ri-Maximum Power Point Converter

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1 Introduction

1.1 Objective

Solar panels are a rising option for power generation due to their decreasing manufacturing cost over the last few years. A problem with solar panels is that they do not autonomously maximize the energy they transmit without a power converter or inverter that has some maximum power point tracking control system to adjust the panels output. The Electrical and Computer Engineering building utilizes solar panels on its roof as well. Power converters have already been made to accomplish such a purpose, but some solar panels in close arrangements such as the ones on top of ECEB encounter a new problem, and that is the issue of partial shading. Partial shading not only blocks the amount of sun a solar panel receives, but also limits the power a panel can output by bottlenecking power transmission from well-lit portions of the panel.

Conventional solar power converters track the maximum power point of the overall solar panel, but with our system we intend to create a converter that splits the panel into three different sections and finding the maximum operating point for each individual section. The benefit this provides is the ability to increase the efficiency and output of each panel. Our power converter also ties into a larger green energy project that this building is a part of where the power generated by the solar panel would be tracked and recorded to display them in an effort to inspire more students to join the power department. Ideally this project would be able to be scaled so every solar panel on the roof had the device attached and reporting data of the individual panels.

1.2 High-Level Requirements

- Converter must be able to take power from the panels and act as a constant current source to attach to a DC rail that will govern our output voltage at up to 425W.
- Converter must be able to find the absolute maximum power point of each of the sections of the panel and track it continuously and convert power with an efficiency of at least 75% between the input and output.
- Converter must be able to send power data wirelessly at least once a minute to be read remotely via a network-enabled PC.

2 Design

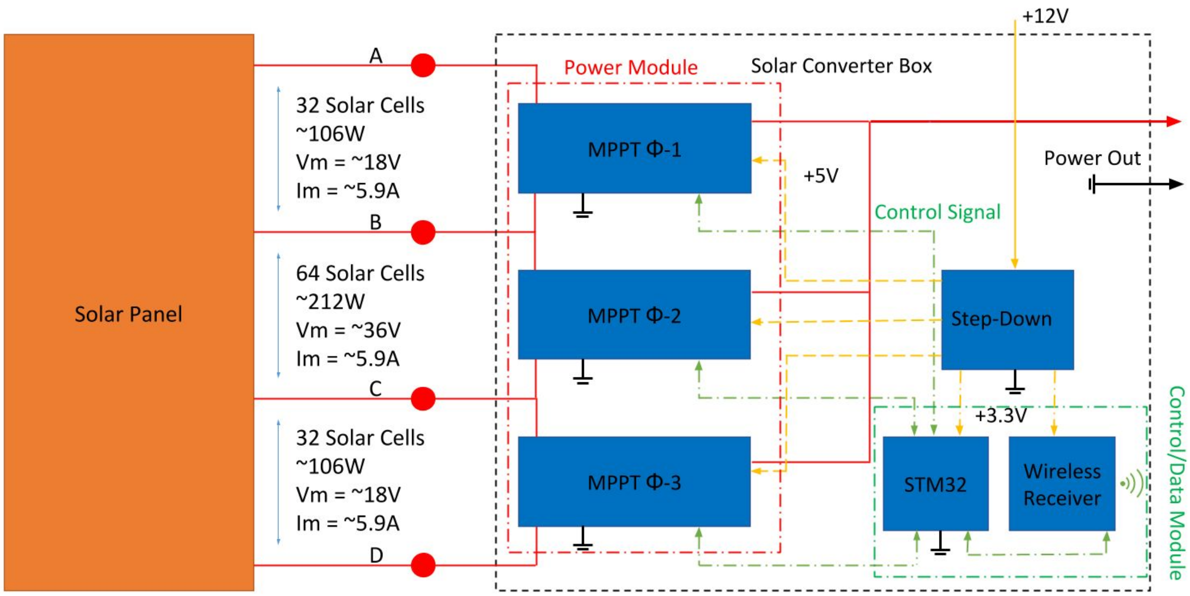

Fig 1. *Block Diagram Describing High-Level Operation of System*

2.1 Solar Panel

The panel we are working with has its specifications listed below, all measurements were taken at a STC of 1000W/m^2, an AM of 1.5, and 25 degrees Celsius.

- Peak Power of 425W (±5%) at 72.9V and 5.83A
- Open circuit voltage of 85.6V
- Short circuit current of 6.18A
- Maximum series fuse of 15A

2.2 Control Unit

2.2.1 Microprocessor

The primary feedback loop for MPPT needs to be done on a microprocessor with an analog-to-digital converter. A STM32F1 was chosen for its ease of use, built in ADC, high operating frequency, and low power consumption.
Requirement 1: Be able to run a control loop across 3 different channels by reading from the ADC at at least 100Hz
Requirement 2: Be able to source/sink >5mA of current on 4 digital output pins simultaneously.
Requirement 3: Be able to simultaneously send 3 PWM outputs with >=8 bit resolution.

Requirement 4: Be able to communicate to the wireless module at 1Kb/sec or greater.

2.2.2 Wireless module

The device will communicate wirelessly via the 802.11 wifi standard to send power data to a server. The esp8266-based wireless module will complete this task and can serially communicate with the STM32F1.
Requirement: The wireless device must be able to communicate at a rate of at least 1Kb/Sec to an access point at least 30 feet away while outdoors

2.2.3 Status LED

The status LED will show if the device was able to successfully connect to the wireless network.
Requirement: Status LED should be visible from outside of the device's enclosure.

2.3 Power Converter

2.3.1 Individual phases

The power converter will be a set of four phases that will be referenced as A, B, C, and D where the A phase refers to the phase of the top 32 cells, B is the top half of the middle 64 cells, C the bottom half of the middle section, and D the bottom 32 cells of the panel. Each section will be controlled separately by our microprocessor except phases B and C will share the same controls. The topology will be based on a forward converter design to incorporate a large amount of isolation between the solar panel and our output. This also helps to avoid ground loops that would introduce significant noise into our voltage and current sensors. Using differential voltage measurements also helps to keep our logic and power ground separate from each other. The logic will be powered by a separate 12V supply that will be stepped down for the devices that need a lower 5V voltage, that voltage will also go through a linear regulator to feed 3.3V to our STM32. Each phase would then handle a max of about 106W of power if each part of the panel is outputting its maximum power.
Requirement: The power output ripple should be smaller than ±5%.

2.3.2 Constant current conversion

The output of the converter needs to act as a constant current source so that in the future a single microgrid controller can control the parallel outputs of the entire solar panel system. To change the output of a forward converter which acts like a constant voltage source, we will use a LM317 for each phase with a PNP transistor to boost the power output.
Requirement: The power output of the device should appear as a current source when connected to an external load less than or equal to the power output of the device.

2.4 Network

2.4.1 Server

The server would consist of a PC connected to the wireless network containing multiple MPPT devices, running software for the devices to report to, but this is outside of the scope of this class.

2.4.2 Wireless Access Point

A compatible wireless access point with a matching protocol is necessary for the devices to communicate with the server.
Requirement: communicate at a rate of at least 1Kb/Sec to the MPPT device at least 30 feet away while outdoors

2.5 Enclosure

The device will be placed outdoors while in use, so it will require a protective enclosure to prevent adverse weather from directly impacting its functionality.
Requirement 1: The enclosure should not reduce the functionality or efficiency of the device.
Requirement 2: The enclosure should allow for external access to ports for power and software updates.

3 Ethics & Safety

3.1 Ethics

This project is in full compliance with the IEEE code of ethics, provided that the design accounts for all necessary safety precautions. All members of the team working on this project will perform work diligently, with attention to personal and public safety, and will report honestly to their peers and mentors on the results of the project. Furthermore, any information acquired from external sources for use in the development of this project will be used with permission of whosoever owns that intellectual property in which case credit will also be given. The software used and developed for this project will similarly be developed adhering to the ACM code of ethics by using the same metrics as above.

Due to the location of the panels, the personnel developing this project must take into account the safety of any person who would be in close proximity to a panel utilizing the system and in general the safety of the people in a building with a panel utilizing the system.

Misuse of this system is unlikely and in the case of misuse, it could be generally asserted that the user is at fault rather than the engineers as is in the case of anyone using public power lines maliciously.

3.2 Safety

The primary concern in this project is that of electrical fires. The system will be enclosed with no leads exposed so the probability of electrical shock to a passerby or person transporting the system is low. Following this concern, we will implement several safety features that constitute a failsafe system.

Electrical fires can be caused in several ways:

- Accumulated dust ignites due to extended contact with hot components
- A power line fails and ignites a flammable material in close proximity to the system and/or panel

The proposed solutions to these issues are addressed as follows in order:

- A ventilation system for the purpose of cooling components will be fitted to the system housing. In addition, this ventilation system will filter any air entering or exiting the enclosure such that a minimal quantity of dust accumulated within the enclosure. In the event of a ventilation system failure, one or multiple thermistors will trigger a shutdown of the system.
- The STM32 microcontroller and software control loop will maintain bounds on the operation of the system such that the power flowing through a module at any given point in time will be within the specifications of all components used. In addition, a fuse will be placed in series with the power distribution lines in order to prevent surges and sustained over-currents