Coupled Inductor Based SIMO Interleaved Step-down Converter

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ABSTRACT: This paper proposes a new coupled inductor based SIMO interleaved step down converter. Multiple output converters are widely used in industrial applications. Designing multi-output converters presents a remarkable challenge for the power supply designers. Converters utilizing a single primary power stage and generating more than one isolated output voltage are called multi-output converters. The basic requirements are small size and high efficiency. This paper mainly investigates a high efficiency coupled inductor based single input multiple output (SIMO) interleavedstep down converter. The proposed converter can step down the voltage of high voltage dc bus generated by the rectifier of an AC utility power to a controllable output voltage of different levels. The interleaved topology of the proposed converter can achieve high step down conversion ratio, high efficiency power conversion and reduced voltage ripples across the load.

KEYWORDS: SIMO, interleaved topology, coupled inductor.

I.INTRODUCTION

The proposed coupled inductor based single input multiple output interleaved step down converter is used to convert the bus voltage in to voltages of three different levels. The basic requirements of multi output converters are small size and high efficiency. Multi stage converter includes several power conversion stages between the PV cell and load of the system. Power conversion stages include DC-DC converter, DC-AC converter, step up converter etc. In this paper the proposed converter utilizes three power switches with different switching frequencies. The proposed system utilizes two coupled inductors. Coupled inductors are actually a pair of inductors and are coupled together so the input to one will result in the output of both. Here the leakage inductor energy of the coupled inductor can be recycled, and the voltage spikes on the power switches can be alleviated. Therefore the objectives of high efficiency power conversion, high step down conversion ratio, and various output voltages with different levels can be obtained.

In addition to paralleling the converters, the interleaving topology can achieve several benefits. Interleaved converters have simple structure and low control complexity. So it can use in applications where, non-isolation and high output current with low ripples are required. Interleaving topology connects one or more converters in parallel to share the power flow between the conversion chains. The main advantage of this topology is reduction in size, weight and volume of inductors and capacitors. And also it can achieve significant reduction of current and voltage ripples. In this proposed converter higher efficiency is realized by splitting the output current into different paths, substantially reducing losses and inductor AC losses in the field of power electronics.

II.LITERATURE REVIEW

In a novel integration scheme of solar photovoltaic (PV) with a large capacity doubly excited induction generator-based wind energy system is proposed by R. G. Wandhare, et al. In this context, the proposed hybrid PV-wind system provides an elegant integration of the wind turbine and solar PV to extract optimum energy from the two sources. The proposed scheme uses both the grid- and rotor-side power converters of doubly fed induction generator to inject PV power into the grid. Thus, it renders a cost-effective solution to PV-grid integration by obviating the need for a dedicated converter for PV power processing. R. Santiago Maciel, et al, proposes a boost converter with integrated power factor correction (PFC) and dc–dc functions for a proton exchange membrane fuel cell (PEMFC) uninterruptable power supply (UPS). Through the use of a passive resonant soft-commutation cell, this besides providing improvements in efficiency and reduced electromagnetic interference produces a naturally controlled supercapacitor charger circuit. Super-capacitors are employed in order to provide a proper start-up of the PEMFC and to improve its dynamic response. A novel high-power input-parallel output-series buck-half-bridge converter is proposed by Q. Du, et

al. The circuit achieves completed coupling from the input so that the mutual effects between modules are eliminated and thus oscillations are avoided. The converter can achieve satisfactory comprehensive performance when the step-up ratio is low and smooth transition is achieved since the circuit has no nonlinear dc gain. L. Gu, K. Jin, et al present a family of switching capacitor regulators. In conventional PWM converters, the dynamic performance is limited by the inductor. Switching capacitor converters utilize the capacitor as the energy transmitter and have good transient response. However, their output voltage cannot be regulated by the duty cycle. H. L. Do proposes zero-voltage-switching synchronous buck converter with a coupled inductor. An additional winding of the filter inductor and a diode are adopted to achieve ZVS turn-on of the power switches and alleviate the reverse recovery problem of the body diode of the synchronous switch. It can achieve a ZVS turn-on of two power switches while maintaining CCM.

III.SYSTEM MODEL AND WORKING

The proposed coupled inductor based SIMO interleaved step down converter is shown in figure1. Here the converter can step-down the voltage of a high-voltage DC bus generated by the rectifier of an AC utility power to controllable three different voltages. The proposed converter has three switches S_1, S_2, S_3 with different switching frequencies. These switches can on and off according to the modes of operation. The circuit consists of two coupled inductors and an auxiliary inductor. L_{P1} and L_{S1} represent the individual inductors in the primary and secondary of the first coupled inductor. L_{P2} and L_{S2} represent the individual inductors in the primary and secondary of the second coupled inductor. L_{aux} is the auxiliary inductor. D_1, D_2, D_3 are the freewheeling diodes. C_1, C_2, C_3 are the filter capacitors across the output loads R_1, R_2, R_3 respectively. V_{bus} is the input bus voltage. The voltages across R_{O1}, R_{O2}, R_{O3} are V_{O1}, V_{O2}, V_{O3} respectively.
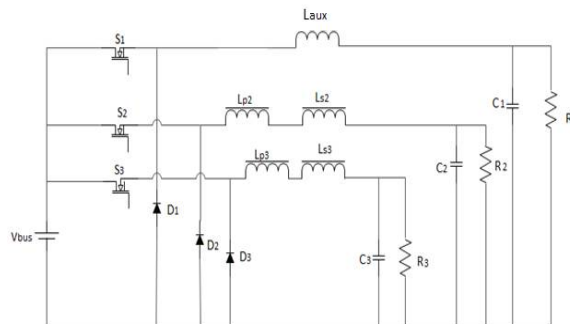

Fig. 1 coupled inductor based SIMO interleaved step down converter

The coupled inductor based SIMO interleaved step down converter has six modes of operation. The switches S_1, S_2, S_3 are on and off according to these modes.
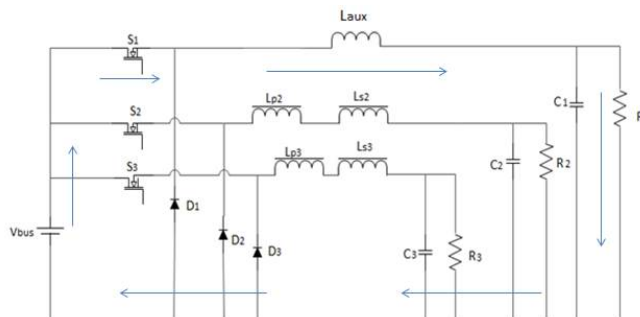MODE 1

Fig. 2 Mode 1 operation of coupled inductor based SIMO interleaved step down converter

The mode 1 operation starts when the switch S_1 is turned on. When the switch S_1 is on, the current i_1 starts to flow through the auxiliary inductor L_{aux}, R_1. The path is shown in figure 2. During this mode the output voltage V_{O1} is obtained across the load R_1.
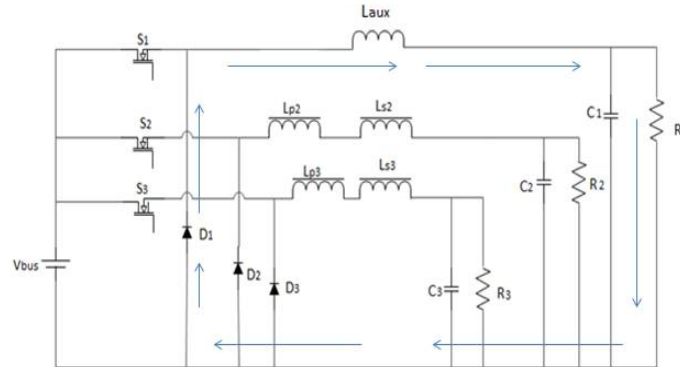
MODE 2

Fig. 3 Mode 2 operation of coupled inductor based SIMO interleaved step down converter

This mode starts when the switch S_1 is turned off. So the current freewheels through the diode D1 through the path as shown in figure 3.
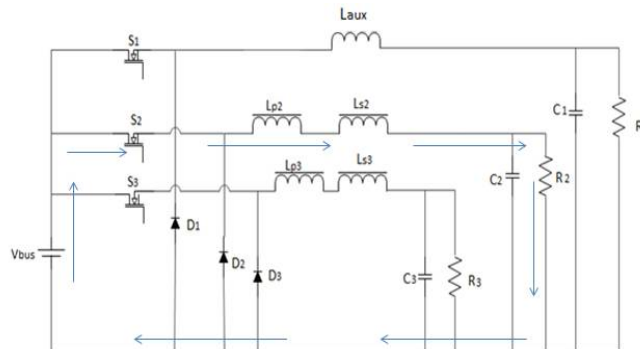MODE 3

Fig. 4 Mode 3 operation of coupled inductor based SIMO interleaved step down converter

Mode 3 starts when the switch S_2 is turned on. So the current i_2 flows through the primary winding L_{p2} and the secondary winding L_{s2} of the coupled inductor and R_2 of the proposed system. During this mode the output voltage V_{O2} is obtained across the load R_2.
MODE 4
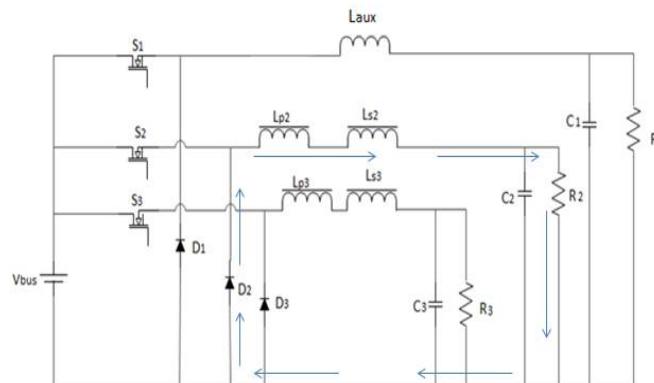
Fig. 5 Mode 4 operation of coupled inductor based SIMO interleaved step down converter

When the switch S_2 is turned off, the mode 4 starts. During this mode the current freewheels through the diode D_2 as shown in the figure 5.
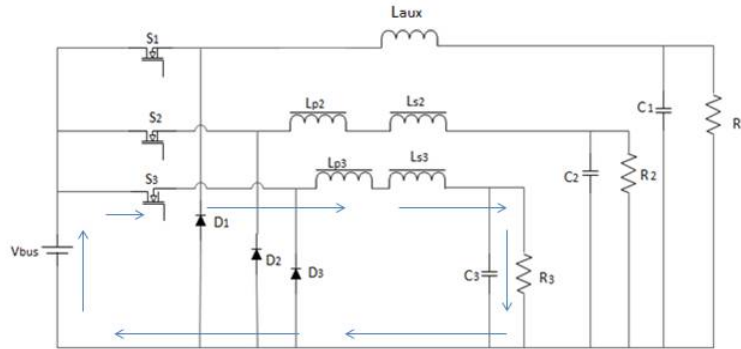
MODE 5

Fig. 6 Mode 5 operation of coupled inductor based SIMO interleaved step down converter

This mode starts when the switch S_3 is turned on. When the switch S_3 is turned on, the current i_3 flows through the primary winding L_{p3}, secondary winding L_{s3} of the coupled inductor and the load R_3 of the proposed system as shown in the figure 6.
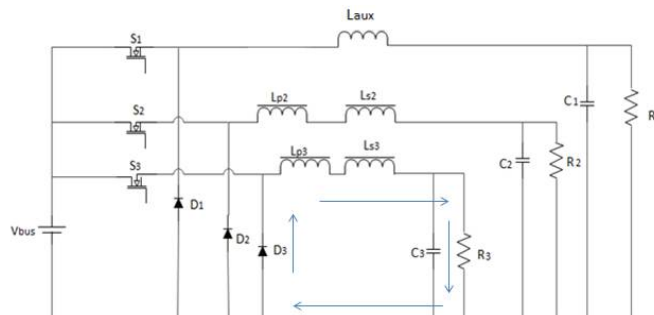
MODE 6

Fig. 7 Mode 6 operation of coupled inductor based SIMO interleaved step down converter

During this mode of operation the current freewheels through the diode D3. Mode 6 operation is shown I the figure 7.

IV.SIMULATION

The simulation result was done in MATLAB/Simulink. The Simulink model of the coupled inductor based SIMO interleaved step down converter is shown in the figure 8. The output voltage waveforms with different levels are obtained. The gate pulses generated for turn on/off of the switches are plotted. Closed loop control is adopted for the proposed system.

Voltage of 14.3V. PF obtained is 0.993 and the circuit gives THD of 10.39%. The hardware implementation gives an output voltage of 24.60 for the bridgeless resonant pseudoboost PFC rectifier and 12V for SC converter. The proposed circuit provides high power factor and low THD. The circuit use single control signal.
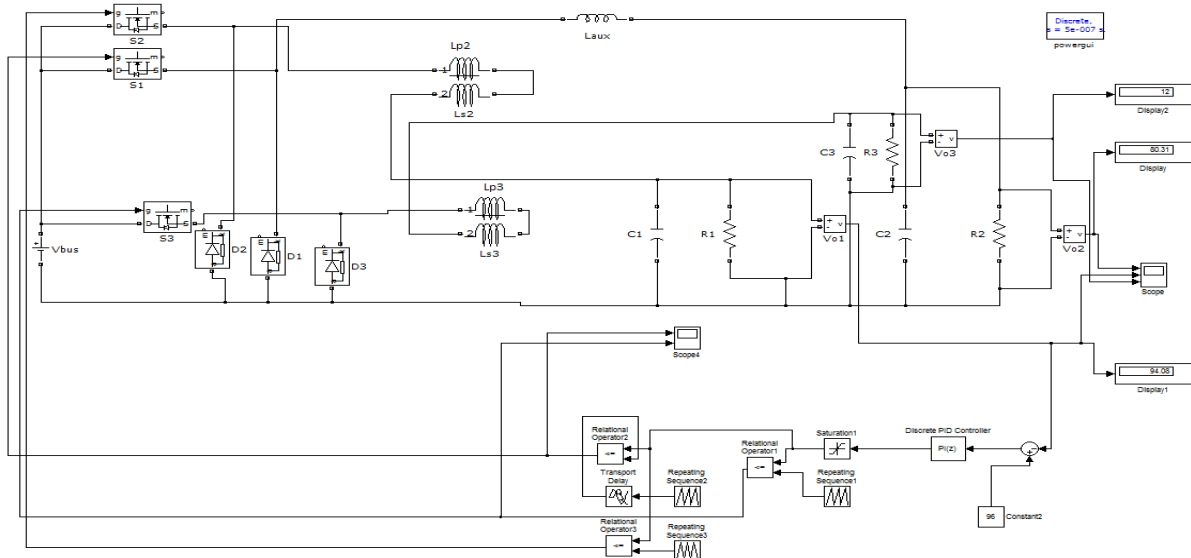
Fig. 8 Simulink model of the coupled inductor based SIMO interleaved step down converter

Here the proposed converter outputs are designed for 12V, 80V, and 96V. The input bus voltage is taken as 150 V. The gate pulses generated for the switches S_1, S_2, S_3 are shown in the figure 9 and 10.
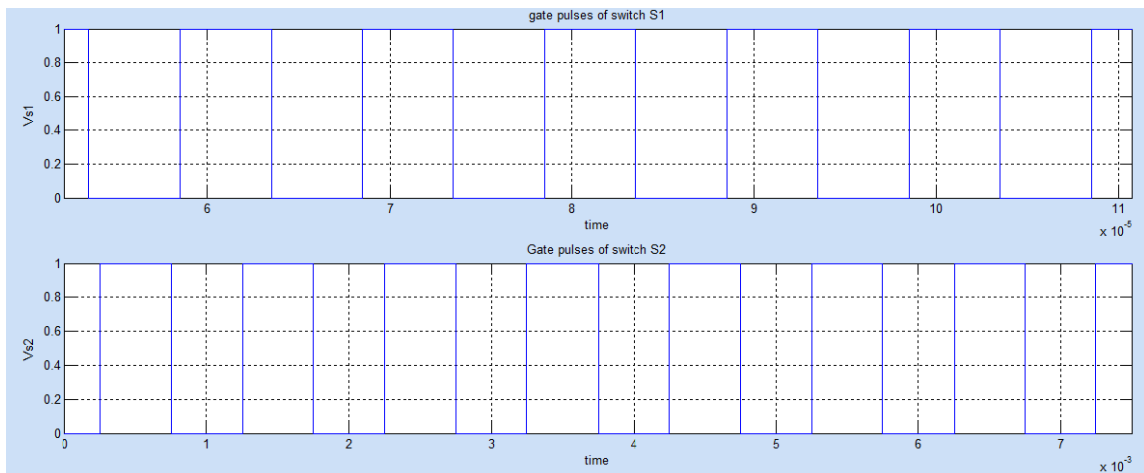

Fig. 9 Gate pulses for the switch S_1 and S_2

The switching frequency designed for the switch S_1 is 2K and for the switch S_2 is 4K.
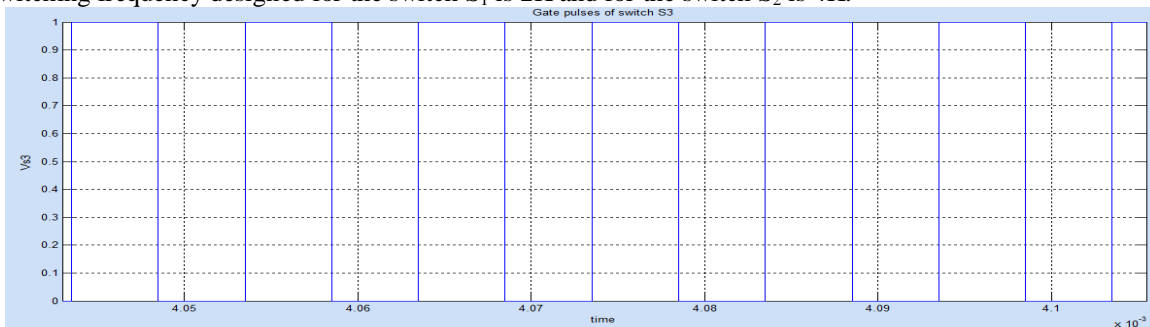

Fig. 10 Gate pulses for the switch S_3

The output waveforms are given in the figures 11. V_{O1}, V_{O2}, V_{O3} are designed for 12V, 80V and 96V respectively. By using PI control we can reduce the peak overshoot.
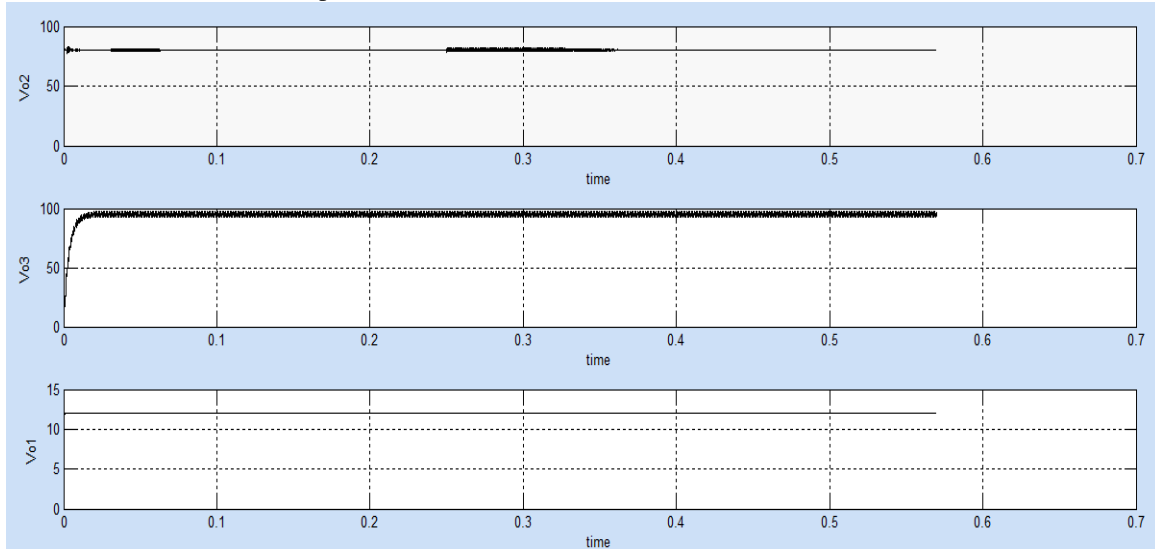

Fig. 11 Simulation result of output voltages of coupled inductor based SIMO interleaved step down converter

V.HARDWARE IMPLEMENTATION

Hardware implementation of the proposed coupled inductor based SIMO interleaved step down converter is given in the figure 12.
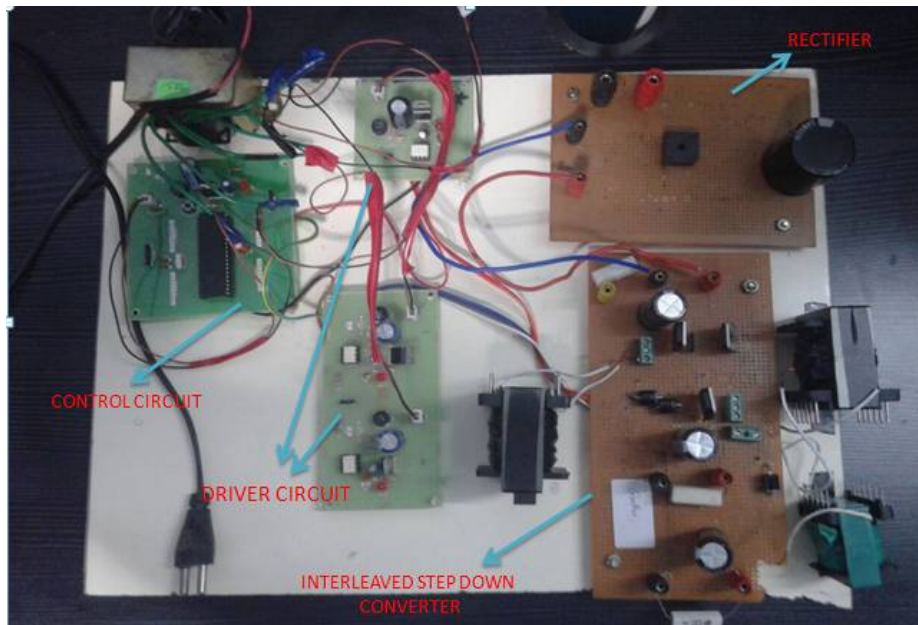

Fig. 12 Hardware implementation of the coupled inductor based SIMO interleaved step down converter

The hardware setup consists of interleaved step down converter, driver circuit, and control circuit. To perform the various operations and conversions required to switch, control and monitor the devices a processor is needed. The processor chosen is ATmega16. The results obtained from the hardware setup are given below.
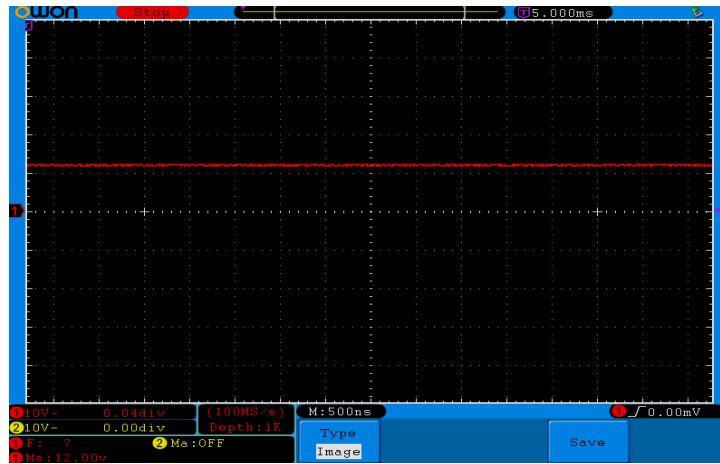
Fig. 13 V_{O1} of the coupled inductor based SIMO interleaved step down converter

V_{O1} of the coupled inductor based SIMO interleaved step down converter is shown in the figure 13. V_{O1} is designed for 12 V.
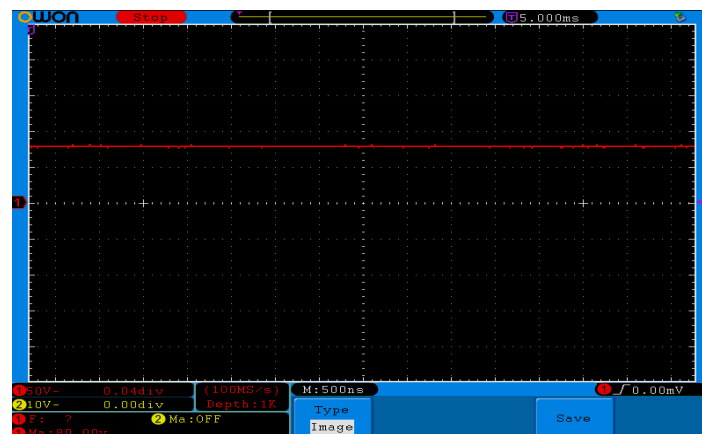

Fig. 14 V_{O2} of coupled inductor based SIMO interleaved step down converter

The V_{O2} obtained from the hardware setup of the proposed system is shown in figure 14. V_{O2} is designed for 80 V.
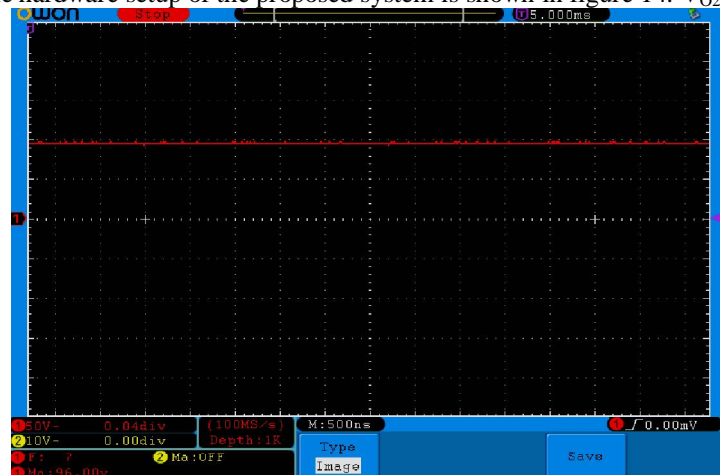

Fig. 15 V_{O3} of coupled inductor based SIMO step down converter

V_{O3} of coupled inductor based SIMO interleaved step down converter is shown in the figure 15. V_{O3} is designed for 96V.

VI. RESULT AND DISCUSSION

The proposed step down converter is shown in the figure 1 and its Simulink model and hardware setup are given in figure 8 and 12.We simulate the system using PI control. We get the simulation results which are given in the figures 9,10 and 11.Then we implement the hardware. The results obtained from the hardware setup of the coupled inductor based SIMO step down converter are given in figures 13, 14, 15. The outputs designed for the proposed system are 12V, 80V, 96V.

VII.CONCLUSION

Coupled inductor based SIMO interleaved step down converter is proposed in this paper. This converter has three output voltages of three different levels. The proposed converter achieves high step down conversion ratio. The interleaved topology adds additional benefits such as reduced voltage ripple in the output load. It also reduces the capacitor size. Experimental results are provided to confirm the converter operation in reference to SIMO operation.

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