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Performance of Bridgeless Converter Based Multiple Output Switched Mode Power Supply for Enhancement of Power Quality

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Abstract
This paper deals with analysis and simulation of new bridgeless buck-boost converter based switched mode power supply with multiple outputs used for personal computers is presented. Conventional switched mode power supplies with diode bridge rectifier having poor power quality characteristic such as total high harmonic distortion, high crest factor, and low input power factor. In order to achieve improvement in power quality for SMPS two stage power factor correction circuit is employed. Discontinuous conduction mode operation of bridgeless converter ensures the proper operation also reduce complexity in the control techniques. The performance of this bridgeless converter is analyzed in different operating condition such as steady state, varying input voltage and varying loads. The performance of this SMPS is simulated in MATLAB/Simulink environment.

Keywords: Input power quality, buck-boost converter, switched mode power supply (SMPS), isolated half bridge VSI , discontinuous conduction mode (DCM).

Introduction
In present scenario rapidly improvement in power electronics devices such as personal computer ,laptops, net books, medical instruments leads to the harmonic pollution in the distributed system. Personal computers are extensively used in all the areas right from education to the industry. Switched mode power supply (SMPS) is an essential part of personal computer. SMPS used in the personal computer for getting multiple DC output voltages of desired magnitude from single phase ac input supply. In conventional method ac to dc rectification is done by diode bridge rectifier followed with electrolytic capacitor. The capacitor present at the input side produces power quality problems such as high dense and distorted input current, high crest factor, high total harmonic distortion, low power factor. This is due to the due uncontrolled charging and discharging of capacitor [1-3]. This will violates the all power quality related standards set by the IEEE-519 and IEC 61000-3-2[4-5].This problem become serious when large numbers of SMPSs are used, due to this current in the neutral increases which turn to increases the size of the of conductor and de-rating of distribution transformer takes place [6-7]. With referring to all these issues SMPS with better power quality has researched .So that they can give better reliability and should draw the input current sinusoidal with high input power factor. Improvement in Power quality performance of SMPS is achieved by adopting power factor correction (PFC) circuit at input side. This PFC enables the low harmonic distortion and high power factor under the input varying conditions as well as load variation condition. Use of non isolated power factor correction circuit at input side of of the power supply gives better power quality. In order to maintain the harmonic content within the limit single stage and two stage voltage conversion is adopted in personal computers. Single stage conversion is easy, compact and cost effective. But it having more complex control techniques, large capacitor size, and poor output voltage regulation. However in two stage voltage conversion the component count is less, simple control technique and having the better output voltage regulation. The common acceptable solution for enhancing power quality at different operating condition for these kinds of converter is non isolated PFC at front end which operates converter in discontinuous conduction mode (DCM).Recent growth in the field of power electronics removes diode bridge rectifier at the input side and making topology bridgeless. Various bridgeless topologies has been used in PFC such as Cuk converter single ended primary inductance converter (SEPIC) ,which reduces the stress on the component, proper thermal management [8-9].but main drawback of this topologies for low power application is that component count is increased and output voltage range is very high. Commonly boost converter is used in two stage PFC, but it has limited output voltage for varying input voltages. Bridgeless boost converter reduces the diode bridge rectifier [10].The buck-boost converter is best suited power factor correction for switched Mode power supply. It provides stiffly output voltage regulation. This also offers low switching stress on component, less conduction losses, and low component requirement. Wei et al [11] have demonstrate a bridgeless buck-boost converter which have three switches in their conduction path that leads to increase in cost.

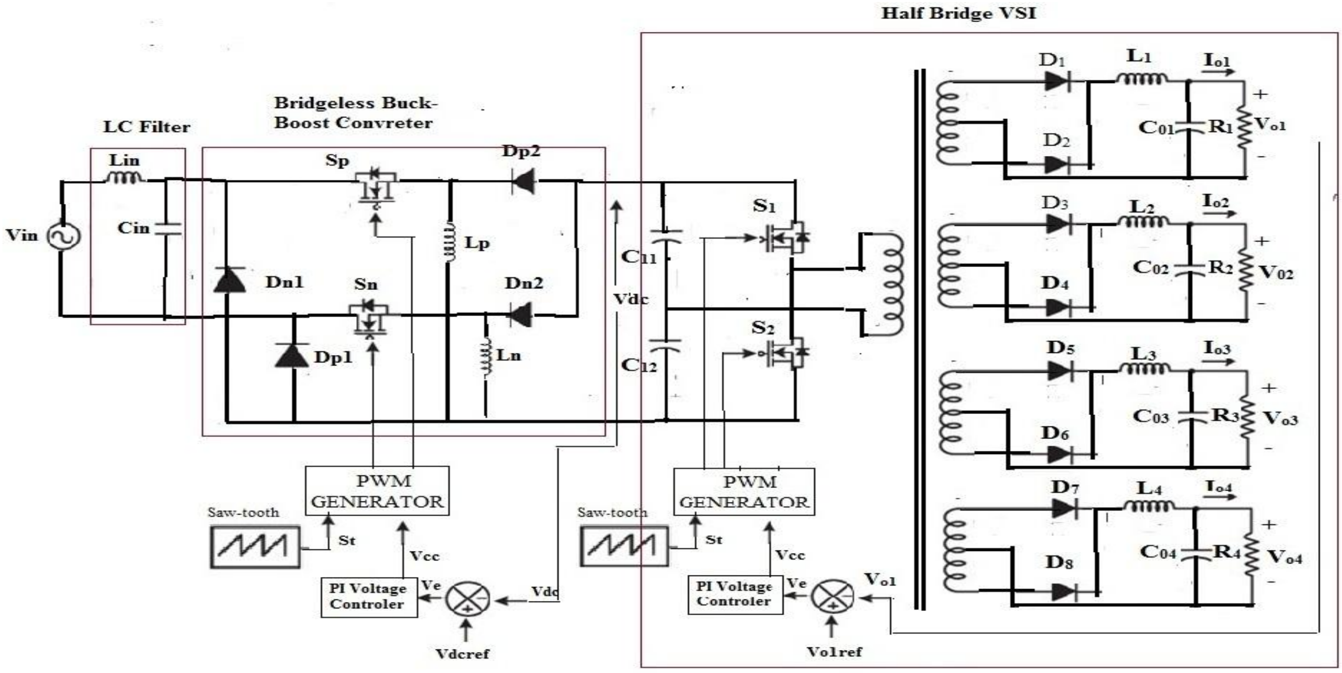


Fig 1-Circuit configuration of proposed multiple output switched mode power

Multiple outputs can obtained by using high frequency transformer which additionally provides high frequency isolation and it effectively uses the core as compared to the other types of converters [12-13].Thus it can be concluded from present literature that, while dealing with power quality improvement in SMPS for bridgeless converter based topology has not be used so far ,so our try is to eliminates the bridge rectifier at front side and making the bridgeless topology to achieve high power quality at the input side. Here two buck-boost converter is to be connected back to back so that they will operate for each positive and negative cycle. This bridgeless buck-boost converter is so designed in discontinuous conduction mode for proper achieving power factor. Output voltage of this converter is controlled by adopting closed controlled loop. This regulated dc output voltage is then given to the half bridge voltage source inverter where we can get multiple outputs with help of high frequency transformer. Thus this proposed bridgeless converter based SMPS is analyzed and simulated in MATLAB under different operating condition. The details of this are given in the following sections.

Configuration Of SMPS On Bridgeless Buck Boost Converter

The detail configuration of proposed bridgeless buck-boost converter based switched mode power supply is as shown in Fig.1. It having consists of two back to back connected buck boost converter, LC filter at input side to reduce harmonics, half bridge voltage source inverter contains high frequency transformer for obtaining multiple outputs. Upper buck boost converter consist of switch Sp, two diodes Dp1,Dp2 with inductor Lp operated during the positive half cycle of ac input supply. The lower buck boost converter consist of switch Sn, two diodes Dn1,Dn2 with inductor Ln which is operated during the negative half cycle of ac input supply. Two inductor are so designed such that they should ensure the discontinuous conduction mode which draws input current sinusoidal with supply voltage The controlled DC output voltage of bridgeless converter via closed control loop is then fed to the half bridge voltage source inverter which is consist of two input capacitor C11 and C12 ,two high frequency switches, high frequency transformer. This transformer special designed such that it having one primary winding and four secondary winding where in order to reduce the current and voltage ripples from the each outputs filters are to be connected to each winding which consist of inductor Lo1,Lo2,Lo3,Lo4 and Co1,Co2,Co3,Co4 where multiple outputs Vo1,Vo2,Vo3,Vo4 are obtained. In order to reduce the losses in high frequency transformer centre tapped configuration is used. The voltages at the output side is controlled by sensing the highest voltage at output side and it is other winding voltages on HFT is to be controlled with help of duty ratio and thus voltage regulation at output side is obtained. Half bridge voltage source inverter is operated in continuous conduction mode.

Working Of Proposed Switched Mode Power Supply Based On Bridgeless Converter.

In this designed system model it consist of two back to back connected buck-boost converter, voltage source inverter, multiple output high frequency transformer. The buck boost converter is properly controlled in discontinuous conduction mode (DCM) for achieving high power factor, less harmonic distortion and other power quality related problems. Selection of DCM over the continuous conduction mode is that it does not require any input voltage sensing so input sensor is not required. The operation this converter explained over one switching cycle is given as follows,

A. Working of Bridgeless Buck Boost Converter

The diode bridge rectifier used for rectification eliminated and two back to back buck-boost converters are connected. This bridgeless topology makes component count lesser. When single phase AC supply is given to the buck-boost converter Then switches in the upper and lower converter are conducted during the positive and negative half cycle. This buck-boost converter is designed in DCM to obtained required power quality target. Discontinuous conduction mode operation takes place into three stages. In first stage when switch Sp in the upper buck-boost converter is getting on for positive half cycle then current in the associated inductor increases from zero value to maximum value such that inductor start for storing the energy. In next stage when switch Sp is turned off and inductor start for the discharge through the output and thus inductor current decreases from maximum value to minimum value. In last state of DCM none of the inductor, switches and diode is conducted. That they are ensuring the proper DCM. In this way one buck-boost converter is conducted for positive half cycle and same lower buck-boost converter is conducted for negative half cycle. This process will repeated for next switching cycle.

B. Working of Half Bridge Voltage Source Inverter

The regulated output of back to back connected buck-boost converter through closed loop is fed as input to the half bridge voltage converter to obtain high frequency isolation, scaling and multiple output. The operation of this VSI for one switching cycle is divided in to the four stages. It having two switches which are on and off as per pluses getting form the PWM generator. In first stage when switching signal is given to the upper switch S1 then current circulating through the primary winding of high frequency transformer and the lower capacitor C11 then diodes associated with this D1,D3,D5,D7 are start for the conducting and current in the inductor Lo1,Lo2,Lo3,Lo4 start for the storing the energy. The stored energy in the output capacitor Co1, Co2, Co3, Co4 discharge through the output load. In the second stage none of switches is conducts and all freewheeling diodes D1-D8 are conducted the stored energy in inductor discharges through the output capacitor thus current in the inductor decrease from maximum value to minimum value. In the third stage lower switch is turned on current is circulated through primary of HFT and the upper capacitor C11 associated inductor L1, L2, L3, L4 start storing energy. And thus current increases from zero value to maximum value. This switch is turned of when the energy stored in the inductor is at maximum value. Thus in next stage all the free wheeling diodes are same sequence of operation is takes as same as in stage two. In this operation half bridge VSI is operated for subsequent cycles.

Design Of Proposed Multiple Output SMPS

This section deals with complete design of proposed multiple output switched mode power supply. The design takes place by taking consideration of change in inductor current during on and off time, all the switches and diodes used in this configuration are taken to be ideal in the nature. Switching frequency selected for proper operation during PWM cycle is considered very high as related to the line frequency.

A. Input Filter Design

In order to eliminate higher order harmonics from input supply it is necessary to use L-C filter at the input side in this proposed configuration. This filter additionally helps for the reducing the harmonic distortion. Capacitor used in this should have maximum value and this can be given as,

$$Cin\max = \frac{\mathrm{Im}\tan\theta}{\omega Vm} \quad (1)$$

Where Vm and Im are the peak value of ac voltage and current. Here θ value is considered to be 10 for maximum value of capacitor.

In order to maintain low ripple contain in input ac supply side proper value of inductor is given as,

$$Lin = \frac{1}{4*\pi^2*fc^2*Cin} \quad (2)$$

Where fc is an cutoff frequency and Cin is value of input capacitor.

B. Selection Of inductor for Bridgeless Buck–Boost PFC Converter

The inductor present in the buck-boost converter plays an very important role for improving power quality. Thus all this inductor in this configuration are selected such that it should ensure the proper discontinuous conduction mode. Value of both the inductor are same and which is given as ,

$$Lp = \frac{DTVavg}{\Delta iLpon} \quad (3)$$

Where D is duty ratio ,T-total period, Vavg-average value of input voltage. In DCM in inductor ripple is maximum which is equal to the twice the input current,

$\Delta iLpon = 2*I_{in}$

Switching time in this DCM is considered as 50 µS.

C. Design of Half bridge voltage source inverter

The two input capacitor present in half bridge voltage source inverter acts low harmonic filter for the harmonics from ac input side. Input supply for this is controlled DC output voltage from the buck-boost converter. As this converter is designed in the continuous conduction mode so no need to require input voltage and current sensing. In this two stage SMPS first stage DC output voltage is feed to the input to next stage which contains the 100Hz frequency component ,in order to reduces this component the two input capacitor are designed as,

$$c = \frac{Idc}{2\omega\Delta Vdc} \quad (4)$$

Where ω is angular frequency, Idc and Vdc are current voltages of first stage converter. ΔV is considered 2% on dc regulated output voltage.

In order to achieving low ripple contains in the output voltage the inductor can be selected as given below,

$$Lo1 = \frac{Vo1(0.5 - Dh)}{fh \times \Delta ilo1} \quad (5)$$

Where T=1/fh is switching time, Vo1 is highest output voltage of secondary of HFT of isolated dc-dc converter and maximum allowable current ripple is considered is 2%.

Control Techniques For Proposed System

As this configuration is consist of two stages so two different kinds of controllers are used independently to control the dc output voltage PFC circuit and isolated dc-dc converter. The details control techniques are discussed as below,

A. Control of Bridgeless Buck-Boost Converter

Voltage follower approach is being adopted for controlling front end PFC circuit. The upper and lower buck-boost converter is switched according to the switching plusses generated from the PWM generator. Voltage error is to be find out between the desired voltage and sensed output voltage. This error signal is then given to the PI controller where it generates controlled dc output. The high frequency saw tooth signal is then compared with the output of PI controller and necessary pluses are generate to switch on and off the switches of bridgeless buck-boost converter.

B. Control of Isolated Dc-Dc Converter

In order to control the isolated DC-DC converter the highest DC output voltage of winding having higher power rating is being sensed. Current mode control is being used to controlling to this converter. The voltage difference error between the sensed dc output voltage and the reference voltage is find out. then it is given to PI controller -2.The controlled dc output of this controller is then compared with high frequency saw tooth signal in the PWM generator. Then according to the width of PWM pluses switches of the isolated dc-dc converter is switched on and off.

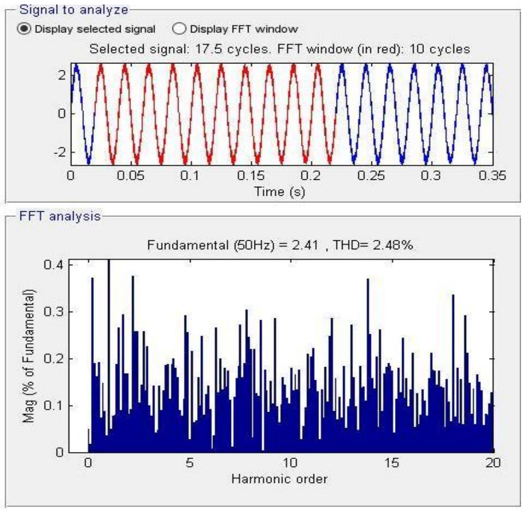
Performance Evaluation Of Proposed Switched Mode Power Supply

The proposed power factor corrected multiple output switched mode supply is being simulated in MATLAB/SIMULINK environment and its performance evaluation is takes place at 220V, 50 HZ supply. In this various parameters such as input voltage, input current, regulated dc output voltage of buck-boost converter, multiple outputs i.e.Vo1, Vo2.Vo3, Vo4 and Io2, Io2, Io3, Io4 of switched mode power supply. Power quality indices such as displacement PF, distortion factor, Power Factor, and input current THD are analysed for assessing improvement in the power quality of single-phase ac mains. Performance analysis of this proposed bridgeless-converter-based SMPS is categorized under following condition,

1. Steady-state condition
2. Varying input voltages
3. Under varying load

A. Performance Under Steady State Operating Condition

This is normal operating condition where SMPS is turned on most of the time. So it is very crucial to check performance of this proposed converter under this condition. Here single phase 220V, 50HZ ac supply is given to the SMPS and various power quality related parameter are to be checked out. Following fig.2(a). Shows that there is considerable improvement in the power quality by reduction in total harmonic distortion and power factor increases up to 0.9995.THD of input ac current is 4.54% which within the limit as set by various standards. Fig. 2(b) shows that elimination of diode bridge rectifier and use power factor correction circuit enables the input current to follow the input voltage. Fig 2 (c) shows multiple output voltages and currents of the SMPS. The two switches in the buck-boost converter reduces the switching stress on switches as shown in fig. 2(d).



. Fig 2 (a)- input ac current and harmonic spectrum

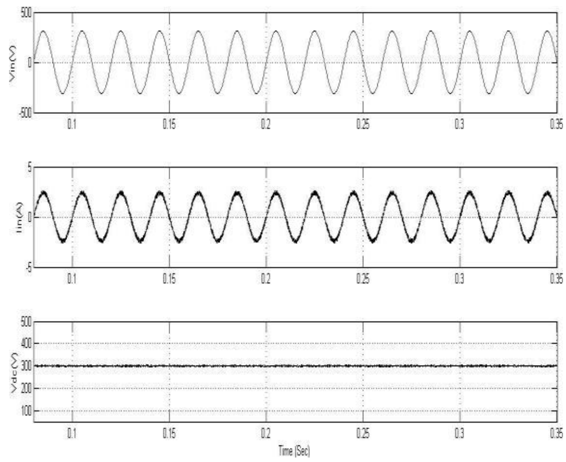
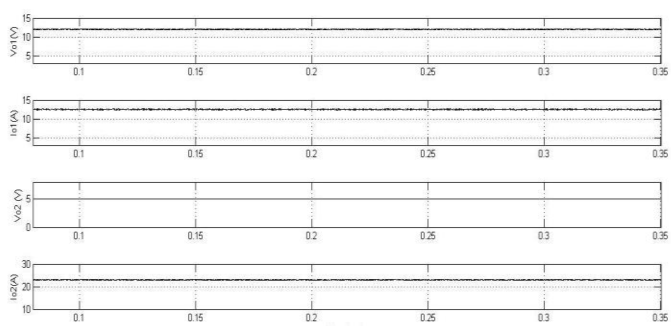


Fig 2 (b) –input current and voltage waveforms



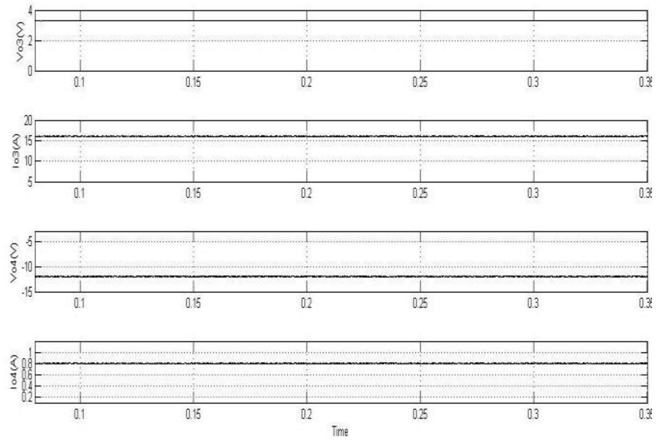


Fig 2 (c)-Multiple output voltages and currents

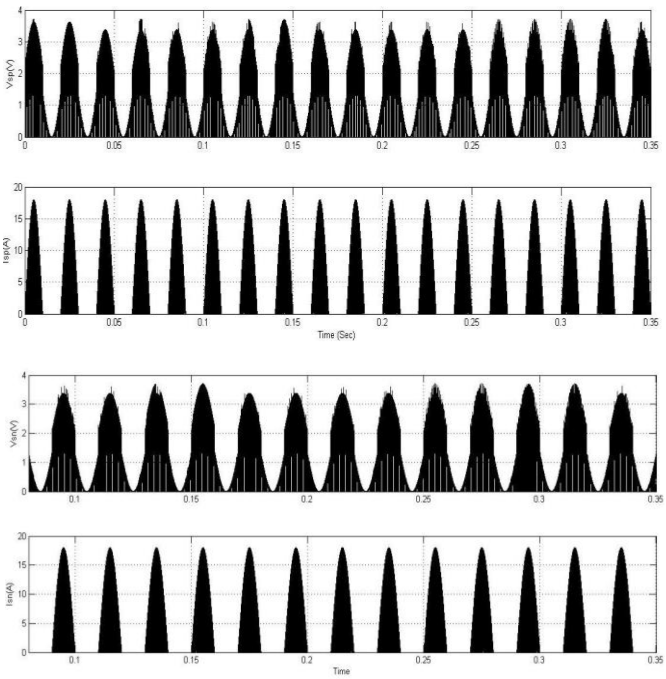


Fig 2 (d)-Voltages and current across the switches

B. Performance Under Varying Input Voltages

In order to valid performance of the proposed multiple output SMPS under varying input voltages, range of voltages 170V-270V is considered. Under all these voltages performance of SMPS is as shown in following figures. From the performance analysis it is found that proposed bridgeless converter is operating satisfactory with improvement in the power quality under this condition.THD of input current for these voltages is as within the limits which is stated in IEEE 519 and IEC 61000-3-2.Power quality indices such as THD ,power factor, Distortion factor ,Displacement power factor are tabulated below table 1,

Table1 power quality indices at various input voltages

Input voltage (rms)	**PF**	**DPF**	**DF**	**I_{inTHD} (%)**
170	0.9955	1	0.9955	2.42
220	0.9995	1	0.9995	2.48
270	0.9983	1	0.9983	5.86

C. Performance under varying loads condition

To find out the performance of proposed SMPS under varying load condition, a step change in the load at +12V and +5V outputs are applied. Load on +12V output is varied from 100% to 20% and load +5V output is varied from 100% to 70%.Thus under this condition output voltages maintain constant with small overshoot and also all power quality indices are within limits.

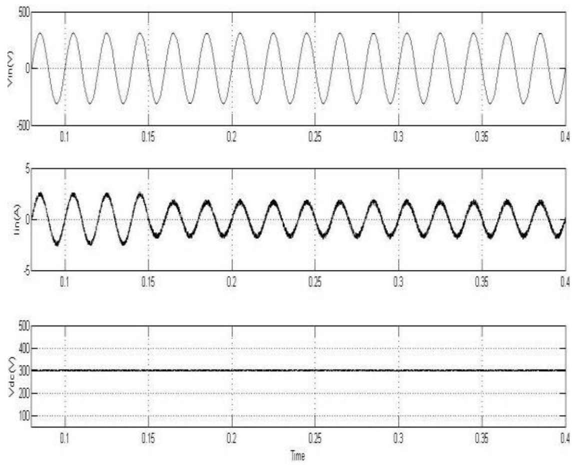


Fig 3 (a) –Input voltage ,current and dc output voltage.

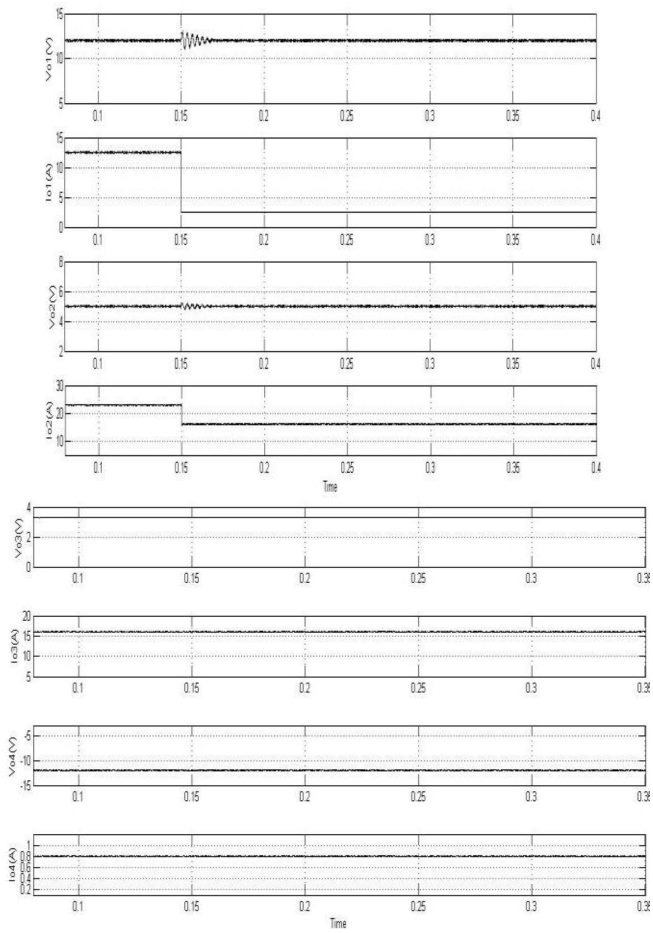


Fig 3 (b)-Multiple output voltages and currents

Conclusion

Bridgeless buck-boost converter based multiple output SMPS has been analyzed and simulated to exhibit its capability to improve input power supply quality. The DCM operation of first stage power factor correction circuit ensure the improvement in the power quality with reduction in total harmonic distortion ,improvement in power factor, displacement factor, reduction in crest factor. The observed from the performance of bridgeless converter based SMPS under steady state, varying input voltages has an potential to improve power quality in terms of THD and power factor at ac input supply. The elimination of diode bridge rectifier reduces the total component count of circuit, due to which conduction losses as well as switching losses are reduced. The multiple output SMPS maintained constant voltage irrespective of changes in the load voltage or deviations in supply voltages. This SMPS shows more reasonable result than conventionally SMPS so it is recommended solution to computer power applications.

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