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Design and Analysis of Multi Input Multi Output Converter for Hybrid Energy Systems

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Abstract : The cost and the size of the converter design plays a crucial role in defining its effectiveness which lead to the development of Multi input and Multi output converters which are becoming popular as they are compact, cost effective and easy to implement. In this paper multi input multi output converter is designed and analysed for Grid-Solar power integration is proposed for uninterrupted power supply. For this converter design four winding transformer is used in which the grid supply is fed to one of the primary winding of the transformer through the rectifier-inverter circuit for power transfer control and the other is fed by the inverted output of the solar energy. Inorder to eliminate the switching losses, the circuit is designed for zero current switching during turn-off and zero voltage switching during turn-on condition The simulation results for the proposed converter configuration is obtained using PSIM environment and the hardware design is developed in the laboratory and their output results are compared and presented in this paper.

Keywords : Multi Input/Multi Output Converters, ZCS/ZVS, Grid-Solar Power Integration, Multi Winding Transformer, PSIM.

1. INTRODUCTION

In the current scenario, there is an increased power demand due to the increasing consumer load which imparts the need for Renewable energy sources and hybrid energy systems. The demand for uninterrupted and good quality power supply was the major challenge for the current hybrid energy systems. In such systems power converters play a vital role in providing a regulated output inorder to maintain the efficiency of the hybrid system. Multiport converters were either isolated or non-isolated type. The energy is transferred from primary sides to secondary sides through multi- winding transformers in isolated topologies. Integrated power converters are capable of interfacing and controlling the energy sources concurrently [1] [2]. Even though the isolated converters were good in voltage transformation and regulation, their weight and cost are high. The above problem had been overcome by using flyback [3] [4] and bridge [5]-[8] configurations were used in multi input single output, multi input-multi output, single input-multi output converters. These converters were used for single input and multi-outputs. But, several isolated multi-output converters were proposed. Initially, buck, boost, SEPIC and Cuk-converter topologies were extended to get multi-outputs [9]-[15] which were designed for power supplies. Two inverter configurations were proposed for the distributed energy system, which consists of grid supply and solar power needs a transformer for integration. A multi-winding step-up transformer was needed in connecting the paralleled connected inverters to the grid. The main drawback of this configuration is

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that it operates at low frequency, which requires a bulk transformer [16]-[20]. To feed AC load, the solar power which is DC has to be converted to AC using an inverter. In the next configuration, multi input DC-DC converter was cascaded with inverter for AC loads. It offered galvanic isolation and high boosting capability. During multiple power processing stages, bulky electrolytic capacitors were required at the DC link. They were extremely sensitive to temperature and their life deteriorated due to increase in temperature. So, capacitor reliability was inadequate for PV inverters. To increase their reliability, to simplify, and reduce the cost, an alternative inverter topology was proposed. In paper [21], two-output ports converter topology for interfacing PV supply and Grid supply through galvanic isolation was proposed. This converter used four winding transformers with two primary windings and two secondary windings. A rectifier-inverter connected the grid supply to the first winding of transformer through controlled power transfer. The solar energy was inverted and applied to the second winding of primary. Two output ports were considered. The circuit was designed to achieve zero current switching when it was turned off and zero voltage switching when it was turned on to alleviate the switching losses [22]. Section 2 described the proposed configuration; Section 3 gave simulation results. Analysis and Hardware validation of the multi input multi output converter is given in section 4 and the Conclusion is given in Section 5.

2. PROPOSED CONFIGURATION

The circuit diagram of the proposed topology is shown in Figure 1. Single phase grid supply is rectified and the rectifier current is smoothened by the filter inductor Lgf and the voltage is smoothened by the filter capacitor Cgf.

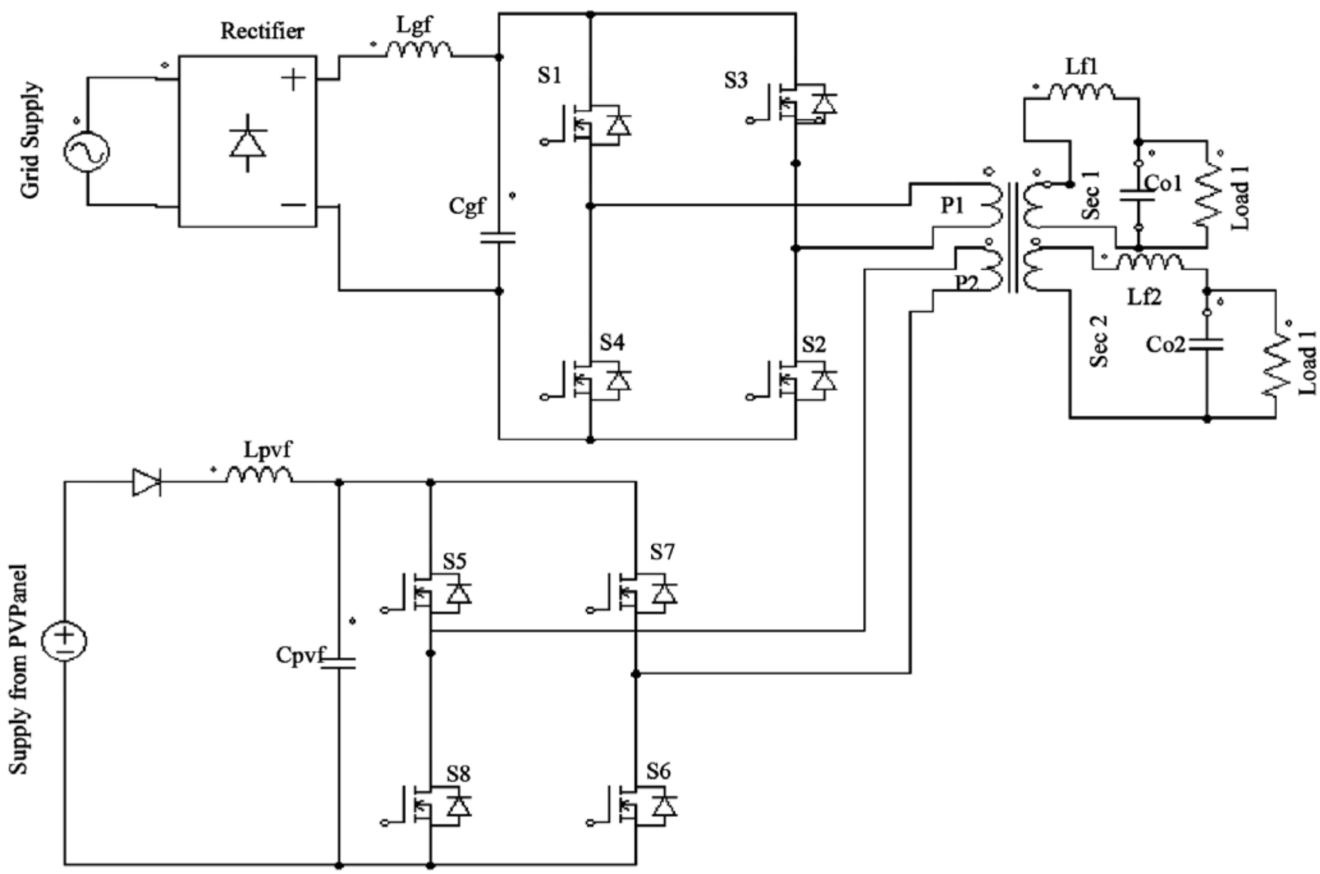

Figure 1: Proposed configuration

The rectified voltage obtained is fed to the inverter 1 consisting of switches S1 to S4. The inverted output is then fed to the primary winding P1 of the transformer. Load 1 is connected to the secondary winding Sec1 of the transformer. The Lf1 and Co1 acts as a LC filter to shape the output voltage to a sinusoidal wave pattern. The primary winding P2 of the transformer is fed by the inverted output obtained from the solar PV panel through the inverter 2 consisting of switches S5 to S8. Lpvf and Cpvf is used at the inverter input to minimize the ripples in current and voltage obtained from the solar output. Load 2 is connected to secondary winding Sec2 of the transformer through the filter inductor Lf2 and filter capacitor Co2 which helps in attaining zero voltage and zero current switching of all the inverter switches in addition to shaping the secondary voltages

3. SIMULATION RESULTS

The proposed prototype was simulated in the PSIM environment. The simulation circuit is shown in Figure 2. The simulation parameters were listed in Table 1.The switching pulses, voltage and current across the switch S1 & S2 and the switch S3 & S4 are shown in Figure 3 and Figure 4. Similarly the switching pulses, voltage and current across the switch S5 & S6 and the switch S7 & S8 are shown in Figure 5 and Figure 6.It is inferred from Figures 4-6, that for all the switches during turn-on, the current through switches is zero and during turn-off ,the voltage across switch is zero which is shown in Figure 7 through which Zero current and zero voltage switching is achieved. Such soft switching technique will alleviate the switching losses so that the effectiveness of the prototype is enhanced.The primary voltages Vp1 and Vp2 and the secondary voltages Vsec1 and Vsec2 are shown in Figure 8 and Figure 9. The load voltages VL1 and VL2 are shown in Figure 10 and Figure 11. The simulation result shows that output voltages are sinusoidal in which Load 1 had a peak voltage of 210 V and load 2 had peak voltage of 115 V.

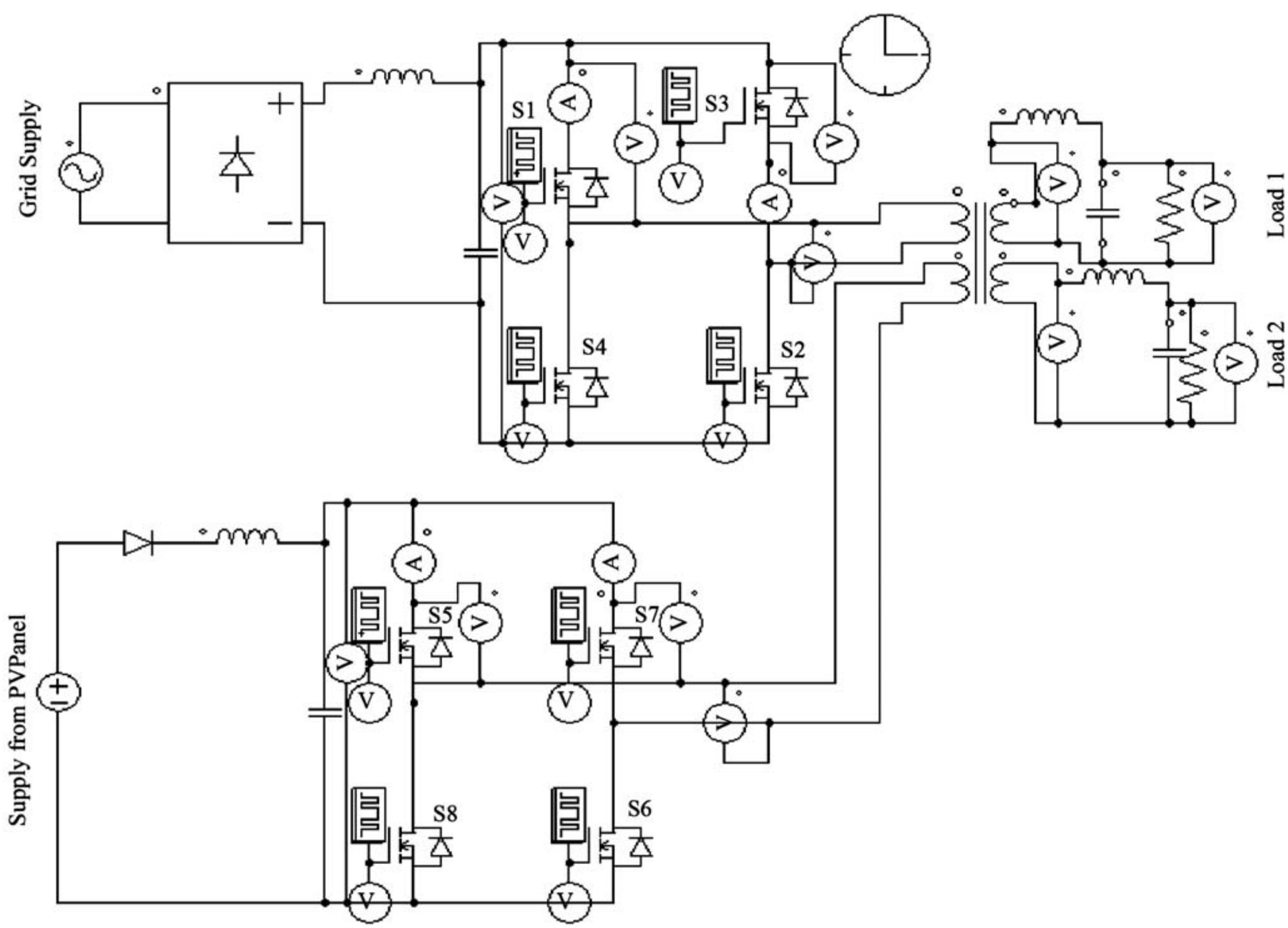

Figure 2: Simulation circuit

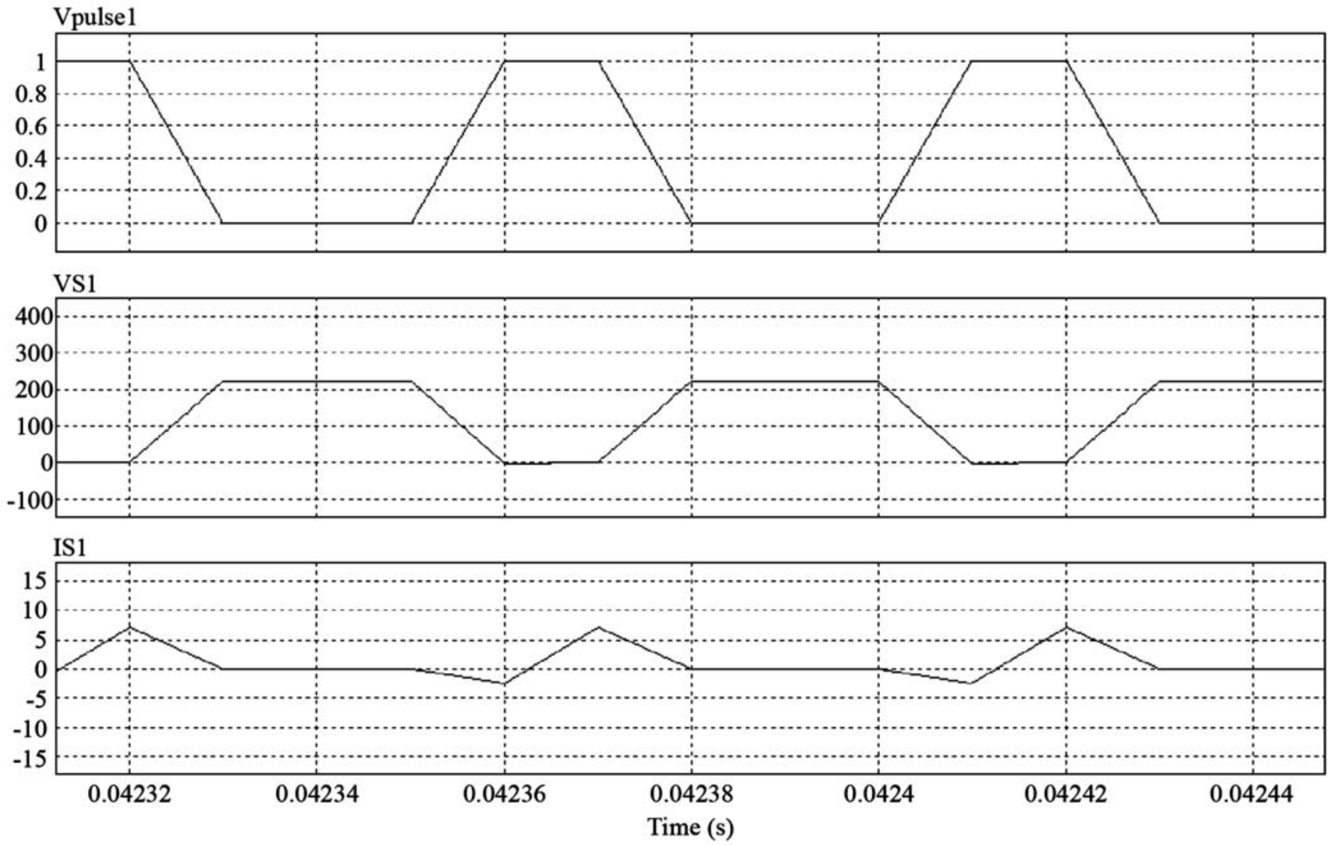

Figure 3: Switching pulse, voltage and current across the switch S1 & S2

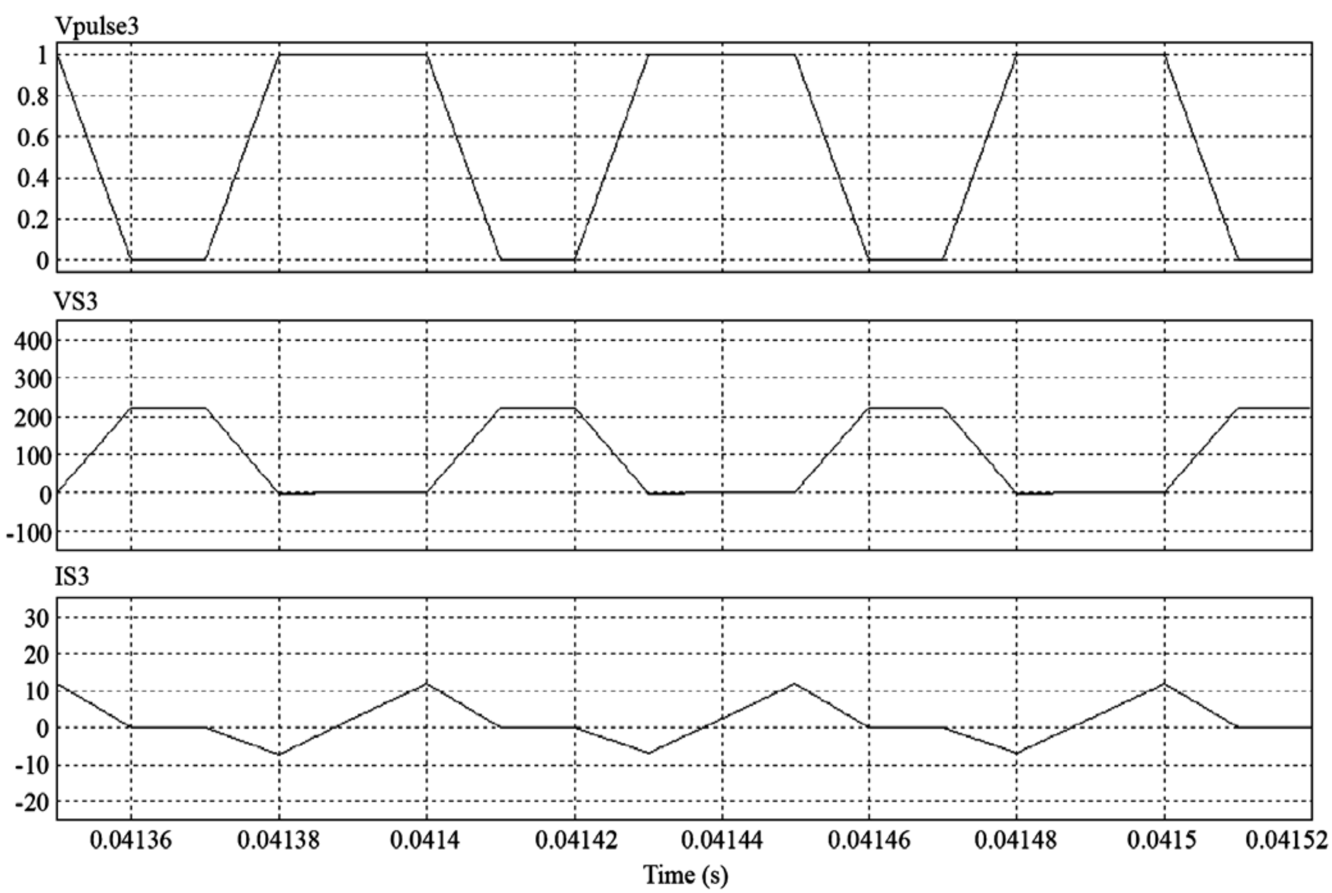

Figure 4: Switching pulse, voltage and current across the switch S3 & S4

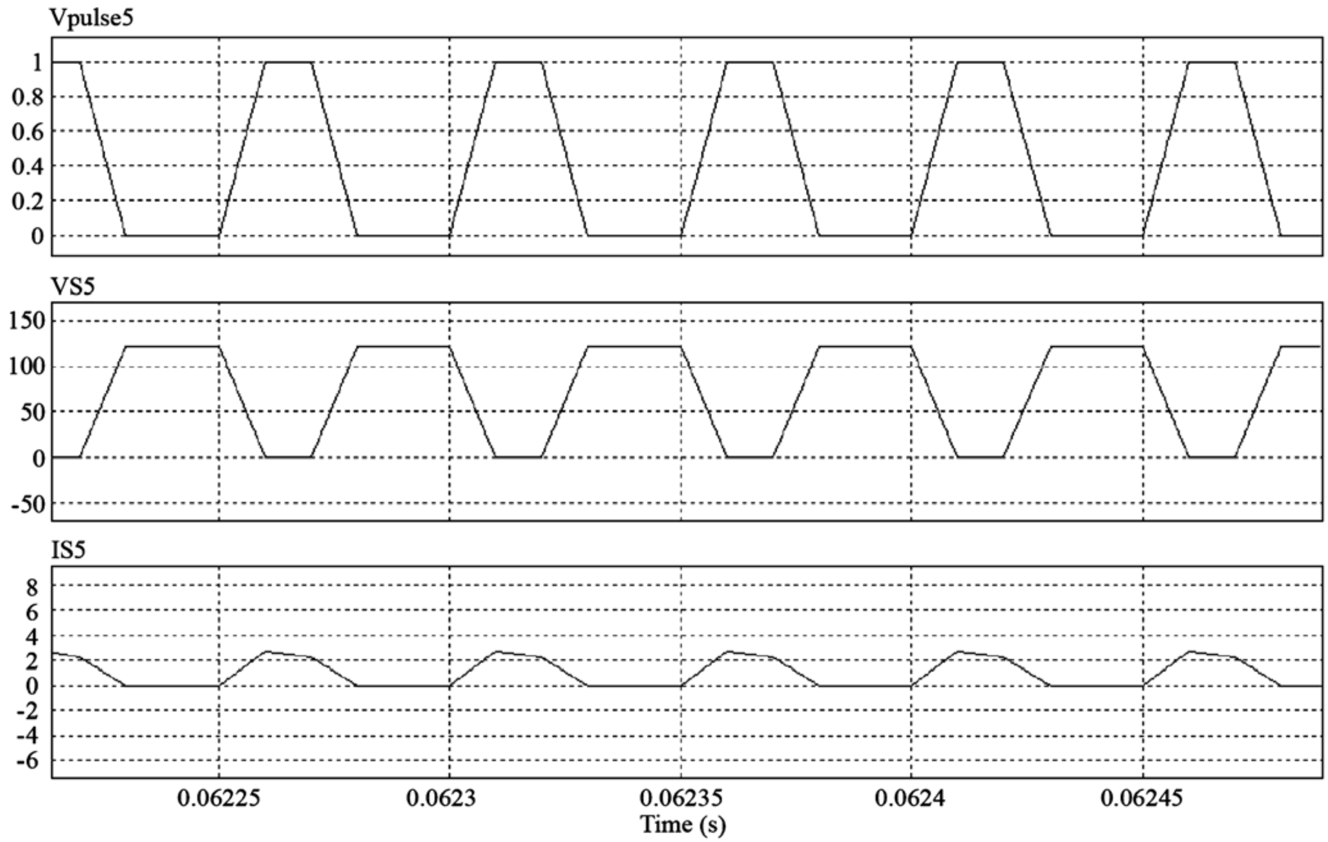

Figure 5: Switching pulse, voltage and current across the switch S5 & S6

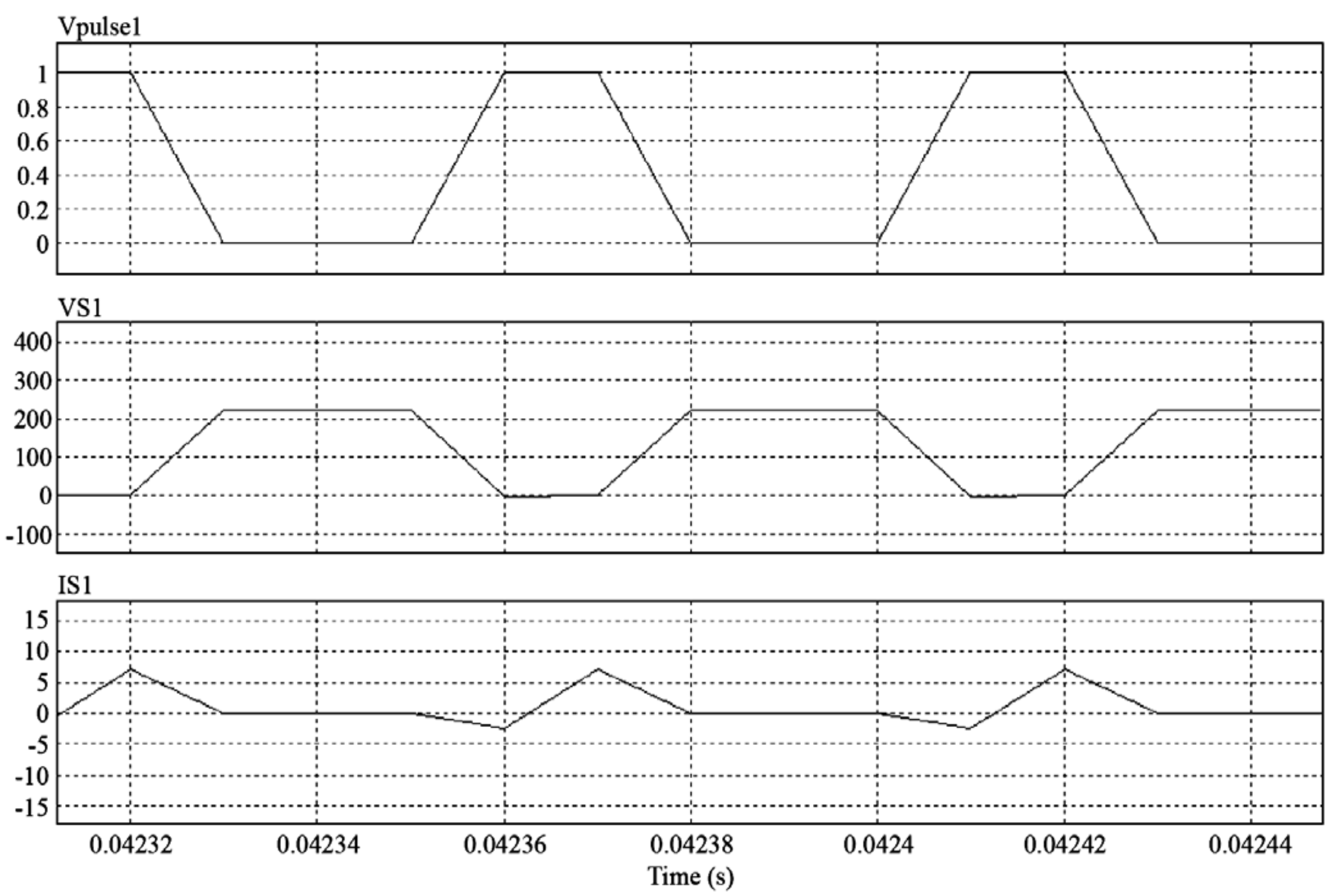

Figure 6: Wwitching pulse, voltage and current across the switch S7 & S8

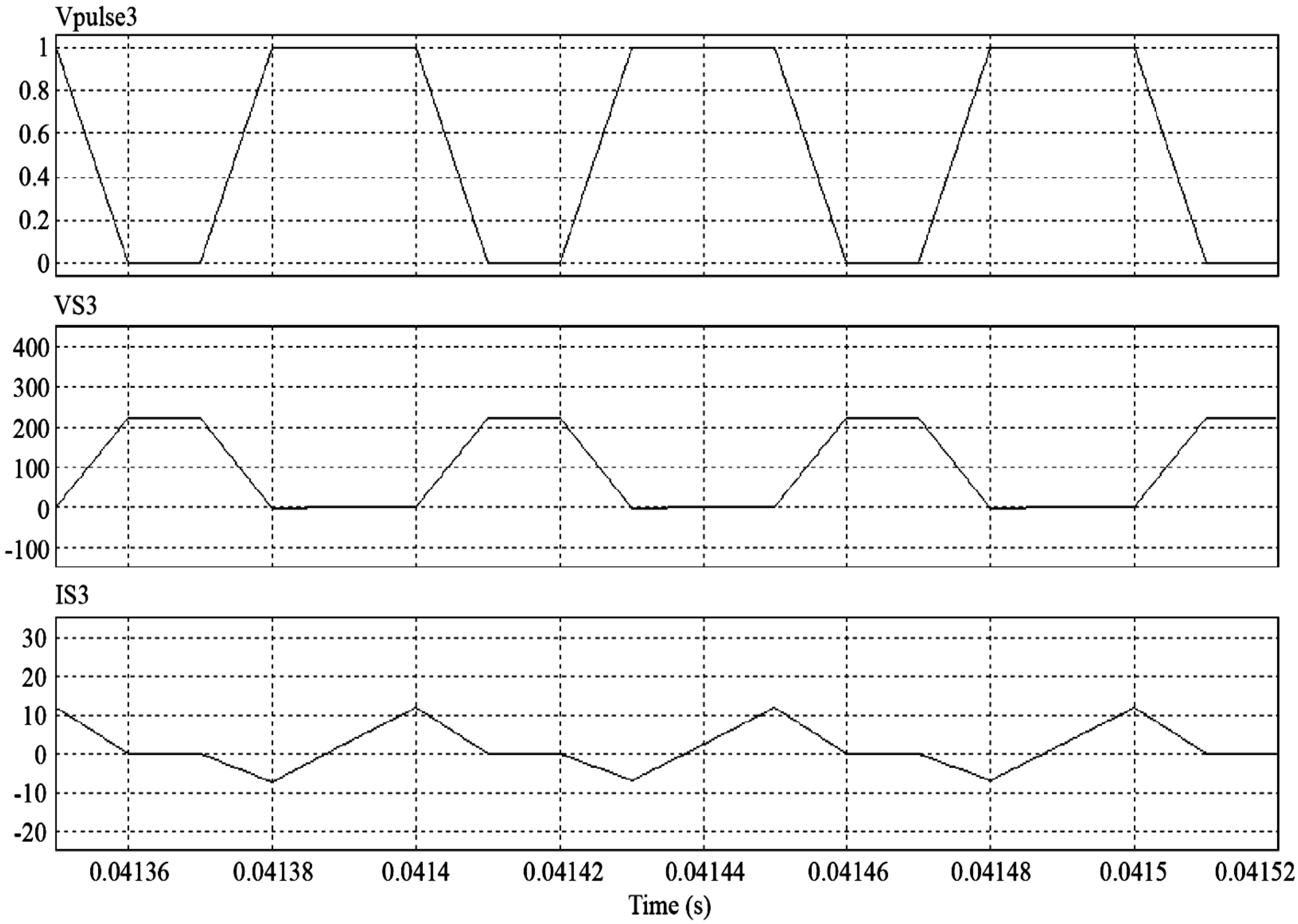

Figure 7: Zero Current and Zero Voltage Switching of switches

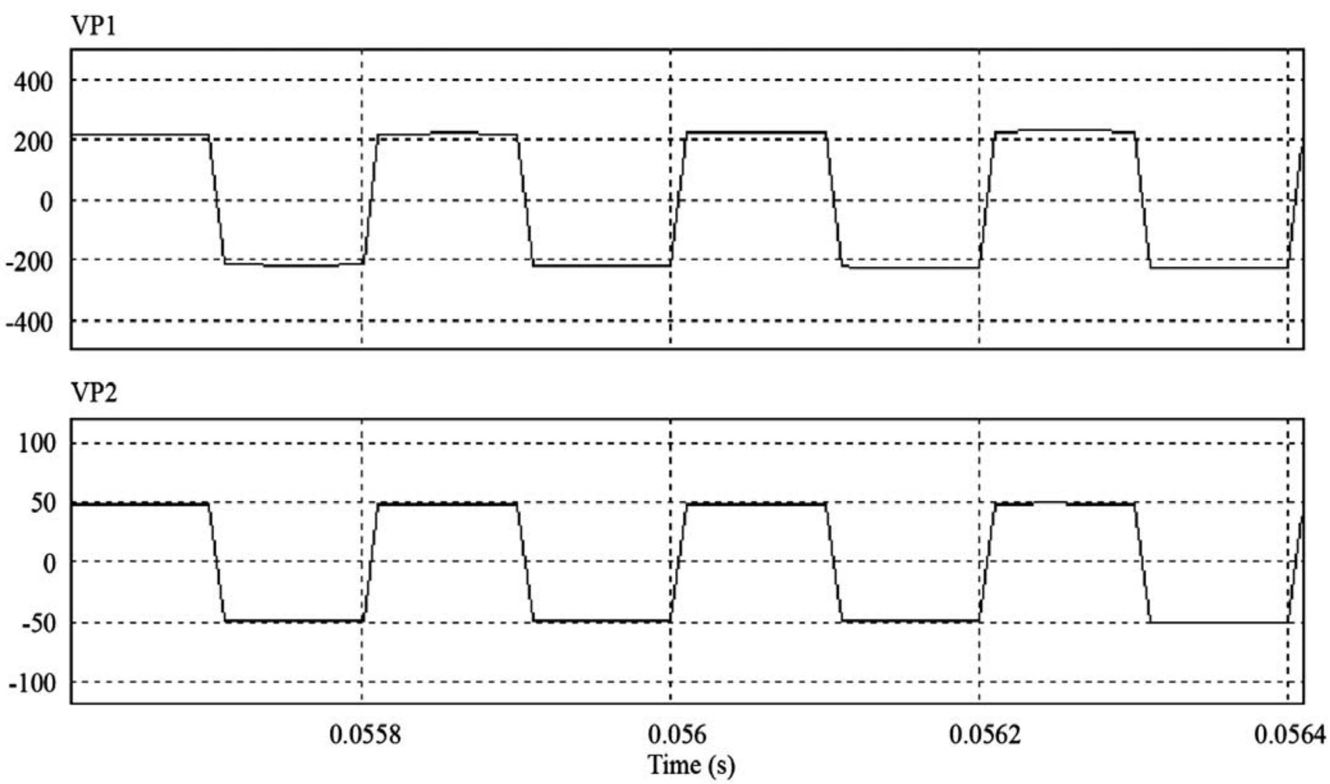

Figure 8: Primary voltages Vp1 and Vp2

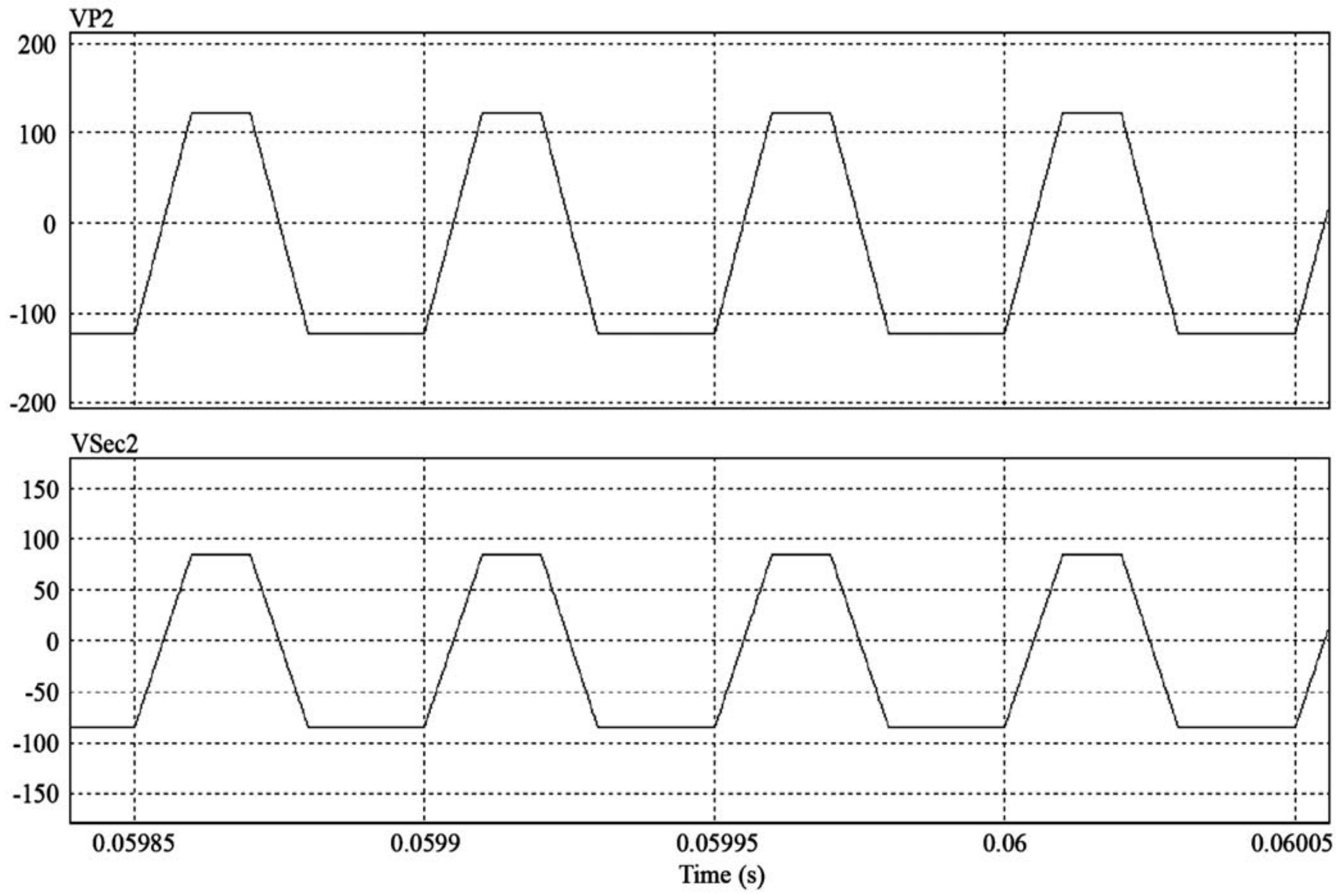

Figure 9: Secondary voltages Vsec1 and Vsec2

Table 1
Simulation parameter

Parameter	*Value*
Lgf	1 μH
Cgf	1000 μF
Lpvf	0.1 μH
Cpvf	1000 μF
Switching Frequency	5 kHz
Lf1	10 μH
Co1	10 μF
Lf2	10 μH
Co2	10 μF
Load 1	12 Ω
Load 2	12 Ω
Grid supply	220 V
Supply from PV panel	50 V

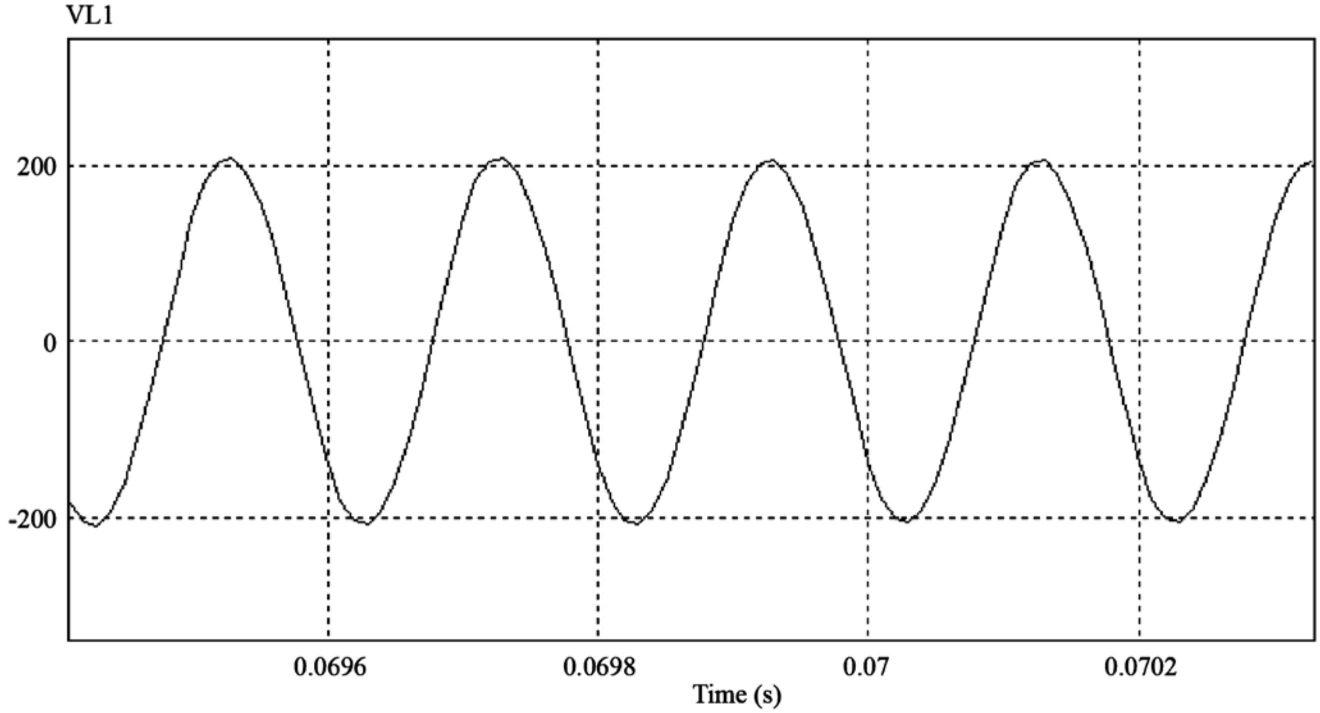

Figure 10: Load1 voltage VL1

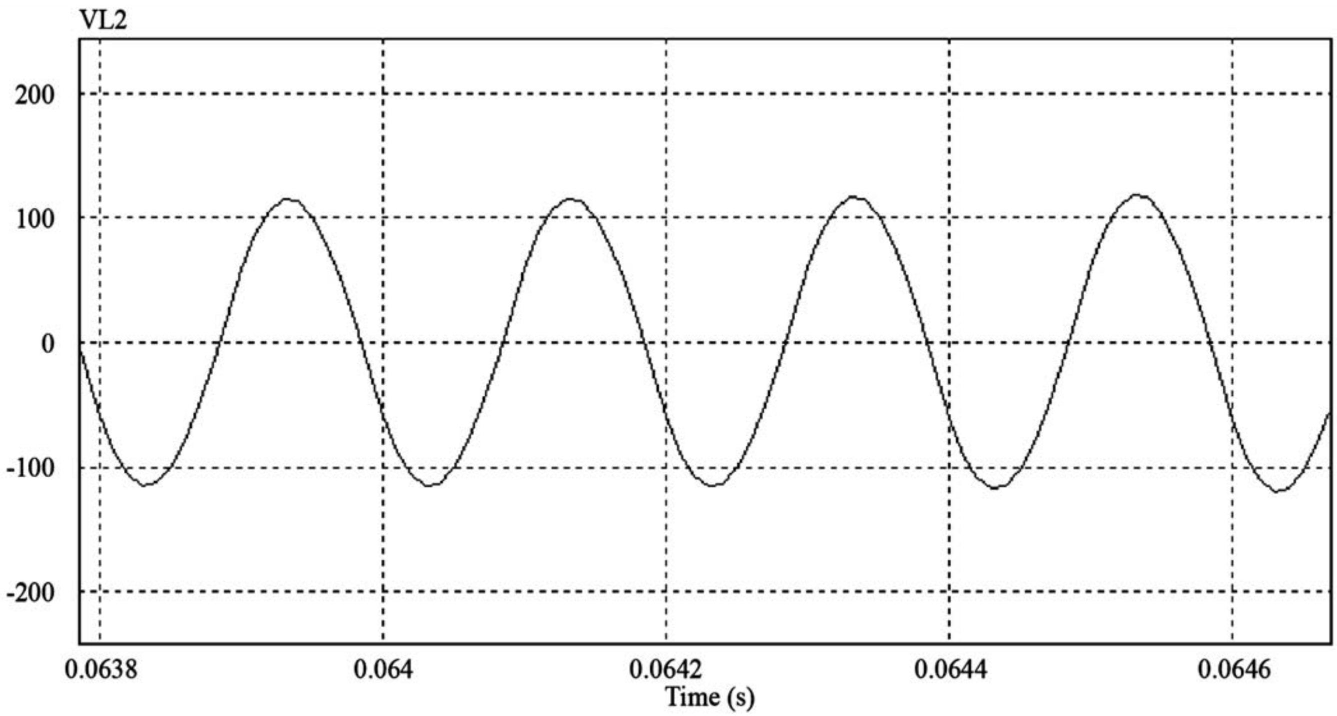

Figure 11: Load2 voltage VL2

4. HARDWARE VALIDATION OF MULTI INPUT MULTI OUTPUT CONVERTER

The hardware setup for Multi input Multi output converter for hybrid system is exposed in figure 12. This prototype consists of PV array, power supply unit, transformers, converter circuit with load arrangement. The output voltage of wind and solar is shown in figure 13 and 14.The switching pulse for inverter 1 and 2 are shown in figure 15 and 17.The driver output pulse and the inverter output voltage of load 1 and load 2 are shown in figure 16,18 and 19.

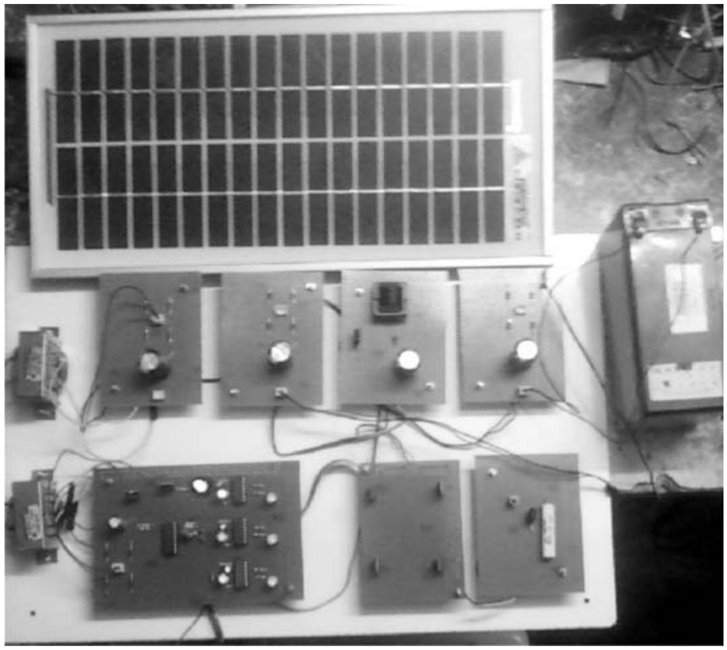

Figure 12: Hardware setup for Multi input Multi output converter

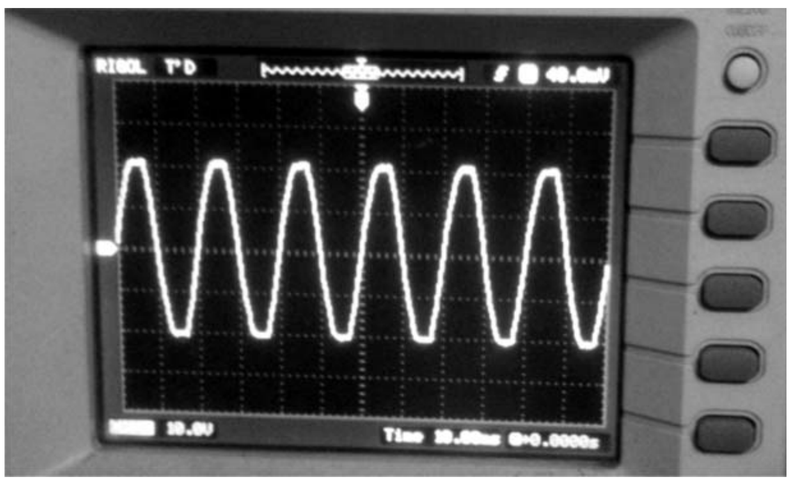

Figure 13: Output voltage of wind

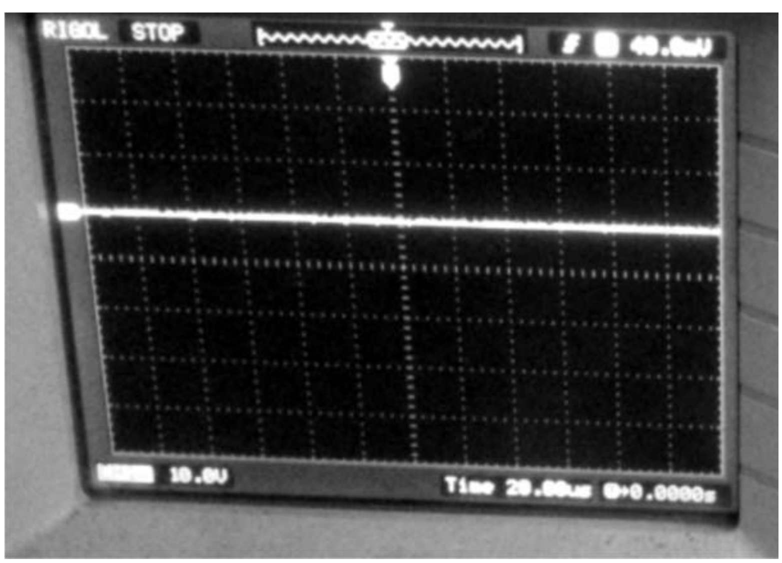

Figure 14: Output voltage of solar

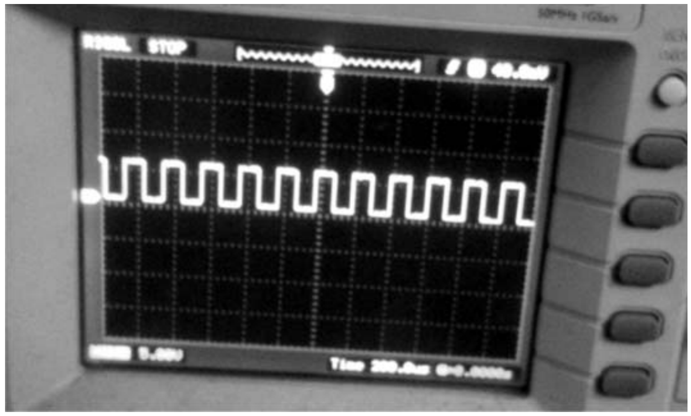

Figure 15: Switching pulse for inverter S1(5V)

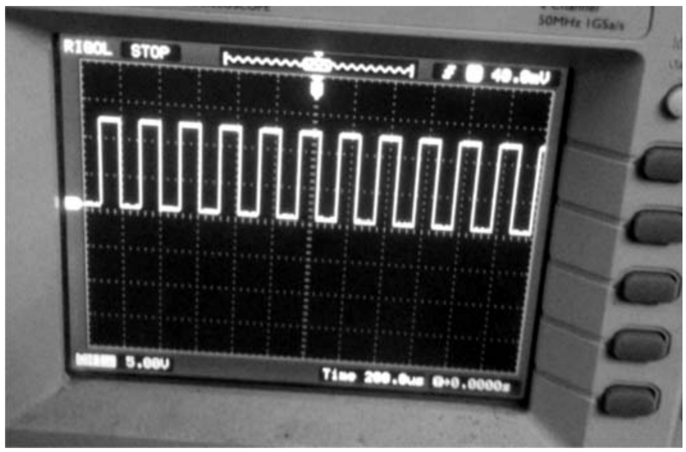

Figure 16: Driver output pulse 10V

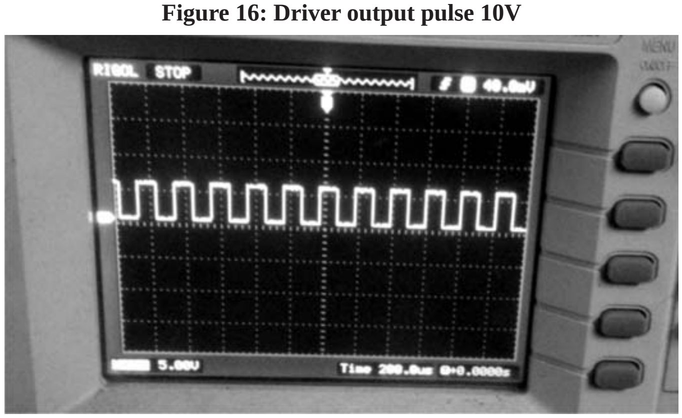

Figure 17: Switching pulse for inverter S2(5V)

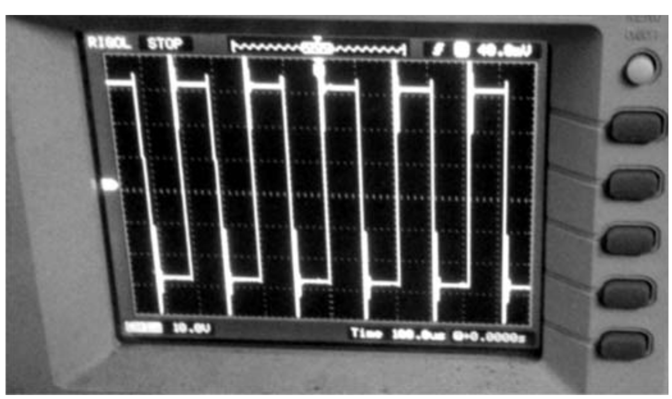

Figure 18: Output voltage of load 1

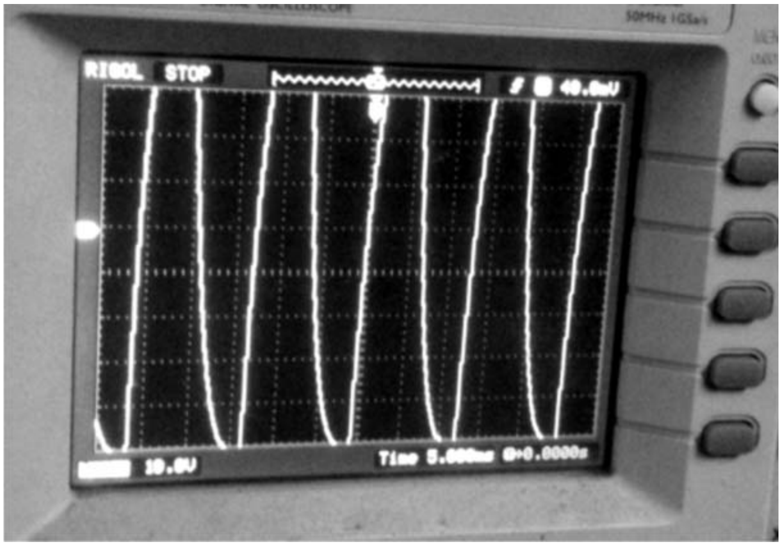

Figure 19: Inverter output voltage of load 2

Table 2

Performance of Multi input Multi output converter

Parameter	*Simulation Output*	*Hardware Output*
Output voltage of Load1	210 V	200 V
Output voltage of Load2	115 V	110 V

The simulation output taken from PSIM model was experimentally validated with the help of hardware setup and comparison of hardware results with the simulation results are shown in Table 2.

5. CONCLUSION

Design of multi input multi output converter for integrating Grid and Solar supply was proposed for two outputs and with the developed hardware, a comparative analysis of the simulation result and the hardware result was performed to validate the prototype. The proposed configuration has galvanic isolation and the switching losses of all the inverter switches are alleviated through the soft switching technique. Sinusoidal output voltages are obtained and this prototype can be further extended to get more than two outputs.

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