

A Doubly-Excited Buck-Boost DC-AC Converter Suitable for Feeding AC Loads from PV Systems

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Abstract–This paper presents a new topology for a DC-AC converter. The main attributes of the proposed converter are the ability for bucking or boosting the input voltage (DC Voltage), gives a sinusoidal output without the need for filters at the load terminals, can be used in feeding AC loads from PV (Photovoltaic) systems and can be used in other several applications. Also, the paper presents the performance, through the power simulation program (PSIM), of the proposed converter in different modes of operation to show the dependability of the proposed converter.

Keywords– Boost, Buck, DC-AC, Power converter, Photovoltaic systems.

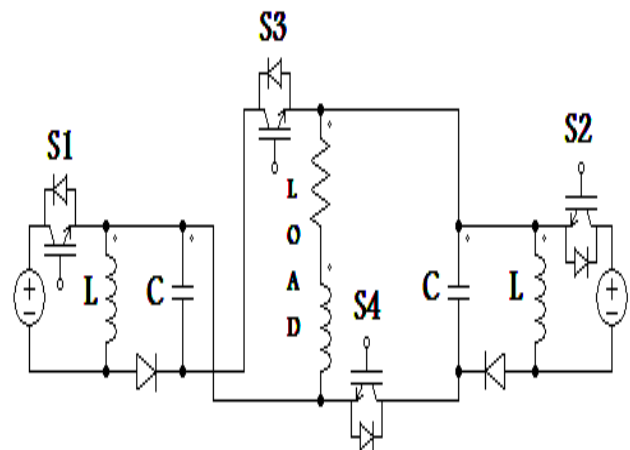
I. INTRODUCTION

DC-AC converters are extensively used in power and industrial applications. They are used to convert the DC voltage to an AC one so that they can be used in DC transmission, electrical drives applications, connection between PV systems and the AC grid and in other several applications. Different topologies for DC-AC converters are reported in several publications [1-6]. This paper presents a new topology for a DC-AC converter. The proposed converter is excited from two separate DC supplies so the name "Doubly-Excited". The proposed converter has several advantages over the classical schemes such as the ability to buck or boost the input voltage, easy to be controlled and gives sinusoidal voltage and current waveforms without the need for filters at the load terminals. These advantages support the use of this converter in several applications. One of these applications is to feed AC loads from photovoltaic systems.

II. CONSTRUCTION OF THE PROPOSED CONVERTER

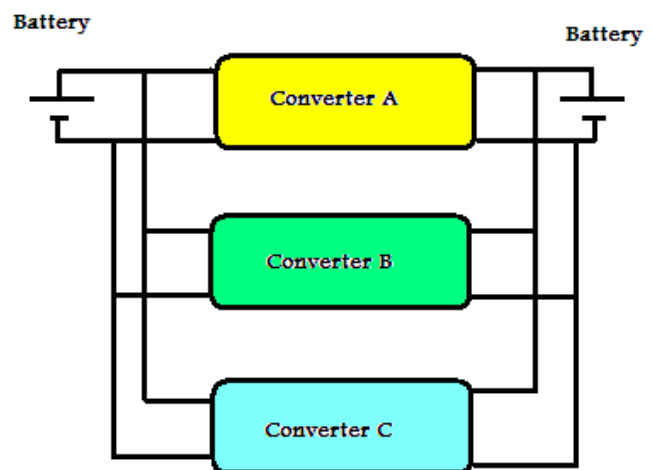
Fig. 1 shows the circuit diagram for only one phase of the proposed DC- AC buck-boost converter. As shown from the figure, the proposed converter is supplied from two separate DC supplies and it consists of two simple choppers feeding a half bridge inverter. The chopper switches are controlled so as to make the capacitor voltage vary in a half-wave sinusoidal manner (The control technique will be described in the next sections). As seen from the figure, the converter contains four switches. This

number will be increased with the increase of the number of output phases. Fig. 2 shows a block diagram for the proposed DC-to- 3-phase AC converter. As shown from the figure the three phase converter consists of three similar single phase converters which mean that the three- phase converter has a number of switches equal to the triple the single-phase one.



Circuit Diagram of a One-Phase of the Proposed DC-to- 3-Phase AC Buck-Boost Converter

Fig. 1



Block Diagram of the Proposed DC-to- 3-Phase AC Buck-Boost Converter

Fig. 2

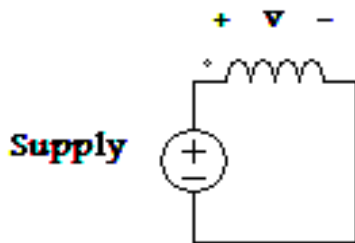
III. PRINCIPLE OF OPERATION

The principle of operation of the proposed converter can be discussed as follows:

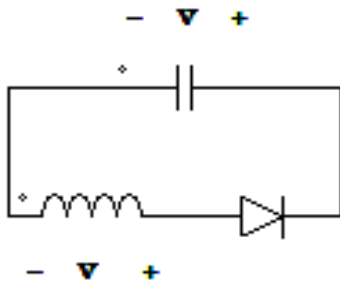
The DC-DC choppers provide DC output voltages lower or higher than the supplies voltage. The principle of operation of each chopper circuit can be discussed as follows:

Figs. 3a & 3b show the modes of operation of the DC-DC chopper. From these figures, the principle of operation of this converter can be discussed as follows:

- When the switch S1 is turned on, the current rises through the inductor and the inductor voltage polarity will be in a direction that opposes the supply polarity.
- When the switch S1 is opened, the inductor reverses its polarity and a current passes through the diode to charge the capacitor C. The capacitor voltage depends on the duty ratio at which the semiconductor switch is switched.

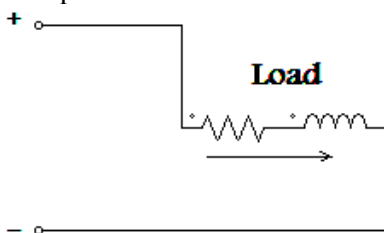


Equivalent Circuit for S1 is Closed
Fig. 3a

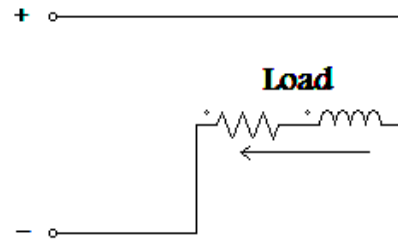


Equivalent Circuit for S1 is Opened
Fig. 3b

The function of the DC-AC converter (Half Bridge Inverter) is to convert the output voltage from the DC-DC converter to AC voltage. Figs. 4a & 4b show the modes of operation of this converter.



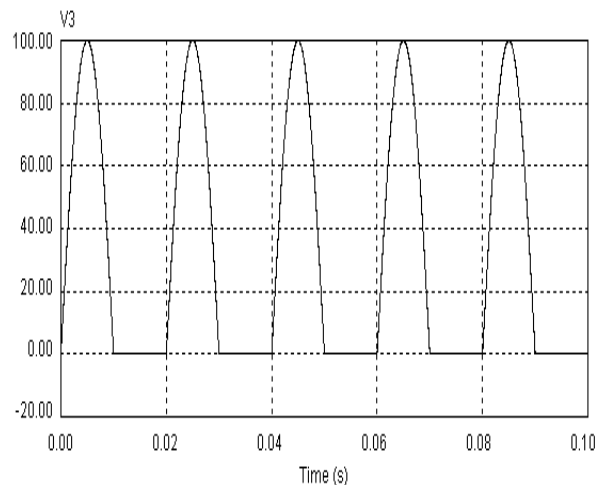
Equivalent Circuit for S3 is Closed & S4 is Opened
Fig. 4a



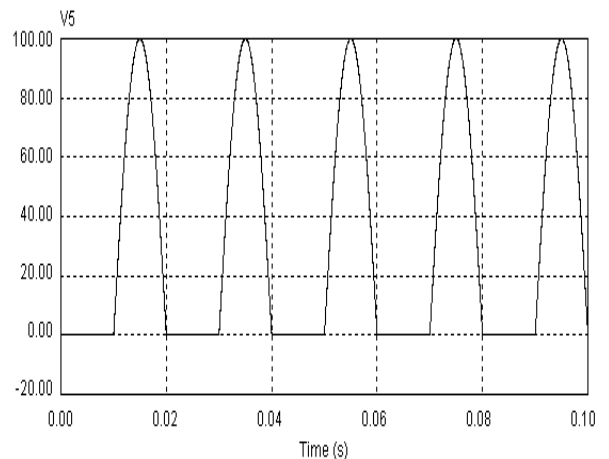
Equivalent Circuit for S3 is Opened & S4 is Closed
Fig. 4b

IV. PRINCIPLE OF CONVERTER CONTROL

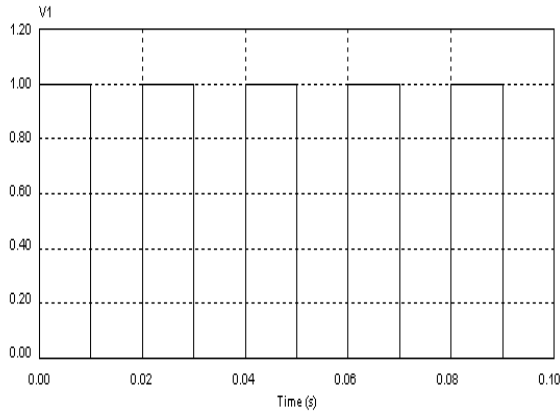
To make the output voltage to be very near to the sinusoidal waveform without the need for filters at the load terminals, the capacitor C voltage shouldn't be a smooth voltage. If the capacitor voltages are controlled to be as in Figs. 5a & 5b, the output voltage will be near to the sinusoidal waveform if the switches of the DC-AC converter are controlled as shown in Figs. 6a & 6b. Fig. 7 shows the predicted output voltage with this control scheme.



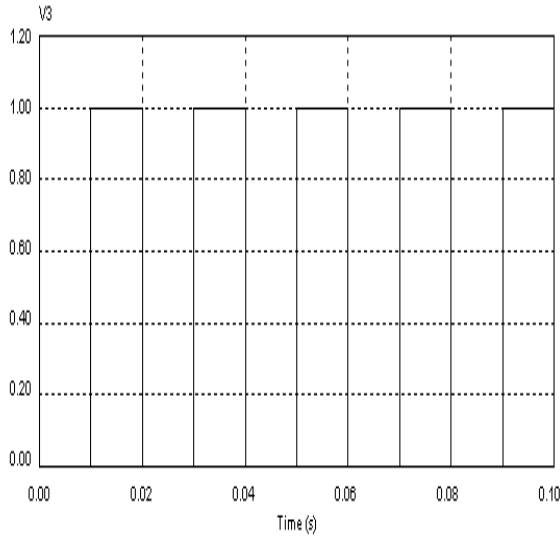
Left Hand Side Capacitor Desired Voltage
Fig. 5a



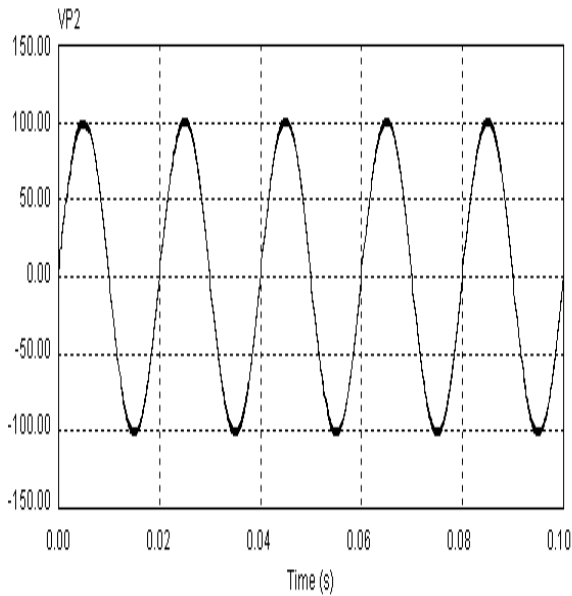
Right Hand Side Capacitor Desired Voltage
Fig. 5b



Control Signal to S3
Fig. 6a



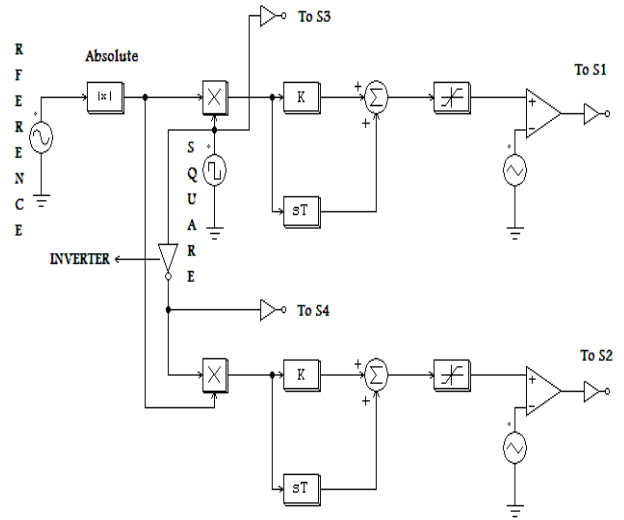
Control Signal to S4
Fig. 6b



Predicted Output Voltage with the Proposed Control Scheme
Fig. 7

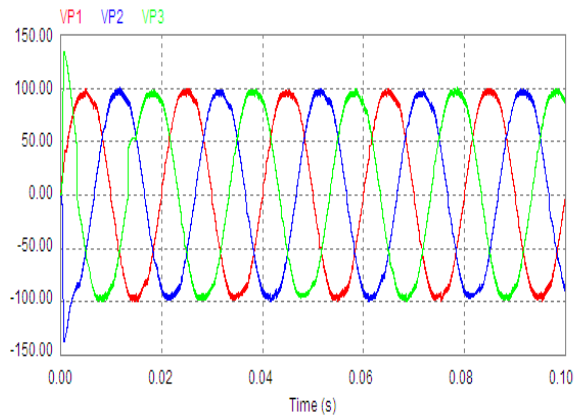
V. SIMULATION OF THE PROPOSED CONVERTER UNDER CLOSED LOOP CONTROL

This section presents the performance of the proposed converter under closed loop control condition as a DC to 3-phase AC converter. The control strategy in this paper has been done as described before in section 4. Fig. 8 shows the schematic diagram of the proposed control for only one-phase. The control for the other two phases is the same but with considering the 120 degree phase shift between the phases. In this paper a simple PD (Proportional Differential) controller has been used. Any type of controllers can be used but the PD is chosen here for simplicity and as it gives a satisfactory performance.

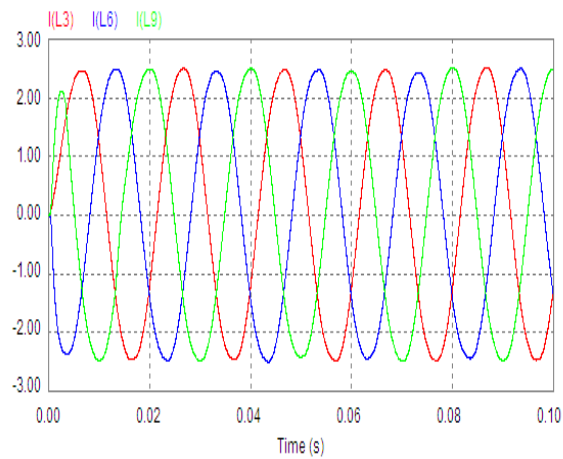


Schematic Diagram of the Proposed Controller
Fig. 8

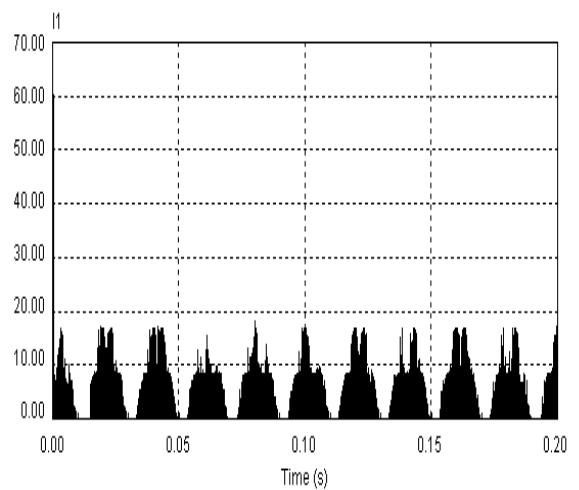
Figs. 9a to 9i show the output voltage, load current, capacitor voltages, supply current and the control signals for a desired output of 50 Hz and 100 volt (Max.).



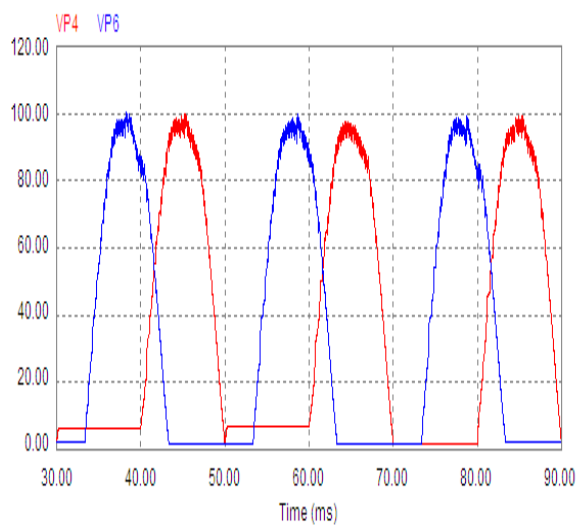
Output Voltage (50Hz, Supply Voltage=100 Volt (DC), RL-Load, Closed Loop)
Fig. 9a



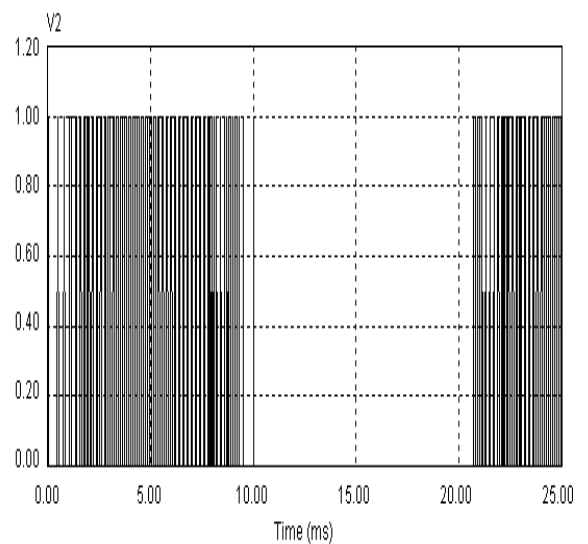
Load Current (50Hz, Supply Voltage=100 Volt (DC),
RL-Load, Closed Loop)
Fig. 9b



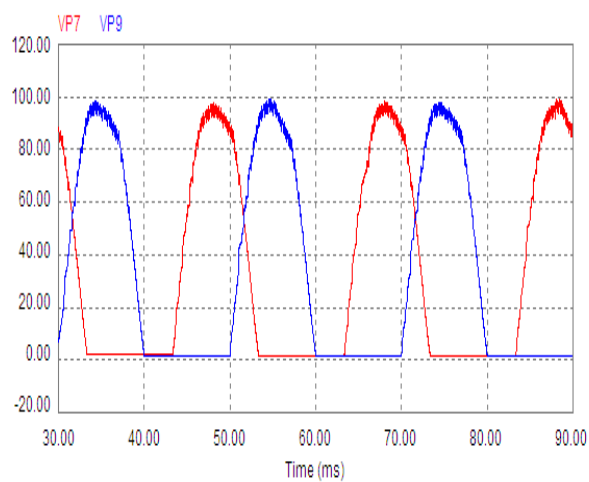
Left Hand Supply Current (50Hz, Supply
Voltage=100 Volt (DC), RL-Load, Closed Loop)
Fig. 9e



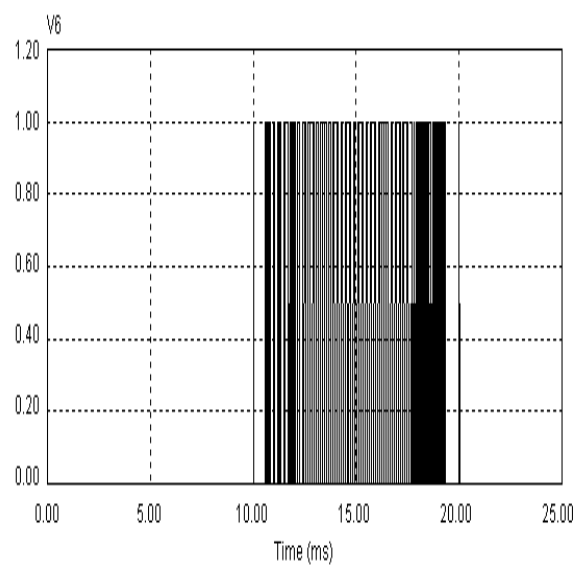
Left Hand Capacitor Voltage for Two Phases (50Hz,
Supply Voltage=100 Volt (DC), RL-Load, Closed
Loop)
Fig. 9c



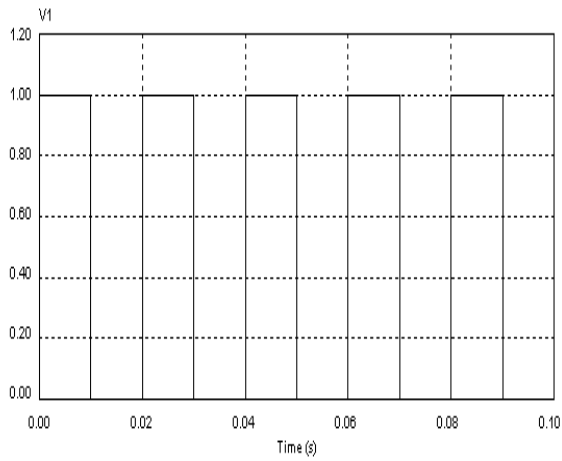
Control Signal to Switch S1
Fig. 9f



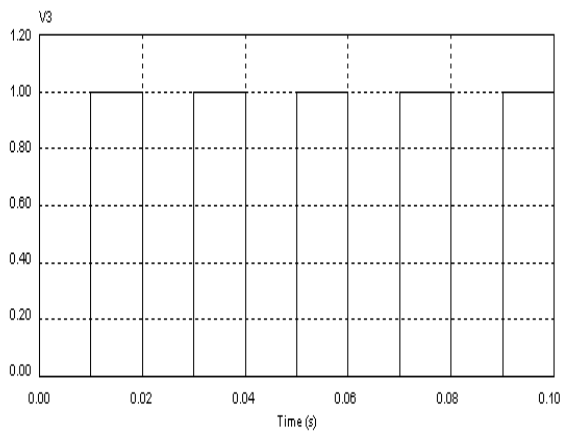
Right Hand Capacitor Voltage for Two Phases (50Hz,
Supply Voltage=100 Volt (DC), RL-Load, Closed
Loop)
Fig. 9d



Control Signal to Switch S2
Fig. 9g

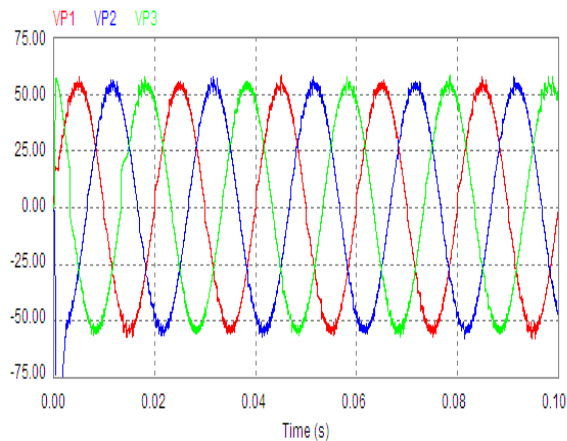


Control Signal to S3
Fig. 9h



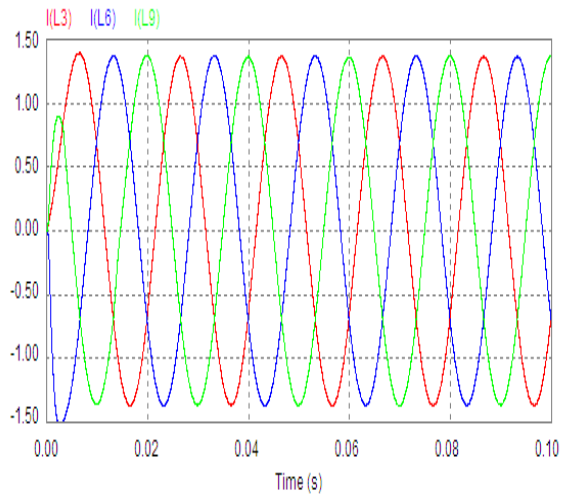
Control Signal to S4
Fig. 9i

From the above figures, one can see that the load voltage and current waveforms are sinusoidal waveforms which mean low harmonic content. Figs. 10a to 10e show the output voltage, load current, capacitor voltages and supply current for a desired output of 50 Hz and 50 volt (Max.).



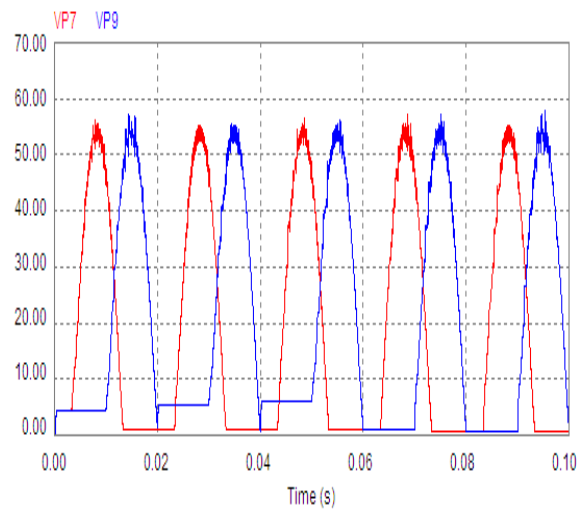
Output Voltage (50Hz, Supply Voltage=100 Volt (DC), RL-Load, Closed Loop)

Fig. 10a



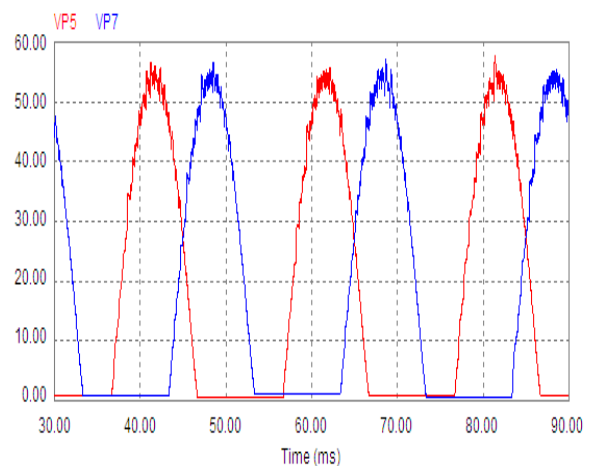
Load Current (50Hz, Supply Voltage=100 Volt (DC), RL-Load, Closed Loop)

Fig. 10b



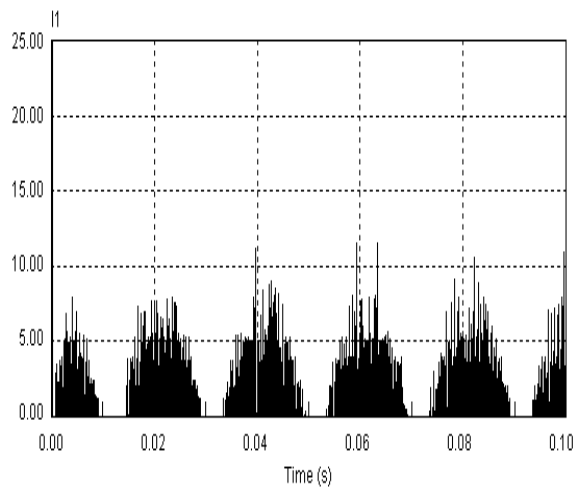
Right Hand Capacitor Voltage for Two Phases (50Hz, Supply Voltage=100 Volt (DC), RL-Load, Closed Loop)

Fig. 10c



Left Hand Capacitor Voltage for Two Phases (50Hz, Supply Voltage=100 Volt (DC), RL-Load, Closed Loop)

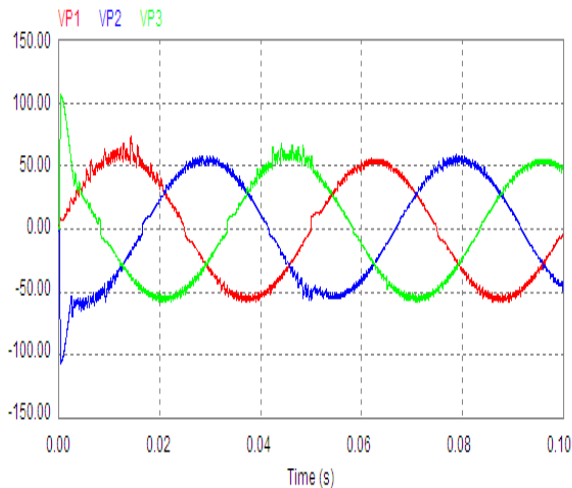
Fig. 10d



Left Hand Supply Current (50Hz, Supply Voltage=100 Volt (DC), RL-Load, Closed Loop)

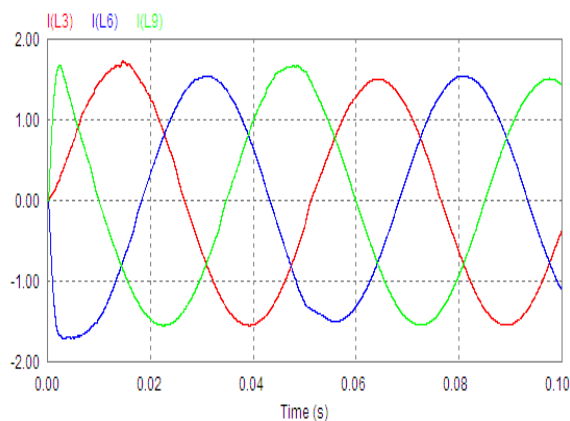
Fig. 10e

Figs. 11a to 11c show the output voltage, load current and capacitor voltage for a desired output of 20 Hz and 50 volt (Max.) with step change in left hand side supply voltage from 100 volt to 80 volt.



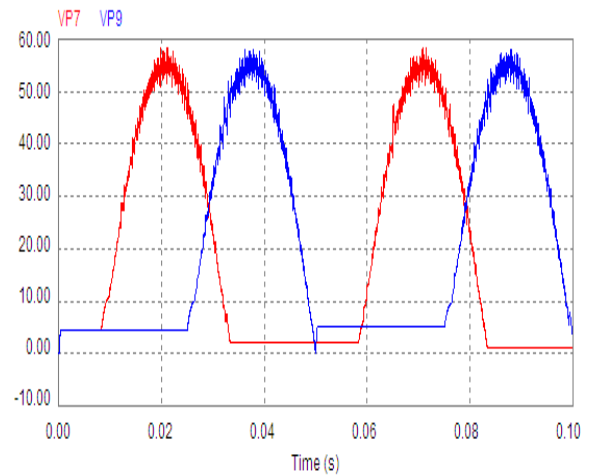
Output Voltage (20Hz, Step Change in supply voltage from 100-80 volt, RL-Load, Closed Loop)

Fig. 11a



Load Current (20Hz, Step Change in supply voltage from 100-80 volt, RL-Load, Closed Loop)

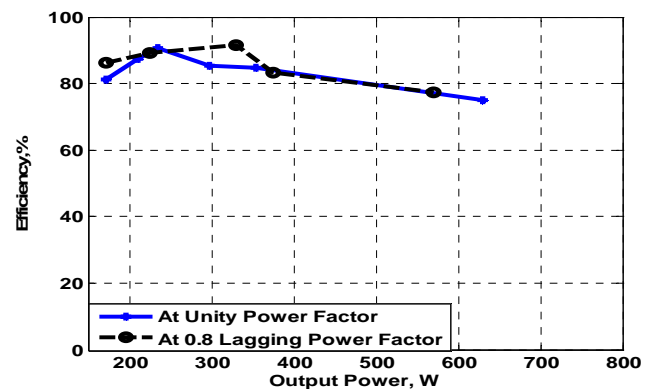
Fig. 11b



Right Hand Side Capacitor Voltage for Two Phases (20Hz, Step Change in supply voltage from 100-80 volt, RL-Load, Closed Loop)

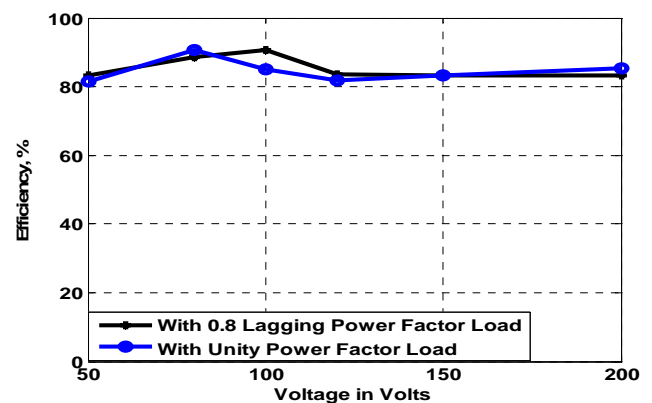
Fig. 11c

Fig. 12 shows the efficiency versus output power. From this figure, it can be shown that the converter efficiency seems to be good. Fig. 13 shows the efficiency versus the input voltage. From this figure, it can be shown that the voltage at maximum efficiency depends on the load power factor but it seems to be near the value of maximum output voltage so that this converter can be designed according this criterion.



Efficiency versus Output Power

Fig. 12



Efficiency versus Input Voltage

Fig. 13

VI. CONCLUSION

A new topology for a DC-AC buck-boost converter has been presented. Control of the proposed converter has been presented in different modes of operation. The proposed control strategy has been found to give a satisfactory performance which supports the use of this converter in several applications.

REFERENCES

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APPENDIX

Circuit Parameters:

Capacitance $C=50$ micro Farad.

Inductance $=1$ milli Henery.

Resistance of the Inductor $= 1$ Ohm.

P Controller Gain $= 15$.

Differentiator Time Constant $= 0.004$ Sec.

Load Resistance $= 35$ Ohm.

Load Inductance $= 0.06$ H.