Comparison of Transformer and Transformer less DC-DC Converters for Medium Power Applications

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Abstract: Normal dc–dc boost converters are able to provide normal voltage gains due to the unavailability of stepping up devices. This paper gives a overview on transformer and transformerless dc–dc converters. The two converters are designed with same specifications. These converters are proposed with a very simple design. In the present scenario these converters are best suited for high quality medium power applications such as telecom loads. The study includes mathematical analysis and simulation steps where the switching frequency is varied depending on the output requirement. Using Simulink linear electrical circuit simulation model, the converter design circuits are compared . In conclusion, simulation results demonstrate the comparison between the transformer and transformerless dc–dc converters.

***IndexTerms* - Flyback converter, flyback transformer, CUK converter, unity-power-factor rectifier.**

I. INTRODUCTION

The Cuk converter is used for getting both stepping up and stepping down output voltage. The magnitude of the output voltage can be either smaller or larger than the input, but there is a reversal in the polarity. The filtering is operation is done by the input inductor for the prevention of large harmonic current. The capacitor C1 is the main source for energy transfer for the Cuk converter. The primary assumptions for this circuit analysis are as before.

Both AC/DC and DC/DC conversion is possible with flyback converter with isolation between the input and outputs. The flyback converter is the modified form of buck-boost converter as the transformer is split to form a inductor, so that the voltage ratios are multiplied with isolation as an additional advantage. The flyback converter is a equivalent to that of a buck-boost converter, but the only difference is the transformer is split into a inductor.

The main design improvements in the circuit components and the leakage inductance of the flyback transformer include the following.

[1]. The semiconductor devices with less internal inductances such as low-profile screw type IGBT and diodes.
[2]. Smaller sized components with reduced current ratings are used in parallel instead of large single component.
[3]. The zero sequence currents are prevented not to flow in the output, the secondary of the flyback transformers are connected in delta with less number of primary turns, less number of winding layers and it allows smaller turns ratio of the transformers..
[4]. Transformer uses distributed air-gapped core, a taller window area, sandwiched windings, and a winding strategy that yields the minimum coil build up while providing the physically closest packaging of winding layers.

II. OPERATIONAL PRINCIPLES OF CUK CONVERTER

The capacitor C1 gets charged by the input source through the inductor L1 when the switch is in off state. The capacitor C transfers the energy charged in the off state through the inductor L2 when the switch is in on state. In a non-isolated Ćuk converter there are two inductors, two capacitors, a switch (usually a transistor), and a diode as basic circuit elements. Its schematic can be seen in figure 1. The output voltage is negative for a inverting converter with respect to the supply voltage. The capacitor C is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode for the transfer of energy.

The output voltage source (C_o) and input voltage sources (V_i) are converted into current sources by the help of two inductors L1 and L2. For a small instant the inductor makes the voltage source as a constant current source. Otherwise there is chance of high energy loss when a capacitor is directly connected to the voltage source. This energy loss for charging a capacitor with a voltage source can be reduced by replacing the voltage source by an current source (voltage source in series with the inductor), which prevents resistive current limiting. The Cuk converter can operate in both continuous and discontinuous current mode same as other basic DC- DC converters.

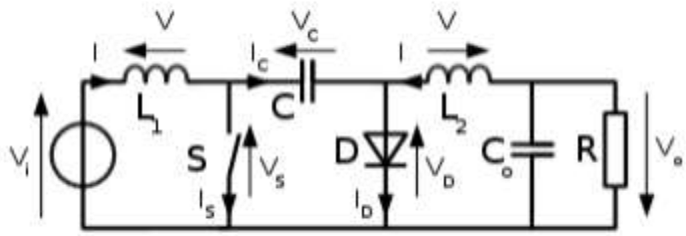

Figure1: Basic Cuk Converter

The advantages Cuk converter is are

- Continuous input current.
- Continuous output current.
- Output voltage can be either greater or less than input voltage.

III. OPERATIONAL PRINCIPLES OF FLYBACK CONVERTER

The isolation between the input and outputs can be done by the flyback converter which is used for both AC/DC and DC/DC conversion. The flyback converter has an additional advantage of isolation along with the same operation as that of buck-boost converter with the inductor split to form a transformer.

When the switch is closed the transformer gets energized and the magnetic flux increases which induces the voltage in the secondary winding with negative polarity and the diode gets reverse biased and the capacitor supplies the energy to the load.

During the instant ,when the switch is opened ,the magnetic flux and primary current gets reduced ,the secondary voltage is having positive polarity and diode gets forward biased and capacitor starts discharging.The output of the converter can generate multiple outputs with extra circuitry by storing energy in the transformer.

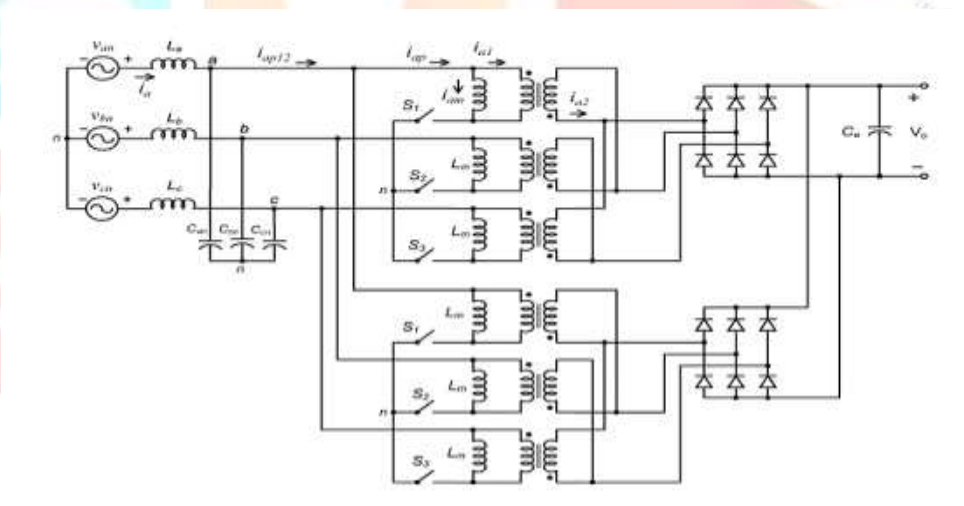

Figure2: Basic Flyback Converter

IV. CONVERTER DESIGN

A. Design of the Cuk Converter

CuK converter is actually the back to back combination of a step up and a step down converter. In order to convert the normal cuk converter into an isoloated cuk converter an additional capacitor along with an AC transformer are added to the cuk converter. Due to this isolation, the output-voltage polarity can be chosen freely. As the isolated Ćuk converter and the non-isolated Ćuk converter can have an output voltage magnitude that is either greater than or less than the input voltage magnitude, even with a 1:1 AC transformer.

The analysis begins with these assumptions:

- Very large inductor are taken to make the currents in them are constant.
- Very large capacitor are taken to make the voltages in them are constant.
- The circuit is operating in steady state, meaning that voltage and current waveforms are periodic.
- Ideal switch and ideal diode are considered.

The design equations obtained are

- Output voltage $V_o = V_s * D/(1-D)$

- Input inductance L1min=$(1\text{-}D)^2$*R/(2Df)
- Output side inductanve L2min= $(1\text{-}D)^2$*3.4/(2f)
- Output side Capacitance C2 = $(1\text{-}D)/(\Delta V_o/V_o*8*L_2f^2)$
- Input side Capacitance C1 = $V_oD/(Rf\Delta V_{c1})$

B. Design of the Flyback Converter

In the design of flyback converter there basically three steps

- Design of the Converter Power Stage
- Three-Phase Flyback Transformer Design
- Design of the Control System

V. EXPERIMENT AND RESULTS

The simulation is done in Matlab 2010A and the outputs currents for the different sets and the total volatges of the output are observed.

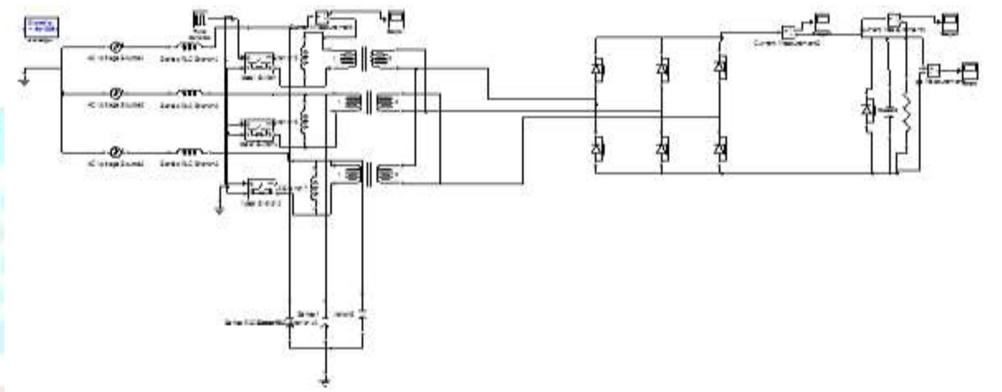

Figure3: Simulation circuit of Flyback non interleaved Converter

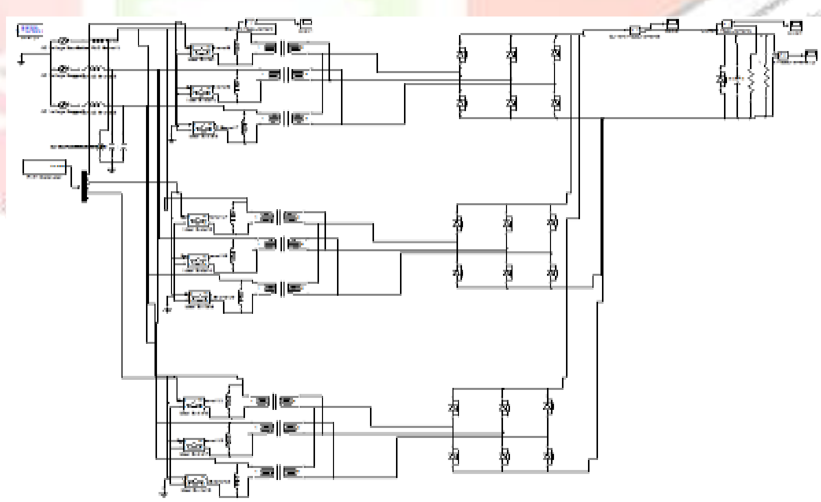

Figure4: Simulation circuit of Flyback interleaved Converter

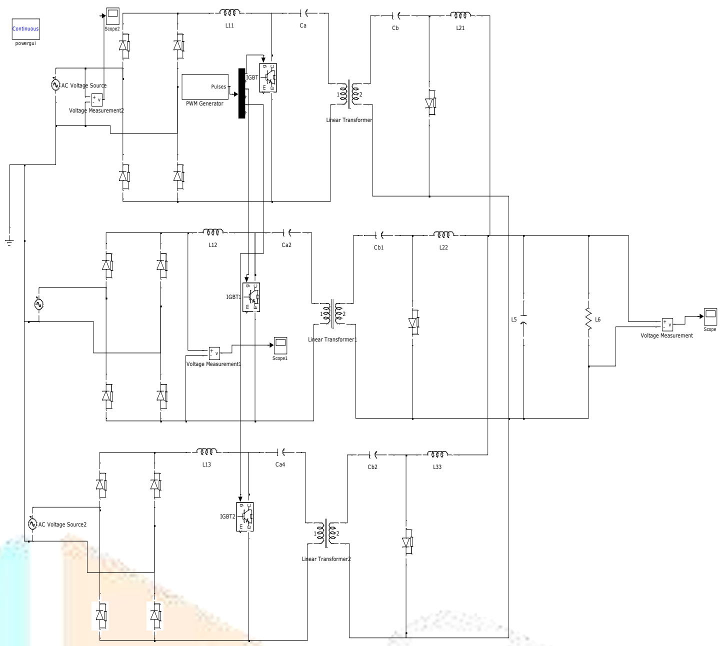

Figure5: Simulation circuit of interleaved Cuk Converter

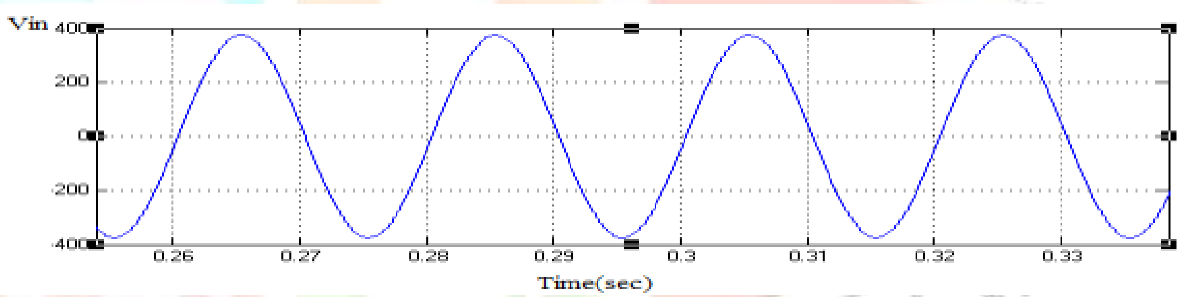

Figure6: Input voltage of Flyback non interleaved Converter

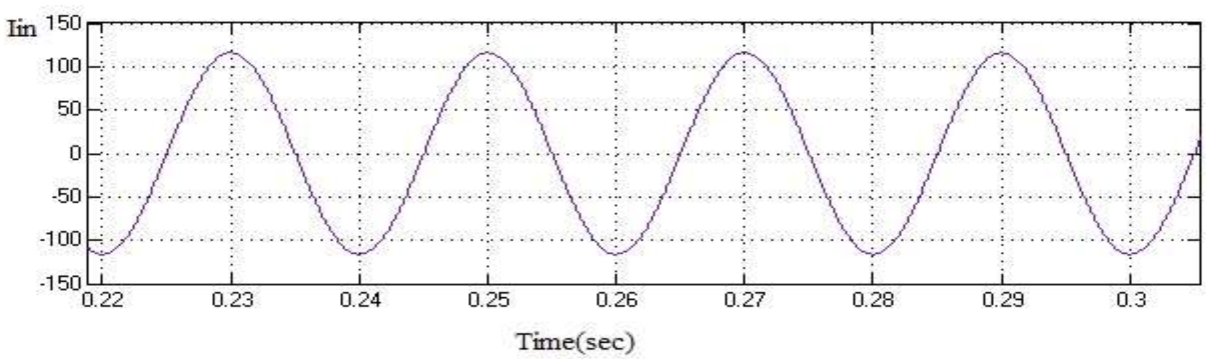

Figure7: Input current of Flyback non interleaved Converter

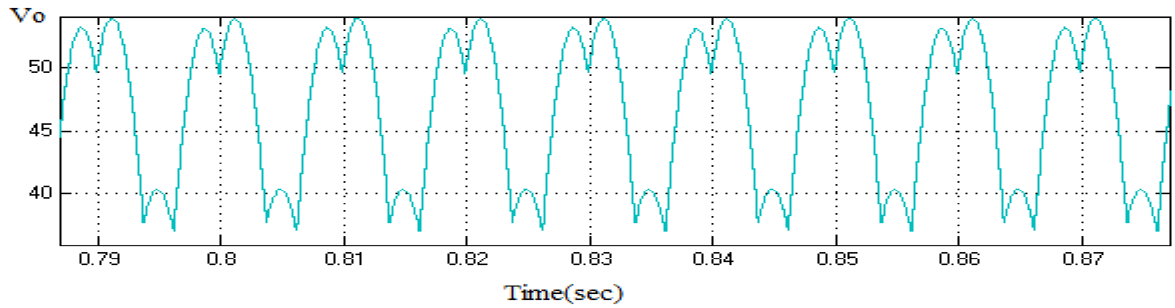

Figure8: Output voltage of Flyback non interleaved Converter

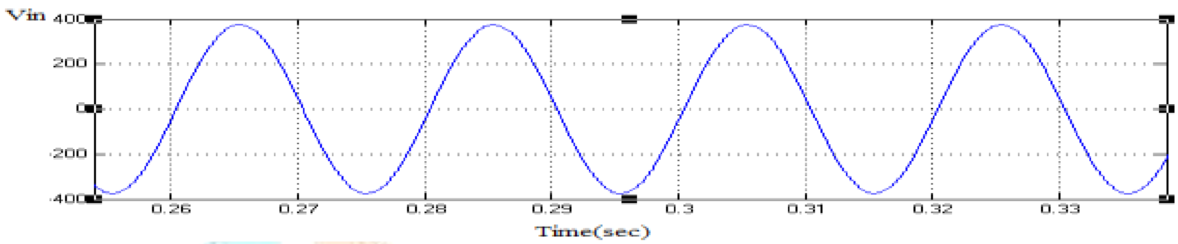

Figure9: Input voltage of Flyback interleaved Converter

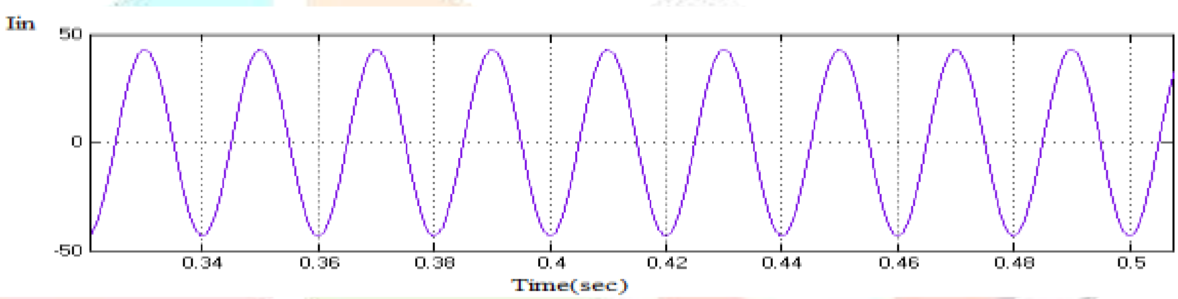

Figure10: Input current of Flyback interleaved Converter

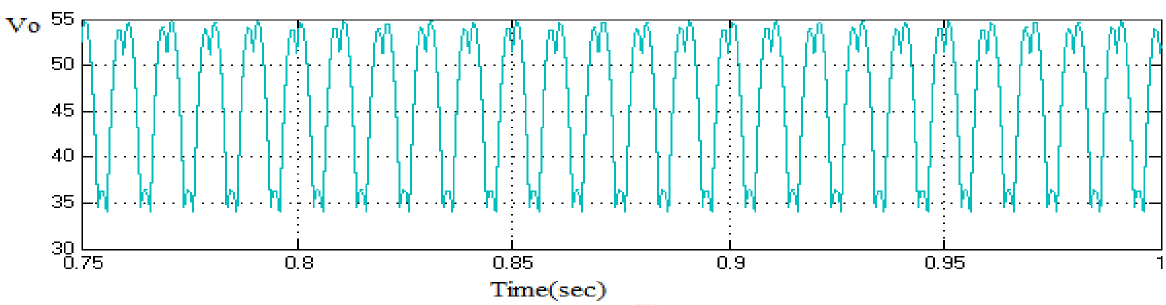

Figure11: Output voltage of Flyback interleaved Converter

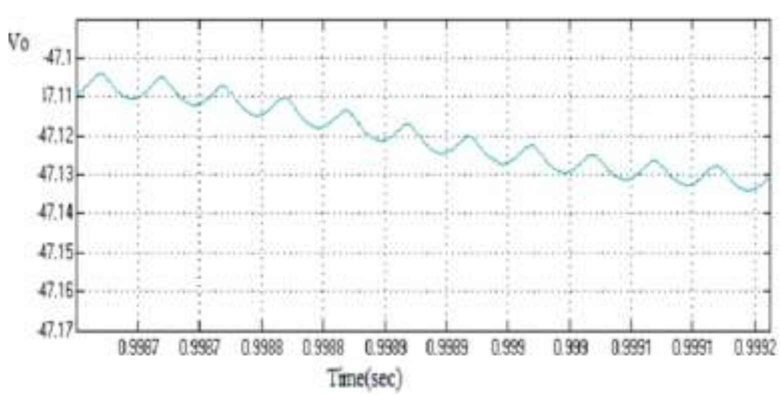

Figure12: Output voltage of interleaved Cuk Converter

Table1: Comparision of Fly back and Cuk Converters

Characteristic	Flyback	Cuk
Output voltage	40~56 v	-48 v
Input voltage RMS	240 v	220 v
Operating freq	20KHz	20KHz
Power	8400 w	
Load resistance	10 ohms	3 ohms
THD	around 1%	0%
Operating Modes	DCM	CM
Output voltage ripple	1%	1%

VI. CONCLUSION

In this paper the comparison between the cuk converter and the flyback converter design and the analysis are studied and the simulation for both interleaved and non interleaved flyback converter are done along with interleaved cuk converter. The results are obtained for same load conditions under ideal switch conditions. This analysis shows that the fly back is more suited for medium power applications and can also be extended for high power applications.

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