The output of the bridgeless buck rectifier is given to a controlled boost converter to get maximized output with improved power factor.

II. PROPOSED CIRCUIT CONFIGURATION

The block diagram of the proposed converter is shown fig.1. The proposed converter has two parts. The first part consists of bridgeless rectifier and the second part consists of boost converter with feedback control.

Bridgeless buck rectifier[1][5] consists of two buck converters and these two buck converters are connected in voltage doubler manner[2]. That means the two buck converters are connected in a parallel input series output manner. The output of this rectifier is given to a boost converter for maximizing the voltage level.

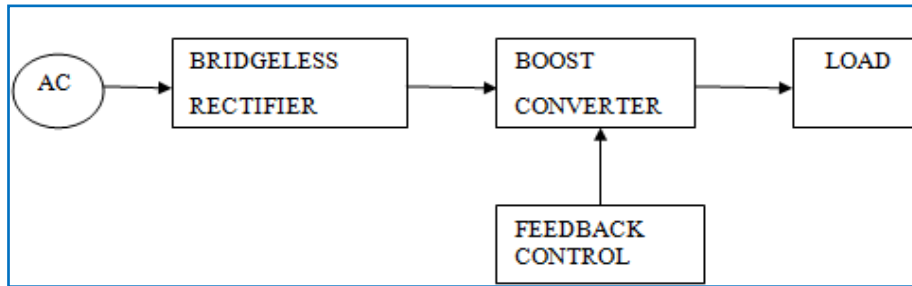


Fig.1. Block diagram of the proposed converter

A. Bridgeless rectifier and boost converter

The circuit diagram of the proposed converter with bridgeless rectifier and boost converter is shown in fig2. The bridgeless rectifier consists of two buck converters connected in a parallel input series output manner. The output of this buck rectifier is given to a boost converter to get a maximized output with improved power factor. During the positive half cycle the upper buck converter consists of switch S_1 and diode D_1 , freewheeling diode D_3 , and inductor L_1 , and capacitor C_1 operates. During the negative half cycle the lower buck converter consists of switch S_2 and diode D_2 , freewheeling diode D_4 and inductor L_2 and capacitor C_2 operates. Boost converter consists of inductor L_3 , switch S_3 , diode D_5 and capacitor C_0 .

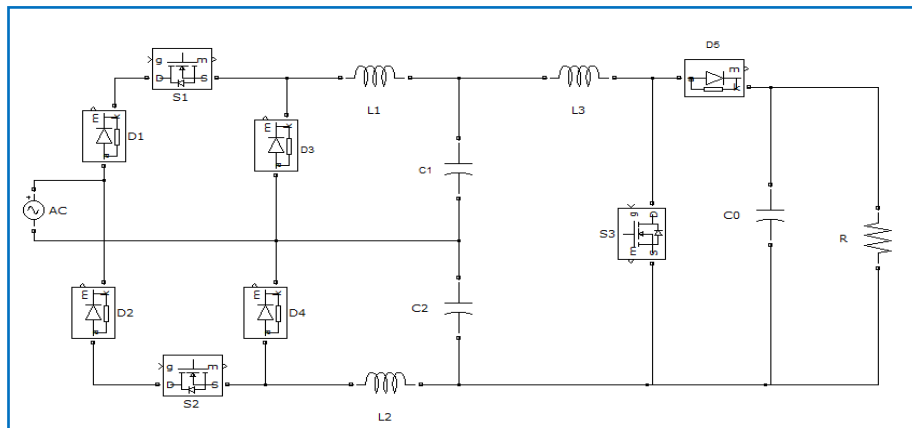


Fig.2. Proposed Converter

During positive half cycle the upper buck converter of the bridge rectifier consists of diode D_1 , switch S_1 , inductor L_1 , capacitor C_1 , freewheeling diode D_3 and the boost converter consists of inductor L_3 , Diode D_5 , switch S_3 and capacitor C_0 operates. When the switch S_1 on inductor L_2 stores energy and when S_1 is off stored energy freewheel through the diode D_3 . The voltage developed across capacitor C_1 is $D V_{in}$ which act as input to the boost converter.

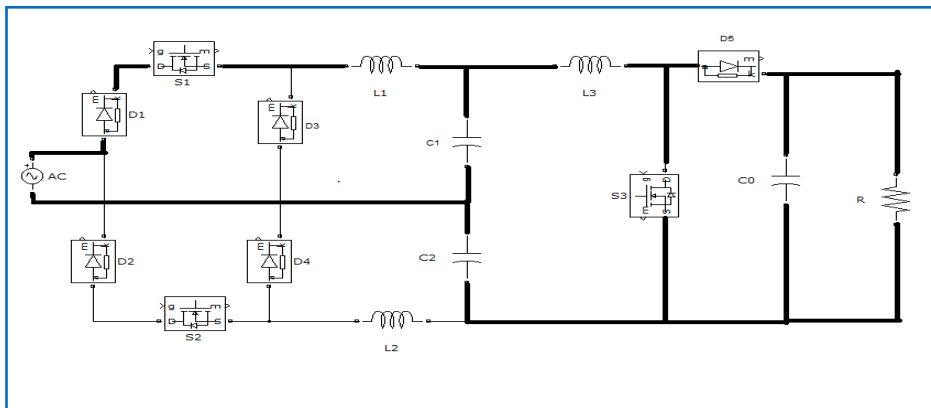


Fig.3. Operation of the circuit during the period when line voltage is positive

During the negative half cycle lower buck converter of the bridge rectifier consists of diode D_2 , switch S_2 , diode D_4 , inductor L_2 and capacitor C_2 and the booster converter operates. When the switch is on inductor L_2 of the lower buck converter stores energy and it is freewheel through diode D_4 when the switch is off. The voltage across the capacitor C_2 is $D V_{in}$ which is given as input to the boost converter. Operation of the circuit during the period when line voltage is positive and negative is shown in fig.3. and fig.4.

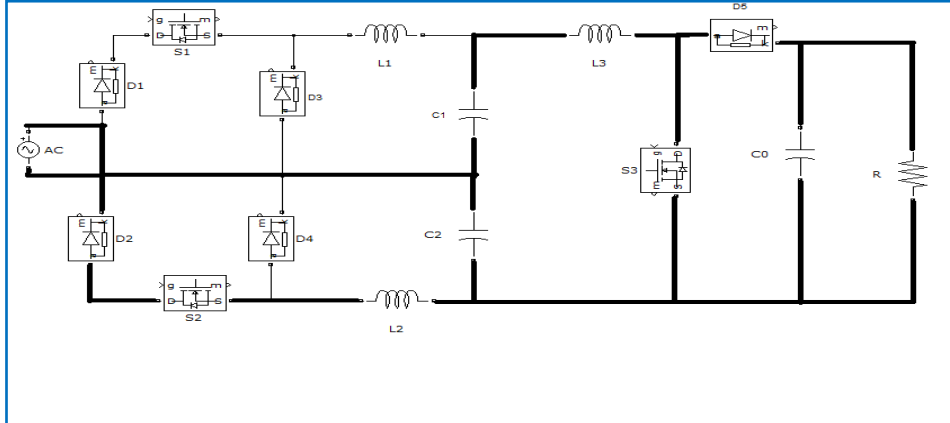


Fig.4. Operation of the circuit during the period when line voltage is negative

B. Feedback control

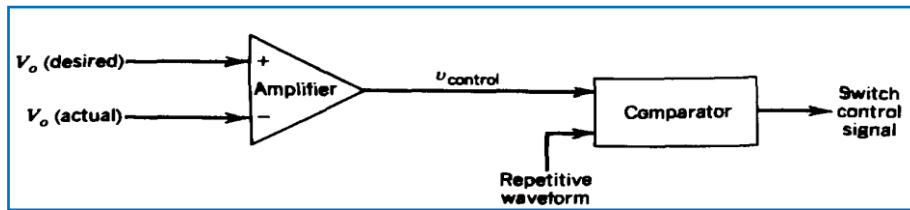


Fig.5. Block diagram for feedback control

Feedback control is provided to boost converter to control the output voltage to the desired level. In a dc-dc converter with a given input voltage the average output voltage is controlled by adjusting the switch on and off durations. The switch control signal will control the state of the switch, which is generated by comparing control voltage $V_{control}$ with a repetitive waveform. The control voltage is generally obtained by amplifying the error signal or difference between actual voltage and desired voltage. Any change in the input voltage is sensed as change in output voltage accordingly the error signal also changes. The error signal is used to change the duty ratio of the switching pulses to keep the voltage constant.

III. SIMULINK MODEL

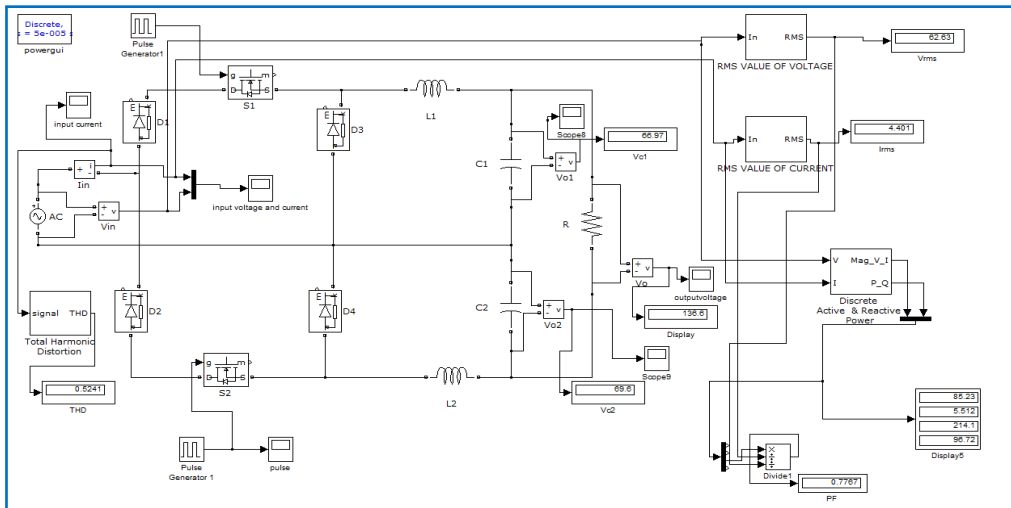


Fig.6. Simulink model of the conventional bridgeless buck rectifier

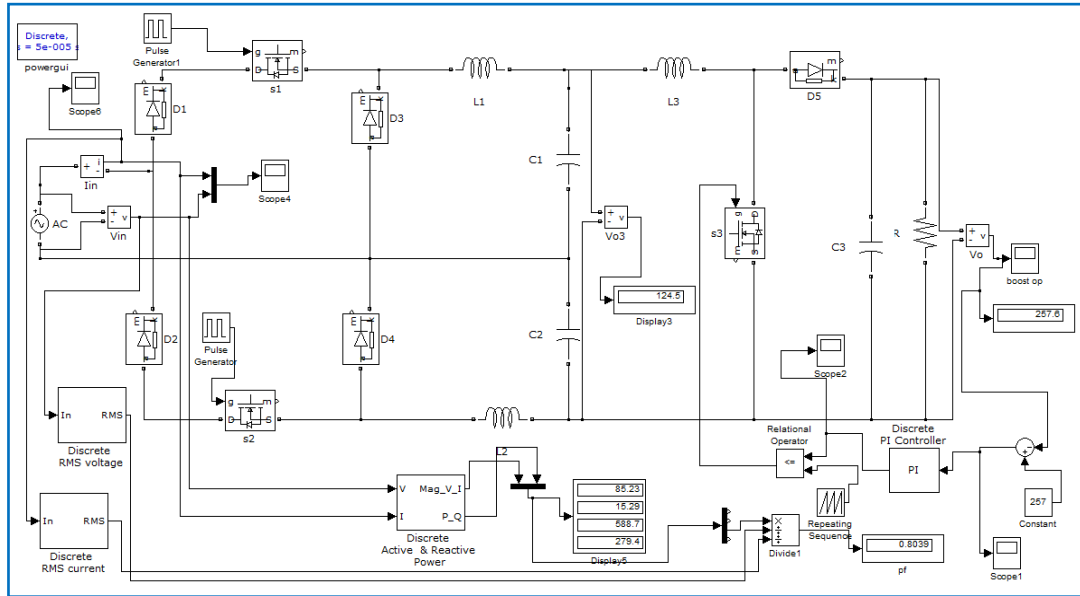
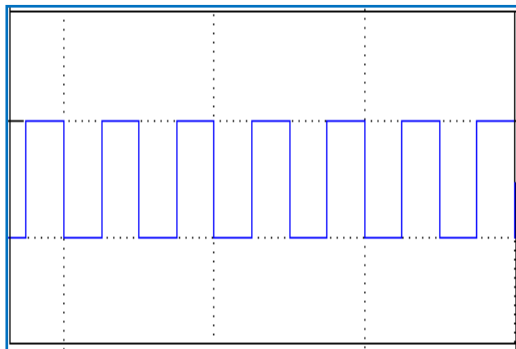


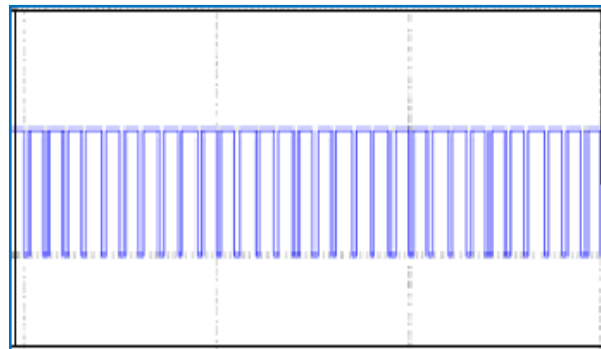
Fig.7. Simulink model of the proposed converter with boost converter and feedback control

IV. SIMULATION RESULT

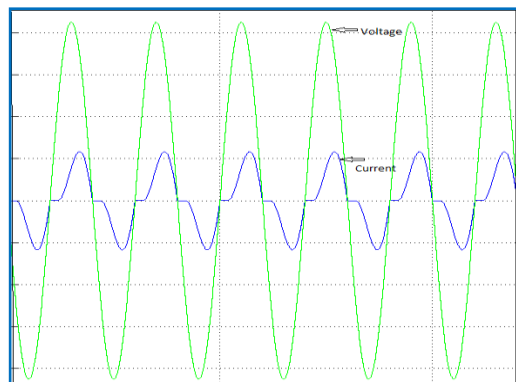
Simulation of the proposed converter and conventional bridgeless buck rectifier is done in MATLAB. Simulink model of the conventional circuit and proposed circuit is shown in fig.7 and fig.8. Simulation is done with an input voltage $V_{rms} = 85$, $f_s = 100$ kHz, $R = 100\Omega$, $L_1 = L_2 = 6$ mH, $C_1 = C_2 = 6000\mu F$, $L_3 = 1$ mH. Bridgeless buck rectifier provide input power factor and the output voltage of .77 and 136 respectively. To improve the input power factor and output voltage range a boost converter with feedback control is connected to the output of the bridgeless buck rectifier. After the addition of boost converter the circuit will provide input power factor and output voltage of .81 and 257 respectively. Simulated waveforms with and without boost converter is shown fig.8. Feedback is provided to the boost converter for controlling the voltage to the desired level. The boost voltage with and without feedback is shown in fig.9. After the feedback control THD is improved from 52% to 40%.



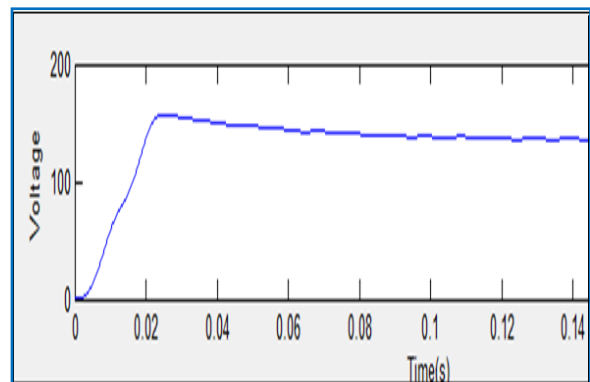
(a)



(b)



(c)



(d)

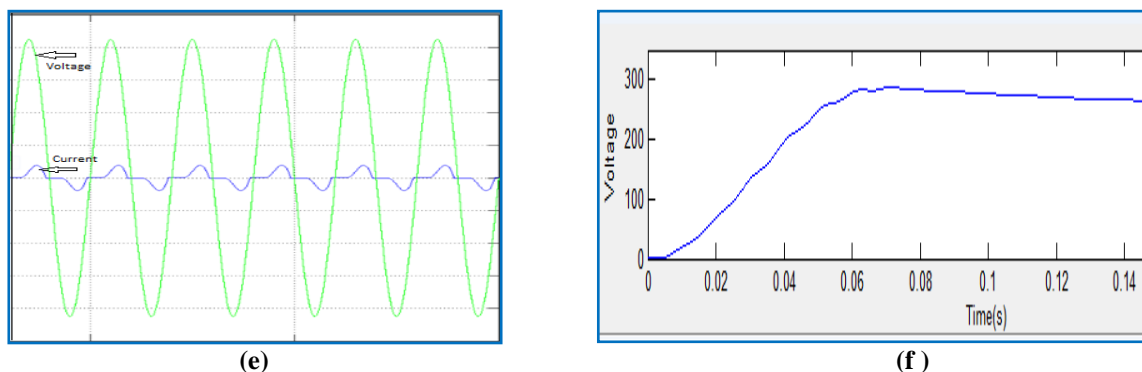


Fig.8. (a) gate signals for s_1, s_2 (b) gate signal for s_3 Simulated waveforms:- with boost converter (c) input voltage and current (d) output voltage without boost converter (e) input voltage and current (f) output voltage

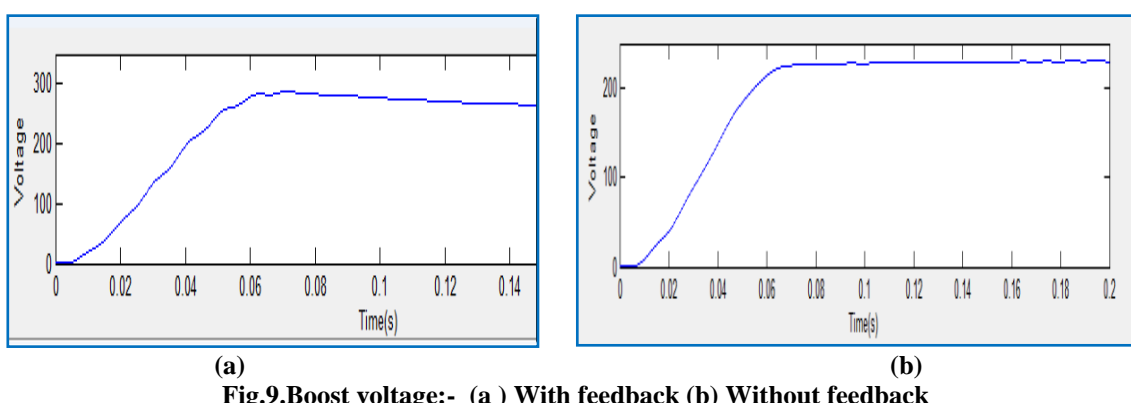


Fig.9.Boost voltage:- (a) With feedback (b) Without feedback

V. CONCLUSION

In this paper, a power factor correction circuit is introduced and it consists of a bridgeless buck rectifier and a boost converter. The main purpose of the boost converter is to maximise the output voltage level. In addition to this, boost converter improve the input power factor also. A feedback is also provided to the boost converter to control the output voltage to a desired value. After the addition of controlled boost converter the circuit will provide an input voltage of 257V with input PF 0.81 and input current THD 40%. This circuit has a bridgeless structure so conduction losses are less. In order to reduce the effect of distorted current we can add this active power factor correction circuit to supply input side of equipments used in industries and domestic applications.

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