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Design and Simulation of LLC Converter on LDC application for low voltage vehicles On-Board

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Abstract: A high efficient LLC converter is proposed for Electric Vehicles (EVs) onboard application. In the proposed converter, the switches on the primary side achieves ZVS(zero voltage switching) and the switches of synchronous rectifier in the secondary side achieve both ZVS and ZCS. The current stress is minimized and efficiency is increased by connecting the LLC converters in parallel, and also the load side current is obtained of nearly200A. A SCC (Switch Controlled Capacitor) strategy is accimilate the sharing of load side current using three phase LLC converter. A 7.5kW (18V/350A) LLC converter is designed and simulated in MATLAB/Simulink software.

KEYWORDS: LLC Converter, Electric Vehicle, Zero Voltage Switching, Switch Controlled Capacitor.

I. INTRODUCTION

Recently, electric vehicles (EVs) have attracted increasing interest because they are causing lesser pollution and also better lower in cost than that of fossil fuel automobiles. Electric vehicle battery devices consist of a constant HV (High Voltage) Lithium-ion battery (voltage range is around 200V - 450V) and LV (Lower voltage) lead-acid battery (voltage range is around 9V - 16V). Famous, High Voltage batteries are applied in driving application of traction machines. Lower Voltage batteries are applied for the secondary power distribution for electric and electronic loads etc. High Voltage batteries are typically charged using the grid with the help of an off-board and an on-board charger. The battery is provided as load is typically charged from an High Voltage battery with the help of lower voltage converter (LDC).

Well-known, the isolated DC-DC converters require integrated LDCs for built-in protection and can achieve high buck ratios (430V - 9V). In this integrated, the section-shift full-bridge converter is adapted from the built-in LDC. Auxiliary built-in inductors are used to make sure that the ZVS is achieved using the switching devices provided in the primary side of the transformer of the proposed converter. Buck circuit with built-in integrated LDC secondary Multi-voltage built-in pulse transformer used to clear the precipitated integrated voltage. Segment-shift bridge based converters is used for LDCs. Since the synchronous load is very high, a built-in integrated double circuit is typically implemented built into the secondary side of the transformer so that the current stress is minimized and the performance of the system is increased.
But, it is much harder to get ZVS and ZCS in a traditional complete bridge type transformer than an LLC transformer. In addition to the multiple power tools required for electric vehicles, the smaller package requires additional power sources of contract size and a power setting of more than 2.5 kW. This suggests that modern LDCs with high energy density should produce over 200 thousand. As a result, it is commonly used in LLC transformers to reduce the transmission losses of the synchronous transformer (SR).

Nowadays, a variety of bandage gap devices (including SiC or GaN) are used to change power components to increase circuit performance.The EVs' structure is as shown in the below figure,

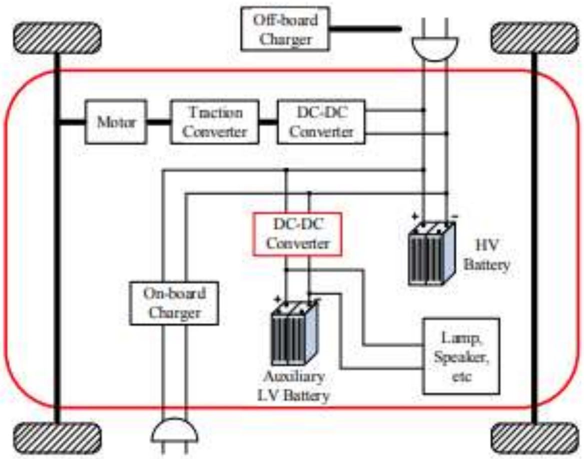

Fig 1: Structure of the Electric Vehicle (EVs).

II. RELATED WORK

In today's world a high-power capacitor or other active (off) cleaning circuit is often used to filter low-grade harmonics. This keeps expansion and energy execution under control. While charging a high voltage (hv) battery, this low voltage battery charger goes about as an AF recipient unit to kill the symphonious current waves in the high voltage battery charger.The proposed converter can charge a level utility expense to hold 4 kW of battery charge and 6.6 kW of channel power. Because of the proposed strategy, the worth of double voltage charging gadgets in electric engines might diminish. The evidence of-idea model with a force of 1.2 kW was comparably evolved and the test showed phenomenal outcomes [1].

This article gives general support techniques to expanding the measure of green mode needed to guarantee voltage transformer exchanging (zvs). The DC/DC converter can be utilized to charge batteries in electric vehicles (EVs).. The proposed control framework can decide the greatest charge of symmetric working infused through the helper circuit, limiting mosfet force and assistant helper misfortunes. The working mode of the proposed technology can manage the charge by changing the switching frequency, making sure that there is enough current to drive the rate and remove the snubber capacitors at a positive moment-death rate.. Effects are used to improve adapter and overall system performance [2].

Due to the growing domestic gas consumption of strong green gas-based cars, increasing environmental pollutants, and high fuel concentrations, the development of natural electric vehicles (EVs) has been important in recent years. The battery region of electric vehicles has some of the finest electrical circuits available, therefore it is crucial that onboard power inverters follow stringent EMC regulations right from the beginning. The variables to consider while choosing passive electromagnetic interference (EMI) filters are the price, length, and weight of the filters, as well as the power discount and the PCBs. A completely integrated DC-based DC-DC controller for low-light batteries is combined with an integrated virtual direct EMI (DAEF) system suggested and investigated in this study. [3].

The active auxiliary power unit (afapm) of a powerful vehicle program is primarily proposed as a dual voltage charging device. However, to achieve dual mode performance, this converter requires transmissions and inductors. Apapm, a fully integrated device for car systems with electric chargers in one section, is presented in the article. As a result, the need for a large capacitor bank or additional horizontal circuit can be avoided, reducing the cost, length and weight of dual- electric charging systems in electric vehicle systems. The 720W prototype is designed to perform at the proposed transformer [4].

III. DESIGN OF LLC CONVERTER

In traditional three-phase LLC transformers, the input and output voltages are the same and both sides are connected in parallel. Load current sharing can be controlled by modulating the resonant capacitor with the same output and input voltage. We therefore designed the proposed transformer to reduce the voltage across the input side of the series connection and the output side of the parallel connection to increase the load current. The basic side current is designed for 30 amps per phase and the load current for 360 amps.

Six transformers with two transformers are used in each phase, basically and in parallel, on the secondary side connected to the synchronous rectifier. The block diagram of the proposed system is shown in the below figure,

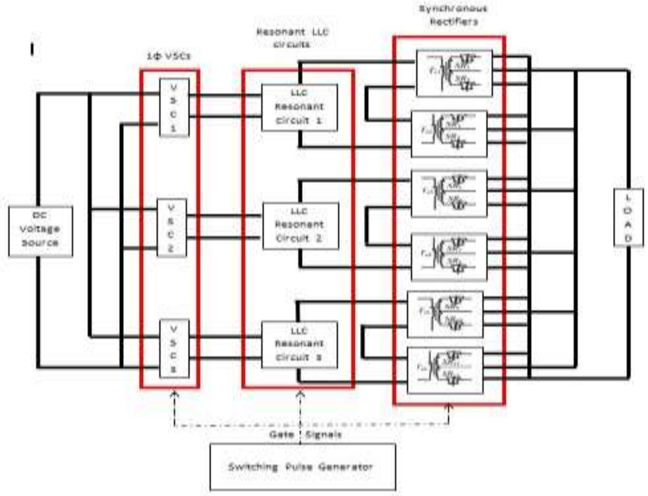

Fig 2: Block Diagram of the Proposed Converter.

The following are the benefits of the proposed LLC transformer with switched capacitor control are,

a) DC-DC multi-phase transformers can handle load current sharing.

b) The operating range of primary and secondary voltages is higher with ZVS on primary side devices and ZCS on secondary side devices.

c) Since the switching frequency of the transformer primary side switches is higher than that of the secondary side transformer switches, the transformer current stress and thus losses can be reduced.

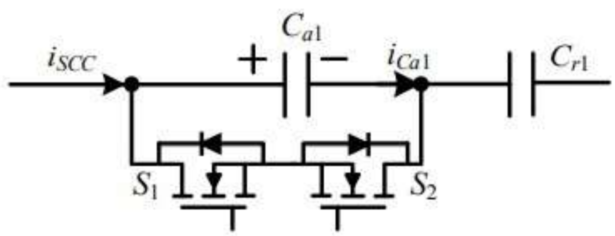

Fig 3: Current flow through the Switched Controlled Capacitor controlling S1 and S2. Switch

S2 is on when ISCC switching current flow is positive, while switch S1 is on when iSCC switching current flow is negative. Both switches work in ZVS mode, and the delay angle changes based on the S1 and S2 switches' running and off times. The S3-S6 secondary side switches, meanwhile, do ZVS.

The ratio of the turns of the transformer is given as follows

$$n = N_p : N_s = V_{in\_max} : V_{0\_min} \quad (1)$$

The number of turns on the primary side of the transformer is Np, while the number of turnson the secondary side is N.

The voltage gain of the LLC transformer in question is as follows

$$M = \frac{nV_0}{V_{in}} = \frac{K}{\sqrt{\left[\left(\frac{\omega_r}{\omega_s}\right)^2 - k - 1\right]^2 + \frac{(\pi^2 \omega_s L p)^2}{64 N^4 R_L^2}\left(\left(\frac{\omega_r}{\omega_s}\right)^2 - 1\right)^2}} \quad (2)$$

Where K = $\frac{L_p}{L_r}$

IV. Implementation

The circuit diagram implemented in the Simulink is as shown in the below figure, The circuit has three H-bridges, each one connected to a 250V DC power supply and to the inverter's output resonance circuit. Two step-down transformers are linked in parallel to each H-bridge on the main side, while the secondary side is connected to the transformer through the H-bridge. Side. Furthermore, the total current generated by each bridge is combined, when the main current is low (around 430 volts) and the primary voltage is significant.

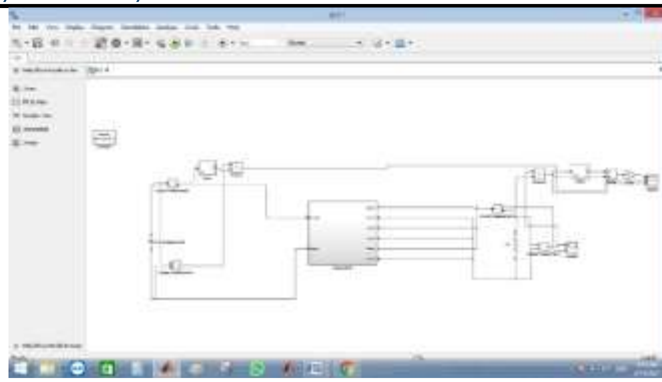

Fig 4: Circuit Diagram of the proposed system.

The modified controller implementation in Simulink is as shown in the below figure,

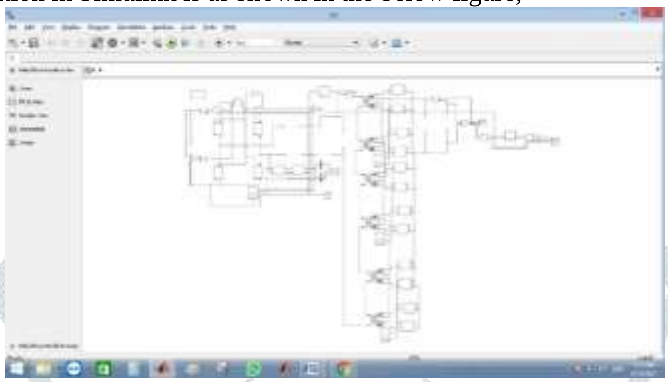

Fig 5: The simulation circuit of the modified converter

V. Results and Discussion

The transformers current, switching voltage of the capacitors, load current and voltage is provided in this section. The primary current of the transformers are provided in the below figure:

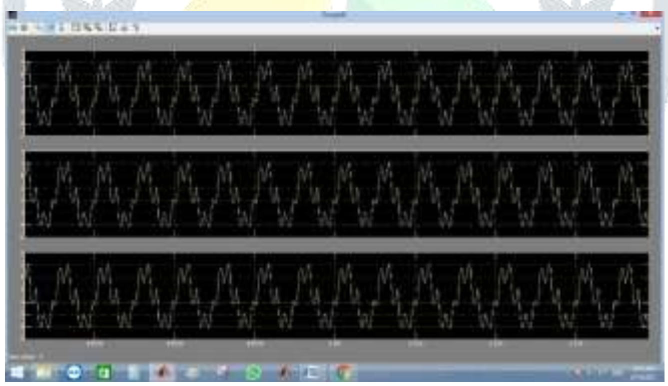

Fig 6: The primary current of the transformers.

The switch voltages along with pulses for the resonant capacitor control is provided in figure 11. In this, when the switch is OFF, the voltage goes to negative and then it reached the positive values of voltage. It leads to the zero voltage switching

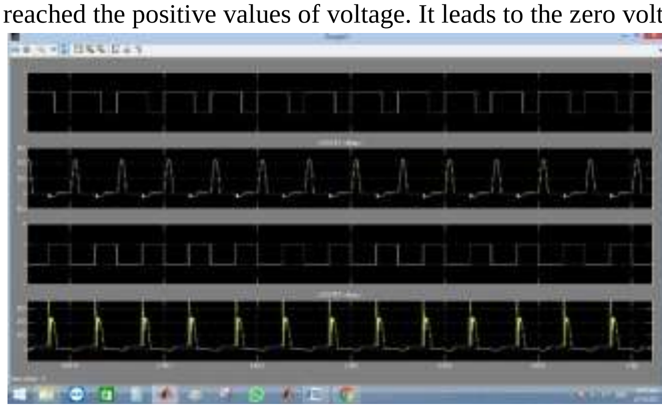

Fig 7: The switch voltages along with pulses for the resonant capacitor control.

The load voltage and current of the proposed converter is provided below figure,at this voltage, the current is approximately 350 amps. This may be used in applications for charging batteries.

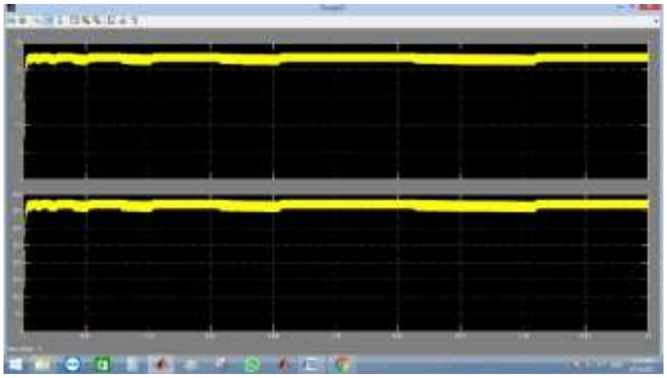

Fig 8: The load voltage and current of the proposed converter.

The load voltage and current of the modified converter is provided below figure,

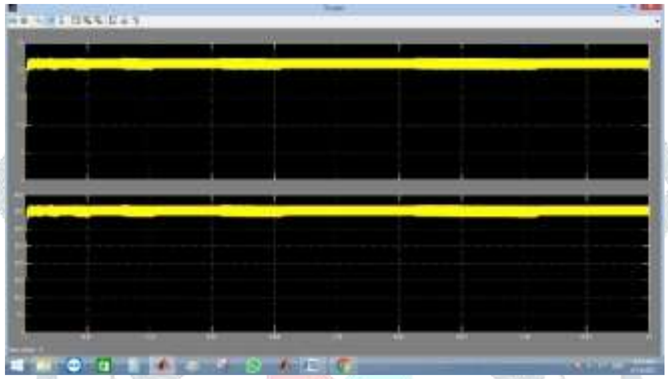

Fig 9: The load voltage and current of the modified converter.

The voltage across the load is approximately 21V, and the current is around 350A. The efficiency of the modified converter(91.2-91.8) is provided below

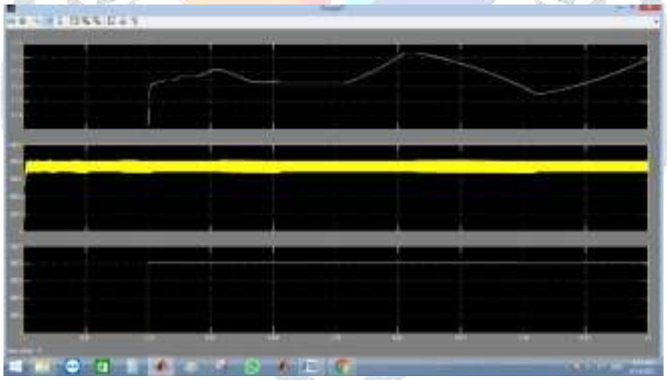

Fig 10: The efficiency of the modified converter(91.2-91.8).

The efficiency of the proposed system is shown in the below figure, The suggested transformer efficiency, according to the study, is between 97.3 and 98.2 percent.

To connect the main and secondary sides, we will use three bridges with 18 primary-side switches and 12 secondary-side switches. Now there are just two bridges, therefore we have a chance to remove twelve switches. Although the power supplied to the rectifier transformer primary is greater than that provided to the three-bridge transformer, the decreased size and cost of the transformer circuit permits an increase in losses.

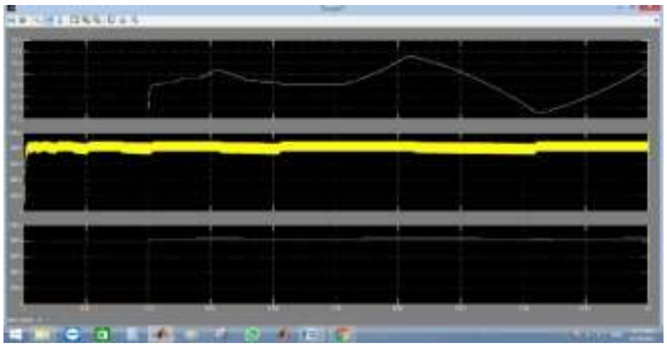

Fig 11: The efficiency of the proposed converter.

VI. Conclusion

In it, the three-phase parallel LLC transformer is designed to reduce the pressure on the secondary side of the transformer. The Switch Managed Capacitor (SCC) strategy is designed so that the variable capacitance can share the current in the three phases of the LLC switch to achieve current pressure reduction. The LLC parameters are set so

that the resonance tank circuit size and capacitor value are set by adjusting the charge ratio of the switches S1 and S2. With the help of this variable capacitance, the load current flowing through each phase is balanced and the power slip is evenly distributed. The number of switching devices used can be reduced by reducing the number of bridges on the primary side of the switch and ensuring that the size and cost of the circuit topology are kept within an acceptable rangewith the accuracy in range of 97.3 and 98.2 percent.

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