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Flexible Solar Inverter

Team Flex

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Executive Summary

A third party member, Mr. Carlton Blue, who wanted to tackle the issue of adding flexibility into solar inverters, brought this project to the department. We conceived a device, which would be affordable and expandable depending on the power need of the consumers.

The first option we pursued was trying to build an inverter circuit where components can be added to achieve flexibility. We soon found out that with time and resources constraints, this option would not be feasible. The alternate method was to implement micro inverters. Micro inverters have several advantages over conventional inverters. The main advantage is that small amounts of shading, debris or snow lines on any one solar module, or even a complete module failure, do not disproportionately reduce the output of the entire array. Each micro inverter harvests optimum power by performing maximum power point tracking for its connected module. Simplicity in system design, simplified stock management, and added safety are other factors introduced with the micro inverter solution.

Experimentation and testing with two micro inverters has shown that micro inverters can be easily implemented to give consumers the freedom to upgrade their PV system power output without the need to replace expensive central inverter.

In the future, we plane to modularize our design by building a box where the customer up grade their inverters by simply plugin a micro inverter in an expansion slot.

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Chapter 1: Introduction and Background

An inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. Static inverters do not use moving parts in the conversion process.

A typical power inverter device or circuit requires a relatively stable DC power source capable of supplying enough current for the intended power demands of the system. The input voltage depends on the design and purpose of the inverter.

An inverter can produce a square wave, modified sine wave, pulsed sine wave, pulse width modulated wave (PWM) or sine wave depending on circuit design. The two dominant commercialized waveform types of inverters as of 2007 are modified sine wave and sine wave.

The AC output frequency of a power inverter device is usually the same as standard power line frequency, 50 or 60 Hz. The AC output voltage of a power inverter is often regulated to be the same as the grid line voltage, typically 120 or 240 VAC, even when there are changes in the load that the inverter is driving. This allows the inverter to power numerous devices designed for standard line power. Some inverters also allow selectable or continuously variable output voltages. A power inverter will often have an overall power rating expressed in watts or kilowatts. This describes the power that will be available to the device the inverter is driving and, indirectly, the power that will be needed from the DC source.

In one simple inverter circuit, DC power is connected to a transformer through the center tap of the primary winding. A switch is rapidly switched back and forth to allow current to flow back to the DC source following two alternate paths through one end of the primary winding and then the other. The alternation of the direction of current in the primary winding of the transformer produces alternating current (AC) in the secondary circuit.

A solar inverter is a component of a photovoltaic system (PV) and can be used for both, grid-connected and off-grid systems. Solar micro-inverters differ from conventional converters, as an individual micro-converter is attached to each solar panel. This can improve the overall efficiency of the system. The output from several micro inverters is then combined and often fed to the electrical grid.

What is a flexible inverter? Flexibility is adding a component to an existing system and increasing out put. So a flexible inverter is a type of inverter where one can add a component or a whole inverter to increase power outputted. Flexibility is so beneficial cause to avoids the need to replace existing inverters saving capital.

Chapter 2: Project Motivation/ Problem Statement

When we consider the true cost of energy, we need to look at the big picture, not just the rate on the utility bill. Conventional fuels have real social, environmental, and economic impacts. There are annual and cumulative costs that stem from all of the pollutants (airborne, solid, and liquid) emitted from mining, processing, and transporting fossil fuels that impact our public health and the environment. Electricity derived from coal and natural gas will never be able to outweigh the energy and continual resources required to produce it. Unlike conventional energy sources, PV systems produce clean electricity for decades after achieving their energy payback in three or fewer years—this is truly the magic of PV technology.

During our problem formulation we asked two key questions. What are the problems for existing solar power owners with string inverters? What is preventing more people in investing PV systems? Limited power expansion flexibility and high initial cost were the resounding answer respectively.

Problem Statement:

Because of expensive equipment and lack of resources, customers need an easy, reliable, and cost-efficient way of adding solar panels to their system

Chapter 3: Current Status of Art

There are two types of inverters used in solar installations today: micro inverter and string inverters. Micro inverters convert electricity from one panel, whereas string inverters convert electricity from multiple panels or a string of panels.
Micro inverters are small inverters rated to handle the output of a single panel. Modern grid-tie panels are normally rated between 225 and 275W, but rarely produce this in practice, so micro inverters are typically rated between 190 and 220 W. Because it is operated at this lower power point, many design issues inherent to larger designs simply go away.

Chapter 4: Design Requirements

The two main design requirements we base our project of were: easy power expansion, avoiding the need to throw away existing inverts, and to do this cost effectively. To achieve power expansion in a cost effective way we implemented micro inverters. In order to prove the concept of flexible power expansion, we used two enphase M250 micro inverters connected in parallel. Table 1 below shows the Data sheet for enphase M250 micro inverters.

Enphase® **M250** Microinverter // DATA

INPUT DATA (DC)	M250-60-2LL-S22, M250-60-2LL-S25	
Recommended input power (STC)	210 - 310 W	
Maximum input DC voltage	48 V	
Peak power tracking voltage	27 V - 39 V	
Operating range	16 V - 48 V	
Min/Max start voltage	22 V / 48 V	
Max DC short circuit current	15 A	
OUTPUT DATA (AC)	**@208 VAC**	**@240 VAC**
Peak output power	250 W	250 W
Rated (continuous) output power	240 W	240 W
Nominal output current	1.15 A (A rms at nominal duration)	1.0 A (A rms at nominal duration)
Nominal voltage/range	208 V / 183-229 V	240 V / 211-264 V
Nominal frequency/range	60.0 / 57-61 Hz	60.0 / 57-61 Hz
Extended frequency range*	57-62.5 Hz	57-62.5 Hz
Power factor	>0.95	>0.95
Maximum units per 20 A branch circuit	24 (three phase)	16 (single phase)
Maximum output fault current	850 mA rms for 6 cycles	850 mA rms for 6 cycles
EFFICIENCY		
CEC weighted efficiency	96.5%	
Peak inverter efficiency	96.5%	
Static MPPT efficiency (weighted, reference EN50530)	99.4 %	
Night time power consumption	65 mW max	
MECHANICAL DATA		
Ambient temperature range	-40°C to +65°C	
Dimensions (WxHxD)	171 mm x 173 mm x 30 mm (without mounting bracket)	
Weight	1.6 kg (3.4 lbs)	
Cooling	Natural convection - No fans	
Enclosure environmental rating	Outdoor - NEMA 6	
Connector type	M250-60-2LL-S22: MC4 M250-60-2LL-S25: Amphenol H4	
FEATURES		
Compatibility	Compatible with 60-cell PV modules	
Communication	Power line	
Integrated ground	The DC circuit meets the requirements for ungrounded PV arrays in NEC 690.35. Equipment ground is provided in the Engage Cable. No additional GEC or ground is required. Ground fault protection (GFP) is integrated into the microinverter.	
Monitoring	Enlighten Manager and MyEnlighten monitoring options	
Compliance	UL1741/IEEE1547, FCC Part 15 Class B, CAN/CSA-C22.2 NO. 0-M91, 0.4-04, and 107.1-01	

Table 1 Data Sheet of the Enphase M250 micro inverter

Chapter 5: Solution Approaches and Top Design

At the beginning of the project the goal was to design and build an inverter circuit capable of accepting components to excessed its power rating. Due to time constraints and the fact that there is only two senior engineering students per group this ideas was deemed not plausible. We started our initial solution generation by focusing on existing technologies and platforms we can build of off. After doing extensive research most of the team members came up with the conceptual design of using micro inverters. The micro inverter approach thus was easily picked as a top design. Even after we picked micro inverters as a top design we still focused a few weeks in finding and generating alternative designs. Finally we refined our top design by providing a description of a micro inverter system, which satisfies the main design requirements of affordability and power expandability. We integrated ideas and concepts from all the conceptual designs we came up with. One such concept integration was the idea of using a modular box where customers can just purchase micro inverters and plug and play functionality with our modular box.

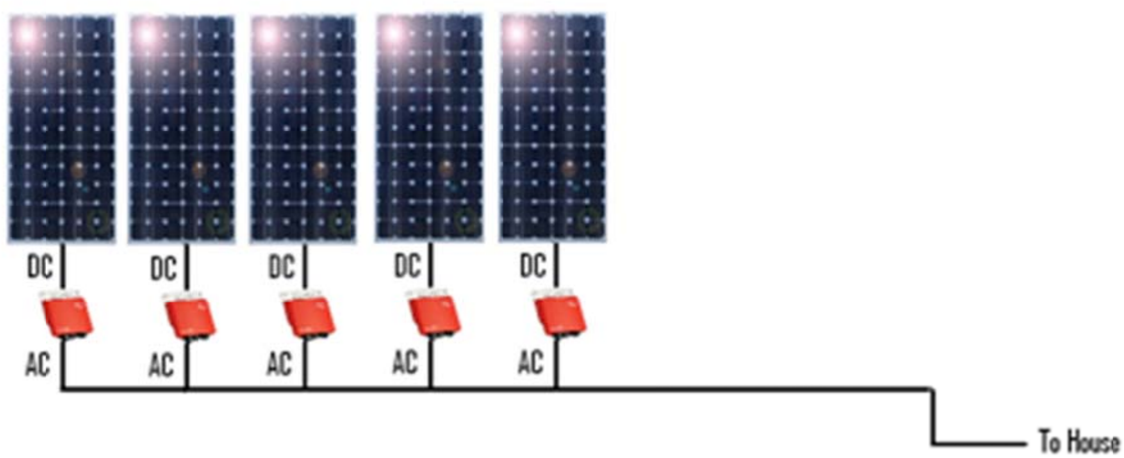

Figure 1 micro inverter conceptual design

Figure 2 Conceptual idea incorporated to top design (Modular box where micro inverters will be housed with a plug and play functionality)

Chapter 6: Project's Final Goal

The final goal for this project will be to integrate our modular box idea. After doing the calculations of how many micro inverters can the rated wires takes, all the wires will be pre wired in the modular box. The 4-pin connector can be used as the connection medium between our modular box and micro inverter. The box should be build based on micro inverter dimensions that will house micro inverters spaciously. Sealing it and painting it a water resistant paint should weatherize the box.

Chapter 7: Project's Spring 2016 Target Goal

The goal for our project for this semester was to research, conceptualize a design, and begin implementation and testing. The design that we came up with utilized a micro-inverter concept where we connected micro-inverters in parallel and converted each solar panel's dc current to ac current. This connection would allow the currents to be added together, thus, increasing the power.

Chapter 8: Implementation, Testing, and Evaluation

In the lab, we didn't have actual solar panels. Instead, we used the solar panel test bench to connect to our micro-inverters.

Figure 3 M250 Micro Inverter

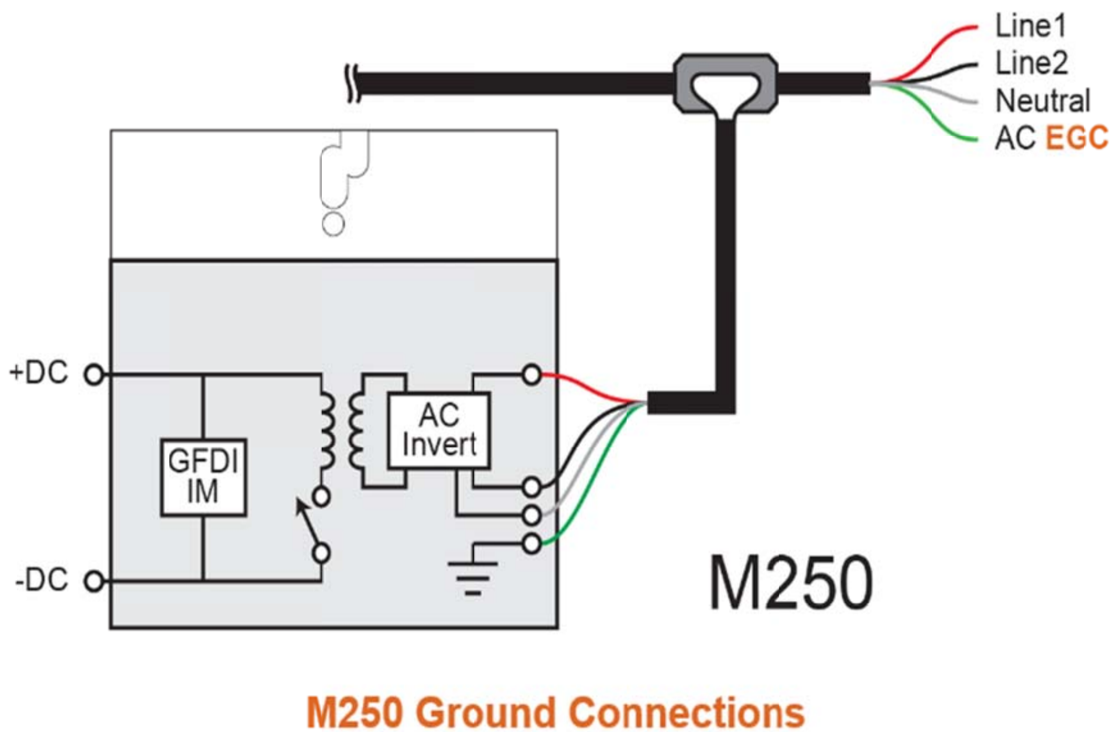

Figure 4 Enphase M250 Micro Inverter internal schematics

As we started implementation we came across some unexpected problems. The main problem was that the two AC signals have different phase angles and was not synced. As a result, we built a syncing circuit so that the two AC signals will be in phase. As our syncing circuit failed to synch, we resolved into just connecting the inverter in parallel and just test if the signals were not synched.

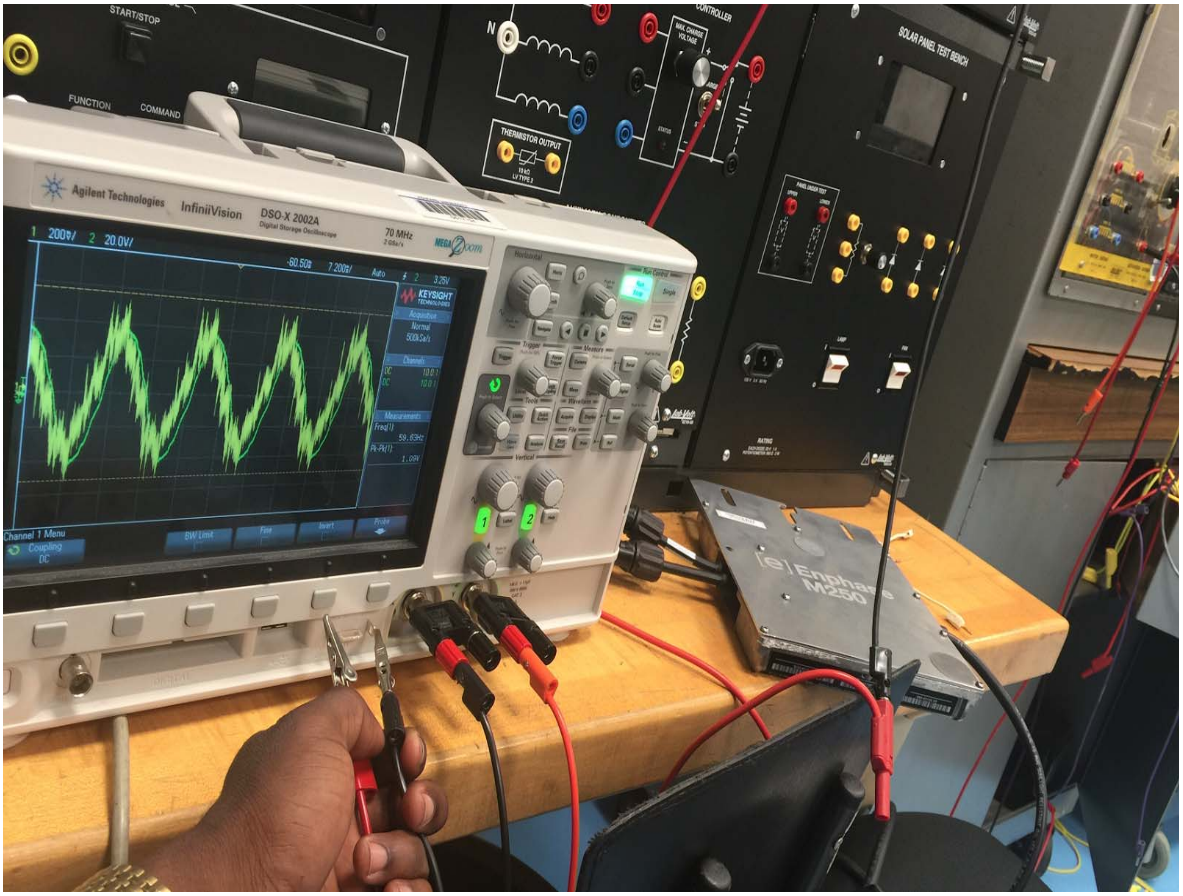

Figure 5 Testing for the output AC signal from two micro inverter connected in parallel

We used the oscilloscope to test the signals. The result was two in phase signals. We suspect that noise was produced as a result of manually splice wires in the inverters.

Conclusion

Our goal with this project was to create modular plug and play micro inverter for use in a solar PV system. The main costs of our design would be the micro inverters, and trunk cable. Despite these costs, they would not amount to as much time and money that would be required to swap and upgrade an existing string inverter. During the course of our project, we had insufficient funds to fully build and test our design. We, also, received out parts on the day before the project was due. Lastly, we had to build more part than we initially planned to because of unexpected issues. We were still able to build and test our design using two micro-inverters. However even with these setbacks there is a great potential in our product being successful. Given a greater amount of time to fine-tune and perfect our design, it would not be difficult to produce a product that would be easy to use and relatively inexpensive.

Recommendation for Future Works

In the future, we would like to test our efficiency and improve it by adding a power optimizer. Also, we want to be able to add more solar panels and successfully sync all of the AC signals perfectly. Lastly, we would like to build a module box for easier access and easy use.

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