

ISOLATED BIDIRECTIONAL DC-DC CONVERTERS IN FUEL CELL ELECTRIC VEHICLE

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Abstract- In recent years, the application of high power isolated bidirectional DC-DC converters has increased in fuel cell vehicles and battery based energy storage systems. The main advantages of fuel cells are clean electricity generation high density current output ability, and high efficiency operation. The fuel cell lacks energy storage capability. So in electric vehicle applications, an auxiliary energy storage device (i.e., lead-acid battery) is always used for a cold start and to absorb the regenerated energy fed back by the electric machine. A bidirectional dc to dc converter is necessary between the energy storage battery and the supply to match the voltage level. The regenerated braking energy can be fed back to store the battery using the DC-DC converter. So here the paper presents an isolated bidirectional DC-DC converter with high conversion ratio which can be used in Fuel cell electric vehicles. The simulation of converter with low voltage of 24 V and high voltage of 200V is done using MATLAB/SIMULINK with fuel cell as the input and BLDC motor as the load.

Key Words: Isolated bidirectional DC-DC converter, Current doubler rectifier; current-fed converter; voltage doubler circuit; high conversion ratio; Synchronous rectifier

1.INTRODUCTION

Electric Vehicles (EVs) with zero or reduced emission have been developing quick in the car market during last decade. The car business sector is quickly changing towards more electric vehicles, since vehicles that use fossil fuel are one of the primary cause for rising energy costs and destructive discharges. Also, decreasing fossil fuel stores are making the move to electric vehicles basic. Before couple of years, propelled Hybrid Electric Vehicles (HEVs) have been popularized and accessible in the business sectors. Fuel-cell (FC) based HEVs are becoming more and more attractive because of a few focal points such as high efficiency and zero harmful emission. DC/DC converters have widely been utilized as a part of FCHEVs. [3]A Fuel cell electric vehicle (FCEV) is a sort of vehicle which employs an energy unit

to power its on-board electric engine. Energy components in vehicles make power to power an electric engine, generally using oxygen from the air and compressed hydrogen. An energy component vehicle that is energized with hydrogen discharges just water and heat, but no tailpipe pollutants, hence it is viewed as a zero-emissions vehicle.

In Electric vehicle, the main energy source is assisted by 2 or more energy storage devices. Batteries and Super capacitors (SCs) are the two oftenly used energy storage devices. By introducing DC-DC converter one can choose the voltage variation of the devices and powers of each devices can be controlled. Power of DC-DC converter depends on the characteristics of vehicle such as top speed, acceleration time from 0-100 km/h, weight, maximum torque, power profile etc. For passenger cars- power- 20KW-100KW.

Fuel cell stack converts the Hydrogen gas and oxygen into electricity to power the electric engine. High output battery stores energy produced from regenerative braking and gives supplemental power to the electric engine. Hydrogen storage tank stores gas packed at extremely high pressure to build driving range. First commercial production fuel cell automobiles being sold in CALIFORNIA by TOYOTA and rented on constrained premise by HYUNDAI.

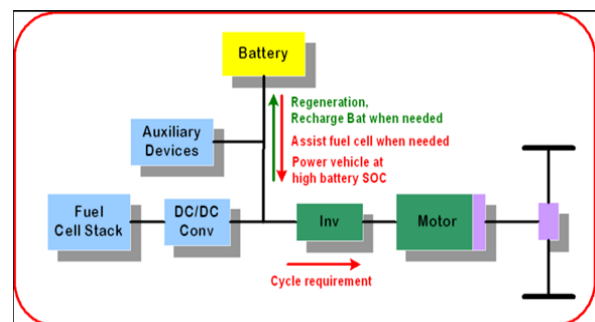


Fig -1: Block diagram of fuel cell electric vehicle

For different applications in fuel cell electric vehicle, Non Isolated and Isolated topologies of DC-DC converters are utilized. For Regenerative braking, On board backup power and Battery recharging Isolated bidirectional topologies are utilized. Boost Full bridge or Boost half bridge. Power flow in

bidirectional is usually from low voltage end such as battery or super capacitor to a high voltage end. That is referred as boost operation. During Regenerative braking, the power flows back to the low voltage end to recharge the battery. That is referred as buck method of operation. So High power bi-directional DC-DC converter have gained a lot of importance.

2. LITERATURE SURVEY

2.1 Isolated bidirectional DC-DC converter

Most of the isolated bidirectional DC-DC converter have the same structure is as shown in the fig. 2. This structure consist of two high frequency switching converters and high frequency transformer are primarily used to maintain the galvanic isolation between two sources. The transformers are used to match the voltage between different stages for the proper design and optimization of different stages .The system transfers the energy in both the directions. These bidirectional DC-DC converter works in two modes i.e. in buck or boost

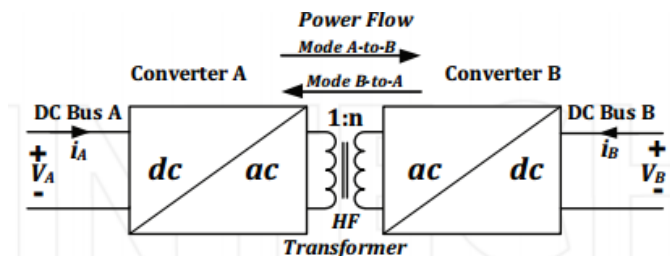


Fig-2: Isolated bidirectional DC-DC converter[16]

Isolated bidirectional dc-dc converters are used in the application of Fuel cell electric vehicles. To obtain a high conversion ratio with an appropriate duty ratio, coupled inductors, switched-capacitor techniques, and cascade techniques can be used to construct a non-isolated bidirectional converter. However, non-isolated converters fail to meet the safety standards of galvanic isolation in many applications.

Converters with high conversion ratios are designed by combining switched-capacitor cells, coupled inductors, switched capacitor techniques[7]-[9],and Z source techniques[9],[10]. Compared with high-step up and high stepdown converters, bidirectional high-conversion Ratio converters can significantly reduce the overall system volume, cost, and number of components.

A high conversion ratio isolated bidirectional dc-dc converter topology is shown in Fig.3. The circuit includes high voltage V_{HV} ; high-voltage capacitor C1, dc-blocking capacitor C2; S1, S2, S3, and S4 are the four active switches; T1 transformer; L1 and L2 two inductors ; a low-voltage capacitor C3; and low voltage V_{LV} . The gate signals of S1 and S2 in the high-step-down stage are interfaced by a phase shift of 180 degree. S3 and S4 are synchronous rectifiers. The gate signals of S3 and S4 are greater than 50 % and are controlled by a phase shift

of 180 degree. The gate signals of S1 and S2 are smaller than 50 % and are controlled by a phase shift of 180 with synchronous rectifiers. [6]

The voltage on the transformer is reduced using the dc blocking capacitor in the high-voltage side, the output current ripple is reduced using the current doubler circuits in the low-voltage side. The energy stored within the leakage inductance is recycled to the dc-blocking capacitor. When the proposed converter is operated with a step-up function, the current ripples and conduction losses of the switches in the low-voltage side is reduced using dual current-fed circuits on the low-voltage side. The voltage-doubler circuit in the high-voltage side increases the conversion ratio. The conversion efficiency of the identified converter is greater when Compared with the conversion efficiency, the efficiency with the synchronous rectifier is greater than that with the antiparallel diode. Active rectification, or synchronous rectification, is a method for improving the efficiency of rectification by replacing diodes with actively controlled switches. Thus, the synchronous rectifier can significantly improve efficiency.

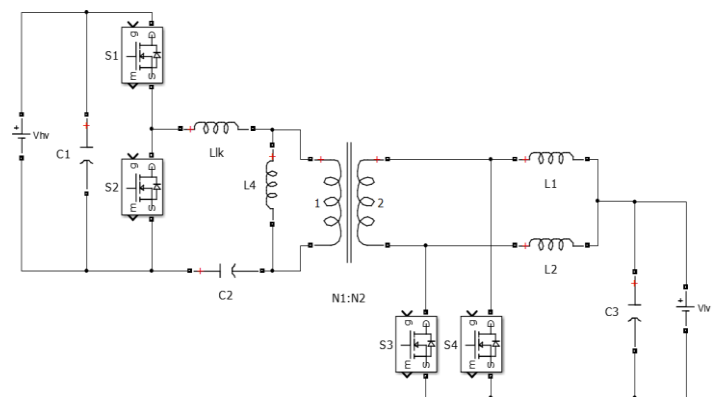


Fig-3: Schematic of high-conversion-ratio isolated bidirectional DC-DC converter.

The features of the identified converter are as follows:

- It provides galvanic isolation.
- Reduced size of transformer.
- It provides high conversion ratio.
- Low-voltage side has low ripple current.
- Synchronous rectifiers improve the efficiency.

3. MATLAB/SIMULINK MODEL

The simulation of the isolated bidirectional DC-DC converter with high conversion ratio has been carried out by MATLAB software and the simulation models are shown. The converter is operated with a low-side voltage of 24 V, a high-side voltage of 200 V, maximum power of 200 W, and a switching frequency of 50 KHz. Simulation of isolated

bidirectional DC-DC converter with R load for both step down and step up operation was done. Then the converter was integrated with BLDC motor and performed motoring operation.

3.1 SIMULATION PARAMETERS

Table-1: Simulation Parameters

PARAMETERS	VALUE
High voltage VHV	200V
Low voltage VLV	24V
Switching frequency fs	50kHz
Output power Po	200W
Inductance L1 And L2	780µH
Output filter capacitor C1	22 F
Output filter capacitor C2	22 F
DC blocking capacitor C3	2200 F
Leakage inductances	7.69µH
Turns ratio N1:N2	1.5:1

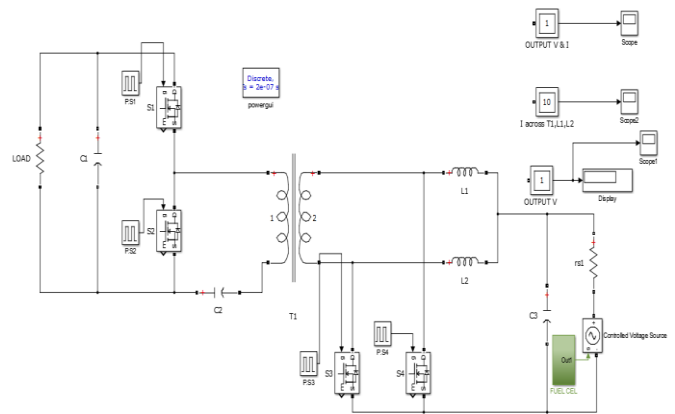


Fig- 5: Simulation circuit of isolated bidirectional DC-DC converter with step up operation

Fig.5. shows the simulation circuit of the isolated bidirectional DC-DC converter with R load .The input voltage given to the converter from the fuel cell is 24 V and the output the voltage is stepped up to 272.4 V.

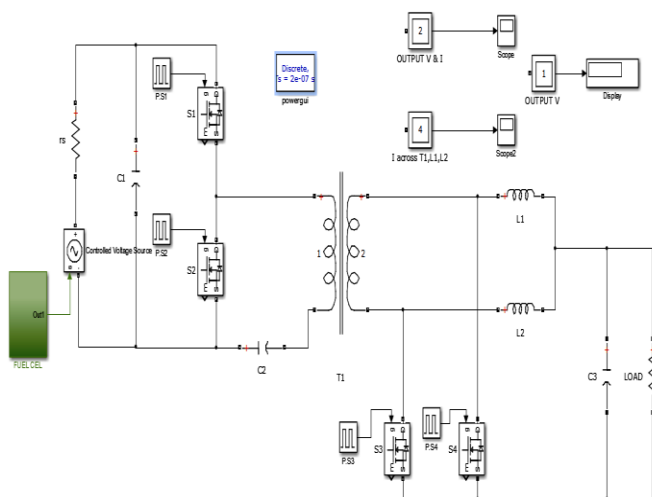


Fig- 4: Simulation circuit of isolated bidirectional DC-DC converter with step down operation

Fig.4. shows the simulation circuit of the isolated bidirectional DC-DC converter with R load .The input voltage given to the converter from the fuel cell is 200 V and the output voltage is stepped down to 16.63 V.

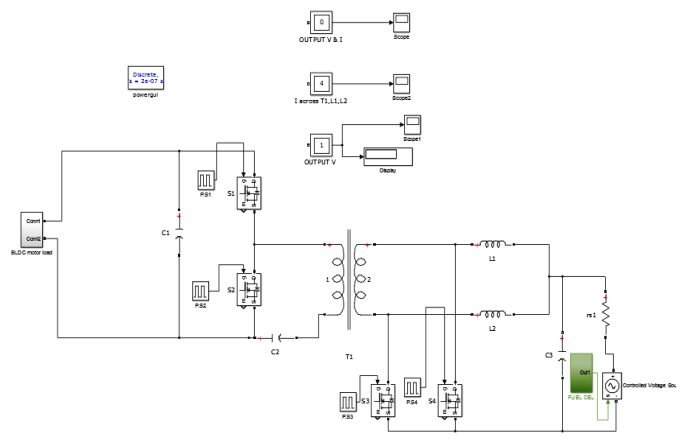


Fig-6:Simulation circuit of isolated bidirectional DC-DC converter with motoring operation

Fig.6. shows the simulation circuit of the isolated bidirectional DC-DC converter .The input voltage given to the converter from fuel cell is 24 V and the voltage is boosted to 270 V.

4. SIMULATION RESULTS

4.1 Simulated output voltage and current waveform of step down operation in isolated bidirectional dc-dc converter

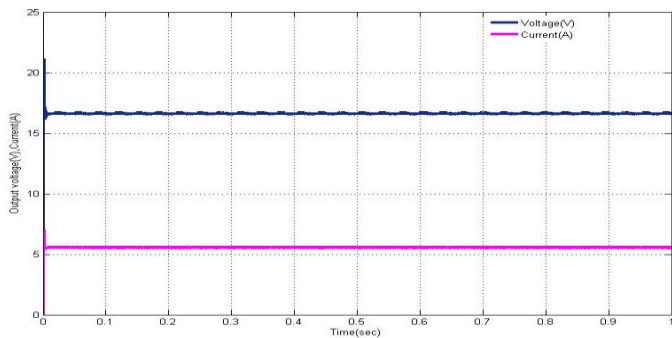


Fig-7: Output voltage and current waveform of Isolated bidirectional DC-DC converter with step down operation

Fig.7. shows the output voltage and current waveform of the isolated bidirectional DC-DC converter .The input voltage given to the converter from the fuel cell is 200 V and the output the voltage is stepped down to 16.63 V.

4.2 Simulated Output voltage and current waveform of step up operation in isolated bidirectional DC-DC converter

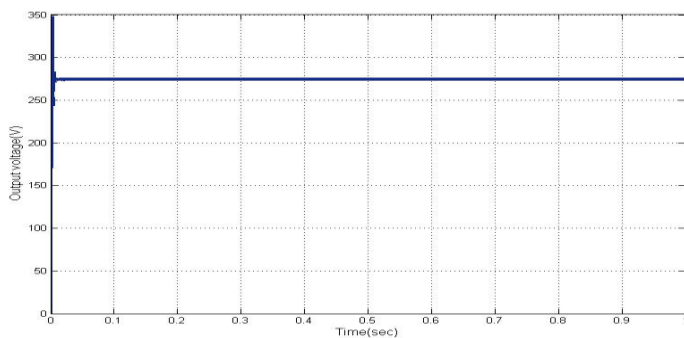


Fig- 8: Output voltage waveform of Isolated bidirectional DC-DC converter with step up operation

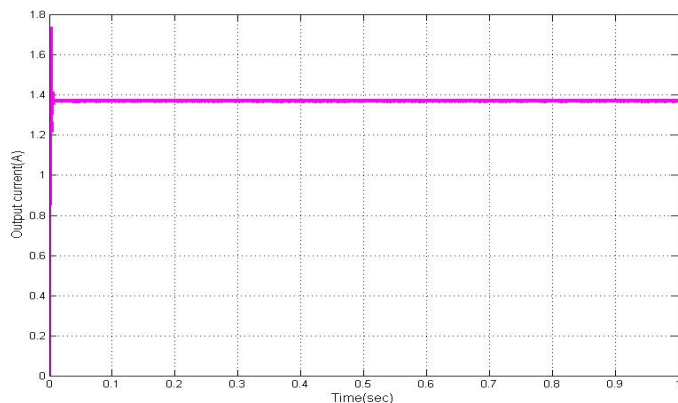


Fig-9: Output current waveform of Isolated bidirectional DC-DC converter with step up operation

Fig.8 and 9 shows the output voltage and current waveform of the isolated bidirectional DC-DC converter with R load .The input voltage given to the converter from the fuel cell is 24 V and the output the voltage is stepped up to 272.4 V

4.3 Simulated Output voltage, Stator current, Rotor speed and Electromagnetic torque of step up operation in isolated bidirectional DC-DC converter

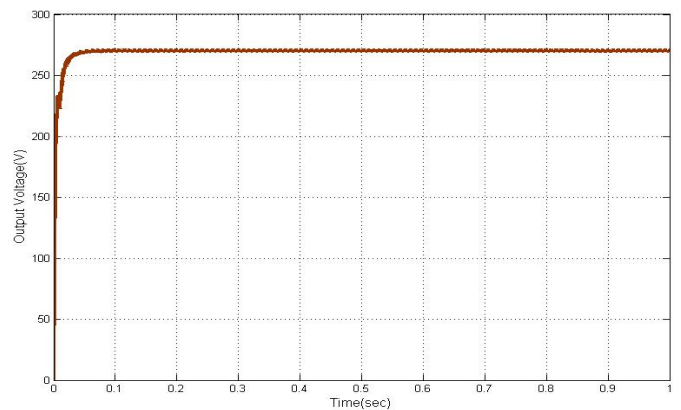


Fig-10: Output voltage waveform of isolated bidirectional DC-DC converter with motoring

Fig.10. shows the output voltage waveform of the isolated bidirectional DC-DC converter .The input voltage given to the converter from fuel cell is 24 V and the voltage is boosted to 270 V.

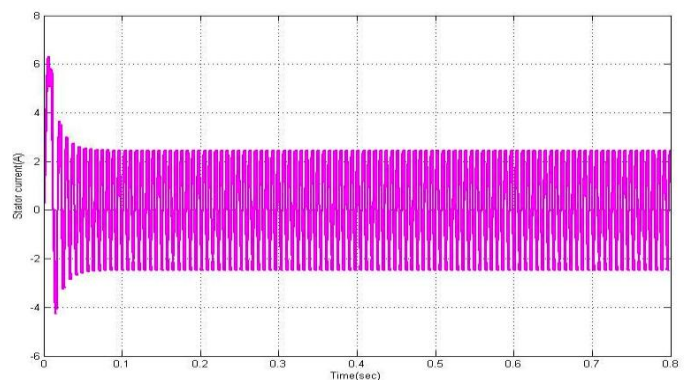


Fig-11: Stator current in BLDC motor fed from isolated bidirectional DC-DC converter

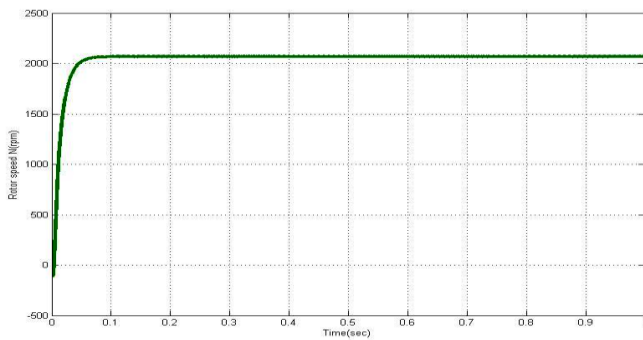


Fig-12: Rotor speed of BLDC motor fed from isolated bidirectional DC-DC converter

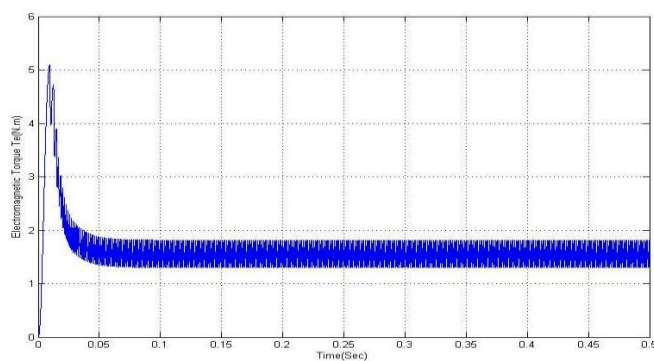


Fig-13: Electromagnetic Torque of BLDC motor fed from isolated bidirectional DC-DC converter

5. CONCLUSION

One of the latest application of DC-DC converter is electric vehicles. Different types of electric vehicles are there, and from that Fuel cell electric vehicle are seen to be better than the other types of electric vehicles since they do not emit carbon dioxide and they are ecofriendly. There are different applications for DC-DC converters in electric vehicles. Non isolated and isolated topologies of DC-DC converters are used for different application. Mostly isolated topologies are used for regeneration application since it can provide galvanic isolation and, high value of transformation ratio results in voltage and current ripple and stress in the switches. Hence isolated bidirectional DC-DC converter topology is suggested for motoring and regenerative braking. Here simulation of isolated bidirectional dc-dc converter with R load was performed. Due to the active rectification in the secondary side of the transformer in the converter, overall efficiency increases. Both step up operation and the step down operation were done and then performed the motoring operation by integration the converter with the BLDC motor

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