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A Comparative Study of Different Topologies of Transformer less AC-DC Converters

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Abstract: The need of single stage transformer less high step-down converters is increasing due to the strict current harmonic regulations in the low power applications. Many topologies are reported that have same characteristics. In this paper 6 topologies are compared each other with respect to their features and analyzed their voltage conversion ratio, number of components, intermediate bus voltage etc. This paper should serve as a convenient reference for future work in the field of power electronic transformer less single stage ac-dc converters.

Keywords: Ac-Dc Converters, Transformer Less Topologies, High Efficient.

1. INTRODUCTION

In early days, for the DC low voltage applications such as LED lighting etc. we are used a simple topology like a high step down transformer with a rectifier and bulk capacitors to reduce the ripples. There is no intention to reduce the current harmonics and about the power factor. Then we were started to consider the input power factor and current harmonics. The evolution of the two stage converters is introduced the concept that the PFC cell with a transformer and a rectifier. In that days boost or buck- boost cells are used as PFC cell due to their inherent PFC correction. The block diagram shows the two stage conversion (Fig1). But it has so many limitations.

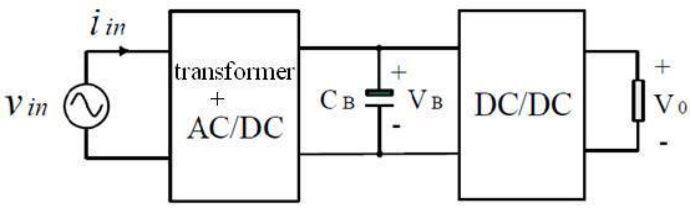

Fig. 1: Block diagram of two stage converter

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Limitations of Two Stage Converters

- The number components used in the two stage converters are very high.
- Losses are high. So the efficiency considerably reduced.
- Cost is high due to mainly the presence of the trans-former
- Bulkness of the circuit

  Leakage inductance of a transformer causes the high current spikes in the circuit

Single Stage Transformerless High Powerfactor High Step down Converters

The problems of the two stage converters is overcome by the single stage converters and the block diagram of a common SS converters is shown in Fig 2

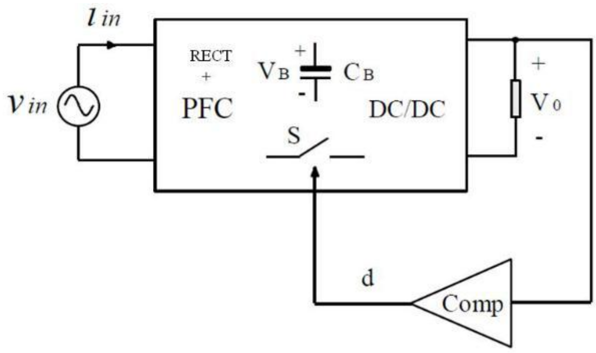

Fig. 2: Block diagram of the single stage converter

Here this converter consists a rectifier, a PFC cell with a DC-DC converter. The absence of transformer is one of the main advantages of the SS converters. But there are also so many SS converter topologies introduced with a transformer. Transformerless SS converters can avoid so many disadvantages of the two stage converters.[1] The SS converters with the boost cell as PFC, has disadvantage that its high intermediate bus voltage. It will cause the component stresses especially for the low voltage applications. If we are using the buck-boost cell as PFC, it required very narrow duty cycle for high step down purposes.it is practically very difficult one.

It consists a power-factor-correction (PFC) circuit is becomes mandatory for maintaining the current harmonics.. So usually we are prefer the SS converters for DC low power applications. For DC low power level applications, usually we require the supply voltage is less than 20V. So it has to convert the main supply AC 230V to that particular DC voltage. For that we have many topologies which are working in voltage input range (90- 270 V_{rms}). Next section will analyse the 5 topologies related to their efficiency, output voltage, intermediate bus voltage, number of components etc. These topologies exhibits high power factor, high step down, transformer less, single stage and AC-DC conversion.

Buck-Boost Buck type AC-DC Converter

Fig 3 shows the proposed high power factor buck-boost buck type AC-DC converter. Here the Buck–Boost cell itself act as a PFC and it is the main advantage over the conventional.

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And the buck cell for the step down purpose. The proposed topology have one switch and it will turn on with a zero current instant. This topology have constant output voltage with a power factor greater than 0.94 . Moreover, the change in load will not affect the voltage stress developed across the switches. The proposed converter suits better for offline PFC applications for a low power range (< 150 W)[1].

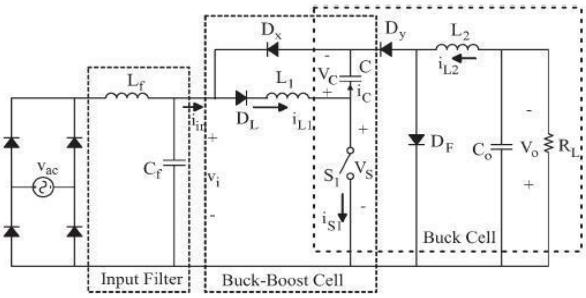

Fig. 3: Buck–Boost Buck type AC-DC Converter [1]

Voltage Conversion ratio

$$M = \frac{V_o}{V_m} = \sqrt{\frac{nD_1}{2K}}$$

Where $\boldsymbol{\eta}$ = Efficiency of the converter
V_o = output voltage V_m = Peak voltage

$$\boldsymbol{D_1 = \frac{T_{on}}{T}}$$

K = Dimensionless factor

$$K = \frac{2L_1}{R_L T_s}$$

T_s = switching time period

The advantages of this converter are including the following:

Zero–current switch turn-on.

The output gets regulated simultaneously along with low voltage stress across the switch due to the presence of capacitor and due to rapid operation of diodes the reverse recovery time is minimised. The power factor gets corrected automatically.

Devices Small low frequency voltage ripple

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To improve the performance of this converter and to make it more practical, the following points should be considered:
Reduction of current density in the switch.
Reduction of losses due to the high frequency switching.

Integrated Buck-Boost Quadratic buck PFC
This topology consists a buck-boost PFC cell with a quadratic buck converter. Due to duty cycle prolonged timing the SS converters will be suitable for isolated applications, but the proposed one is with high frequency operation so it is more suitable for non-isolated applications with less voltage stress, ZCS and simple control. Which keeps the output voltage more regulated one [2]. Here the working is obtained by merging a front-end buck-boost converter and quadratic dc-dc buck converter, as shown in Fig. 1.

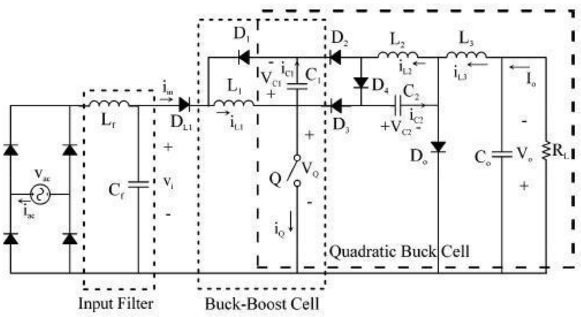

Fig. 4: Buck-Boost Quadratic Buck PFC converter [2]

The buck-boost converter operates in discontinuous conduction mode for the purpose of isolation and it also provides a good power factor with stepping down the voltage level. Hence, the resultant buck boost quadratic buck (BBQB) converter better suits in extreme voltage step-down applications. Along with that, the related characteristics of the proposed converter shown in Fig. 1 also removes the inrush current problem and also act as a protection circuit during over current.

Both converter section operated in DCM, creates the following advantages:

Inherent PFC capability with ZCS
The switch Q operates independently without depending on load current and the reverse recovery time is reduced due to the presence of diode. The response time of this converter is too fast so the output gets controlled smoothly to improve the performance of this converter and to make it more practical, the following points should be considered:

Reduction of losses due to high switching frequency Number. A component is high so the overall conduction losses are high.

In addition, using Boundary Conduction Mode (BCM), and Inductor L3 the efficiency of the converter will increases due to less core loss, by removing the peak currents. Due to the presence of output capacitor Co, the ripple current will also get reduced.

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Resonance-Based Buck Converter for Power LED Applications

For increasing the efficiency, lifetime and power consumption of LED ballast. The converter has to be more efficient with the help of non-isolated converters. With small duty cycles for these converters, it is possible to consume very low voltage compared to the existing one. But the problem exists in the freewheeling action of diodes, in order to achieve the smaller duty ratio with assistance of resonance, it is possible to improve the efficiency of converters.

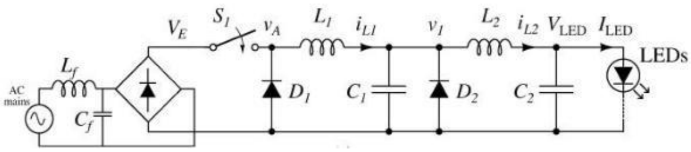

Fig. 5: Résonance Assisted Buck Converter [3]

Mostly for this ballast dimming, the continuous mode of operation is preferred, If DCM is employed it will also increases efficiency and also reduces the stress generated. So, the lifetime of the converter gets increased. The cascaded converters limit the brightness of LED and the switching ripples gets filtered by the storage capacitors. The converters get operated in DCM and CCM respectively. The efficiency of this converter is increased due to the intermediate storage.

This topology has the several advantages:

Allows simple duty cycle control
Resonance assisted filter eliminates the current ripples
Low cost and high density electrolytic capacitors were employed in this topology

Integrated Buck Buck-Boost converter

This topology is also a transformer less and used for universal line applications. In this topology, the direct power transfer is obtained by the voltage sharing capacitors with low voltage stress less than 13-V across the elements and high power factor without having a transformer. Less number of components was involved due to the absence of transformer, the storage on inductor is controlled by the switch of the converter.
Here an Integrated buck-buck-boost (IBuBuBo) is proposed. It has a buck converter and PFC cell. The buck converter reduces the voltage level thereby the power consumption gets reduced. Moreover, transformer is eliminated which reduced the number of components involved. The operation of this converter involves two modes, Mode A and Mode B as shown in Fig 7.

Without transformer, intermediate low voltage profile can be generated;
Easy to control with a single-switch;
Output voltage is positive;
Conversion efficiency is high and
Series connection of switch to the input will be able to provide Input surge current protection.

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To improve the performance of this converter and to make it more practical, the following points should be considered:
The intermediate bus capacitor and output capacitor are bulk one. It may be cause to increase the cost of the circuit.
Bulkness

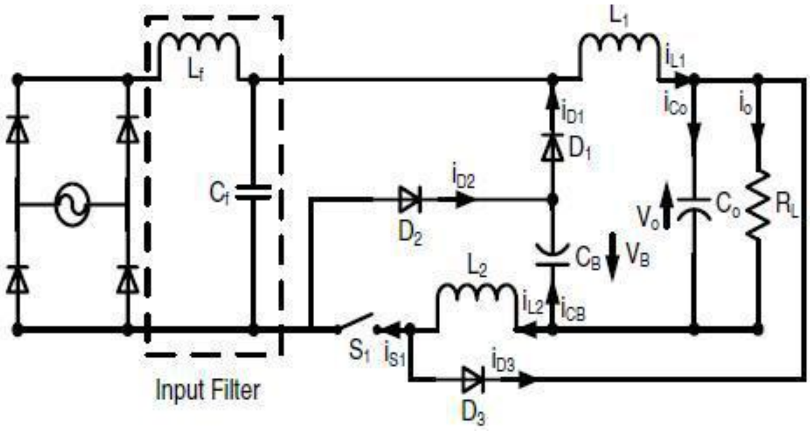

Fig. 6: integrated Buck Buck–Boost converter[4]

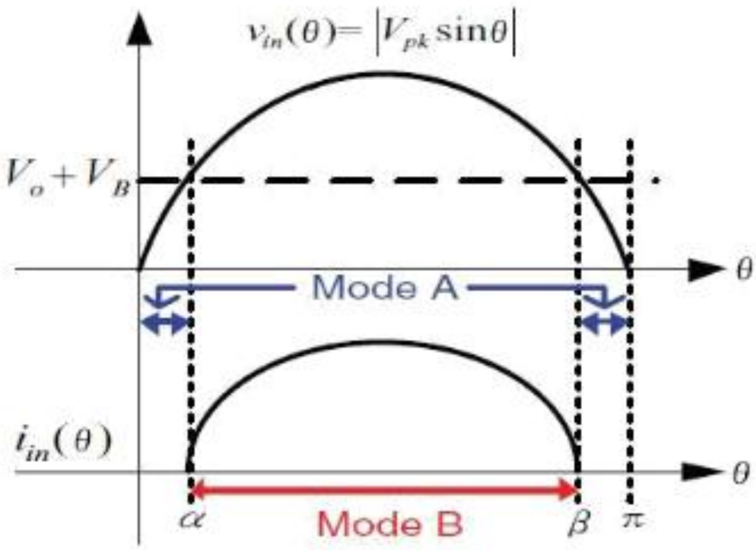

Fig. 7: Input Voltage and Current waveforms

Valley–Fill SEPIC–derived PFC topology
LED lamps are mostly used due to its high efficiency, less power consumption, compact size and high brightness. But the problem faced it due to its non-linearity behaviour it creates variation in power factor. So, the power factor correction is required. Due to its low amps consumption the reduction in current has to be obtained by a typical power supply. The SEPIC driven converter do reduces the voltage stress, and improves the power factor as shown in Fig 8.

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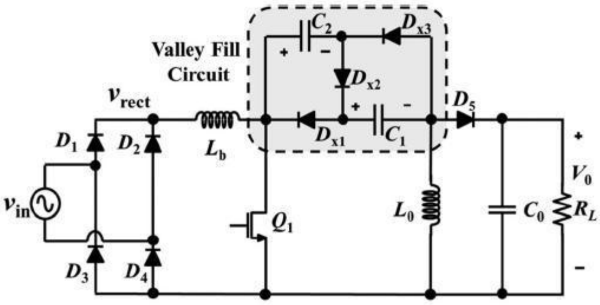

Fig. 8: Valley–Fill SEPIC derived converter [5]

By operating this converter in discontinuous conduction mode (DCM), the use of electrolytic capacitor can be eliminated, by the mean time it maintains high power factor and efficiency. Since the capacitor storage is reduced, the efficiency of the converter can be doubled as compared to the original circuit. The first section improves the power factor and second section dim the light brightness

Integrated Boost Buck–Boost AC-DC Converter

The schematic of the proposed converter, which consists of a boost PFC cell and a buck boost dc/dc cell, is shown in Fig 9. Both cells are operated in DCM. This will works in range of universal input voltages. There are four stages of operation for this circuit. Two switching frequencies are commonly used in this topology: 100 kHz for 90 to 150 Vrms and 200 kHz for 150 to 270 Vrms [6].

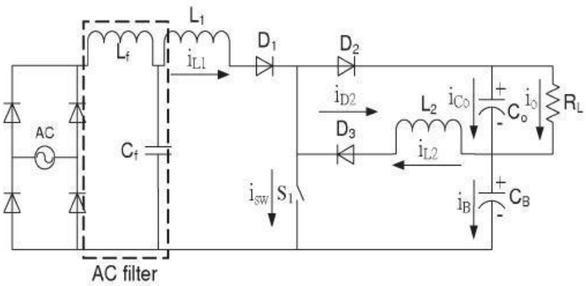

Fig. 9: Integrated Boost Buck-Boost AC-DC converter[6]

The converter has the following advantages:

Due to direct power transfer, the inductance ratio can be easily adjusted, which promotes sharing of bus voltage and the voltage across the capacitors.

The efficiency will be high and the power factor is maintained in good range.

The frequencies are separated with respect to the universal line input range respectively;

Cost is low due to the absence of transformer.

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The main disadvantage of this topology is the high switching frequency compared to the other topologies

2. CONCLUSION

The limitations of the conventional two converters in high step-down low power applications are analysed and 6 topologies, which are published in previous papers, are summarized and classified. The concluding table should serve as a useful guide in choosing the right converter topology for various electrical systems. Table 1 presents the comparison of high step-down high power factor transformerless AC-DC converters with respect to their various performance parameters.

On comparing the isolated SS solutions, the size and cost were reduced in the proposed circuit, The voltage regulation Is maintained smoothly with better power factor maintenance on comparing the other topologies. Cost is low due to the absence of snubber, demagnetizing circuits, and transformer.

Table 1: The comparison between the topologies

Parameters	[1]	[2]	[3]	[4]	[5]	[6]
Diode	4	3	2	3	1	3
Switch	1	2	1	1	1	1
Inductor	2	3	2	2	2	2
Capacitor	2	2	2	2	2	2
Int.bus voltage	86V	209V	N/A	130V	N/A	400V
O/p condition	-20V/50W	-48V/111.52W	19V/13.7W	19V/100W	50V and 45V ;50W	100V/100W
sw.frequency	60kHZ	100kHZ	20kHZ	60kHZ	53kHZ	200kHZ

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