

Closed Loop Control of Non-Isolated Bidirectional Dc/Dc Converter

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Abstract: – In this project a bidirectional dc-dc converter using ZVS technique employs a coupled inductor is implemented. In step-up mode, the coupled inductors are parallelly charged and serially discharged to get a high output voltage gain. In step-down mode, the coupled inductors are serially charged and parallelly discharged to get a low output voltage gain. Current system using ordinary switching techniques, so that the switching loss is very high. Therefore more heat will dissipated. In ZVS technique, heat loss is minimum. So we can increase the life span of switches. Moreover, we can increase the output voltage. The proposed converter aims to reduce the switching current. It has higher step-up and step-down voltage gains than the conventional bidirectional dc-dc converter. For the same electric conditions, the proposed converter's and the conventional bidirectional converter's efficiency, voltage gain, output voltage and switching current will differ. Here closed loop control is used. By using a PID controller, we can obtain a high output voltage and high gain by controlling the duty cycle of switches.

I. INTRODUCTION

A DC to DC converter is an electronic circuit which converts direct current from one voltage level to another. It is a type of power converter. DC to DC converter are used in portable electronic devices such as cellular phones and laptop computers, which are supplied from batteries primarily. Such electronic devices mostly contain several sub-circuits, that are different from that supplied by the battery or any external supply, may be higher or lower than the supply voltage. Moreover, the battery voltage decreases as its stored power is decreased. Switched DC-DC converters offer a method to increase voltage from a partially lowered battery voltage, thereby save the space instead of using a no. of batteries. Most DC-DC converters will regulate the output. High efficiency LED power sources, belong to the type of DC-Dc converters, which regulates the current through the LEDs, and the charge pumps will double or triple the input voltage.

A bidirectional DC-DC converter is used for dc-dc conversion process. The power converter has two full bridge converters, one act as inverter and other as rectifier. This bidirectional DC-DC converter is suitable for electrical vehicle applications. It has advantages of simple circuit with soft switching implementation (ZVS), without additional devices. It has high efficiency and simple control. These advantages make the converter applicable for low, medium and high power applications; mainly for auxiliary power supply in fuel cell vehicles and power generation. It is used in applications where high power density, low cost, low weight and high reliability power converters are required. Micro Controller is used to create pulses for switches. It triggers, operates and controls MOSFET devices. PWM technique is used to reduce the harmonics and noises in the circuit.

II. CLASSIFICATION

Most of the existing bidirectional DC-DC converters has the basic circuit structure shown in Figure 1, which is fed by a current or voltage on one side. Based on the auxiliary energy storage and conduction period, the bidirectional dc-dc converter can be classified into buck and boost converters. The buck type have energy storage placed on the high voltage with low conduction period, and the boost type have it placed on the low voltage side with high conduction period.

It is classified into two types:

- Isolated DC/DC Bidirectional Converter
- Non-Isolated DC/DC Bidirectional Converter

a. Isolated Dc/Dc bidirectional Converter

In the Bidirectional DC-DC Converters, isolation is done by using a transformer. The transformer will cause additional cost and losses. The transformer can isolate the voltage sources and match the impedance between them. So it is used for galvanic

isolation purposes. Inductance is provided between two current sources. Full bridge, half bridge or push-pull circuits are used for isolated bidirectional dc-dc converter. Galvanic isolation between inverter and converter circuits, high output voltage gain, high power applications and additional safety are its advantages.

b. Non- Isolated Dc/Dc Bidirectional Converter

In Non- Isolated Bidirectional DC-DC Converter there is no transformer. Isolated Bidirectional DC-DC Converter is used for galvanic isolation purposes. This will add additional size, weight and cost. So transformer-less type is preferred. Non- Isolated Bidirectional DC-DC Converter is used in high power, space craft applications and in applications where low weight and size is required. It is a combination of step-up and step-down stages. It has antiparallely connected rectifier and inverter circuits. In motor drive operations, the step-up stage is used to increase battery voltage. Step-down stage is used to break current in vehicle regenerative braking.

In order to reduce the disadvantages of Isolated Bidirectional DC-DC Converter, here we are using a Non- Isolated Bidirectional DC-DC Converter.

III. A.STEP-UP MODE

ZVS technique is used to control the switches. Here S1 and S2 are the main switches and S3 is the auxiliary switch.

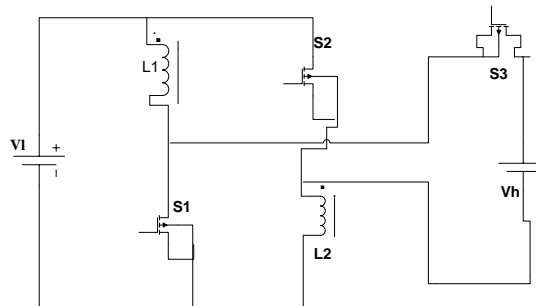


Figure.1 Conventional bidirectional dc-dc converter.

The inductance of the coupled inductors are same, because their primary and secondary windings are same.

$$L_1 = L_2 = L$$

The mutual inductance is given by, $M = k\sqrt{L_1L_2} = kL$

where k is the coupling coefficient of the coupled inductor.

The voltages across L1 and L2 is:

$$v_{L1} = L_1 \frac{di_{L1}}{dt} + M \frac{di_{L2}}{dt} = L \frac{di_{L1}}{dt} + kL \frac{di_{L2}}{dt}$$

$$v_{L2} = L_1 \frac{di_{L1}}{dt} + M \frac{di_{L2}}{dt} = L \frac{di_{L1}}{dt} + kL \frac{di_{L2}}{dt}$$

The bidirectional converter has two modes of operations: continuous mode (CCM) and discontinuous mode (DCM).

a) CCM Operation

1) Firstly S1 and S2 are conducting and S3 is in OFF position. The supply from the low voltage side is passed to the coupled inductors. They get parallelly charged. Capacitor get charged towards the load. Here, the voltage across the two inductors are same and they may be equal to V_L .

$$v_{L1} = v_{L2} = V_L$$

2) Now, S1 and S2 get turned off. That time, S3 is in ON condition. Now the inductors are seriesly charged. Now energy is supplied to capacitor and load. Here current across the two inductors are same.

$$i_{L1} = i_{L2}$$

$$v_{L1} + v_{L2} = V_L - V_H$$

The state-space method is given by,

$$\frac{DV_L}{(1+k)L} + \frac{(1-D)(V_L-V_H)}{2(1+k)L} = 0$$

The voltage gain can be calculated by the equation :

$$G_{CCM(step-up)} = \frac{V_H}{V_L} = \frac{1+D}{1-D}$$

b) DCM Operation

1) Firstly S1 and S2 are conducting and S3 is in OFF position. Operation is similar to that of CCM mode. Current flowing through L1 and L2 are same.

$$I_{L1p} = I_{L2p} = \frac{V_L D T_s}{(1+k)L}$$

2) Here, S1 and S2 is in OFF condition. S3 is conducting. The coupled inductors are seriesly charged. The low voltage supply will energises the capacitor and the load. The current through the two inductors will becomes zero.

3) There is a time interval in which S1 and S2 are continuing in OFF position and S3 is in ON mode. Now the energy in the two inductors becomes zero. So current also becomes zero. Capacitor will get discharged.

$$D_2 = \frac{2DV_L}{V_H - V_L}$$

The current through the capacitor is :
$$I_{cH} = \frac{\frac{1}{2}D_2 T_s I_{L1p} - I_o T_s}{T_s} = \frac{1}{2}D_2 I_{L1p} - I_o$$

Finally, the voltage gain is,
$$G_{DCM(step-up)} = \frac{V_H}{V_L} = \frac{1}{2} + \sqrt{\frac{1}{4} + \frac{D^2}{(1+k)T_{LH}}}$$

B. STEP DOWN MODE :

ZVS technique is used to control the switche S3. Switches S1 and S2 are not active here. The two modes of operation, CCM and DCM are explained below :

a) CCM Operation

1) Firstly S3 is conducting and S1 & S2 are in OFF position. The supply from the high voltage side is passed to the coupled inductors, capacitors and the load. Inductors get serially charged. And the current across them are same.

$$i_{L1} = i_{L2}$$

$$v_{L1} + v_{L2} = V_L - V_H$$

2) S1 and S2 are conducting and S3 is in OFF position. Energy of the coupled inductors are discharged to the capacitor and load. The conductors are parallely connected. Voltage flowing through L1 and L2 are same.

$$v_{L1} = v_{L2} = -V_L$$

The voltage gain can be calculated by the equation :

$$G_{CCM(step-down)} = \frac{V_L}{V_H} = \frac{D}{2-D}$$

b) DCM Operation

1) Firstly S3 is conducting and S1 & S2 are in OFF position. Operation is similar to that of CCM mode.

2) S1 and S2 are conducting and S3 is in OFF position. Energy of the coupled inductors are discharged to the capacitor and load. The conductors are parallely connected. The current through the two inductors will becomes zero first. After that, the increment of curret through the two inductors are same and it can be derived as below :

$$I_{L1p} = I_{L2p} = \frac{(V_H - V_L) D T_s}{2(1+k)L}$$

3) There is a time interval in which S1 and S2 are continuing in ON position and S3 is in OFF mode. The energy stored in the coupled inductor is zero. Now the energy in the two inductors becomes zero. So current also becomes zero. Capacitor will get discharged towards the load.

$$D_2 = \frac{D(V_H - V_L)}{2V_L}$$

Finally, the voltage gain is,

$$G_{DCM(step-down)} = \frac{V_L}{V_H} = \frac{2}{1 + \sqrt{1 + \frac{16(1+k_{LL})}{D^2}}}$$

IV. ZVS TECHNIQUE

In the applications of bidirectional dc-dc converter, efficiency is the main parameter. Many soft switching techniques are used to improve the efficiency. ZVS means, the switch is turn ON only at zero voltage. By doing like this, the switching losses and power losses can be eliminated. ZVS can be applied in both forward and reverse directions without the help of an external device. By this we can reduce the no. of components, thereby the size and cost of equipment get reduced.

Normal switching technique has high switching and heat loss. But ZVS has low heat loss, high output voltage and can increase the life span of switches. Switching current and frequency can also be reduced.

V. ADVANTAGES

- ZVS has low heat loss
- High output voltage
- Can increase the life span of switches
- Switching current and frequency can be reduced

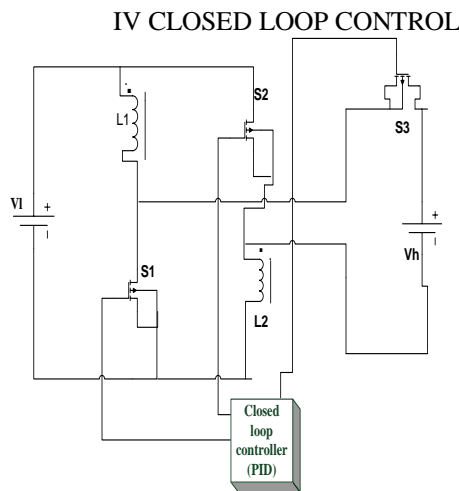


Figure.2 Closed loop control of bidirectional dc-dc converter.

Closed loop control is more advantageous than open loop control. Output can be fed back to input. By doing like this, no energy get wasted during regenerative braking. Using closed loop control, we can control the duty cycle of the switches and thereby we can obtain a high output voltage gain.

VI. PID CONTROLLER

Mainly there are three types of controllers used:

- P controller
- PI controller
- PID controller

P controller means Proportional controller. It is simpler than other controllers. But it has large error signal. Its settling time is also very large.

PI controller means Proportional Integral controller. It produces error signal which is smaller than P controller. But it takes more time to settle.

PID means Proportional Integral Differential controller. It has a very small error signal. And its settling time is also very small. By controlling the duty cycle of switches, a PID controller will obtain a high output voltage, high voltage gain, and it helps to decrease the noise disturbances. Because of these advantages, here we are using a PID controller.

Figure 3 shows the block diagram of a PID controller-based bidirectional DC-DC converter. A DC supply is given to the bidirectional DC-DC converter. Then the output is given to the load. This output is taken and compared with a reference signal by using a comparator. The reference signal is a previously set value. The difference between the output signal and the reference signal is the error signal. This is then given as input to the PID controller. The PID controller will control the duty cycle of the switches by using a pulse generator. And finally, it obtains a high output voltage.

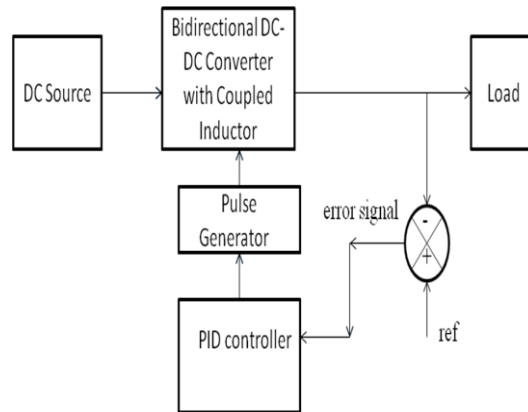


Figure.3 Block diagram of bidirectional dc-dc converter.

VII. SIMULATION RESULT

Closed loop control for step up operation

Closed loop control is applied across the first switch and the auxiliary switch for getting step up operation. From the graph, it is seen that the frequency is 50kHz and we get an output voltage of 140V.

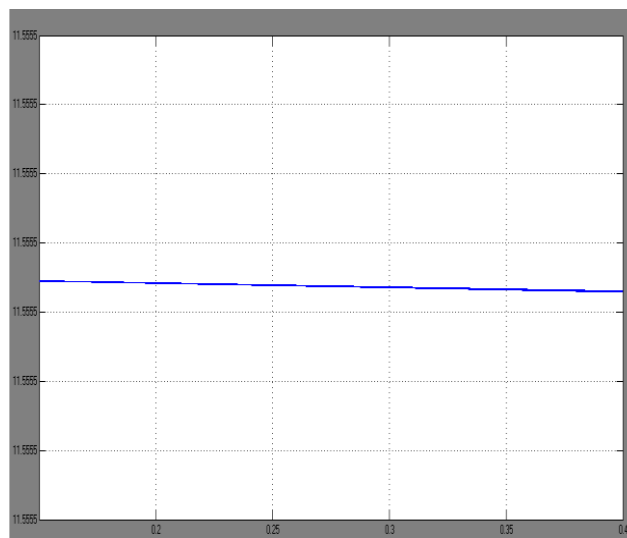


Figure.4 Closed loop control for step up operation

Closed loop control for step down operation

Closed loop control is applied across the second switch and the auxiliary switch for getting step down operation. The frequency is 50kHz and we get an output voltage of 11V.

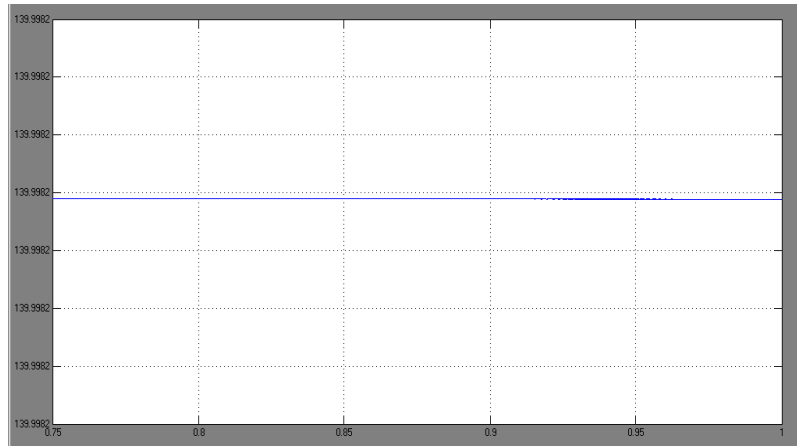


Figure.5 Closed loop control for step down operation.

ZVS technique for step up operation

ZVS technique is applied across the first switch and the auxillary switch for getting step up operation. From graph , it is seen that we get an output voltage of 52V.

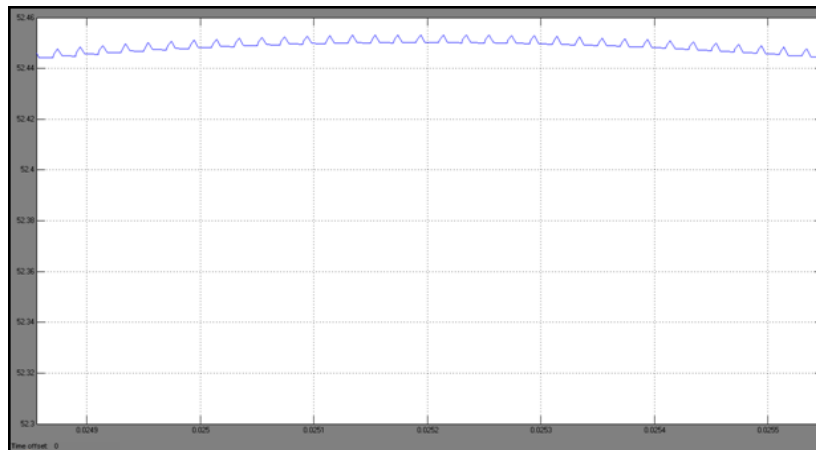


Figure.6 ZVS technique for step up operation

ZVS technique for step down operation

ZVS technique is applied across the second switch and the auxillary switch for getting step down operation. From graph , it is seen that we get an output voltage of 12V.

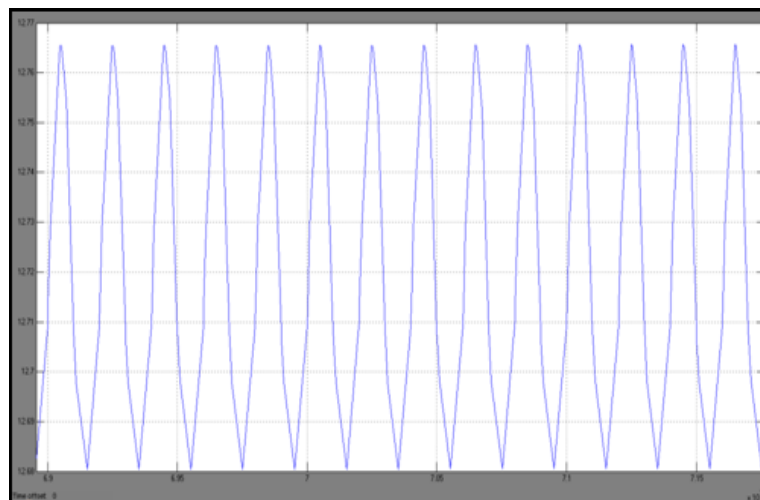


Figure.7 ZVS technique for step down operation

VIII. CONCLUSION

In this paper a ZVS based bidirectional dc-dc converter is used. It has a very simple circuit diagram. The converter has The proposed converter has higher step-up and step down voltage gains and lower average value of the switch current than the conventional bidirectional boost/buck converter. And also by using the ZVS technique, we can reduce the heat loss and thereby can increase the life span of switches. ZVS reduces the switching current and frequency and a high output voltage is obtained the switching current and frequency and a high output voltage is obtained. Closed loop control is advantageous than open loop control. By using a PID controller, we can obtain a high output voltage and high gain by controlling the duty cycle of switches.

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