Efficiency Enhancement of Flexible Mode Bridgeless Boost Rectifier

S. Nagaraj, R. Ranihemamalini, L. Rajaji

Abstract: ***Most of the devices in power system become faulty due to the large content of harmonics present in voltage and current. It is mainly caused by the conduction losses in the system. At first, it is necessary to determine the extent of harmonic present by calculating the total harmonic distortions i.e., root over sum of the integral harmonics divide by fundamental harmonic. Later, identification of type of method for reducing harmonics is essential. In this project we are mainly focusing on two types of PFC bridge boost rectifier to improve the efficiency for low and high input voltage range. It using back to back bridgeless PFC boost rectifier for high input voltage and for low input voltage range, three level bridgeless boost rectifiers respectively. Fast recovery diode instead of normal diodes for better reliability and efficiency is utilized. The end model is obtained by combining two circuits BTBBL (Back to back bridgeless boost PFC) and TLBL (Three level bridgeless boost PFC) to get the FMBL (Flexible mode bridgeless boost PFC). Due to presence of less no of components, conduction losses are less hence less distortion is observed with improved efficiency. A simulation is carried out for all three models using MATLAB Simulink platform. In hardware, TLP250 driver for MOSFET is used and which is interfaced with PIC microcontroller. The hardware results are obtained that validates the simulation results.***

Keywords: Harmonic distortion, bridgeless boost converter, multi-level converter.

I. INTRODUCTION

In this paper two PFC rectifiers are utilized for the improvement of efficiency. First model is BTBBL (Back to Back Bridgeless Boost Rectifier), second is TLBL (Three Level Bridgeless Boost Rectifier) [1-2]. Both the circuit models are working at different range of inputs. BTBBL PFC is used for high input voltage range and TLBL is used for low input voltages. The efficiency of the rectifier is known as rectification efficiency defined as ratio of power delivered (DC) to the input power (AC)[3-4].

Many devices in power systems and power electronics are faulty due to the presence of harmonic contents. So it is essential to measure and limit the harmonics presence in the voltage and current waveforms.

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The efficiency of the devices highly relies on the harmonics present in the supply and also due to the conduction losses [5-6]. The possible solutions for eradicating the above issues are reduction in components present in the circuit. It also promises for improved power factor and efficiency at the source side [7-8].

The most common solution is conventional PFC rectifier which is mostly used in electronics devices like computer. However, it results in more conduction losses due to input current which flows through two bridge diodes [9-10].

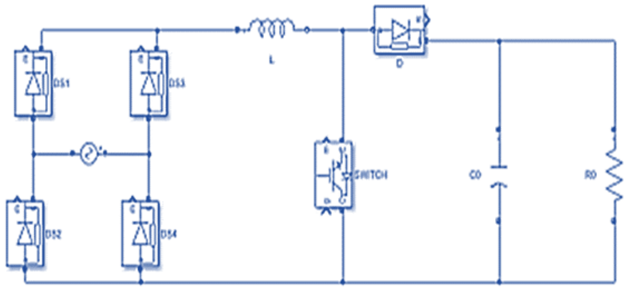

Fig. 1. Conventional PFC Rectifier

In this conventional type, it uses four diodes connected antiparallel at first mode S_1 and S_4 are on. In second cycle S_3 and S_4 are on as shown in figure 1. Similarly, the working of the circuit makes the current always flows continuously and hence more conduction losses appear in this circuit [11-13]. Though this circuit are used in various applications, it has major drawbacks where conduction is discontinuous modes whereas losses will be less [14-15].

II. MODELLING OF PROPOSED TOPOLOGY

A. DDBL PFC And BTBBL PFC Rectifier

The proposed circuit model has better efficiency than the conventional type of rectifier DDBL PFC and BTBBL PFC circuit since it has very less noise interference which makes the system to be highly reliable and durable. Here it uses discontinuous mode of conduction and hence less conduction losses. TLP 250 is used in bridge rectifier to drive the MOSFETs power switches. It has slow propagation delays and offers control firing pulses.

The TLP25 acting as driver circuit has input and output stage with power supply. The pin configuration of TLP250 is described below. Pin 1 and 4 meant for no connection. The pin 8 denotes the power supply. Pins 2 and 3 are inputs to the LEDs. Pin 6 indicates the output pin. Supply is given at pin 8 is as shown in figure 2.

Fig. 2. TLP 250 in bridge rectifier

B. DDBL PFC Rectifier

Both of these circuits have better efficiency but magnetic core utilization is low since multiple inductors are placed. Hence those circuits are only used for high voltages ranging (220-240) rms. Capacitor is connected at the output will act as a filter to reduce ripples. Diodes of S1, S2 are slow recovery diodes and F1, F2 are fast recovery diodes. Fast recovery diodes have fast switching characteristics and better efficiency.

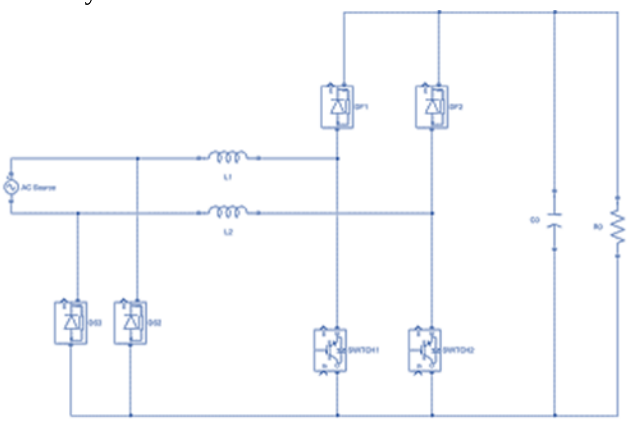

Fig. 3. DDBL PFC Rectifier

These diodes are durable and reliable. In these circuit switch1 is in series with F1 diode where as switch2 is in series with F2. The presence of inductors introduces conduction losses as it is placed in the input side of the rectifier circuit. Two slow diodes are connected in arallel and S1, S2 work at different modes as depicted in figure 3.

C. BTBBL PFC Rectifier

In BTBBL (back to back bridgeless boost PFC. rectifier), both diodes are connecting is series with each other. During first cycle both fast recovery diodes are working and slow recovery diodes can be treated as short-circuits. The (+ve) of power supply is always connected to capacitor. High efficiency can be achieved in this circuit under high range of supply voltages. But conduction losses are highly reduced under high voltage ranges. This circuit model also has wide range of applications where high input voltage rating is used for general purposes. The circuit has been designed for high voltage ratings. It is essential to design a model with lower rating of voltages also since most of the appliances used in day to day life require low rating. The working of BTBBL rectifier is shown figure 4 as it operates in different modes of conduction at high input voltage ranges.

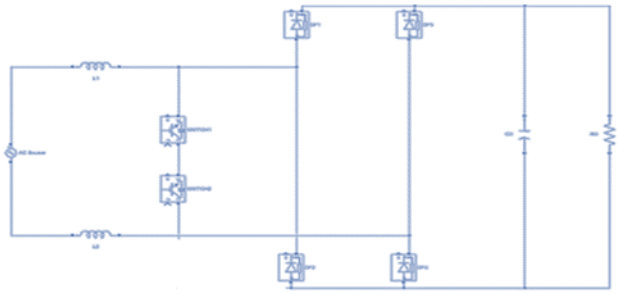

Fig. 4. BTBBL PFC Rectifier

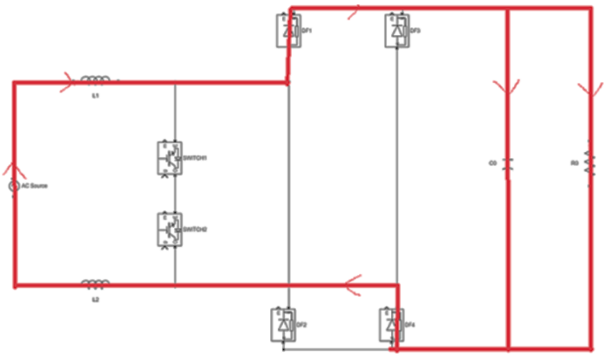

Fig. 5. BTBBL working

The flow of current at high input voltage range termed as BTBBL mode. The other mode which the circuit can work is by switching ON S1 and S2 as shown in figure 5.

D. TLBL PFC Rectifier

This circuit is also simpler as compared to other circuits as there is less number of components in operation path. During each mode of working, there exists one diode at a time hence the conduction losses gets highly reduced. This circuit is mostly utilized in industrial applications. In the circuit, split capacitors are connected and, in this circuit, no slow recovery diodes are present. Both diodes are fast recovery diodes and only one inductor is used so that conduction losses are also less. S1 and S2 are two switches connected in series. During first mode of operation, C1 discharges and current flows back to the supply and in second mode of operation, C2 get discharge and current flow to the negative terminal of the supply as illustrated in figure 6. From the above circuits and its explanations, we can see that DDBL PFC, BTBBL PFC can work in wide range of input voltages. But it is less efficient at low voltage levels. Similar is in the case of TLBL PFC it gives high efficiency under low voltage ranges. Hence a circuit can be made by combining both the circuits BTBBL and TLBL. Then the circuit can be worked for different voltage ranges for both high and low ranges. Final circuit is termed as FMBL (Flexible Mode Bridgeless Boost PFC) rectifier.

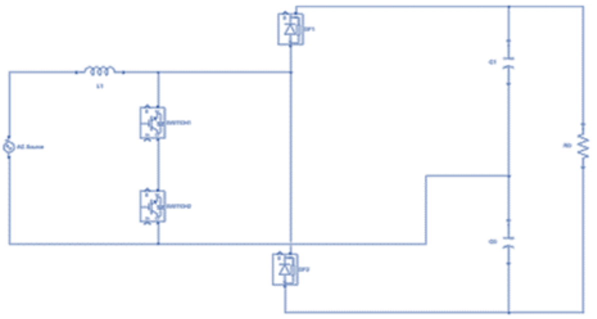

Fig.6. TLBL PFC Rectifier

E. FMBL PFC RECTIFIER

FMBL is flexible mode bridgeless boost PFC. this circuit is formed by connecting both BTBBL and TLBL circuits.so that it can work for both high and low input voltage range.so these type of rectifiers have wide range of industrial applications. It is basically a boost rectifier flexible mode bridgeless boost PFC rectifier.so we can see the results in hardware output that output voltage increases compared to the input is shown in figure 7.

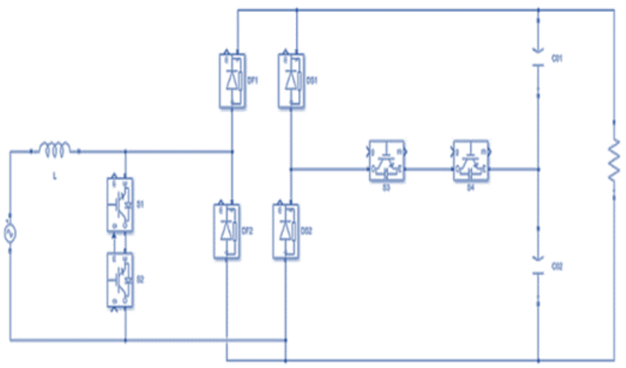

FIG.7. FMBL PFC RECTIFIER

III. MODES OF OPERATIONS

This circuit can work at different voltages ranges 100-120- and 220-240-volt rms. when the range is 100-120 Volt rms, the circuit which can be referred as TLBL PFC circuit while S3 and S4 remains ON. Similarly, when range is 220-240, the BTBBL circuit can be used in devices and S3 AND S4 remains off. The circuit can be operated in four different modes and input ranges

$$V = \frac{Ldi}{dt} \text{(S1 and S2 is ON)} \quad (1)$$

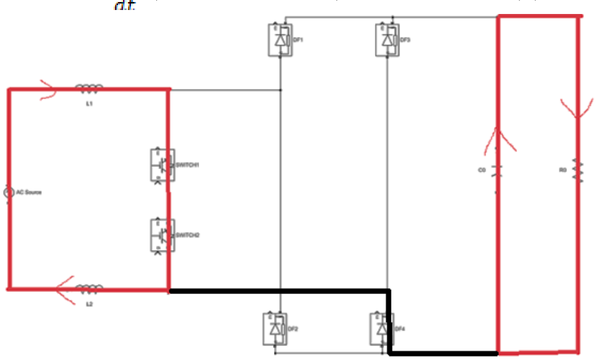

Fig.8. Mode 1 operation

When the low input range is given, S3 and S4 is ON. Figure 8 shows S1 and S2 is ON which is termed as TLBL mode. Similar process can be carried out when S3 and S4 is OFF and like these FMBL circuit works and the second mode of operation is termes as BTBBL. The obtained circuit model is FMBL known as flexible mode bridgeless boost PFC operating at both low and high input voltage ranges. Hence this circuit is efficient for reducing the circuit conduction losses and harmonic distortion as well as improved efficiency and power factor.

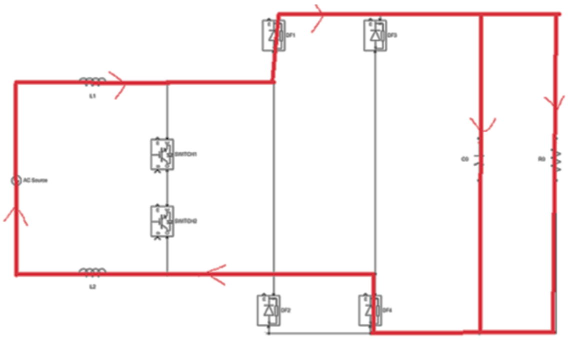

Fig.9. Mode 2 operation

In the next mode of operation S3 and S4 is on but S1 and S2 is off while the input has (+ve) power supply voltage. Under high input range, L1 and L2 are two inductors connected in series with (+ve) and (-ve) half of the supply voltage. Later, D1 and D3 are on and current is fed back to the input supply at (-ve) terminal and the capacitor is discharge through load. D2 and D4 are off during the next mode of operation. RED lines represented in the circuit indicate the flow of current.

When a (-ve) half cycle is given as input, there exist a reverse flow of current across mosfets i.e. switches as compared to other cases. C0 is the capacitor connected at the output across R load and it is discharge. S1 and S2 are on and S3 and S4 are off in this state, hence V<0.

$$V= \frac{Ldi}{dt} \text{(S1 and S2 is ON)} \quad (2)$$

S1 and S2 is on, equation (1) represents voltage while inductor stores energy. In second cycle inductor releases its stored energy which is stored during the first cycle. Equation (2) represents the release of stored energy.

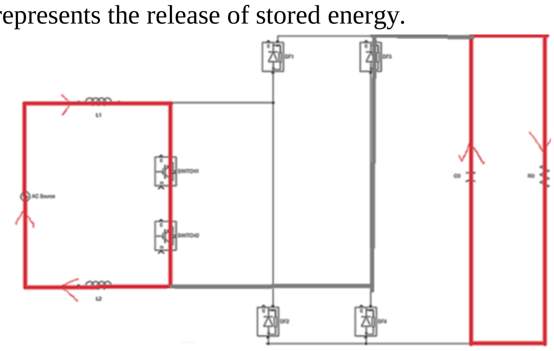

Fig.10. Mode 3 operation

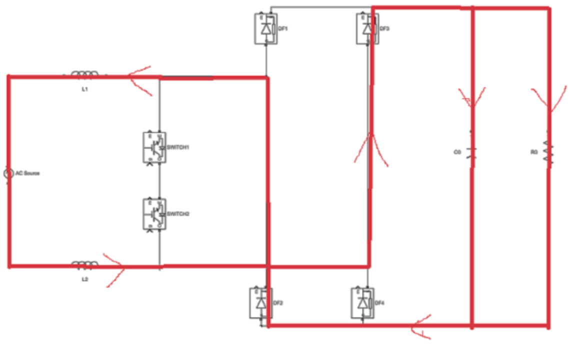

Fig.11. Mode 4 operation

In this mode, when (-ve) cycle as supply arises, S1 and S2 is off. The flow of current is similar in the before case as inductor stores energy and then it discharges through load. The expressions remain same in the case irrespective of the switches and diodes. In this case too inductor releases its stored energy. The modes of operation are explained and it is illustrated in figure 8 to 11.

IV. RESULTS AND DISCUSSION

The efficiency of rectifiers known as RECTIFIATION EFFICIENCY is calculated using equation (3). It is defined as output power that is DC divide by input power that is AC. The proposed simulation circuit is depicted in figure 12.

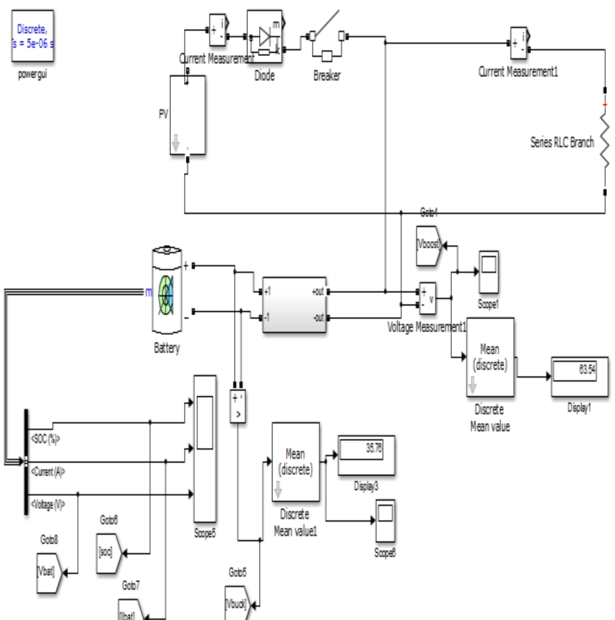

Fig. 12. Proposed Simulation Circuit

$$\text{EFFICIENCY}=\frac{\textit{Power output}}{\textit{power iput}}*100 \quad (3)$$

Output power, voltage square divide by resistance at output which is DC is found using equation (4).

$$P= V^2/R \qquad (4)$$

Input power is AC and can be calculated using equation (5) as product of voltage and current.

$$P= V*I \qquad (5)$$

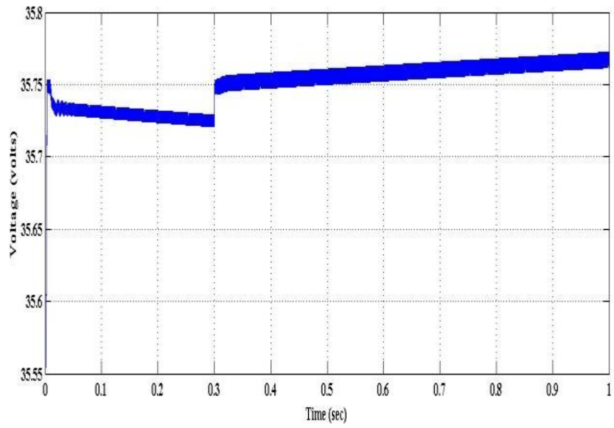

Fig.13.Input Voltage supplied V_{in} = 35.3 V

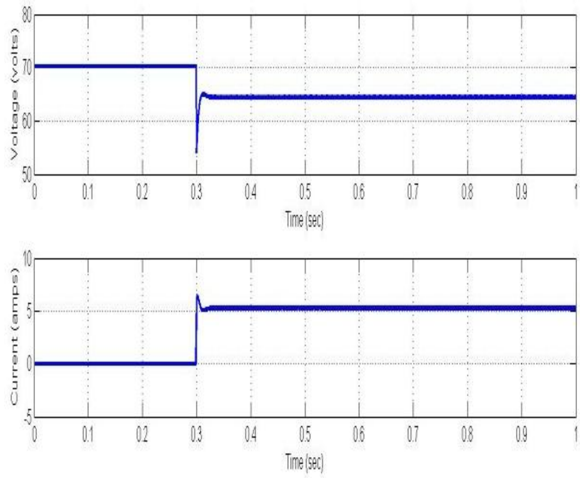

Fig.14. Output Voltage and Current Waveforms V_{in} = 64.5 V, I_{in} = 5.2A

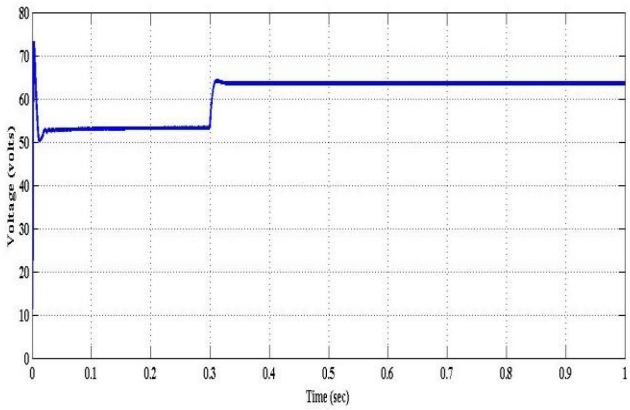

Fig.15. Boost Voltage supplied to load V_{Boost} = 63.54 V

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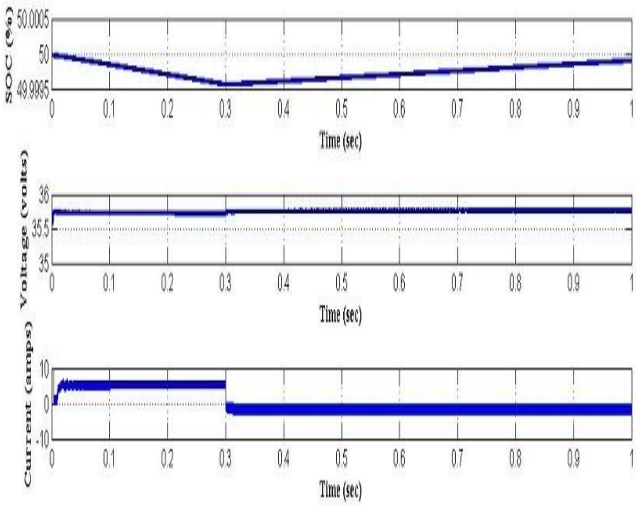

Fig. 16. Simulation Result of Battery Voltage = 35.75V, current = 4.7A ,SOC = 50%

Hence FMBL PFC RECTIFIER (Flexible mode bridgeless boost PFC rectifier) boost the input voltage at the output side. So the above circuit shows the tabular reading of the hardware circuit. Waveforms of the input and output of the hardware is obtained using DSO (Digital Storage Oscilloscope). The input and output voltage of proposed method are shown in figure 13 to16 respectively.

V. EFFICIENCY CALCULATION

Rectification efficiency = $\frac{Power\ delivered\ (DC)}{Input\ Power\ (AC)}$

Reading taken from multimeter

1. Input voltage = 70 volt
2. Output voltage = 110 volt
3. Load resistance = 10k ohm
4. Input current = 20mA

Power delivered = V^2/R

= (110*110)/10*1000

= 1.21kW

Input power = V*I

= 70*2 = 1.4kW

Efficiency = $\frac{1.21}{1.4} * 100$

= 86.4%

VI. CONCLUSION

Fast recovery diodes are used in the circuit since their fast switching characteristics and reliability are better. For high input ranges BTBBL PFC rectifier should be used to achieve better efficiency. For low input ranges TLBL PFC rectifier should be used. By combining both TLBL and BTBBL i.e. FMBL PFC rectifier is designed. Hence efficiency and power factor can be improved using lesser no of components as well as boosting the input voltage.

The range of voltage, 120 volts is considered to be low and 120-220 is considered to be high voltage range. So as per the requirement, the proposed rectifiers can be utilized. Hence efficiency of rectifier (Rectification Efficiency) is calculated.

The results reveals that the efficiency is about 86% which is high due to less conduction losses and less components in the FMBL circuit. Hence by using three PFC boost rectifiers, efficiency is increased as per the input voltages above circuits.

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