Simulation of a Bi-directional Buck-boost Converter and Application for the Vehicle to Grid, Grid to Vehicle

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***Abstract*— This paper presents a bidirectional buck-boost converter for bidirectional power flow, electric vehicle applications, and for power flow from source to load and load to source. Which is a vehicle to grid and grid to vehicle in terms of electric vehicle applications. The simulation has been done on a bidirectional buck-boost converter in MATLAB software using a hybrid energy storage system. Simulation proves the suitability for usage in electric vehicle applications and a hardware prototype has been created of the bidirectional buck-boost converter to verify the results of the converters working. In this converter soft switching can be used to reduce switching losses at many parts and to increase the overall efficiency of the bidirectional buck-boost converter.**

Keywords: battery, bi-directional converter, soft switching, grid to the vehicle, vehicle to grid

I. INTRODUCTION

A converter can work in both directions that is it can flow power in both directions of the circuit with the help of a bidirectional converter.[1] A bidirectional can be of many types but mainly it is divided into isolated and non-isolated. A bidirectional buck-boost converter is capable of working in boost mode and buck mode. In general bidirectional has a source side a load side. The components in between can be varied. A bidirectional buck-boost converter is shown in figure 1. In a mode, we can feed power to the load and in another mode, the load can also feed the power back to the source. The main applications of bidirectional converters are mainly related to an electric vehicles. As in the present time electric vehicle is used for their cleanliness and low impact on the environment. In these converters, there is generally one side which is the high-voltage side, and the other is the low-voltage side.

As in these converters, many passive components and switches have been used, so there are many losses generated from turning ON and OFF the power switches consisting in the converter as its very fast transition of voltage and currents occurs on the power switches.SO one remedy to reduce the switching losses is to incorporate soft-switching in the converter. Soft-switching is used to reduce switching losses and to improve power density. Mainly there are two types of basic soft-switching zero voltage mode and zero current mode. It can further be classified as series, parallel, or series-parallel form.

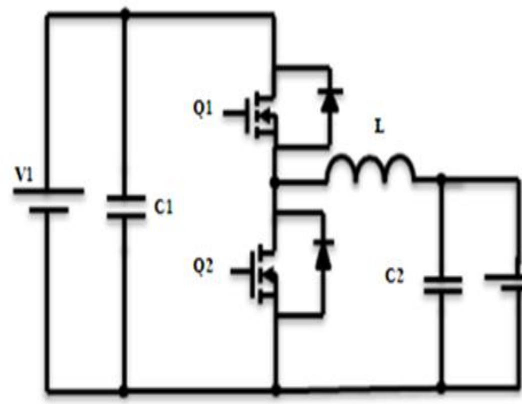

Fig. 1. Bi-directional buck-boost converter

In this converter, a Li-battery and supercapacitor have been used to make a hybrid energy storage system. This is done to overcome the drawback from the Li-batteries is that batteries are too low to meet the peak demand for power. So, Li-batteries and supercapacitors can overcome this drawback to make the circuit useful and meet the higher power demand/density.

A. Simulating the bi-directional converter in MATLAB

B. Boost mode

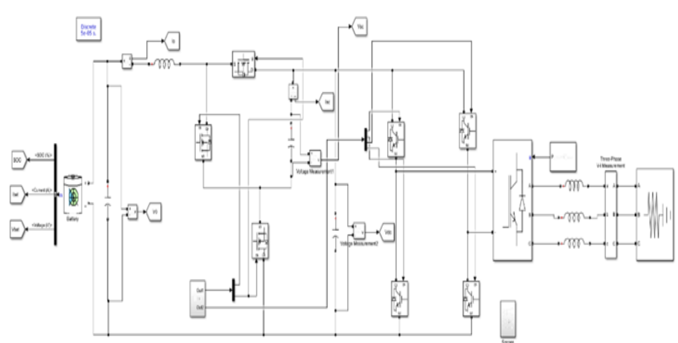

Fig. 2. Bi-directional converter during boost mode operation

C. Results of boost mode

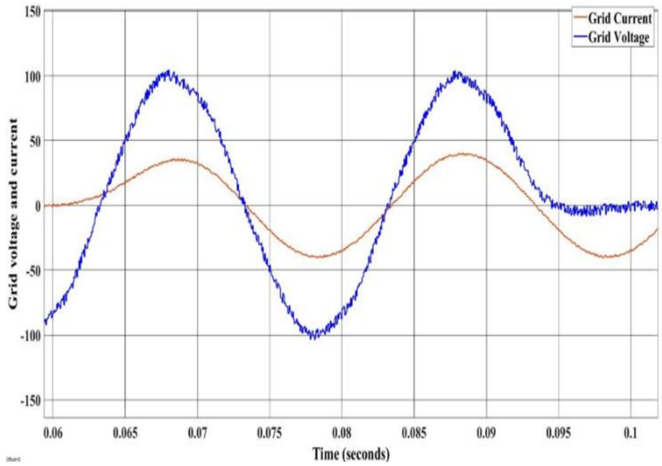

Fig. 3. Grid voltage and grid current

Figure 3 represents the grid voltage and grid current during the boost mode operation of bi-directional converter simulation. During the boost mode, the grid voltage and grid current are injected at the very same time to achieve the unit power factor.

So, the simulation waveforms of the grid voltage are in a phase of grid current.

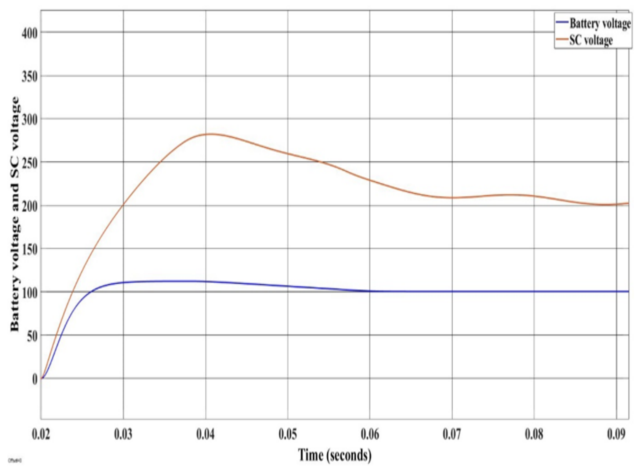

Fig. 4. Battery voltage and supercapacitor voltage

From figure 4 we are getting the waveforms of battery voltage and supercapacitor voltage. In this case, the battery voltage of 100V is increased to 200V supercapacitor voltage.

TABLE I. DESIGN PARAMETERS

Parameter	Value	Unit
Li-battery voltage	100	V
Supercapacitor voltage	200	V
Grid Voltage	100	V
Grid voltage frequency	50	Hz
Switching frequency	5	kHz
Supercapacitor	2	F

The design parameters have been used during the simulation as we can see the values are reflected in the waveforms.

The Boost mode waveforms and results are getting as we desired to get from the bidirectional buck-boost converter when used in boost mode.

D. Buck mode

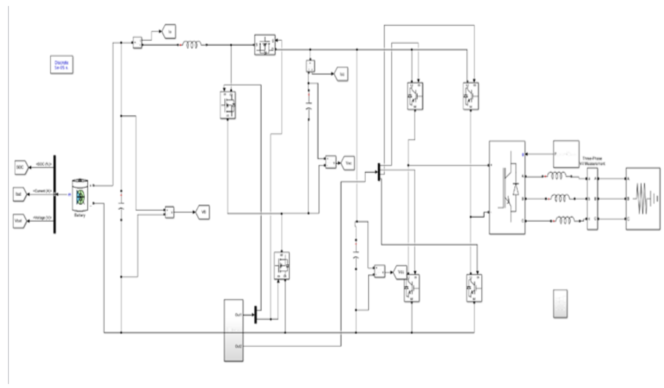

Fig. 5. Bi-directional converter during buck mode operation

E. Results of buck mode

In the bidirectional converter to work as a buck mode, the converter must work in the grid to vehicle mode that is the power flows from the load end to the source end.

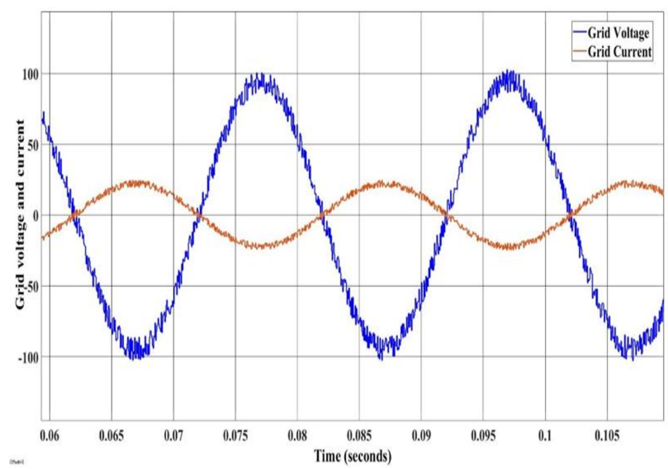

Fig. 6. Grid voltage and grid current waveform from simulation

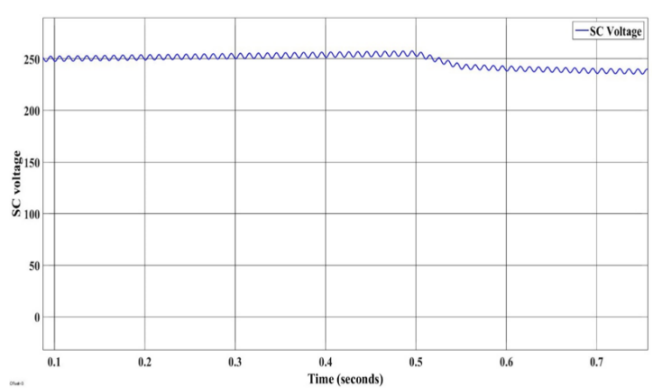

Fig. 7. SC voltage

Figure 6 shows the main waveforms when the bidirectional buck-boost converter is operating in buck mode. As we know in this mode power is flowing in the reverse direction, so grid current is in reverse phase with the grid voltage. As we have seen in boost mode this is in the unit phase. Figure 7 shows the output waveform of the supercapacitor(SC voltage) to time.

II. HARDWARE AND IMPLEMENTATION

In the hardware when we are not using any soft-switching technique it is running in hard switching mode.

A hardware prototype of the bidirectional buck-boost converter has been made on a small scale to verify the validity of the bidirectional process and also the process of boost mode and buck mode.

III. RESULTS AND FUTURE SCOPES

In this model, we have taken two batteries 1 and 2. In mode 1 during charging battery, 2 from battery 1 is taken as the source and in this mode battery,

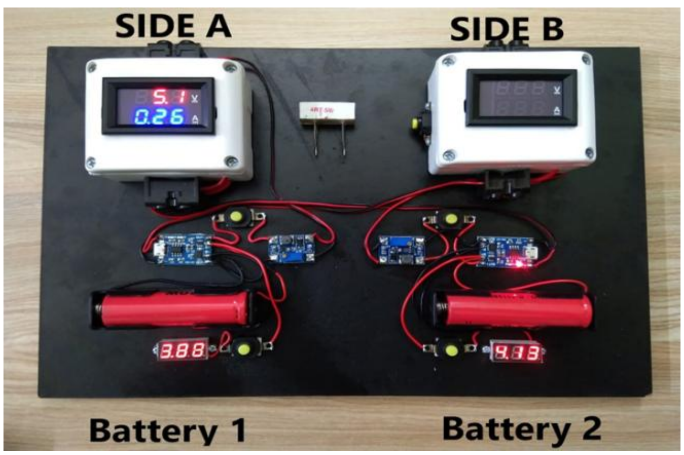

Fig. 8. In the above figure, we can see Battery 1 and 2, Side A and B

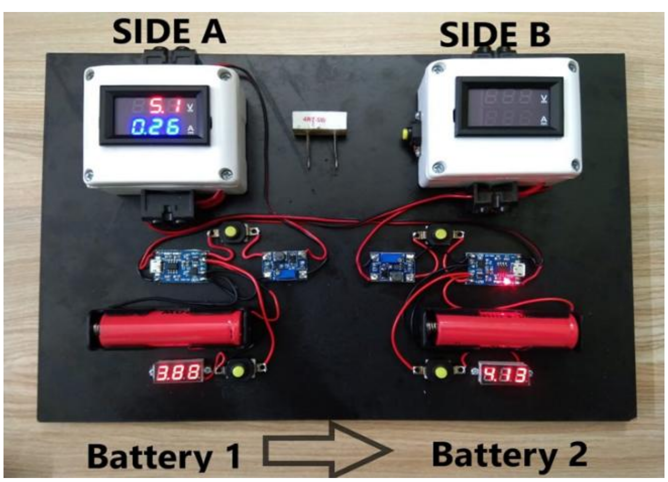

Fig. 9. Battery 2 as load and Battery 1 as a source in this battery 2 is getting charged.

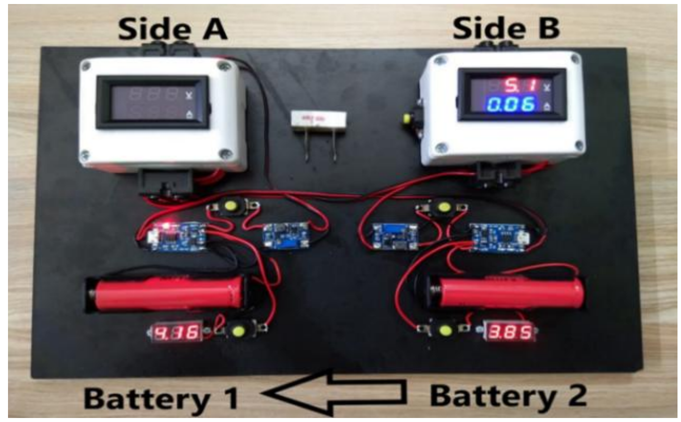

Fig. 10. In this mode battery 2 acting as source and charging battery 1

This hardware the batteries is charged and after that, the circuit is not getting any external source. The charging process is done with only charge present in the battery.

Fig. 11. During charging the battery

This circuit in module MC34063 indicates the charging of the battery. When the red light is shown the battery is charging as referred to Fig.11.

Fig. 12. Battery fully charged

This circuit in module 34063 shows blue light when the battery is fully charged. Fig. 11 and Fig. 12 show the charging of battery 2. The same is applicable for charging the battery 1.

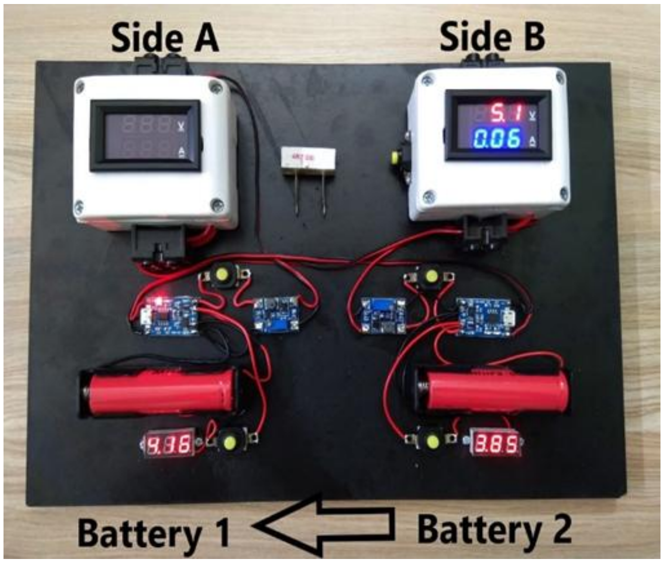

Fig. 13. Battery 2 acts as a source and Battery 1 acts as a load

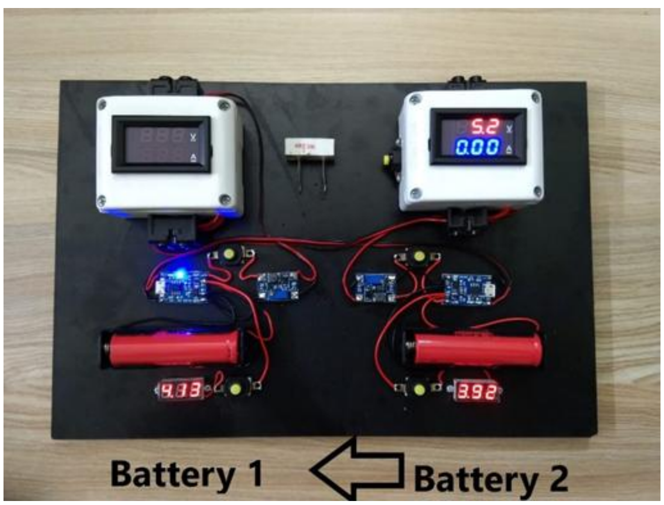

Fig. 14. Full charged Battery 1 indicated by blue light in the circuit

Battery potential difference is fluctuating as we need a reference voltage from the battery for soft switching, but we cannot get a reference voltage from the battery as the potential difference is fluctuating and in this circuit, we are not using any external source. If we get stable reference voltage then with the help of an op-amp at the point when the voltage is getting full at the battery then from that we can get the reference, as we are not using any external source. The source is only two batteries. When a battery is getting charged from a battery(acting as a source). The voltage of the primary battery getting low that's why the output we cannot maintain. So, soft switching cannot be achieved.

IV. CONCLUSION

We have successfully built a bidirectional converter which is verified with a small prototype hardware model. The converter is capable to work in both ways. In MATLAB software we have simulated the converter that can be used for applications related to the vehicle to grid and grid to vehicle application in the electric vehicle and renewable energy sector. At last, soft switching is not successfully achieved but it can be achieved in the future, and it can be developed and incorporated into the circuit.

A. Further scope of development

Battery potential difference is fluctuating as we need a reference voltage from the battery for soft switching, but we cannot get a reference voltage from the battery as the potential difference is fluctuating and in this circuit, we are not using any external source. If we get stable reference voltage then with the help of an op-amp at the point when the voltage is getting full at the battery then from that we can get the reference, as we are not using any external source. The source is only two batteries. When a battery is getting charged from a battery(acting as a source). The voltage of the primary battery getting low that's why the output we cannot maintain. So, soft switching cannot be done in this circuit. In the future, we can get more information regarding the reference and how to get a stable reference for the soft-switching mode.

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