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Implementation of LLC DC-DC Converter Based On Dual Transformer

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Abstract
A hybrid full bridge/half bridge LLC circuit resonant converter based on dual transformers is suggested. While the switching frequency is identical to the resonant frequency, which aids in the design of the magnetic components, the output voltage is controlled by a fixed frequency phase shift pulse width modulation control technique. The current stress and power distribution of both transformers with two distinct situations are used to examine the turns-ratio design for the two transformers. The suggested converter can provide switching across the entire load range and a wide input voltage. Ultimately, a 1KW prototype converter is constructed, and tests are run throughout a wide input-voltage and complete load range.

Keywords: *DC-DC Converter, LLC Converter, Dual Transformer*

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I. INTRODUCTION

The objective of this research work is to design and resonant LLCDC–DC converteremployingfixedswitchingfrequencybasedondual-transformer with wide input- voltage range to get better voltage. In order to preserve energy and save the environment, renewable energy resources (RES) are being used more and more[1]. These resources' intermittent nature presents a number of difficulties for their high efficiency, broad voltage range, and multiple functions. Dc-dc power converters are needed to function with a wide voltage range in many applications, including renewable energy systems, electrical vehicle chargers, communications power supplies, and light-emitting diode (LED) drivers, since they provide a controlled and stable output[2]. For these reasons, dc-dc power converters with excellent efficiency over a broad voltage range are essential. Isolated dual active converters (DAB) are the most desirable of the different dc–dc power converter topologies because of their intrinsic qualities, which include gentle switching, high power applications, galvanic isolation, and high efficiency[3]. Secondary Converter: This block reverse-converts the AC voltage that comes from the transformer[4].

II. BLOCK DIAGRAM

The block diagram shows a simplified version of a DC-to-DC converter. It displays the basic components that convert one DC voltage level to another.
DC Source: This is the source of the voltage from DC that will be converted.
Primary Converter: This block can perform a variety of tasks based on the specific DC-to-DC converter design. On rare occasions, it might be a circuit that regulates the DC voltage.
Transformer: This part changes the DC voltage from the primary converter to an AC voltage. With the transformer, the voltage can be stepped up (higher voltage) or stepped down (lower voltage).

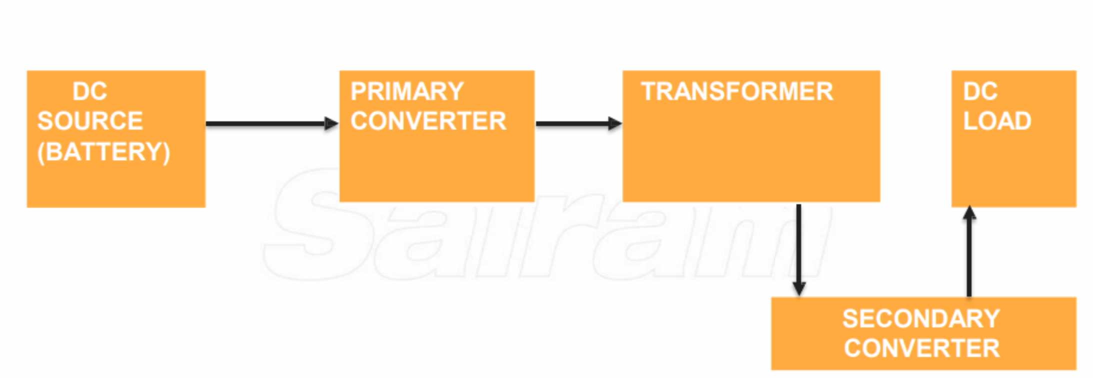


Figure 1: Block Diagram

III. DESIGN CALCULATIONS OF DUAL TRANSFORMER BASED LLC CONVERTER

Designing a dual transformer-based LLC converter involves careful consideration of various factors to ensure optimal performance. Firstly, specifications such as input and output voltages, maximum power, efficiency targets, and switching frequency are defined. Then, transformer design is critical, necessitating the calculation of turns ratios and magnetizing inductance for each transformer to match input and output voltage requirements and resonate properly with the LLC tank circuit. Selection of suitable semiconductor devices and passive components follows, ensuring they can handle voltage and current levels while minimizing losses[4]. Component values for LLC resonant elements are calculated to achieve desired resonant frequency and output power. Control circuitry is designed to regulate output voltage and maintain ZVS/ZCS operation. Simulation and validation through software and prototype testing validate the design[5]. Finally, efficiency analysis is conducted to ensure compliance with specified targets, with room for optimization identified for enhanced performance.

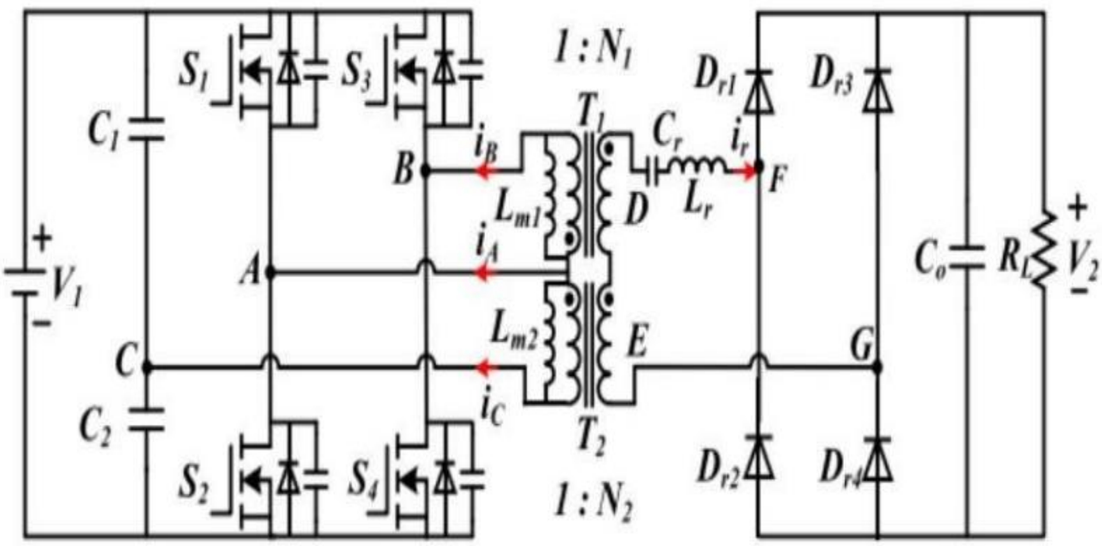


Figure 2: Dual Transformer Based LLC Converter

FORMULA USED IN THE CIRCUIT DIAGRAM:

The circuit can be analyzed in steady-state operation, assuming that the input and output voltages and currents are constant.

The following equations can be used to describe the behaviour of the LLC DC-DC converter

1) Input voltage V in=V dclink + V input ripple where V dclink is the voltage across the DC link capacitor, and V input ripple is the input voltage ripple caused by the input filter circuit.

2) DC link capacitor voltage: V dclink = (1-D) Vin Vout/D
where D is the duty cycle of the MOSFET switches, and V out is the output voltage.

2) LLC resonant tank circuit:

   a) Resonant frequency fres = 1 / (2 pi sqrt(Lp C p)) where Lp and Cp are the inductance and capacitance of the LLC resonant tank, respectively.

b) Quality factor: Q= sqrt(L p/C p) Rp.
where Rp is the resistance of the primary winding of the transformer.

IV. SIMULATION USING SIMULINK

Once satisfied with the simulation results, consider building a physical prototype for experimental validation. Compare the experimental results with the simulation to ensure accuracy[6]. In summary, simulating an LLC resonant converter involves modeling the circuit, implementing control strategies, analyzing performance under various conditions, and optimizing the design for efficiency and reliability. This process helps engineers understand the converter's behaviour before physical implementation, reducing development time and costs.

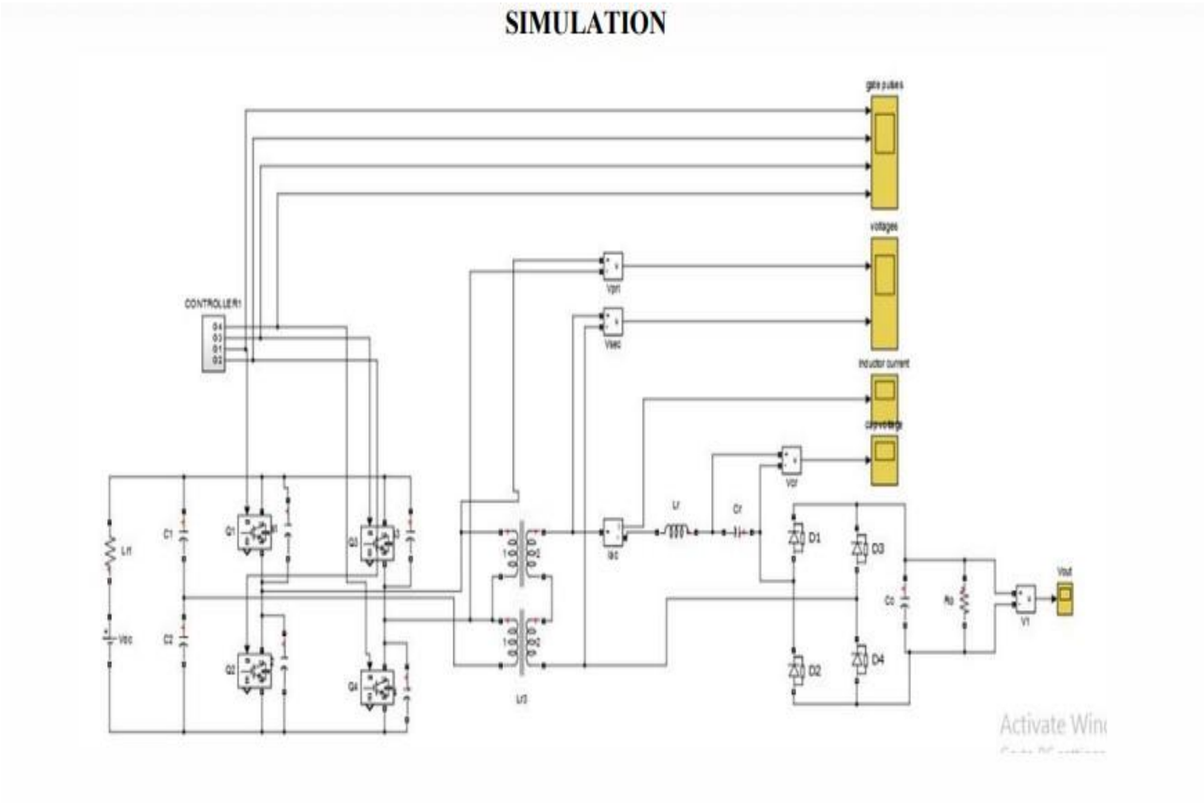


Figure 3: Simulation Circuit

Building the system model is then accomplished through a series of steps: The necessary blocks are gathered form the library browser and placed in the model window. The parameters of the blocks are then modified to correspond with the system we are modeling. Finally, the blocks are connected with lines to complete the model. Each of these steps will be explained in detail using our example system. Once a system is built, simulations are run to analyze its behaviour[7].

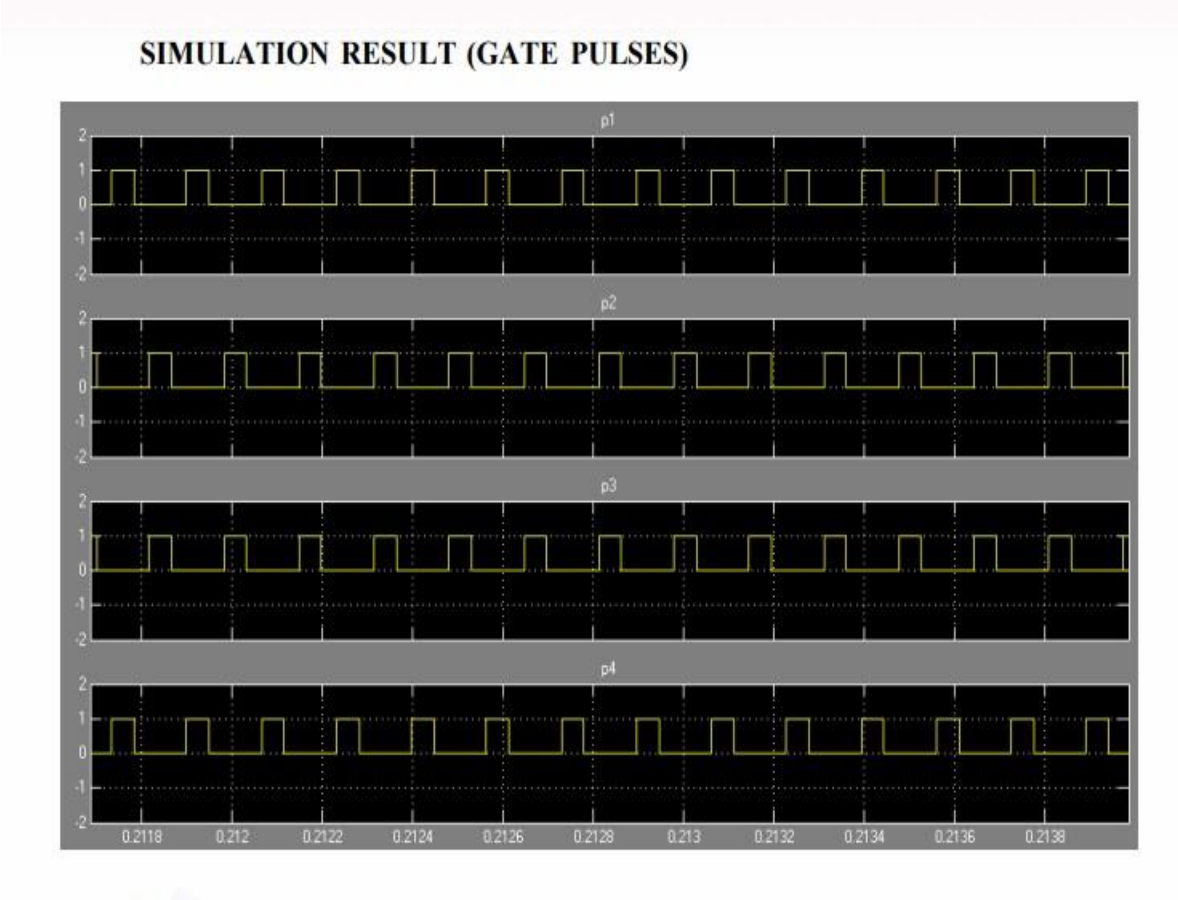


Figure 4: Simulation Result (Gate Pulse)

The results can be verified using MATLAB/SIMULINK. MATLAB is used for computing , visualizing and programming very easily using certain notation of mathematics. Signal analysis can be performed by MATLAB. The simulation starts by starting the MATLAB, where the Simulink library is present, click it and using browser menu select 'model' and thus the results of our model are present there in that particular section. In order to use the SIMULINK browser we need to use the MATLAB running in the background. For control purposes the analysis of simulation is performed using the MATLAB/SIMULINK[8] . Most people use MATLAB as it helps them to try different ideas into simulation where it can be tested with various parameters and different values for different devices.

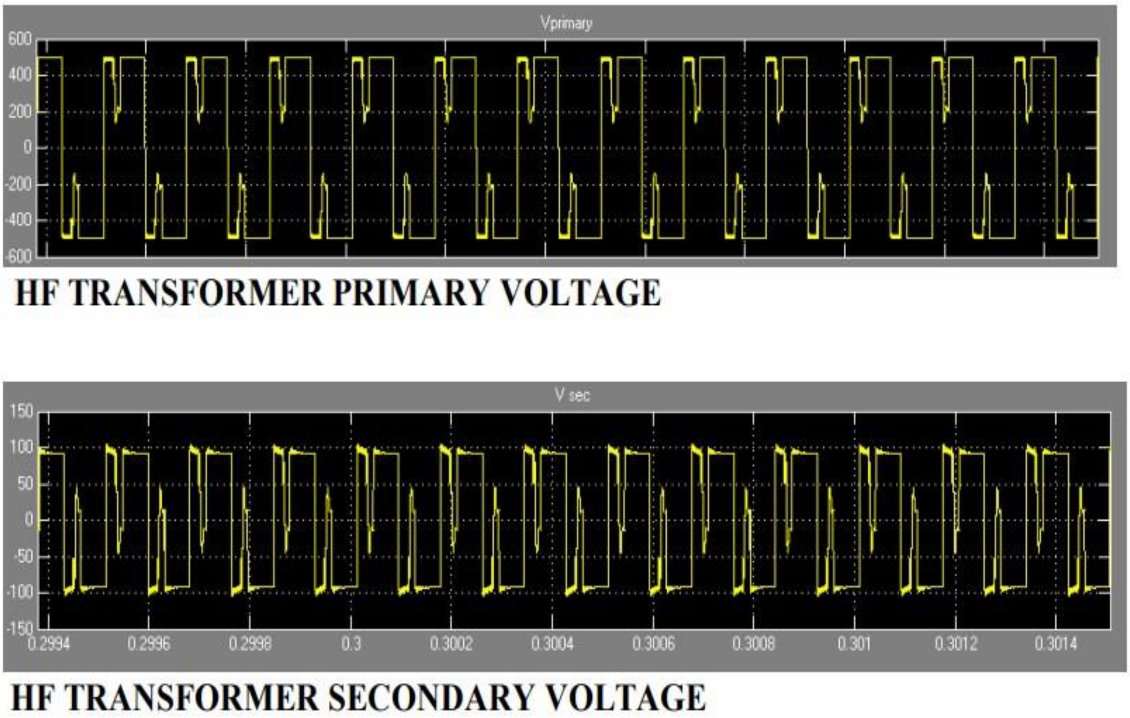


Figure 5: Simulation Result Waveforms

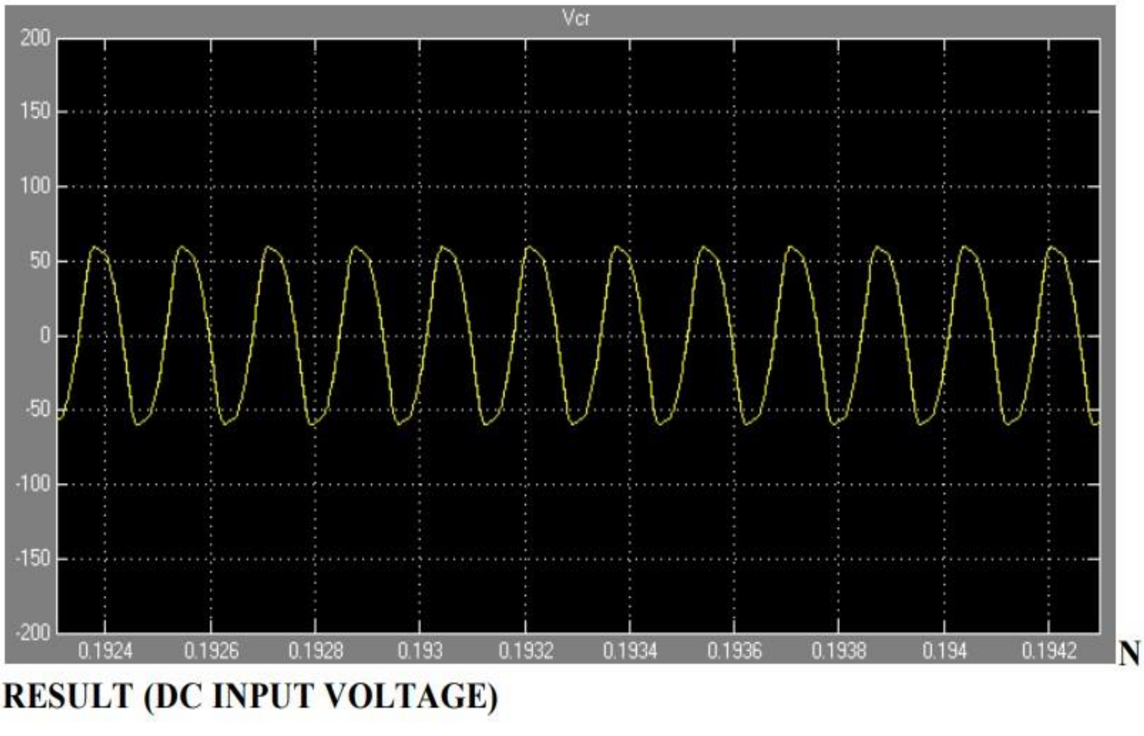


Figure 6: DC Input Result

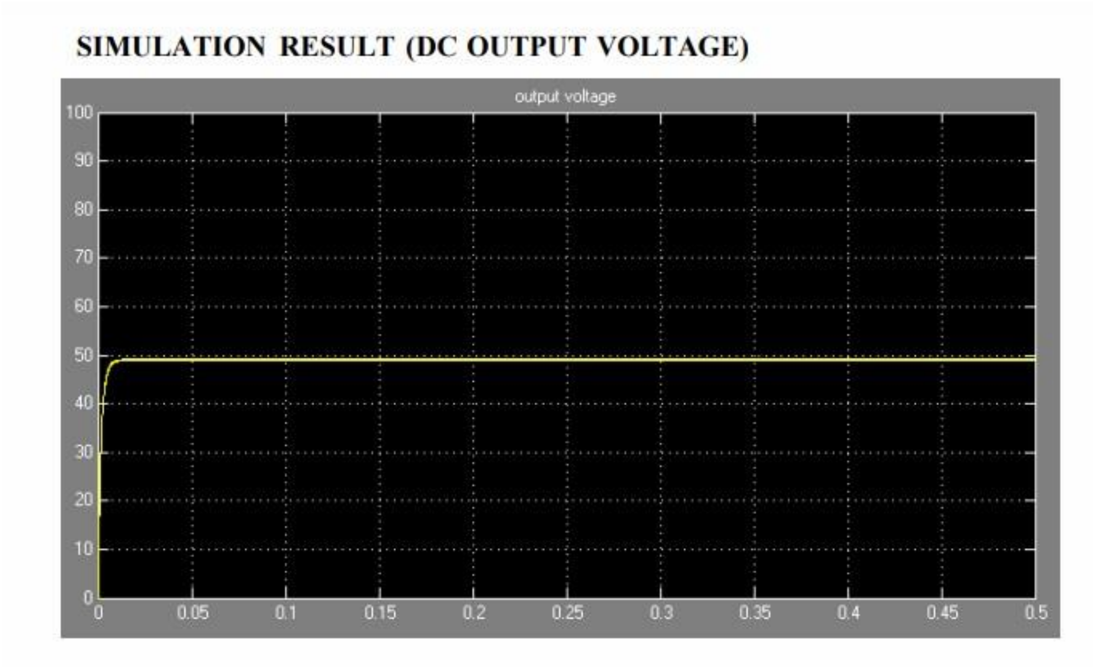


Figure 7: DC Output Result

V. HARDWARE

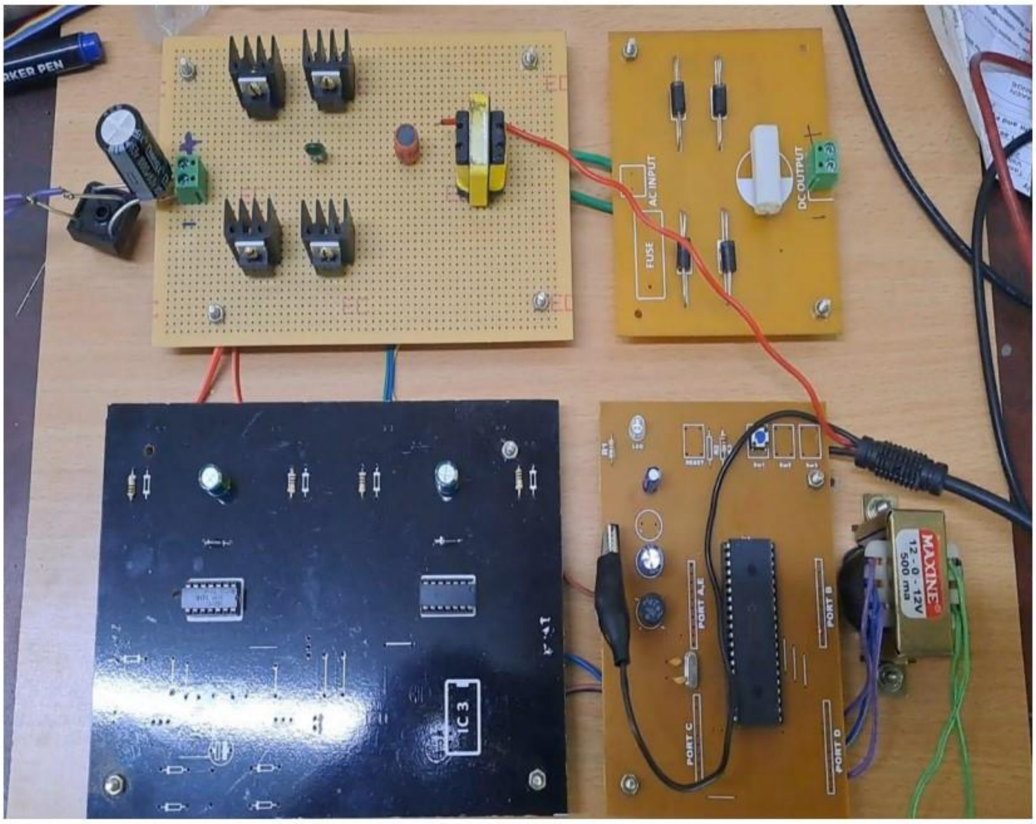
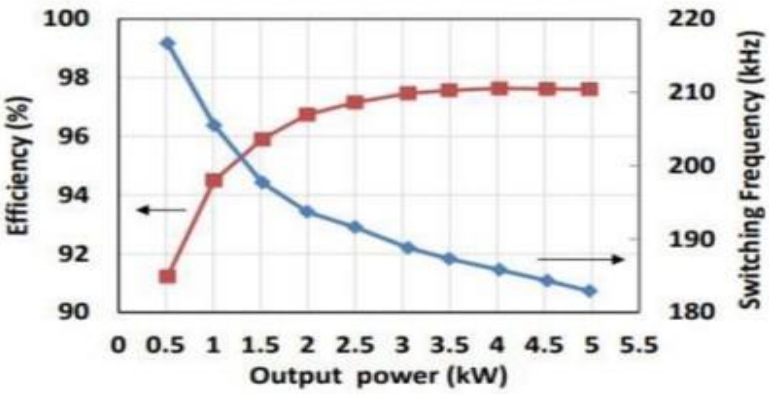


Figure 8: Hardware Model

6.2 HARDWARE RESULT



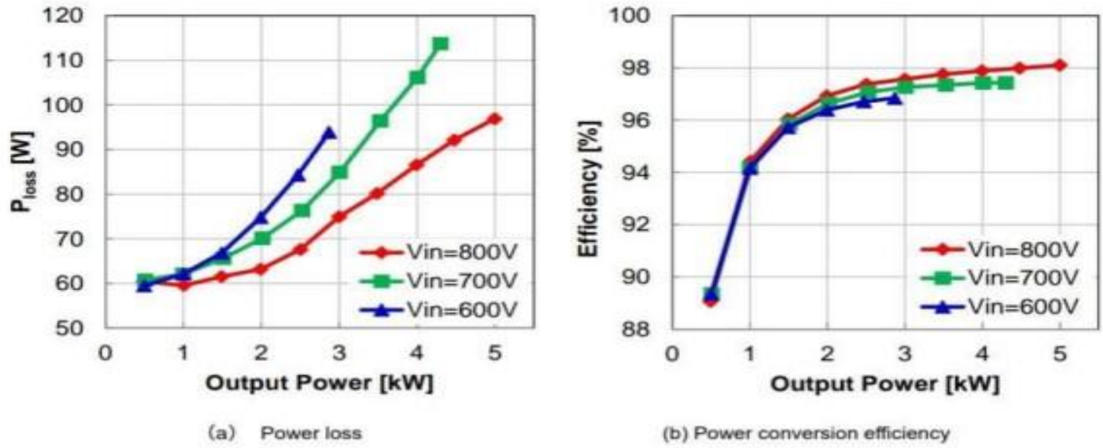


Figure 9: Hardware Result

VI. CONCLUSION

In this paper, a hybrid LLC resonant converter with twin transformers for wide input voltage applications is suggested. The suggested converter combines FB and HB circuits in a hybrid fashion. It has a constant resonant frequency and uses a straightforward phase-shift PWM control to adjust the output voltage, which makes the design of the magnetic components simpler. Two instances with different turns ratios have been looked at and compared in order to determine the best design for the turns ratio of the two transformers. There is also a description of the impact of the resonant capacitor on the peak resonant current and the turn-off currents of the switches. To validate the suggested converter's characteristics, a 1-kW prototype is developed and tested[9]. The prototype's dynamic and steady-state performance are evaluated, and the findings of the experiment are reported.

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