Modelling and Simulation of DC-DC Interleaved Boost Converter FED with Renewable Energy (PV) System for High Performance

[1]Sunil Kumar Jain, Member IEEE and [2]Dr. Manish Kumar Srivastava
[1]*Electrical Engineering Department, SHUATS Allahabad, India*
[2]*Electrical Engineering Department, SHUATS Allahabad, India*

Abstract
In the prospect solar energy will be extremely significant energy source. Over 45% of necessary energy in the world will be generated by photovoltaic module. So, it is necessary to focus our forces in order to reduce the application costs and to increase their performances. In order to reach this last aspect, it is important to note that the output characteristic of a photovoltaic module is nonlinear and changes with solar radiation and temperature. Therefore a maximum power point tracking (MPPT) technique is required to track the peak power in order to make full operation of PV array output power under varying conditions. In the power generation sector, Natural Resources like Solar, Wind, Tidal, Geothermal, Hydro etc have forever played a very important role. Out of these solar PV (photo voltaic) is most popular due to its considerable compensation. Conventional boost converter and interleaved boost converter are widely used topologies in photovoltaic systems. However, they have negative sides of varied efficiency level under changed weather conditions. Therefore, this paper proposes, interleaved boost converter with MPPT & novel switch adaptive control to maximize efficiency.

Keywords - *DC-DC Boost Converter,* Interleaved Boost Converter, *Efficiency, Maximum Power Point Tracking (MPPT)* & novel switch adaptive control, *Photovoltaic (PV) System*.

I. INTRODUCTION

Photovoltaic (PV) creation is gaining increased importance as renewable source due to a number of advantages such as absence of fuel cost, low maintenance, and pollution-free operation [1] [2]. The energy productions of PV generators vary significantly depending upon temperature and irradiance. Renewable energy sources with low output voltage, such as the fuel cell stacks and photo-voltaic (PV) generation system, have received a great attention in research fields because they appear to be the possible solutions to the environmental problems [3]-[5].

Energy sources with low output voltage such as fuel cell stacks and photo-voltaic (PV) generation system attracts many researchers because they appear to be the possible solutions to the environmental problems. DC-DC converters are an important component as power electronics interfaces for photovoltaic generators and other renewable energy sources. Most renewable power sources, such as photovoltaic power systems and fuel cells, have quite low-voltage output and require series connection or a voltage booster to provide enough voltage output [6]-[9].

Figure 1 shows a block diagram of used standalone PV system

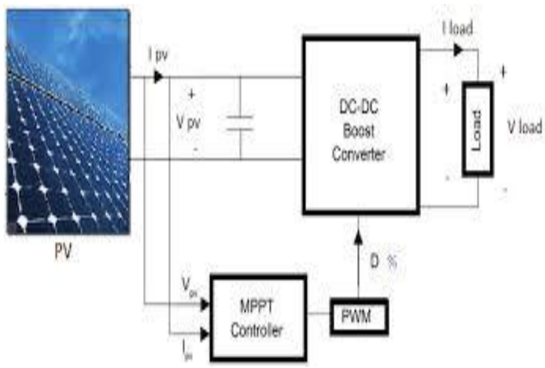


Figure 1: Block diagram of introduced standalone PV system with MPPT controller

In stand-alone PV system applications, it is of much importance that maximum power is extracted from the solar panel and delivered to the load whenever possible. For this reason, a dc-dc power electronic converter is incorporated into the system such that the load is connected to the solar panel through it, controlled by a Maximum Power Point Tracking (MPPT) algorithm. Unfortunately, in practice, the efficiency of the power electronic converter stage is heavily dependent on the operating point of the solar panel which is mainly determined by solar irradiation and temperature [10]. Nature decides whenever irradiation and temperature changes, hence the output power of the solar panel might change at any time.

Due to the non-linear nature of the PV output power, it is of essential that its maximum power which can be obtained from it is tracked at all times and fed to the load. An MPPT is used for tracking the PV maximum power under any operating condition and the dc-dc boost converter is used to step up the voltage and fed to the load. The two main types of dc-dc converter topologies that are predominantly employed in stand-alone PV system are the conventional dc-dc boost converter and interleaved dc-dc boost converter.

One of the two dc-dc boost converters aforementioned offer better efficiency under weak operating point of the solar panel, whilst the other offer improved efficiency under strong operating point of the solar panel [10]. The standalone PV system developed can be used to power TVs, Compact Disc (CD) players, Laptops, etc. A perturbation and observation algorithm is used to guarantee maximum PV power that is generated from the PV panel; also the proposed switch control is used to operate the interleaved boost converter at high efficiency all times under changeable weather [11].

One of the most commonly utilized converter topology in PV applications is the simple boost converter shown in Figure 3. The disadvantages of conventional boost converter are high voltage stress for the switch and large peak current for the power devices and passive components [35]. This problem can be overcome by using an alternative power converter topology, such as an interleaved boost converter [2].

II. PV SYSTEM WITH MPPT

In this paper, an analysis of a PV-fed interleaved boost converter (IBC) has studied. An IBC with two boost converters connected in parallel has considered for this work. The component of the studied system include the PV panel, a boost converter (conventional or IBC), load, maximum power point tracking (MPPT) using the Perturb and Observe (P&O) algorithm method and maximum power point tracking (MPPT) using the Perturb and Observe (P&O) algorithm method with novel switch adaptive control .

III. MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking, frequently referred to as MPPT, operates Solar PV modules in a manner that allows the modules to produce all the power they are capable of generating. MPPT algorithms are used to obtain the maximum power from the solar array based on the variation in the irradiation and temperature. Among several techniques, the Perturb and Observe (P&O) method and the Incremental Conductance (IC) algorithm are the most commonly applied algorithms. The flow chart is explaining Perturb and Observe (P&O) method as

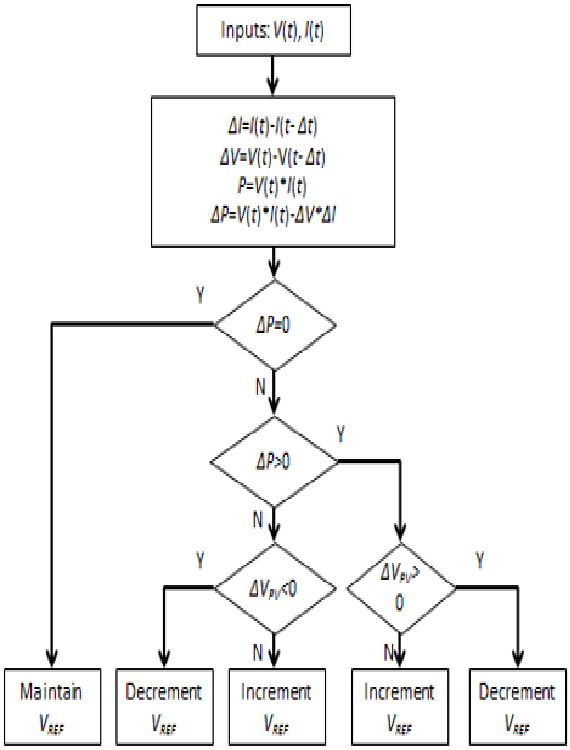


Figure 2: Flow chart of perturb and observe method

IV. DC-DC BOOST CONVERTER

In a boost converter, the output voltage is greater than the input voltage – hence the name “boost”. A boost converter is shown below:

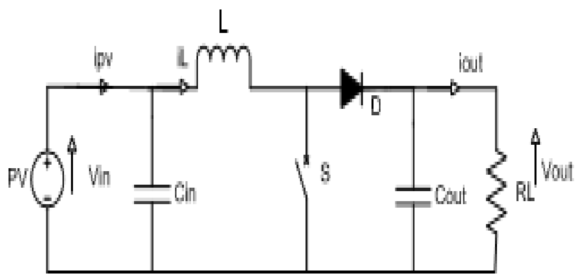


Figure 3: Circuit diagram of Conventional Boost Converter

Power for the boost converter can taken from any suitable DC sources, such as DC generators, batteries, solar panels and rectifiers. The method that changes one DC voltage to a different DC voltage is called DC to DC conversion. Generally, a boost converter is a DC to DC converter with an output voltage greater than the source voltage. It is sometimes called a step-up converter since it "steps up" the source voltage. Since power (P = V I) must be conserved, the output current is lower than the source current. [10]

The function of boost converter can be divided into two modes, Mode 1 and Mode 2. Mode 1 begins when switch 1 is switched on at time t=0. The input current rises and flows through inductor L and switch 1.

Mode 2 begins when switch 1 is switched off at time t = t1. The input current now flows through L, C, load, and diode D. The inductor current falls until the next cycle. The energy stored in inductor L flows through the load.

$$V_{out} = V_{in} / (1- D)$$

So, it is clear that the output voltage is related directly to the duty cycle. The main challenge when designing a converter is
the sort of inductor to be used. The inductance is inversely proportional to the ripple current. So, to reduce the ripple, a larger inductor should be used. [11] [12]

III. DC-DC INTERLEAVED BOOST CONVERTER

A two phase interleaved boost converter is mainly used in high input to high output voltage conversion applications and also the interleaved boost converter is used to reduce the current ripple in both input and output. In interleaved boost converter the number of phases is increased with the ripple content in input the complexity of the circuit is increased thereby the cost of implementation also increasing [13].

Therefore to minimize the ripples, size and cost of input filter a two phase Interleaved boost converter fed photovoltaic generation system is simulated using MATLAB/Simulink software in this paper.

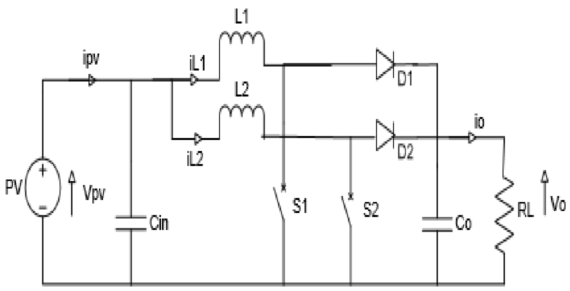


Figure 3: Circuit diagram of Interleaved Boost Converter

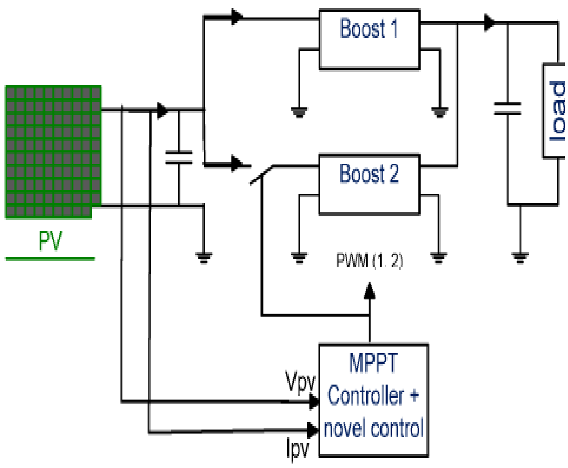


Figure 4: Block diagram of introduced standalone PV system with MPPT & Novel switch adaptive control

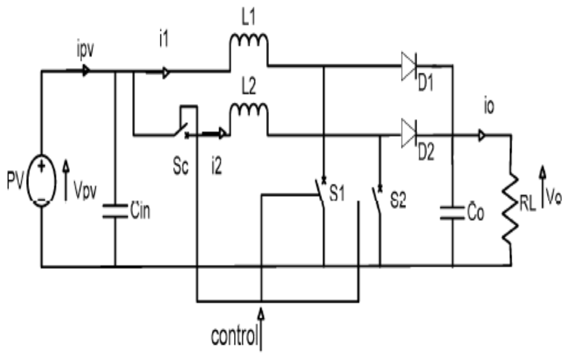


Figure 5: Interleaved boost converter with novel switch adaptive control

The advantages of interleaved boost converters are reducing input current ripple, increasing efficiency, improving reliability etc. The number of switching devices, number of inductors and diodes are same as the number of phases used in the circuit [14]. The circuit diagram of two phase interleaved boost converter is shown in figure 3. The gating pulses of the power electronic switches are shifted by,

$$360^\circ/n$$

Where 'n' is the number of phases

$$360^\circ/2 = 180^\circ$$

The controller has several advantages; it minimizes system losses, and helps the interleaved converter to operate with maximum power conversion efficiency at all times, and under a wide range of atmospheric conditions. Moreover, the control scheme can be achieved with no significant additional hardware and, in terms of microprocessor implementation it is computationally light [15-34].

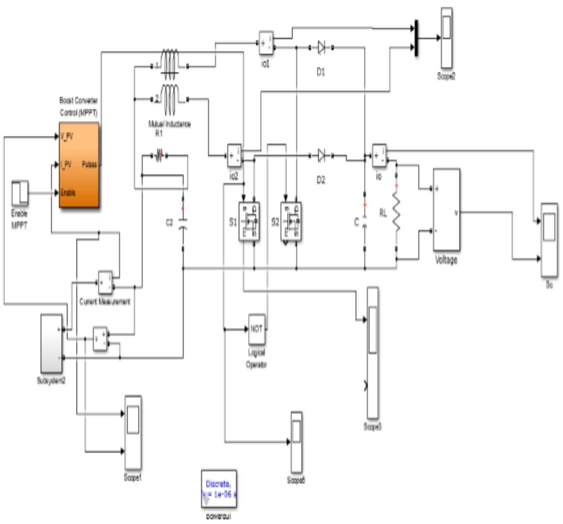


Figure 6: MATLAB Simulation Model of Interleaved Boost Converter

PV module parameter
At Irradiation G = 1000 w/m^2, Temperature T=25^{0}C, P_{mp} = 50 W, I_{sc} = 3.07 A , V_{oc} = 22.1 V , I_{mp} = 2.8 A , V_{mp} = 17.9 V.

IV. SIMULATION RESULT & ANALYSIS

Table 1: Simulation Model Parameter of Conventional Boost Converter with MPPT Controller

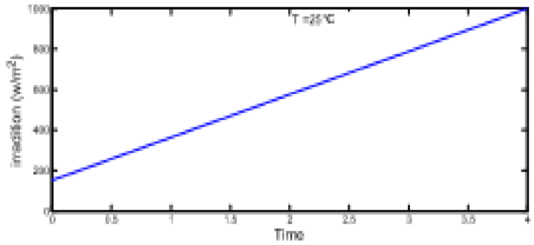
S. No	Parameters for an BC	Value
1.	Switching Frequency	20kHz
2.	Inductor (L)	1mH
3.	Capacitor (C_{in} & C_{out})	9.4 µF & 44 µF
4.	Resistance (R)	195Ω
5.	Switching devices	MOSFET
6.	Switching devices	Diode

Table 2: Simulation Model Parameter of Interleaved Boost Converter with MPPT Controller

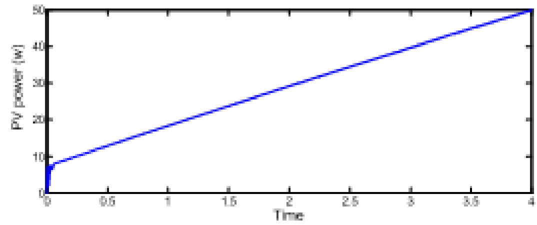
S. No	Parameters for an IBC	Value
1.	Switching Frequency	20kHz
2.	Inductor (L_1 & L_2)	1mH
3.	Capacitor (Cin & Cout)	9.4 µF & 44 µF
4.	Resistance (R)	195Ω
5.	Switching devices	2*MOSFET
6.	Switching devices	2*Diode

Table 3: Simulation Model Parameter of Interleaved Boost Converter with MPPT & Novel switch adaptive control

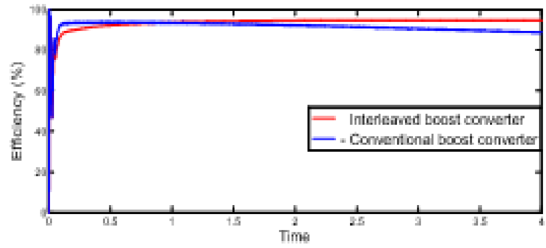
S. No	Parameters for an IBC	Value
1.	Switching Frequency	20kHz
2.	Inductor (L_1 , L_2)	1mH
3.	Capacitor (C_{in} & C_{out})	9.4 µF & 44 µF
4.	Resistance (R)	195Ω
5.	Switching devices	2*MOSFET
6.	Switching devices	2*Diode
7.	Switch-connection (Sc)	MOSFET



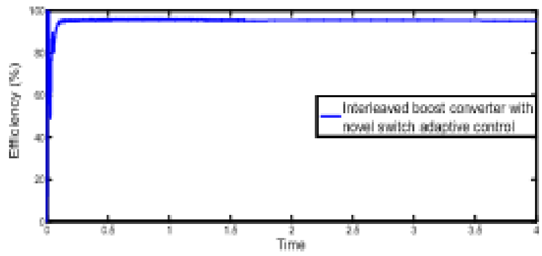
(a)



(b)



(c)



(d)

Figure 7: The PV system with resistive load (a) Irradiation in rise with 25˚C; (b) Solar panel power under increasing irradiation; (c) Efficiency of conventional and interleaved boost converters; (d) Efficiency of interleaved boost converters with novel switch adaptive control

The simulation result has shown the efficiency performance of presented converters under change in irradiation condition. The presented converters are simulated with resistive load 195 Ohm and supplied by a solar array rated at 50 Watts maximum with a rising irradiation profile as shown in figure 7(a) and figure 7 (b). As can be seen in figure 7(c), the conventional boost shows a reduction in efficiency when the PV power reaches approximately 24 Watts, whilst the interleaved boost still shows an improving efficiency characteristic when the PV power increase. Figure 7(d) shows that the interleaved boost converter with novel switch adaptive control has a stable efficiency of around 95%.

V. CONCLUSION

The efficiency of a interleaved boost converter with novel switch adaptive control has improved in photovoltaic system under changeable irradiation condition. The interleaved boost converter circuit has extremely attractive characteristics, such as low current ripple at the input and output stages, low device stress. In this paper, an analysis of a PV-fed conventional boost converter, interleaved boost converter (IBC) and interleaved boost converter (IBC) with novel switch adaptive control has studied.

VI. ACKNOWLEDGEMENT

The authors would like to show gratitude to Motilal Nehru National Institute of Technology Allahabad and Indian Institute of Technology (Banaras Hindu University) Varanasi for its valuable supports when this research is conducted and this manuscript is prepared.

REFERENCES

[1] Chihchiang, H., Jongrong, L. and Chihming, S. (1998) Implementation of a DSP-Controlled Photovoltaic System with Peak Power Tracking. IEEE Transactions on Industrial Electronics , 45, 99-107.

[2] Veerachary, M., Senjyu, T. and Uezato, K. (2003) Neural Network-Based Maximum- Power-Point Tracking of Coupled-Inductor Interleaved-Boost-Converter-Supplied PV System Using Fuzzy Controller. IEEE Transactions on Industrial Electronics,50,749-758.

[3] Cacciato M., Consoli A., Attanasio R., and Gennaro F. 2006. A multi-stage converter for domestic generation systems based on fuel cells. In Proc. IEEE Ind. Appl. Soc. Conf., vol. 1, pp. 230–235.

[4] Veerachary M., Senjyu T., and Uezato K. 2003. Neural-network based maximum-power-point tracking of coupled-inductor interleaved-boost converter- supplied PV system using fuzzy controller. In IEEE Trans. Ind. Electron., vol. 50, no. 4, pp. 749 – 758.

[5] Wang D., He X., and Zhao R. 2008. ZVT Interleaved Boost Converters with Built-In Voltage Doubler and Current Auto-Balance Characteristic. In IEEE Trans. Power Electron.,vol. 23, no. 6, pp.2847–2854.

[6] Kobayashi K., Matsuo H., and Sekine Y., 2006. Novel solar-cell power supply system using a multiple-input DC–DC converter. In IEEE Trans. Ind. Electron., vol. 53, no. 1, pp. 281–286.

[7] Mazumder S. K., Burra R. K., and Acharya K., 2007. A ripple mitigating and energy-efficient fuel cell power-conditioning system. In IEEE Trans. Power Electron. , vol. 22, no. 4, pp. 1437–1452.

[8] Hsieh Y., Hsueh T., and Yen H. 2009. An Interleaved Boost Converter With Zero-Voltage Transition. In IEEE Trans. Power Electron., vol. 24, no. 4., pp. 973–978.

[9] Wang C.M. 2006. A new single-phase ZCS-PWM boost rectifier with high power factor and low conduction losses. In IEEE Trans. Ind. Electron., vol. 53, no. 2, pp. 500–510.

[10] A.Berasategi , C. Cabal, C. Alonso and B. Estibals. “European Efficiency Improvement In Photovoltaic Applications By Means Of Parallel Connection Of Power Converters”, UPS, INSA, INP, ISAE; LAAS; F-31077 Toulouse, France, 2009. pp 1, 4-5.

[11] D.M.Mitchell, “DC-DC Switching Regulator Analysis”, New York: McGraw-Hill, 1988.

[12] Muhammad H. Rashid, “Power Electronics, Circuits, Devices, and Applications”, Third Edition, Pearson Education, Inc., 2004.

[13] Seyezhai and Mathur ‗Analysis, design and experimentation of interleaved boost converter for fuel cell power source‘, International Journal of Research and Reviews in information sciences, Vol. 1, No. 2, pp: 62 -66 2011.

[14] S.Sumalatha and D. Kavitha “Two phase interleaved DC-DC converter”, International Journal of Electrical and Electronics Engineering (IJEEE) Vol.1, Issue 1 Aug 2012, pp.67-82.

[15] Dolara, A., Faranda, R. and Leva, S. (2009) Energy Comparison of Seven MPPT Techniques for PV Systems. Journal of Electromagnetic Analysis and Applications , 1, 152-162.

[16] Chih-Yu, Y., Chun-Yu, H., Fu-Kuei, F. and Ke-Horng, C. (2012) Highly Efficient Analog Maximum Power Point Tracking (AMPPT) in a Photovoltaic System. IEEE Transactions on Circuits and Systems I : Regular Papers, 59, 1546-1556.

[17] Esram, T. and Chapman, P.L. (2007) Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. IEEE Transactions on Energy Conversion , 22, 439-449.

[18] Faranda, R. and Leva, S. (2008) Energy Comparison of MPPT Techniques for PV Systems. Wseas Transactions on Power S ystems , 3, 447-455.

[19] Sera, D., Kerekes, T., Teodorescu, R. and Blaabjerg, F. (2006) Improved MPPT Method for Rapidly Changing Environmental Conditions. IEEE International Symposium on Industrial Electronics, 2, 1420-1425.

[20] Yu, W.S., Qian, H. and Lai, J.-S (2010) Design of High-Efficiency Bidirectional DC-DC Converter and High-Precision Efficiency Measurement. IEEE Transactions on Power Electronics, 25, 650-658.

[21] Berasategi, A., Cabal, C., Alonso, C. and Estibals, B. (2009) European Efficiency Improvement in Photovoltaic Applications by Means of Parallel Connection of Power Converters. Proceedings of the 13 th European Conference on Power Ele ctronics and Applicati ons , 8-10 September 2009, 1-10.

[22] Sarnago, H., Mediano, A. and Lucia, O. (2012) High Efficiency AC-AC Power Electronic Converter Applied to Domestic Induction Heating. IEEE Transactions on Power Electronics , 27, 676-3684.

[23] Qun, Z. and Lee, F.C. (2003) High-Efficiency, High Step-Up DC-DC Converters. IEEE Transactions on Power Electronics , 18, 65-73.

[24] Dwari, S. and Parsa, L. An Efficient High-Step-Up Interleaved DC-DC Converter with a Common Active Clamp. IEEE Transactions on Power Electronics , 26, 66-78.

[25] Li, W.H., Zhao, Y., Deng, Y. and He, X.N. (2010) Interleaved Converter with Voltage Multiplier Cell for High Step-Up and High-Efficiency Conversion. IEEE Transactions on Power Electronics, 25, 2397-2408.

[26] Watanabe, K., Campelo, F., Iijima, Y., Kawano, K., Matsuo, T., Mifune, T. and Igarashi, H. (2010) Optimization of Inductors Using Evolutionary Algorithms and Its Experimental Validation. IEEE Transactions on Magnetics, 46, 3393-3396.

[27] Kobayashi, Y., Ishibashi, S., Shirakawa, K., Toriu, J., Matsuki, H. and Murakami, K. (1992) New Type Micro Cloth-Inductor and Transformer with Thin Amorphous Wires and Multi-Thin Coils. IEEE Transactions on Magnetics , 28, 3012-3014.
[28] Eyssa, Y.M., Abdelsalam, M.K., Boom, R.W., Huang, X., McIntosh, G.E. and Waynert, J. (1989) Design and Optimization of Hydrogen Cooled Pulsed Storage Inductors for Electromagnetic Launchers. IEEE Transactions on Magnetics , 25, 174-179.
[29] Kulkarni, J.P., Augustine, C., Byunghoo, J. and Roy, K. (2010) Nano Spiral Inductors for Low-Power Digital Spintronic Circuits. IEEE Transactions on Magnetics ,46, 1898-1901.
[30] Weitzel, C.E., Palmour, J.W., Carter, C.H., Moore, J.K., Nordquist, K.K., Allen, S., Thero, C. and Bhatnagar, M. (1996) Silicon Carbide High-Power Devices. IEEE Transactions on Electron Devices ,43, 1732-1741.
[31] Wa, L.P., Yim, S.L., Cheng, D.K.W. and Xiu, L.C. (2000) Steady-State Analysis of an Interleaved Boost Converter with Coupled Inductors. IEEE Transactions on Indu strial Electronics ,47, 787-795.
[32] Veerachary, M., Senjyu, T. and Uezato, K. (2003) Maximum Power Point Tracking of Coupled Inductor Interleaved Boost Converter Supplied PV System. IEE E Pr oceedings of Electric Power Applications ,
[33] 150, 71-80.
[34] Bidoggia, B., Spiazzi, G., Buso, S., Lequeu, T. and Ventura, L. (2008) Design of a Fuel Cell Based Backup System for Telecoms Applications. Proceedings of IEEE 30 th International in Telecommunications Energy Confer ence , 2008, 1-8.
[35] Seyezhai, R. (2011) Design Consideration of Interleaved Boost Converter for Fuel Cell Systems. SSN College of Engineering, Chennai.
[36] Wa, L.P., Yim, S.L., Cheng, D.K.W. and Xiu, L.C. (2000) Steady-State Analysis of an Interleaved Boost Converter with Coupled Inductors. IEEE Transactions on Indu strial Electronics, 47, 787-795.

AUTHORS PROFILE

Mr. Sunil Kumar Jain He is persuing Ph.D. from electrical engg. Deptt. at SIET , AAIDU (SHUATS) Allahabad. He published some technical papers in countries journals & conferences . He is a member of IEEE. He has four year of teaching experinece. He received his M.Tech with Power Electronics & ASIC Design from MNNIT Allahabad in 2011. He received his B.Tech with Electrical Engg. from M.M.M. Engg. College Gorakhpur in 2009.

Dr. Manish Kumar Srivastava He is a head of department in electrical engg. , SIET , SHUATS. He published several technical papers in leading countries journals. He authored technical book in the field of instrumentation . He has several year of teaching experinece. He was Director of MVIET & AIET Allahabad approximately four year.He is an associate professor in electrical engg. Deptt. at AAIDU (SHUATS), Allahabad. He received his Ph.D. from AAIDU (SHUATS), Allahabad in 2009. He received his M.Tech from MNNIT Allahabad in 2005. He received his B.E. from Magadh University, Bodhgya in 2001.