A SINGLE PHASE, SINGLE STAGE THREE LEVEL BOOST DC- DC CONVERTER

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ABSTRACT

A Single Phase, Single Stage three level boost dc-dc converter that operates with a single controller with standard PWM technique to obtain regulated dc output voltage is presented in this paper. The operation of the converter is explained and its feasibility is confirmed with experimental results.

Keywords: *dc-dc power conversion, three level converters, single stage converter***.**

I. INTRODUCTION

DC-DC power converters are employed in a variety of applications, including power supplies for personal computers, office equipment, spacecraft power systems, laptop, computers and telecommunications equipment as well as dc motor drives. The input to a dc-dc converter is an unregulated dc voltage. The converter produces a regulated output voltage V, having a magnitude (and possibly polarity) that differs from input voltage. The conventionally used converters are cascade or interleaved boost converter to obtain the required high voltage gain [1],[2].Though the required high gain is achieved by cascading and interleaving, it results in high ripple current and relatively higher losses which restrict the operation at high efficiency and high gain. Further, these topologies resulted in incremental cost and complexity of the control circuit hence it is not preferred. Transformers or coupled inductor were used in isolated topologies with required turn's ratio to achieve the required voltage gain [1]. These topologies are bulky as they employ transformers. Transformer with high turns ratio is not preferred due to high leakage at the secondary which causes switching losses at the output. This type of converters suffers from limited switching frequency, increased transformer losses and increased voltage stress [2]. Hence in order to full fill all the requirements the concept of multi level converter is introduced. The use of multilevel converter requires only low voltage devices as each device blocks only one voltage level. Some of the advantages of multilevel dc–dc converter compared to traditional topologies are i) low harmonic distortion ii) low voltage stress iii) low EMI noise iv) low switching frequency and v) high efficiency [2]. This paper proposes a three level dc–dc converter topology. The three level boost converter combines the basic boost converter and three level inverter operation into a single stage converter. A new three level dc–dc single-stage converter that can operate with standard PWM technique is proposed. The purpose of this converter to achieve power factor correction and to obtain the regulated dc output voltage, where converter can operate with lower peak voltage stresses across the switches and the dc bus capacitors as it is a three-level converter The outstanding features of the converter is that an output current will be continuous when the converter is operating from maximum load to at least half of the load. This converter provides variable output voltage with good efficiency. The paper introduces a new converter explains its basic operating principles, modes of operation, discusses its features and its design.

II. CONVERTER OPERATION

The proposed converter, which is shown in Fig. 1, integrates boost converter into a three-level dc/dc converter. The boost section consists of boost inductor Lin, boost diode Dx1 and switch S4, which is shared by the multilevel DC-DC section. When S4 is off, it means that no more energy can be captured by the boost inductor. In this case diode Dx2 prevents input current from flowing to the mid-point of capacitors C1 and C2 and diode Dx1 conducts and helps to transfer the energy stored in the boost inductor Lin to the dc bus capacitor. Diode Dx3 bypasses Dx2 and makes a path for circulating current. Although there is only a single converter, it is operated with two independent controllers. One controller is used to perform PFC and regulate the voltage across the primary-side dc bus capacitors by sending appropriate gating signals to S4. The other controller issued to regulate the output voltage by sending appropriate gating signals to S1 to S4. It should be noted that the control of the input section is decoupled from the control of the dc-dc section and thus can be designed separately. The gating signal of S1, however, is dependent on that of S4, which is the output of the input controller. The gating signals for S2 and S3 are easier to generate as both switches are each ON for half a switching cycle, but are never ON at the same time.

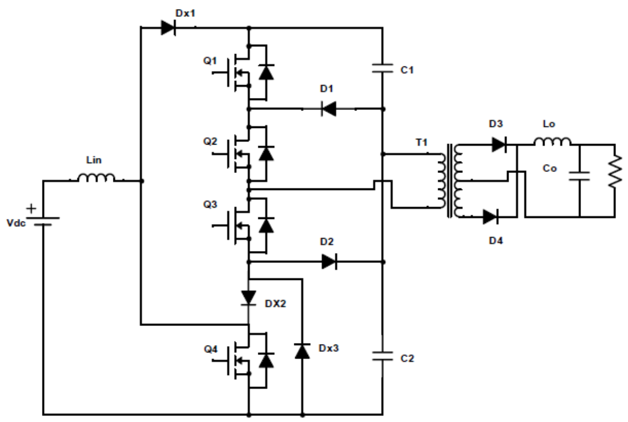

Fig 1: Proposed converter

Typical converter waveforms are shown in Fig. 2, and equivalent circuit diagrams that show the converter's modes of operation are shown in Fig. 3 .As the input line frequency is much lower than the switching frequency, it is assumed that the supply voltage is constant within a switching cycle. The converter has the following modes of operation.

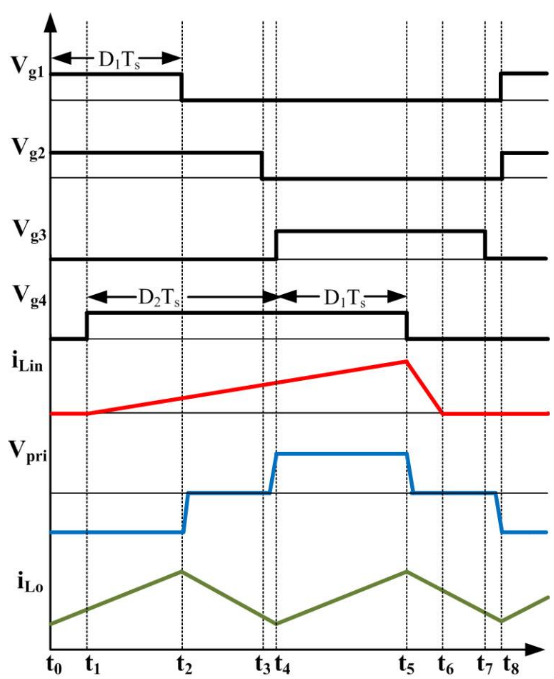

Fig 2: Typical waveforms of the converter

Mode 1 ($t_0 < t < t_1$):
During this mode, switches S1 and S2 are ON and energy from DC bus capacitor C1 is transferred to the output load. In the output section, a positive voltage of (Vpri/n)-Vo (where n is the ratio of primary to secondary transformer turns) is impressed across Lo and the current through it rises.

Mode 2 ($t_1 < t < t_2$):
In this mode, S1 and S2 remain ON. The energy from dc bus capacitor C1 is transferred to the output load. At the same time, the diode bridge output voltage V_{rec} is impressed across input inductor Lin so that the current flowing through this inductor rises.

Mode 3 ($t_2 < t < t_3$):
In this mode, S1 off and S2 remain ON .The energy from dc bus capacitor C1 is transferred to the output load. At the same time, the diode bridge output voltage V_{rec} is impressed across input inductor Lin so that the current flowing through this inductor rises voltage V_{rec} is impressed across input inductor Lin so that the current flowing through this inductor rises.

Mode 4 ($t_3 < t < t_4$):
In this mode, S1 and S2 are OFF and S4 is ON. The current in the primary of the transformer charges capacitor C2 through the body diode of S3 and Dx3.

Mode 5($t_4 < t < t_5$):
In this mode, S3 and S4 are ON. Energy flows from capacitor C2 flows into the load while the current flowing through input inductor Lin continues to rise.

Mode 6($t_5 < t < t_6$):
In this mode, S4 turns off. The current in input inductor flows thorough the diode Dx1 to charge the capacitors C1 and C2. The current in the transformer primary flows thorough the S3 and D2. This mode ends when the inductor current reaches zero. Also during this mode, the load inductor current freewheels in the secondary of the transformer.

Mode 7($t_6 < t < t_7$):
In this mode, the load inductor current freewheels in the secondary of the transformer. This mode ends when the switches S3 turns off.

Mode8 ($t_7 < t < t_8$):
In this mode, S3 is OFF and the current in the primary of the transformer charges capacitor C1 through the body diodes of S1and S2. Finally, converter reenters Mode 1.

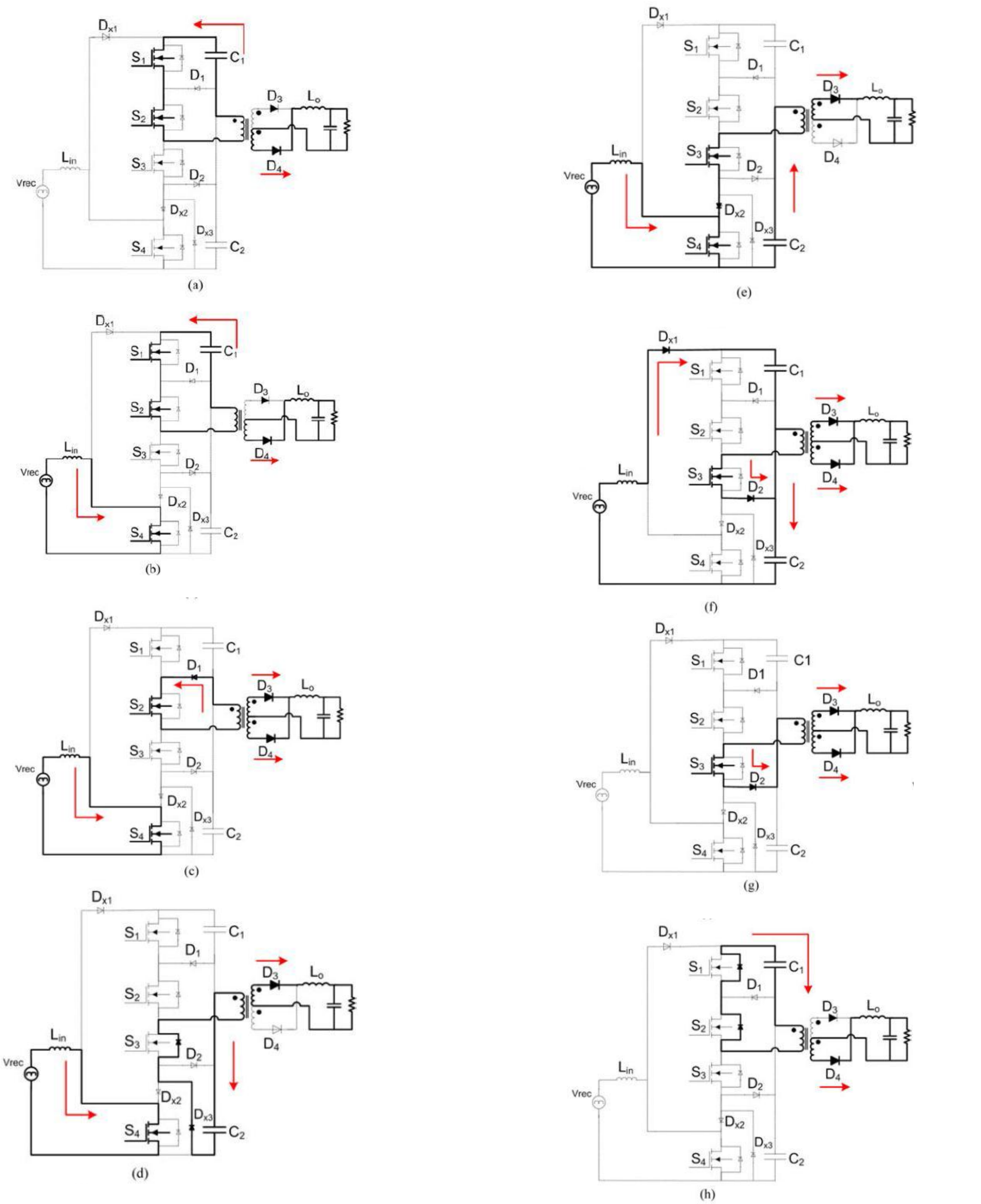

Fig 3: Equivalent circuits for each operation stage for the converter(a) Mode 1 (t_0< t t_1)(b) Mode 2 (t_1< t < t_2) (c) Mode 3 (t_2 < t < t_3) (d) Mode 4 (t_3< t t_4). (e) Mode 5(t_4< t< t_5) (f) Mode 6(t_5 < t <t_6) (g) Mode 7(t_6 < t < t_7). (h) Mode8 (t_7< t<t_8).

III. EXPERIMENTAL RESULT

The experimental circuit scheme of the proposed converter is tested for different loads and duty cycle. The corresponding output voltage is noted down. The resulting waveforms for the proposed converter are discussed in this section. The proposed converter can operate with universal input voltage and with a better efficiency, less distorted input current and wider load operating range.

TABLE 1: Fixed duty cycle, variable load &V_{dc}=12V.

Load(R) ohms	T_{ON}=2×10μs	T_{ON}=2.2×10μs	T_{ON}=2.4×10μs
1000	55.7V	58.2V	67.5V
900	53.7V	57.6V	66.8V
800	52.2V	55.7 V	66.2V
700	50.9V	55.7V	65.2V
600	49.7 V	54.7V	63.8V
500	47.8 V	53.1V	62V
400	44.4 V	50.5V	58V
300	42 V	47.7V	55.2V

TABLE 2: Variable duty cycle, fixed load=1000ohms, V_{dc}=12V.

T_{ON}	Output voltage
1.2×10μ sec	10.67 V
1.6×10μ sec	20.42V
1.8×10μ sec	32.16 V
2×10μ sec	47.8 V
2.2×10μ sec	55.5 V
2.4×10μ sec	60.5 V
2.6×10μ sec	66.6 V
2.8×10μ sec	72.5 V

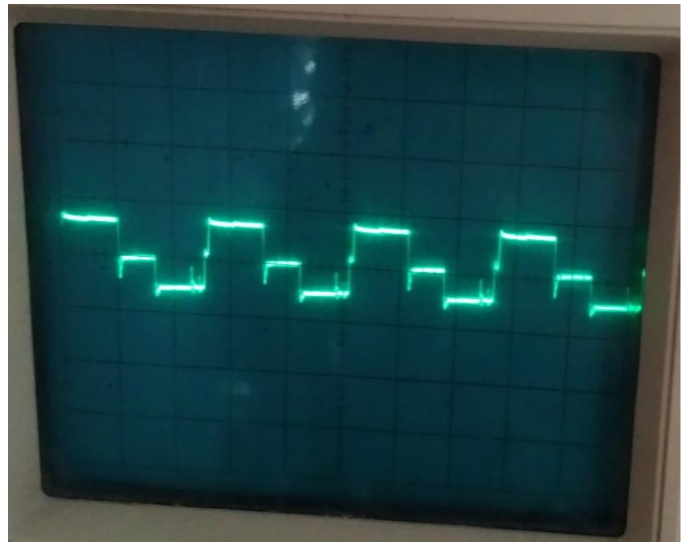

Fig 4: Three level inverter output across primary of transformer

Fig 5: The complete hardware set up

IV. CONCLUSION

A new multilevel single-stage boost dc-dc converter is proposed in the paper .The proposed single stage dc-dc converter with PWM technique allows for optimizing the efficiency of the converter and as well as reduces the harmonic distortion. As the proposed converter is a single stage converter hence the size and cost of the converter is less. The converter can operate with lower peak voltage stresses across the switches and the dc bus capacitors as it is a three-level converter. This allows for greater flexibility in the design of the converter and ultimately improved performance.

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