iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 Issue: III Month of publication: March 2015

DOI:

www.ijraset.com Volume 3 Issue III, March 2015
IC Value: 13.98 ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

IGBT based Multiport Bidirectional DC-DC Converter with Renewable Energy Source

S.Gautham
Final Year, UG student, Department of Electrical and Electronics Engineering, P. B. College of Engineering, Chennai

***Abstract* —Future renewable energy systems will need to interface with several energy sources such as fuel cells and photovoltaic array with battery backup. For standalone systems, backup storage is required for dynamic response. A three port dc- dc converter hence finds applications with such systems. In this project, it has been proposed to use Insulated Gate Bipolar Transistors (IGBTs) for performing the switching and inverting operation. The use of LLC circuit is investigated to reduce the effects of radio and electromagnetic interference. Hence, the output of the bidirectional converter shall have improved efficiency and soft switching operation.**
***Keywords* — Bidirectional power, three port converter, three winding transformer, IGBT**

I. INTRODUCTION

The bidirectional dc-dc converter along with energy storage has become a promising option for many power related systems including renewable energy systems. It provides improved efficiency and performance by the system. Bidirectional dc-dc converters can deliver energy in two directions. It is generally needed to actively control the power flow between energy storage and load while regulating the bus voltage during source and load voltage changes. The use of same components to achieve bidirectional power provides an efficient and galvanically isolated topology that is actively used in battery charge and discharge. The use of three port converter is necessitated as it accommodates a primary source and storage and combines their advantages automatically, while utilizing a single power conversion stage to interface the three power ports. Having the two energy inputs, the instantaneous power can be redistributed in the system in a controlled manner.

A second advantage of using such a system is that the primary source only needs to be sized according to the average power consumed by the load for a specific application, not necessarily to the peak power. Such operation would avoid over sizing of the primary source and is economically beneficial.

Moreover, with the auxiliary storage, not only can the system dynamics be improved, but also the storage can serve as a backup energy source in the event of a main source failure. This paper investigates the improvement in efficiency and performance of the converter by the use of IGBT and LLC resonant circuit. The use of this resonant converter helps in reducing switching losses with the inherent advantage of low electromagnetic and radio interference. Also, it is required to limit the impedance to the lowest possible value as it is inversely proportional to the power flow and hence may affect the output power, which subsequently has an effect on the system's efficiency.

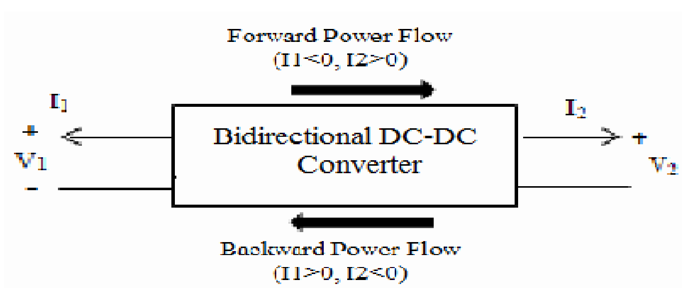


Fig. 1. Illustration of Bidirectional Power Flow

Volume 3 Issue III, March 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

II. CONSTRUCTION

The need for the use of bidirectional converter is derived from the fact that the renewable energy resources such as solar energy, though intermittent, are not available at all times. Hence it is required to use storage systems in the circuit which may act as a source during the absence of the primary source (solar energy, in this project). Batteries of various capacities depending on the maximum demand of the load can be used.

The circuit consists of three ports (hence the name multiport) and employs inverter and rectifier circuits. Also the three winding transformer used to step up the voltage obtained from the source uses the principle of electromagnetic induction for its operation.

The first port consists of the primary source (solar energy tapped by PV cells) and an inverter circuit (formed by IGBTs). Its output is ac and is given as the input to the primary of the transformer. The port two consists of rectifier circuit and the load (which is variable in nature). Port three is connected to the tertiary of the transformer and it consists of the battery (storage element) and inverter circuits. The use of this port is required only when the source in port one is not able to supply the required input. Hence this port acts as the primary of the transformer when the primary source (solar energy) in port one is unavailable. During reduced load conditions or in case of regenerative braking, the excess power that is available is stored in the battery (port three). Depending on the maximum load connected, the battery capacity is determined.

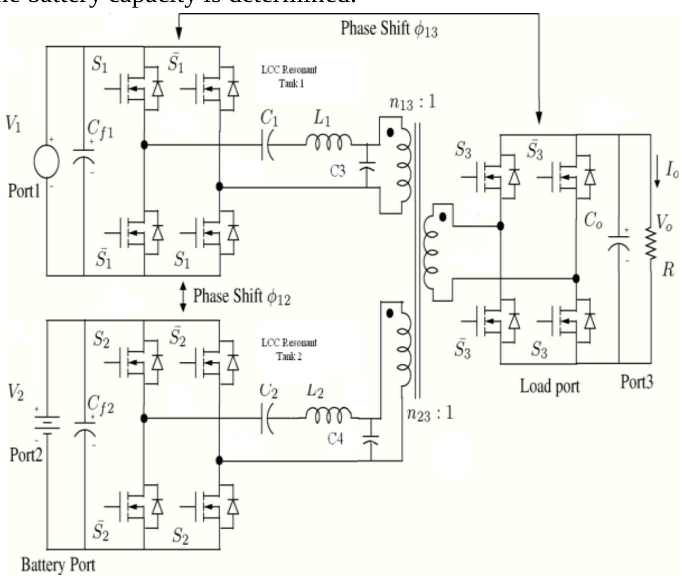


Fig. 2. Three port DC-DC converter (LCC model)

A. Advantages Of IGBTS

The inverter circuit is obtained by suitable connection of IGBTs. These devices have superior qualities over MOSFETs. IGBTs have low on-state losses and higher voltage and current ratings with low switching losses which shall ultimately increase the power input to the transformer. This results in higher output voltage and results in overall higher efficiency of the circuit when compared to the use of MOSFETs in the inverter circuit.

B. Role Of Transformer

The rating of the transformer depends on the number of turns in the three windings. It also determines the maximum load that can be connected to the system. It is expected to have same number of turns in windings of both primary and tertiary of the transformer. The secondary of the transformer (to which port two is connected) has higher number of windings in case of step up transformer operation. The transformer works on the basis of mutual induction. The role of the transformer is also to provide isolation and voltage matching. The turns ratio of the transformer is calculated using the relation given below:

$$\frac{N_1}{V_1} = \frac{N_2}{V_2} = \ldots\ldots\ldots = \frac{N_N}{V_N} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

The equation (1) represents the turns ratio formula where,

$N_1, N_2, ..., N_N$ = number of winding turns

$V_1, V_2, ..., V_N$= port voltages

The power throughput must be highest of all possible situations. The use of resonant circuits ensures fixed switching frequency; hence transformer is related to phase shifts and leakage inductances.

The port two consists of inverter circuit which performs the rectification operation. The output obtained is dc which is then given to the load. However, if the load does not draw the full current supplied or if the load is regenerative, then the surplus power is transferred to the battery in port three. The battery hence charges to the maximum value. During increased load conditions or during the absence of the main source, the battery supplies the required power. The port three also consists of the rectifier/inverter circuit to supply or draw power from the battery, as the case may be.

C. LCC Resonant Circuit-Advantages

It is known that ac contains ripples. Hence resonant circuits are used to smooth the ripples. This circuit is implemented after the inverter circuit (in port one) and before the rectifier circuit (in port three), as shown in figure 2.The use of LCC resonant circuits has two advantages over the use of series LC circuit or parallel LC circuit. Firstly, the voltage conversion characteristics allows the converter to operate in wide load range (from no load to full load), where in the parallel LC circuit loses regulation at full load while series LC circuit may lose regulation at no load. The LCC behaves more like parallel LC circuit under at no load and series LC circuit under full load. Secondly, the LCC circuit has inherent short circuit protection.

The figure 2 shows the use of MOSFETs in the inverter circuits which shall be replaced by IGBTs in the proposed circuit, for reasons already stated. IGBTs combine the advantages of both MOSFETs and that of BJTs.

III. WORKING

The implementation of the circuit in figure 2 offers high efficiency due to the presence of LCC circuit. The change proposed in the resonant circuit is the replacement of this LCC circuit with LLC circuit, as shown in figure 3. The LLC circuit offers the same advantages as that of the LCC circuit. In addition, a LLC circuit can be optimized at high input voltage. Both zero voltage switching and zero current switching is possible over the entire region. Also, IGBTs shall replace the MOSFET as the switching device.

The solar cells (PV cells) in port one, absorb the solar rays and generate electricity. The dc power is fed to the inverter circuit which consists of four IGBTs, one pair of which is in parallel with another. Each of the two IGBTs (in one pair) is in series with each other. This inverter circuit converts the dc into ac and it is given as the input to the primary of the transformer through a LLC circuit which helps in improving the efficiency of the circuit by reducing losses. The transformer transfers the power from port one to port two without change in frequency. The ac power thus obtained is rectified to give dc output. This dc output is greater than the dc input. The load (shown as the RC circuit in figure 3) can hence be driven. In a scenario when the load does not require full power, the same is transferred to port three. The ac input in port three is rectified and the output of this rectifier circuit is given to the storage device (battery). During reduced power input from port one or during peak load demand, the battery shall supply power to the load.

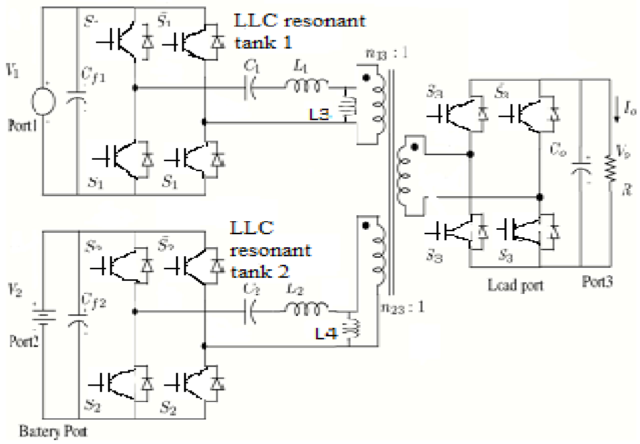


Fig. 3. The proposed circuit (LLC model)

To ensure the power from port 1 is transferred to port 2 or port 3 correctly at the right and the required time, a microcontroller (AT89C51) circuit is added to figure 3. The microcontroller receives an external supply. It is connected to the power MOSFET, IR2110, which acts as the switching device. In the next sections, these devices are described.

IV. AT89C51 MICROCONTROLLER

The control circuit consists of PIC buffer, LED, voltage regulator, transformer, diodes, and resistors. If it is used to produce DC, a rectifier is used. A capacitor is used to smooth the pulsating current from the rectifier. Some small periodic deviations from smooth dc with remain, which is known as ripple. These pulsations occur at a frequency related to the ac power frequency (for eg., a multiple of 50 Hz.) .The transformer 230/15 V with a current input signal is first converted into dc by using rectifier and is further smoothened. The output signal is given to the voltage regulator 7805, since the microcontroller used requires 5V. The 5 volts supply is then used to trigger the microcontroller, then further from the microcontroller to the buffer and then to the isolation circuit and then finally to the power circuit.

In 40 pin AT89C51, there are 4 ports designated as P_1, P_2, P_3 and P_0. All these ports are 8 bit bidirectional ports, that is, they can be used as both input and output ports. Except P_0, which needs external pull ups, rest of the ports have internal pull ups. When 1s are written to these port pins, they are pulled high by the internal pull ups and can be used as inputs. These ports are also bit addressable and so their bits can also be accessed individually.

Port P_0 and P_2 are also used to provide low byte and high byte addresses, respectively, when connected to an external memory. Port 3 has multiplexed pins for special functions like serial communication, hardware interrupts, timer inputs and read-write operation from external memory. AT89C51 has an inbuilt UART for serial communication. It can be programmed to operate at different baud rates. It has total of six interrupts.

The Atmel AT89C51 is a powerful micro computer which provides a highly flexible and cost-effective solution to many embedded control applications.

V. IR2110 POWER MOSFET

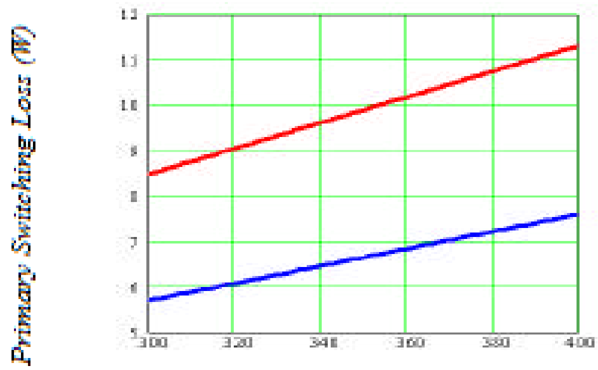
A gate driver is provided between the microcontroller output signal and power transistor that accepts a low-power input from a controller IC and produces the appropriate high-current gate drive for a power IGBT. Gate drivers may be implemented as dedicated ICs discrete transistors, or transformers. They can also be integrated with a controller IC. The IR2110 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. Logic inputs are compatible with standard CMOS, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

VI. LLC CONVERTER

The advantages of LLC converter has been discussed in the above text. The following graph (figure 4) provides a primary side switching loss comparison between PWM converter and LLC converter. It is seen that the switching loss in LLC converter is 40% less than that of PWM converter.

The red line in the graph shows the curve for the PWM converter. The blue line on the graph shows the curve for the LLC converter. As is shown in the graph, the primary switching losses if PWM converter is used accounts to more than 11W in case of a 400V supply while it is a little more than 7W if LLC circuit is used.



***Vin (V)* Fig.** 4: Primary side switching loss comparison

VI. APPLICATIONS

The multiport bidirectional DC-DC converter offers high dc output voltage. This converter can be implemented in the areas of power generation using single or multiple renewable energy source(s).

REFERENCES

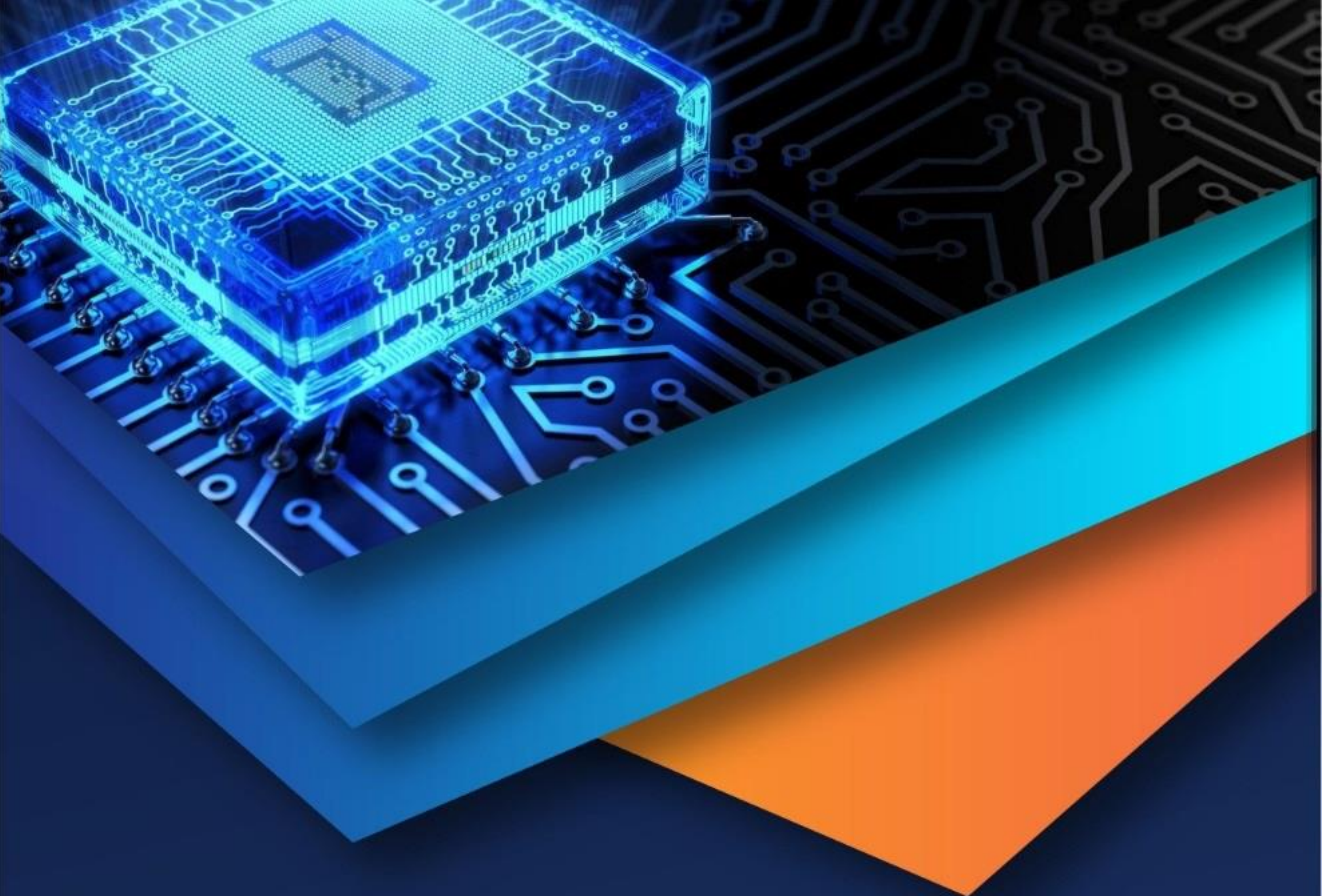
[1] Tao H, Duarte.J.L, and Hendrix. M. A.M, (2009) "High-power three-port three phase bidirectional DC-DC converter," in Proc. IEEE Ind. Appl. Soc. 42nd Annu. Meet. (IAS 2007), pp.2022-2029

[2] Prabhaja.P.S, Purushothaman.R ,(2014) "Multiport bidirectional DC-DC converter for electric vehicle" in IJETR,vol.1,issue 4,pp.669-673

[3] Dhivya.B, Damodharan.S,(2013)"Analysis of Multiport DC-DC Converter in Renewable Energy Sources" in IJRET, vol.2,issue 10,pp.181-184.

[4] Venmathi.M, Ramaprabha.R,(2013)"A comprehensive survey on multiport bidirectional DC-DC converters for renewable energy systems" in ARPN Journal of Engineering and Applied Sciences,vol.8,No.5,pp.348-356.

[5] Bo Yang, Fred C. Lee, Alpha J. Zhang, Guisong Huang, (2002)"LLC resonant converter for front end DC-DC conversion" in IEEE, vol.2, pp.1108-1112



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429