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Soft Switching Bidirectional DC-DC Converter for Hybrid Electric Vehicle Applications

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Abstract: *This paper explained about switching losses in prescribed circuit. Batteries are the primary energy-storage devices in ground vehicles. Now-a-days battery fed electric drives are commonly being used for electric vehicles Applications, due to various advantages, such as nearly zero emission, guaranteed load levelling, good transient operation and energy recovery during braking operation. To full fill these requirements converters with bidirectional power flow capabilities are required To connect the accumulator (battery) to the dc link of the motor drive system .In the present work closed loop operation of bi directional dc-dc converter feeding a dc series motor. Bi-directional dc-dc converter having some switching Losses. so we have to reduce these switching losses by using Soft switching technique .The confirmation of circuits operation and waveforms, measurement ofconversionefficiency, and loss analysis are verified using of MATLAB.*

Keywords: *LLC resonant converter, soft switching, zvs and zcs, boost chopper circuit*

Bidirectional dc-dc converters are the key components of the traction systems in Hybrid ElectricVehicles. Recently many Bidirectional dc-dc converter topologies have been reported with soft switching technique to increase the transfer efficiency. Bidirectional converters using coupled inductor were introduced for soft switching technique. For minimizing switching losses and to improve reliability, zero voltage switched technique and zero current switched technique were introduced for Bidirectional converter. This paper deals with the use of Bi-directional d c-dc converter for a battery fed electric vehicle drive system. A closed loop speed control technique of the proposed battery fed electric vehicle is designed and implement using PI controller.

II.BASIC CONCEPT OF ISOLATED BI-DIRECTIONAL DC-DC CONVERTER:

I. Introduction To Bidirectional Dc-Dc Converter:

Bidirectional DC–DC converters are used to transfer the power between two DC sources in either direction. 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 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.For achieving zero emission, the vehicle can be powered only by batteries or other electrical energy sources. Batteries have widely been adopted in ground vehicles due to their characteristics in terms of high energy density, compact size, and reliability. This can be applied in Hybrid Electric Vehicle (HEVs) with a battery as an energy storage element to provide desired management of the power flows. In hybrid electric vehicle energy storage devices act as catalysts to provide energy boost. Recently bi-directional dc-dc converter are widely researched and developed for various applications such as battery charger discharger, electric vehicles and UPS systems. In case of the battery fed electric vehicles (BFEVs), electric energy flows between motor and battery.

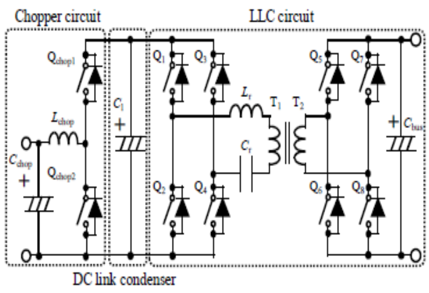

Figure.1. Bi-directional DC-DC converter

A. *circuit description:*

Above Fig.1 shows an isolated bidirectional dc-dc converter .which contained bi-directional boost chopper circuit and full bridge type LLC converter. The full bridge type LLC converter is used for isolation.The bi-directional boost chopper circuit consisting of an input capacitor *Cchop*, input inductor L_{chop}, IGBT switch Q_{chop1}, Q_{chop2}, the full bridge type LLC converter consisting of a DC link capacitor $C_{1,}$at the primary side full bridge type converter consisted of four switches,and resonant capacitor C_r and inductorL_r, transformer, four switches in the secondary side and smoothing capacitor $C_{bus.}$

A. *Circuit principle*

Generally,switching of the bi-directional chopper circuit shows hard switching and to prevent from short-circuit, there is dead time for on/off of switch *Q*chop1, *Q*chop2. Pulse Wide Modulation (PWM) control and Constant Current (CC) control are adopted for the bi-directional boost chopper circuit and battery current respectively. The isolated bi-directional DC-DC converter is driven with duty 50%. Dead time for the switch *Q*1, *Q*4, *Q*5, *Q*8 and *Q*2, *Q*3, *Q*6, *Q*7 is set up. On the switching, the ZCS operation is realized with the resonant of the inductor $L_r$and capacitor*Cr* for the switches *Q*1~ *Q*8. As mentioned before, the duty for the isolated bi-directional DC-DC converter is fixed so that current and voltage control isn't required.

Now operation principle of isolated bi-directional DC-DC converter is explained. Fig.2 shows the operation stages for discharge and Fig.3 shows the operation stages for charge. The operation stages ofthe isolated bi-directional DC-DC converter are as follows. In this explanation, the operationstages for the charging time of the isolated bi-directional DC-DC converter and the operationstages of the bi-directional chopper circuit are omitted. And also, the positive voltage and current direction of the capacitor *C*r and inductorL_r for the resonant is defined as the arrow direction in Fig.2 and Fig.3

II. Modes Of Operation

Mode1: Q_1,Q_4,Q_5,Q_8 these four switches are turned on. The resonant voltage of the capacitor *C*r is positivelycharged in this moment and then resonant capacitor *C*r starts to discharge. After that,the resonant voltagecapacitor *C*r crosses zeroand completes to charge negatively. The current ofinductorL_r is approximately zero.

Mode2: The switches Q_1, Q_4, Q_5 and Q_8 , turn on since the resonant current of the inductor *L*r is zero.For the cause of ZCS operation is realized beacuase there is no current switching.Every switch can be tuned off After that, they are in the dead time period.

Mode3:The beginning of this mode starts from the dead time period. All the switches are in off state. After finishing the dead time period, the switches *Q*2, *Q*3,*Q*6, and *Q*7 turn on. At this time, the ZCS operation is achieved since the switch current gradually increases by the resonant capacitor *C*r and inductor *L*r. In this moment, the resonant voltage across the capacitor *C*r is negative voltage.

Mode4: The switches *Q*2, *Q*3, *Q*6, and *Q*7 turn on and then the resonant capacitor *C*r starts to discharge with resonant. After that, the resonant capacitor *Cr* charges positively due to the resonant. In other words, the current and voltage of the resonant capacitor*Cr* and inductor *L*r change in contrast to *Mode1*.

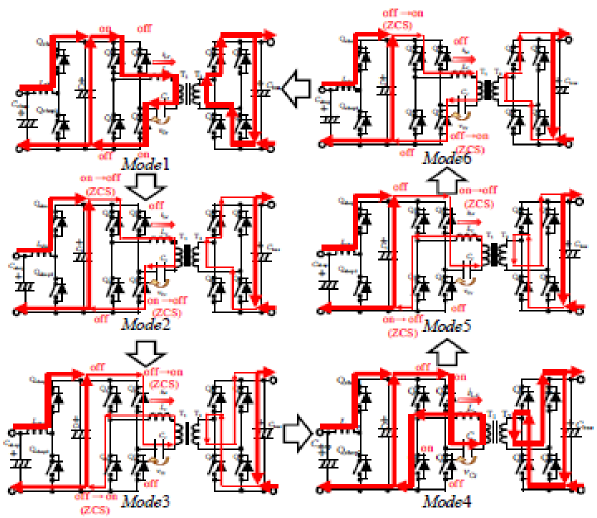

Figure 2. Operation stages for discharge

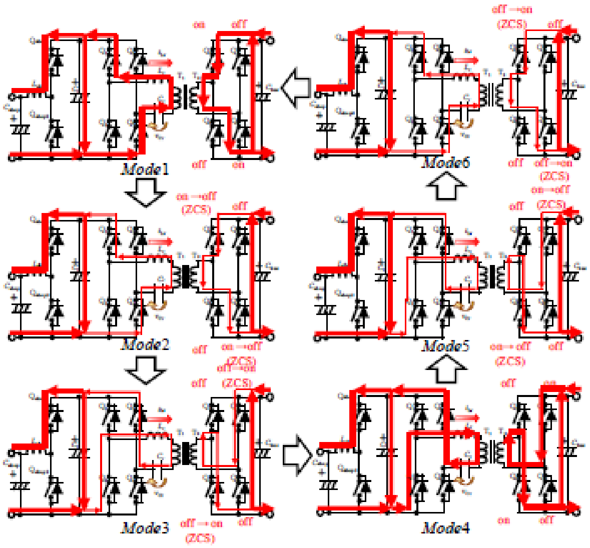

Figure 3. Operation stages for charge

Mode5: The resonant current of inductor *L*r becomes approximately zero, and then the switches *Q*2, *Q*3,*Q*6, and *Q*7 turn on. Accordingly, the ZCS operation is realized. After that, each of the switches turns off and the mode moves to next mode

Mode6: In the beginning of this mode, all switches are in the off state. Finishing the dead time period, the switches*Q*1, *Q*4, *Q*5, and *Q*8 turn on. At this moment, the ZCS operation is realized since the current gradually rise up with the resonant. After
turning on the mode moves to *Mode1*.

III. Evaluation For 10kw Prototype

A. Circuit Structure of 10kW:

10Kw prototype of the isolated bidirectional dc-dc converter is shown in fig.4 and which is built and tested, circuit structure of 10kw prototype is shown in fig.5.

B. Experiment Results:

The terminal voltage waveform of IGBT on the bus line is shown in fig.6, the voltage waveform of the resonant capacitor *C*r, and current waveform of the resonant inductor *L*rin the charging time of 10kW. And also, Fig.7 describes the terminal voltage waveform of IGBT on the bus line, the voltage waveform of the resonant capacitor *C*r, and current waveform of the resonant inductor *L*rin the discharging time of 10kW.

Figure.4 Contrivance for 10[kW] type

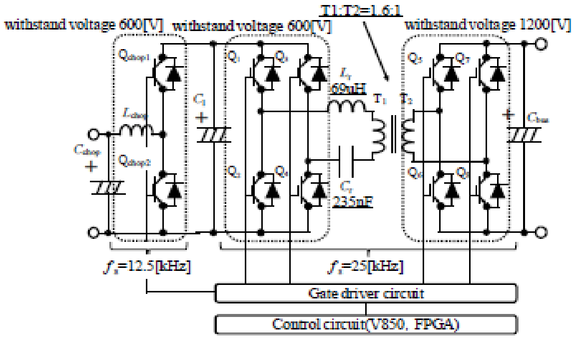

Figure.5 [10kw] circuit structure

Above fig.5 shows circuit structure of 10kw prototpe.in this we have to consider transformer ratio 1.6:1 and also used PI controller.

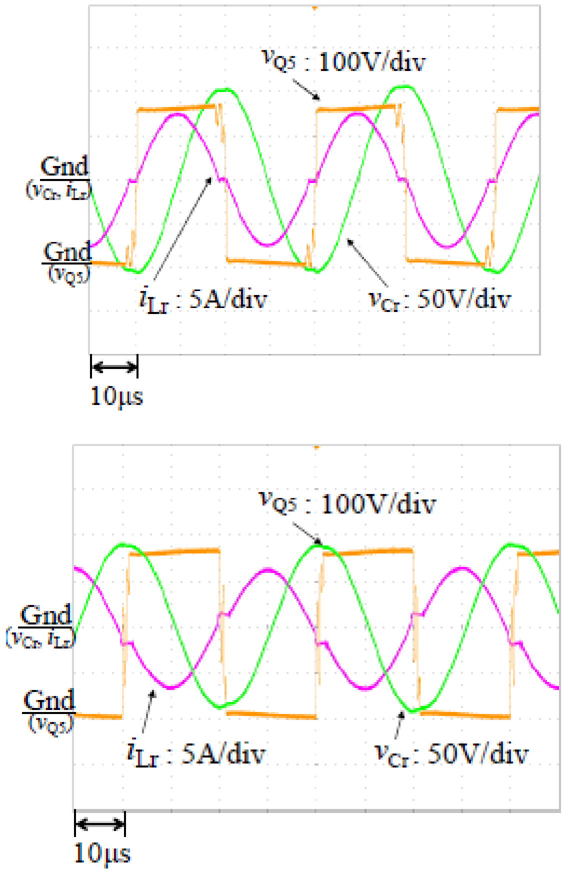

Figure.7 Voltage and current waveform of 6.5[kW] in the discharging

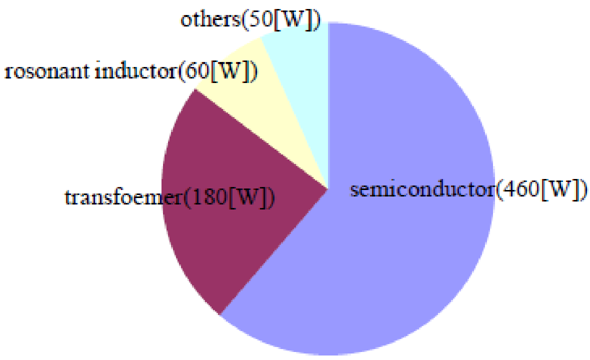

Figure.8 Loss analysis result in 10[kW]

Power semiconductor devices occupies 50% of losses so we have to reduce these switching losses and to improve efficiency by using soft switching techning.

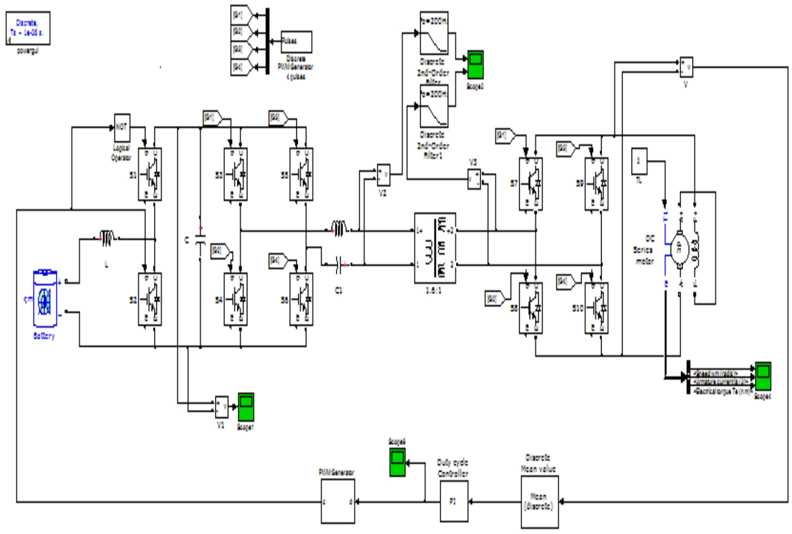

Figure.9 matlab model of 10kw prototype

Figure.6 Voltage and current waveform of 10[kW] in the charging

fig.9 shows implementation example of 10kw prototype.Battery is connected at the input side,and also we have to choose dc series motor instead of other motors because of it has high starting torque and this motor running at 1000rpm at the output side.The proposed topology is simulated using MAT lab simulink software and it is observed and output is verified. D.C. series motors are ideal for large loads and industrial applications and also used for loads such as cranes, hoists, elevators, trolleys and conveyors, but are also used for automobile starters.

IV. Simulation Results

In order to verify the speed of the dc series motor and also voltage at the boost chopper circuit, simulation model has been developed using of Matlab/Simulink. Both the simulation and experimental analysis are done for a bidirectional dc-dc converter with dc series motor. as this topology has been proved to be attractive for large loads and indusrial applications.

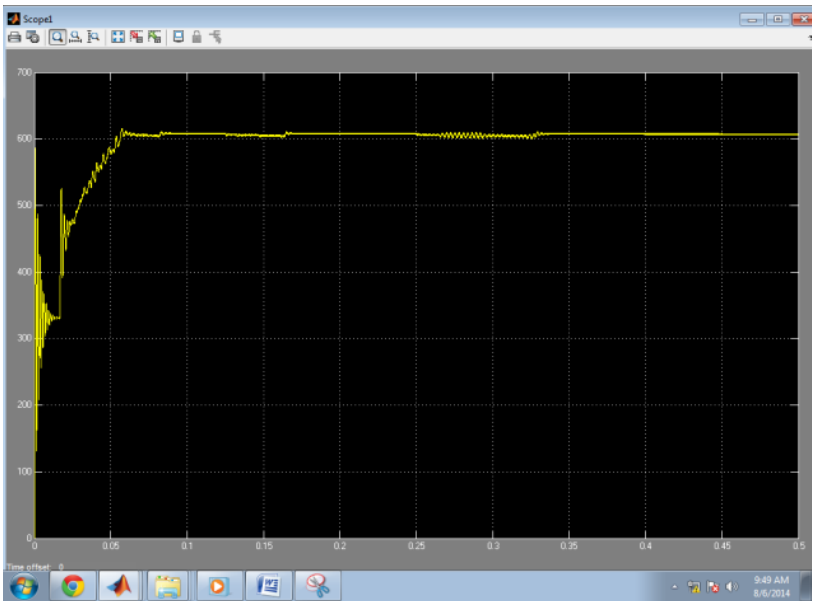

Figure.10 voltage versus time at the boost chopper circuit.

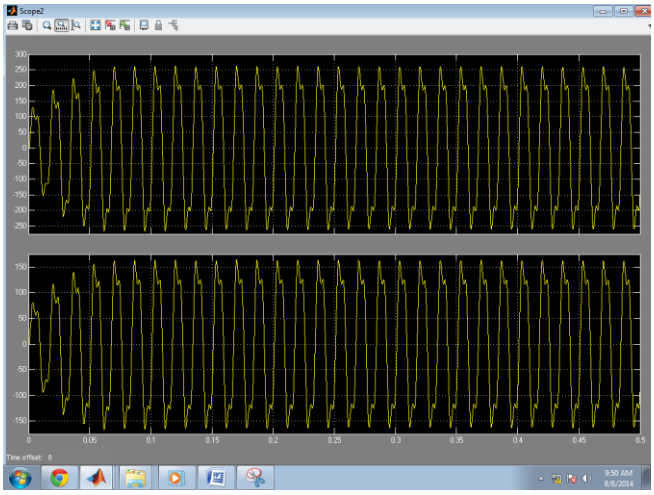

Figure.11 voltage versus time at the primary and secondary of the transformer

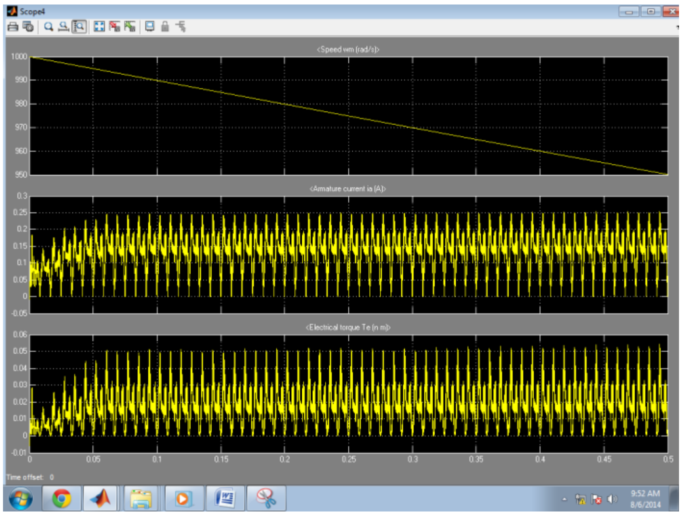

Figure.12 speed,armature current and torque of the dc series motor

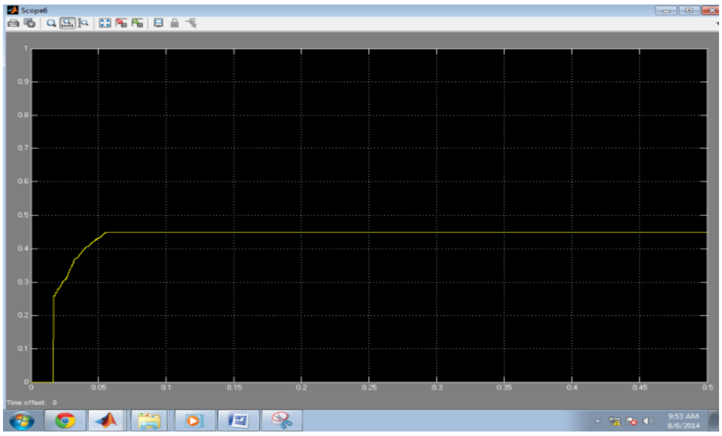

Figure.13 duty cycle ratio

V. Conclusion

In this paper circuit operation,waveforms,loss analysis for an isolated bidirectional dc dc converter and speed of the dc series motor can be observed.In this work we demonstrate the performance of a battery operated electric vehicle system and it shows satisfactory performance at different driving condition. The proposed control technique with PI controller find suitable for this electric drive.

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