

# Design and Implementation of Full Bridge Five Level LLC Resonant for High Battery Chargers Power Application

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**ABSTRACT:** This paper presents the full bridge five level LLC resonant converters for high power battery applications. Five levels LLC resonant converter generate the output voltage with less THD, same way we can achieve the perfect ZVS of MOSFETS. By this one we can improve the efficiency, lifetime of the battery. Nowadays resonant converters are the very wide range power converter for high power application to reduce the switching losses. In this paper we can implement multi-level inverter with resonant converter concept for reducing the harmonics. Now a days five level inverters having the wide range application for reducing the losses, and we can get maximum voltage gain.

**KEYWORDS:** dc-dc converter, ZVS soft switching, Simulink.

## I. INTRODUCTION

Among the various ZVS PWM dc-dc converters, the zero-voltage-switching (ZVS) HB LLC resonant converters have been used for reducing the current and voltage stress and switching losses of the components. Therefore, the HB dc-dc converter for charging the battery system needs to operate wide range voltage more than the conventional converters. In this paper, HB LLC resonant converter is proposed for battery charger of onboard. It is possible to operate wide range voltage in the high switching frequencies. This converter is verified experimentally on 250V~450V output voltage prototype. The magnetizing inductance of the transformer and  $C_r$  is the resonant capacitor. Operating mode of the LLC resonant converter.

## II. BLOCK DIAGRAM

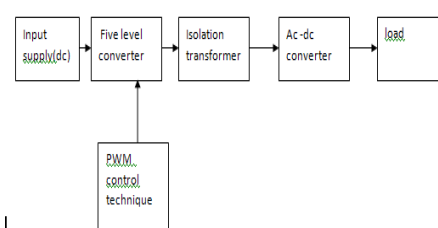


Fig:1 block diagram dc-dc converter

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## III. CIRCUIT DIAGRAM & ANALYSIS

The most commonly used multilevel topology is the diode clamped inverter, in which the diode is used as the clamping device to clamp the dc bus voltage so as to achieve step sin the output voltage. Figure 3.1 shows the circuit for a diode clamped inverter for a three-level and a four-level inverter. The key difference between the two-level inverter and the three-level inverter are the diodes  $D_{1a}$  and  $D_{2a}$ . The devices clamp the switch voltage to half the level of the dc-bus voltage. In general the voltage across each capacitor for an N level diode clamped inverter at steady state is  $V_{dc}/n-1$ . Although each active switching device is only required to block  $V_{dc}/n-1$ , the clamping devices have different ratings. The diode-clamped inverter provides multiple voltage levels through connection of the phases to a series of capacitors. According to the original invention, the concept can be extended to any number of levels by increasing the number of capacitors. Early descriptions of this topology were limited to three-levels where two capacitors are connected across the dc bus resulting in one additional level. The additional level was the neutral point of the dc bus, so the terminology neutral point clamped (NPC) inverter was introduced however, with an even number of voltage levels, the neutral point not accessible, and the term multiple point clamped (MPC) is sometimes applied. Due to capacitor voltage balancing issues, the diode-clamped inverter implementation has been limited to the three level. Because of industrial developments over the past several years, the three level inverter is now used extensively in industry applications. Although most applications are medium-voltage, a three-level inverter for 480V is on the market.

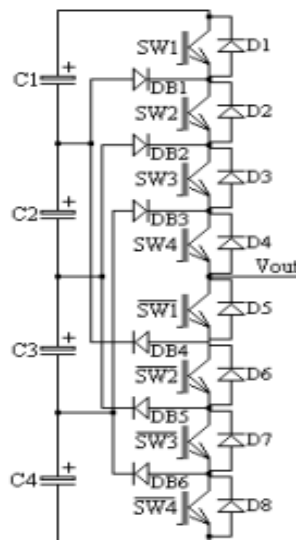


Fig:3 Switching Circuit with diode Clamping

Fundamental switching frequency. From Table 2.1 it can be seen that for the voltage  $V_{dc}/2$  all the upper switches are turned on, connecting point a to the  $V_{dc}/2$  potential, see Figure For the output voltage  $V_{dc}/4$  switches S2, S3, S4 and S01 are turned on and the voltage is held by the help of the surrounding clamping diodes D1 and D01 For voltage levels  $V_{dc}/4$  or  $V_{dc}/2$  clamping diodes D2 and D02 or D3 and D03 hold the voltage, respectively. For the voltages  $\pm V_{dc}/2$  the current, when both voltage and current are positive (positive current goes out from the inverter), goes through the four top or bottom switches.

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Table 1

	SW1	SW2	SW3	SW4	Vout
mode 1	on	on	on	on	2E
mode 2	off	on	on	on	E
mode 3	off	off	on	on	0
mode 4	off	off	off	on	-E
mode 5	off	off	off	off	-2E

Fig: 2Switch diagram

### MODE:1

In mode 1 the switches sw1,sw2,sw3,sw4 on condition,thenout put voltage is the 2E

Mode2:

In mode 2the switch sw1 is off ,sw2,sw3,sw4 are on ,then out put voltage is the E

Mode-3

In mode 3 the switches sw1,sw2 off,sw3,sw4 on,thenout put voltage is the 0

Mode4:

In mode 3 the switches sw1,sw2 ,sw3 are off sw4 on, then out put voltage is the -E

Mode5:

In mode 3 the switches sw1,sw2 ,sw3 are off sw4 on, then out put voltage is the -2E

## IV. CONVERTER TOPOLOGY AND CONTROL

The primary means in reducing the power converter size has been through loss reduction for reduced cooling systems and frequency increase for reduced passive components. The components, packaging, circuit, and control all play roles in the compact power converter design. This section discusses the converter topology and control. Component selections and design, as well as system packaging, will be presented in the later sections. The key converter system specifications are listed in Table.

### IV.I TOPOLOGY

In order to meet the system requirements, many different topologies for pulsed-power converters are investigated. In general, these topologies can be classified into three broad categories, namely, matrix pulse generator, PWM converter, and resonant converter. The output voltage of a matrix pulse generator can simply be calculated by  $n$  times of the input voltage when  $n$  switches are involved [1], [2]. If  $n = 1$ , only one block is involved, which is also called as direct drive pulser. Although the matrix pulse generator is a very simple circuit producing a high-voltage pulse without any pulse transformers, this type of system is very expensive, bulky, and inefficient. The PWM converter has also been used, including boost [1], flyback [2], Ward [4], and full-bridge PWM converters [2], [1], [4]. For a capacitor load, the load condition widely varies during the charging process, which is almost like changing initially from short circuit to open circuit at the end. As a result, the ZVS cannot be achieved or guaranteed during the whole charging period in PWM converters, or they require a complex control scheme and an additional circuit for an efficient charging. The resonant converter topologies are widely used for pulsed-power converters, including discusses optimizing the resonant network for battery charger on board.

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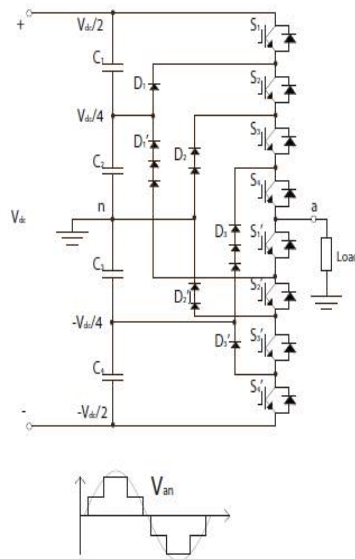


Fig.4 the Five -Level Dc/Dc Converter

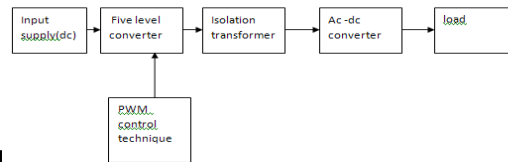


Fig:5block daigram of five level converter

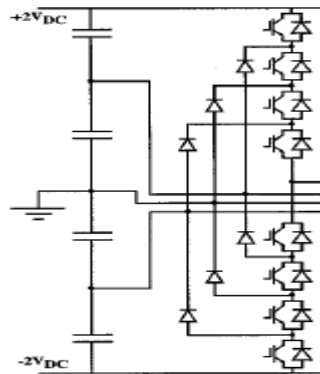


Fig: 6five level structure

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Output Voltage	$S_1$	$S_2$	$S_3$	$S_4$	$S'_1$	$S'_2$	$S'_3$	$S'_4$
$\frac{V_{dc}}{2}$	1	1	1	1	0	0	0	0
$\frac{V_{dc}}{4}$	0	1	1	1	1	0	0	0
0	0	0	1	1	1	1	0	0
$-\frac{V_{dc}}{4}$	0	0	0	1	1	1	1	0
$-\frac{V_{dc}}{2}$	0	0	0	0	1	1	1	1

Fig: 6.a Modes of a operation

## V. DESIGN PROCEDURE FOR BATTERY CHARGER

Exact analysis of LLC resonant converters [4] leads to a complex model that cannot be easily used to derive a handy design procedure. [4] In this paper, we are using the first harmonic approximation (FHA) which enables the analysis of resonant converters by means of classical complex ac-circuit analysis. Fig. 3 shows the AC equivalent circuit of the LLC resonant converter

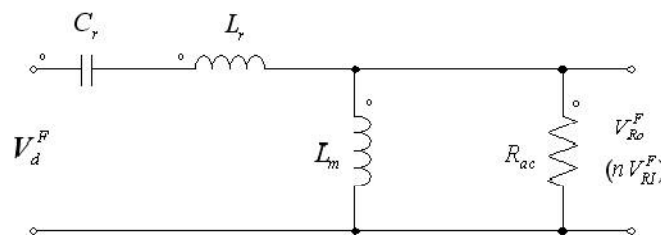


Fig: 7 AC equivalent circuit of LLC resonant converter

The primary side circuit is replaced by a sinusoidal current source,  $I_{ac}$  and a square wave of voltage,  $V_{RI}$  appears at the input to the rectifier. Considering load resistance shown in the primary is obtained as

$$R_{ac} = \frac{8n^2}{\pi^2} R_o$$

Using the AC equivalent circuit of Fig. 3, the voltage gain is obtained as

$$M(f_n, \lambda, Q) = \frac{1}{\sqrt{(1 + \lambda - \frac{\lambda}{f_n^2})^2 + Q^2 (f_n - \frac{1}{f_n})^2}} \quad (2)$$

## VI. SIMULATION RESULTS

In order to show validity of design consideration for battery charger on board, SIMULATION converter has been tested. The LLC resonant converter for battery charger on board is shown in

The output voltage of LLC resonant converter is 240-450V considering the battery cell characteristic. The maximum gain to cover the output voltage variation is as below.

The transformer turn ratio: 0.63

The maximum gain: 1.45

The minimum gain: 0.91

The maximum quality factor  $Q_{max}$ : 0.5

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By selecting the resonant frequency as 107 kHz, the Resonant network is determined as  $L_m=45\mu\text{H}$ ,  $L_r=10\mu\text{H}$ , and  $C_r=220\text{nF}$ . Fig.6 shows the operation waveforms for light load condition with output voltage of 300V. Where,

## Simulation results analysis and discussion

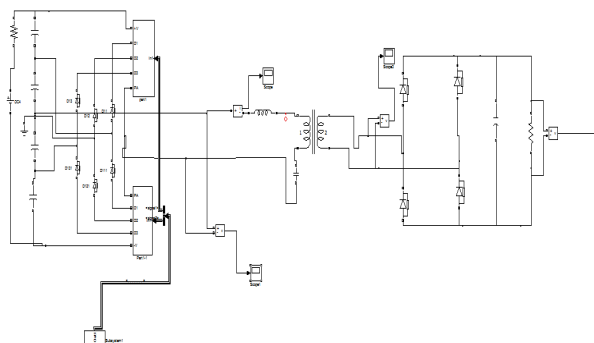


Fig: 9 FIVE level dc-dc converter

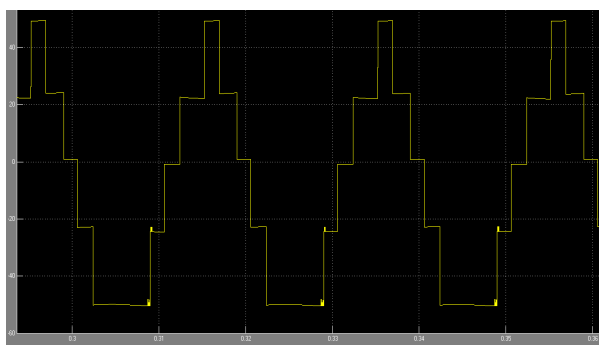


Fig:10 five level output voltage

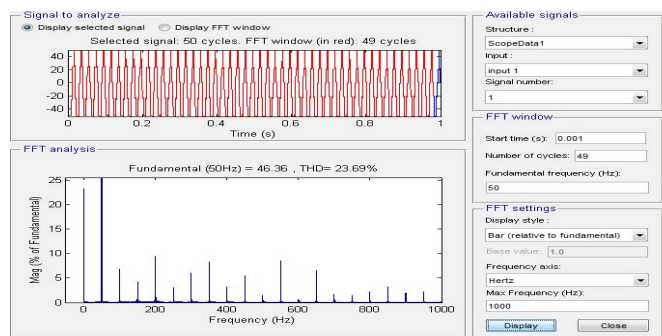


Fig:11Fft Spectrum Of Five Level Voltage

The above figure shows the three level dc-dc converter simulation results that wave form contain the THD 23.22%

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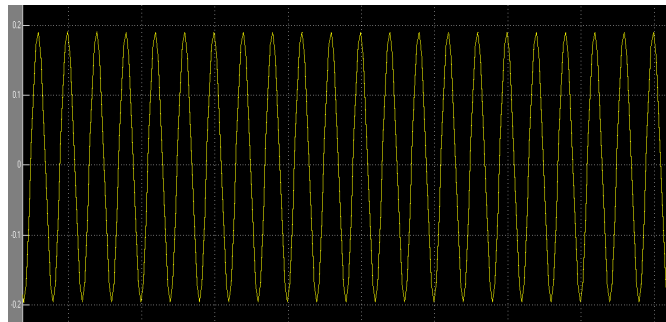


Fig: 12 current flowing through primary winding

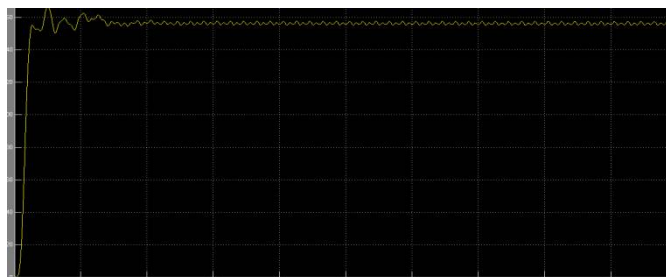


Fig: 13 five level dc-dc converter output voltage

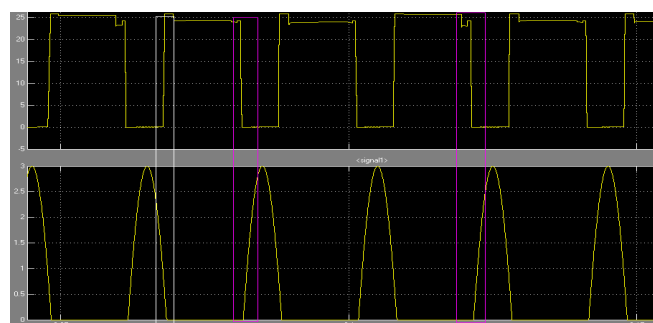


Fig: 14 zvs condition of five level dc-dc converter

## VII. CONCLUSIONS

The full bridge five level LLC resonant converters for high power battery applications. Five levels LLC resonant converter generate the output voltage with less THD, same way we can achieve the perfect ZVS of MOSFETS, by this one we can improve the efficiency, lifetime of the battery. Now a days resonant converters are the very wide range power converter for high power application to reduce the switching losses. In this paper we can implement multi-level inverter with resonant converter concept for reducing the harmonics. Now a days five level inverters having the wide range application for reducing the losses, and we can get maximum voltage gain



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