Comparison of Conventional and ZCS Non-Isolated Bidirectional Buck-Boost Converter for Battery Applications

[1]Nidhi A V,[2]Satish B A
[1]Student,[2]Asst. professor
[1]Power electronics(EEE),
[1]Dayananda Sagar College of Engineering, Bangalore, India.

Abstract: With the increase in the population growth the energy consumption has also increased. Due to this the fossil fuels have also started depleting. This forces the need for generation through alternate sources. Solar power plants are seeking more attention in this scenario. Solar plants require a back-up storage arrangement, since the generation of power is not 24x7. Hence energy storage devices such as batteries are provide for storage of power during the peak hours of generation. For this purpose bidirectional converters (BDC) are used which facilitates the power in both the directions i.e., both charging and discharging the battery. In this paper we are presenting the comparative study of a conventional and a zcs implemented bidirectional buck-boost converter on the basis of switching losses. The simulation work is done using MATLAB simulation software and the results are given in the paper.

IndexTerms - energy storage devices, bidirectional converter, boost converter, buck converter, PWM, renewable energy resources, zero current switching

I. INTRODUCTION

A microgrid is nothing but a number of electric power sources and loads connected to the single bus. These sources and loads operate synchronously. The best and well known example for the DC micro grid is a solar power plant. Due to increase in power consumption the demand for electric power generation has also increased. Now-a-days solar power has become prominent source for electricity generation. But since the solar power can't be harnessed 24x7, the solar power plant is provided with the back-up system. It is done with the help of Energy Storage Devices (ESD). The ESDs used can be fuel cell, batteries, fly wheels etc…

The ESDs can be interfaced to the microgrids with the help of DC-DC converters. The DC-DC converters play a vital role in conditioning the power as per the requirement. The DC-DC converters used can be BUCK or BOOST or BUCK-BOOST converter. The main requirement of the converter is to charge as well discharge the battery, for this purpose it will be convenient to use a bidirectional converter (BDC). The BDC enables the power flow in both the directions. The basic configuration of dc grid system with the BDC is as shown in figure 1

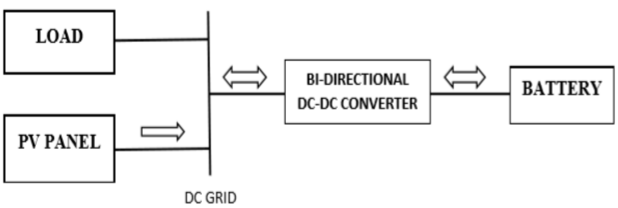

Figure 1, Basic configuration of DC grid with BDC system.

As shown in the fig 1.1 the PV panel supplies power to the load as well charges the battery with the help of the converter. The bi-directional converter operates in two modes:

- **Buck mode:** In the presence of the DC grid, the battery is charged and the converter operates as a buck converter.
- **Boost mode:** In the absence of the DC grid, the battery supplies power to the grid and the converter now operates as a boost converter.

- This paper presents a comparison between the conventional BDC and a ZCS implemented BDC. The conventional BDC needs only one energy storage element and it enables the power flow between two sources in either direction. It uses two bidirectional switches such as MOSFETs or IGBTs. But this topology has high switching losses which are due to hard switching. To overcome this defect we have a ZCS implemented BDC with reduced switching losses. Analysis is done using MATLAB software for same input and output power ratings. The paper is arranged as: Section II gives information regarding the two converters used for the analysis, Section III presents the simulation work done and the results, Section IV give the conclusion.

II. DESCRIPTION OF THE CONVERTERS

2.1 Conventional BDC

The non-isolated bidirectional buck boost converter is as shown in figure 2 ,

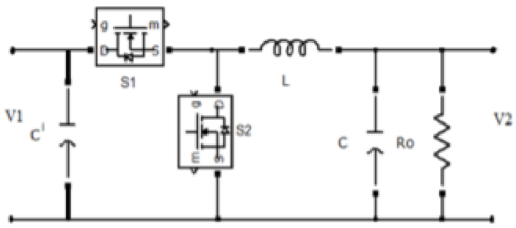

Figure 2, Circuit of conventional BDC

In the above fig.2 we can see that the converter consists of two bidirectional switches S1 and S2. The switches used can be MOSFETs or IGBTs. The converter works in two modes of operation i.e., buck mode and boost mode. In the buck mode the power flows from source to the load i.e., the battery is charged. In the boost mode, the power flows from load to source i.e., the battery is discharged. During buck mode switch S1 is switched on and during the boost mode switch S2 is switched on enabling forward and reverse flow of power respectively.

2.2ZCS bidirectional converter

A soft switched bidirectional converter using zero current switching is used for the analysis and comparison. It makes use of auxiliary switches to achieve soft switching. The auxiliary switches are turned ON when the current across the main switches is zero. It operates in buck and boost mode to enable the charging and discharging of the battery. The non-isolated bidirectional converter is shown in the figure 3

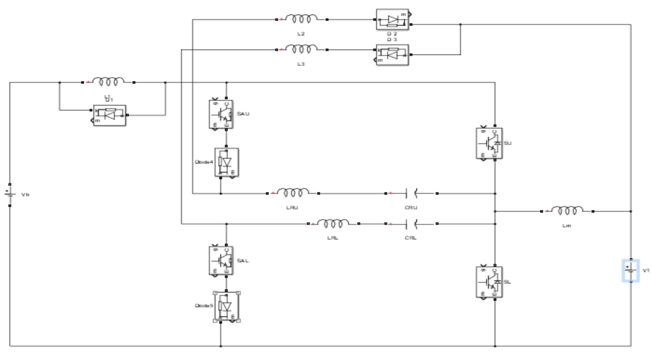

Figure 3 ZCS bidirectional converter

The non-isolated bidirectional converter consists of two auxiliary switches to enhance the soft switching. The inductor L_1 acts as the energy transfer element. Inductors L_2 and L_3 are used to limit the current across the main and auxiliary switches. The inductors L_{RU} and L_{RL} and capacitors C_{RU} and C_{RL} forms the resonant circuit for buck and boost mode respectively.

III. SIMULATION RESULTS

The simulation work is done with the help of the MATLAB simulation software. The output results of the conventional and ZCS implemented bi-directional converter are analyzed.

3.1 Conventional BDC

The simulation model for the conventional BDC in buck mode is shown in the figure 4. The simulation is carried out at 0.55 duty cycle.

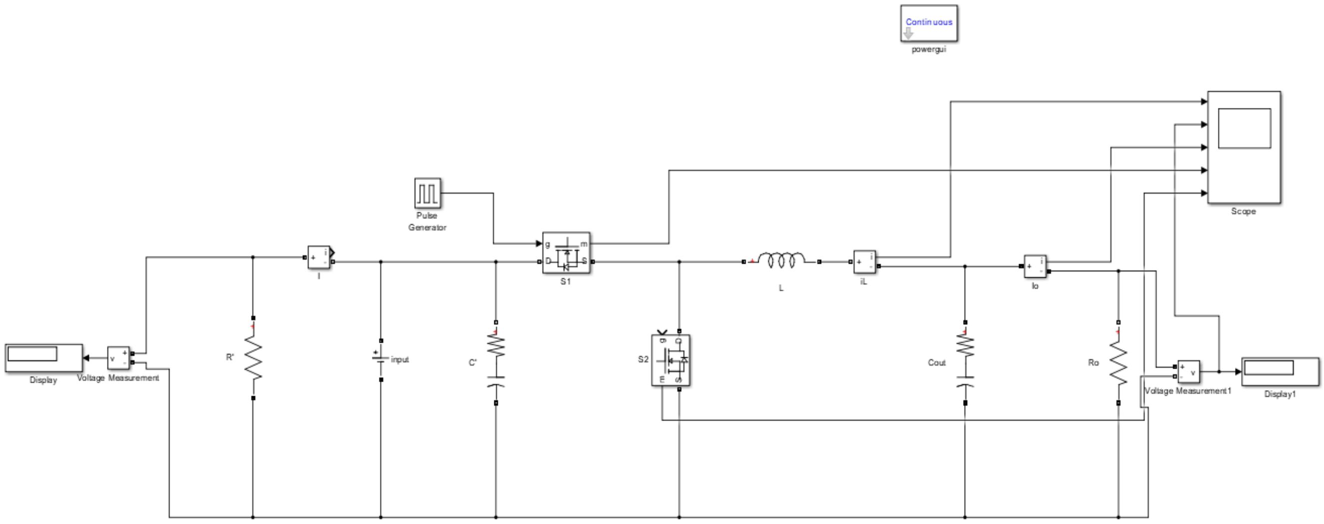

Figure 4. simulink model of conventional bdc in buck mode

The simulation results of the conventional BDC in buck mode is as shown in figure 5.

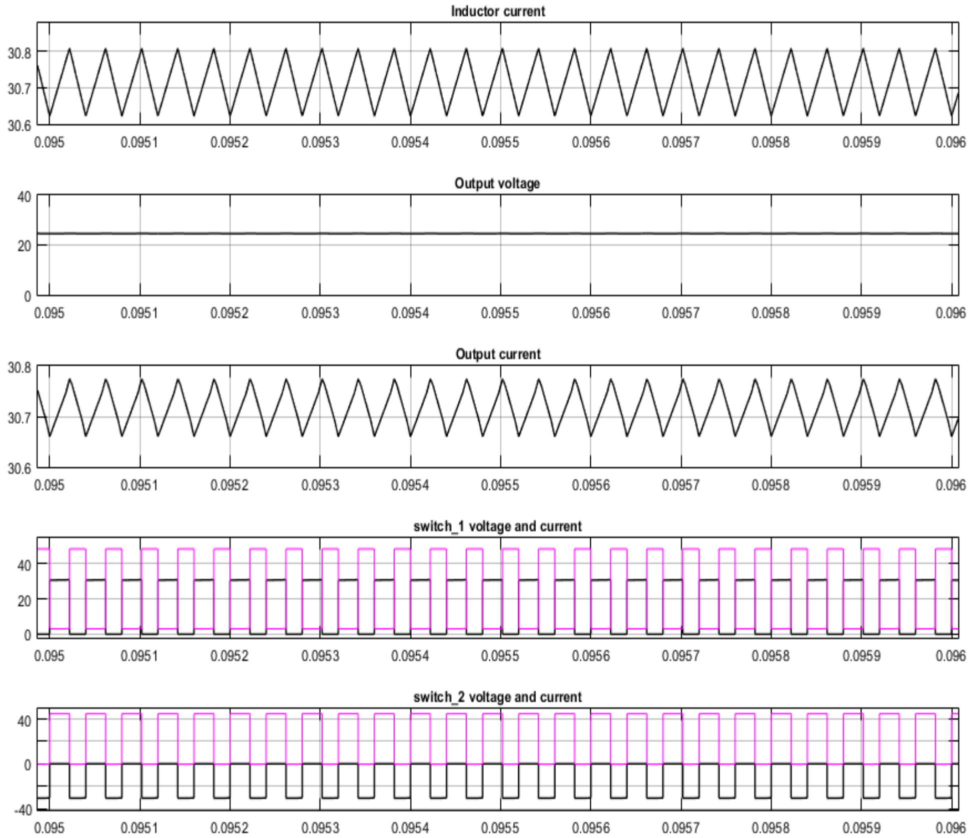

Figure 5. Waveforms of inductor current, output voltage, output current, switch voltage and currents respectively in buck mode

From the figure 5 we can see that the ripple in inductor current is about 0.2A, the output voltage obtained is 24V for input of about 48V.

The simulation model for the conventional BDC in boost mode is shown in the figure 6. The simulation is carried out at 0.55 duty cycle.

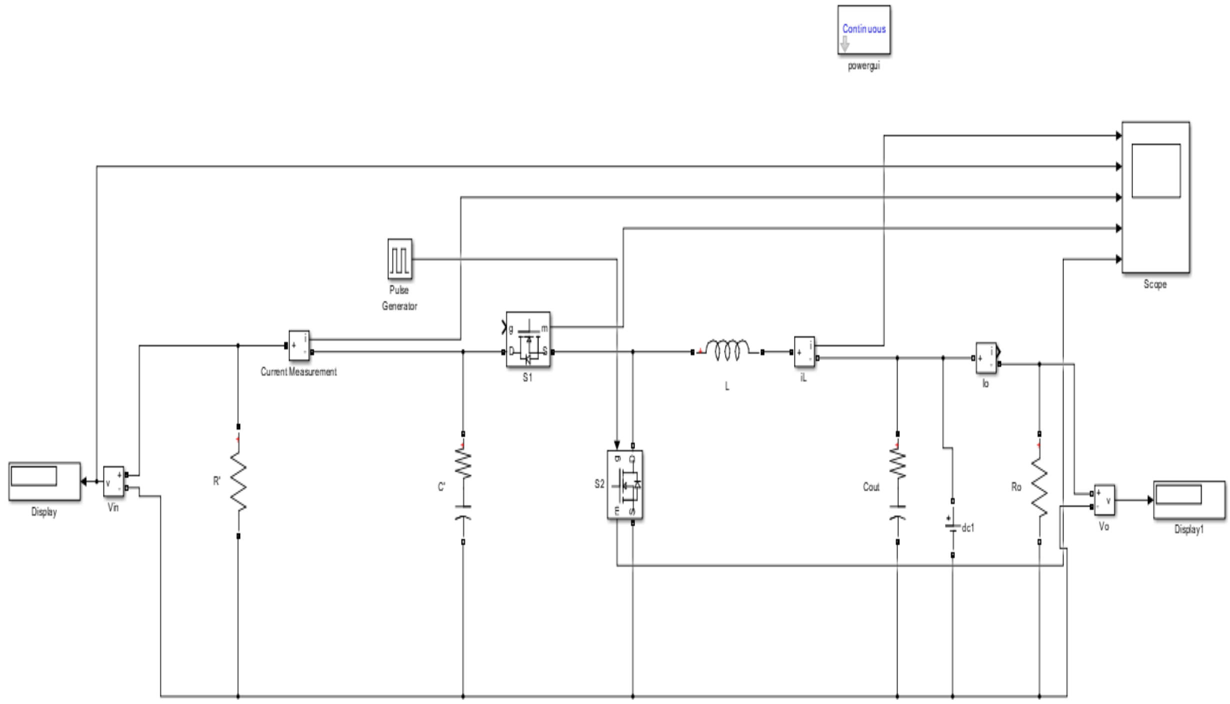

Figure 6. Simulink model of conventional bdc in boost mode

The simulation results of the conventional BDC in boost mode is as shown in figure 7.

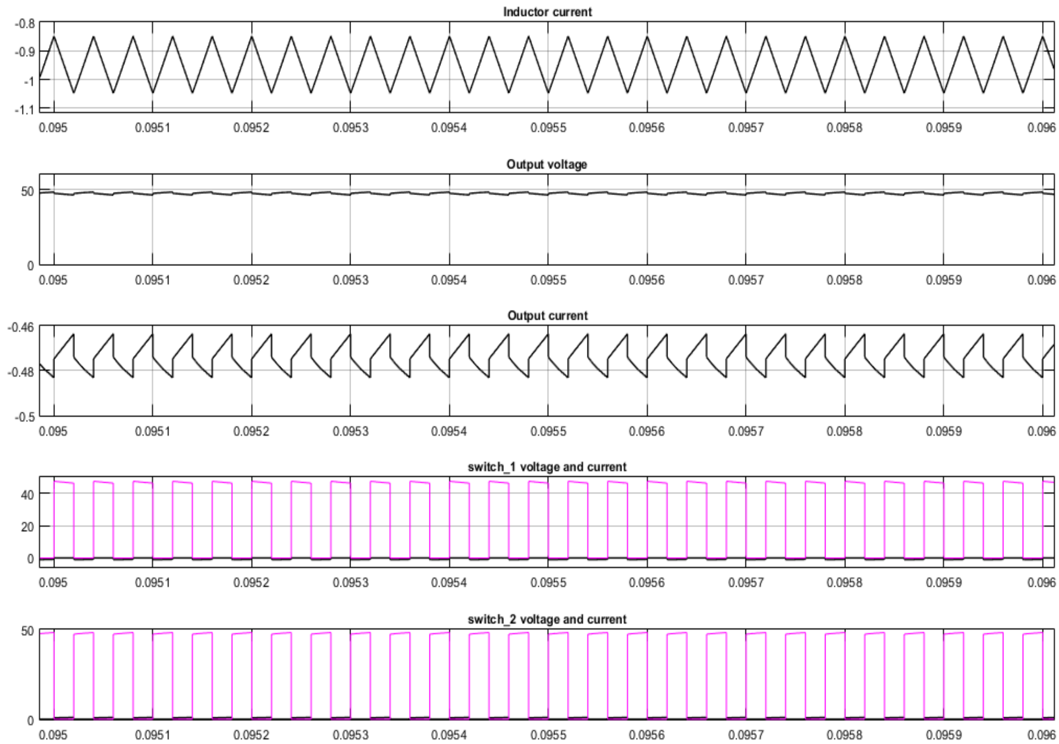

Figure 7. Waveforms of inductor current, output voltage, output current, switch voltage and currents respectively in boost mode

From the figure 7 we can see that the ripple in inductor current is about 0.2A, the output voltage obtained is 48V for input of about 24V.

3.2ZCS bidirectional converter

The simulation model for the conventional BDC in buck mode is shown in the figure 8. The simulation is carried out at 0.55 duty cycle.

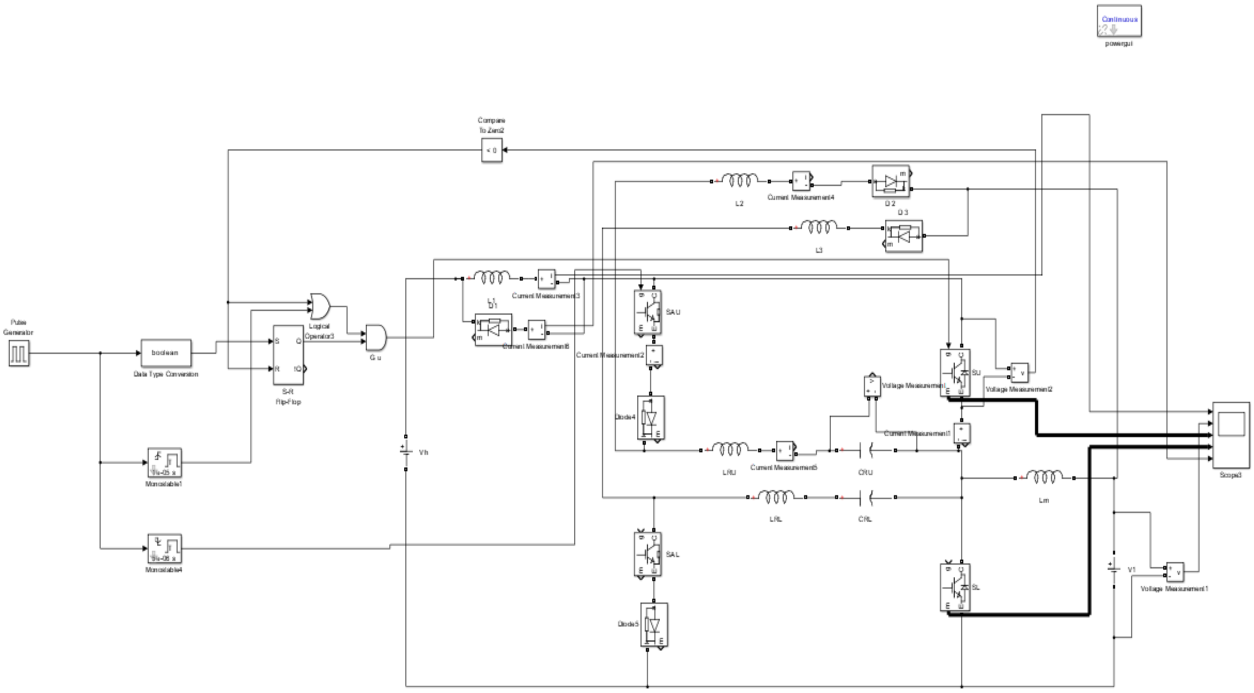

Figure 8. simulink model of ZCS bidirectional converter in buck mode

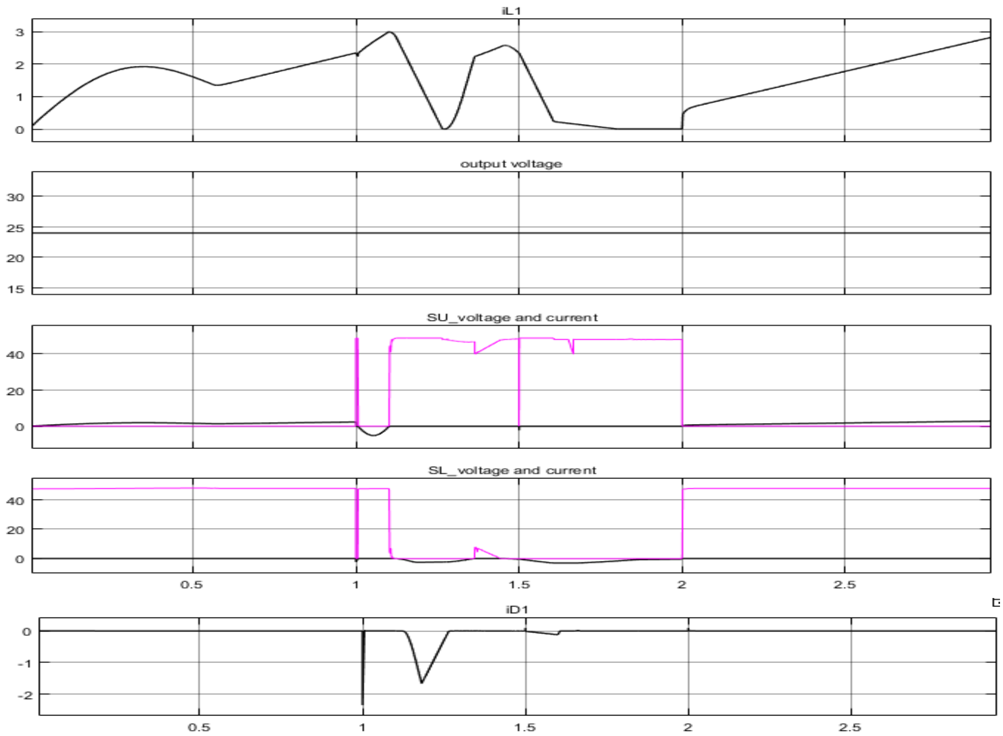

Figure 9. Waveforms of inductor current, output voltage, switch voltage and currents and diode current respectively in boost mode

From the figure 9 we can see that the output voltage obtained is 24V for input of about 48V.

The simulation model for the conventional BDC in buck mode is shown in the figure 10. The simulation is carried out at 0.55 duty cycle.

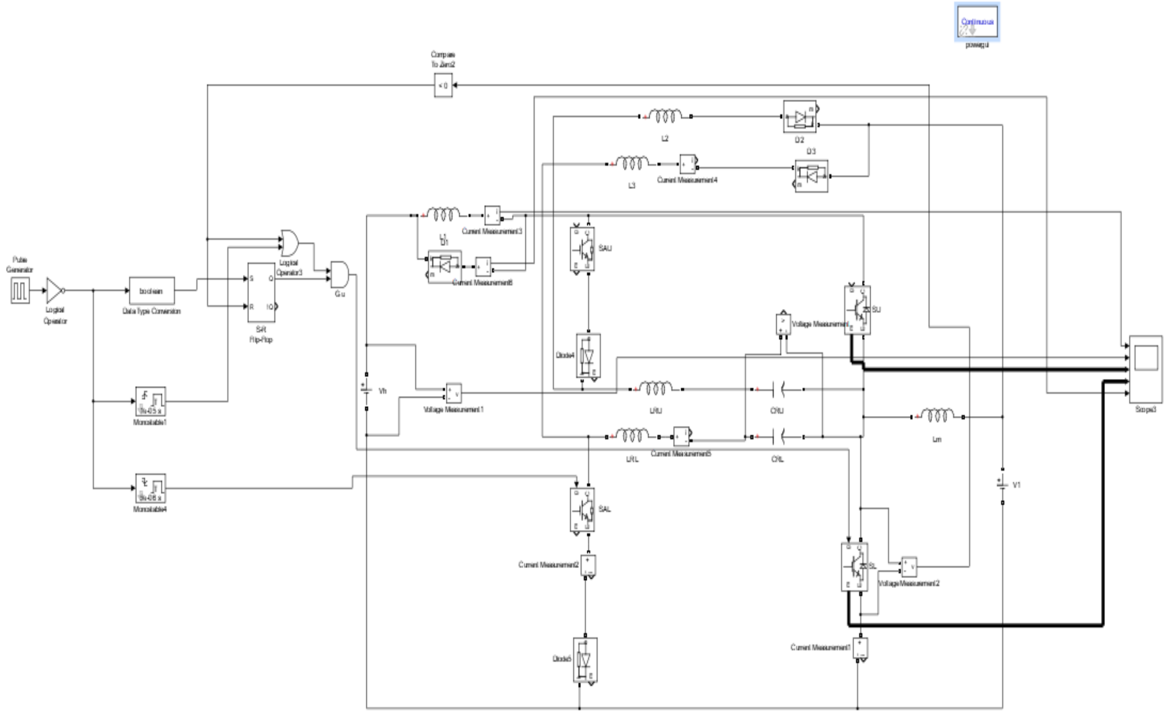

Figure 10. simulink model of ZCS bidirectional converter in buck mode

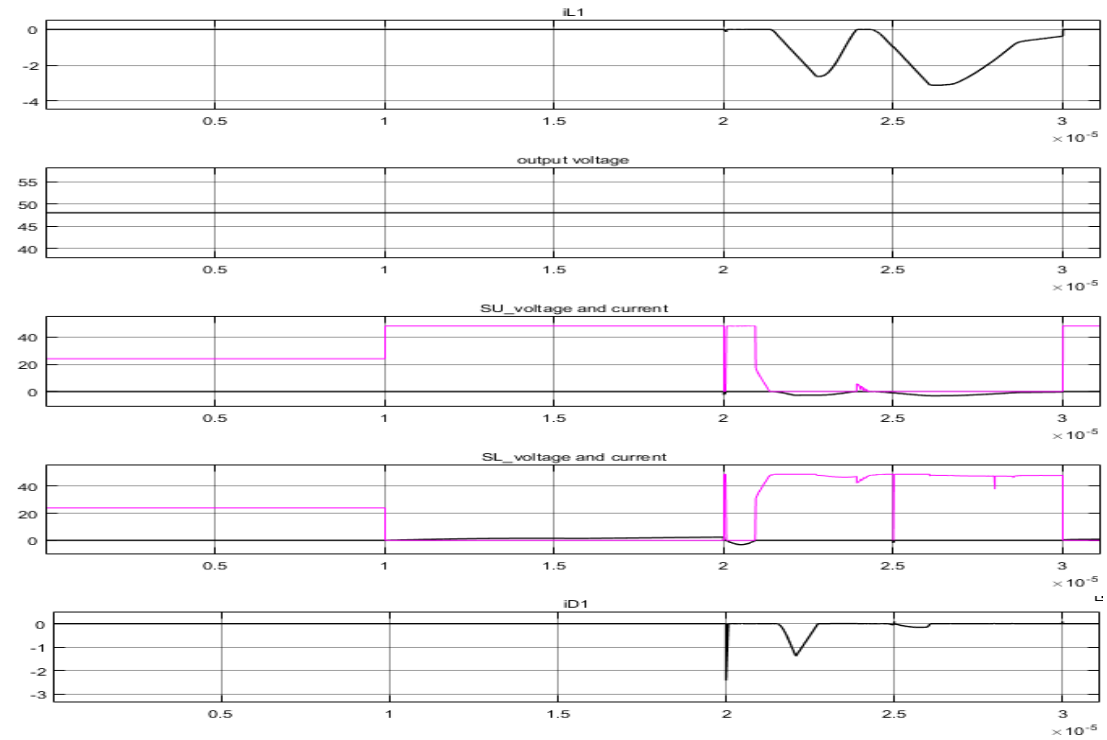

Figure 11. Waveforms of inductor current, output voltage, switch voltage and currents and diode current respectively in boost mode

From the figure 11 we can see that the output voltage obtained is 48V for input of about 24V.

VI. ANALYSIS

The performance of the converters is as shown in the table 1 below,

Table 1. Performance comparison of conventional and ZCS bidirectional converter

parameters	Conventional (buck)	Conventional (boost)	ZCS (buck)	ZCS (boost)
Input current	Continuous	Discontinuous	Continuous	Continuous
Stress(V)	50	55	45	45
Input voltage(V)	48	24	48	24
Output voltage(V)	24	48	24	48

From the table 1, we can see that the stress across the switches has been reduced.

V. CONCLUSION

In this paper, the conventional and the ZCS implemented bidirectional converter is explain in both buck and boost mode. The simulation of the conventional bidirectional converter is carried out using MATLAB in both buck and boost mode . The simulation of ZCS implemented bidirectional converter in both buck and boost mode is carried out using MATLAB simulation software. The output results for the same are presented in the paper and the performance analysis is done for the both. We can conclude the by implementing soft switching technique i.e., ZCS the stress across the switch can be reduced which in turn reduces the switching losses. Further the output voltage levels can be increased for the industrial application purpose.

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