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Power Equalizer Application for Partially Shaded Photovoltaic Module

Parneet Kaur Chowdhary, Ashita R. Shandilya, Sanket R. Wankhade, Pravin S Khade
Department of Electrical Engineering
Guru Gobind Singh Polytechnic, Nashik, Maharashtra, India
parneet.chowdhary@ggsf.edu.in, ashita.shandilya@ggsf.edu.in
sanket.wankhade@ggsf.edu.in, pravin.khade@ggsf.edu.in

Abstract: *A PV module is partially shaded when the light cast upon some of its cells is obstructed by some object, creating a shadow. To protect the shaded cells from being destroyed and to minimize losses in power production, PV modules are equipped with bypass diodes. They prevent the shaded cells from working under reverse voltage by short-circuiting them, thus allowing the other cells to work at their normal current. This work represents to implement topology for working under reverse voltage, thus allowing the other cells to work at their normal current and mode analysis.*

Keywords: PV modules

I. Introduction

The world pays growing attention to the renewable, clean, and practically inexhaustible energy sources. Photovoltaic (PV) installations are a familiar reference in this landscape, ranging from small (less than 5 kW) residential plants to larger (thousands of kilowatts) grid-connected PV yields. They can also compose hybrid power systems, along with other renewable energy sources. PV systems are roughly composed of two parts: the PV modules and their power electronics (PE) applications. While dispersed between these two parts, all PV research themes seek to improve productivity, power, efficiency, safety and reliability. One of the biggest reliability issues of PV systems is the difference between its expected and actual power outputs. This problem can be called PV mismatch, even though there is no consensus in the literature. It can have many sources, and the one addressed in this paper is the partial shading of PV modules. This system proposes a topology based on a battery equalizer as a PV- module embedded application for partial shading. An in-depth theoretical analysis of this topology is made in order to show its adaptability to the PV and its potential against partial shading. It is then designed, tested and validated in area l PV module under partial shading. Finally, it is compared with other PV-module-embedded applications. This system is organized as follows.

1.1 PV Module

A PV module can be considered a voltage-controlled current source connected in parallel with a diode. The output current depends on the available sunlight and the temperature of the module. Its output characteristics maybe described by a graph called current-voltage(I-V)curve. The unit used to measure the available power which can be drawn from the sun is called irradiance. 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 powerpoint (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 B.

1.2 PV Mismatch

An Overview PV mismatch is the difference between the expected and actual power outputs of a PV module or plant. It can be classified according to its sources as internal or external. Internal mismatch is caused by imperfections within PV modules or cells, such as aging, poor solder bonds, impurities in the silicon crystal or variability in production. External mismatch has its sources outside of the PV modules, such as interconnections and converter losses or shadows.

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Many researchers are dedicated to improve the efficiency of inverters or proposing different topologies associated with more efficient MPP tracking algorithms. This focuses its study on external mismatch caused by partial shading and the PV-module- embedded PE topologies dedicated to its mitigation.

1.3 Problem of the Partial Shading in PV Modules

A PV module is partially shaded when the light cast upon some of its cells is obstructed by some object, creating a shadow. In this paper, a shadow is considered to have a shape and opacity. The opacity of the shadow is called shading factor (SF), varying from zero to one. An SF of zero means that all the available irradiance shines on the PV module. On the contrary, an SF of one means that all available irradiance is unaltered by the shadow before reaching the PV module. The shape of the shadow is determined by its length and width. The number of shaded cells or cell groups connected in parallel determines the width of the shadow. Its length represents the number of shaded cells or cell groups connected in series. The cells composing the PV modules studied in this work are all considered to be connected in series. Thus, their shadows have no width. The shaded PV cells will produce less current than the others, which will lead to one of the two scenarios.

1. The other cells impose their current over the shaded cells, making them work under negative voltage, dissipating power and risking destruction.
2. The MPPT will track the current of the shaded cells, imposing it over the others and making them produce less energy. To protect the shaded cells from being destroyed and to minimize losses in power production, PV modules are equipped with bypass diodes. They prevent the shaded cells from working under reverse voltage by short-circuiting them, thus allowing the other cells to work at their normal current. However, bypass diodes deform the V-I curves while activated, Some authors have proposed many tracking algorithms in an effort to compensate this phenomenon. Other authors have proposed PE topologies directly embedded to the PV module.

II. System Description

2.1 Basic Block Diagram

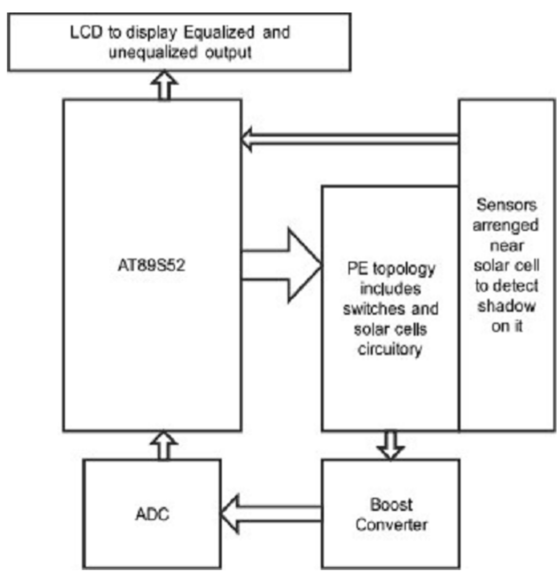

Fig. 1. Block Diagram for Power Equalizer Application For Partially Shaded Photovoltaic Module

The Block Diagram gives an overview of the proposed system and its associated PV module. It is called equalizer system, 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 and relays will operate, 3. The PE topology presented here in after, 4. The sensors, which capture the information needed by

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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. From it, the modes of operation of the elements that compose the control strategy of the system will be presented.

2.2 Working Principle of PE Topology

The topology proposed in this is shown in Fig. Even though it is similar to the battery equalizer in their functionalities, sizing, and limits are different. The step-up dc/dc converter and its MPPT control technique are modeled in this part by a cur- rent source. The topology and its implementation challenges are analyzed. The proposed equalizer has eight transistors (K2- K9),ten diodes(D1-D10), four capacitors(CICIV), and an inductor (L). The PV module is represented by four cell groups (PVI-PVIV). The transistors are voltage bidirectional but current unidirectional due to the diodes, which impose one single current o/p. Its single inductor can be charged by the available voltage of any unshaded cell group(s). The stored energy is then used to support the shaded cell group(s) by connecting the inductor in parallel to them, thus creating a alternative path to the excess MPPT current. In normal operating conditions, the switching pattern imposes rapid variations in voltage and current to the cells. To alter these, each cell group has a capacitor connected to it.

III. Methodology

3.1 Shadows in PV Systems

A shadow is a random phenomenon that changes the light that shines over a PV module. It can be considered as 2- D, having a length and a depth. Its length is equivalent to the number of cell groups covered by the shadow, while its depth, also called shading factor (SF), describes how much power carried by light, or irradiance, has been altered. An SF of zero means that there is no shadow, while an SF of one means that the totality of the irradiance is altered. Both of these dimensions are random phenomena. They depend on the environmental conditions, the shape of the objects surrounding the PV module, and the seasons of the year. The impact of a shadow with an SF of 0.5 and a length of 1 (one shaded cell group) is illustrated by its V-I curves. In Figure, at the operation point 35 V and 1.6 A, all cell groups are producing but their current is limited by those shaded. At the operation point 20 V and 3.8 A, only the unshaded cells are producing. The shaded ones are in reverse bias, protected from destruction by bypass diodes. Eitherway, part of the power is post due to the shaded conditions [8]. To avoid this situation, several authors have proposed dedicated power electronics systems, which are embedded in the PV module.

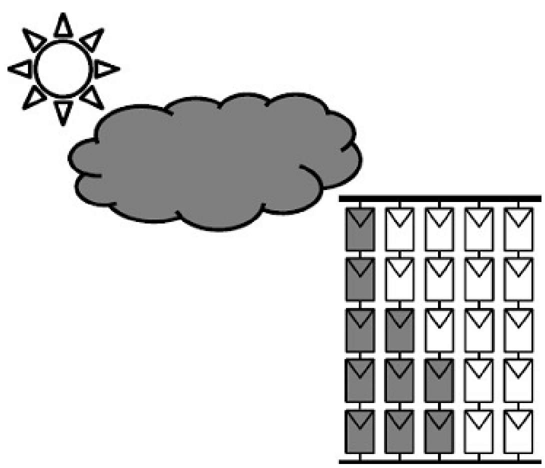

Fig. 2. PV system under partially shaded conditions caused by passing cloud

3.2 PV Embedded System

Every PV embedded system (PES) seeks to make the current and voltage of the PV cells different while keeping them connected together. By doing so, they weaken the impact of the shadow over the entire module, PV equalizer topology. strong local impact over the PV cells. This is called the power independence principle. There are two families of PES:

series and parallel. The series PES manipulate the operating point of each cell group separately. They are called distributed maximum power tracking systems in the current literature. The parallel PES balance the current production by connecting the cell groups to one or several inductors, thus erasing local power points. Return energy architecture generation control circuit, or PV equalizer are its three main examples in the current literature. The PV equalizer has been shown as among the most efficient parallel PESs, depending on the shadow

3.3 Proposed PE Topology

The topology proposed in this is shown in Fig. Even though it is similar to the battery equalizer in, their functionalities, sizing, and limits are different. The step-up dc/dc converter and its MPPT control technique are modeled in this part by a cur- rent source. The topology and its implementation challenges are analyzed. The proposed equalizer has eight transistors (K2- K9),ten diodes(D1-D10),four capacitors(CICIV), and an inductor (L). The PV module is represented by four cell groups (PVI-PVIV). The transistors are voltage bidirectional but cur- rent unidirectional due to the diodes, which impose one single current o/p. Its single inductor can be charged by the available voltage of any unshaded cell group(s). The stored energy is then used to support the shaded cell group(s) by connecting the inductor in parallel to them, thus creating a alternative path to the excess MPPT current. In normal operating conditions, the switching pattern imposes rapid variations in voltage and current to the cells. To alter these, each cell group has a capacitor connected to it.

IV. Results And Discussion

Hardware Results: The result of projected power equalizer under partially shaded condition of PV module is compared with the simple series connected PV module under partially shaded condition and it is found that with the use of equalizer for partially shaded PV module gives much better power compared to conventionally connected PV module under partially shaded condition.

Sr.No.	Condition	With Topology	Without Topology
1	1 Cell Shaded	16 V	8 V
2	2 Cells Shaded	8 V	4 V
3	3 Cells Shaded	4 V	2 V

V. Conclusions And Future Works

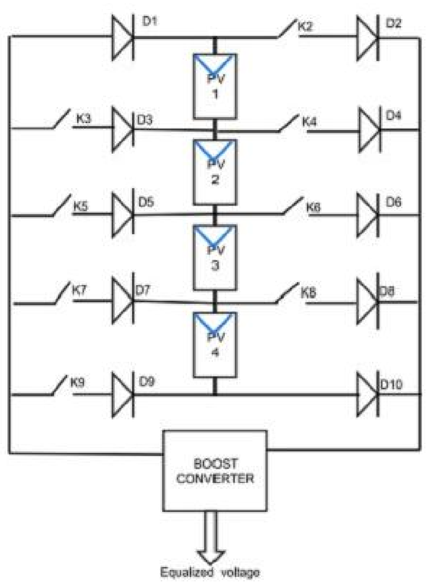

Fig. 3. Topology Proposed

5.1 Conclusions

A PV equalizer system is an very flexible power electronics structure embedded on a PV module. Its main objective is to mitigate the effects of partial shading by sharing the excess current of the unshaded cells with the shaded ones. An embedded PE structure premeditated for compensating the effect of partial shading in PV modules has been studied in this article. Its topology is based on a battery equalizer, giving it its name: PV power equalizer. The planned equalizer redistributes the produced energy between the unshaded and the shaded PV cell through the use of one single inductor (Boost converter). The result of proposed power equalizer under partially shaded condition of PV module is compared with the simple series connected PV module under partially shaded condition and it is found that with the use of power equalizer for partially shaded PV module gives much greater power compared to simple series connected PV module under partially shaded condition.

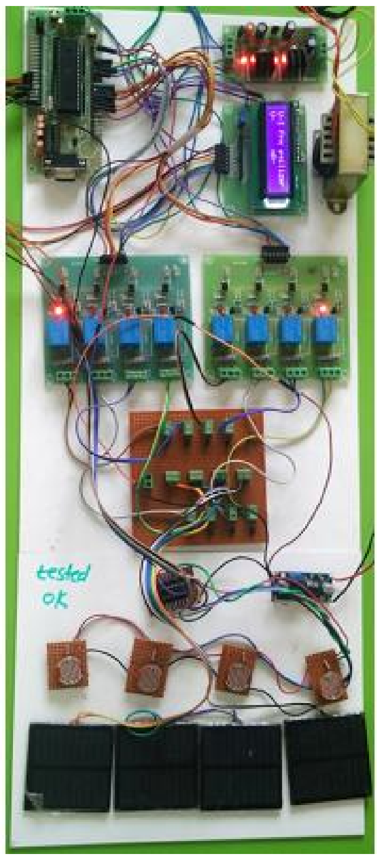

Fig. 4. Working Model

5.2 Future Works

1. Microgrid: The world has recently seen the impact of the combination of two technologies. Solar power is starting to show the potential for more mainstream use in the region, In a recent announcement solar cell stacked in panel have been reported to double the efficiency of the output. We believe that this system will likely produce electricity that is cheaper than the supply from traditional coal-red generators. Solar power energy obviously cannot replace fossil fuels completely until the problem of banking some of what is collected during the day, for use at night is solved but at this sort of cost it can make a useful contribution.
2. Monitoring parameters using different technologies which will give proper loss free generation.
3. IOT based grid supply monitoring for efficient working.
4. Manufacturing and integration will be possible as per our requirement.

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