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Single Phase Unidirectional High Efficiency Multilevel Bridgeless Pfc Rectifiers

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Abstract - This project work describes multilevel unidirectional PFC rectifier topologies is suited for applications that gives high efficiency and high power density. The reduced conduction losses are obtained through the use of single converter instead of conventional configuration. The implementation of bridgeless power factor correction (PFC) with low common mode noise is presented in this paper. The topology survey is obtained in several boost power factor corrected converters which offer high efficiency, high power factor and low cost. The hysteresis current control technique for Diode Bridge with two power switches is adopted to achieve high power factor and low harmonic distortion.

Keywords - ***PFC,*** switching loss, High power density, voltage stress.

I. INTRODUCTION

A unidirectional high power factor single-phase ac-dc system assembled by cascading a single-phase diode bridge and a boost dc-dc converter. This converter system, known as conventional single-phase power factor correction (PFC) boost-type rectifier, has many interesting features that justify its extensive use in industry for power conversion below 1 kW, namely: it requires only one fast-switched diode, Db; it employs a single switch, Sb; the gate signal of Sb and the measurement circuits for the input/output voltages can be referenced to the same potential, i.e., the negative output voltage terminal; the inductor Lb current can be measured with a shunt resistor also referenced to the negative output voltage terminal; it ca n be operated with relatively low complexity modulation and control strategies, where low cost dedicated analog integrated circuits can be employed; it displays relatively low common mode (CM) emission levels.As a result, this ac-dc converter typically features low production cost. Unfortunately, the current across Lb is carried through three semiconductor devices in every operation stage, causing relatively high conduction losses. Additionally, in order to achieve high power density and/or low input current total harmonic distortion (THD), this circuit needs to operate at high switching frequencies, which can lead to unacceptably high switching losses since the switch and diode must commutate the full dc- link voltage.

This work presents new three- level unidirectional single phase high power factor rectifier topologies that combine many features of the bridgeless rectifiers. The topologies shown in present three distinct dc voltage levels per converter arm for controlling the input current, which not only leads to a substantial volume reduction of the boost inductor, but also to lower switching losses when compared to the conventional two- level PFC rectifiers depicted. In addition, the proposed converters can also achieve lower conduction losses than the conventional system, as in some conduction states only two semiconductor devices carry the inductor current and some of the semiconductors are rated for one half of the dc- link voltage. These characteristics make the new rectifiers well-suited for applications aiming for high efficiency and/or high power density.

A single-stage bridgeless power-factor-correction (PFC) rectifier based on flyback topology is presented in this paper[1]. The proposed rectifier substantially improves efficiency and power factor without the use of additional isolation stage. The proposed design is suitable for wide-range input low-power off line applications. [2] This paper presents a high power factor rectifier with reduced conduction and commutation losses for telecommunication applications. The reduced conduction losses are obtained through the use of a single converter, instead of the conventional configuration, composed of a four-diode front-end rectifier followed by a boost converter. [3] This work presents a stability evaluation for a single-phase boost PFC converter employing digitally implemented input current self-control to achieve close to unity power factor. Both analog and digital approaches for the proportional compensator are studied and the effects of transport delays found in digital controllers. [4] This paper presents a bridgeless single-stage, single phase circuit topology consisting in the association of a full-bridge isolated DC-DC converter with only one input inductor connected to the grid and two rectifier diodes, to provide sinusoidal input current wave shaping. [5] In this paper, interleaved boost topology is employed in the first stage for power factor correction (PFC) and to reduce total harmonic distortion (THD). Results of the analyses show that the first stage PFC converter achieves THD less than 4% and power factor. [6] This paper presents simple zero-voltage switching (ZVS) interleaved boost power factor correction (PFC) ac/dc converter used to charge the traction battery of an electric vehicle from the utility mains. The proposed topology consists of a passive auxiliary circuit, placed between two phases of the interleaved front-end boost PFC converter, which provides enough current to charge and discharge the MOSFETs' output capacitors during turn-ON times. Therefore, the MOSFETs are turned ON at zero voltage. [7] In this paper, both differential-mode (DM) and common-mode (CM) inductors are first discussed. The methods for both DM and CM inductor winding capacitance cancellation are then proposed. Electromagnetic interference (EMI) is efficiently reduce the effects of winding capacitance and therefore improve the inductor's filtering performance. [8] In this paper, Primary-side sensing (PSS) technique can be used for the output voltage. This new PSS sampling technique is then implemented for the power factor correction (PFC) of a flyback converter. A multi-mode control strategy can improve sampling accuracy at the

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zero-crossing of the rectified input voltage. Experimental results are shown to verify the feasibility of PSS technique realized with digital control technique. [9] The implementation of a bridgeless PFC boost rectifier with low common-mode noise is presented in this paper. The proposed implementation employs a unique multiple-winding, multi core inductor to increase the utilization of the magnetic material. [10] This paper presents a high power factor rectifier with reduced conduction and commutation losses for telecommunication applications. The reduced conduction losses are obtained through the use of a single converter, four diode front-end rectifier followed by a boost converter .

II.DESCRIPTION OF THE SCHEME

In the proposed rectifier was evaluated on a 110-kHz, 750-prototype circuit that was designed to operate from a universal ac-line input (85–264 Vrms) and deliver up to 1.9 A at a 400-V output. Since the drain voltage of boost switches S1 and S2 is clamped to bulk capacitor *CB*, the peak voltage stress on each boost switch is approximately 400 V. The peak current stress on boost switches S1 and S2, which occurs at full- load and low line, is approximately 13.3 A. Therefore, an IPP60R099CS MOSFET (*V*DSS = 600 V, *I*D25 = 19 A,

*R*DS = 0.099 Ω) from Infineon was used for each boost switch. Boost diodes D1 and D2 were implemented with SDT08S60 SiC diode (*V*RRM = 600 V, *I*FAVM = 8 A) from Infineon, and two diodes of bridge rectifier D15XB60 (*V*RRM = 600 V, *I*FAVM = 15 A) from Shindengen were used as diodes D3 and D4 .The structure of the common-core inductor. The cores of inductor *LB* are 58928-A2 (high flux core, μ = 160, OD = 1.09__) from Magnetics. A magnet wire (30 turns, AWG# 16) was used for each winding of *NA*1, *NA*2, *NB*1, and *NB*2. shows a picture of the common-core inductors used in the experimental circuit. Finally, two high voltage aluminum capacitors (470 μF, 450 VDC) were used for bulk capacitor *CB*. Picture of the constructed boost inductors for the dual-boost PFC rectifier with return diodes in(an eight-pin continuous-conduction- mode PFC controller) from Infineon was used in the experimental prototype circuit because it does not require line voltage sensing. If a conventional PFC controller was used, such as UCC3854, a relatively complex input-voltage-sensing circuit would be required. It should be noted that switches S1 and S2 are operated simultaneously by the same gate signal from the controller. Although both switches are always gated, only one switch, on which the positive input voltage is induced, i.e., switch S1 in carries positive current and delivers the power to the output. The other switch, on which the negative input voltage is induced, i.e., switch S2 in does not influence the operation since its body diode that is effectively connected in parallel with D4conducts.To compare the performance of the proposed rectifier and conventional PFC rectifiers, the same prototype hardware.

- ❖ To achieve Optimal power factor
- ❖ To Minimized switching loss
- ❖ To Increase High power density
- ❖ To Reduced voltage stress
- ❖ To Improved life and efficiency

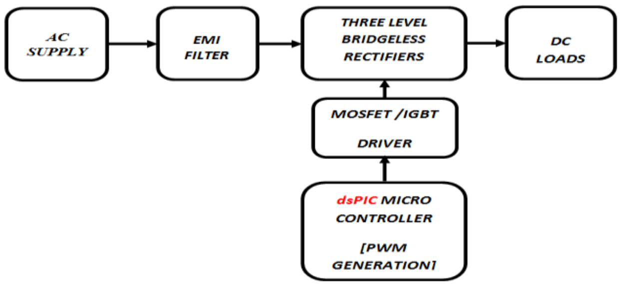

Figure 1.block diagram of 1 ϕ pfc rectifier

In this circuit bridgeless PFC rectifier is used to improve the power factor by reducing the switching losses. They have used two MOSFETS for anti parallel connection. Six new rectifier circuits are proposed, where the dc-load plus the dc- link capacitors are replaced by two dc voltages (Vo=2) and the single-phase power grid plus filters and ac-side boost inductor are replaced by bidirectional current sources.These rectifier concepts are suitable solutions for increasing the efficiency of wide input voltage rang single-phase high.

A. Bridgeless Pfc Boost Rectifier

Fast-Escalating and extremely challenging high-efficiency requirements for ac/dc power supplies for notebooks, desktop computers, workstations, and servers, spelled out in the U.S. Environmental Protection Agency (EPA) Energy Star and climate savers computing initiative documents, are forcing designers to look for any possible opportunity to minimize power losses. Recently, in an effort to improve the efficiency of the front-end PFC rectifiers, many power supply manufacturers and some semiconductor companies have started looking into bridgeless PFC circuit topologies. Generally, the bridgeless PFC topologies, also referred to as dual boot PFC rectifiers, may reduce the conduction loss by reducing the number of semiconductor components in the line current path.So far, a number of bridgeless PFC boost rectifier implementations and their variations have been proposed. In this paper, a systematic review of the bridgeless PFC boost rectifier implementations that have received the most attention is presented. Performance comparison between the conventional PFC boost rectifier and a representative member of the bridgeless PFC boost rectifier family is performed. Loss analysis and experimental efficiency evaluation for both continuous- conduction mode (CCM) and discontinuous-conduction mode (DCM)/CCM boundary operations are provided.

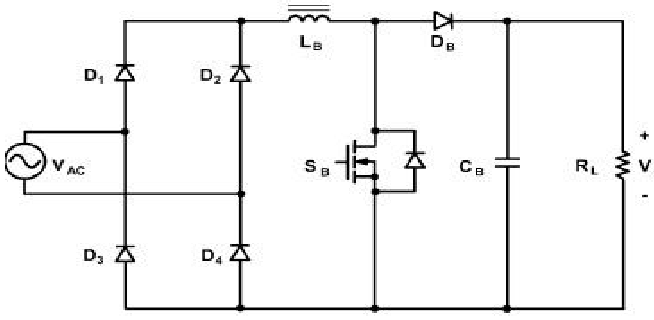

Figure 2. Pfc Rectifier

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The basic topology of the bridgeless PFC boost rectifier . Compared to the conventional PFC boost rectifier, one diode is eliminated from the line-current path, so that the line current simultaneously flows through only two semiconductors, resulting in reduced conduction losses. However, the bridgeless PFC boost rectifier in Fig. 2 has significantly larger common- mode noise than the conventional PFC boost rectifier. In fact, in the conventional PFC boost rectifier, the output ground is always connected to the ac source through the full-bridge rectifier (slow-recovery diodes), whereas, in the bridgeless PFC boost rectifier in Fig. 2, the output ground is connected to the ac source only during a positive half- line cycle, through the body diode of switch, while during a negative half- line cycle the output ground is pulsating relative to the ac source with a high frequency (HF) and with an amplitude equal to the output voltage. This HF pulsating voltage source charges and discharges the equivalent parasitic capacitance between the output ground and the ac line ground, resulting in a significantly increased common-mode noise.

B. Emi Filter

An EMI filter, or electromagnetic interference filter, is an electronic passive device which is used in order to suppress conducted interference that is present on a signal or power line. EMI filters can be used to suppress interference that is generated by the device or by other equipment in order make a device more immune to electromagnetic interference signals present in the environment. Most EMI filters consist of components that suppress differential and common mode interference.

Types of EMI Filters

There are many different kinds of EMI filters. At Future Electronics we stock many of the most common types categorized by type, case size / dimension, impedance, maximum DC resistance, capacitance and rated current. The parametric filters on our website can help refine your search results depending on the required specifications.

The most common values for capacitance are 100 pF, 470 pF, 1 nF, 2.2 nF and 22 nF. We also carry EMI filters with capacitance up to 27 µFcurrent can have a range between 1 mA and 100 A, with the most common EMI filters having a rated current o f 200 mA, 300 mA, 2A or 6Future Electronics has a full EMI filter selection from several manufacturers that can be used to design an RFI EMI filter, DC EMI filter, AC EMI filter, 3 phase EMI filter, Ethernet EMI filter, EMI air filter, EMI line filter, EMI suppression filter, EMI power filter, EMI noise filter or any circuit that may require an EMI filter. Simply choose from the EMI filter technical attributes below and your search results will quickly be narrowed in order to match your specific EMI filter application.

C. Capacitor

A capacitor (formerly known as condenser) is a device for storing electric charge. The forms of practical capacitors vary widely, but all contain at least two conductors separated by a non-conductor. Capacitors used as parts of electrical systems, for example, consist of metal foils separated by a layer of insulating film. Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies and for many other purposes.

Theory of operation

A capacitor consists of two conductors separated by a non-conductive region called the dielectric medium though it may be a vacuum or a semiconductor depletion region chemically identical to the conductors. A capacitor is assumed to be self-contained and isolated, with no net electric charge and no influence from any external electric field. The conductors thus hold equal and opposite charges on their facing surfaces, and the dielectric develops an electric field. In SI units, a capacitance of one farad means that one coulomb of charge on each conductor causevoltage of one volt across the device .The capacitor is a reasonably general model for electric fields within electric circuits. An ideal capacitor is wholly characterized by a constant capacitance C, defined as the ratio of charge ±Q on each conductor to the voltage V between them.

$$C = \frac{Q}{V}$$

Sometimes charge build-up affects the capacitor mechanically, causing its capacitance to vary. In this case, capacitance is defined in terms of incremental changes:

$$C = \frac{\mathrm{d}q}{\mathrm{d}v}$$

$$W = \int_{q=0}^{Q} V\,\mathrm{d}q = \int_{q=0}^{Q} \frac{q}{C}\,\mathrm{d}q = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ.$$

D. Inductor

An inductor (or reactor) is a passive electrical component that can store energy in a magnetic field created by the electric current passing through it. An inductor's ability to store magnetic energy is measured by its inductance, in units of henries. Typically an inductor is a conducting wire shaped as a coil; the loops help to create a strong magnetic field inside the coil due to Ampere's Law. Due to the time-varying magnetic field inside the coil, a voltage is induced, according to Faraday's law of electromagnetic induction, which by Lenz's Law opposes the change in current that created it. Inductors are one of the basic components used in electronics where current and voltage change with time, due to the ability of inductors to delay and reshape alternating currents. Inductors called chokes are used as parts of filters in power supplies or to block AC signals from passing through a circuit.Inductors are used extensively in analog circuits and signal processing. Inductors in conjunction with capacitors and other components form tuned circuits which can emphasize or filter out specific signal frequencies. Applications range from the use of large inductors in power supplies, which in conjunction with filter capacitors remove residual hums known as the mains hum or other fluctuations from the direct current output, to the small inductance of the ferrite bead or torus installed around a cable

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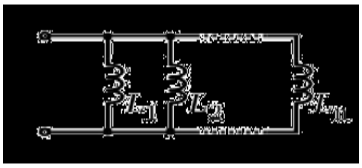
to prevent radio frequency interference from being trans mitted down the wire.Smaller inductor/capacitor combinations provide tuned circuits used in radio reception and broadcasting, for instance.Two (or more) inductors that have coupled magnetic flux form a transformer, which is a fundamental component of every electric utility power grid. The efficiency of a transformer may decrease as the frequency increases due to eddy currents in the core material and skin effect on the windings. Size of the core can be decreased at higher frequencies and, for this reason, aircraft use 400 hertz alternating current rather than the usual 50 or 60 hertz, allowing a great saving in weight from the use of smaller transformers.



$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}$$

Inductor construction

An inductor is usually constructed as a coil of conducting material, typically copper wire, wrapped around a core either of air or of ferromagnetic or ferric magnetic material. Core materials with a higher permeability than air increase the magnetic field and confine it closely to the inductor, thereby increasing the inductance. Low frequency inductors are constructed like transformers, with cores of electrical steel laminated to prevent eddy currents.The effect of an inductor in a circuit is to oppose changes in current through it by developing a voltage across it proportional to the rate of change of the current. An ideal inductor would offer no resistance to a constant direct current; however, only superconducting inductors have truly zero electrical resistance.The relationship between the time-varying voltage v(t) across an inductor with inductance L and the time-varying current i(t) passing through it is described by the differential equation:

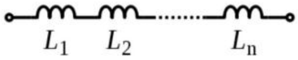
$$v(t) = L\frac{di(t)}{dt}$$

When there is a sinusoidal alternating current (AC) through an inductor, a sinusoidal voltage is induced. The amplitude of the voltage is proportional to the product of the amplitude (IP) of the current and the frequency (f) of the current.

$$i(t) = I_P \sin(2\pi f t)$$
$$\frac{di(t)}{dt} = 2\pi f I_P \cos(2\pi f t)$$
$$v(t) = 2\pi f L I_P \cos(2\pi f t)$$

In this situation, the phase of the current lags that of the voltage by π/2.Inductors in a parallel configuration each have the same potential difference (voltage). To find their total equivalent inductance (Leq):

The current through inductors in series stays the same, but the voltage across each inductor can be different. The sum of the potential differences (voltage) is equal to the total voltage. To find their total inductance:



$$L_{eq} = L_1 + L_2 + \cdots + L_n$$

III. SIMULATION AND RESULTS

The below figure shows the circuit of the proposed system. Here only two MOSFETS are used for reducing of switching losses. In this circuit 10% to 100% if p0 the measured efficiency is found between the range of 98 % and 98.6%. Additionally the THD rate can be improved with high efficiency.

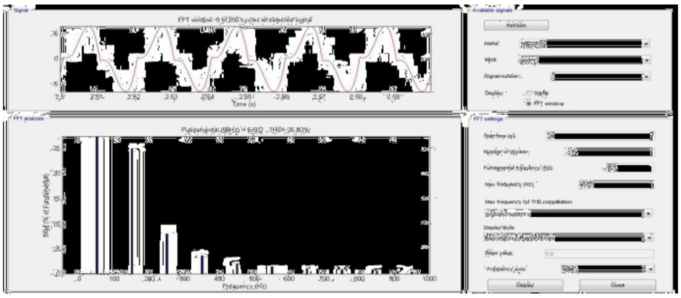


Figure 3.Simulation Diagram

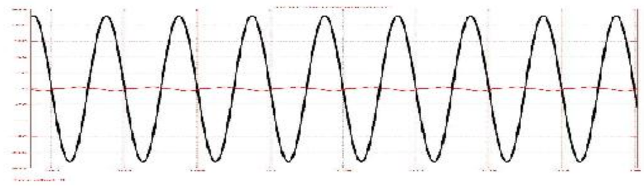


Figure 4 Input Voltage Waveform

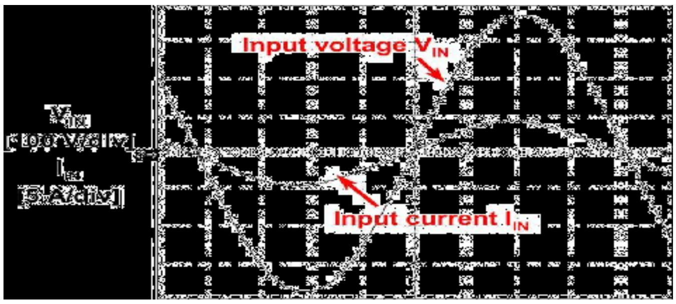


Figure 5 Output Voltage Waveform

The above figure shows the output voltage and the current. Here ripples are reduced to lower level. The main waveform obtained with the designed prototype operating at 3kw which is presented in the above circuit.The above figure shows the output voltage of the proposed system and it causes high efficiency. It is noted that all commutations occur with a voltage level equivalent to half the output voltage.

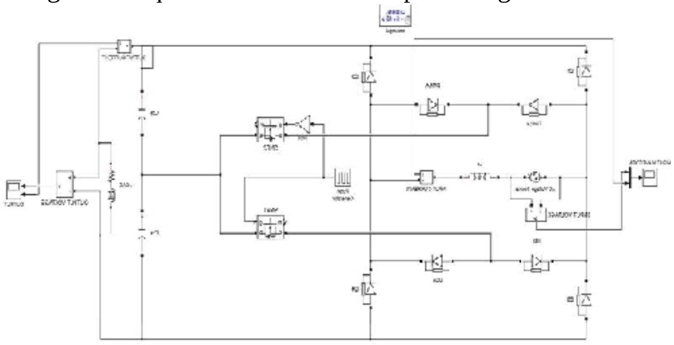


Figure 6 Analysis Of FFT Windows

The analysis of FFT windows is in 250 cycles with signal. This can reduce the ripples in the circuit and improve the power factor. The result shows that the high power density of the input current and the THD rating will be 2.18% have been measured.

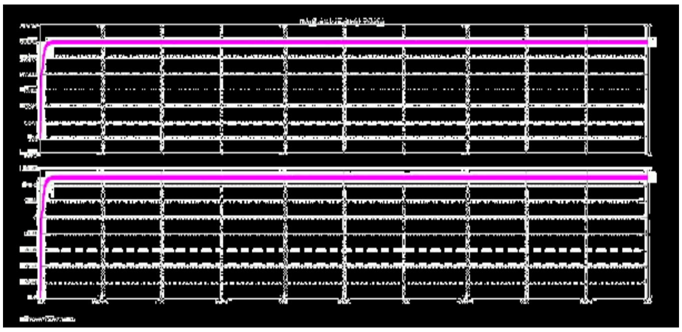


Figure 7 Output Power

The measured total harmonic distortion (THD) and power factor (PF) of the converter at low line and high line are summarized in Table I. The measured THD and PF of the proposed rectifier at minimum line and full- load are approximately 3.5% and 99.9%, respectively, while those at maximum line and full- load are approximately 7.9% and 99.1%, respectively. It should be noted that THD and PF performance of the bridgeless boost PFC circuits in general, including the proposed circuit in Fig. 7, is primarily determined by the PFC control approach and a proper control-loop compensation rather than the power stage components. In fact, since the proposed circuit in Fig. 7 operates as a conventional PFC circuit during each half line cycle, its THD and PF performance is the same as that of the conventional circuit with same control design. The measured quasi-peak EMI of the conventional dual-boost PFC rectifier, the dualboost PFC rectifier with return diodes, and the proposed dual-boost PFC rectifier.

IV.CONCLUSION

The objective of this project started from the literature survey by observing different research works and combining multiple observations into a single work. The Mathematical Modeling has increased the Performance of this simulated work efficiently. For a Resistive Load of 100Ω, the output power is increased with an efficiency of 95% and the efficiency vs. output voltage shows the effectiveness and the stability of the system. In this Proposed Method, the multilevel high efficiency unidirectional single phase PFC rectifiers which is well suited for applications aiming for high efficiencies and high power factor have been proposed in this work.

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