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Interleaved Dual Switch Isolated DC to DC Converter with Voltage Tripler for Fuel cell Applications

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Abstract: *Renewable energy technologies are clean source of energy that have a much lower environmental impact than conventional technologies as well as will not ever. Among them the cells are the most reliable as they are not climate and location dependent unlike solar and wind energy. They are clean and efficient at any size, they can be located at almost anywhere. But like all other renewable sources fuel cells also come with low output voltage, so in order to utilize this energy efficiently, it needs to be boosted to high DC voltage by using high efficient power converter. Boost converter is used in the low to high dc/dc applications which is basically a current fed converter in order to produce high voltage. As a large step up is required in DC converter used for fuel cells, so, isolated boost converter is desirable. It consists of a transformer which isolates the input side from output to avoid any damage to fuel cells. The stress on the switch used in this converter is very high due to high current at the input. A new interleaved and isolated boost converter is proposed in this paper that has two inductors in parallel at the input to share current that reduces stress on the switches. As two inductors are used and switches are fired with 180 degree phase shift, the current ripple is smaller. High frequency transformer is used which reduces magnetic size and secondary turns of the transformer which in turn minimizes losses. The proposed converter is employed with voltage multiplier which further boosts the DC link output voltage to a high value. The above all advantages will make the converter system more compact and less cost system. The proposed converter is designed and simulated for 500W with an input voltage of 40V and the output from the converter obtained is 350V with a load current.*
Keywords: *Current fed, Interleaved DC-DC boost converter, Isolated transformer, Voltage multiplier.*

I. Introduction

Renewable energy system such as fuel cells required a suitable power converter to make it efficient that is to convert the variable low voltage of fuel cell stack to high DC bus voltage to further convert it into AC grid voltage.

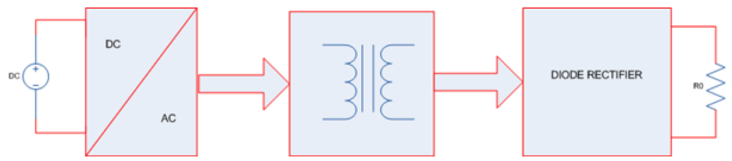

Fig1. Circuit topology of boost converter

The reasons for using boost converter for fuel cell application are simplicity in circuit and system design, high conversion efficiency compared to other converters and reduced voltage stress on devices. However, source behavior like input current ripple also influence the design of power converter which has to be below a particular value to meet the reliability requirements of fuel cells. It is no longer sufficient and advantageous to use an LC input filter for reducing input current ripple for high power application.

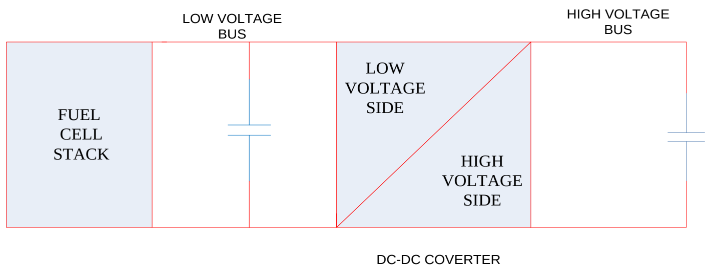

Fig2. Basic isolated boost converter

Interleaved isolated boost converter is one such converter that is suitable for this application. Isolation is required for safety purpose. The proposed converter has reduced input current and output ripple, handles high current at the input and high voltage at the output for a medium (>250W) to high(>1000W) power application with low cost, high efficiency and high power density.

In general, interleaved isolated boost converter consists of N-paralleled boost converters and generated power by interleaving technique. 2-phase interleaved is chosen since the ripple content gets reduced with increase in number of phase. If number of phase is increased further circuit becomes very much complex without much decrease in ripple content, there by increasing cost of implementation. Though interleaved boost converter has more inductors in comparison to conventional boost converter, increasing the complexity of converter, it is preferred and advantageous because of low ripple content in the input current and output voltage.

In order to design a compact, low weight and low cost converter, high frequency operation is required as it reduces the size of transformer, filters and other reactive elements. The proposed interleaved isolated boost converter with voltage multiplier has lower current and voltage stresses for high power application.

II. Operation of Interleaved Isolated Boost Converter

The converter comprises of three blocks. They are an interleaved isolated boost converter, a high frequency transformer which is used to isolated the converter from voltage multiplier and step up the voltage and a voltage multiplier which is used to rectify AC into DC and multiply the transformer output voltage.

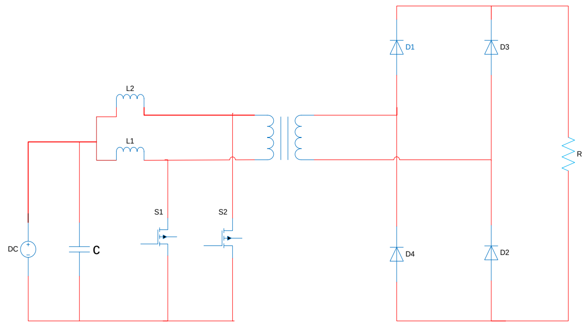

Figure3. Block diagram of the interleaved isolated boost converter

In this proposed converter switching is performed by phase shifted switching signals due to which input current ripple reduces, which is beneficial for the life of the fuel cells. This interleaved isolated boost converter works efficiently when two switches are switched using the phase shifted signals which overlap for a fraction of second. The two boost MOSFETS gates are 180 degrees phase shift with respect to each other and always have a duty cycle greater than 0.5.While switching the MOSFETSs using the 180 degree phase shifted signals the converter has four modes of operation.

Mode-1

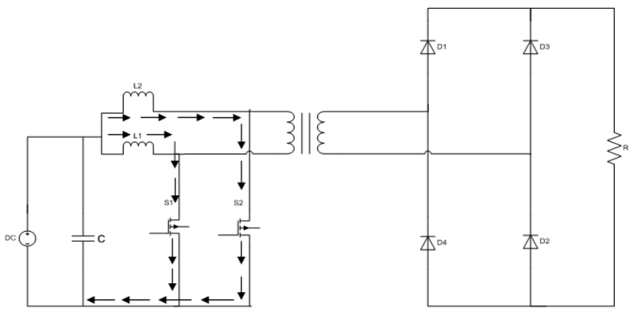

Figure4. Mode1 equivalent circuit

In mode-1 both the switching signals are high or we can say that S1 and S2 are in on state. These two closed switches create a path for the input current which is shared equally by input side inductors and flow from the source through both the inductors and completes the path as shown in figure4. Both inductors store energy when the input current flows.

Since, both the switches are closed no current flows through primary winding of high frequency transformer. So, there is no active power flows from the primary side to the secondary side of the transformer but this happens for the minimum time only when both the signals are overlapped.

Mode-2

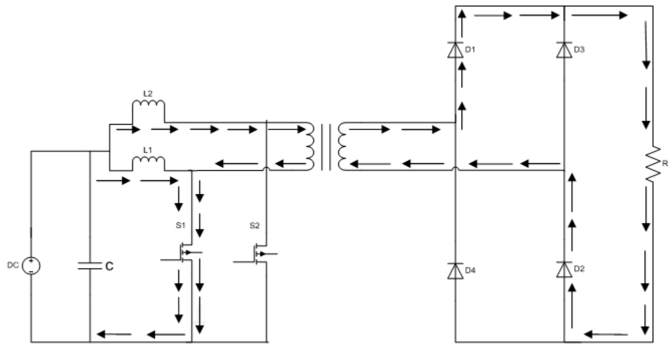

Figure5. Mode-2 equivalent circuit diagram

In mode-2, 1st switching signals continues to be high but the second signal goes to be high but the second signal goes low that is S1 will be ON state and S2 will be OFF state. Similar to mode-1 switch S1 creates the path for the input current to flow from the source through both the inductors and completes the path as shown in the figure5.

The first inductor continues to store energy but as S2 is in OFF state the second inductor dissipates energy through transformer winding. There is active power flow from the primary side to the secondary side of the transformer due to the current flow through the high frequency transformer's primary winding.

Mode-3

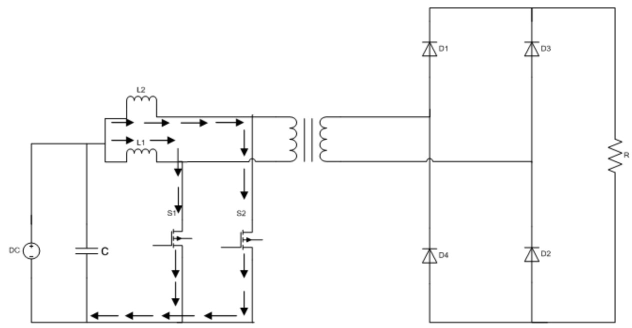

Figure 6. Mode-3 equivalent circuit diagram

In mode-3, second switching signal will go high that is both S1 and S2 will be in ON state. Input current flows from the source through the closed switches and is shared equally by the input side inductors to complete the path. Both the inductors to complete store energy when the input current flows.

There is no current flow through the transformers primary winding as both the switches are closed .So, there is no active power flow from the primary side to the secondary side of the transformer.

Mode - 4

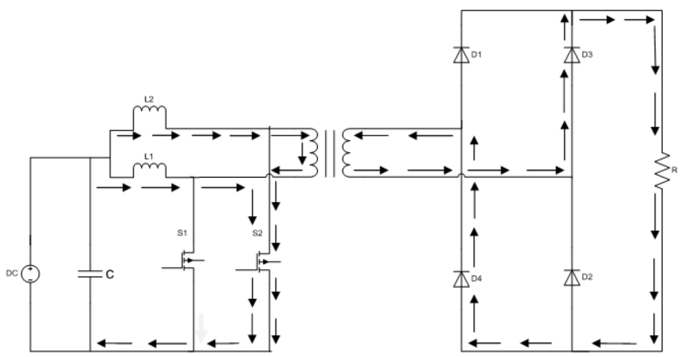

Figure7. Mode-4 equivalent circuit diagram

Mode 4 operation similar to mode 2 operation .In mode 4, the first switching signal goes low for the first time that is only will be in the ON state and will be in OFF state .Input current flows from the source through both the inductors and switch and completes the path as shown in figure 7.There is active power flow from the primary side to the secondary side of transformer due to current flow through transformers primary winding.

Thus the interleaved isolated boost converter operates in four different modes and boosts the voltage with reduction in input current ripple and improvement in efficiency.

Table1: Modes of operation of converter

Modes	MOSFET 1	MOSFET 2	Inductor 1	Inductor 2
Mode 1	ON	ON	Stores the energy	Stores the energy
Mode 2	ON	OFF	Stores the energy	Dissipate the energy
Mode 3	ON	ON	Stores the energy	Stores the energy
Mode 4	OFF	ON	Dissipate the energy	Stores the energy

III. Simulation Results of the Proposed Converter

A two phase interleaved isolated boost converter with two input inductors are simulated in PSIM. The values for different components and parameters for the converter are L1=800µH, L2=800µH, C (filter) =10µF, f=100KHZ, and R=245&490(full load &half load) with output voltage = 343V (both full load and half load) is obtained for an input voltage V_{in}=40V. The two mosfet gates are 180° phase shifted with respect to each and have a duty cycle >0.5 (up to 0.65) Fig.9&21Shows the input voltage of both full load and half load .The converter circuit is simulated for both half load and full load. Efficiency is higher in both the cases in comparison to other converter topologies. Input current ripple is smaller due to interleaved operation ripple is smaller due to interleaved operation of two isolated boost converter cells. Fig.18&30 Shows the output voltage for full load and half load.

Full Load

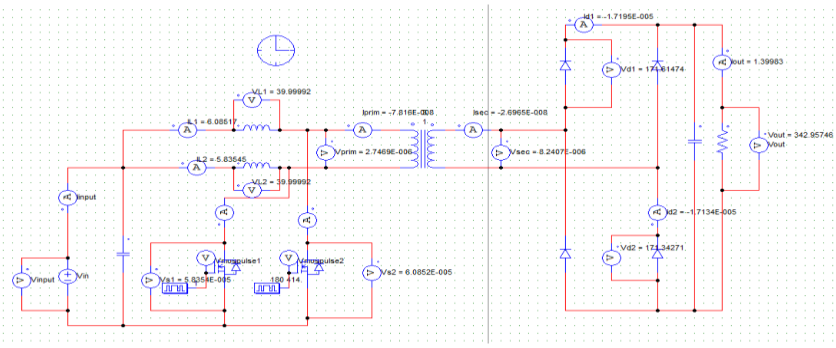

Figure8.PSIM simulation of interleaved isolated boost converter for full load

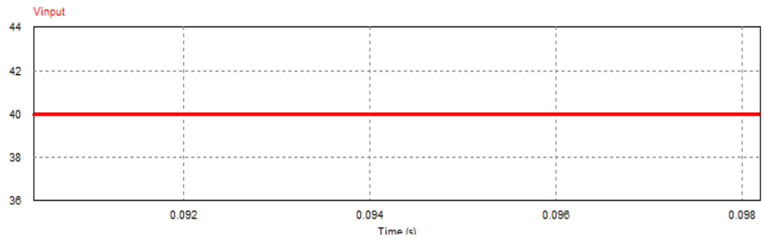

Figure9. Input voltage waveform

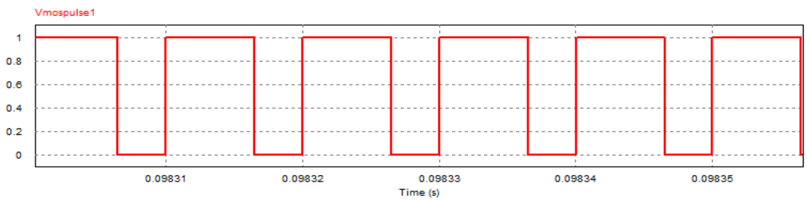

Figure 10: Mosfet voltage pulse 1

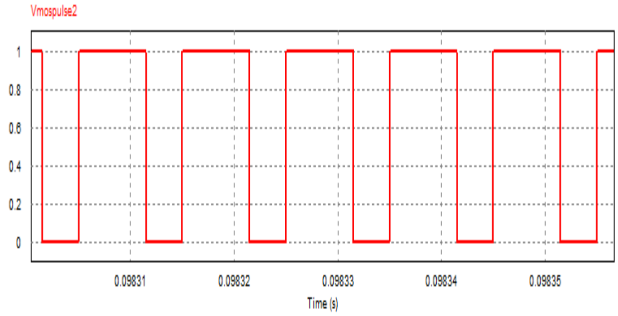

Figure11.Mosfet voltage pulse 2

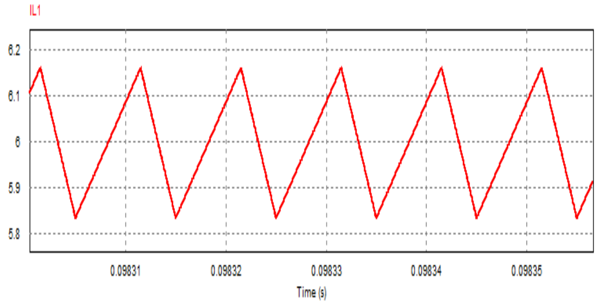

Figure12. Inductor current 1

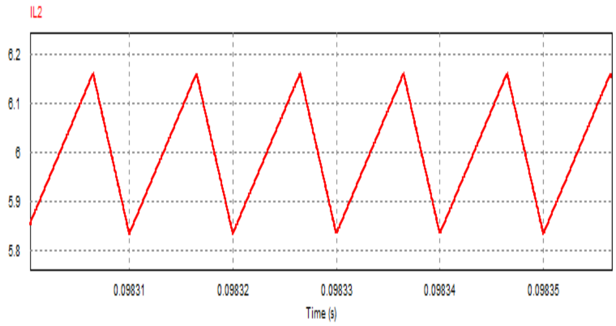

Figure13. Inductor current 2

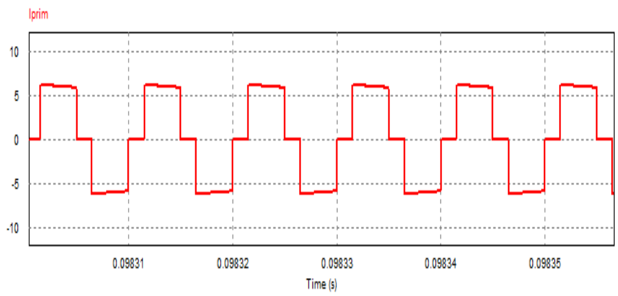

Figure14. Primary current of transformer

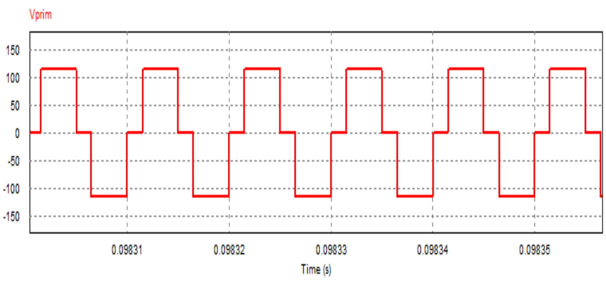

Figure15.primary voltage of transformer

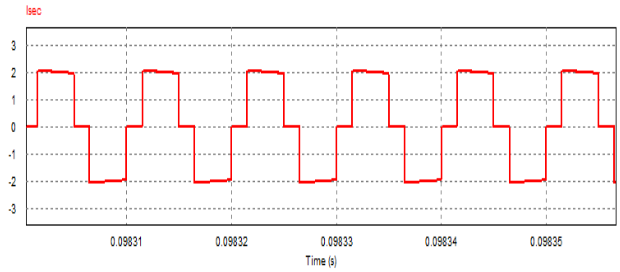

Figure16.secondary current of transformer

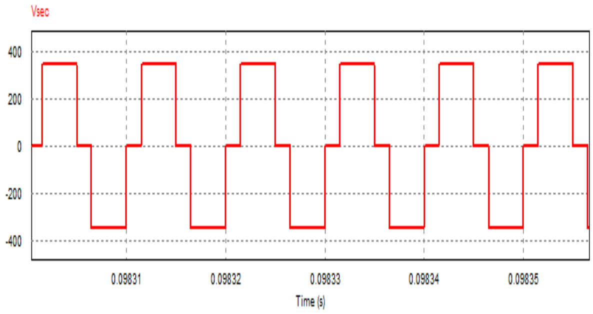

Figure17. Secondary voltage of transformer

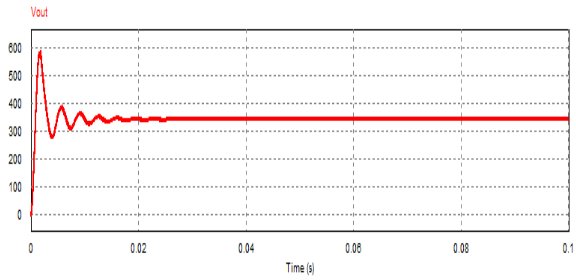

Figure18.Output voltage

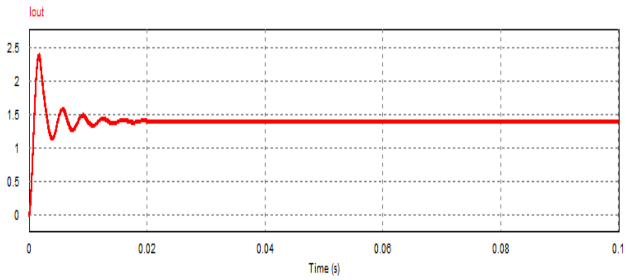

Figure19.output current

Half Load

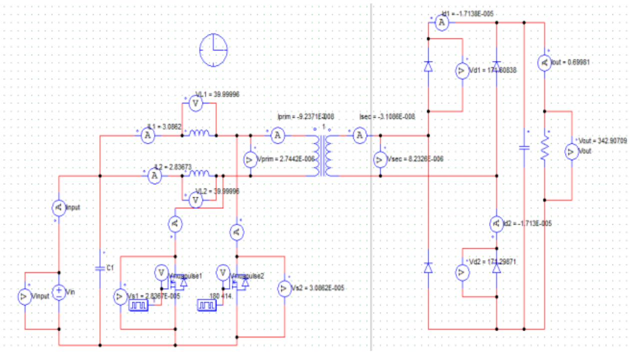

Figure20.PSIM simulation of isolated interleaved boost converter for half load

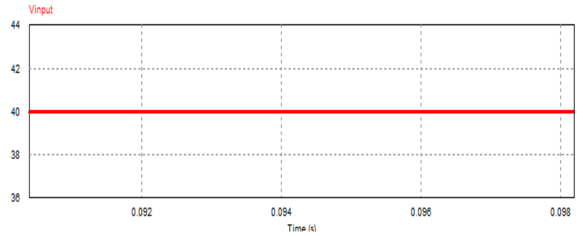

Figure21.inputvoltage

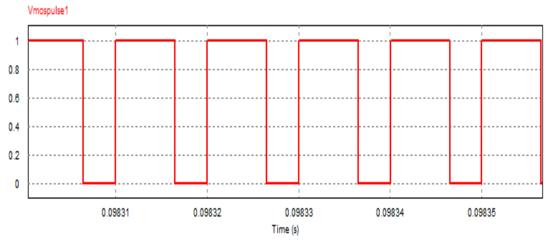

Figure22.Mosfet voltage pulse 1

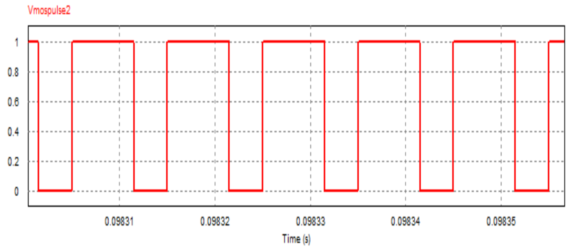

Figure23. Mosfet voltage pulse 2

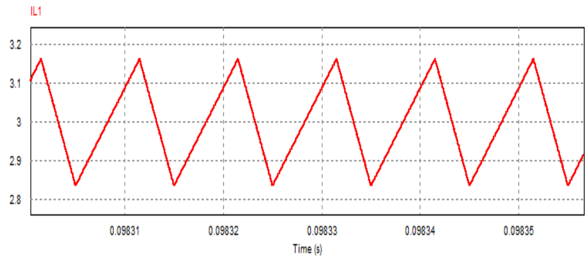

Figure24.inductor current 1

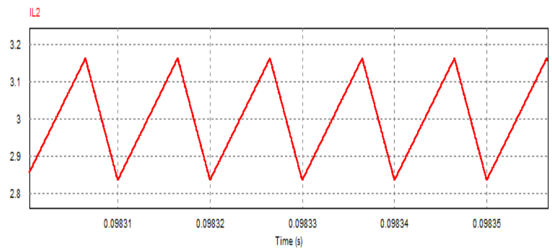

Figure25. Inductor current 2

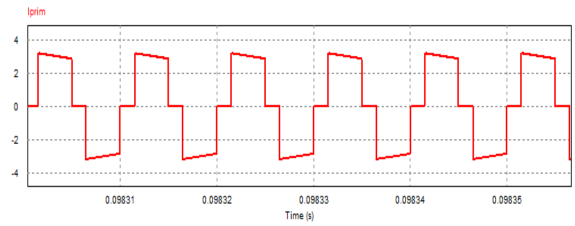

Figure26. Primary current of transformer

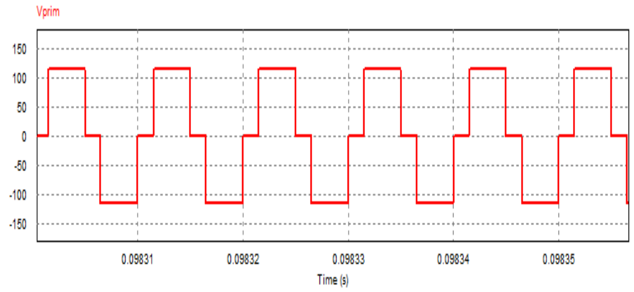

Figure27. Primary voltage of transformer

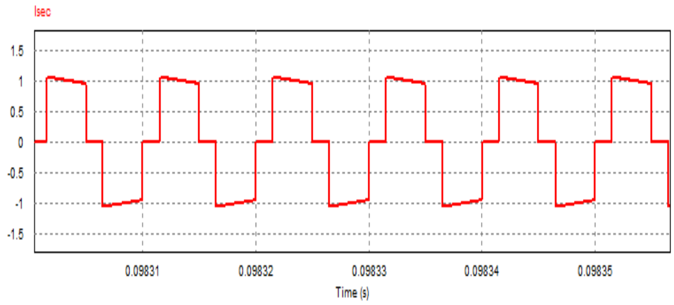

Figure28. Secondary current of transformer

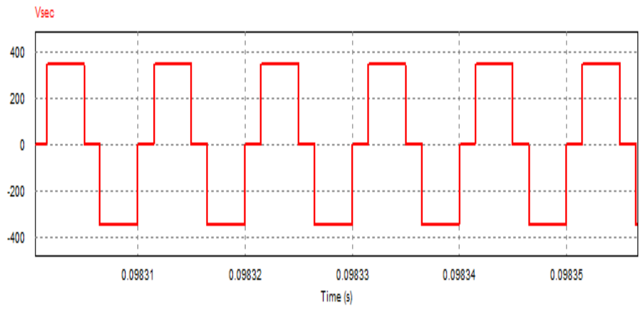

Figure29. Secondary voltage of transformer

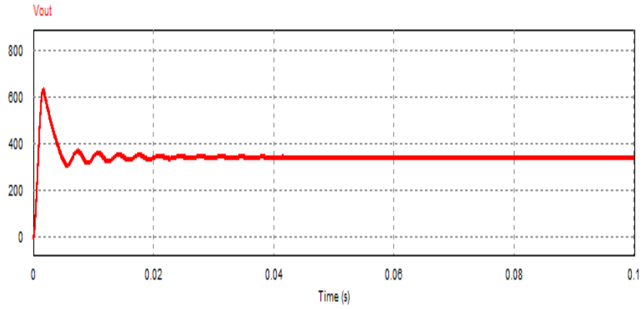

Figure30. Output voltage

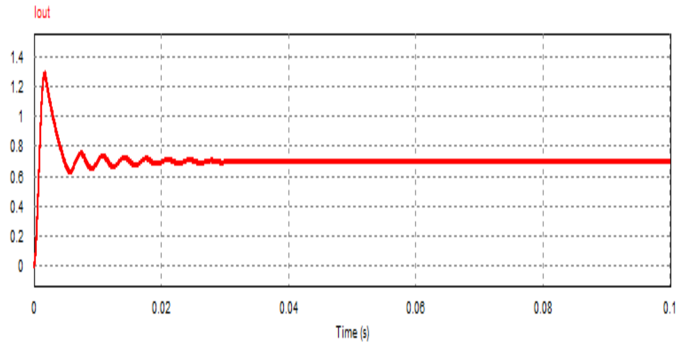

Figure31.Output current

IV. Conclusion

An interleaved isolated boost converter based on the basic isolated boost converter is proposed for fuel cell application. In this converter ,the input inductor are connected in parallel to equally share the input current and due to phase shifted operation of the converter the input current ripple reduces which enhances the life of the fuel cell stack. The proposed converter handles high current at the input and high voltage at the output for high power applications with low cost, high power applications with low cost, high power density and using PSIM9.0 and verified with steady state operating waveforms.

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