



BRADLEY
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Photovoltaic Microgrid Inverter Modeling and Control

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Table of Contents

1. Introduction	3
Problem Statement	3
2. Technical Approach and System Models	4
2.1. Subsystems	5
2.2. Research Tasks	6
2.3. Software Validation	6
2.4. System Integration	7
3. Preliminary Results	7
4. Timeline	10
5. Budget	10
6. Conclusion	10
7. References	11

1. 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 1.1, the amount of renewable energy compared to other sources is small. 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 an extremely small portion of all energy production as seen in Figure 1.1. 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 it allows 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.

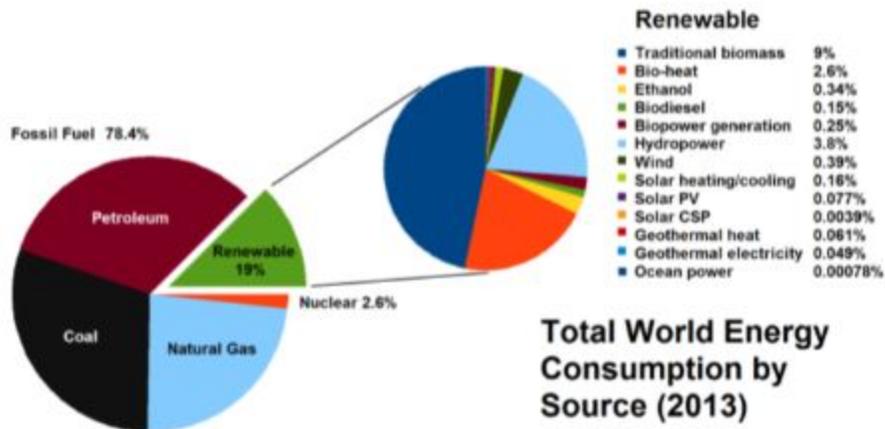


Figure 1.1: World Energy Consumption (2013) [1]

Problem Statement

The signal which will be received from the solar array is a DC signal, and in order for the power grid to be able to use this signal it is required to be inverted into AC power. The PV system can be broken into two subsystems which are the DC-DC converter and DC-AC inverter. The DC-DC converter which will be used is to be a step-down buck converter in order to minimize losses. The design and implementation of both of these subsystems, as well as developing a signal

tracking algorithm to ensure maximum power output, are the problems this project will explore.

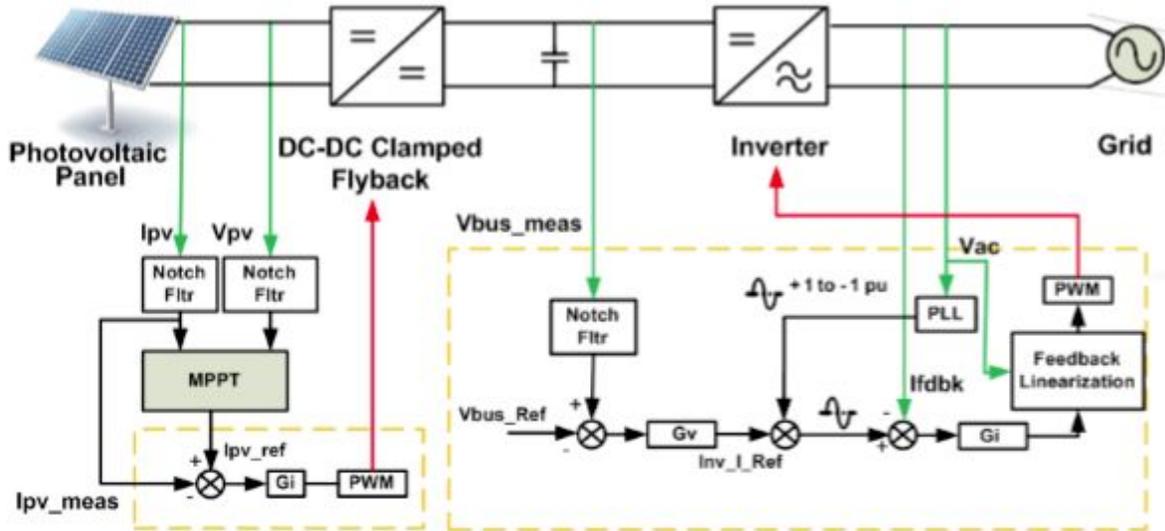


Figure 1.2: System Overview [1]

2. Technical Approach and System Models

As previously stated, the system will be broken into two basic subsystems which are the DC/DC buck converter and the DC/AC inverter. A basic block diagram which outlines the construction of the microinverter can be seen in Figure 2.1.

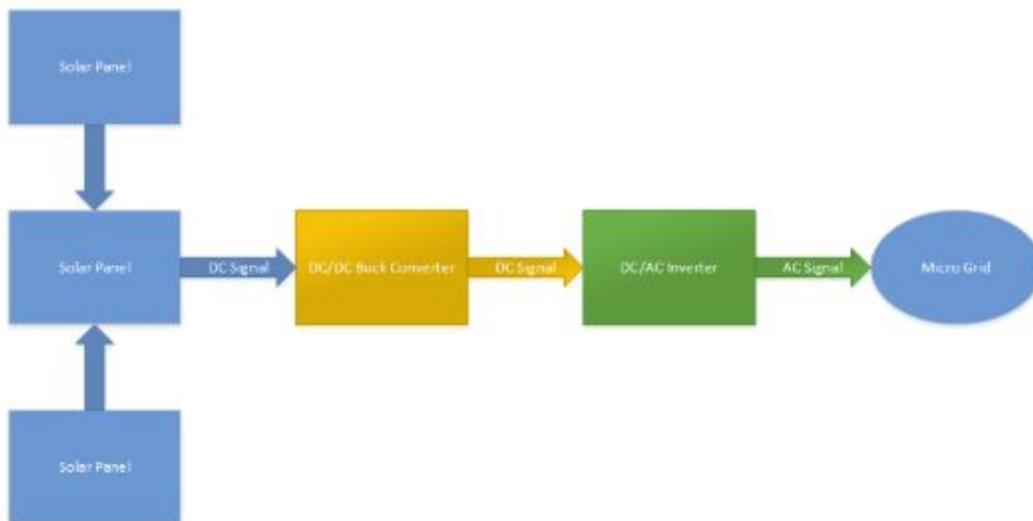


Figure 2.1: System Block Diagram

2.1. Subsystems

A DC/DC converter is to be used as the first subsystem within our design, which can be either a buck converter or a boost converter. A basic buck converter topology can be seen in Figure 2.2. Buck converters are used to step voltage levels down from one higher source level, to a lower output voltage. This voltage drop allows the buck converter to power electronics which otherwise would be overloaded by a high voltage input. An example of this stepping down can be seen in Figure 3.2.

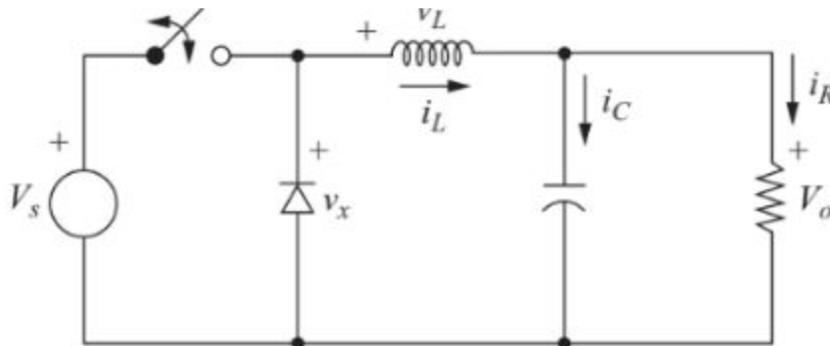


Figure 2.2: Buck Converter [3]

Boost converters can also be utilized within this system in lieu of a buck converter, and a simple boost converter topology can be seen in Figure 2.3. A boost converter is much like its buck counterpart, however instead of stepping voltage down, the boost converter can instead boost the signal from a low voltage level to a higher one. In addition to modifying the voltage level, the DC/DC converter subsystem will be used to track the maximum power point from the source signal, which allows the system to operate at maximum efficiency.

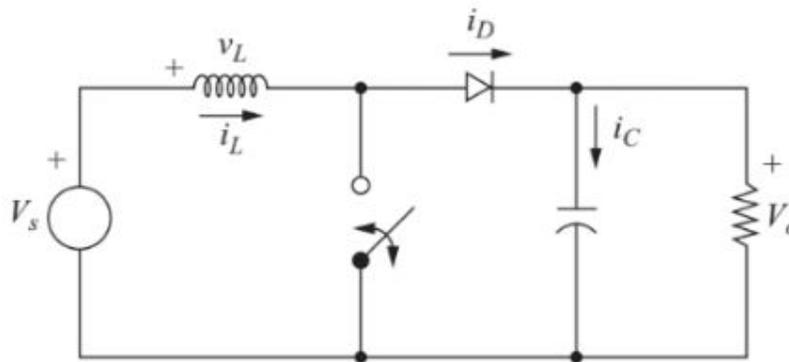


Figure 2.3: Boost Converter [4]

Aside from a DC/DC converter, an DC/AC inverter also is required, and a basic topology for this subsystem can be seen in Figure 2.4. The point of the DC/AC inverter is to take the modified DC signal and convert it into a signal which can be effectively used by the power grid which the system will be connected to.

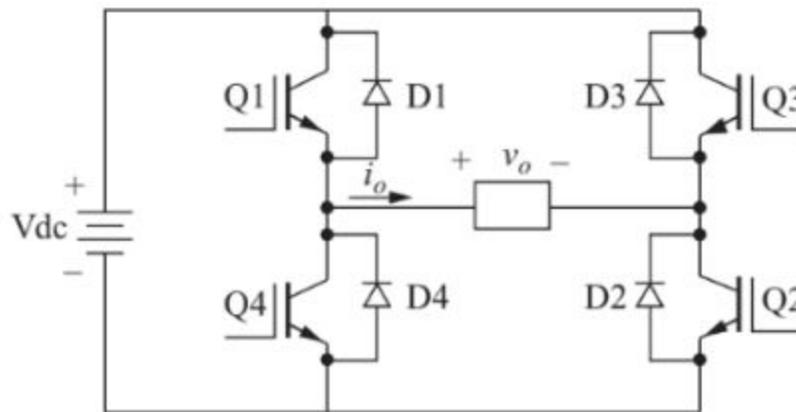


Figure 2.4: DC/AC Inverter [5]

2.2. Research Tasks

1. Buck converter modeled in PSpice fully functional.
2. Design controller for tracking reference voltage.
3. Buck converter working with physical model.
4. Fully functioning inverter model in PSpice.
5. C2000 board operational.
6. Connect DC power source to buck converter and connect buck converter to inverter for final testing.

2.3. Software Validation

PSpice will allow us to have insight on how to implement control algorithm to help track the input DC voltage coming from the solar panels. The software simulation will also allow us to see the current draw on components so we can be mindful of the circuit. Once we can confirm our PSpice model is functioning correctly, physical implementation will not be as difficult.

2.4. System Integration

Input voltage in the real system comes from an array of solar panels, however for testing purposes a DC source is planned to be used. This input can be fed into our DC/DC converter, where the control algorithm helps track the simulated variable input minimizing power loss. The stepped down voltage then goes through a boost converter to step up the voltage to become usable for heavy load. The DC signal then passes through the C2000 Inverter, as seen below in Figure 2.3, which results in an AC output in single phase.

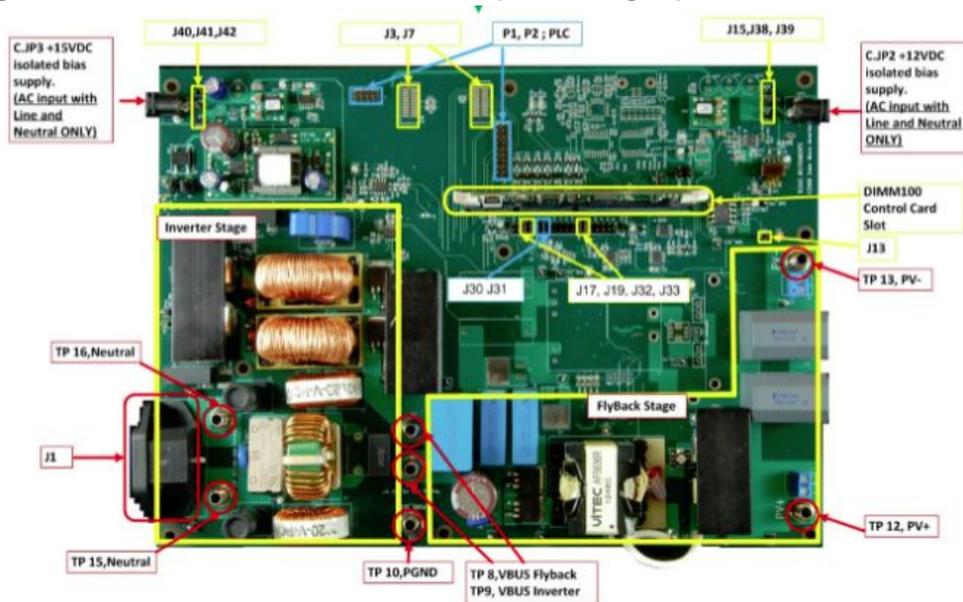


Figure 2.3: C2000 Board [2]

3. Preliminary Results

Recreating the circuit shown in figure [3.1] on page 316 in Daniel Hart's *Power Electronics* [6], we were able to obtain an output voltage in similar fashion to the output voltage shown below in figure [3.3]. This confirms the circuit we built is close to how it is being used in the power electronics book. Once the output is consistent with input changes, we can continue moving forward with implementation onto a breadboard.

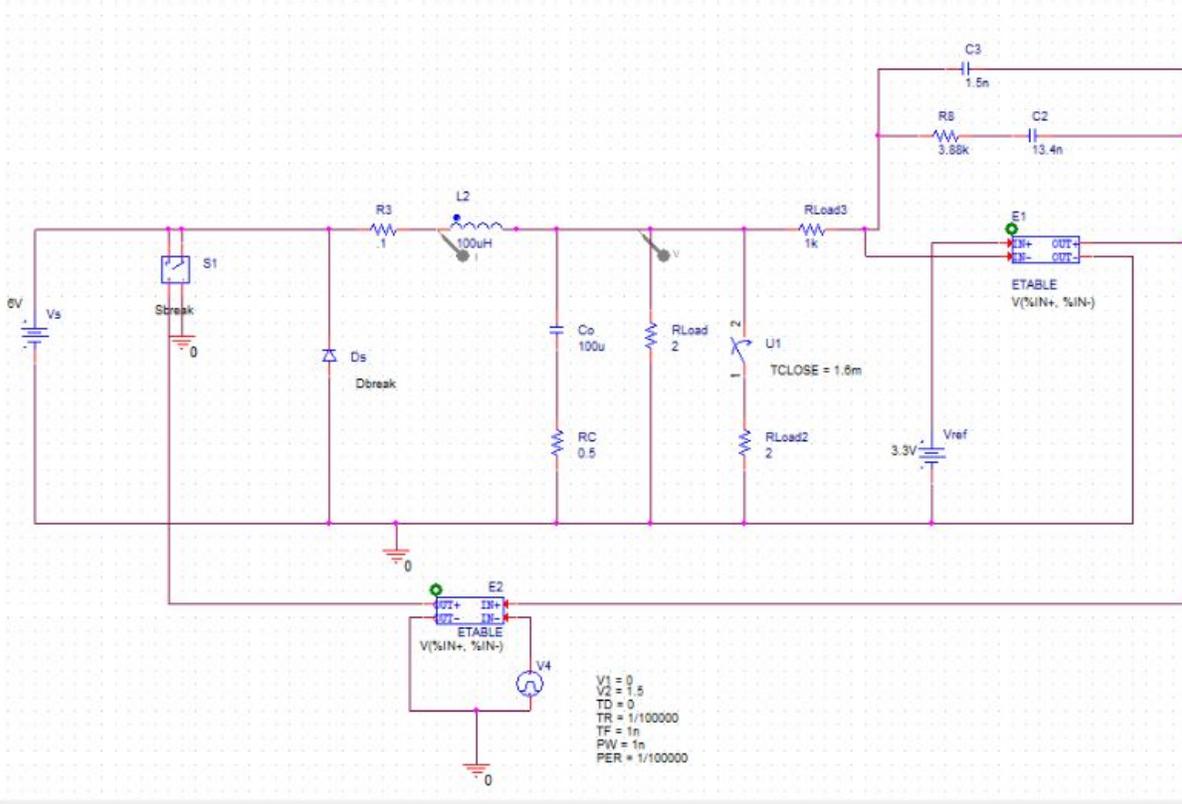


Figure 3.1: Buck Converter with Compensator in Pspice

In figure [3.1], we are recreating the buck converter with compensator that is on page 316 of *Power Electronics*. Some of the parts were not in the general library but can be found in the following libraries:

- ETABLE parts can be found the ABM library folder.
- TCLOSE switch can be found in the Eval library folder.
- Sbreak S1 switch can be found in the Breakout library folder.

The Buck converter with compensator from the book did not behave how we initially believed it would. The output of the system gave us a voltage higher than the reference voltage which is not ideal. The output should be matching the input voltage to the lower reference voltage by recreating the signal using the saw-tooth PWM generator located at the bottom side of the circuit. The purpose of the saw-tooth signal is to compare the input with the reference voltage and recreate the reference signal, using the input signal.

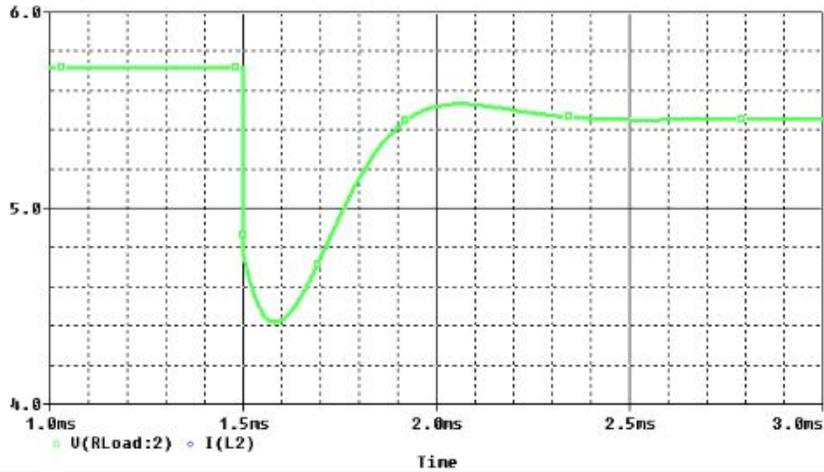


Figure 3.2: Voltage Output of Buck Converter

The load change shown in the figure above is shown when a switch is closed at 1.5ms after the circuit becomes active. The switch closing provides additional load to the circuit represented by the 2 ohm resistor the switch is connected to in figure [2.2]. The problem we encountered with the circuit shown on page 316 in *Power Electronics* is that the circuit does not track the reference voltage for the output. The goal of this circuit is to take a DC input and match its DC output to a reference voltage. The model is using an input voltage of 6 V and a reference voltage of 3.3 V. In figure [3.2], the PSpice model does not have the output track the reference voltage because it is giving an output of

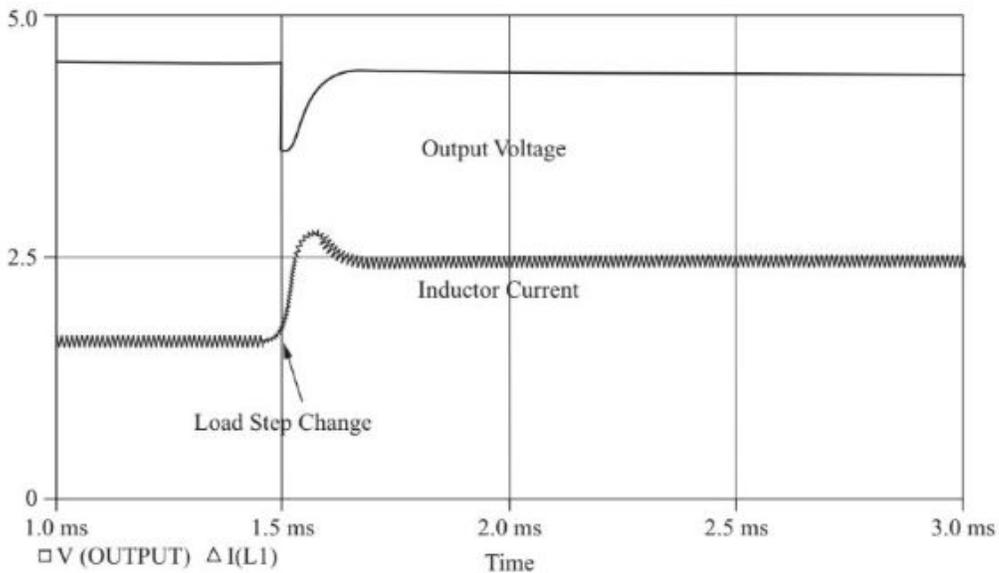


Figure 3.3: Expected Output Voltage [6]

approximately 4.8 V. We are moving forward with our PSpice model by modifying the

way the *Power Electronics*' circuit handles the reference voltage. Adding a buffer voltage to the input of the comparator should keep all the values in the range of the saw tooth generated pwm. This will give the system a more robust way to track the input voltage.

4. Timeline

November & December	PSpice model fully functioning for buck converter with controller. Set up website
January	Model Boost Converter in PSpice
February	Model Inverter in PSpice and implement buck, boost and inverter on breadboard.
March	Refine physical design and explore possibility of implementing 3 phase as an output of our system.
April	Finalize physical design

5. Budget

The buck converter cost about \$200, the boost converter costs about \$30, and the C2000 inverter cost \$800. We will be using the DC power source in lab to simulate the solar panels, rather than using them so that we do not have to buy solar panels. Software such as MATLAB/Simulink and Pspice is also needed, however these tools are provided and common amongst the industry.

6. Conclusion

Due to the environmental impact of finite fossil fuels on our atmosphere, it is imperative that we take the necessary steps towards sustainable energy sources such as solar power. Our system improves power efficiency in microgrids with its precise variable input tracking. This helps prevent power loss through tracking. Better power efficiency makes implementing solar microgrids much more desirable than fossil fuel generator alternatives.

7. 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].
3. D. Hart, "Power Electronics." New York: McGraw-Hill, 2011, p. 199.
4. D. Hart, "Power Electronics." New York: McGraw-Hill, 2011, p. 212.
5. D. Hart, "Power Electronics." New York: McGraw-Hill, 2011, p. 337.
6. D. Hart, "Power Electronics." New York: McGraw-Hill, 2011, p. 316.