Summary Report

Project Title: Design of Novel Bidirectional DC-DC Converter for Battery Energy Storage System Used in Microgrid.

Authors: Logan Fehringer, Michael Boyd, Christopher Charnes, Shad Elam, and Mohd. Hasan Ali, The University of Memphis.

Correspondence: Mohd. Hasan Ali (mhali@memphis.edu)

Summary: This research was conducted as an undergraduate design project, where four undergraduate students registered for the senior level design course (EECE 4280) in the Fall 2021 semester at the University of Memphis. This project was about a novel bidirectional DC-DC converter for a battery energy storage system used in a microgrid. The goal to this project is to produce a bidirectional DC-DC converter that employs two boost converters controlled by a single controller to reduce loss of voltage though ripple. There are many issues with a conventional Bidirectional DC-DC Converter (BDC). It has ripple which is the loss of power as well as large voltage spikes during operation change. This occurs because the conventional BDC has a buck mode (Step Down) operation. The conventional BDC is a half-bridge converter that works as separate Buck converters to charge the battery and Boost converter to discharge the battery this requires that it has two controllers for the two semiconductor switches. Our proposed DC-DC Bidirectional converter is able to use a single controller to operate both insulated gate bipolar transistor (IGBT) switches. These problems are all corrected using this project desired novel bidirectional DC-DC converter.

During the process of developing our design we looked into existing Bidirectional converters and found that many used a buck and boost style of operation. We were interested in designing a converter that used only boost type Dc converter in a back-to-back topography. To achieve this, we had to look at how the Boost converters would be able to connect to each-other and at the same time allow a bi-directional functionality. We achieved this by placing diodes at the batteries to guide the flow of current with the batteries in series for charging and in a parallel formation for discharging. During the testing process we made some altercations to our design, mainly in the amount of voltage to be used. We originally had over 500V for our batteries as to use for a large micro grid, but we decided that we needed to lower that amount to 24V per battery for the prototype created. We then choose to make our initial circuit to be a single battery setup to allow for safe testing and proof of concept for our design.

To decompose our design, we had to split the sections into two major components such as the battery and the DC-DC converter. The batteries would require a diode configuration that would place the batteries in a series (charge) or parallel (discharge) configuration. This required a design implication of required diode direction. We decided that to achieve this with a two-battery configuration we needed at the minimum of 3 diodes (2 for the parallel route and 1 for the series route). The next step in the decomposition process was determining the filter of the DC voltage. The final step in the decomposition process was breaking down the DC-DC converter. The IGBT was a very important component because it allows the configuration of our inductors as well as at attachment of the controller expected in the PV system. This will allow the modes to be selected as well as the PWM from the controller to boost the current for a symmetrical gain.

Results: The following are the simulations that support our claims that our design is most importantly bidirectional but also reduces the ripple.

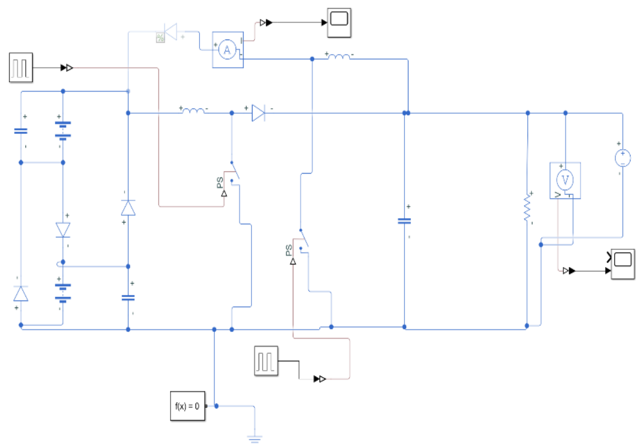

Figure 1: Circuit Diagram.

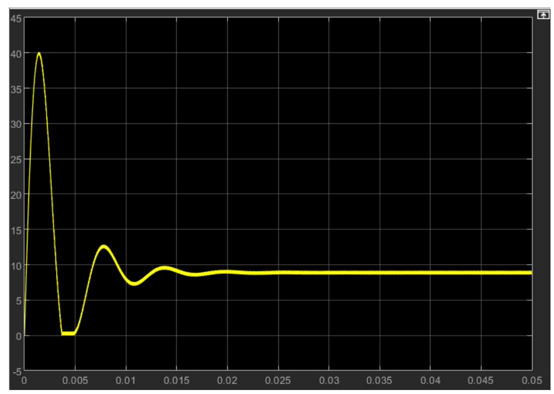

Figure 2: Discharge Current.

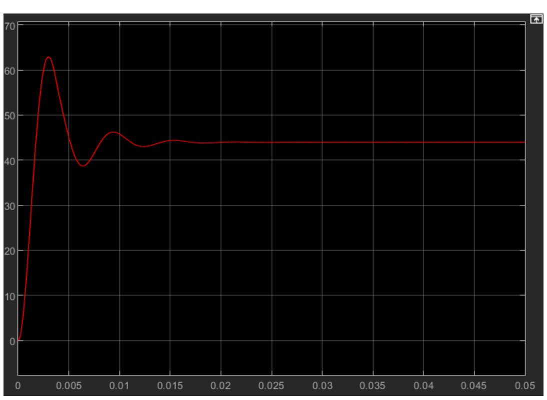

Figure 3: Discharge Voltage.

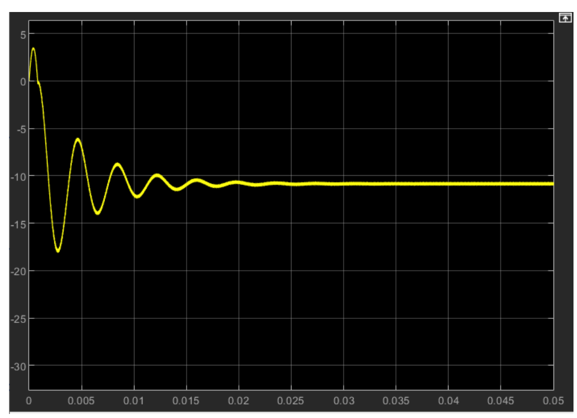

Figure 4: Charge Current.

In the circuit seen in figure 1 multiple switches can be seen. They work as follows S1 and S3 are used for discharge mode. S1 is attached to the controller which gives a pulse modulated width. This allows the voltage to be boosted by from 24V to 42V. S3 allows the batteries to configure into parallel formation. Then when we flip the switches S2 and S4 to turn our circuit into charge mode. S2 is the PWM and S4 allows the batteries to align into series configuration.

Figures 2, 3, and 4 show the discharge current, discharge voltage, and charge current, respectively. We can observe in the simulations that the current flows in a counter clockwise direction which displays as negative current, during charge mode and clockwise and displays as positive current. These simulations allowed us to compare our physical results to ensure proper operation.

The prototype of this product is a single battery configuration (Figure 5) that has the same characteristics as the desired finalized design. This prototype allows for bidirectional flow from and to a battery and micro grid. In figure 6 the successful transfer of voltage is seen from the batteries to the desired load. The prototype single battery is a clear proof on concept. We also created the dual battery configuration of the product as our final product (Figures 7 and 8).

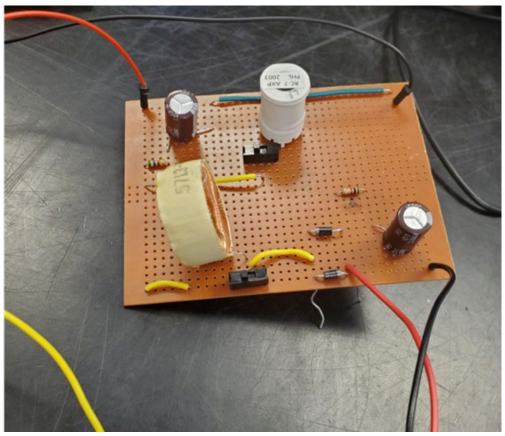

Figure 5: PCB Of Single battery Configuration.

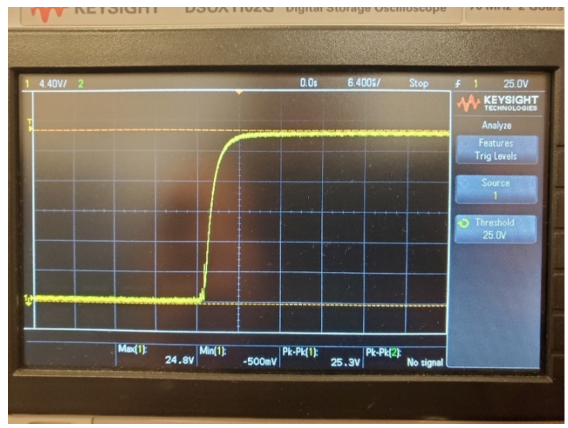

Figure 6: Oscilloscope Data from Physical circuit.

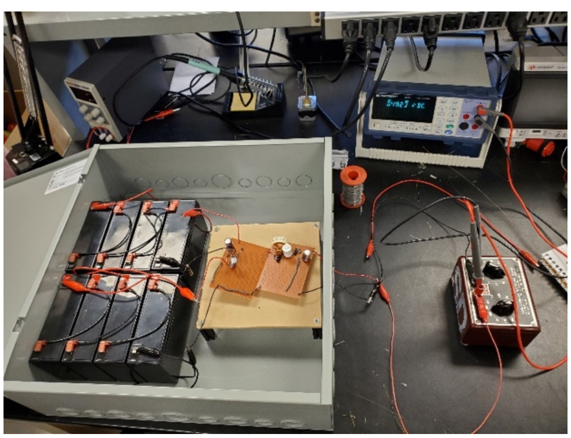

Figure 7: Final Product (Dual Battery Open Case) .

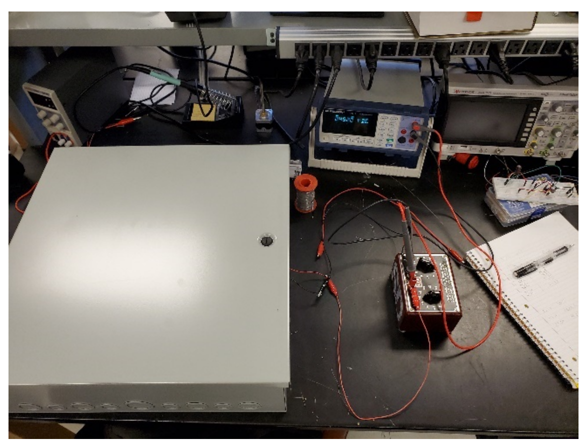

Figure 8: Final Product (Dual Battery Closed Case).

Conclusion: This project was overall a success. We created the dual battery configuration and most importantly our goal was to prove that our circuit could successfully transfer electricity bidirectionally to and from a battery source from a solar powered micro-grid. The proposed project has potential impact on the relevant field and application. The major advantage of this project is that the proposed converter uses two back-to-back boost converters with two battery voltage levels, which eliminates step-down operation to obtain symmetric gains and dynamics in both directions. In discharge mode, two battery sections are in parallel connection at a voltage level lower than the grid voltage. In charge mode, two battery sections are in series connection at a voltage level higher than the grid voltage. Moreover, the novel converter adds no complexity to the control system and does not incur considerable power loss and capital cost. The proposed solution can be useful to power electronics manufacturing companies and electric power industries. Thus, the proposed solution has a great commercial potential in the field.

References

1) Keshavarzi, Morteza Daviran and Mohd Hasan Ali, "A Novel Bidirectional DC-DC Converter for Dynamic Performance Enhancement of Hybrid AC/DC Microgrid," Electronics, vol. 9, no. 10, 2020, p. 1653., doi:10.3390/electronics9101653.
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3) Matsui, Ryoji, and Kazuhito Nishimur. *Bidirectional Dc/Dc Converter and Power Conditioner*. 17 Feb. 2011.