ISSN (Print) : 2320 – 3765
ISSN (Online) : 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 9, September 2015

Power Factor Improvement using Bridgeless Resonant Pseudoboost Rectifier Based on Fuzzy Logic Control

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ABSTRACT: A new single phase bridgeless converter topology with a power factor correction (PFC) is proposed. Less number of components is the main highlight of bridgeless resonant pseudoboost power factor correction rectifier compared to other topologies . In this the input diode bridge is absent and there is only one diode in the current path during each stage of the switching cycle .The rectifier is designed to work in resonant mode to achieve power factor close to unity in a very simple manner. Fuzzy logic control strategy for pseudoboost PFC is presented in this paper. Here the controlling action was established through a fuzzy Logic controller. It gives a faster output voltage response as compared to openloop.

KEYWORDS: Bridgeless rectifier , power factor correction (PFC) , Total harmonic distortion(THD)

I. INTRODUCTION

AC sine wave of frequency 50Hz is normally given as the input for power electronic applications. This is then converted to DC for the proper functioning of power electronic devices. The circuits which are used to convert supply ac voltage to a particular dc voltage for the working of power electronic devices are called rectifiers. Large output capacitors are present in rectifiers to reduce the output voltage ripple and these capacitors will be charged to the peak value of the input voltage. Thus it is evident that the current in this case will be large and also discontinuous. Hence rectifiers presents the demerits of poor power quality in terms of injected current harmonics, voltage distortion and poor power factor at input ac mains**.**

Power factor correction (PFC) has now become a very important field in power electronics. .Power factor correction can be broadly classified into two **-** passive and active. In passive PFC, only passive elements are used to shape the input line current and the output voltage cannot be controlled. In the case of active PFC circuit, an active semiconductor device is used together with passive elements to shape the input current .In this the output voltage can be controlled.

Most of the PFC rectifiers utilize a boost/buck–boost topology converter at their front end due to its high power factor (PF) capability[1-3].Buck or buck boost topology is used in most of the power factor correction circuits due to its capability for high power factor .However, there are considerable losses in the diode bridge in conventional power factor correction .In these circuits, the current flows through three power semiconductor devices during each switching cycle interval . The forward voltage-drop across the bridge diodes degrades the converter efficiency, especially at low-line input voltage. As a remedy to these concerns, considerable research efforts have been focussed on the development of more efficient bridgeless PFC circuit topologies .A bridgeless PFC circuit allows the current to flow through a minimum number of switching devices . Thus the conduction losses can be greatly reduced in the converters, This has led to higher efficiency and lower cost .

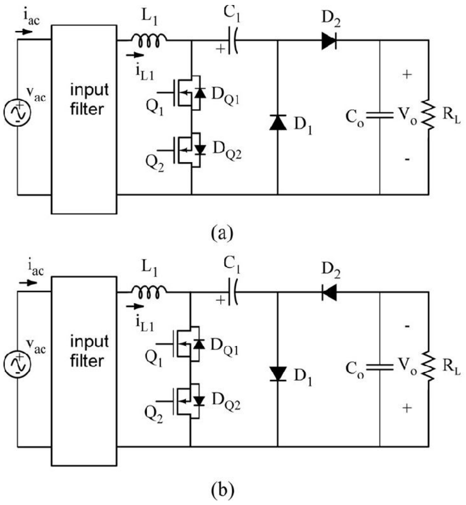
One such bridgeless topology uses bridgeless single ended primary inductance converter (SEPIC) for power factor correction[4] . In this ,the number of component conducted at each subinterval mode is reduced compared to other existing topologies. The capability to reshape the input current is inherent since this circuit is operated in DCM. Another bridgeless power factor correction rectifier uses a buck converter that substantially improves efficiency at low line of the universal line range[5] . By eliminating the input bridge diodes, the rectifier’s efficiency was further improved.

A totem-pole boost bridgeless power factor correction rectifier with simple zero current detection along with full-range zero-voltage switching (ZVS) operates at the boundary of discontinuous-conduction mode and continuous-conduction mode[6]. Compared to the boundary dual boost bridgeless rectifier, the required number of power components is reduced by one third and two current transducers can be eliminated in this particular topology. This rectifier can also be a good candidate for interleaving operation to upgrade the power level. Boost converters operating in CCM is also popular because reduced electromagnetic interference levels result from their utilization. A bridgeless boost converter based on a three-state switching cell (3SSC), with advantages of reduced conduction losses with the use of magnetic elements with minimized size, weight, and volume is another topology[7].

However, most of the bridgeless PFC converters suffers from the following drawbacks like high component count, components are not fully utilized over whole ac-line cycle, complex control etc. Many of the topologies need additional diodes and/or capacitors to minimize EMI.

Thus finally , a bridgeless PFC circuit based on a modified boost converter is introduced. Compared with other single phase bridgeless topologies, the proposed pseudoboost rectifier has low component count, a single control signal, and non-floating output. The proposed converter is intended for low-power applications since it operates in DCM. The converter components are utilized fully during the positive and negative ac-line cycle[8].

II . BRIDGELESS RESONANT PSEUDOBOOST PFC RECTIFIER



(a)

(b)

Fig.1 Bridgeless Resonant Pseudoboost Rectifier a)positive output polarity , b) negative output polarity

Power factor correction, high efficiency with low component count can be obtained using the proposed bridgeless resonant pseudoboost topology. The bridgeless resonant pseudoboost converter has a single control signal, non floating output , and low component count .These are the main highlights of using this rectifier for power factor correction application. This operates in DCM and can be used for low power applications.

This rectifier is designed to operate in discontinuous-conduction mode (DCM) during the switch turn-on interval and in resonant mode during the switch turnoff intervals. As a result, the switch current stress is similar to the conventional DCM PFC converter, while the switch voltage stress is higher. Also, the two power switches $Q_1$and Q_2 can be driven by the same control signal, which significantly reduces the complexity in control.

III. OPERATING PRINCIPLE

Stage 1: This stage starts when the switch Q_1 is turned on. Body diode of Q_2 is forward biased. Diode D_1 reverse biased due to the voltage across C_1 .The diode D_2 is reverse biased by the voltages vc_1 +Vo. The inductor current (L_1) increases with input voltage and the voltage across the capacitor C_1 remains constant .

Stage 2 : This stage starts when the switch Q_1 is turned off and the diode D_2 is turned on providing path for the inductor current. Diode D_2 is reverse biased during this stage. The input voltage through diode D_2 excites the tank circuit consisting of the inductor L_1 and the capacitor C_1. This stage ends when the inductor current reaches zero. As a result the diode D_2 gets turned off . Capacitor C_1 is charged until it reaches a peak value during this stage .

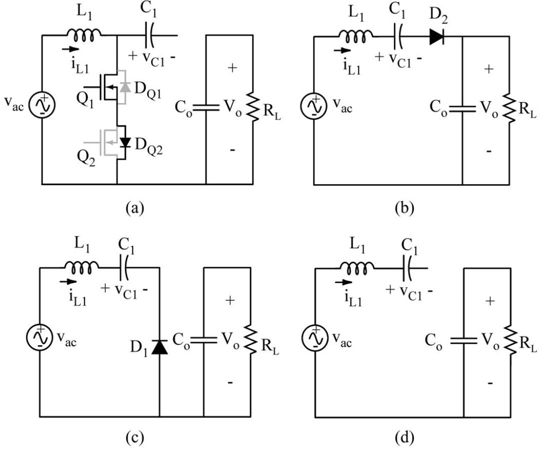


Fig.2 Toplogical stages of the converter during one switching period T_s

Stage 3 : In this stage diode D_1 is forward biased to provide path for the negative half cycle of the resonating inductor current. This stage also ends when the inductor current reaches zero. The peculiarity of this stage is that the diode D_1 is turned on and off under zero current conditions. With a constant input voltage the capacitor is discharged until it reaches the constant voltage v_x.

Stage 4 : During this stage all switches are in their off position. Inductor current will be zero and the capacitor voltage will remain constant. The duration of this stage must be greater than or equal to zero.

IV. DESIGN PROCEDURE

Due to the resonant non linear nature of the converter, an iterative design procedure is involved.

- The voltage Conversion Ratio

$$M = \frac{Vo}{Vm} \qquad \text{.... (1)}$$

- To ensure DCM operation, the value of the normalized switching frequency (F) must be less than one. In this design procedure , F is chosen to be 0.8.

- The critical inductance required to maintain DCM operation

$$L1 \leq \frac{RLTs}{4}\left(\frac{F}{\pi}\right)^2 \qquad \text{.... (2)}$$

- The value of the resonant capacitance

$$C1 = \frac{1}{L1(2\pi fr)^2} \qquad \text{.... (3)}$$

- Maximum value of Peak switch current

$$IQ - pk, n = \frac{\alpha}{M} = \frac{\omega r\ d1\ Ts}{M} \qquad \text{.... (4)}$$

- The following condition must be satisfied

$$\omega r\ d1\ Ts + \sin^{-1}\left(\frac{4\ iQ-pk,}{4+iQ-pk^2}\right) + \pi \le \frac{2\pi}{F} \qquad \ldots.\ (5)$$

V. VOLTAGE REGULATION USING FUZZY LOGIC CONTROL

Closed loop control is used for controlling the output voltage. A fuzzy control system is a non linear control system based on fuzzy logic which is a mathematical system .This system analyses the analogy input values in terms of logical variables which take the continuous values between 0 and 1.There are three steps involved in a fuzzy control- Fuzzification, Rule base and defuzzification. There are two inputs for fuzzy controller, the error and change in error. In fuzzification step , the membership functions are designed for the input. It is actually the conversion of a crisp input value to a fuzzy value. Seven fuzzy levels or sets are chosen for error (e), change in error (e) and the output.

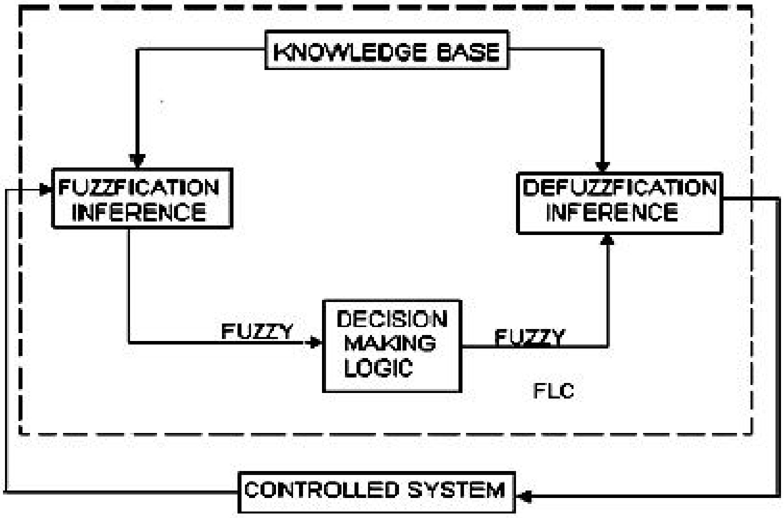


Fig. 3 Basic configuration of Fuzzy Logic Control

The next step is to provide the rule controlling the working of a Fuzzy control system. Different control laws have to be made based on the operating conditions and this will improve the performance of the system. The last step is Defuzzification . In this stage, the fuzzy values are converted into crisp values.

VI . SIMULATION RESULTS AND DISCUSSION

Parameter	Value
Tank inductor , L1	100µH
Tank capacitor , C1	65nF
Filter inductor , Lf	1mH
Filter capacitor , Cf	1µF
Output capacitor	470µF
RMS input voltage	85V
Output voltage	240V
Output power	115W

Table I . Simulation Parameters

The above table shows the values of various components used for simulation. The switch duty cycle is set to 40%. A small high frequency filter is inserted to filter the pulsating high frequency inductor L_1 ripple current. The bridgeless resonant pseudoboost power factor correction rectifier circuit is simulated using MATLAB in Open loop mode and closed loop mode. Fuzzy logic controller is employed to control the circuit.

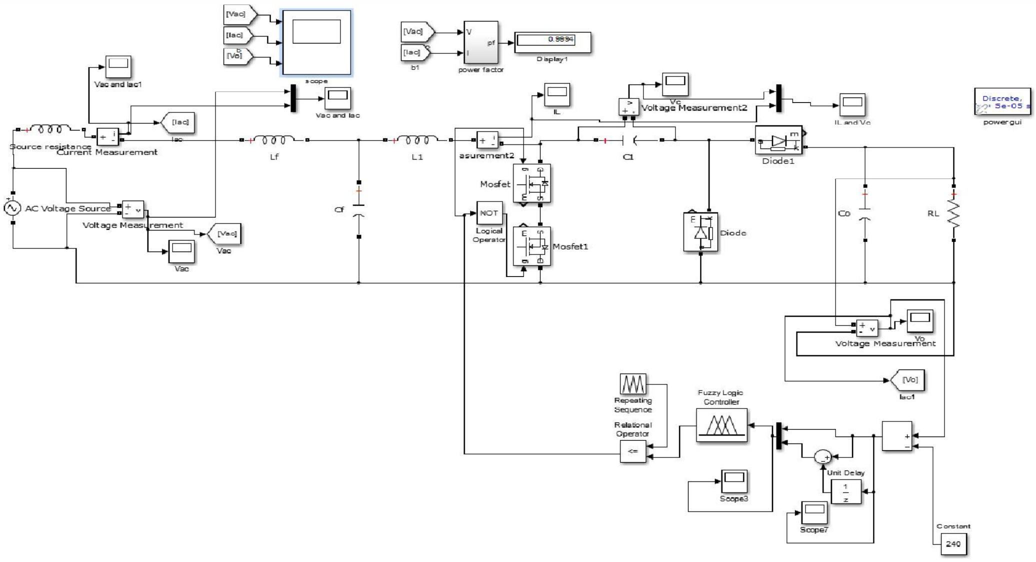


Fig 4 . Simulink model for Fuzzy controlled bridgeless resonant pseudoboost PFC rectifier

The figure above shows the simulink model of bridgeless resonant pseudoboost rectifier controlled using fuzzy logic control. The proposed converter of Fig. 1 is designed to operate in DCM during the switch turn-on interval and in resonant mode during the switch turnoff interval. Hence , the switch current stress is similar to the conventional DCM PFC converter. Also , the two power switches can be driven by the same control signal, which significantly reduces the complexity in control circuitry. An isolated gate drive is required for the power switch Q_1 .

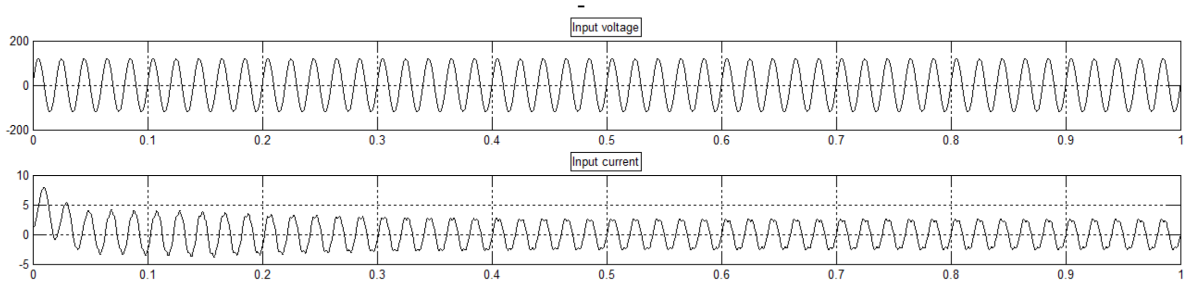


Fig 5. Input voltage and input current waveform

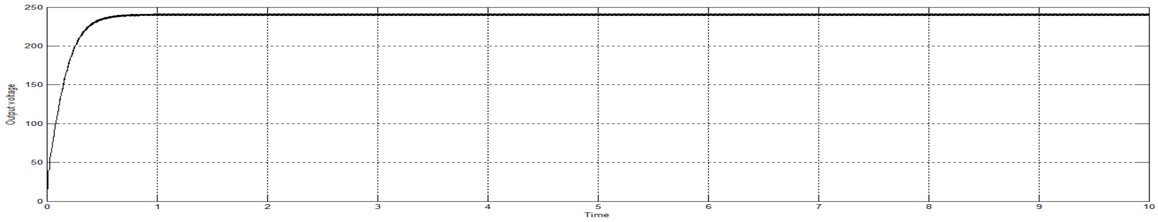


Fig 6. Output voltage waveform

It is evident from the above figure that the input current is in phase with the input voltage .Using the fuzzy control , the output voltage is regulated. As seen from the simulink model given above , the power factor is improved to 0.9994 which is almost near to unity.

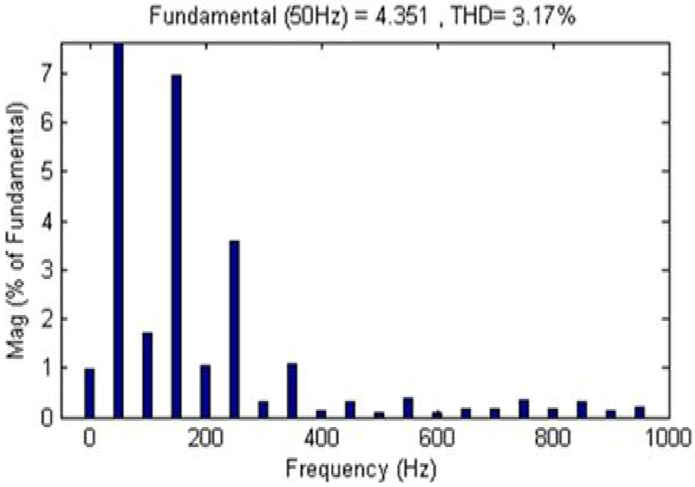


Fig 7. THD analysis

The THD value obtained is very low (3.17%). Total harmonic distortion can be defined as the ratio of the sum of the currents of all harmonic components to the current of the fundamental frequency. THD is used to characterize the power quality of electric power systems/

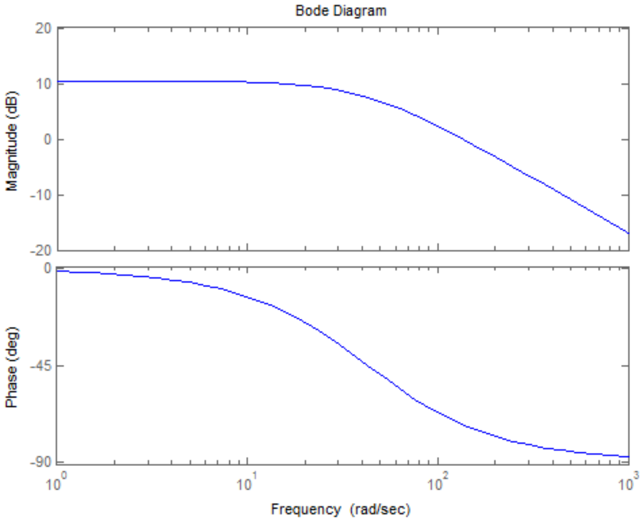


Fig 8 . Control to output frequency response

The performance of the rectifier is investigated with the help of average small signal model .The figure above shows the bode plot of the open loop control voltage to output voltage transfer function of the system. It is evident from the bode diagram that the system is stable.

VII . CONCLUSION

A single phase AC to DC bridgeless resonant pseudoboost PFC rectifier is discussed and simulated. The low component count and the high efficiency makes this rectifier topology the best candidate for low-power PFC applications. Performance of the converter is verified by simulation in MATLAB/SIMULINK environment in both open loop mode and closed loop mode. For the closed loop control Fuzzy controller is used. Fuzzy controller provides better output voltage regulation. To maintain the same efficiency, the circuit can operate with a higher switching frequency.

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(An ISO 3297: 2007 Certified Organization)

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BIOGRAPHY

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DOI: 10.15662/IJAREEIE.2015.0409056