Middle-East Journal of Scientific Research 19 (7): 960-965, 2014
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2014.19.7.1486

Analysis and Design of a Isolated Bidirectional DC-DC Converter for Hybrid Systems

G. Ramu

Department of Electrical and Electronics Engineering,
Bharath University, Chennai, India

Abstract: Multi-port converter with three active full bridges, two series-resonant tanks and a Multi-winding transformer is proposed. It uses a single power conversion stage with high-frequency link to control power flow between batteries, load and a renewable source such as fuel cell. The converter has capabilities of bidirectional power flow in the battery and the load port. Use of series-resonance aids in high switching frequency operation with realizable component values when compared to existing converter with only inductors. The converter has high efficiency due to soft-switching operation in all Multi bridges. Steady-state analysis of the converter is presented to determine the power flow equations, tank currents and soft-switching region. Dynamic analysis is performed to design a closed-loop controller that will regulate the load-side port voltage and source-side port current.

Key words: Battery charger · DC-DC converter · Multi-port converter · Virtual isolation

INTRODUCTION

A Multi-port converter operating at constant switching frequency and retaining all the advantages of a Multi-port structure is proposed. The converter has capabilities of bidirectional power ?ow in the battery and the load port. The converter has high efficiency due to soft-switching operation in all Multi bridges. Power flow between ports can be controlled by and phase-shifting the square wave outputs of the Multi active bridges.

Basic Concept of Bidirectional DC-DC Converter: The bidirectional dc-dc converter along with energy storage has become a promising option for many power related systems, including hybrid vehicle, fuel cell vehicle, renewable energy system and so forth [1-11]. It not only reduces the cost and improves efficiency, but also improves the performance of the system. In the electric vehicle applications, an auxiliary energy storage battery absorbs the regenerated energy fed back by the electric machine. In addition, bidirectional dc-dc converter shown in Figure 1 is also required to draw power from the auxiliary battery to boost the high-voltage bus during vehicle starting, accelerate and hill climbing. With its ability to reverse the direction of the current flow and thereby power, the bidirectional dc-dc converters are being increasingly used to achieve power transfer between two dc power sources in either direction [2].

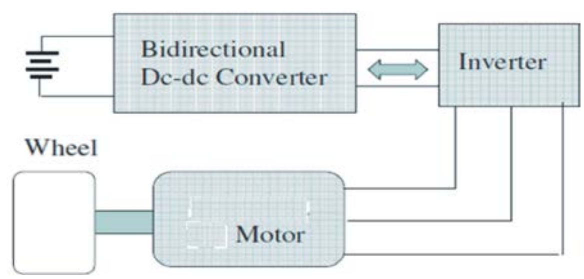

Fig. 1: Power from the auxiliary battery to boost the high-voltage bus during vehicle starting

In renewable energy applications, the multiple-input bidirectional dc-dc converter can be used to combine different types of energy sources. Figure 2 shows a fuel cell based system for domestic applications. [3-12]. The multi-input bidirectional dc-dc converter is the core that interconnects power sources and storage elements and manages the power this bidirectional dc-dc converter features galvanic isolation between the load and the fuel cell, bidirectional power flow, capability to match different voltage levels, fast response to the transient load demand, etc.

Corresponding Author: G. Ramu, Department of Electrical and Electronics Engineering,
Bharath University, Chennai, India.

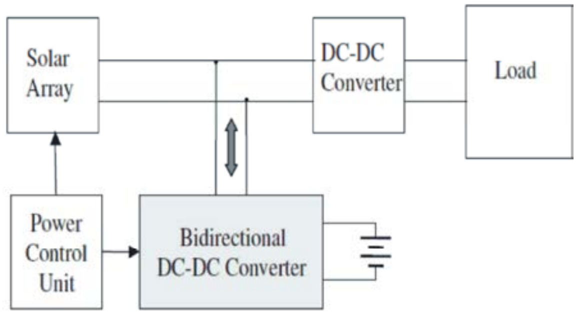

Fig. 2: Photovoltaic power system with bidirectional converter

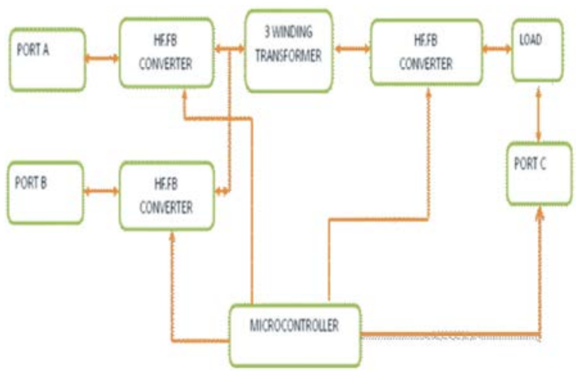

Fig. 3: Block diagram of multi-port converter

Recently, clean energy resources such as photovoltaic arrays and wind turbines have been exploited for developing renewable electric power generation systems. The bidirectional dc-dc converter is often used to transfer the solar energy to the capacitive energy source during the sunny time, while to deliver energy to the load when the dc bus voltage is low. A photovoltaic power system with bidirectional converter is shown in Figure 2. The bidirectional dc-dc converter is regulated by the solar array photovoltaic level, thus to maintain a stable load bus voltage and make fully usage of the solar array and the storage battery [4].

In this dissertation, a background description and review of the state-of-the-art bidirectional dc-dc converters are presented firstly to define this work and its novelty. Then, the challenges will be identified related to the design and control issues in the present non-isolated bidirectional dc-dc power converter [5-13]. The improved system is proposed with the advantages of high efficiency, simple circuit and low cost. The detailed design and operation considerations are analyzed and described. A unified power stage model is investigated and developed. A novel unified controller is proposed and digitally implemented with the digital signal processor (DSP). The proposed controller provides a freely power flow control in both directions. Simulation results from the proposed circuit are given to verify the operation principles.

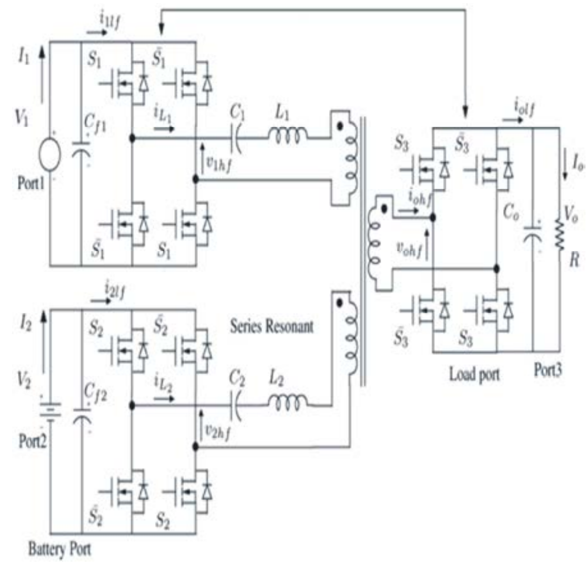

Fig. 4: Circuit diagram of multi-port converter

Multi-Port Bidirectional DC-DC Converter

Circuit Descriptions: A Multi-port converter with Multi active full bridges and a THREE-winding transformer is proposed. It uses a single power conversion stage with high-frequency link to control power flow between batteries, load and a renewable source such as fuel cell. The converter has capabilities of bidirectional power flow in the battery and the load port. Use of series-resonance aids in high switching frequency operation with realizable component values. The converter has high efficiency due to soft-switching operation in all Multi bridges.

[14] The Block diagram of multi-port converter shown in Fig. 3. It consists of three port high frequency full bridge converter, three winding transformers and micro controllers. High frequency full bridge converters are operates at inversion and rectification mode. The three winding transformers are used in isolation purpose.

Circuit Operations: The multi port converters are operates at four modes. These modes are given below.

Mode 1: Port a Positive Mode: When port A is supplying power to the load, the current path will flow in positive direction. The switches M1 and M4 will conduct. The magnetizing current is flowing through the three winding transformer the switches M9 and M12 will conduct. At the time the port B is charging.

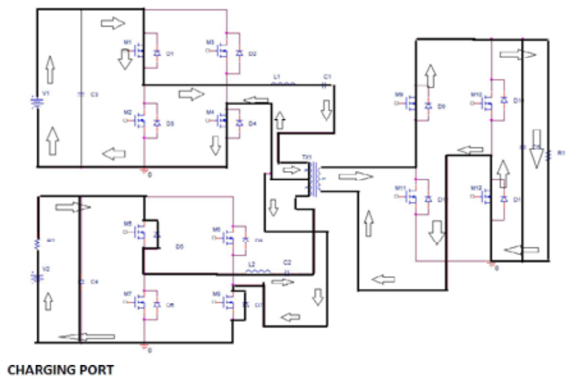

Fig. a: Port A positive mode operation

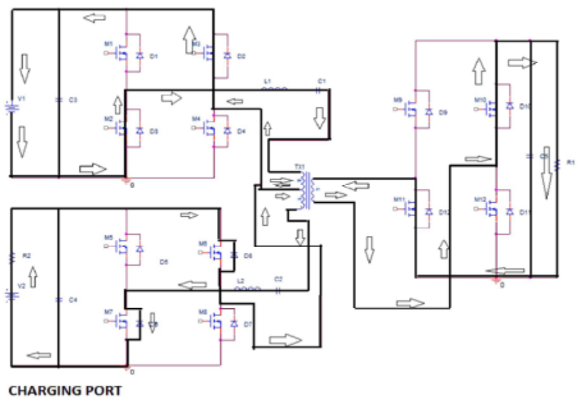

Fig. b: Port A negative mode operation

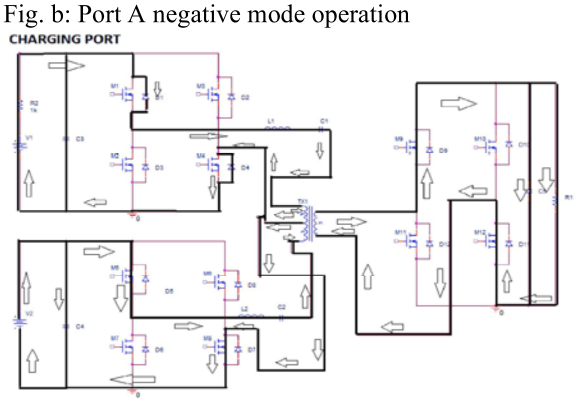

Fig. c Port B positive mode operation

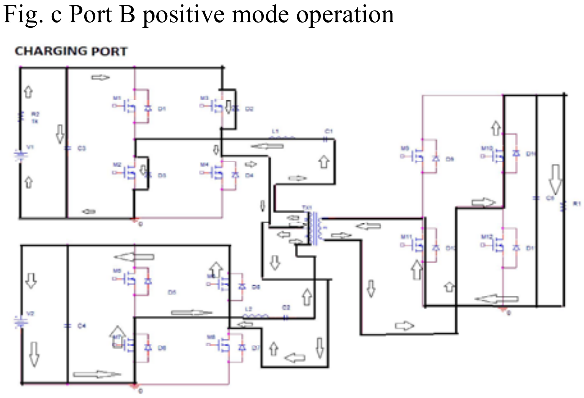

Fig. 6 Port B negative mode operation

Mode 2: Port A-Negative Mode: When port A is supplying power to the load, the current path will flow in negative direction. The switches M2 and M3 will be conduct. The magnetizing current is flowing through the three winding transformer the switches M10 and M11 will conduct. At the time the port B is charging.

Mode 3: Port B-Positive Mode: When port B is supplying power to the load, the current path will flow in positive direction. The switches M5 and M8 will be conduct. The magnetizing current is flowing through the three winding transformer the switches M9 and M12 will be conduct. At the time the port A is charging.

Mode 4: Port B-Negative Mode: When port B is supplying power to the load, the current path will flow in negative direction. The switches M7 and M6 will be conduct. The magnetizing current is flowing through the three winding transformer the switches M10 and M11 will be conduct. At the time the port A is charging [15-17].

RESULTS AND DISCUSSION

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN.

AC Voltage Source block into the circuit1 window. Components have disappeared so that the icon now shows a single resistor.

The simulation diagram of multi port converter is shown in Figure It consists of three ports. They are namely main port, battery port and load port. It is operates three modes. Under running condition any one port supplying, one port is charging, another one is load port.

Mode I: The below figure represents the Simulation Diagram of multi port converter for mode I

Figure 5 Shows the simulated diagram of Proposed Multi port converter for Mode I. Under running condition the main port is supplying and the battery port is charging.

Triggering Pulses: The below wave form represents the waveform representation triggering pulse signal of switches $M_{1,}$ M4 and $M_{2,}$ M3.

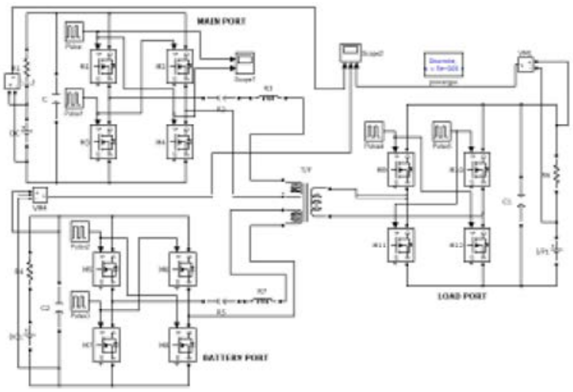

Fig. 5: Simulation Diagram of Proposed Multi port converter for mode I

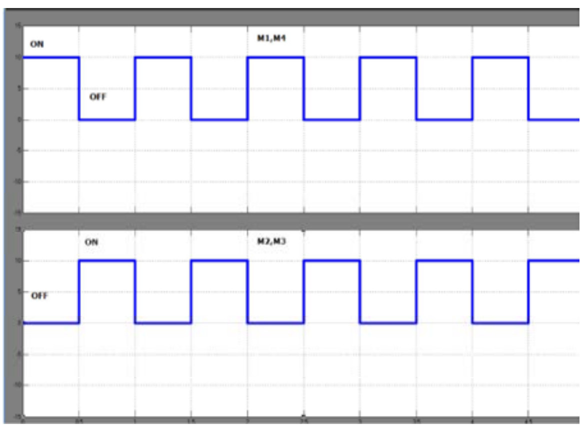

Fig. 6: Simulated gate Triggering pulses

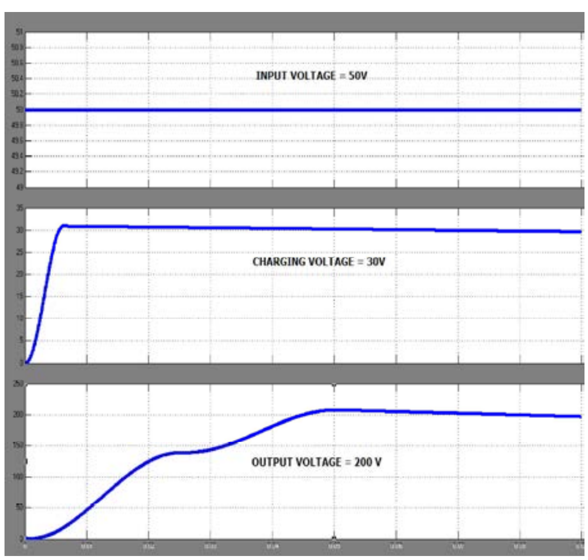

Fig. 7: Simulated Output voltage waveforms

Figure 6 Shows the simulated gate Triggering pulses, which is measured by connecting a single scope measurement.

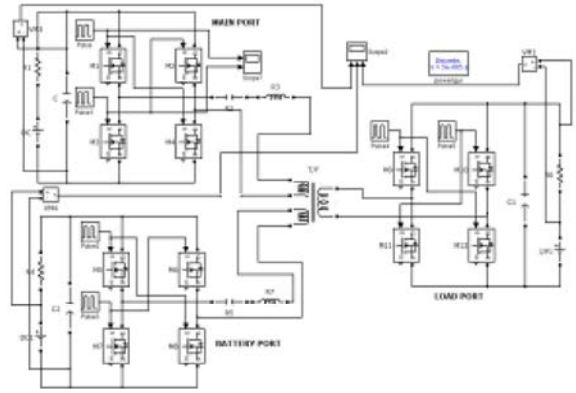

Fig. 8: Simulation Diagram of mode II

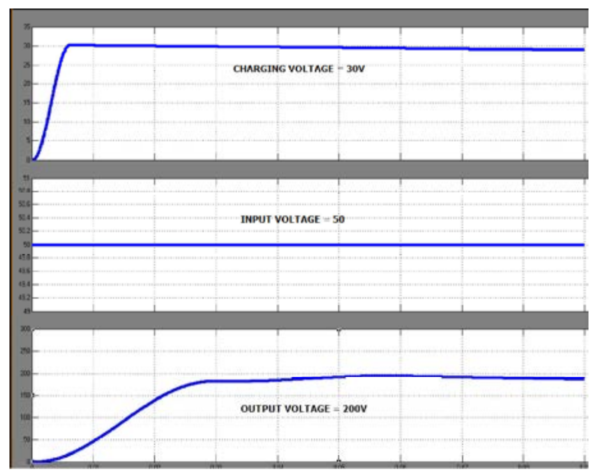

Fig. 9: Simulated output and input voltage waveforms

Simulated Output Voltage: The below figure represents the Simulation Diagram of multi port converter for mode I.

Figure 7 Shows the simulated output voltage, which is measured across the output of resistive loads by connecting a voltage measurement with scope.

Mode II: The below figure represents the Simulation Diagram of multi-port converter for mode II.

Figure 8 shows the simulated diagram of Proposed Multi port converter for Mode II. Under running condition the main port is charging and the battery port is supplying.

Simulated Output Voltage: The below figure represents the Simulation Diagram of multi port converter for mode II.

Figure 9 Shows the simulated output and input voltage, which is measured across the output of resistive, loads by connecting a voltage measurement with scope.

Mode III: Reverse Mode: The below figure represents the Simulation Diagram of multi-port converter for reverse mode.

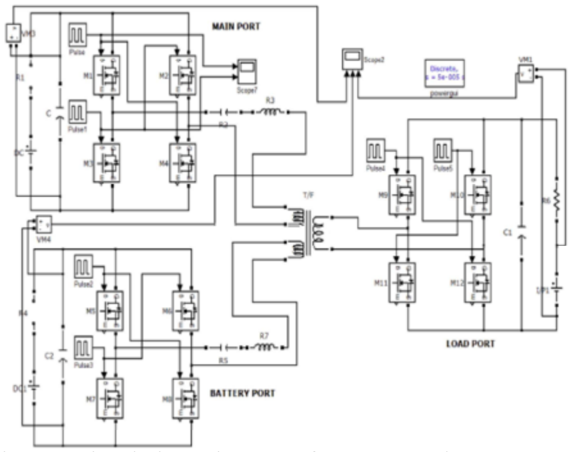

Fig. 10: Simulation Diagram of reverse mode

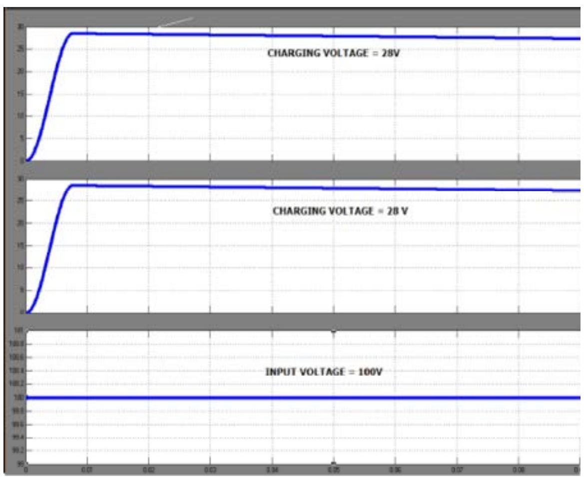

Fig. 11: Output and input voltage waveforms for reverse mode

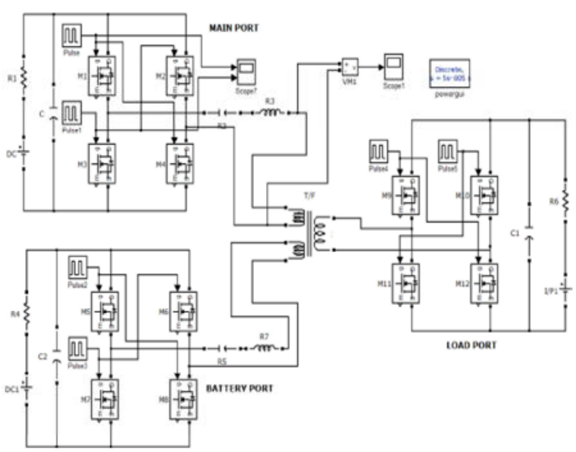

Fig. 12: Simulation Diagram of resonant condition

Figure 10. Shows the simulated diagram of Proposed Multi port converter for Mode 3. Under running condition the load port is supplying and the main battery and battery port is charging.

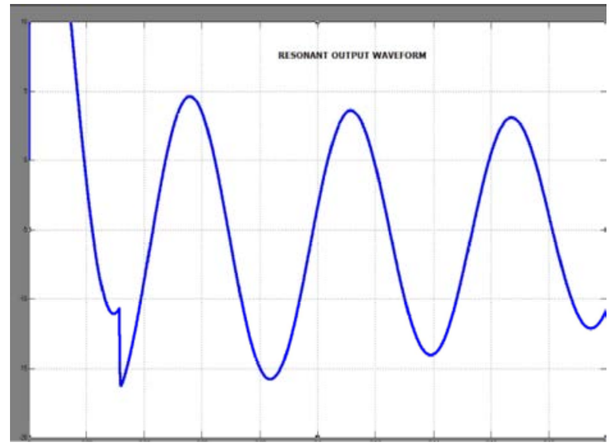

Fig. 13: Resonant output wave form

Output Waveforms of Reverse Mode: Figure 11 shows the simulated output and input voltage, which is measured across the output of resistive, loads by connecting a voltage measurement with scope.

Resonant Condition: The below figure represents the Simulation Diagram of multi port converter for resonant condition.

Figure 12 shows the simulated diagram of idle port bidirectional dc-dc converter, where PWM technique applied for this topology.

Resonant Output Wave Form: Figure 13 Shows the simulated resonant output voltage, which is measured across transformer winding by connecting a voltage measurement with scope.

CONCLUSION

This project deals with the implementation of simulation for bidirectional dc-dc converter, which allows transfer of power flow between the two dc sources in either direction. This converter can reverse the direction of flow of current and thereby power, while maintaining the voltage polarity unchanged. Simulation of charging and discharging mode of bidirectional dc power supply was done successfully and waveforms are obtained. This bidirectional power flow is achieved by using same power components hence will minimize the hardware.

REFERENCES

1. Al Atrash, H., F. Tian and I. Batarseh, Jan, 2007. Tri-modal half-bridge converter topology for three-port interface," IEEE Trans. Power Electron., 22(1): 341-345.

2. Chen, Y.M., Y.C. Liu, S.C. Hung and C.S. Cheng, May 2007. Multi-input inverter for grid-connected hybrid pv/wind power system," IEEE Trans. Power Electron., 22(3): 1070-1077.
3. Duarte, J.L., M.A.M. Hendrix and M.G. Simoes, Mar. 2007. Three-port bidirectional converter for hybrid fuel cell systems, IEEE Trans. Power Electron., 22(2): 480-487.
4. Liu, D. and H. Liu, Sep, 2006. A zvs bi-directional dc-dc converter for multiple energy storage elements," IEEE Trans. Power Electron., 21(5): 1513-1517.
5. Peng, F.Z., M. Shen and K. Holland, May 2007. Application of z-source inverter for traction drive of fuel cell battery hybrid electric vehicles," IEEE Trans. Power Electron., 22(3): 1054-1061.
6. Su, G.J. and L. Tang, Nov, 2008. A multiphase modular, bidirectional, triple-voltage dc-dc converter for hybrid and fuel cell vehicle power systems, IEEE Trans. Power Electron., 23(6): 3035-3046.
7. Tao, H., J.L. Duarte and M.A.M. Hendrix, 2007. High-power three-port three phase bidirectional dc-dc converter, in Proc. IEEE Ind. Appl. Soc. 42nd Annu. Meet. (IAS), pp: 2022-2029.
8. Tao, H., J. Duarte and M. Hendrix, Mar, 2008. Three-port triple-half-bridge bidirectional converter with zero-voltage switching, IEEE Trans. Power Electron., 23(2): 782-792.
9. Tao, H., A. Kotsopulos, J.L. Duarte and M.A.M. Hendrix, May 2006. Family of multiport bidirectional dc-dc converters," Inst. Elect. Eng. Proc. Elect. Power Appl., 153(15): 451-458.
10. Tao, H., A. Kotsopoulos, J. Duarte and M. Hendrix, Mar. 2008. Transformer-coupled multiport ZVS bidirectional dc-dc converter with wide input range," IEEE Trans. Power Electron., 23(2): 771-781.
11. Vijayaragavan, S.P., B. Karthik, T.V.U. Kiran Kumar and M. Sundar Raj, 2013. Analysis of Chaotic DC-DC Converter Using Wavelet Transform, Middle-East Journal of Scientific Research, ISSN:1990-9233, 16(12): 1813-1819.
12. Vijayaragavan, S.P., B. Karthik, T.V.U. Kiran Kumar and M. Sundar Raj, 2013. Robotic Surveillance For Patient Care In Hospitals, Middle-East Journal of Scientific Research, ISSN:1990-9233, 6(12): 1820-1824.
13. Vijayaragavan, S.P., T.V.U. Kiran Kumar and M. Sundar Raj, 2013. Study of effect of MAI and its reduction in an OCDMA system, Middle-East Journal of Scientific Research, ISSN:1990-9233, 16(12): 1807-1812.
14. Vijayaragavan, S.P., T.V.U. Kiran kumar and M. Sundar Raj, 2013. Study of Effect of Mai and its reduction in an OCDMA System, Middle-East Journal of Scientific Research, ISSN:1990-9233, 15(12): 1803-1808.
15. Pattanayak Monalisa and P.L. Nayak, 2013. Green Synthesis of Gold Nanoparticles Using Elettaria cardamomum (ELAICHI) Aqueous Extract World Journal of Nano Science and Technology, 2(1): 01-05.
16. Chahataray Rajashree and P.L. Nayak, 2013. Synthesis and Characterization of Conducting Polymers Multi Walled Carbon Nanotube-Chitosan Composites Coupled with Poly (P-Aminophenol) World Journal of Nano Science and Technology, 2(1): 18-25.
17. Parida, U.K., S.K. Biswal, P.L. Nayak and B.K. Bindhani, 2013. Gold Nano Particles for Biomedical Applications, World Journal of Nano Science and Technology, 2(1): 47-57.