Microgrid Inverter Modeling and Control

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Introduction

Due to the continued usage of fossil fuels in order to reach increasing electricity needs, the environment is being damaged at an alarming rate. Renewable energy sources are a more environmentally friendly alternative as opposed to conventional energy sources, due to the minimal carbon footprint that is left behind; however as seen in Figure 1, the amount of renewable energy compared to other sources is very little. Solar energy is one of these renewable sources, and one that in the near future will see a lot of growth due to it currently only accounting for roughly 6% of all energy production as seen in Figure 1. The system that is being proposed is a photovoltaic (PV) micro-inverter which will be attached directly to a power grid. The advantage of a microgrid is that they allow for increased control of power distribution, reduction of power losses, and most importantly is the ability to operate without a connection to the main power grid. The goal of this project is to design an advanced control algorithm for both a DC-DC converter as well as a DC-AC inverter which are used within the PV microgrid system.

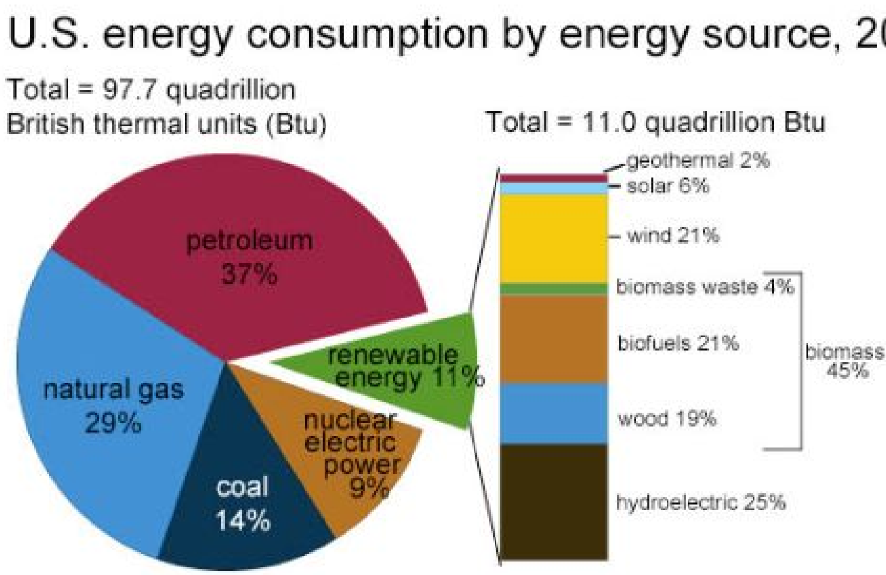

Figure 1. 2017 US Power Sources

Problem Statement

The PV system can be broken into two subsystems which are the DC-DC converter and DC-AC inverter. The DC-DC converter is either a step-down buck converter, or a step-up boost converter, and this depends on what output voltage is required. In Figure 2, an example of a PV system which utilizes a boost converter is shown. The design and implementation of both of these subsystems, as well as developing a signal tracking algorithm to ensure max power output, are the problems this project will explore.

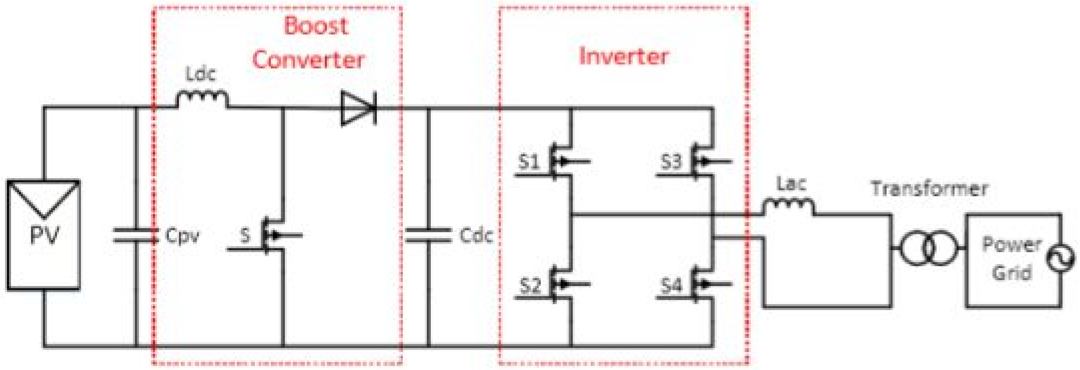

Figure 2. PV System

Research Tasks

The first point of this system which will be researched is the modeling and control of the DC-DC converter. Shown in Figure 3 is an example of a boost converter, similar to the one used within the PV system in Figure 2. Figure 4 also displays a buck converter, which is an alternative DC-DC converter that may be used within the system depending on the grid requirements. This converter will either step-up or step-down our DC input signal which is provided by a PV solar array.

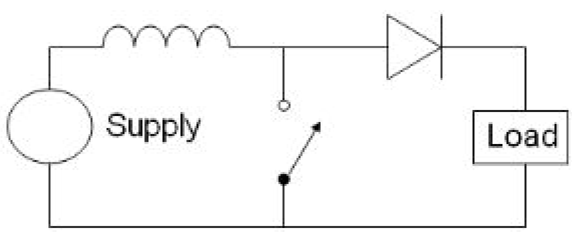

Figure 3. Boost Converter

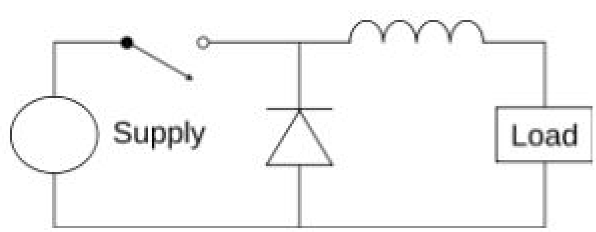

Figure 4. Buck Converter

The next point of research will be the modeling and control of a DC-AC inverter. An example of one of these inverters is both shown as a subsystem within Figure 2, and additionally a more advanced block diagram can be seen in Figure 5. This inverter is designed to convert the signal from a DC signal into an AC source, which can then be used by the microgrid to power whatever load is required.

These subsystems will first be modeled in MATLAB/Simulink before being implemented in on the microcontroller. The microcontroller which will be used is the C2000 MCU, which can be seen in Figure 6. Once implemented, we will then be able to fist test our system using a DC source in place of a solar array, with the use of a solar panel being used later.

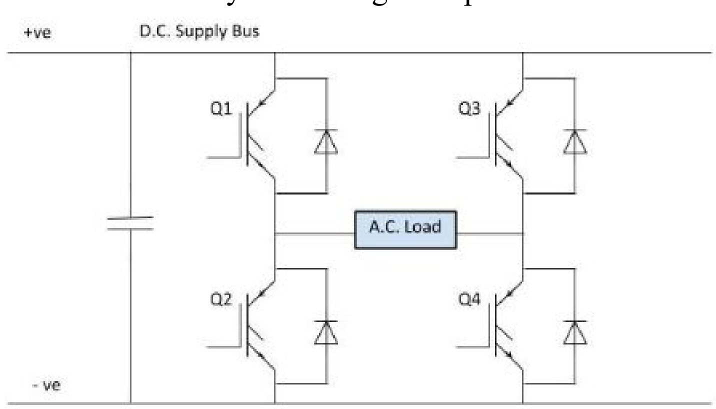

Figure 5. DC-AC Inverter

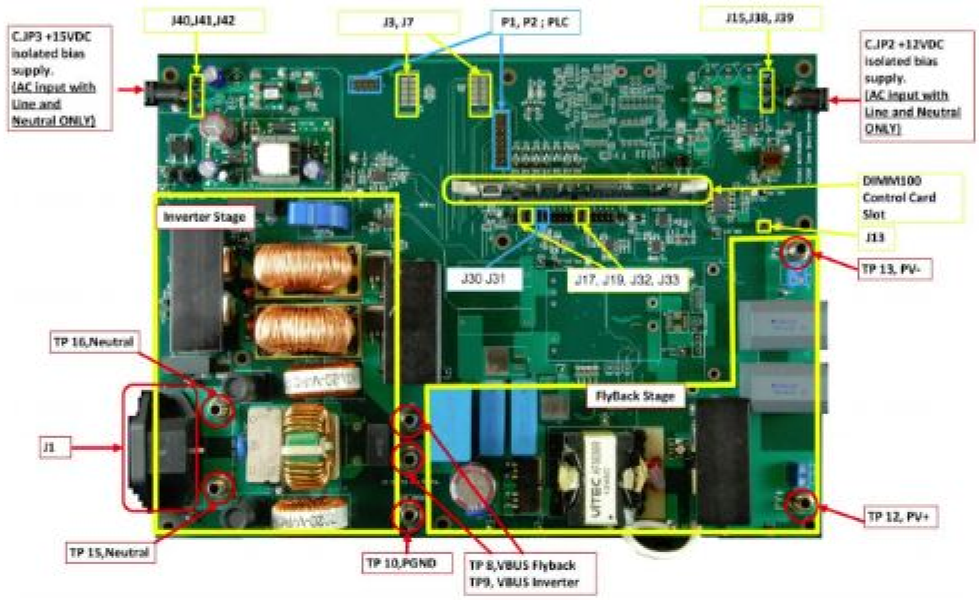

Figure 6, C2000 MCU

Timeline

Modeling and testing of boost and buck converters in Pspice and Matlab will be completed by the end of October. Building the buck and boost design using available components in lab will be completed by the end of November. Our next task is the implementation of the C2000 for the single phase inverter, that will be completed by winter break. Once we figure out what components and systems we need in order to continue testing, we will order them before the start of the 2019 spring semester. By the end of January we want to have our control model simulated and working. In the month of February, we will implement the control algorithms with the our system and the C2000 inverter. For March, we will be modeling the system and implementing available components in the lab. In April we will be finalizing our system and exploring stretch goals.

Conclusion

The main goal of this project is to simulate and develop a single phase photovoltaic microgrid inverter which would account for all energy generation when completely disconnected from the main power grid. The solar energy market has a lot of room for growth and, when paired with a microgrid, this state of the art system would have a very positive impact on the environment, as well as allowing the user the ability to operate without a connection to the main power grid. Development and modeling of a DC-DC converter, DC-AC inverter, and creating an advanced control algorithm are the main tasks that must be completed in order to create a fully functional PV microgrid.

References

[1] Y. Lu, "Advanced grid-tied photovoltaic micro-inverter", University of Canterbury, Christchurch, New Zealand, 2015.

[2] Texas Instruments, "Digitally controlled solar micro inverter design using C2000 Piccolo microcontroller," TIDU405B datasheet, Oct.2014 [Revised June 2017]