IJEEE

International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 3, Issue 9, September 2016)

Single-Inductor Dual-Output Buck–Boost Power Factor Correction Converter

Shankar Moguthala
Assistant professor Dept of EEE
Siddhartha Institute of Engineering & Technology
Ibrahimpatnam, R R Dist Hyderabad India
Shankarmoguthala40@gmail.com

G Sathish Goud
Assistant professor Dept of EEE
Siddhartha Institute of Engineering & Technology
Ibrahimpatnam, R R Dist Hyderabad India
Satish.eng07@gmail.com

***Abstract*—A single-inductor dual-output (SIDO) buck–boost power factor correction (PFC) converter operating in critical conduction mode is proposed in this paper. By multiplexing a single inductor, each output of the SIDO buck–boost converter can be regulated independently. Compared with a conventional two-stage multiple-output converter, the SIDO buck–boost PFC converter benefits from significant overall cost saving, small size, and lightweight. Moreover, the efficiency of the SIDO buck–boost PFC converter can be improved due to single-stage power conversion. The control strategy and characteristics of the proposed converter are analyzed. The efficiency, power factor, total harmonic distortion, and output accuracy are verified using the experimental results.**

***Index Terms*— Critical conduction mode (CRM), power factor correction (PFC), single-inductor dual-output (SIDO), single stage, time multiplexing (TM).**

I. INTRODUCTION

MULTIPLE-OUTPUT ac/dc power converter has been becoming popular with fast development of consumer electronics and LED lighting [1]–[3], such as multilevel voltage supply systems, current balancing for multiple LED string driving, RGB LED lighting, etc. IEC 61000-3-2 class C for lighting equipment establishes a strict requirement for the input current harmonic content of power converters [4]. Power factor correction (PFC) is usually used to provide a sinusoidal input current. Hence, research of multiple-output ac/dc power converter with low cost and high power factor (PF) is important.

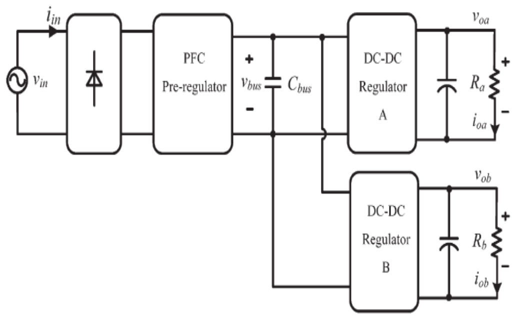
In order to achieve a high PF and to accurately regulate the output voltages or currents of a multiple-output ac/dc converter, a conventional multiple-output ac/dc power converter consisting of two-stage power conversion is utilized, as shown in Fig. 1, where the PFC preregulator provides the dc bus voltage *v* bus and parallel-connected dc-to-dc regulators are used to regulate the output voltage or output current from v_{bus} [5].
The circuit configuration of the multiple-output ac/dc converter shown in Fig. 1 is complex and suffers from high cost, with multiple inductors and controllers required [6], [7]. Moreover, the two-stage power conversion with PFC pre-regulator and dc-to-dc converters suffers from lower efficiency and higher volume and cost. However, the single-stage PFC converter can achieve high PF and output current or voltage regulation at the same time [8], [9]. Hence, it has drawn more and more attention in recent years.

A fly back PFC converter with multiple secondary windings is a typical single-stage multiple-output converter, where only one output can be well regulated. Multiple secondary windings in the transformer lead to cross-regulation due to leakage inductance, forward voltage drop of diodes, and series resistance of the windings [10]. Moreover, only voltage output regulation can be achieved, while multiple current outputs are hard to regulate independently. In order to achieve a highly accurate regulation of multiple-output converters, the magneticamplifierpostregulator approach is applied in [11] and [12], but it still requires multiple inductors and windings.

A single-inductor multiple-output (SIMO) converter with only one inductor benefits from significant overall cost saving, small size, and light weight, which make it as one of the most suitable and cost-effective solutions for multiple-output power supplies. SIMO dc/dc converters in mobile application have been studied in recent years [13]–[17]. In some offline applications, such as LED lighting, single-stage PFC converters are preferred. A single-stage buck–boost PFC converter has the advantage of low cost and high PF, which make it widely applied in single-output no isolated general lighting applications [18]. In this paper, a novel single-inductor dual output(SIDO) buck–boost PFC converter operating in critical conduction mode (CRM) is proposed. Its control strategy and corresponding characteristics are analyzed. Independent regulation of each output can be achieved in this converter by multiplexing a single inductor. Compared with a conventional two-stage multiple-output converter, the proposed converter benefits from significant overall cost saving, small size, lightweight and high power conversion efficiency due to single stage power conversion. The proposed converter can also be easily extended to realize the SIMO buck–boost PFC converter to fulfill different system requirements.

This paper is organized as follows. In Section II, the SIDO

Buck–boost PFC converter is proposed and analyzed. The design considerations and analysis are described in Section III.The experimental results including efficiency, PF, total harmonic distortion (THD), and output regulation accuracy are given in Section IV, and Section V summarizes the conclusion drawn from the study.



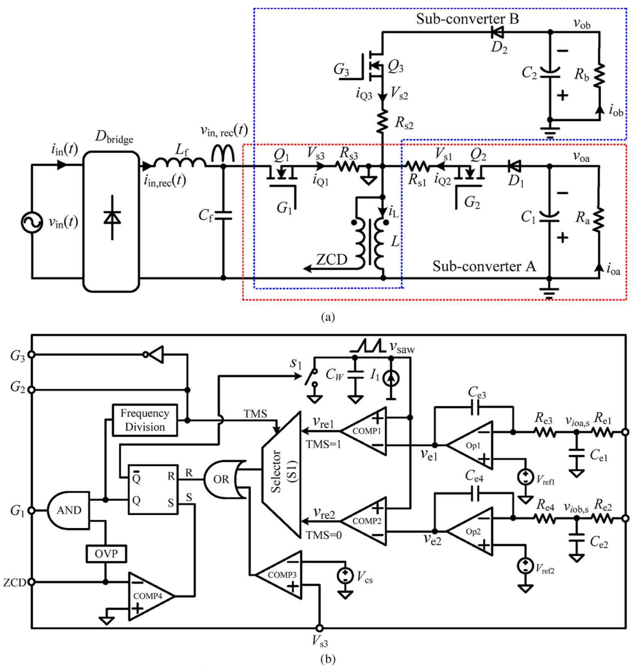


Fig. 1. Block diagram of a conventional multiple-output ac/dc power converter with a high PF.

Fig. 2.Proposed SIDO buck–boost PFC converter.(a) Power stage. (b) Controller

II.PROPOSED SITO BUCK BOOST PFC CONVERTER

From the Fig.2(a),the power stage of the SITO buck-boost converter consists of a diode bridge Dbridge; an input filter consisting of Lf and Cf; five switch networks consisting of Q1,Q2,Q3,Q4,and Q5 and their corresponding sense resistors Rs1,Rs2 , and Rs3;four freewheeling diodesD1,D2,D3,and D4; a time multiplexing inductor L; and three output filter capacitors C1,C2, and C3.Q2,Q3,Q4, and Q5 are the time multiplexing control switches of each output. The switch Q1 is always in on condition. When Q2 IS Turned on and Q3 is turned off, the converter transfers power to output B, and when Q2 is turned off and Q3 is turned on, the converter transfers power to output A. For the third output the switch Q4 is turned on and Q5 is turned off that time the capacitor C stores the charge .After charging the capacitor the switch Q4 is turned off and the switch Q5 is turned on, the converter transfers power to the output C.

Fig.2 (b) shows the control loop of the SITO buck-boost PFC converter with three constant output currents. Rs1, Rs2, and Rs3 are series connected with the switch Q1, Q2, and Q3, respectively, and heir common point is set as signal ground. The average freewheeling current of the inductor for each sub converter in a half line cycle is equal to the corresponding output current, and it can be detected as the output current for control.Vs1, Vs2, and Vs3 are the sense voltages across sense resistors Rs1, Rs2, and Rs3, produced by inductor freewheeling currents iQ2,iQ1,and iQ3.The average of Vs1 and Vs2 is used as the output current information for each output.Vs3 is used as the cycle by cycle current limit signal for over current protection. The comparators compare the voltage COMP[i](i=1,2) compare ve[i](i=1,2) with saw-tooth signal to generate reset signals vre1 and vre2 for timing multiplexing(TM) selector S1,respectively,ve1 and ve2 are the compensated error voltages between each output and reference current vref[i](i=1,2).The time multiplexing signal(TMS) is divided by 2 frequency the RS flip flop is high. The zero current detection (ZCD) signal of the inductor is given as the input to the set terminal of the RS flip flop. The ZCD signal, which is coupled by the auxiliary winding of the inductor from the two outputs, also reflects as the output voltage information .Over voltage protection (OVP) will be triggered, when the output voltage is higher than the set Value of the controller. The voltage of the auxiliary winding (zero cross detection) will change to negative, when the inductor is decreases to zero. The SITO buck boost PFC converter operates in varied frequency with ZCD. The gate signal is given to the switch using controllers. The gate pulse g4 and g5 are same as the g2 and g3.And I is given to the Q4 division signal of the RS flip flop output, is used to control the output. When TMS=1,vref1 is selected by S1,and ioa will be regulated to Vref1/Rs1;similarly,when TMS=0,iob is regulated as Vref2/Rs2.The saw-tooth generator(reset) is zero when Q1 is turned off and will be set again when the Set terminal of and Q5 switches

III.DESIGN CONSIDERATION AND POWER FACTOR ANALYSIS

In this section, the SITO buck-boost PFC converter operating in CRM mode. This mode is analyzed under following assumptions.

1) All the components are shown in the Fig.2

2) Switching frequency is higher than the line frequency.

International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 3, Issue 9, September 2016)

3)Input voltage is a rectified sine wave, that is Vin,rec(t)=|vin(t)|=vp|sin(wL(t)|,where vp is the amplitude of the sine wave.

4) The output voltages voa, vob and voc are constant ,they have ac ripple in the steady state.

5) The bandwidth of the PFC converter in the control loop is usually much lower than the rectified line frequency.

6) The error voltage of three outputs is constant within each half of the line cycle.

The PF of the SITO buck-boost PFC converter can be obtained as

$$\mathrm{PF} = \frac{\sqrt{2}\int_0^{\pi} \frac{\sin^2 \omega t}{k+\sin \omega t}\, d(\omega t)}{\sqrt{\pi}\sqrt{\int_0^{\pi} \frac{\sin^2 \omega t}{k^2+2k\sin \omega t+\sin^2 \omega t}\, d(\omega t)}}.$$

By using MATLAB Fig.4 shows the PF of the SITO buck-boost PFC converter, its shows that by increase the value of k, power factor will be close to 1.

The value of k is determined by k1,k2 and α.Let λ=α2 and it is defined as the power ratio of Po,A,Po,Band Po,cby using MATLAB,The relationship of PF ,k1,k2 and λ ..PF will be seriously affected when λ increases. It clearly tells that k1 is equal o k2.

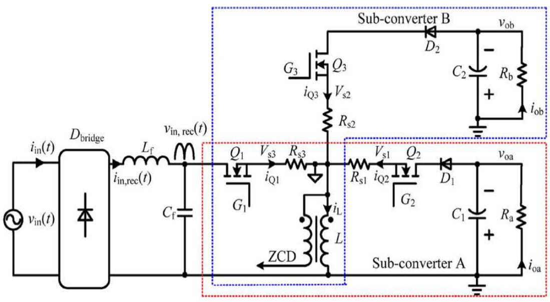


Fig. 3. Block diagram of a conventional multiple-output ac/dc power converter with a high PF.

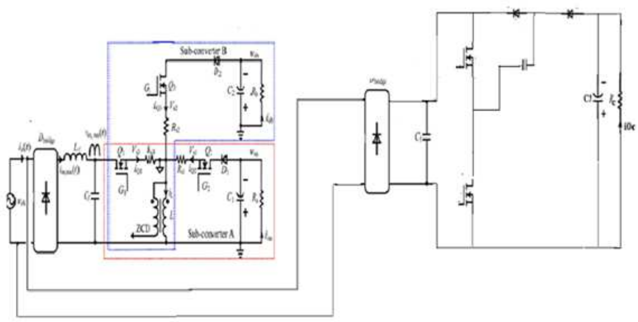


Figure 3 Circuit Parameters Of The Buck-Boost PFC Converter

A 30.75-W prototype of the proposed CRM SITO buck-boost PFC shown in Fig.2 is built to verify the theoretical analysis. Each output current of the proposed CRM SITO buck-boost PFC is constant. The prototype parameters of SITO are shown in Table I. The voltage is varying from 100 o 240 Vac .According to the analysis L is designed as 180μH.Lf and Cf are used to provide switching noise attenuation. And also it is used to achieve low displacement angle between the input voltage and current .A low frequency requires a low cut off frequency of the input filter, it will automatically increase the size of the filter. Here Lf and Cf is filter. Here Lf and Cf are .designed as 1mH and 220nF considering a wide input voltage

Variable	Definition	value
V_{in}	Input voltage	100_240Vac
R_a	Rated load resistor of output A	300Ω
i_{oa}	Current of output A	-0.2A
R_b	Rated load resistor of output B	300Ω
i_{ob}	Current of output B	-0.25A
R_c	Rated load resistor of output C	300Ω
i_{oc}	Current of output C	0.78A
L	Inductor	180μH
L_f	Input filter inductor	1mH
C_f	Input filter capacitor	220nF
C_1,C_2	Output filter capacitor	220μH
C_3	Output filter	800μH
C_4	Output filter	500μH
D_1,D_2,D_3 ,D_4	Diode	ES2J

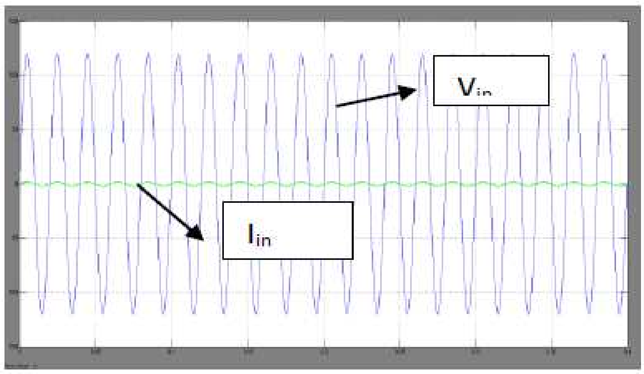
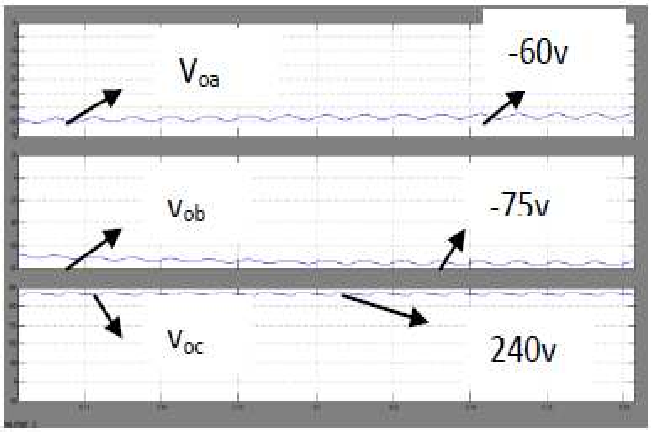


Figure.4. Shows The Vin And Iin Waveforms Of The Sito Buck-Boost Pfc Converter At 110v



International Journal of Ethics in Engineering & Management Education

Website: www.ijeee.in (ISSN: 2348-4748, Volume 3, Issue 9, September 2016)

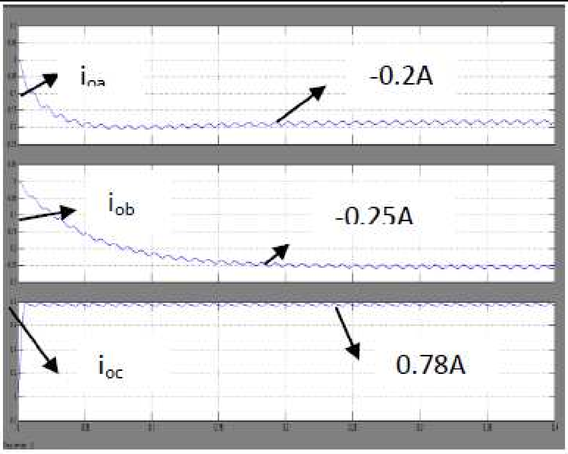


Figure.5 Voltages of Sub Converter
Figure.6 Currents Of Sub converter A,B And C A,B And C

V.CONCLUSION

A SIDO buck–boost PFC converter operating in CRM has been proposed in this paper. Detailed control strategy analysis and design considerations have been presented. Each output can be regulated independently in this converter by multiplexing single inductor. Compared with conventional two-stage multiple-output ac/dc converters, the proposed single-stage multiple-output ac/dc converter benefits from significant overall cost saving, small size, and light weight of the device. Experimental results have been presented to verify the analysis results and to demonstrate the advantage of the proposed converter. Although only the dual-output converter is discussed in detail in this paper, the proposed converter can be easily extended to realize SIMO PFC converters with different topologies to fulfill different system requirements.

REFERENCES

[1]. J.-K. Kim, S.-W.Choi, C.-E.Kim, and G.-W. Moon, "A new standby structure using multi-output full-bridge converter integrating fly back converter,"*IEEE Trans. Ind. Electron.*, vol. 58, no. 10, pp. 4762–4767,Oct. 2011.

[2]. Q. Xiaohui, S.-C.Wong, and C.-K. Tse, "No cascading structure for electronic ballast design for multiple LED lamps with independent brightnesscontrol," *IEEE Trans. Power Electron.*, vol. 25, no. 2, pp. 331–340,Feb. 2010.

[3]. J. Cardesín, J. Ribas, E. LópezCorominas, and M. A. Dalla Costa, "LEDpermanent emergency lighting system based on a single magnetic component,"*IEEE Trans. Power Electron.*, vol. 24, no. 5, pp. 1409–1416,May 2009.

[4]. *Electromagnetic Compatibility (EMC) Part 3-2: Limits—Limits for HarmonicCurrent Emissions (Equipment Current ≤ 16 A per Phase)*, Int.Std. IEC 61000-3-2, 2009.

[5]. M. Arias *et al.*, "Design of a soft-switching asymmetrical half-bridgeconverter as second stage of an LED driver for street lighting application,"*IEEE Trans. Power Electron.*, vol. 27, no. 3, pp. 1608–1621, Mar. 2012.

[6]. H.-J. Chiu and S.-J. Cheng, "LED backlight driving system for large-scaleLCD panels," *IEEE Trans. Ind. Electron.*, vol. 54, no. 5, pp. 2751–2760,Oct. 2007.70–75, Nov. 2005.

Authors:

Shankar Moguthala, Received M.Tech degree in Electrical& Power Engineering from JNTU Hyderabad. Presently He is working as Assistant Professor In Siddhartha Institute of Engineering &Technology, Hyderabad. He is life member of **Indian Society for Technical Education** at present he is working in area of Machines, Power Systems Power Quality, FACTS and Neural Networks &fuzzy logic.

G. Sathish Goud, has Received his B.Tech degree in Electrical and Electronics Engineering from JNTUH, Hyderabad, India and M.Tech degree in electrical power systems from JNTU Hyderabad, India. He is life member of Indian Society for Technical Education. Presently He is working as Assistant Professor In Siddhartha Institute of Engineering & Technology, Hyderabad. His is doing currently research in Fuzzy logic controllers, ANN and electrical power systems, power electronic &drive