International Journal of Applied Power Engineering (IJAPE)
Vol. 4, No. 1, April 2015, pp. 23~29
ISSN: 2252-8792

A New Advanced Topology for Photo Voltaic Applications

Sreedhar.M, C.K.Panigrahi, Abhijit Dasgupta, J.Pati
School of Electrical Engineering, KIIT University

Article Info

Article history:

Received Feb 2, 2015
Revised Mar 6, 2015
Accepted Mar 27, 2015

Keyword:

DC-DC Converter
PV Applications
Step up converter
ZCS

ABSTRACT

This article proposes a high efficient DC-DC step-up converter with a single switch. This is particularly suited for Photo Voltaic (PV) applications, automotive applications, battery operated vehicles etc., in which voltage is stepped up from 10V to 500V. This converter operates at 100 kHz due to which switching losses are comparatively high. This topology proposes a scheme to mitigate power losses across the switch and to achieve high efficiency by Zero Current Switching (ZCS) at “Turn ON and Turn OFF” states. Proposed converter uses a single switch to reduce the losses in the converter and 98% overall efficiency has been observed in the converter. The proposed converter is verified by its experimental results.

Corresponding Author:

Sreedhar Madichetty,
School of Electrical Engineering,
KIIT University,
Bhubaneswar, INDIA.
Email: madichetty.sreedhar@gmail.com

1. INTRODUCTION

The field of DC-DC converters has witnessed many rigorous investigations leading to successful operation in Photo Voltaic (PV) systems. The ever increasing demand of industry for stability, adjustability and accuracy of control of power electronic equipment at very high voltages led to the development of relatively less total harmonic distortion (THD) based modern power electronic static converters. Although solid state power electronic switches, such as the IGBTs have brought well-marked variance in control techniques, nonetheless the main disadvantage is that they produce heavy loss in the converter switches. Many converters are operating with dual switches which produce more loss on systems which are operated with PV cells. Hence, it though of opportunity to reduce the switches in DC-DC converters with less losses. Thus there is always scope of reducing losses in DC to DC conveters.Also it has developed a control mechanism to control the switches in synchronism with the switches. It also uses a single voltage sensor there by the cost of equipment also reduces. The use of a single voltage sensor and the application of an OPAMP as comparator can reduce the cost of the circuit.

High step-up DC-DC converters have multiple usages in day to day life, such as applications powered by battery sources, PV cells, and high intensity discharge (HID) lamp ballasts etc.,This calls for qualitative performance improvement of their operations.As an example, most commonly used headlamps in automotive applications are HID lamps, where the start-up voltage is up to 200 V-500V, the DC–DC converter needs to boost the 12 V/24V of the battery source voltage available in vehicle up to 200 V-500V during its steady-state operation. Normally this achieved with the help of inverter-rectifier cascaded connection, which is a most uneconomical approach. Conventional boost converters are able to achieve high step-up voltage gain as required for applications in heavy duty operating conditions.

In practice, however, the voltage gain of the DC-DC converters are limited owing to the losses associated with the main power switches. The switch-off and switch-on losses due to the main power switch will degrade the efficiency of the converter. In order to increase the conversion efficiency and voltage gain, a number of modified boost converter topologies have been proposed [1–5] in literature. Hence, in order to overcome the above mentioned drawback, this work proposes a high efficient topology with soft switching scheme. In [1], it proposes an isolated DC converter and its experimental verification is shown in [2]. For micro source applications [3-5] such as fuel cells, applications isolated DC converters has been proposed. The detailed analysis and its experimental verification have been shown in [4]. A new robust control mechanism was proposed in [6-8] and new topologies for DC-DC converters was proposed [9-11] to reduce losses in the system. Also, a type of Zero Voltage (ZVS) and Zero Current Switching (ZCS) was proposed to reduce [12-16] the losses. Hence by keeping all above improvements and drawbacks in consideration, it proposes a new DC_DC converter with single switch with a single voltage sensor which will be discussed in following sections.

This paper is organized in five sections. Section -1 introduces the relevant literature survey about DC – DC converters. In section -2, modeling of proposed converter has been put forward. In section-3, this article discuss about the simulation and experimental results of proposed controller; and in the last section, the conclusive remarks have been been provided.

2. PROPOSED TOPOLOGY AND ITS OPERATION

In this section the proposed topology and its modes of operation has been presented. Primarily, the switching scheme has been proposed and shown in fig.1. In which the output voltage of the converter has been sensed and compared with required reference and the resultant signal has been passed through the voltage of converter compare with the required reference and obtained signal has been passed through the modulator as shown in figure 1.

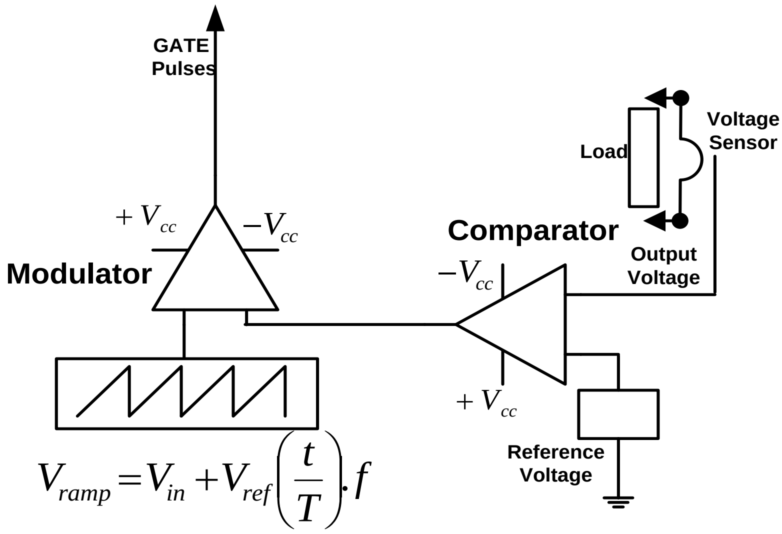

Figure. 1 Gate driver for circuit for proposed DC-DC converter

The basic proposed converter topology is shown in fig. 2 and its gate driver circuit is shown in figure 1.The proposed DC-DC converter basically consists of a battery source with its voltage as $V_{in}$and its input current as I_{in}; converter is comprised of diodes D_1, D_2 and D_3;inductors L_1, L_2 and L_3 with its respective voltages and currents as V_{L1}, V_{L2} ,$V_{L3}$and I_{L1}, I_{L2} ,I_{L3}; capacitors C_1, C_2 and C_3 with its respective voltages and currents as V_{C1}, V_{C2} ,$V_{C3}$and I_{C1}, I_{C2} ,I_{C3}; load voltage and load current as V_L and $I_L$respectively; 'T' is the total time taken for a duty cycle, V_{ramp} is the voltage given to modulator in ramp wave, $_{ref}$ is the reference voltage that needs to obtain at the output terminals of converter, 'f' is the operating frequency of the switch S_1;the voltage across the switch is denoted as V_{S1}.Where $L_1$and L_3 are coupled inductors. The input voltage for modulator is taken as $+V_{cc}$ and$-V_{cc}$.

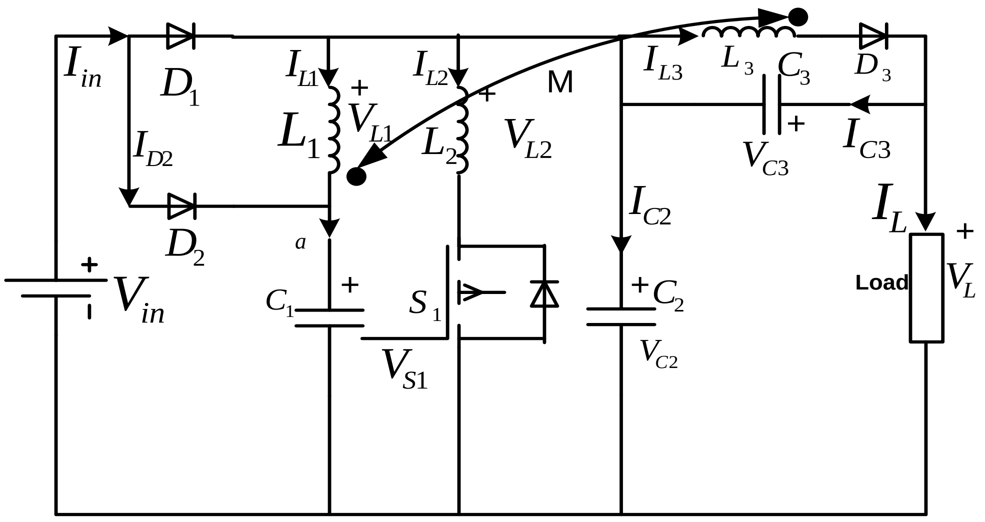

Figure. 2 Proposed DC-DC converter topology

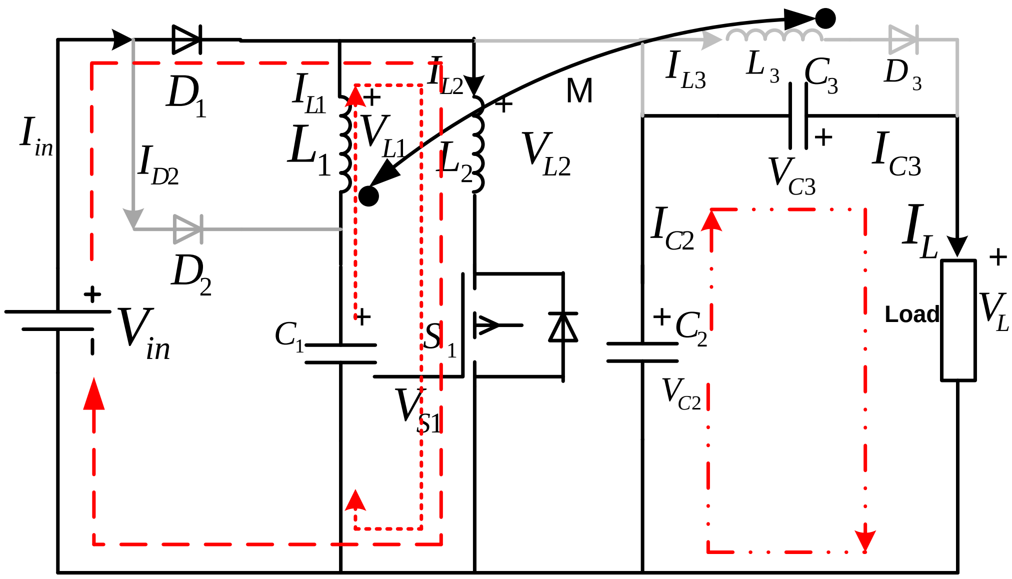

Figure. 3(a) Proposed converter showing mode-1 operation

Mode 1$(0 < t_0 < t_1)$: Initially it is assumed that the capacitor C_2 and C_3 was fully charged. When the switch $S_1$is turned ON, the diode D_1 will become forward biased as shown in figure 2 (a).Since the inductor is placed in series with the switch it does not allow sudden change in current and hence zero current switching takes at the time of switch ON. The currents will follow the path $+V_{in}$-D_1-L_2- S_1- $-V_{in}$.On the other hand, the capacitor $C_1$is delivering the energy to coupled inductorL_1. At this instant the inductor L_1 is trying to discharge the energy to L_3 due to its coupling effect. Next, the capacitor's C_2 and C_3 are continuing to deliver its energy to the load and it is maintaining the required voltage at the terminals as show in fig. 3(a). The voltage is calculated after several algebraic express as shown in (1).

$$V_0 = D.V_{c1} + (D + 1)V_{c2} \tag{1}$$

Where 'D' is the duty cycle of the switch "$D = \frac{T_{on(Swicth\ ON\ time)}}{T(Total\ time\ )}$"

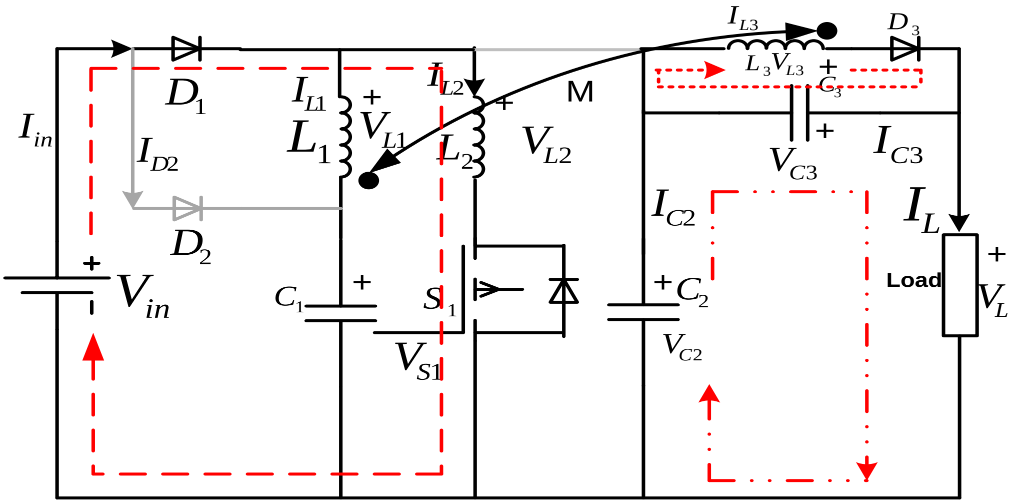

Figure. 3 (b) Proposed converter showing mode-2 operations

Mode 2$(t_0 < t_1 < t_2)$*:* At this instant the switch S_1 still is in ON condition. The coupled inductor L_1 transfers the energy to L_3 and then L_3 starts delivering the energy to capacitor C_3 to charge. Still the capacitor C_2 still continous to deliver the energy to load as show in fig. 3(b).

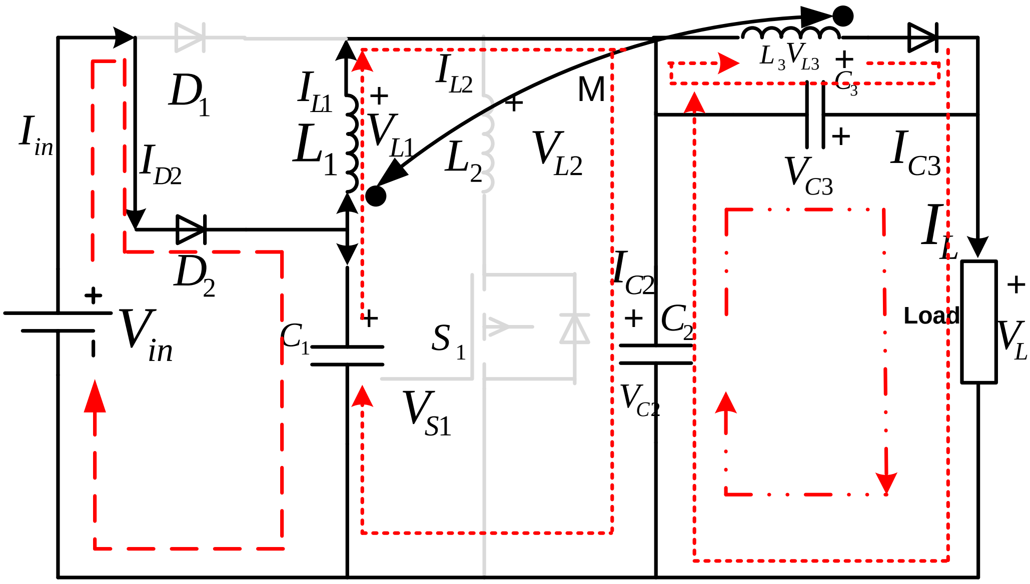

Figure. 3 (c) Proposed converter showing mode-3 operations

Mode 3$(t_1 < t_2 < t_3)$*:* At this instant still the switch S_1 is turned in to OFF condition by removing the gate pulse. Due to presence of L_2 the switch S_1 ensures the zero current switching. Once the switch S_1 is OFF, D_1 becomes forward bias. The current will follows the path of $+V_{in}$-D_2-C_1- $-V_{in}$. Here the input current will splits the current in to two ways such as one is to energise the capacitor C_1 and other is to couple inductor L_2 as show in figure 3(c). The input current splits into two ways so that one will energize the capacitor C_1 and the other is to the coupled inductor L_2.

Mode 4$(t_3 < t_4 < T)$*:* At this instant still the switch S_1 is still in OFF condition. At this instant, the current will follows the path of $+V_{in}$-D_2-C_1- $-V_{in}$.The capacitor C_1 is trying to charge up to its capacity and coupled inductor will dissipates energy in its internal magnetic circuit as shown in figure 3(d).

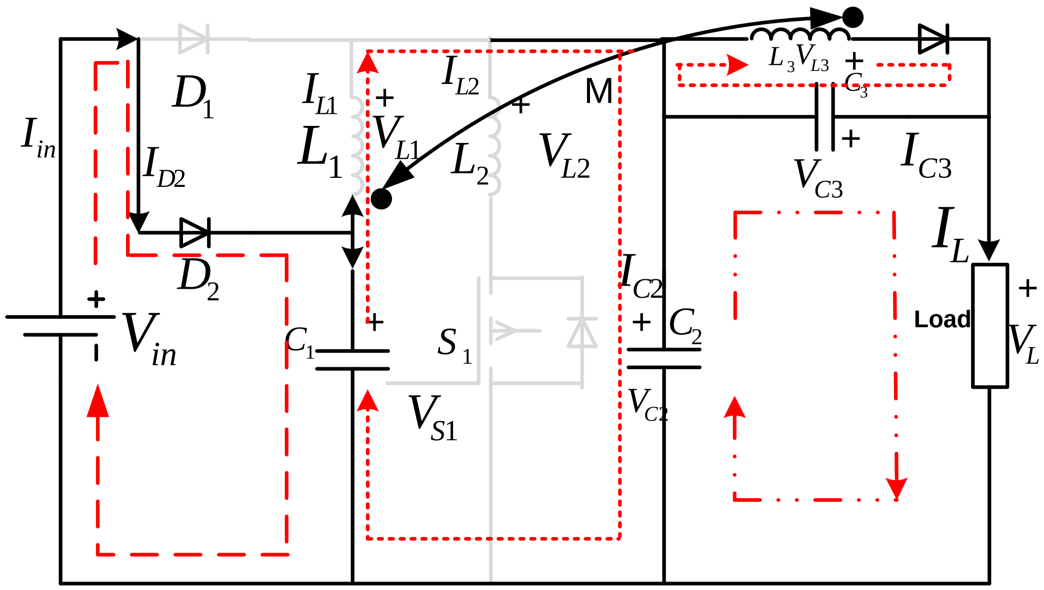

Figure. 3(d) proposed converter showing mode-3 operation

3. EXPERIMENTAL VERFICATION

In this section the proposed topology has been verified by its experiments and results have been discussed.

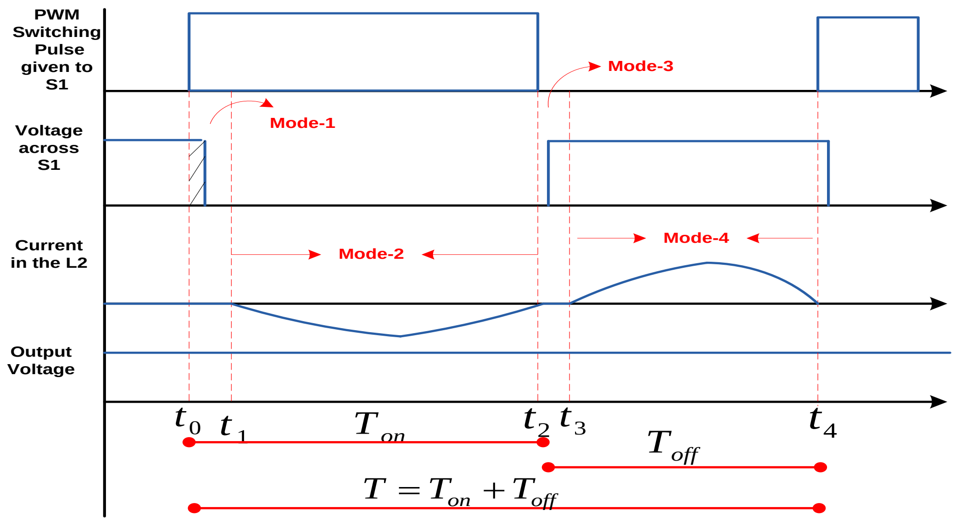

Figure. 4 Output waveforms for the proposed converter in continuous conduction mode

All modes of operation in terms of their output wave forms is shown in figure (4).

Figure 4 shows the switching operation of DC-DC converter. The obtained switching pulses from modulator have been given to the switch and its current and voltage waveforms as per modes of operation have been given. The proposed topology has been verified experimentally and shown in fig.(5).It shows currents through the coupled inductors L_1 and L_3 and inductor which is in series with the switch L_2.The ZCS condition has been verified at turn ON and OFF times of switch. The current passing through the inductors along with its switching voltages is shown in fig. (5). this experiment has been verified at 24 V and at 12 V input voltages by different loadings. By experimental analysis, the ZCS achieved at ON and condition and ZVS is obtained at OFF condition by which the losses of system has been reduced drastically. At 12V, the highest efficiency achieved is up to 98.1% at 50% of full load; in case of full load condition, the efficiency is achieved up to 94.3%. When the 24V input voltage, the efficiency is achieved up to 95.5% at full load condition, while at 50% of full load, the maximum efficiency is 98.3%.

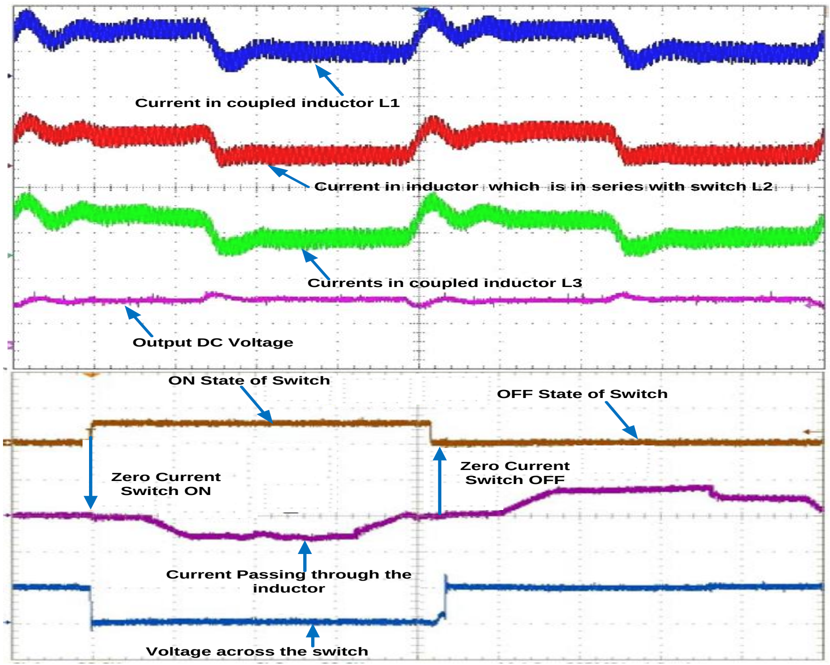

Figure. 5 Experimental Output waveforms for the proposed converter in continuous conduction mode

4. CONCLUSION

The article has been proposed a high efficient DC-DC converter with the principle of zero current switching schemes operated with single switch. The modes of operation with its experimental results have been reported and efficiency of system has achieved 98.3% at 24V DC input at 50% of its load condition.

5. PARAMETERS CONSIDERED

V_{in} 12/24V, L_1, L_2,L_3, C_1, C_2,C_3 are 26μH,12μH,26μH,880μf,220μf,220μf respectively.f_s=100kHz; Output power P_0 =500W; D_1, D_2D_1, D_3 are STUS5B8;S_1 is IXAN0065.

REFERENCES

[1]. Wu, G.; Ruan, X.; Ye, Z., "Non-Isolated High Step-Up DC-DC Converters Adopting Switched-Capacitor Cell," Industrial Electronics, *IEEE* Transactions on , vol.4 PP, no.68-69, pp.1,1,2014

[2]. Wu, G.;., "Non-Isolated High Step-Up DC-DC Converters Adopting Switched-Capacitor Cell-Part-II," Industrial Electronics, *IEEE* Transactions on , vol.10PP, no.99-102, pp.1,1,2014

[3]. Andrade, AM.S.S. Dreher, J.R.; da S Martins, M.L., "High step-up integrated DC-DC converters: Methodology of synthesis and analysis," Power Electronics Conference (COBEP), 2013 Brazilian, vol., no., pp.50,57, 27-31 Oct. 2013.

[4]. "Novel High Step-Up DC-DC Converter for Fuel Cell Energy Conversion System"by Shih-Kuen Changchien; Tsorng-Juu Liang; Jiann-FuhChen;Lung-ShengYangin the *IEEE* Transactions on Industrial Electronics, vol.57, no.6, June 2010, pp.2007-2017

[5]. "A Cascaded High Step-Up DC-DC Converter With Single Switch for Microsource Applications,"by Shih-Ming Chen; Tsorng-Juu Liang; Lung-Sheng Yang; Jiann-Fuh Chen Power in the *IEEE* Transactions on Electronics, vol.26, no.4, pp.1146-1153, April 2011

[6]. Omosebi, Ayokunle, Xin GAO, James Landon, Kunlei Liu, Aaron M. Cramer, and Zhiao Li. "Bi-Directional DC/DC Converter Coupled with Capacitive Deionization for Efficient Desalination." In Meeting Abstracts, no. 50, pp. 2293-2293. The Electrochemical Society, 2014.

[7]. J. Dudrik and N. D. Trip "Soft-switching PS-PWM DC-DC converter for full-load range applications", *IEEE* Trans. Ind. Electron., vol. 57, no. 8, pp.2807 -2814 2010

[8]. J. A. Carr , B. Rowden and J. C. Balda "A three-level full-bridge zero-voltage zero-current switching converter with a simplified switching scheme", *IEEE* Trans. Power Electron., vol. 24, no. 2, pp.329 -338 2009

[9]. D. V. Ghodke , K. Chatterjee and B. G. Fernandes "Modified soft-switched three-phase three-level DC/DC converter for high-power applications having extended duty cycle range", *IEEE* Trans. Ind. Electron., vol. 59, no. 9, pp.3362 -3372 2012

[10]. H. Wang , H. S. H. Chung and A. Ioinovici "A class of high-input low-output voltage single-step converters with low voltage stress on the primary-side switches and high output current capacity", *IEEE* Trans. Power Electron., vol. 26, no. 6, pp.1659 -1672 2011

[11]. T. Qian, B. Lehman, "Buck/half-bridge input-series two-stage converter," IET Trans. on Power Elect., Vol.3, No. 6, pp. 965-976, 2010.

[12]. F.Liu, J. Yan, and X. Ruan, "Zero-voltage and zero-current-switching PWM combined three-level DC/DC converter"," *IEEE* Trans. on Ind. Elec., vol.57, pp. 1644 – 1654, 2010.

[13]. Xiaotian Zhang; Green, T.C.; Junyent-Ferre, A, "A New Resonant Modular Multilevel Step-Down DC–DC Converter with Inherent-Balancing," Power Electronics, *IEEE* Transactions on , vol.30, no.1, pp.78,88, Jan. 2015

[14]. Chuanlin Zhang; Junxiao Wang; Shihua Li; Bin Wu; Chunjiang Qian, "Robust Control for PWM-Based DC–DC Buck Power Converters With Uncertainty Via Sampled-Data Output Feedback," Power Electronics, *IEEE* Transactions on , vol.30, no.1, pp.504,515, Jan. 2015

[15]. Engel, S.P.; Stieneker, M.; Soltau, N.; Rabiee, S.; Stagge, H.; De Doncker, R.W., "Comparison of the Modular Multilevel DC Converter and the Dual-Active Bridge Converter for Power Conversion in HVDC and MVDC Grids," Power Electronics, *IEEE* Transactions on , vol.30, no.1, pp.124,137, Jan. 2015

[16]. Gowaid, IA; Adam, G.P.; Massoud, AM.; Ahmed, S.; Holliday, D.; Williams, B.W., "Quasi Two-Level Operation of Modular Multilevel Converter for Use in a High-Power DC Transformer With DC Fault Isolation Capability," Power Electronics, *IEEE* Transactions on , vol.30, no.1, pp.108,123, Jan. 2015

BIIOGRAPHIES OF AUTHORS

Mr.Sreedhar Madichetty graduated in Electrical & Electronics Engg from Jawaharlal Nehru Technological University, Anantapur in the year 2010, post-graduated from Kalinga Institute of Industrial Technology University; Bhubaneswar in Power Electronics and drives in 2012 .He has 2 years of industrial experience and two years of academic experience. At present he is working as a lecturer at BITS, Pilani, Practice school division; India. He has authored more than 20 research papers in the areas of power electronics, Power electronic analysis of electrical machines, power filters, industrial electronics, static VAR compensation, and analysis and digital control of electric drives, Automatic Generation control, and implementation of new optimization techniques.

Dr Chinmoy kumar Panigrahi completed B.Sc. (Engg) in 1990 and M.E. in Electrical Engg with specialization in "Power System Engineering" in 1997 from U.C.E.Burla, (presently VSSUT, Sambalpur), He completed PhD (Engg) in Electrical Engineering in 2007 from Jadavpur University, Kolkata. He was the former reader in EEE Department, B.I.T.Mesra Ranchi. Currently, he is the Professor and Dean, School of Electrical Engineering, KIIT University, Bhubaneswar, Odisha. He has guided 04 nos of PhD Scholars, 26 nos of M.Tech Scholars and 10 nos PhD Scholars are continuing. He has a lot of publication in referred Journal and Conferences. His area of interest is Power System Operation and Control, Power Electronics, soft computing Techniques, Power System restructuring and Renewable Energy systems.

Prof.Abhijit Dasgupta graduated in Electrical Engg from Regional Engineering College (NIT), in the year 1977, post-graduated from Indian Institute of Technology, Kanpur, in Power Electronics in 1980 .He has 21 years of industrial experience and 12 years of academic experience. At present he is Professor, School of Electrical Engineering, KIIT University, and Bhubaneswar, India. He has authored more than 12 research papers in the areas of power electronics, Power electronic analysis of electrical machines, power filters, industrial electronics, static VAR compensation, and analysis and digital control of electric drives, Automatic Generation control, and implementation of new optimization techniques.