

Design and Implementation of Non-Isolated Full Bridge LLC Resonant Converter

Meera M¹, Vinoth J¹, Muruganandam M²

PG Scholar, Department of EEE, Muthayammal Engineering College, Rasipuram, Namakkal, Tamilnadu, India ¹

Professor, Department of EEE, Muthayammal Engineering College, Rasipuram, Namakkal, Tamilnadu, India ²

ABSTRACT: In this paper, a non-isolated full bridge LLC resonant converter is proposed. This converter combined the advantages of both resonant converters and non isolated technique. This proposed system can achieve most qualities of isolated LLC resonant converter like zero voltage switching and very low turn off loss for all MOSFETs. By this technique, the turns of transformer can be largely reduced which in turn the current through secondary windings is also reduced. Thus, the transformer loss is effectively decreased. Here a comparison of isolated LLC resonant converter and Non-isolated LLC Resonant converter is made. The main aim of this project is to reduce the switching loss of the MOSFETs by using LLC resonant converter and also to improve the efficiency of the converter without providing any isolation.

KEYWORDS: LLC resonant converter, ZVS, ZCS

I. INTRODUCTION

Resonant converters are generally used for applications which require for a high power density and high energy efficiency. By applying soft-switching technique, the switching frequency is selected much higher than the switching frequency of a similar hard-switching converter thus the volume required for the passive components is severely reduced, providing high power densities and high power conversion efficiencies. LLC resonant converter is an alternative approach for converters to reduce switching losses and to improve the life time of the MOSFETs. In addition to this, it reduces or eradicates the energy circulating in the converter by applying zero voltage switching (ZVS) and zero current switching (ZCS).

To minimize the size of passive components in the point-of-load (POL) buck converter, a high switching frequency is desirable. However, the typical buck converter possesses large turn-on, driving, and turn-off losses at high switching frequencies. The typical benefits of LLC resonant converters are a lack of turn-on loss and little turn-off loss for the primary side switches and nearly ZCS (zero current switching) for the output rectifier, which are suitable for high-frequency DC/DC applications. However, the large turn's ratio of the transformer is an issue due to the high ratio of input and output voltage.

The proposed non-isolated LLC converter can achieve ZVS, low turn-off loss and a self-driven synchronous rectifier. Due to the non-isolated technique, the turn's ratio of the transformer is also reduced. High power density and high efficiency are the incentive for both point-of-load (POL) and the voltage regulator (VR) for processors. Thus, high switching frequency is essential for small passive components. However, the conventional buck converters have several serious issues at high frequency such as high switching loss, high driver loss and high body diode loss of the synchronous rectifier [1, 2].

The typical benefits of non-isolated full bridge LLC resonant converter [3-8], like no turn on loss, small turn off loss for the switches in primary side and nearly ZCS (Zero Current Switching) for output rectifier, are appropriate for high frequency DC/DC application. However, the large turn's ratio of transformer is a serious issue due to high ratio of input and output voltage.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

By non-isolated technique the high conduction loss of buck converter due to the high voltage ratio can be relieved [9-12]. Depending upon the type of non-isolated connection [10], the DC/DC converters can attain self-driven, synchronous rectifier (SR) low current stress and low transformer turns ratio. The turn's ratio and conduction loss can be reduced.

Based on non-isolated techniques and LLC resonant converters, the non-isolated full bridge LLC resonant converter is proposed as another solution to future VR and POL converters. This converter combines the merits of both resonant converters and non-isolated structure. This concept also can be extended to other resonant converters. LLC resonant converters possess additional merits compared to other converters such as it can regulate the output voltage over wide voltage range with small switching frequency and it can achieve ZVS over entire operating range with excellent efficiency.

II. CONVENTIONAL SYSTEM

Soft switching topologies are used to increase the efficiency as well as it allow for better frequency operation so it is very much preferred by the power designers. The LLC resonant structure permits the zero voltage switching of the main switches thereby reducing the switching losses and improving the efficiency. LLC resonant converter can achieve efficiency up to 96%.

Soft switching technique will also eradicate the switching losses thereby possibly reducing the generation of EMI. Here the switches are turned-on and turned-off at the zero crossing of their voltage or current waveforms. ZVS is mostly preferred in the converters having MOSFET.

The isolated LLC resonant converter is getting a lot of attention because of its high efficiency through zero voltage switching (ZVS). A full-bridge isolated LLC resonant converter can achieve low switching loss and low circulating energy.

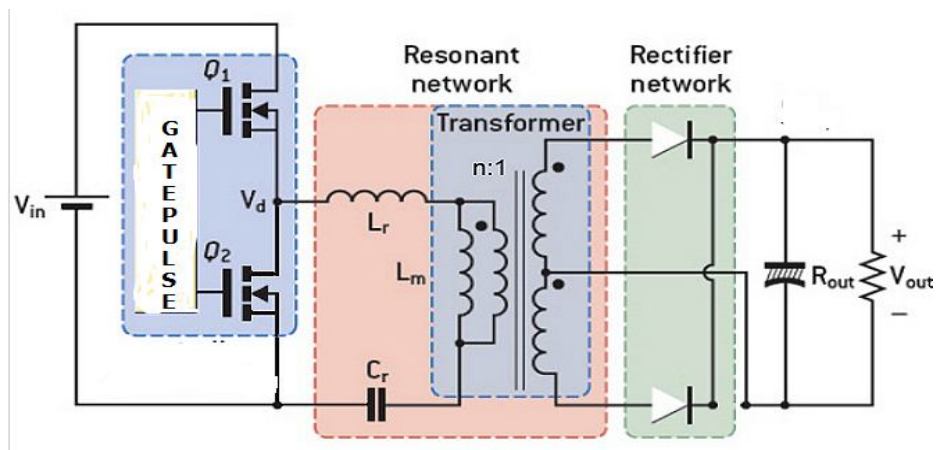


Fig.1. Isolated LLC resonant converter

Among these advantages this structure has its own drawbacks that are the high transformer ratio and gain distortion occurs mainly by parasitic components, such as resonant inductances and stray capacitances distributed to the high frequency transformer. The schematic of a conventional isolated LLC Resonant converter is plotted in fig.1.

III. PROPOSED SYSTEM

For applications like high power density and high efficiency, LLC resonant converter is widely used. LLC resonant converter can achieve zero-voltage switching (ZVS), low turn off loss for primary side switches and ZCS for

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

output rectifier. Generally, LLC resonant converter is isolated by transformer. In [9-12], the non-isolated full-bridge structure of PWM converters shows their benefits for low conduction loss and driven loss. This concept can also be applied for the non-isolated structure which brings some benefits to resonant converters.

A. Block Diagram

The block diagram of proposed system is based on the full bridge Non-isolated LLC resonant Converter is shown in fig.2. LLC resonant converter is a promising alternative for converters to reduce switching losses and to improve the life time of the MOSFETs[13-16]. LLC resonant converter reduces or eradicates the energy circulating in the converter by applying zero voltage switching and zero current switching.

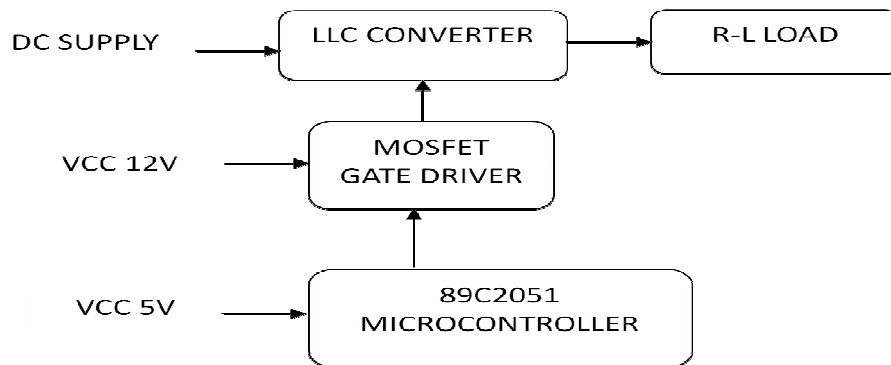


Fig.2. Block diagram of Proposed System

230V AC supply is given to the step-down transformer which steps down the voltage to 12V. The obtained 12V AC is rectified and supplied to the non-isolated LLC resonant converter. Another step down transformer provides a 5V AC supply to the microcontroller and buffer circuit, which in turn controls the gate drivers to trigger the switches. The gate driver circuit also provides isolation to the controller circuit from the resonant converter.

B. Operating Principle of Proposed System

Fig.3. shows the circuit diagram of the proposed system having non-isolated structure[16-19]. With this proposed non-isolated LLC resonant converter transformer windings and SR current can be reduced, which means that this proposed system possess simpler magnetic structure, less conduction loss and high efficiency.

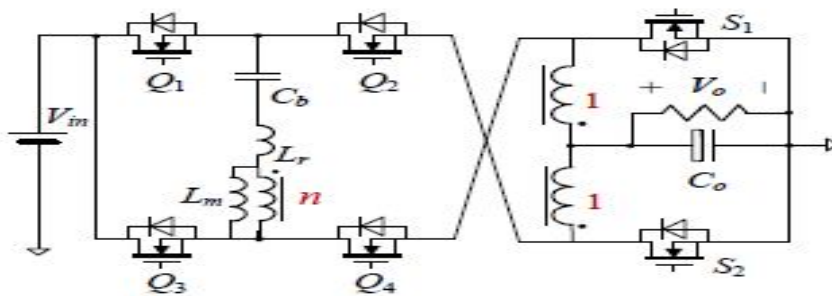


Fig.3. Non-Isolated Full bridge LLC resonant converter

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

C.Modes of operation:

This section reveals the operating principles of the Non-isolated full bridge LLC resonant converter. The direction of the power flow of each mode is analyzed in the next section. The proposed system comprises of two modes of operation. The operating modes are described as follows.

Mode 1

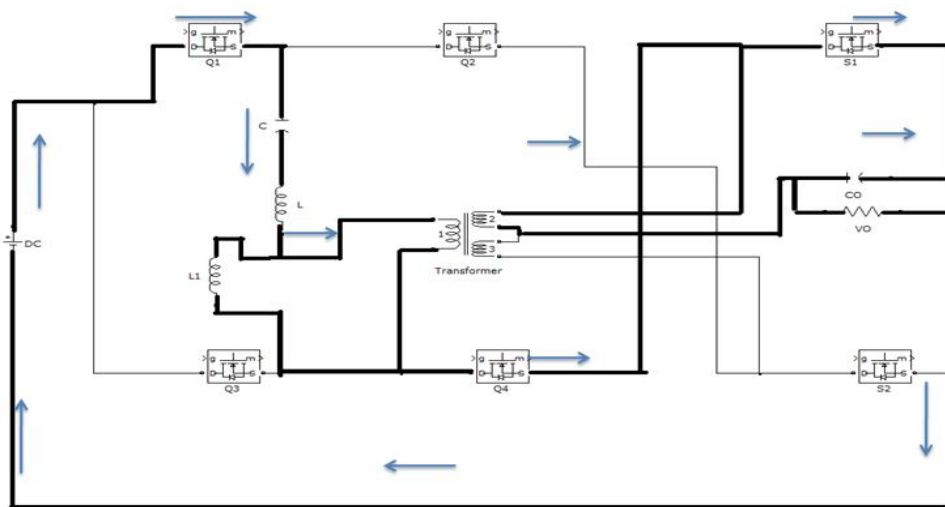


Fig.4. (a) Mode I

In this mode the switches Q_1 and Q_4 are turned ON and Q_2 , Q_3 are turned OFF. The primary current helps to deliver the energy to the load [19-23]. Thus the current through the secondary windings and the device S_1 is effectively reduced. Meanwhile, the input voltage is in phase with the current through S_1 . Thus it is easy to drive switch S_1 using the input voltage which can save much driving loss.

Mode 2

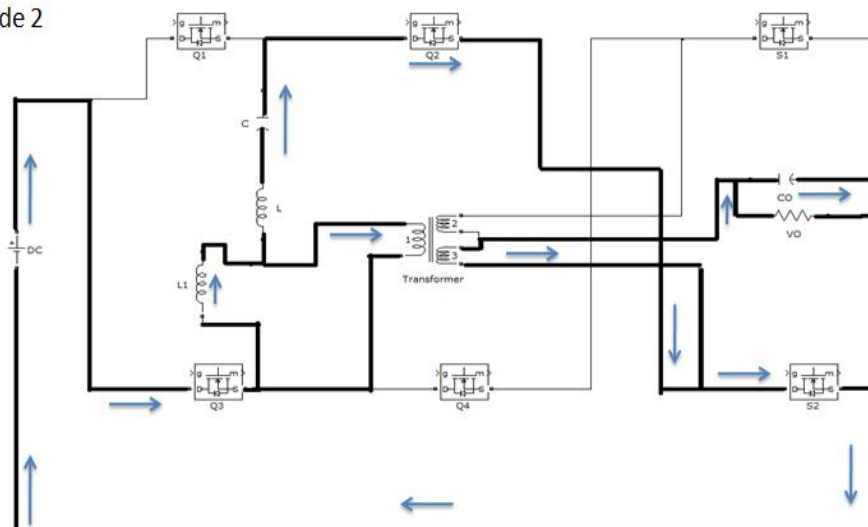


Fig.4. (b) Mode II

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

In this mode the switches Q_3 and Q_2 are turned ON and Q_1 , Q_4 are turned OFF. The primary current helps to deliver the energy to the load. Thus the current through the secondary windings and the device S_2 is effectively reduced. The rest of the operations are similar to that of mode I.

D.Simulation and its results:

For the designer to understand how a circuit and its control are working, simulation is the efficient way. It is the cheaper way to make a thorough analysis instead of building the actual circuit. A simulation can find out the possible problems thereby new circuit concepts and parameter variations can be done easily. The most commonly used and the simplest software tool for the simulation studies is MATLAB/Simulink [23-26]. MATLAB is a high performance language used for technical computing. MATLAB is used for analysis and development. The toolboxes in MATLAB are used to learn and apply the specialized technology. The non-isolated full bridge LLC resonant converter is simulated by using MATLAB software. The simulation of the proposed system is shown in the figure.5.

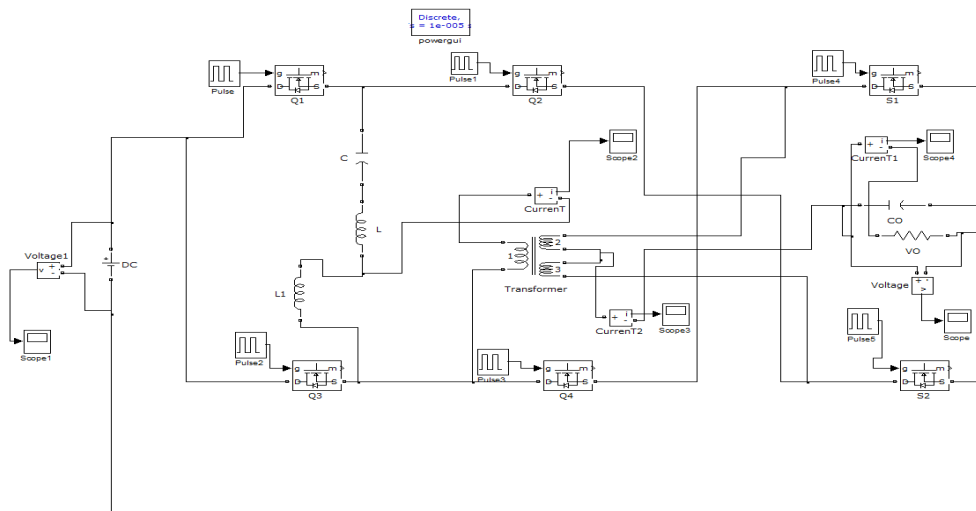


Fig.5. Simulation of Non-isolated Full-bridge LLC Resonant Converter.

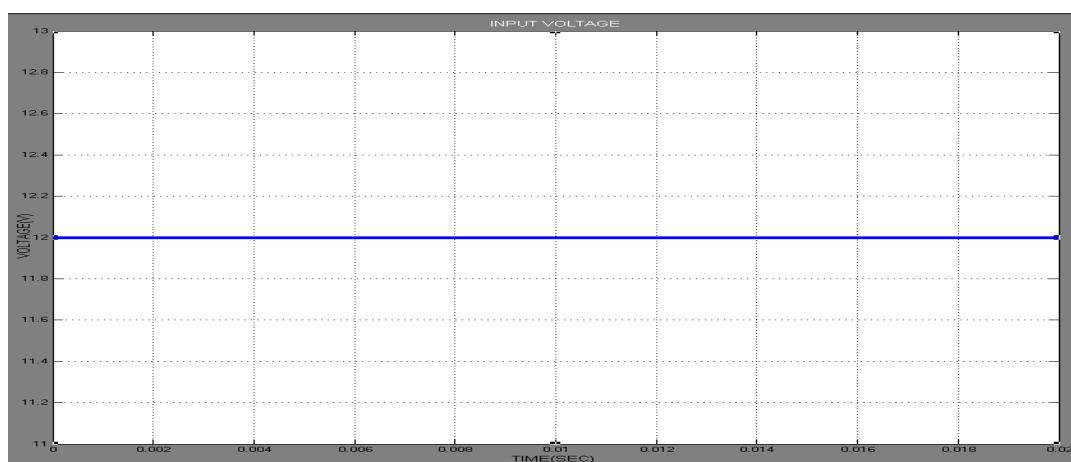


Fig.6. Input Voltage

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

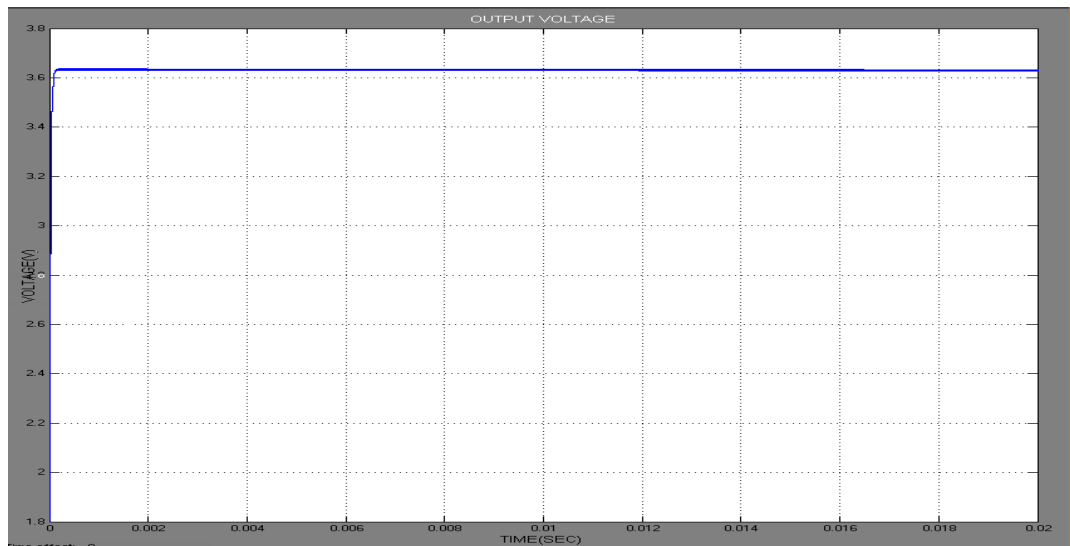


Fig.7. Output Voltage

Figure 6 and 7 shows the input voltage and the corresponding output voltage of the proposed system non-isolated LLC resonant converter. In case of simulation while supplying 12 volt we get an output as 4 volt. Thus the output voltage of the proposed system has been regulated and hence the overall efficiency is increased [26-28]. In addition to this, it reduces the turn-off losses, number of turns in the transformer thereby reducing the turns ratio and current stress on the switching devices which in turn reduces the conduction losses of the entire converter system.

IV. CONCLUSION

This project as a result gives solution to unregulated voltage; therefore the system can be used in various applications for its high power density and high efficiency. This system seems to be more efficient when compared to converters using isolation techniques, because it can reduce the current stress on the switches. Here the efficiency of about 90%-95% can be achieved. This converter has combined the benefits of resonant converters and non-isolated structure. This system has four improved advantages simultaneously, including the reduced transformer's turn's ratio, regulated output current, wide current gain and reduced switching losses.

In future this non-isolated technique can be implemented in PWM converters so that conduction loss, driven losses are reduced. This can be implemented in home appliances, street lamps, chargers and other electric devices – regulates the output voltage by adjusting the operating frequency. This can also be implemented in photovoltaic (PV) grid-connected power system in the residential applications where high step-up, low cost and high-efficiency dc/dc conversion is achieved.

REFERENCES

- [1] Xu, P.; Wei, J.; Lee, F.C.;, "The active-clamp couple-buck converter-a novel high efficiency voltage regulator modules," APEC 2001. Sixteenth Annual IEEE. Vol.1,no.,pp.252-257 vol.1,2001.
- [2] Peng Xu; Jia Wei; Kaiwei Yao; Yu Meng; Lee, F.C.;, "Investigation of candidate topologies for 12 V VRM," APEC 2002. Seventeenth Annual IEEE, vol.2, no., pp.686-692 vol.2, 2002.
- [3] Yang, F. C. Lee, A. J. Zhang, and G. Huang, "LLC resonant converter for front end dc/dc conversion," in *Proc. IEEE APEC*, 2002, pp. 1108-1112.
- [4] Y. Gu, Z. Lu, L. Hang, Z. Qian, and G. Huang, "Three-level LLC series resonant DC/DC converter," *IEEE Trans. Power Electron.*, vol. 20, no.4, pp. 781-789, Jul. 2005.
- [5] Fu, Y. Liu, F. C. Lee and M. Xu, "A Novel Driving Scheme for Synchronous Rectifiers in LLC Resonant Converters," *IEEE Trans. Power Electron.*, vol. 24, no. 5, pp. 1321-1329, May 2009.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

- [9] X. Xie, J. C. P. Liu, F. N. K. Poon, and M. H. Pong, "A novel high frequency current-driven synchronous rectifier applicable to most switching topologies," *IEEE Trans. Power Electron.*, vol. 16, no. 5, pp.635–648, Sep. 2001.
- [10] X. Wu; B. Li; Z. Qian; R. Zhao, "Current Driven Synchronous Rectifier with Primary Current Sensing for LLC converter," in *Proc. IEEE ECCE, 2009*, pp. 738-743.
- [11] B. Lu; W. Liu; Y. Liang; F. C. Lee; J.D. van Wyk, "Optimal design methodology for LLC resonant converter," in *Proc. IEEE APEC*, 2006, pp. 19-23.
- [12] Kaiwei Yao; Lee, F.C.; Yu Meng; Jia Wei; , "Tapped-inductor buck converters with a lossless clamp circuit," *APEC 2002. Seventeenth Annual IEEE* , vol.2, no., pp.693-698 vol.2, 2002.
- [13] Guo, J.; , "Double-ended transformer-based multi-phase converters," *INTELEC '03. The 25th International* , vol., no., pp.104-109, 23-23 Oct. 2003.
- [14] Jinghai Zhou; Ming Xu; Julu Sun; Lee, F.C.; , "A self-driven soft switching voltage regulator for future microprocessors," *Power Electronics, IEEE Transactions on* , vol.20, no.4, pp. 806- 814, July 2005.
- [15] Ming Xu; YuanchengRen; Jinghai Zhou; Lee, F.C.; , "1-MHz selfdriven ZVS full-bridge converter for 48-V power pod and DC/DC brick," *Power Electronics, IEEE Transactions on* , vol.20, no.5, pp. 997- 1006, Sept. 2005.
- [16] 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
- [17] 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
- [18] 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
- [19] 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
- [20] 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
- [21] 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
- [22] 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