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DESIGN OF SINGLE STAGE INTEGRATED BRIDGELESS-BOOST PFC CONVERTER

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Abstract:
DC power supplies are used in the extreme way in almost all electronic and electrical appliances eg : personal computers, audio sets, TV, Adapters etc. This paper discusses the reduced high conduction losses & increased efficiency of the proposed integrated Bridgeless-Boost PFC converter. By modifying the circuit according to the technology and the necessity the overall power factor can be improved to the expectation of user. The cause of having low power factor in the bridgeless power factor converter is the presence of two energy conversion stages. These stages cause more conduction losses into the circuit.
In this paper, concept of highly efficient single stage integrated Bridgeless-Boost power factor correction converter is proposed. Introduction of the Bridgeless-Boost rectifier is given in the first section i.e. SECTION I showing how the BBPFC overcomes the drawbacks of the conventional boost PFC circuit. SECTION II explains the different approaches used for integration of PFC circuits. In SECTION III the proposed circuit is introduced and its complete operating modes are explained. Then finally superiority of the proposed circuit is verified by doing the simulation and verifying the results in the last section. Complete experimental analysis of the circuit is done on 230V ac, 50 Hz.
Thus this paper introduces the Integrated Bridgeless-Boost PFC Converter along with the verification with the simulated and experimented results.

1. Introduction

Nowadays, extreme use of DC supplies inside the most of the electrical and all electronics appliances led to an emerging demand for power supplies that draw current with minimum power factor i.e. almost unity [1]. Lots of international line current harmonics standards like IEC-6000 3-2 or European line current harmonics IEC- 1000 3-2, have moved towards significant efforts in developing AC-DC converters .Recently EN61000 3-2 by North America has imposed some limits on the harmonics of line current causing the demand of unity power factor and reduced THD proficiently.
The presence of non-linearity produce voltage fluctuations &imbalance in the network system which causes low powerfactor in the system. High frequency PFC circuits which are able to fetch the current wave form almost exact replica of the input voltage wave form from the grid supply, have been most recent topics of research in the power system. For household appliances and large size panels they impose an unacceptable increment in cost and complexity in the power unit. A full bridge rectifier along with a large bulky capacitor is the basic block of the PFC converter. The main and basic principle of operation of conventional boost PFC is to do the rectification of ac line voltage & then doing the filtering with large electrolytic capacitors. The result of these rectifiers is distorted waveforms having lower power factor and lower efficiency.
Bridgeless boost PFC circuit i.e. BBPFC is a highly efficient technology which eliminates diode bridge rectifier and the losses are reduced as there is minimum no of semiconductor component in the path of the flow of inductor current, along with this component count of the circuit is also reduced making it economical for worldwide use in industries specially.
To further increase the power factor of the circuit and to minimize the effect of the distortion an integrated Bridgeless-Boost converter is proposed which provides increment in the efficiency of the circuit by providing a single stage operation instead of two stages as into the basic or further developed bridgeless PFC circuits.

2. Power Factor Correction Techniques

a. Two stage technique :

In the active PFC stage we can use any of the present converters but gradually we use boost converter as it provides the continuous output. Boost topology is the best topology for doing the power factor correction. These converters have generally high frequency inductors, capacitors diodes in their architecture. Now the PFC controller which is used to sense the input voltage & input current provides the feature of tracking input voltage by the input current.
The active PFC stage provides a roughly and loosely regulated output voltage V_R having small harmonic ripples in it across the bulk capacitor C_B. Generally the range of regulation of V_R is not so much wide i.e. 380-400 VDC and the input voltage ranges from 40 V to 295 V.

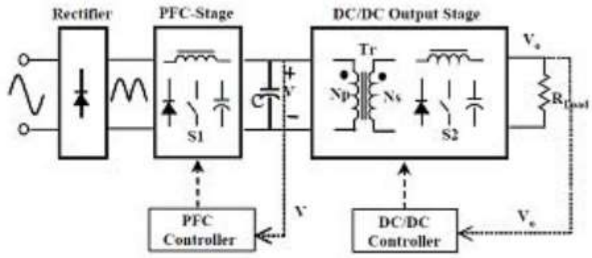

Fig.1 General Structure of Two Stage PFC

b. Single Stage Technique :

In this type of approach we need only PFC converter in a necessary way for improving power factor & accordingly the performance of the converter. We don’t need an additional switch converter for doing the regulation of voltage V. Output power factor correction is achieved automatically by the principal of the circuit. We don’t need extra control circuitry. Since during the PFC improvement power between input and output is pulsating we need capacitor C to store the extra energy generated during PFC improvement. In single stage we reduce the component & it is useful at lower power applications specially. In this stage we get almost unity power factor.

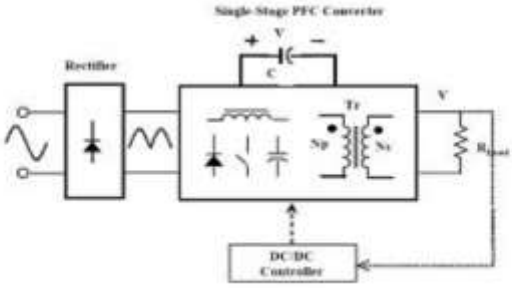

Fig. 2 General Structure of Single Stage PFC

3. Design Approach Of The Proposed Circuit

Usually all power supplies contain two stage approach for their proper operation of the circuitry. According to this approach we need an extra circuitry of DC-DC regulator to perform the regulation of the output to provide the efficient output after PFC regulation. In this approach we need two switches containing PFC stage current and DC-DC regulation current respectively.

In single stage we need only one switch for entire operation of the circuit. This only switch contains large amount of current providing both PFC and regulating current. So we need a bigger sized switch due to which the efficiency of the circuit may be decreased because larger switch produce more switching losses.

To eliminate this problem we will use two switches in the proposed circuit M1 and M2.Thus by eliminating all the demerits of the existing bridgeless PFC circuit and the single stage technique on which this circuit will work Single Stage Integrated Bridgeless-Boost Converter Circuit is proposed which provides higher efficiency, higher power factor and lower THD. In this circuit these two diodes are used to provide the current limiting factor as the two stage operation will take place in single one.

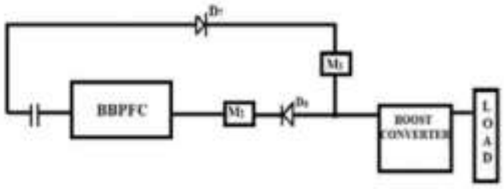

Fig.3 Blocked diagram of proposed circuit

4. Configuration Of Proposed Circuit

Circuit configuration of the proposed circuit is as shown in fig.4. In this circuit the bridgeless PFC boost circuit is used as power factor conversion circuit providing higher power factor by having minimum component count in the current flow path of the inductor current& integrated bridgeless-boost converter provides highly regulated output voltage as it contains a different power loop.

The chopper circuit along with half wave rectification is the base circuit for the development of the proposed integrated bridgeless-boost PFC circuits. Development of the circuit is done on how the ripple free waveforms are obtained in halfwave rectifier with chopper circuit. The complete configuration of the proposed circuit is as follows.

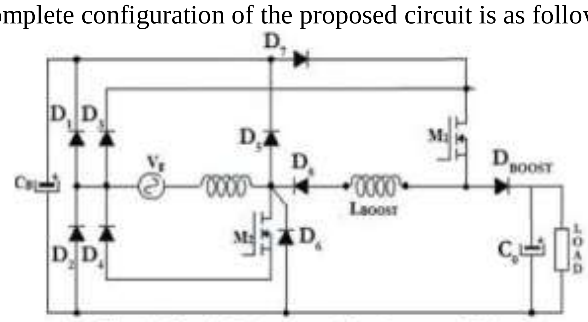

Fig. 4 Circuit Diagram of the Proposed Circuit

In the integrated Bridgeless-Boost PFC converter there are two states of current flow depending upon the ability of the inductor L of accumulating energy by putting inductor in the circuit. The current flows into the inductor L along with rectification of the current into circuit by operation of the switch M1 andM2.These switches repeatedly gets ON and OFF thus energy gets accumulated into the inductor. Due to the electromotive force of the inductor the bulk capacitor C_B stores energy to provide tightly regulated output voltage.

a. Positive Half Cycle

During positive half cycle let us consider that at time instant T0switch M1 is turned ON. Diode 3 is forward biased so due to this current flow from the path Vg-D3-M1-L_{BOOST}-L_{BBPFC} and energy gets accumulated into the inductor L_{BOOST} and L_{BBPFC}. At the same time the inductor L_{BOOST} of the boost converter which is used as the post regulator discharges energy accumulated in it along with the energy stored in the capacitor Co and thus we get the regulated boost up output at the output port of the circuit. Thus both the workings, power factor correction and the regulation of the output takes place in same cycle.

Mode I (T0, T1): Switch M1 is turned ON.

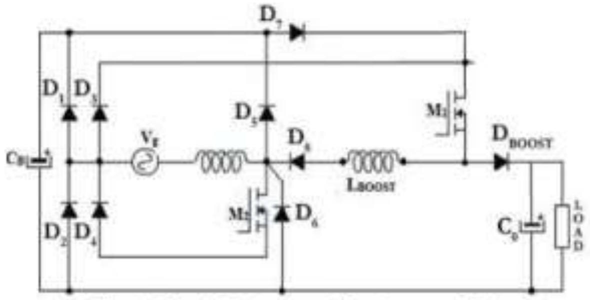

Fig. 4 Circuit Diagram of the Proposed Circuit

MODE 2[T1-T2]: Switch M1 is turned OFF

Now M_1 is turned OFF so now the inductor L_{BBPFC} discharges the energy and current flows through the path Vg-D_1-C_B-D_6. So with the amount of this discharged current the bulk capacitor C_B gets charged by storing the energy in it.

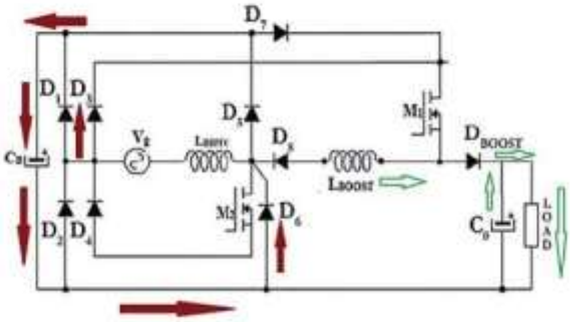

Fig. 5 (b) Mode-2

At the same time the inductor L_{BOOST} of the boost converter which is used as the post regulator discharges energy accumulated in it along with the energy stored in the capacitor Co and thus we get the regulated boost up output at the output port of the circuit.

b. Negative Half Cycle

During negative half cycle similarly the power MOSFET switch M_2 is turned ON. Now input current starts flowing through the path Vg-L_{BBPFC}-M_2-D_4 and the inductor is charge din reverse direction to that in mode I. At the same time capacitor C_B gets discharged and it provides energy to the boost converter which is used as the DC-DC regulator & we get the regulated output. Thus again in this mode similar to mode I of positive half cycle regulation and power factor correction is done in the same stage.

Mode III [T2-T3]: Switch M2 is turned ON

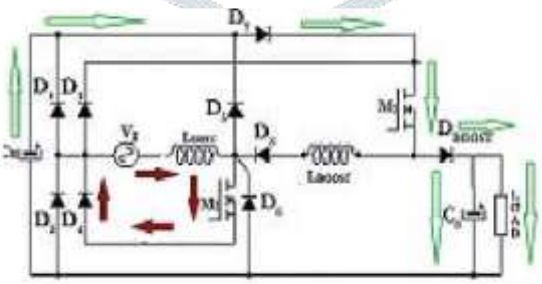

Fig. 5 (c) Mode 3

Switch M_2 is turned OFF so L_{BBPFC} gets discharged in reverse direction charging the C_B at the same time by following the path Vg-L_{BBPFC}-D_5-C_B-D_2.D_8 diode is used generally to avoid the over blowing condition in the circuit by preventing the flow of the current in L_{BOOST} of the integrated boost converter during the negative half cycle.

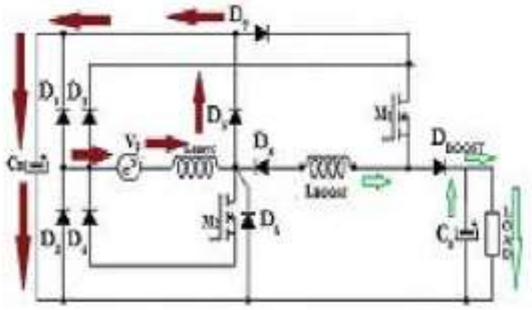

Fig. 5 (d) Mode 4

At the same time again the DC-DC post regulator i.e. the boost converter's inductor L_{BOOST} discharges the energy along with the capacitor C_0. So we get the regulated output at the load in the continuous way. From the complete working of the circuit it is clear that the power factor correction and the voltage regulation is being done at the same time using this integrated technique. Because of this now there just one stage of the energy conversion in the circuit making the circuit more efficient as the conduction losses are controlled. In single stage integrating technique we need to use only single switch but here we have used two switches.

In the single stage current of both stages i.e. power factor correction and the voltage regulation flows through the single switch which somewhere increases the switching losses of the circuit as the size of the required switch will be larger. To avoid this condition in our circuit we have done the integration in the single stage technique but still used two switches to overcome the drawback of single stage technique. Thus this circuit is controlling the switching losses as well as the conduction losses and efficiency is therefore improved. Power factor of the circuit is almost nearer to the theoretically mentioned value of 0.95 and the efficiency is 90%. THD count. of the circuit is almost nil in this circuit which is proved by doing the simulation of this proposed circuit in the next section.

5. Simulation Results

A single stage integrated Bridgeless-Boost PFC converter is proposed and fully tested. Simulink model of the proposed circuit is shown in fig. 6.

The observed waveform of input current and input voltage of the proposed circuit is shown in fig. 7(a) and output voltage and current waveforms are shown in fig. 7(b). Thus we find that at 230V, 50HZ input we get 0.94 power factor (fig.7(c))and its efficiency is almost increased to 10-12 % i.e. 90.48%(fig. 7(d)). THD of this proposed circuit is 1.53% which is almost 50% lower than the existing recent technology i.e. bridgeless PFC circuit.

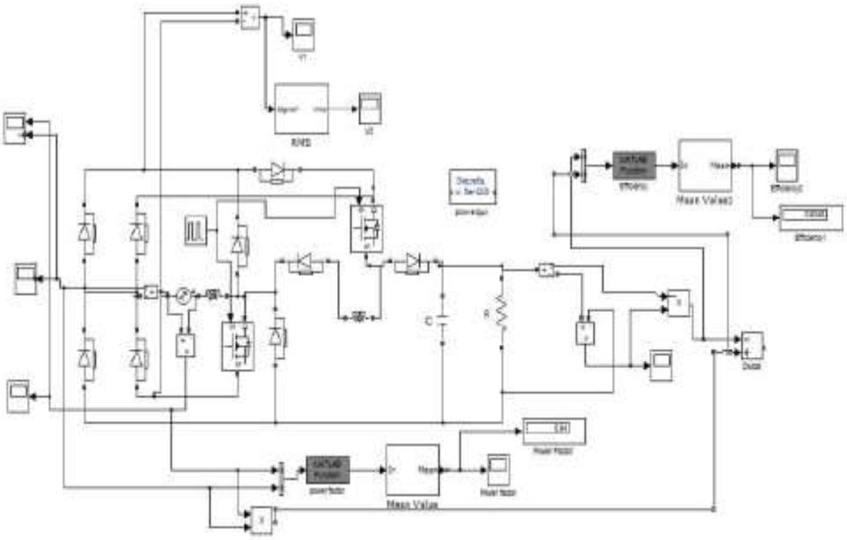

Fig.7 Simulink Model of Proposed Circuit

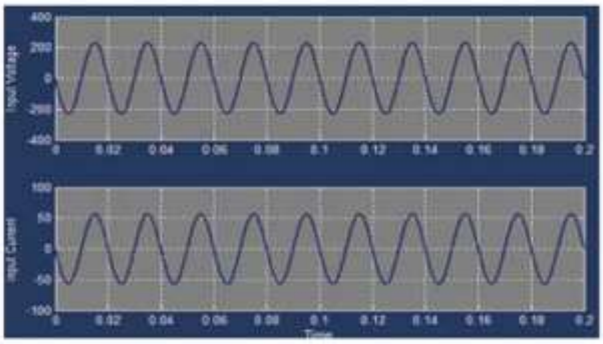

Fig. 7(a) Input Voltage and Current Waveform of Proposed Circuit

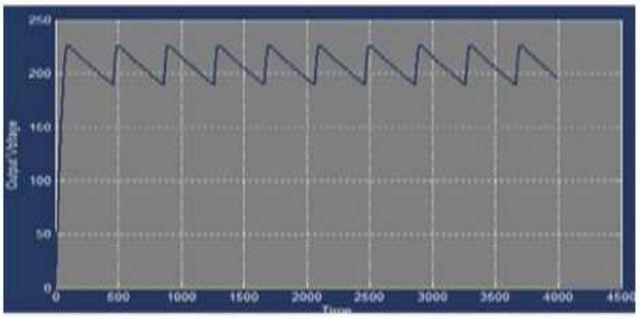

Fig. 7(b) Output Voltage Waveforms of Proposed Circuit

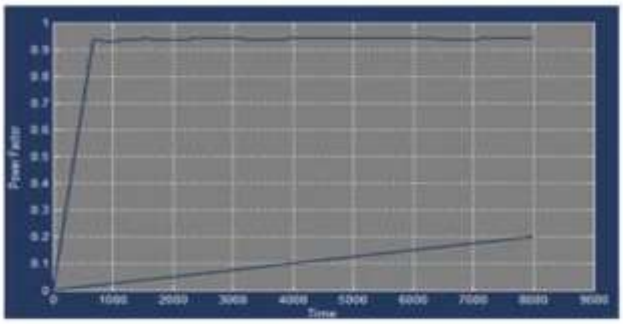

Fig. 7(c) Power Factor of the Proposed Circuit

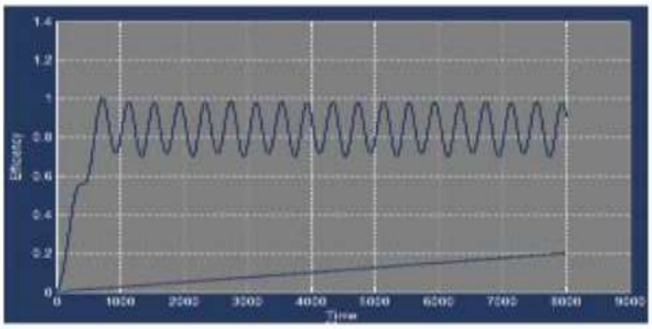

Fig. 7(d) Efficiency of the Proposed Circuit

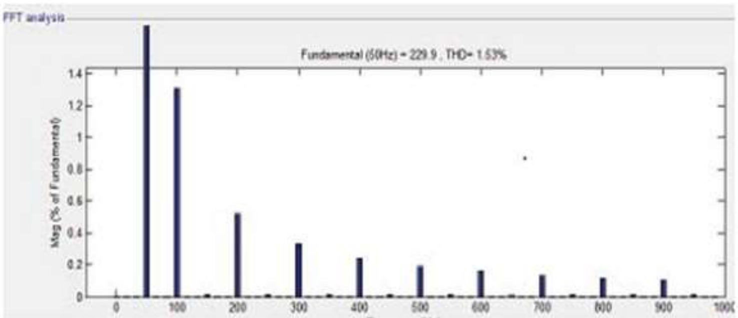

Fig.7 (e) FFT analysis of the proposed circuit

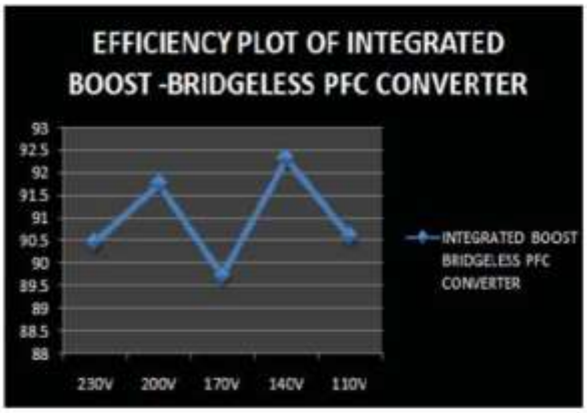

Fig.8 Efficiency of the Proposed Circuit

Conclusion

In this circuit charging of inductor L_{BOOST} and due its electromotive force the regulation of output occurs at the same time and same stage hence drawback of the two stage operation is minimized. While on the other hand switching losses which may occur in single stage due to presence of a single large switch is reduced by using two switches M_1 and M_2.Thus this integrated circuit provides better efficiency almost91%, more power factor almost unity and distortion free waveforms as the THD is reduced to 1.53%.

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