



An Optimized converter for serially connected PV panels

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Abstract

Renewable energy, particularly solar, is becoming a focus of interest nowadays with more and more studies in the subject, which seek new ways for energy harvesting and try to improve existing ones.

The traditional method for harvesting solar energy consists of photovoltaic (PV) cell modules connected serially in order to achieve a sufficient DC voltage that can be then inverted efficiently. One major drawback of this method reminds the known phrase "a chain is only as strong as it's weakest link", meaning that a shaded, dirty or malfunctioning cell module will reduce the efficiency of all the cells in the chain.

Existing solutions for overcoming the shading problem include tracking every PV module's maximum power point (MPP) and feeding it's energy to the chain in the optimal way. The problem with these methods is that they suffer from energy conversion losses even from unshaded modules since the entire module's energy is converted.

In our project we solve the shading problem using a novel method based on voltage comparison using a switched capacitor converter (SCC). It's purpose is to keep the weaker modules in their MPP by raising the voltage on them towards the voltage on near modules.

The main advantage in our method over existing solutions is that only the necessary energy for stabilizing the chain passes though the system causing significantly less conversion losses.

Overview

SCC based stabilizer

In our work we've been exposed to an idea based on a switched capacitor converter (SCC), that wasn't yet researched or tried in the solar power area. We recognized it as a stable ground for further research, and decided to go on and extend the research. The conclusion was clear: the idea is simple and easy to implement with low costs and a minimal amount of design complications. It's capabilities can be greater than current solutions.

Our goal is to create a situation where cells with different capabilities will be able to be simultaneously in their maximum power point (MPP), which means being linked together in a chain and yet having different currents flowing through them. In terms of current we create a bypass for differential current to flow in between the PV modules, by charging a capacitor at the stronger

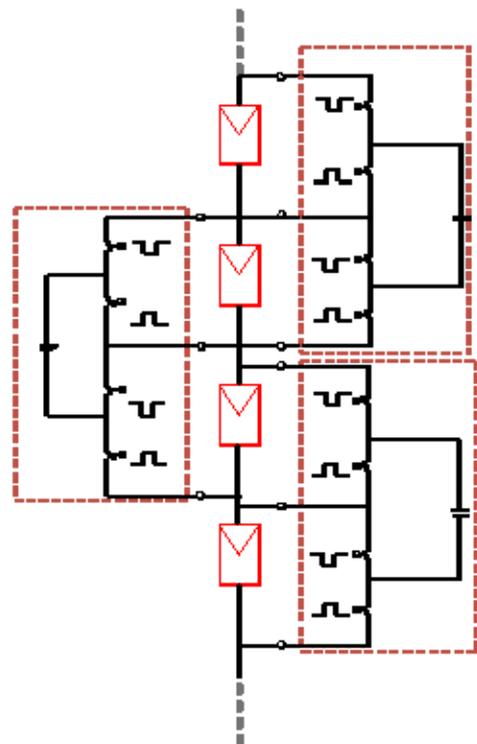


Figure 1: A schematic view of the connection of an SCC based stabilizing system. The PV modules can be seen in the middle, and each dashed square represents a stabilizing module

module, and discharging on the weaker. In terms of voltage the 1:1 SCC compares the voltages of two neighboring cells.

The SCC can be implemented by a “flying capacitor” which is a capacitor that has both terminals switched. The conversion ratio will be 1:1 and the energy flow is bi-directional depending on the voltage drops in the chain. The overall system contains independent stabilizing modules connected, as can be seen in Figure 1, in between every two PV modules enabling the flow of differential currents within the chain and keeps the PV modules in MPP.

The Stabilizer Module

Block Diagram

Figure 2 shows the different parts needed for the module with the connections between them as follows:

1. Balancing capacitors: needed to keep the voltage in the modules steady in between switching cycles of the SCC.
2. Switching system + capacitor: effectively the “FlyCap” SCC.
3. DC buffer – a unique system that floats the mosfet gates in the switching system to the right operation levels. This system enables us to use standard non-floating drivers.
4. Drivers – standard drivers designed for the mosfets.
5. Microcontroller unit (MCU) – sends the relevant PWM signals to the mosfets, depending on system information from the system sensors.
6. System sensors – Monitors PV voltages and currents, and delivers it to the MCU
7. Power Supply Unit (PSU) – feeds the active parts of the system with needed power.

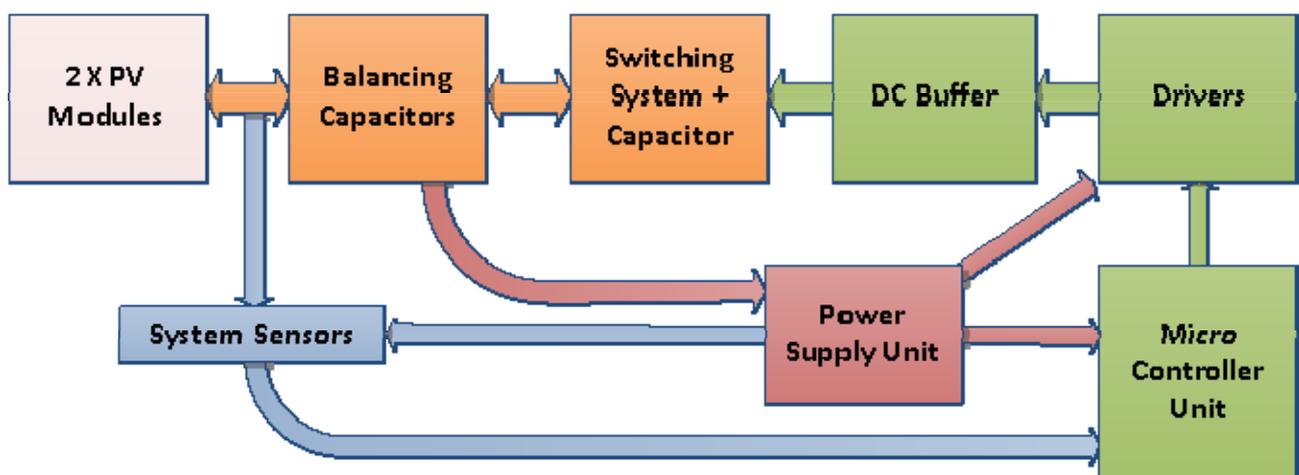


Figure 2: A general block diagram of the stabilizer module. different colors represent different function categories.

Results

Characteristics of a clean PV module connected serially with a partially shaded PV module With Vs. without the stabilizer system

This is a measurement intended to measure the energy generation capabilities of two PV modules in a scenario of different irradiances on each, connected in series. The panels were connected to a rheostat as a load as shown in Figure 5 to scan through the P-V characteristic. The measurement includes a control measurement without the stabilizer module and a measurement with it in order to see the improvements. The partial shading on one module was done by putting a semi-clear glass blocking about 50% of the

total power output. Figure 6 for both the total power output.

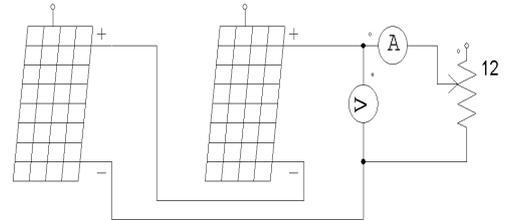


Figure 3: The setup for the characteristics measurements of two modules with different irradiances connected serially.

covering most of the module, irradiance. P-V characteristics in experiments show a large increase in

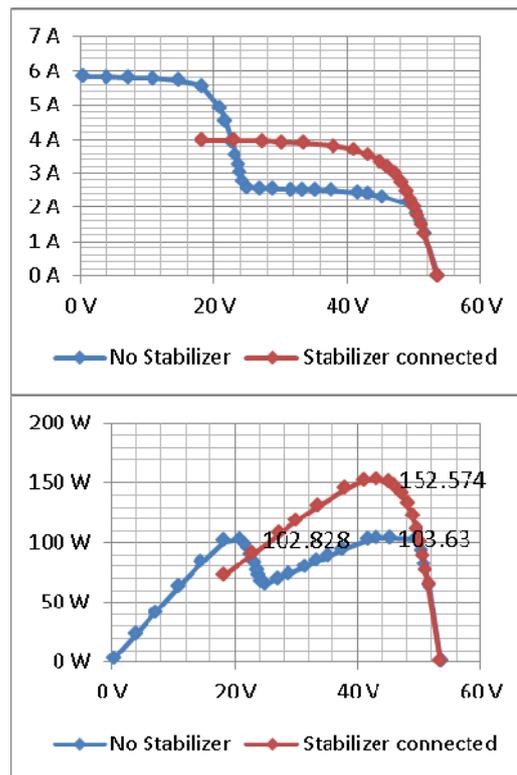


Figure 4: Measured P-V and I-V Characteristics for the experiment. The connected stabilizer increases the output of the tested system by about 50%.

Measuring the energy loss for a system consisting of a clean PV module connected serially with a partially shaded PV module, With Vs. without a stabilizer module.

This experiment measures the energy loss for different irradiances of the shaded PV module, set up as the previous experiment. Here we added Watt meters to the outputs of the PV modules and output of the system. The lost power is then measured by:

$$P_{loss} = P_{1(MPP1)} + P_{2(MPP2)} - P_{O(MPP)}$$

The addition of the stabilizer gained us up to about 60 watts, and the minimal system efficiency was 92%, instead of 60% without the stabilizer.

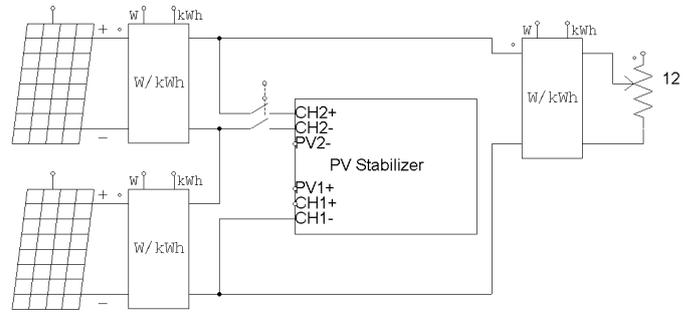


Figure 5: The setup for the efficiency measurements of two modules with different irradiances connected serially.

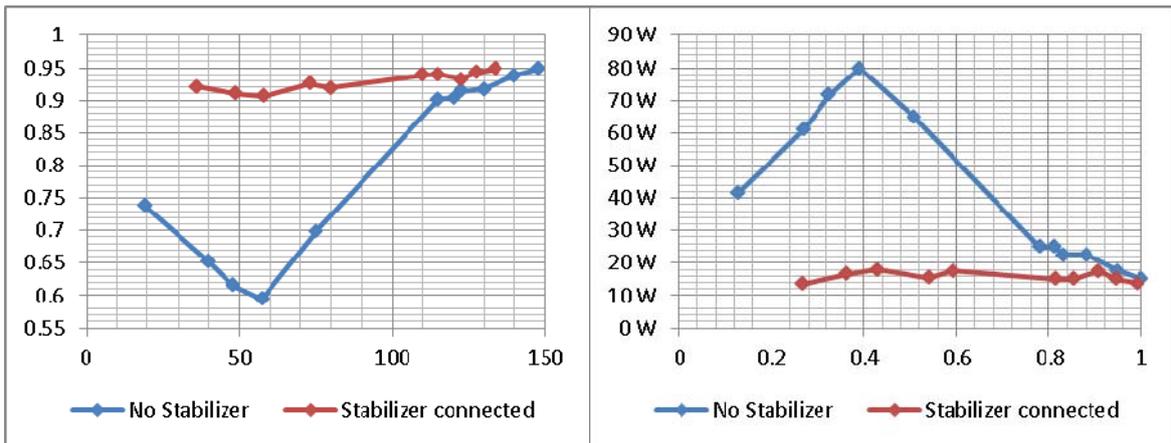


Figure 6: Left: Characteristics of total efficiency by irradiation levels. Right: Characteristics of unused power in the system by irradiation levels

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