

A Simple and Efficient Interleaved Buck Converter for Battery Charging Application

S.LakshmiPriya¹, R.K Raghav², M.Muruganandam³, S.Saravanan³

PG Student, Dept. of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India ¹

Assistant Professor, Dept. of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India ²

Professor, Dept. of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India ³

ABSTRACT: This paper proposes a simple and efficient interleaved buck converter (IBC) having low switching losses and improved step-down conversion ratio, which is suitable for photovoltaic battery charging application where the input voltage is high. It is similar to the conventional IBC, but in proposed IBC the two active switches are connected in series and a coupling capacitor is connected in the power path such as cuk ,sepic and zeta converters. The proposed IBC shows that the voltage stress across all the active switches is half of the input voltage before turn-on or after turnoff when the operating duty is below 50%. The capacitor charging and discharging depends upon the turn on and turn off operation of the switches and switching losses can be reduced considerably.

This allows the proposed IBC to have higher efficiency and operate with higher switching frequency. By operating with the higher switching frequency, the proposed IBC has a higher step-down conversion ratio and a smaller output current ripple compared with a conventional IBC. The features, operation principles and relevant analysis results of the proposed IBC are presented in this paper. The validity of this study is confirmed by the experimental results of prototype converters with 38-45V input, 12V/1.9A output.

I. INTRODUCTION

In applications with the improved step-down conversion ratio, and high output current with low ripple are required, an interleaved buck converter (IBC) has received a lot of attention due to its simple structure [1]-[6]. However, the conventional IBC shown in the fig .1.1. All semiconductor devices suffer from the input voltage, and hence high-voltage devices rated above the input voltage should be used. High-voltage-rated devices have generally poor characteristics such as high cost, high on resistance, high forward voltage drop, severe reverse recovery, etc. In addition, the converter operates under hard switching condition. Thus, the cost becomes high and the efficiency becomes poor. And, for higher power density and better dynamics, it is required that the converter operates at higher switching frequencies [7].

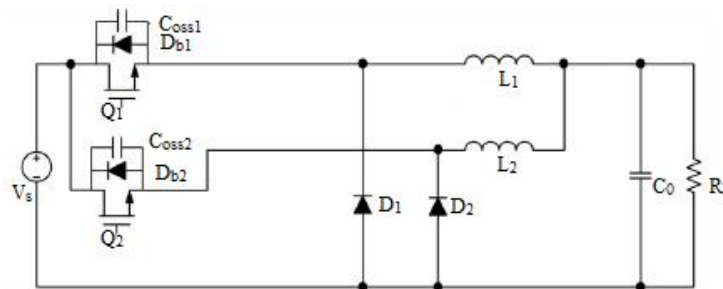


Fig .1.1 Conventional Interleaved Buck Converter

To overcome the afore mentioned drawbacks of the conventional IBC [8]-[10] in three-level buck converters are introduced. The voltage stress is half of the input voltage in the converters. However, so many components are required for the use of IBC. An IBC with a single-capacitor turn-off snubber is introduced [11]. Its advantages are that

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

the switching loss associated with turn-off transition can be reduced, and single coupled inductor implements the converter as two output inductors. An IBC with active-clamp circuits is introduced in order to avoid discontinuous mode of operation and reducing losses [12]. In the converter, all active switches are turned ON with zero-voltage switching (ZVS). In addition, a high step-down conversion ratio can be obtained and the voltage stress across the freewheeling diodes can be reduced. An IBC with zero-current transition (ZCT) is introduced to reduce diode reverse recovery losses. The ZCT is implemented by only adding an inductor into the conventional IBC. However, in spite of these advantages, the converter suffers from high current stress, because the output current flows through each module in a complementary way. And it still has the drawbacks of the conventional IBC.

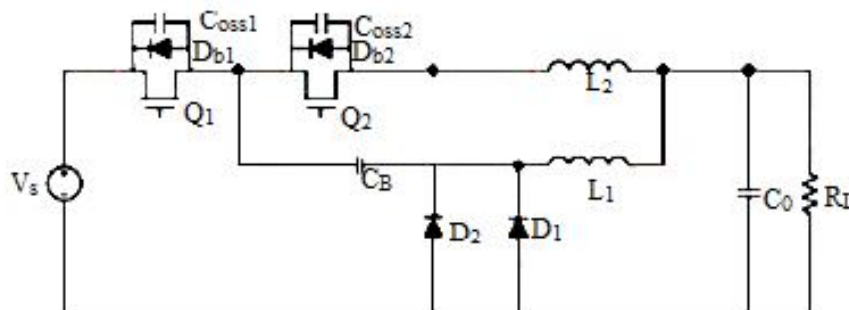


Fig.1.2 Proposed Interleaved Buck Converter

An IBC with two winding coupled inductors is introduced [13]-[14]. The converter has the following advantages. Since it operates at continuous conduction mode (CCM), the current stress is lower than that of DCM IBC. The voltages across all semiconductor devices can be reduced by adjusting the turn ratio of the coupled inductors, which allows that although it operates with hard switching, the switching losses can be reduced and the proposed IBC is shown in the fig .1.2. Additionally, a high step-down conversion ratio can also be obtained.

II. BLOCK DIAGRAM

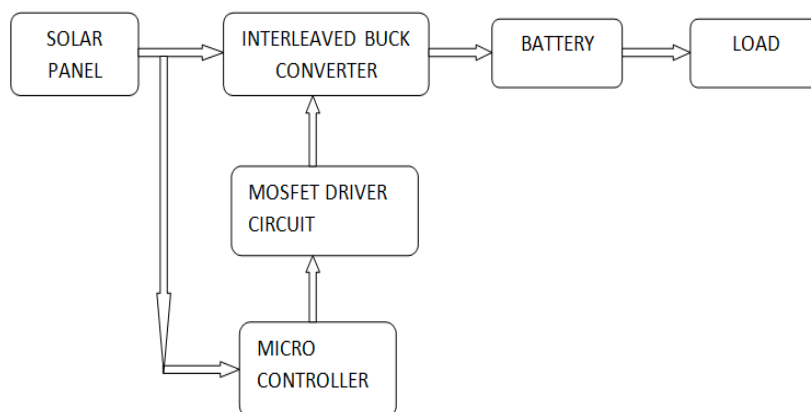


Fig .2.1 Block diagram of interleaved buck converter

The fig .2.1 shows the block diagram of interleaved buck converter and it explains as follows. From the solar panel only the voltage and current is sensed and the calculated output is given to the converter and the microcontroller. The microcontroller generates the triggering angle to the driver circuit and it generates gate pulse to the switches in the converter circuit. Finally the output is stored in the battery for future applications.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

III. MODES OF OPERATION

Mode I:

Mode 1 begins when Q_1 is turned ON. Then the current of L_1 (i_{L1}) flows through Q_1 , C_B and L_1 and the voltage of the coupling capacitor V_{cb} is charged. The current of L_2 (i_{L2}) freewheels through D_2 . During mode 1 the voltage across L_1 (V_{L1}) is the difference of the input voltage V_s , the voltage of the coupling capacitor V_{cb} , and the output voltage V_o , and its level is positive. Hence, i_{L1} increases linearly from the initial value. The voltage across L_2 (V_{L2}) is the negative output voltage. The mode operation is shown in the fig. Hence, i_{L2} decreases linearly from the initial value. The voltage across Q_2 (V_{Q2}) becomes the input voltage and the voltage across D_1 (V_{D1}) the difference of V_s and V_{cb} .

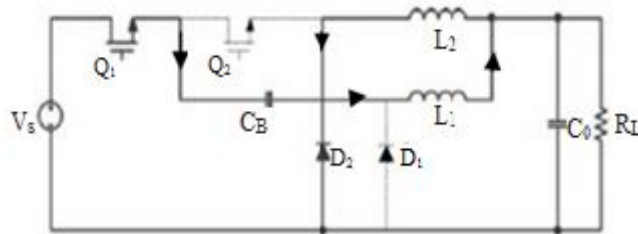


Fig .3.1 Operation of Mode 1

MODE II:

Mode 2 begins when Q_1 is turned OFF. Then the current of L_1 (i_{L1}) and L_2 (i_{L2}) freewheels through diode D_1 and D_2 respectively. Both V_{L1} and V_{L2} become the negative V_o . And hence i_{L1} and i_{L2} decreases linearly. During this mode the voltage across Q_1 (V_{Q1}) is equal to the difference of V_s and V_{cb} . And V_{Q2} becomes V_{cb} and it is shown in the fig.3.2.

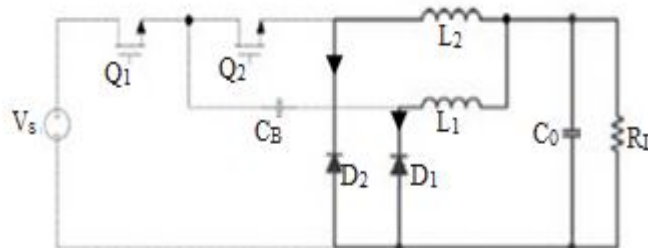


Fig .3.2 Operation of Mode 2

Mode III

Mode 3 begins when Q_2 is turned ON. Then the current of L_1 (i_{L1}) freewheels through D_1 and the current of L_2 (i_{L2}) flows through D_1 , C_B , Q_2 and L_2 . Thus the V_{cb} is discharged. During this mode, V_{L2} is equal to the difference of V_{cb} and V_o and its level is positive. Here i_{L2} increases linearly and i_{L1} decreases linearly. Hence the V_{L1} is the negative V_o .

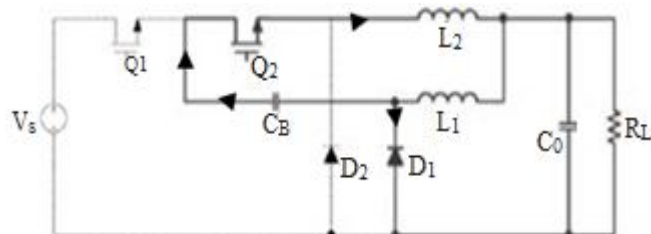


Fig .3.3 Operation of Mode 3

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

MODE IV

Mode 4 operates as mode 2.

IV. MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking (MPPT) algorithm is widely used control technique that varies the electrical operating point to extract maximum power available from the solar cell of photovoltaic (PV) module. By using an intelligent algorithm, it ensures that the PV module always operates at its maximum power point. Several MPPT algorithms have been proposed in different literatures like Perturb & Observe (P&O), Incremental Conductance, Constant Voltage, Constant Current and fuzzy based algorithms.

MPPT TECHNIQUE	SPEED VARIATION	IMPLEMENTATION COMPLEXITY	SENSING PARAMETERS
Perturb & Observe (P&O)	Varies	Low	Voltage
Incremental Conductance	Varies	Medium	Voltage , current
Constant Voltage	Medium	Low	Voltage
Constant Current	Medium	Medium	Current

Table 4.1 Comparison between MPPT techniques

i) Perturb & Observe

Perturb & Observe (P&O) is one of the simplest method. By using only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost is less and hence it is easy to implement.

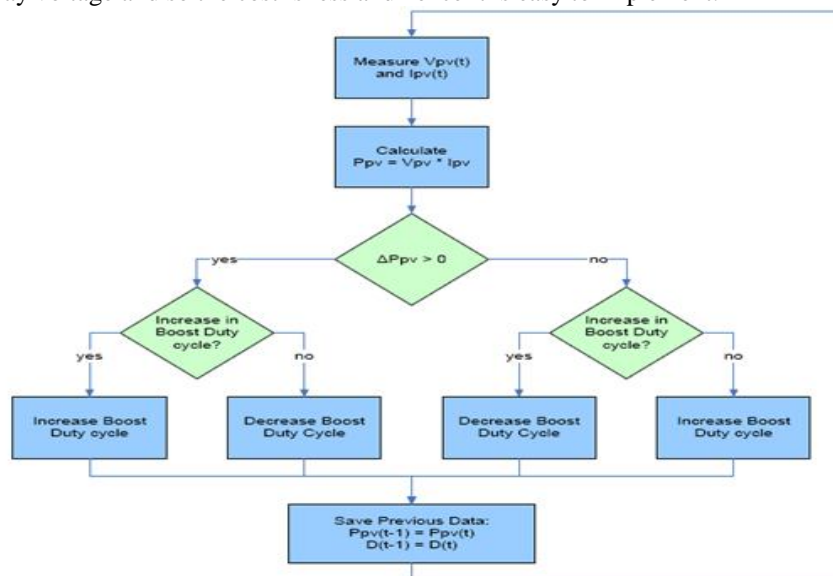


Fig.4.1 P & O algorithm

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Perturb & Observe (P &O) algorithm's time complexity is very less but on reaching very close to the Maximum power point(MPP) it doesn't stop at the MPP and continuously works in both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm. Therapid change of irradiation level (due to which MPPT changes) was not taken into an account and ends up with a wrong calculation due to the change in MPP because of perturbation. To avoid this problem another algorithm incremental conductance method was introduced. In this algorithm a slight perturbation is introduced in the system. The perturbation changes the power of the module. The perturbation is continued in the same direction, if the power of the system increases due to its perturbation. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses [20-21]. In this method, the device (controller/inverter) adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. In this Fig.4.1 shows the P & O even though this method is very common, this method can result in oscillations of output power. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Due to the ease of implementation Perturb and observe is the most commonly used in MPPT's method. This method results in top -level efficiency, which provided a proper predictive and adaptive hill climbing strategy is also adopted.

ii) PV curve

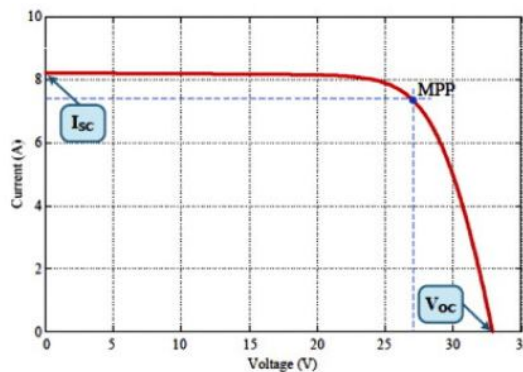


Fig 4.2 Model PV Characteristic curve

A PV array under constant uniform irradiance has a current–voltage (I–V) characteristic as shown in the fig.4.2. After reaching the maximum power the current starts to decrease with slight increase in voltage. The maximum power point voltage and current is 7.5A and 27V respectively.

V.SIMULATION AND RESULTS

This is an effort to understand the behaviour of the system by means of a graphical representation, which essentially consists of representations of individual components of the system together with the signal flow between these components. A graphical interface is used to convert a block diagram directly into Simulink and simulate the operation of the system. We note that a well-grounded use of Simulink requires some knowledge of control technology and systems theory.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

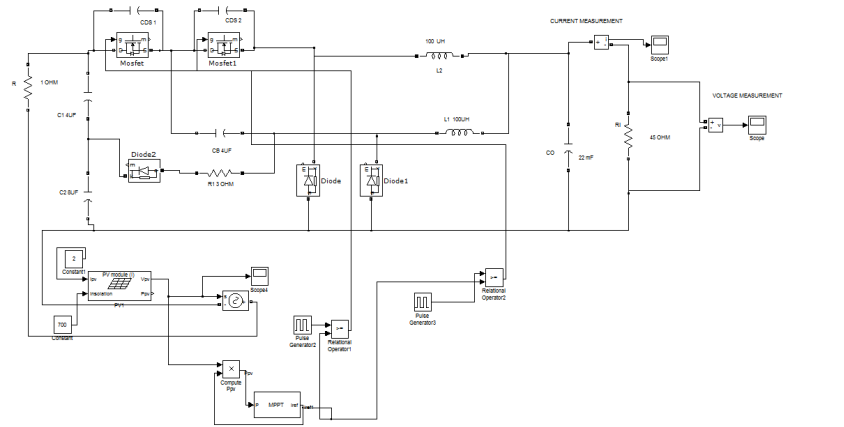


Fig .5.1 Simulation Circuit Diagram

The fig.5.1 shows the simulation circuit for interleaved buck converter for battery charging application. The table 5.1 shown the input and output values.

INPUT VOLTAGE	38 VOLTS
OUTPUT VOLTAGE	12 VOLTS
OUTPUT CURRENT	1.9A
CAPACITOR VALUE	22µF
INDUCTION VALUE	100µH

Table.5.1 Input and output values

The fig.5.2 shows the input values from the pv panel.

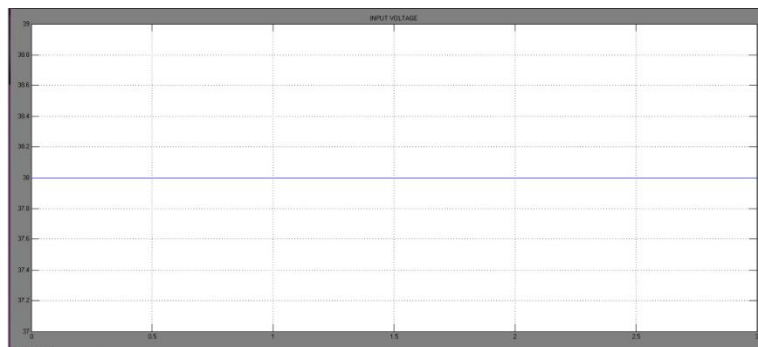


Fig.5.2 Input Voltage

The output voltage is reduced to 12V from 38V input and it is used for battery charging applications.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

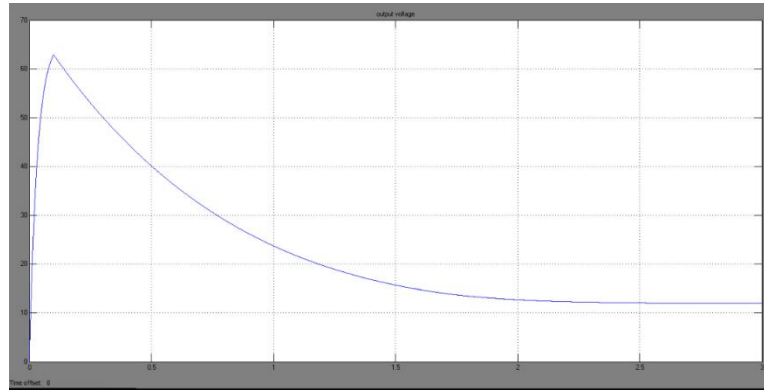


Fig.5.3 Output Voltage

The fig.5.4 shows the output current of the PV system

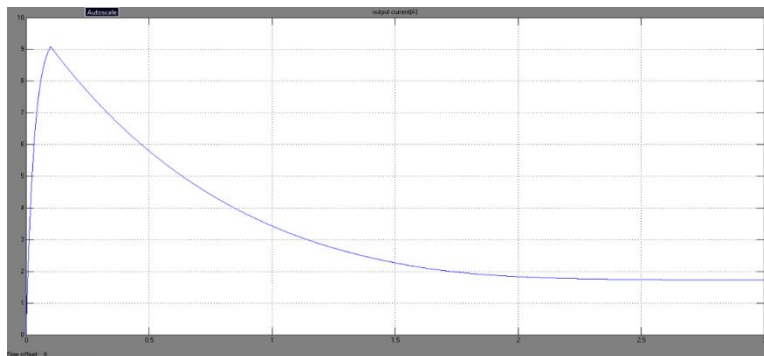


Fig.5.4 Output Current

VI.CONCLUSION

Thus a new Interleaved Buck Converter is proposed in this paper. The main advantage of the proposed IBC is that since the voltage stress across active switches is half of the input voltage before turn-on or after turn-off when the operating duty is below 50%, the capacitive discharging and switching losses can be reduced considerably. Since the voltage stress of the freewheeling diodes is half of the input voltage in the steady state and can be quickly reduced below the input voltage during the cold startup, the use of lower voltage-rated diodes is allowed. From these results, the efficiency of the proposed IBC is higher than that of the conventional IBC and the improvement gets larger as the Switching frequency increases. Moreover, it is confirmed that the proposed IBC has a higher step-down conversion ratio and a smaller inductor current ripple than the conventional IBC. Therefore, the proposed IBC becomes attractive in applications where non isolation, step-down conversion ratio with high input voltage, high output current with low ripple, higher power density, and low cost are required.

REFERENCES

- [1] P. L. Wong, P. Xu, B. Yang, and F. C. Lee, "Performance improvements of interleaving VRMs with coupling inductors," IEEE Trans. PowerElectron., vol. 168, no. 4, pp. 499–507, Jul. 2001.
- [2] R. L. Lin, C. C. Hsu, and S. K. Changchien, "Interleaved four-phase buck-based current source with isolated energy-recovery scheme for electrical discharge machine," IEEE Trans. Power Electron., vol. 24, no. 7, pp. 2249–2258, Jul. 2009.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

- [3] C. Garcia, P. Zumel, A. D. Castro, and J. A. Cobos, "Automotive DC-DC bidirectional converter made with many interleaved buck stages," *IEEE Trans. Power Electron.*, vol. 21, no. 21, pp. 578-586, May 2006.
- [4] J. H. Lee, H. S. Bae, and B. H. Cho, "Resistive control for a photovoltaic battery charging system using a microcontroller," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2767-2775, Jul. 2008.
- [5] Y. C. Chuang, "High-efficiency ZCS buck converter for rechargeable batteries," *IEEE Trans. Ind. Electron.*, vol. 57, no. 7, pp. 2463-2472, Jul. 2010.
- [6] C. S. Moo, Y. J. Chen, H. L. Cheng, and Y. C. Hsieh, "Twin-buck converter with zero-voltage-transition," *IEEE Trans. Ind. Electron.*, vol. 58, no. 6, pp. 2366-2371, Jun. 2011.
- [7] X. Du and H. M. Tai, "Double-frequency buck converter," *IEEE Trans. Ind. Electron.*, vol. 56, no. 54, pp. 1690-1698, May 2009.
- [8] K. Jin and X. Ruan, "Zero-voltage-switching multiresonant three-level converters," *IEEE Trans. Ind. Electron.*, vol. 54, no. 3, pp. 1705-1715, Jun. 2007.
- [9] J. P. Rodrigues, S. A. Mussa, M. L. Heldwein, and A. J. Perin, "Threelevel ZVS active clamping PWM for the DC-DC buck converter," *IEEE Trans. Power Electron.*, vol. 24, no. 10, pp. 2249-2258, Oct. 2009.
- [10] X. Ruan, B. Li, Q. Chen, S. C. Tan, and C. K. Tse, "Fundamental considerations of three-level DC-DC converters: Topologies, analysis, and control," *IEEE Trans. Circuit Syst.*, vol. 55, no. 11, pp. 3733-3743, Dec. 2008.
- [11] Y. M. Chen, S. Y. Teseng, C. T. Tsai, and T. F. Wu, "Interleaved buck converters with a single-capacitor turn-off snubber," *IEEE Trans. Aerosp. Electronic Syst.*, vol. 40, no. 3, pp. 954-967, Jul. 2004.
- [12] C. T. Tsai and C. L. Shen, "Interleaved soft-switching coupled-buck converter with active-clamp circuits," in *Proc. IEEE Int. Conf. Power Electron and Drive Systems.*, 2009, pp. 1113-1118.
- [13] K. Yao, Y. Qiu, M. Xu, and F. C. Lee, "A novel winding-coupled buck converter for high-frequency, high-step-down DC-DC conversion," *IEEE Trans. Power Electron.*, vol. 20, no. 5, pp. 1017-1023, Sep. 2005.
- [14] K. Yao, M. Ye, M. Xu, and F. C. Lee, "Tapped-inductor buck converter for high-step-down DC-DC conversion," *IEEE Trans. Power Electron.*, vol. 20, no. 4, pp. 775-780, Jul. 2005.
- [15] M. Muruganandam M. Kirubavathi, G. Dineshkumar, "Fault Current and Overvoltage Limitation in a Distribution Network with Distributed Generation units Through Superconducting Fault Current Limiter", *International Journal of Engineering Research & Technology*, vol.3 , issue. 11, pp. no. 1442-1445, Nov. 2014
- [16] S.Ramkumar and M.MuruganandamS.Saranraj, A.Sasipriya, "A Voltage Controlled PFC SEPIC Converter Based PMBL DCM Drive for Air - Conditioners Using Fuzzy Controller", *International Journal of Advanced and Innovative Research*, vol. 3, issue. 11, pp. no. 358-362, Dec. 2012
- [17] M.MuruganandamHarisNaveena.C , S.Dhanapriya," Evaluation of Diabetic Macular Edema From Color Retinal Images", *International Journal of Advanced and Innovative Research*, vol.3, issue.12, pp.no, 284-287, dec.2014
- [18] J Vinoth, T Muthukumar, M Muruganandam," Implementation of Distributed Maximum Power Point Tracking for Partially Shaded PV Systems", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol.4, issue,2, pp. 702-709, feb.2015
- [19] P Ranjitha, V Dhinesh, M Muruganandam," Soft Switching with Cascaded Transformers to Drive the PMDC Motor", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol.4, issue,2, pp. 787-794, feb.2015
- [20] G Maruthaipandian, S Ramkumar, M Muruganandam," Design and Implementation of BLDC Motor Using Regenerative Braking for Electric Vehicle", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol.4, issue,2, pp. 694-701, feb.2015
- [21] S LakshmiPriya, RK Raghav, M Muruganandam," A Thirteen Level Inverter Design Based on Hybrid MLI Topology for Minimum THD", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol.4, issue,2, pp. 976-983, feb.2015