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ENHANCEMENT OF POWER QUALITY FOR MULTIPLE OUTPUTS SWITCHED MODE POWER SUPPLY BASED ON BRIDGELESS CONVERTER

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Abstract— In this paper design, analysis and simulation of new power factor correction multiple output switched mode power supply based on bridgeless buck-boost converter is proposed. Conventional SMPS with diode bridge rectifier depict power quality related indices such as high distortion in input current, low power factor. In order to resolve this problem new bridgeless converter based SMPS is proposed. Comparing with conventional topologies the proposed topology reduces conduction losses and improves power quality. The performance evaluation of multiple output SMPS is done under steady state, varying input voltage. The performance of this SMPS is simulated in MATLAB/simulink environment.

Keywords—input power quality,multiple outple switched mode power supply (SMPS),discontinous conduction mode,DC-DC converter;power factor.

I. INTRODUCTION

Switched mode power supply (SMPS) are extensively used in various application such as machine tools, industrials securities, support supplies with PLCs and personal computers. Switched mode power supplies (SMPS) commonly employed to power up the different parts in personal computer (PCs). It is economical to use multiple output SMPS for different output voltage levels rather than using single DC-DC converters for each voltage range. Multiple outputs of SMPS is mainly applicable for PCs to power up USB, Mouse, monitor and many digital and analog circuits. Normally in SMPS, diode bridge rectifier followed with capacitor filter at front end are used to convert AC to DC,DC-DC converter and high frequency transformer is used for obtaining isolation, multiple outputs and voltage scaling. This topology leads to poor power quality of the system mainly high THD (Total harmonic distortion), low power factor, poor voltage regulation, high conduction losses & high crest factor for AC input current.[1] Due to increasing awareness towards power quality many manufactures related to power supply implemented power factor correction circuit at utility interface side so that they can maintain power quality standards as stated by IEEE 519 & IEC 61000 [2]-[3]. This become serious problem when large numbers of PCs are connected at common point, due effect like overloading of neutral conductor, noise, voltage distortion & de-rating of transformer [4].

In order to overcome from these problems improved power quality SMPS are researched that they should be capable of drawing the sinusoidal current with high power factor. For obtaining improved power quality performance power factor correction (PFC) circuit is adopted in SMPS at the point of utility interface [5]-[7]. So single stage and two stage conversion of AC voltage to DC voltage is takes place in personal computer which will help for maintaining harmonic contain within limits. PFC employed in power supplies able to provide low harmonic distortion, high power factor at different operating condition. Also they provide the better output voltage regulation. For single- stage SMPS, normally AC input supply is given to the diode bridge rectifier (DBR) whose output is processed by multiple output PFC isolated dc-dc converter of dc output voltage [8].but drawback of this type of SMPS is that it uses high value capacitor at the output and also produces stress on the components. Thus to overcome from these problems two stage SMPS preferred. Two stage SMPS is commonly used solution for medium power rating SMPS application personal computer (PCs).In this type first stage is used for enhancing power quality at the point of common coupling and the second stage is exclusively used for regulation output voltage. In order to get satisfactory performance power factor correcting circuit is used at front side, which will help for drawing input current sinusoidal with voltage so it will results in increases power factor as well as low harmonic distortion in current. The next important thing is to decide in which mode front end converter should operate. If cost is criteria for selection then discontinuous conduction mode (DCM) is selected for operation otherwise continuous conduction mode is selected. Because in CCM extra voltage and current sensor is required for sensing which makes it costlier. Also operation converter in DCM reduces the stress on devices. So for better operation PCs front end converter is designed in DCM.

In power factor correction circuit boost converter is commonly choice which is used in various industrial application, but major drawback of this is in cannot be used over wide input voltage range of ac supply [9]. In the same way buck converter also limited range of application for

Paper ID: EE27

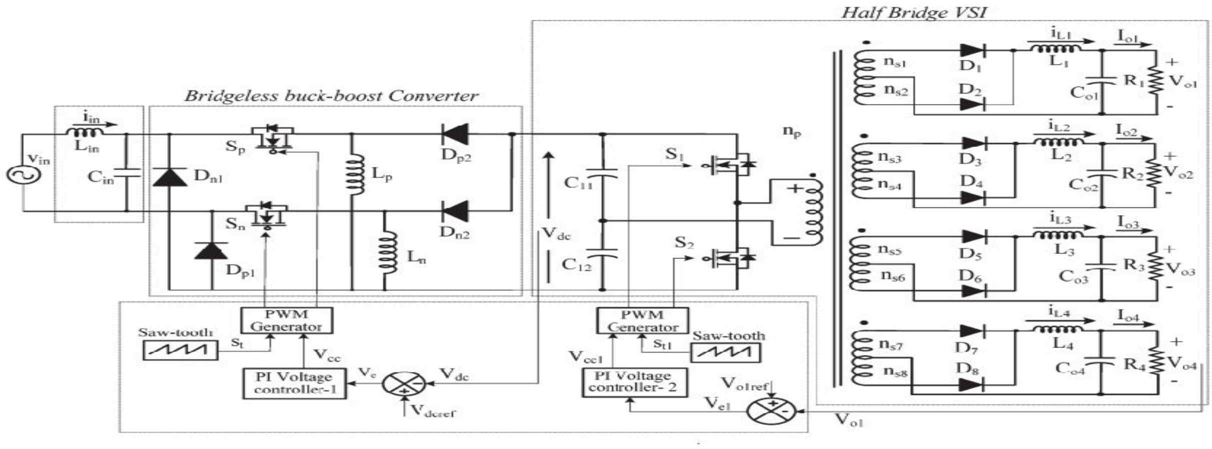


Fig 1-Circuit configuration of proposed multiple output switched mode power

computer power supply due to its limitation in output voltage range [10].Recent growth in the power electronics has disable the us diode bridge rectifier at front side, which will results in improvement in power quality at input ac side. There are different types of bridgeless converter topologies are been researched such as CUK converter ,single ended primary inductance converter are to proposed which will reduces the conduction losses, better thermal management and low stress on components [11-13].As dealing with this converters, components count is increased for low power SMPS application. Wei et al. have presented bridgeless buck-boost converter, in that topology it uses three switches which increase the conduction losses as well as component in the circuit. Computer power supply require multiple outputs for its operation ,for getting multiple output half bridge voltage source inverter is used. For isolation of output high frequency transformer is used. Advantage of using this type of transformer is better utilization of core which cost effective solution as given in [14-17].

It can be stated that from available literature bridgeless converter topology has not been used for the switched mode power supply. So in this paper we made an attempt for improving the power quality of input ac supply which is degraded due to operation of SMPS in personal computers. Operations of bridgeless buck boost converter eliminate use of diode bridge rectifier, so that input current drawn by the converter is in phase with the supply voltage. In proposed two stage multiple output switched mode power supply bridgeless buck –boost converter is operate for both positive as well as negative cycle as a first stage in second stage regulated output voltage of dc-dc converter is given to the half bridge voltage source inverter in which high frequency transformer is used for isolation and for getting multiple outputs. The advantage of this configuration is that it reduces requirement of sensors to sense the input voltage and current due to operation of dc-dc converter in discontinuous conduction mode. Detailed design, analysis and performance is given following sections.

II CIRCUIT CONFIGURATION OF PROPOSED BRIDGELESS CONVERTER BASED SMPS

In this configuration it involves two buck boost converter, PFC,voltage source inverter ,high frequency transformer, high frequency switches, diodes. Following diagram shows detailed arrangement of each components When single phase AC supply is given to the input of two back –boost converter then high frequency component in supply is eliminated with help of L-C filter.Lin &Cin as shown in figure during operation this boost –boost converter which is placed at upper side is conducted with help of one high-frequency switch Sp, inductor Lp, and two diodes Dp1andDp2. Similarly, the bottom buck–boost converter that operates during the negative half cycle consists of one high-frequency switch Sn, inductor Ln, and two diodes Dn1and Dn2 and lower converter is conducted for negative half cycle. [1].Both the inductor in converter designed in such way that they should ensure the Discontinuous mode operation of converter so that it will improve power factor of the susytem.now in the operation of voltage source inverter capacitor placed at input side of VSI acts as filter for DC output of buck-boost converter. closed control loop technique is employed for controlling the output of DC converter. This regulated output voltage is feed to the voltage source inverter for obtaining multiple output. The half-bridge VSI consists of two input capacitorsC11and C12, two high-frequency switchesS1andS2, and one multiple output high-frequency transformers (HFT). The HFT is consist of one primary winding and four secondary windings which are connected in center-tapped configuration to reduce the losses[1].inductor L1,L2,L3 L4 and capacitor C01,C02,C03,C04 are used to limit the ripples present in voltage and current. Highest output voltage is sensed for controlling purpose of voltage source inverter.

Paper ID: EE27

III.WORKING OF BASED BRIDGELESS-CONVERTER MULTIPLE-OUTPUT SMPS

This designed system model consist of two back to back buck-boost converter, voltage source inverter, multiple output high frequency transformer. The buck boost converter is appropriately controlled for obtaining high power factor and low THD. The operation of converter for one switching cycle is given as follows,

A. Working Of Bridgeless Buck Boost Converter

This bridgeless buck-boost converter is consists of upper and lower switch which are conducted for positive and negative cycle input ac voltage respectively. In order to achieve high power factor this converter is operated in the discontinuous conduction mode (DCM).When we deal with DCM operation it should be takes place in three stages .In first stage when pulse given to the switch then inductor associated with it start for storing energy from input ac supply, during this stage inductor current increases from minimum value to maximum value. In second stage switch is get turned off and inductor starts for discharging through capacitor so that inductor current decreases from maximum value to minimum value. In the last stage nighters' neither diode nor switches are conduct so that inductor current become zero during this stage. zero current of inductor itself ensure the DCM operation. like this lower buck boost converter is operated for the negative half cycle.

B. Working Of Half Bridge Voltage Source Inverter

The output of dual buck-boost converter is controlled Dc voltage which is given as a input to the half bridge voltage source inverter for voltage multiplying, isolation & for getting multiple outputs. Working of half bridge VSI for one switching cycle is divided in to four sub stages. In first stage out of two switches when upper switch is tuned on it starts for conducting current through primary winding of transformer and lower capacitor. During this diodes D_1, D_3, D_5, D_7 on the secondary side are forward biased and the current will flow through respective inductor so that inductor current increases while output capacitor discharging through the load. In second stage of operation both switches are turned off and all the diodes on secondary side are comes in freewheeling mode. Due to this inductor start for deceases .In third stage lower switch is turned on and current will flows through upper capacitor and primary winding of the high frequency transformer. The diode son secondary side D_2, D4, D6, D8 is conducting due to which inductor current start for storing the energy. Switch is turned off when energy in inductor becomes maximum. In fourth stage all diodes on secondary are in freewheeling mode and same operation is repeated as given the second stage.

IV.DESIGN OF PROPOSED MULTIPLE OUTPUT SMPS

In order to simulate the performance of proposed bridgeless buck –boost converter based SMPS it is important to find to out the values of the entire component. To obtain the proposed design all the diodes and switches are considered as ideal. The switching frequency selected here is very high as compared to the line frequency.

A. Design Of Input Filter

Input ac supply is directly given to this filter. The purpose of design of this filter is to reduce higher order harmonics also it reduces the distortion from ac supply. So in this L-C type maximum value of capacitor is calculated as[22],

$$Cin\max = \frac{\text{Im}\tan\theta}{\omega Vm} \tag{1}$$

Where Vm and Im are the peak ac voltage and current. By substituting all the values we get 409nF.for θ value is considered 1^0 for maximum value of capacitor.

In order to maintain the low ripple at input ac side inductor value is given as below,

$$Lin = \frac{1}{4*\pi^2 * fc^2 * Cin} \tag{2}$$

Where fc is an cutoff frequency. Thus value for inductor is obtained as3.07mH.

B. Design Of Bridgeless Buck–Boost PFC Converter

The inductors present in the configuration of buck –boost converter are essentially designed in such way that they will ensure discontinuous conduction mode of operation. Inductor value is calculated bases on change in inductor current in one switching cycle is zero, ripple current is given as,

$$Lp = \frac{DTVavg}{\Delta iLpon} \tag{3}$$

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

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

Thus by substituting all values inductor is calculated as 607µH but to ensure DCM inductor value is considered as 60 µH for switching time 50µS.

C. Design of Half bridge voltage source inverter

The design of this isolated dc-dc converter is takes place in continuous conduction mode .In this converter the input voltage and input current need not be sensed because they are already regulated. The current flow through and voltage across

Paper ID: EE27

itself repeat in each switching cycle. When both switches and the diode are turnoff for some switching cyle then output inductor value is calculated as,

$$Lo1 = \frac{Vo1(0.5 - Dh)}{fh \times \Delta ilo1} \quad (4)$$

Where $T=1/f_h$ is switching time, Vo1 is highest output voltage of secondary of HFT of isolated dc-dc converter. Thus output inductor L_{o1} with switching frequency 60KHZ and maximum allowable current ripple of 2% for 12V output of current 12.5A is 0.08mH.In this way other output inductor with their ripple can be calculated as given by above formula L_{o2}=0.018mH, L_{o3}=0.016mH, L_{o4}=1.25mH.respectivally.

Output of first stage that is power factor correction circuit is input to the isolated dc-dc converter. The two input capacitor is as filter for reducing the 100Hz ripple present from input ac supply. To follow input current with input voltage i.e. proper power factor operation this isolated dc-dc converter is designed in the continuous conduction mode. Thus capacitor value can be found as,

$$c = \frac{Idc}{2\omega\Delta Vdc} \quad 5$$

Thus two capacitor values C11 and C12 can found as 0.63mF where ω is 314rad/s,I_{dc} is 1.27A and Δ V is considered 2% on dc regulated output voltage.

V.CONTOL SCHEME FOR PROPOSED SYSTEM

In this two stage multiple output SMPS two separate control techniques are used in order to control the DC output voltage of bridgeless buck boost converter and isolated dc-dc converter.

A. Control Of Bridgeless Buck-Boost Converter

The front end bridgeless buck-boost converter is controlled by employing voltage follower approach .In this dc output buck-boost converter is regulated. The two switches are to be switched on and off according switching pluses from the PWM converter. Here the sensed output voltage and reference voltage is given to the PI controller then it generates the error signal which is given to the PWM generator where it is to be compared to the high frequency saw tooth signal. And finally gate pluses for the switches in power correction circuit are to be given.

B. Control For Isolated Dc-Dc Converter

Current mode control techniques are used for the controlling purpose of this converter. In this technique highest output voltage of the high frequency transformer is sensed. The difference between this signal and reference voltage is calculated by PI controller .The output of this controller is compared with high frequency saw tooth signal and PWM pluses are to be given to the two swatches of isolated dc-dc converter.

VI. RESULT ANALYSIS OF PROPOSED SWITCHED MODE POWER SUPPLY

Performance of this proposed multiple output SMPS is simulated MATLAB/Simulink environment. In this various waveforms such as input voltage, input current, DC output voltage of buck-boost converter, multiple outputs i.e.V_{o1},V_{o2}.V_{o3},V_{o4} and I_{o2},I_{o2},I_{o3},I_{o4} of switched mode power supply. power quality indices such as displacement PF, distortion factor, Power Factor, and input current THD are analyzed to examine improvement in the power quality of single-phase ac mains. Performance verification of the proposed bridgeless-converter-based SMPS is carried out for following condition:

1. Steady-state condition
2. Varying input voltages

A. Performance for Steady State operating Condition-

This is normal operating condition where Switched mode power supply operated continuously. So it very essential to check the performance of multiple output SMPS under this kind of condition. Following fig (2) shows that bridgeless buck-boost converter based SMPS can significantly improves power quality of ac input supply. In this condition performance of multiple output switched mode power supply is analyzed by operating SMPS on 220V ac rms voltage with full load. The input voltage and current waveform are shown in following fig(3)a. From fig.2 it is shows that elimination diode bridge rectifier by bridgeless topology increases the power quality of ac mains supply by reduction in the total harmonic distortion with maintaining power factor 0.9976. The harmonic distortion in the input current is 4.53%.The regulated output voltage of buck boost converter is as shown in fig. Multiple outputs of switched mode power supply with their output voltages and output currents are also shown in fig (3) b. The fig (4) shows that bridgeless converter topology will helpful for reducing the switching stress on the switches.

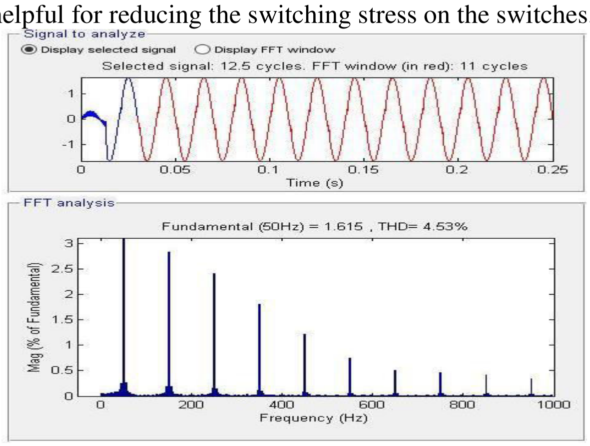
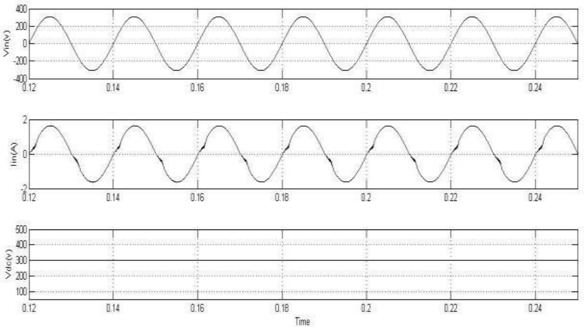
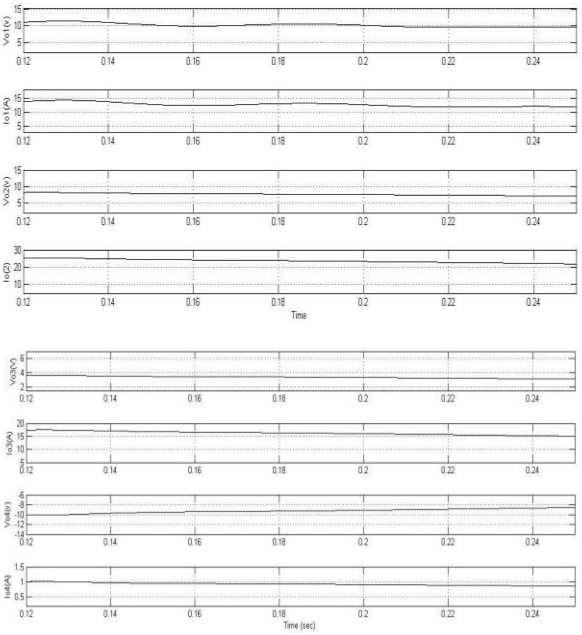


Fig 2- input ac current and harmonic spectrum

Paper ID: EE27

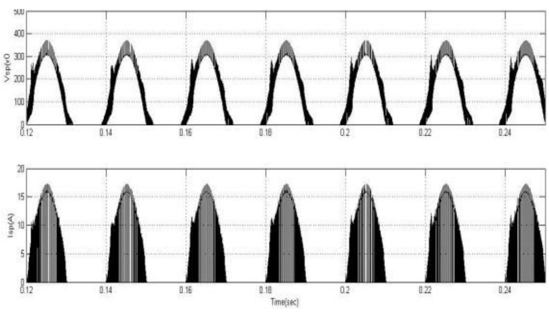


(a)



(b)

Fig3 -(a) input voltage, current and dc output voltage (b) Output voltage and output currents of multiple output SMPS



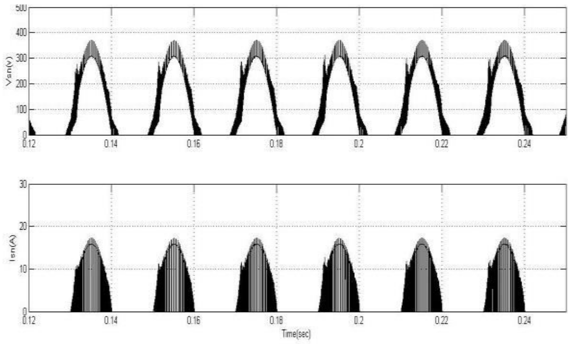


Fig 4 -Voltage across Switch Sp and Sn and Current through switches.

2) 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 IEEE519 and IEC 61000-3-2.Power quality indices such as THD ,power factor, Distortion factor ,Displacement power factor are tabulated below table,

Table1 power quality indices at various input voltages

Input voltage (rms)	PF	DPF	DF	I_{inTHD} (%)	I_{in} (A)
170	0.9955	1	0.9955	2.42	2.01
220	0.9976	1	0.9976	4.53	1.62
270	0.9983	1	0.9983	5.86	1.342

VII CONCLUSION

The bridgeless based converter multiple output SMPS gives the better efficiency and good power quality performance at steady state as well as varying input voltage conditions. All the power quality measurements are well within the limits set by IEC-3-2.This SMPS gives the better voltage regulation due to use of buck-boost converter .Operation of buck boost converter in discontinuous mode gives better power factor and reduction in the total harmonic distrotion.As the number of component used has reduced so switching losses as well as conduction losses are minimized. 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.

Paper ID: EE27

APENDIX

Nominal input ac supply voltage	220 V, 50 Hz
half-bridge VSI input voltage	300V
multiple dc output voltages/currents	12 V/12.5 A, 5 V/23 A, 3.3 V/16 A, and−12 V/0.8A

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