International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Fuzzy Controlled Bridgeless Resonant Pseudoboost Rectifier for Power Factor Correction Applications

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Abstract: A ***single phase Ac-DC bridgeless converter topology with a power factor correction (PFC) is proposed. Less number of components is the main advantage of using bridgeless resonant pseudoboost rectifier for power factor correction compared to other conventional topologies . In this topology , the input diode bridge is absent and in the current path there is only one diode during each stage of switching cycle .This rectifier is designed to work in resonant mode to achieve power factor close to unity in a very simple manner. Fuzzy logic control for resonant pseudoboost PFC rectifier is presented in this paper. Fuzzy control provides a much faster output voltage response as compared to openloop.***

Keywords: Bridgeless rectierFuzzy logic control , Power factor correction ,Resonant converter , Total harmonic distortion.

1. Introduction

Normally AC sine wave of frequency 50 Hz given as input is then converted to DC for the proper functioning of power electronic devices. Those circuits used for converting this supply ac voltage to a particular dc voltage for the working of power electronic devices are called rectifiers. Large output capacitors are needed in rectifiers to reduce the output voltage ripple and these capacitors will be charged to the peak value of input voltage. From this it is evident that the current in this case will be large and also discontinuous. Hence rectifiers present the problems of poor power quality in terms of voltage distortion, injected current harmonics, and poor power factor at input ac mains. Here lies the importance of power factor correction.

Most of the PFC converters uses a boost or buck–boost topology converter at their front end as it has high power factor (PF) capability [1-3].Buck or buck boost topologies are used mostly in power factor correction circuits due to its capability for high power factor . Apart from high power factor , there are considerable losses in the diode bridge in conventional power factor correction circuits .In these topologies, the current flows through three power semiconductor devices in each switching cycle interval . The forward voltage-drop across the bridge diodes degrades the efficiency of the converter, especially at low line of input voltage. As a good solution to these problems, many research works have been focused on the development of more efficient bridgeless power factor correction circuits .A bridgeless PFC rectifier circuit allows the current to flow only through a minimum number of switching devices. The major advantage is that the conduction losses are greatly reduced in the converters, This has given way to higher efficiency and a much lower cost .

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

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].

2. Power Factor and Power Factor Correction

In simple terms, power factor is defined as the ratio of real power to apparent power. Power factor is a number between 1 and 0. When the power factor is not equal to 1, it is an indication that the current waveform does not exactly follow the voltage waveform. The closer the power factor is to 1 the closer the current waveform follows the voltage waveform. The displacement power factor is related to the phase angle while distortion power factor is related to shape of the waveform. Displacement power factor comes due to the phase displacement between the current and voltage waveforms caused by the presence of reactance in the power supply system while harmonic distortion is responsible for distortion power factor.

Power factor correction techniques can be divided into passive and active .In Passive PFC, only passive elements are used in addition to the diode bridge rectifier, to improve the shape of the line current. An active PFC is a power electronic system that is designed to have control over the amount of power drawn by a load and in return it obtains a power factor as close as possible to unity. A combination of the reactive elements and some active switches are in order to increase the effectiveness of the line current shaping and to obtain controllable output voltage.

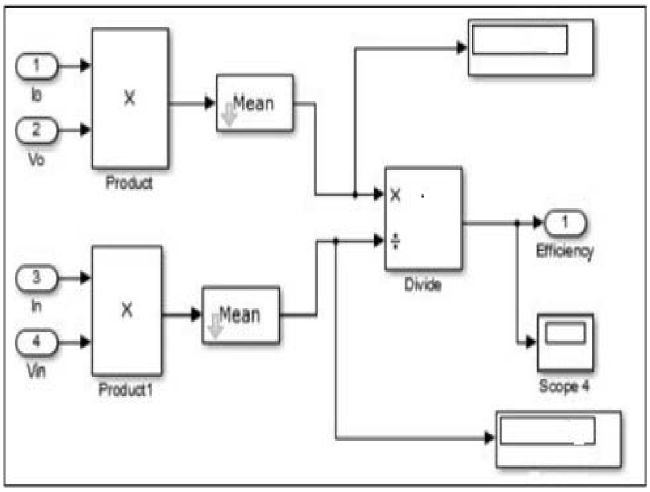

Figure 1: Power factor measurement block

3. Bridgeless Resonant Pseudoboost PFC Rectifier

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

- **Stage 1:** This stage starts when the Q_1 is turned on. Body diode of Q_2 is forward biased by the current i_{L1}. Diode D_1 is reverse biased because of the voltage across capacitor C_1 and diode D_2 by the voltages vc_1 +Vo. The inductor current i_{L1} increases with the input voltage linearly and the voltage across the capacitor C_1 remains constant at v_x .
- **Stage 2:** This stage starts when Q_1 is turned off and D_2 is turned on providing path for the inductor current. During this stage diode D_1 is reverse biased. The input voltage through diode D_2 excites the tank circuit consisting of the inductor L_1 and the capacitor C_1 which is illustrated in the figure. This stage ends when the resonant inductor current reaches zero value and thus the diode D_2 gets turned off . In this stage Capacitor C_1 is charged until it reaches a peak value.
- **Stage 3:** In this stage diode D_1 is forward biased to provide path for the negative half cycle of the resonating current. This stage also ends when the inductor current reaches zero value. The diode D_1 is turned on and off under zero current conditions. The capacitor is discharged until it reaches the constant voltage v_x with a constant input voltage.

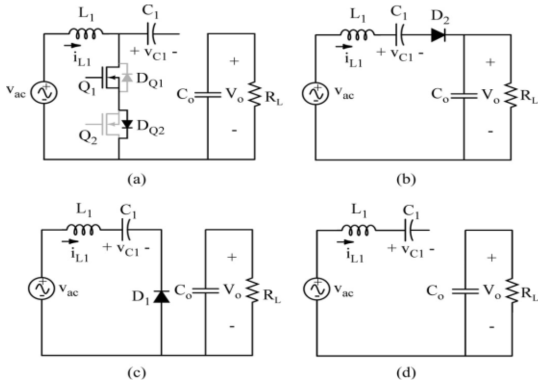

Figure 2: Topological stages of the converter during one switching period

- **Stage 4:** In the final stage, all switches are in their off condition. Inductor current will be zero and the capacitor voltage will remain constant at a value v_x . The duration of this stage must be greater than or equal to zero for the converter to operate as specified.

4. Voltage Regulation Using Fuzzy Logic Control

Closed loop control is for controlling the output voltage. There are many types of control like PI control , hysteresis current control , peak current mode control , average current mode control , fuzzy logic control etc. In this paper fuzzy logic control is used. A fuzzy control system can be described as a non linear control system based on fuzzy logic which is a mathematical system .This system analyse the analog input values in terms of logical variables.The three steps involved in a fuzzy control are the following-Fuzzification, Rule base and defuzzification. The two inputs for fuzzy controller are the error and change in error. In the fuzzification step , the membership functions are designed for the input. Actually fuzzification is the conversion of a crisp input value to a fuzzy value. There are seven fuzzy levels or sets chosen for error (e), change in error (e) and the output.

e \ Δe	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

Figure 3: Fuzzy rule

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

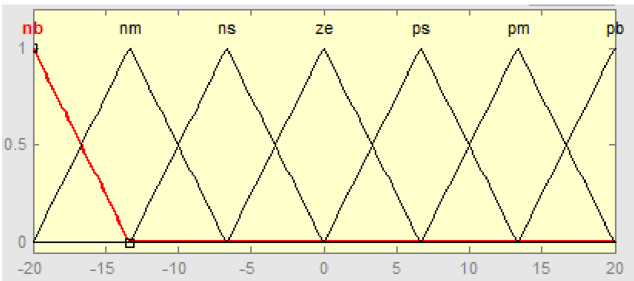

Figure 4: Membership function for error

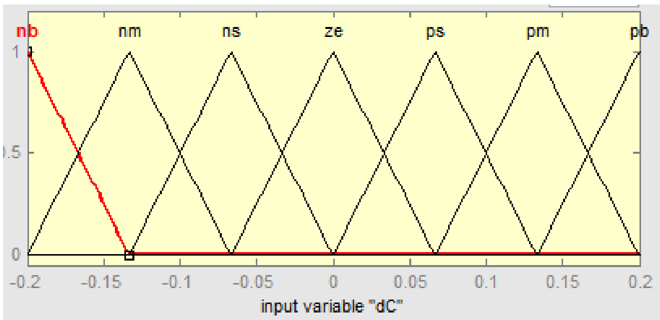

Figure 5: Membership function for change in error

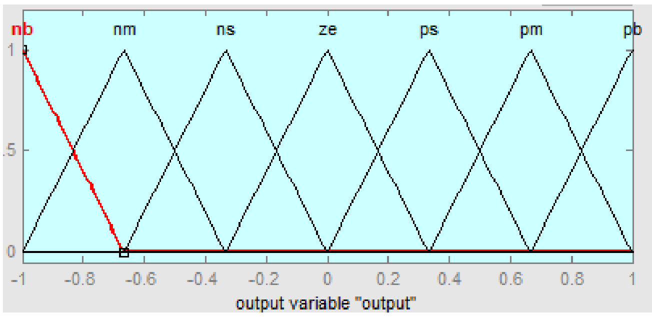

Figure 6: Membership function for output

The switch duty cycle is 40%. A high frequency filter is inserted for filtering 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 and closed loop mode using Fuzzy logic control. Fuzzy logic controller is found as an efficient way to control the circuit.

The figure below shows the simulink model of fuzzy controlled bridgeless resonant pseudoboost rectifier. The proposed rectifier is designed to operate in discontinuous conduction mode during the switch turn-on interval and in resonant mode during the switch turnoff interval. Thus, the switch current stress is similar to the conventional discontinuous conduction mode power factor correction converter topologies. Another advantage is that the two power switches can be driven by the same control signal, which reduces the complexity in control circuitry.

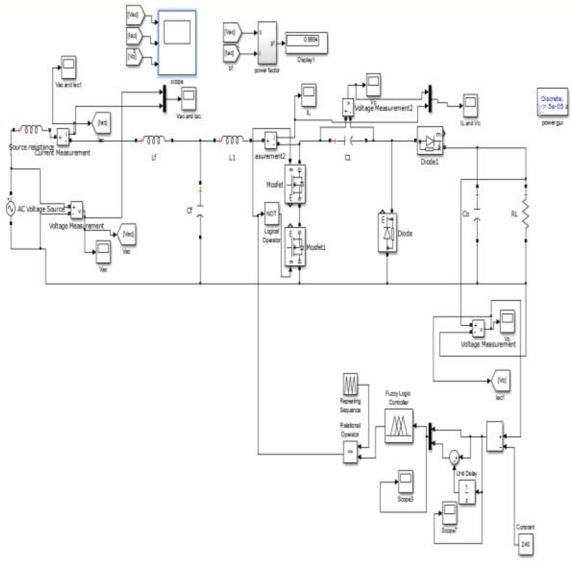

Figure 7: Simulink model for Bridgeless resonant pseudoboost PFC rectifier

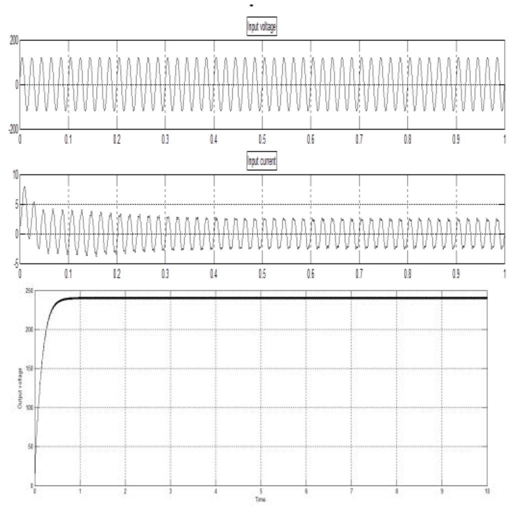

Figure 8: Waveforms for input voltage, input current, output voltage

It is clear from the above figure that the input current is in phase with input voltage .Using the fuzzy control , the output voltage is regulated to a constant dc value. The power factor is improved using the proposed topology to 0.9994 which is almost near to unity.

5. Conclusion

A single phase AC to DC bridgeless resonant pseudoboost PFC rectifier is studied and simulated. High efficiency and low component count makes this rectifier topology the best candidate for low-power PFC applications. Performance of the proposed converter is verified by simulation in MATLAB/SIMULINK in both open loop mode and closed loop mode using Fuzzy logic control.

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