Power Equalizer Application for Partially Shaded PV Cells Using Microcontroller

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Abstract- *This project deals with a photovoltaic (PV)-module embedded power-electronics topology derived from a power equalizer. The photovoltaic equalizer is a promising response to the problems of partial shading in photovoltaic modules and equipped with a network of transistors. This system can connect itself to the un-shaded cells of the photovoltaic module, gather their excess current, and share it with the shaded cells. The topology can equalize the overall energy of the PV module with buck-boost converter. The parameters and operating points of particular solar cells change depending on the solar cell temperature and the level of solar irradiance. The proposed model can provide realistic behavior of partially shaded photovoltaic module required in simulation tools used in the development of a micro inverter. The model was confirmed by measurements performed on the tested photovoltaic module. The results are compared to similar topologies dedicated to mitigate partial shading in PV applications.*

Keywords- MPPT, Partial shading, Solar cell, AT89S52

I. INTRODUCTION

Photovoltaic (PV) modules are connected in series to form a PV string. Strings connected in parallel form a PV array. The difference in the maximum power point (MPP) current I_{MPP} of identical PV modules of the same string oriented in the same way arises due to a variety of reasons of which partial shading is the most prominent. The world pays growing attention to the renewable, clean, and practically inexhaustible energy sources. In photovoltaic (PV) arrays, cells are conventionally connected in series to obtain the desired voltage. In higher voltage applications, bypass diodes may be placed beyond groups of cells to avoid mismatched or shaded cells. When multiple power peaks are encountered, conventional MPP tracking algorithms (that are employed to track the single power peak that is encountered during uniform illumination) are ineffective.

1.1 PV CELL

A PV module is voltage-controlled current source connected in parallel with a diode. The output current depends on the available sunlight and the temperature of the module. The unit used to measure the available power, which can be drawn from the sun, is called irradiance and expressed in W/m^2. To maximize the power output of the PV plant, either its current or its voltage is controlled to stay as long and as close as possible to the maximum power point (MPP). The algorithm that guarantees this optimum output is called maximum power point tracker (MPPT). It is associated with the PE dc/dc converter connected to the plant. A converter and its associated MPPT are using a hill-climbing control strategy to control the voltage of the PV module, keeping it constant at V_{MPP}.

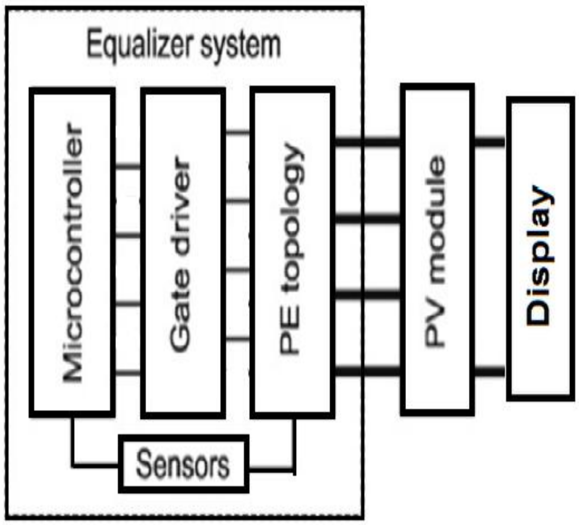
1.2 MPPT

As was already explained, MPPT algorithms are crucial in PV applications because the MPP of a solar panel alter with the irradiation and temperature, so the use of MPPT algorithms is enforced in order to obtain the maximal power from a solar array.

Over the past decades, many methods to find the MPP have been developed and published. These techniques vary in many conditions such as required sensors, complexity, cost, range of capability, concurrence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. A complete review of 19 different MPPT algorithms can be found.

Amidst these techniques, the P&O and the InCond algorithms are the most accepted. These techniques have the advantage of an easy implementation but they also have drawbacks, as will be shown later. Alternative approach based on distinct principles are fuzzy logic control, neural network, fractional open circuit voltage or short circuit current, current sweep, etc. Most of these methods yield a local maximum and some, like the fractional open circuit voltage or short circuit current, give an approximated MPP, not the exact one. In normal conditions the V-P curve has only one maximum, so it is not a problem.

II. SYSTEM ARCHITECTURE



The state-of-the-art PV-module-embedded PE technologies dedicated to the PIP are mainly divided in two applications: series and parallel.

Series applications use highly efficient PE topologies connected to each cell group of the PV module and dedicated to locally track their MPP. They convert the dc current of the PV modules either directly to ac or to another dc level, which is then sent to a central inverter. They are often called distributed MPPT (DMPPT) or micro converters in the current literature.

Parallel applications use inductors to share the energy among cell groups. They eliminate local MPP created by the shadow, replacing them with one global MPP. They are called generation control circuit (GCC), returned energy architecture (REA), or active bypassing.

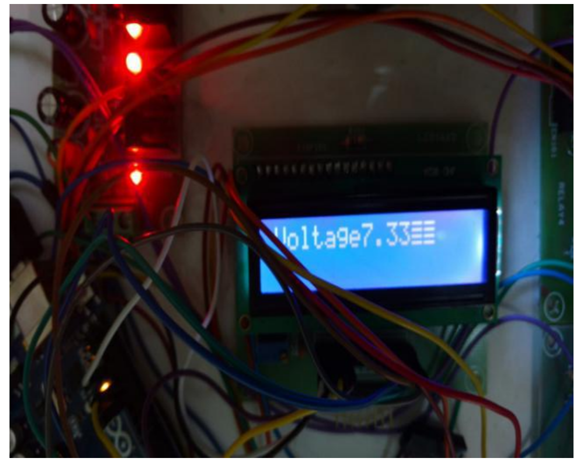
The equalizer system, is being composed of four parts:

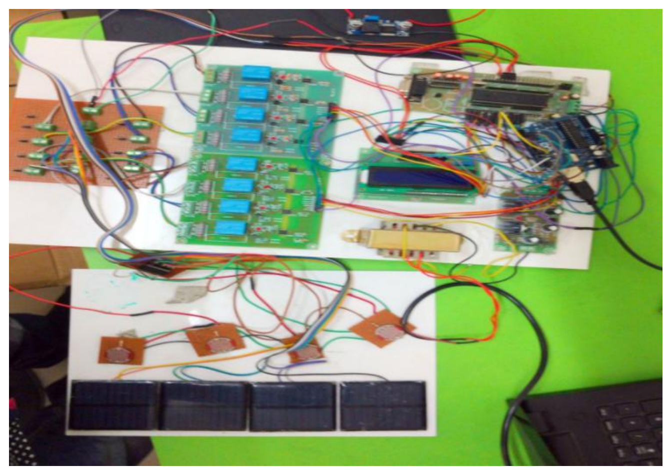
1) The microcontroller that stores the control algorithm of the system;
2) The gate driver, which translates the commands from the microcontroller into higher currents that can activate the transistors;
3) The PE topology presented hereinafter;
4) The sensors, which capture the information needed by the control algorithm.

The control algorithm of the equalizer will be based on how the transistors will be activated and the information retrieved through the sensors. Thus, the physical operation of the system will be explored first. From it, the modes of operation of the elements that compose the control strategy of the system will be presented.

All information derived from these two studies will be used to compare the performance of the equalizer to other equivalent applications in the light of the cited challenges.

III. RESULTS





IV. CONCLUSIONS

This study presents an experimental comparison of the maximum power point tracking efficiencies of several MPPT control algorithms that are discussed in the literature. The scope of the study was limited to those algorithms thought to be applicable to low-cost implementations with currently available hardware. The results suggest that, on the basis of maximum power point tracking efficiency, the perturb-and-observe method, already by far the most commonly used algorithm in commercial converters, has the potential to be very competitive with other methods if it is properly optimized for the given hardware. Incremental conductance performed as well as P&O, but in general its higher implementation cost would not be justified by any improvement in performance.

The parasitic capacitance approach could not be achieved in our experimental set-up, and some doubt exists as to whether it could be implemented in most commercial PV power converters because of the use of large input capacitors. Finally, as expected, the MPPT efficiency increases gained by using the perturb-and-observe and incremental conductance algorithms make them favourable over the simpler constant voltage method.

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