Design metrics and Performance Exploration of Asymmetric HBLLC converter

Jenifer.A
Assistant Professor
R.M.K. Engineering College
Ajr.eee@rmkec.ac.in

Dr.Y.Sukhi
Assistant Professor
R.M.K. Engineering College
ysi.eee@rmkec.ac.in

Anil Kumar N
Assistant Professor
Sree Vidyanikethan Engineering College
anilkumar.n@vidyanikethan.edu

Saran
Student
R.M.K. Engineering College

K.Balaji
Student
R.M.K. Engineering College

Article Info
Page Number: 5854-5861
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: 25 March 2022
Revised: 30 April 2022
Accepted: 15 June 2022
Publication: 15 October 2022

Abstract

This study presents an asymmetric half-bridge (HB) resonant DC-DC converter. This converter is derived by integrating a buck–boost, on the input side with the HBLLC resonant converter. The buck boost converter on the line side gives the supply voltage to the secondary which boosts it hence the conduction losses is less. An asymmetric pulse width modulation (PWM) control is used to get broad range of input. This converter gives high efficiency, less conduction losses and it is proved by testing the system in Matlab simulation package.

Keywords: DC-DC resonant converter, Asymmetric, Half bridge LLC converters

1. Introduction

The electronic devices which convert one level of voltage to another level of voltage and stabilize the voltage are DC-DC converters. It finds its application in laptops, data centers, electric vehicles, mobile phones, satellites etc. Moreover it is used in renewable applications like Photovoltaic, Wind and in fuel stacks which is the need today. These DC-DC converters are of many types' linear mode (regulators), hard switching mode (Isolated & non isolated types) and soft switching mode (Resonant converters- ZVS & ZCS) [2,3,4]. Comparing all the types' resonant converters works high efficiency because the switching losses are minimal since ZV and ZC switching is done. The topology of resonant converters can be of half bridge and full bridge. Single stage converters are mostly to limit the number of components used but the conduction losses are more. Hence two stage converters were used but they suffer from low power density, less efficiency problems [1]. To avoid this integration of two converters by combining a buck boost converter in the primary end and an HBLLC resonant converter in the secondary end. This hybrid converter has advantages like less cost, high efficiency. An asymmetric converter is one of the most encouraging topologies for low-power applications, like television and Drove drivers, due to its modest number of parts [5].

The HBLLC converter at the secondary end will receive a voltage greater than input voltage by V_{clink}. The V_{clink} will be the addition of the capacitor voltage V_{cb} and the supply voltage V_s. The Vclink is given as

$$V_{clink}= V_{cb}+V_s \qquad (1)$$

The Voltage at the capacitor C_b will be the voltage from the buck boost converter. The Vcb is given as

$$V_{cb}=DVs/ (1-D) \qquad (2)$$

Where

D- Duty cycle of buck-boost converter

Fig 1 shows the circuit diagram of the converter. The passive elements are Lr-resonant inductor, Cr- resonant capacitor, Lm- magnetizing indutor. When the load is minimum, the resonant frequency is produced by Lm+Lr and Cr. When load is maximum, the resonant frequency is produced by Lr and Cr. The gain k=1 at resonant frequency fo. The gain at resonant frequency does not vary. MOSFET is used as main switches and synchronous rectifiers are used instead of diodes to reduce conduction losses.

Parameters	**Specifications**
Supply voltage	36 V
Output Power	360W
Output Voltage	24 V
Output Current	10A
Line regulation	≤1%
Load regulation	≤1%
Efficiency	(Vin=36V and Io=10A)≥90%
Switching frequency	50 KHz
Resonant frequency	100KHz

Table 1 *Design Parameters*

2. Design Metrics

The transformer turns ratio for the estimated values is calculated as

$$n = \frac{\frac{nominal\ input\ voltage}{2}}{nominal\ output\ voltage} = 0.75 \text{ app to } 1 \qquad (3)$$

The maximum and minimum values of gain are

$$M_{min} = \frac{n\times(V_{o\_min}+V_F)}{V_{in\_max}/2} = 0.335 \quad (4)$$

$$M_{max} = \frac{n\times(V_{o\_max}+V_F+V_{loss})}{V_{in\_min}/2} = 0.763 \quad (5)$$

The load at full load and minimum load are

$$R_e = \frac{8\times n^2}{\pi^2}\times\frac{V_0}{I_0} = 1.556 \text{ ohm} \quad (6)$$

$$R_{min} = \frac{8\times n^2}{\pi^2}\times\frac{V_0}{I_0} = 1.313 \text{ ohm} \quad (7)$$

The resonant capacitor and inductor are

$$C_r = \frac{1}{2\pi\times Q_c\times f_0\times R_e} = 18.3 \text{ n F} \quad (8)$$

$$L_r = \frac{1}{(2\pi\times f_0^2)C_r} = 10 \text{ µH} \quad (9)$$

$$L_m = L_n \times L_r = 3 \text{ µH} \quad (10)$$

The resonant frequency is given as

$$f_0 = \frac{1}{2\pi\times\sqrt{L_r\times C_r}} = 100 \text{ KHZ} \quad (11)$$

All the components are designed and the calculated values are used in the simulation.

3. Simulation results

The switching waveforms and modes of operation are shown in figure 2 & 3. The proposed converter is simulated in MATLAB/SIMULINK package and the simulation diagram is shown in figure 4. The results of output voltage and current are shown in figure 5.

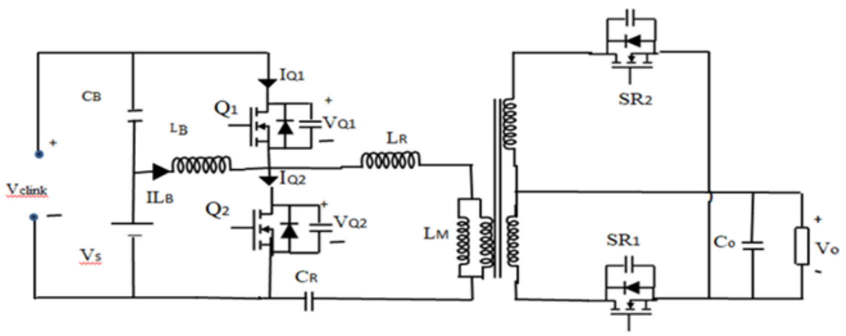


***Figure 1** Schematic diagram*

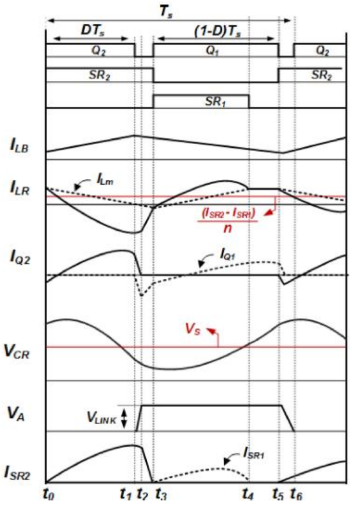
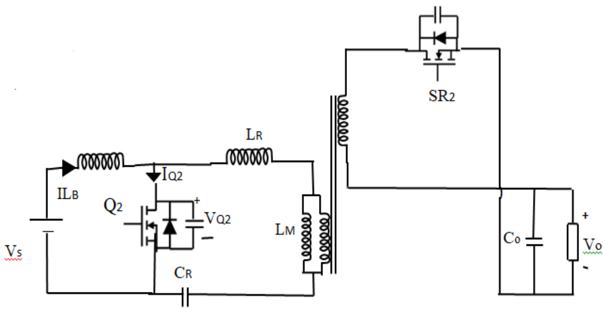
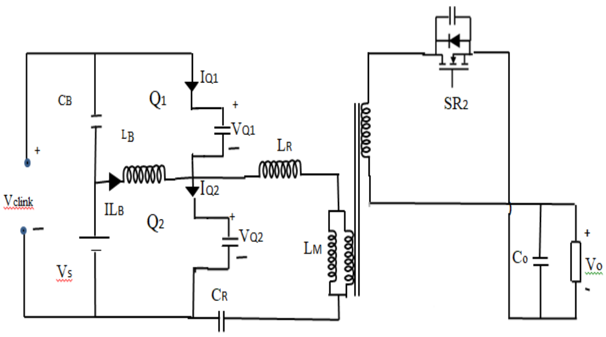
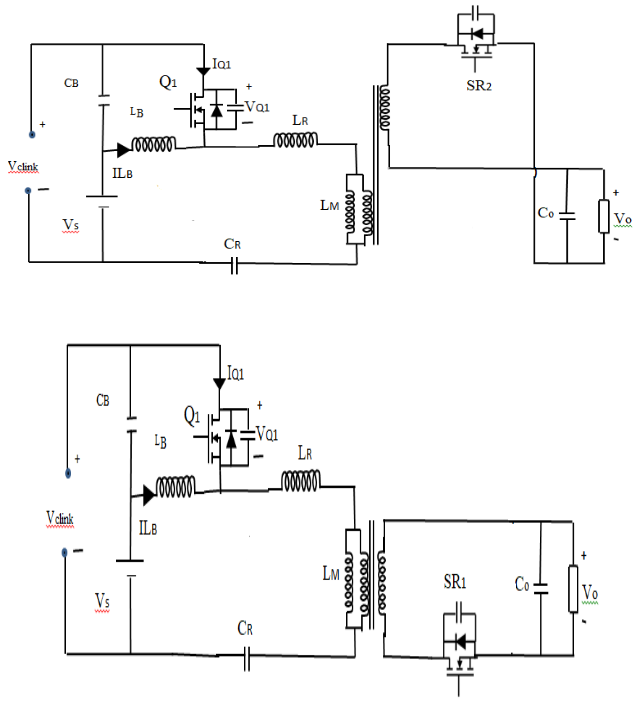


Figure 2 *Switching waveforms*

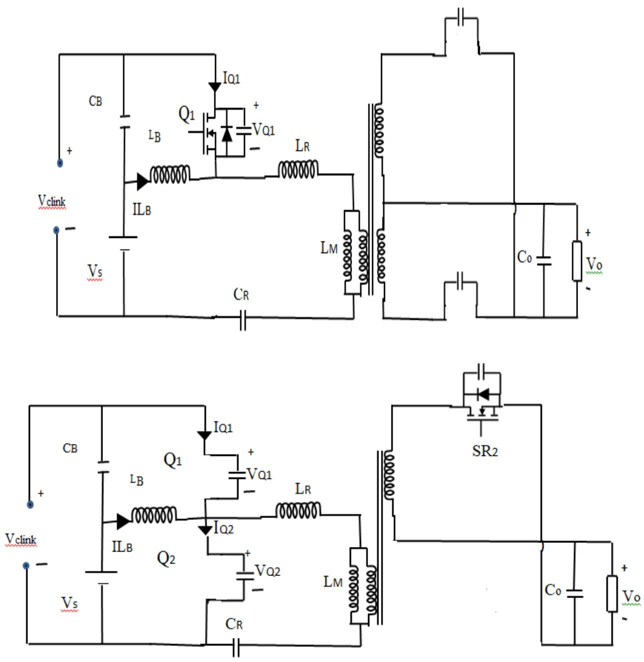




Interval 1(t_0-t_1) *Interval 2(t_1-t_2)*



Interval 3(t_2-t_3) *Interval 4(t_3-t_4)*



Interval 5(t_4-t_5) *Interval 6(t_5-t_6)*

Figure 3 *Operating Modes*

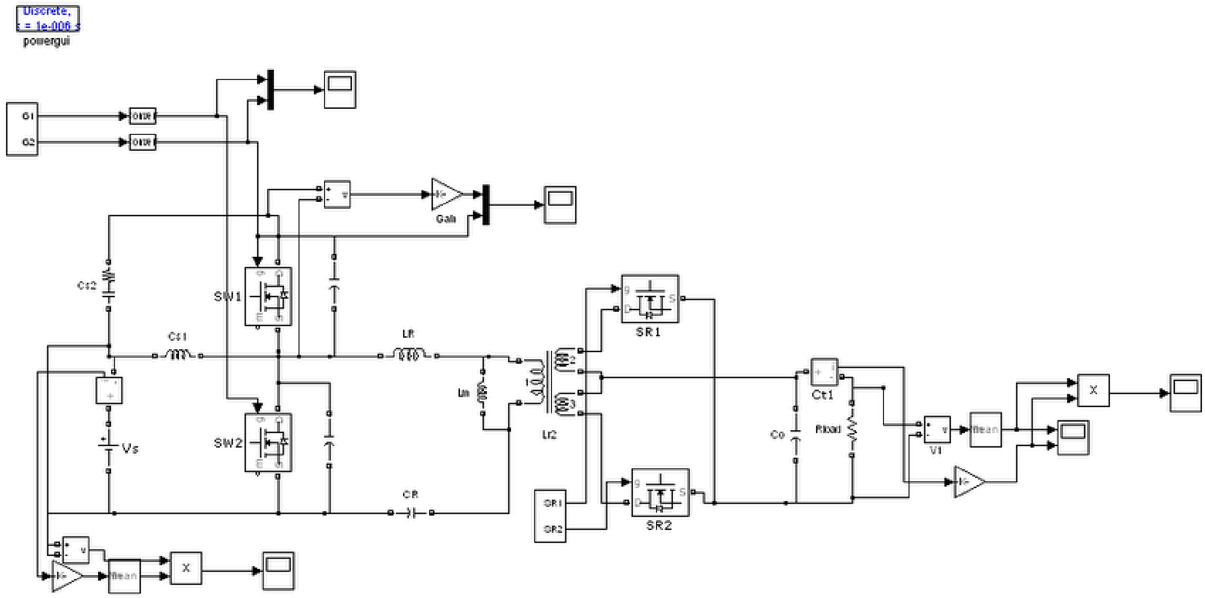


Figure 4 *Simulation Circuit of the converter*

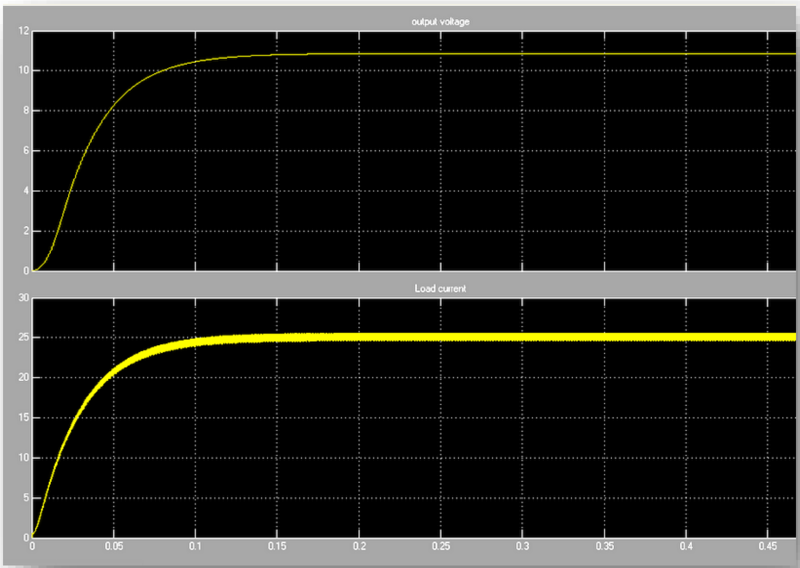


Figure 5 *Output voltage and output current waveforms*

The frequency response of the converter is shown in figure 6.

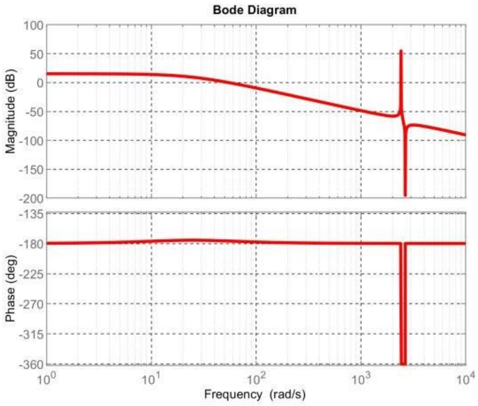


Figure 6 *Output voltage and output current waveforms*

4. Comparison

The comparison of Asymmetric Half Bridge resonant converter with various resonant converters like single and two stages are given in this session. Table 2 shows the comparison of the 3 converters. It indicates that A LLC converter gives better performance than the other two converters.

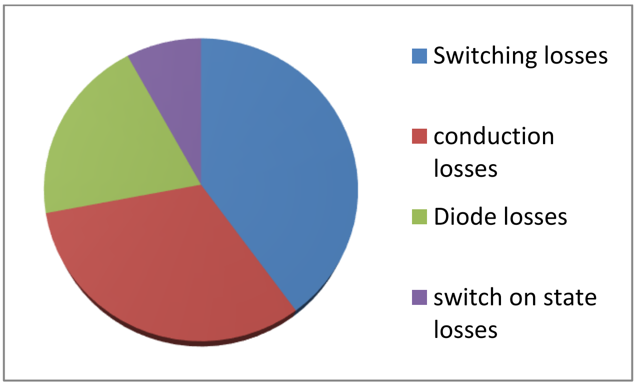


Figure 7 *Losses associated with A LLC converter*

S. No	Parameter	S stage LLC	T stage LLC	A LLC
1	Efficiency	Low	Moderate	High
2	Conduction loss	High	Less	Less
3	Structure	Simple	Complex	Moderate
4	Power Density	Low	Low	High
5	Wide range of input	No	Yes	Yes

Table 2 *Comparison of LLC converters*

5. Conclusion

The article discusses an Asymmetric Half bridge converter. Simulation is carried out in simulink and the results are given. Results reveal that Asymmetric half Bridge converter is robust than other converters. It can be extended to EV applications as it has high power density.

6. References

1. A. Jenifer, Y. Sukhi, V. Karthika, A. Fayaz Ahamed "Design Specifications and Performance analysis of Single and Two Stage HB LLC Converters" International Journal of Innovative Technology and Exploring Engineering (IJITEE) 2019. DOI: 10.35940/ijitee.A1040.1191S19
2. Y. Jang and M. M. Jovanovic, "A new soft-switched DCDC front-end converter for applications with wide-range input voltage from battery power sources," in Proc. 25th Telecommun. Energy Conf., Oct. 2003, pp. 770–777.
3. S. Luo and I. Batarseh, "A review of distributed power systems Part I: DC distributed power system," IEEE Aerosp. Electron. Syst. Mag., Vol. 20,Issue No. 8, Aug. 2005, pp. 5–16. DOI: 10.1109/MAES.2005.1499272
4. Bo Yang, Fred C lee,Alpha J.Zhang,Guisong Huang "LLC Resonant converter for front end DC/DC conversion" in APEC. Seventeenth Annual IEEE Applied Power Electronics Conference and Exposition (Cat. No.02CH37335) March 2002. DOI: 10.1109/APEC.2002.989382
5. Hong Huang "Designing an LLC resonant converter" Texas Instruments.