



Reconfiguration solution for shaded PV panels using switching control



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ABSTRACT

This paper applies a new dynamical electrical array reconfiguration strategy on photovoltaic (PV) panels arrangement based on the connection of all PV panels on two parallel groups to reach the 24 V requested by the considered load and providing a maximum output current by connecting in series the two groups. If one of the PV panels or more are shaded, dusty or faulty the connection of the others in the same group will be automatically modified to maintain the requested load output voltage. This dynamical reconfiguration allows also limiting the lost power, due to the incriminate panel, by switching off this panels and reconfiguration the topology. As a result, a real time adaptation of a switch matrix allows a self-ability to maintain a constant load voltage. Moreover, a minimum number of PV panels are switched off by isolating the effect of unhealthy panels. In addition, the proposed solution can also be applied for identifying and locating the shaded, dusty and faulty panel. Experimental setup has been built and the results validate the proposed method.

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1. Introduction

The pollution caused by fossil fuel gives the priority to the use of renewable energies in different regions all over the world. Solar energy is the most important energy, it is the most well distributed, is renewable and has no hazard for atmosphere. However, PV panel has a problem when it is shaded by clouds, dust or other obstacles [1,2]. Shading PV panels cause voltage drop at its terminals and consequently reduce extracted power. In addition, the shaded or dirty PV panels affect the unshaded or the clean ones. This is also true when Maximum Power Point Tracking (MPPT) is used for groups of PV panels [3,4]. It is proven that shading and dust cause the same effect on the considered PV panel.

PV panels have different operating points, those points depend mainly on the solar radiation density. Hence, strategies for selecting the best operating point, which have a maximum power at each moment, are requested. Accordingly, MPPT is largely proposed as a solution for the shaded PV panels [5,6]. However, when shading is partial, there will be a new problem. In this case, the maximum power points are different for the different PV panel groups (connected to one MPPT controller). Therefore multi-MPPT can be proposed. Nevertheless, in this case, all PV panels have an MPPT

controller which is far from being economically optimal. In general, two principal techniques have been introduced as a solution for this problem:

1.1. Passive techniques

Two solutions are used in this method for reducing partial shading losses; the first one is by-pass diodes [7], which have been introduced to protect shading panels from hot spot effects and increasing the overall PV partial shading panel's efficiency. However, the main disadvantage of these diodes is preventing PV panels from producing maximum possible power in case of partial shading [8]. The other solution is changing PV array interconnection. This last one has been achieved using one of the following configuration types: Series–Parallel (SP) (Fig. 1(a)), Total-Cross-Tied (TCT) (Fig. 1(b)) and Bridge-Linked (BL) (Fig. 1(c)). It has been shown that BL and TCT configurations result in a large MPP configuration. However, the higher number of interconnections slightly increases the loss of the PV system due to the additional cable loss. In this approach, the large adaptive bank significantly increases installation cost and requires a complicated control algorithm [8,9].

1.2. Active techniques

Three categories have been noticed in this technique:

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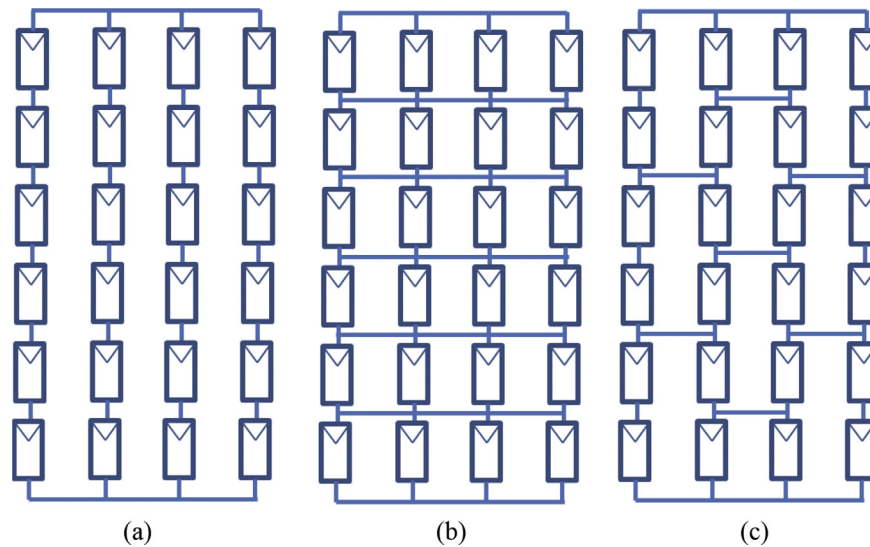


Fig. 1. Different interconnection schemes in passive techniques [8].

1.2.1. Multi-tracker inverter

The shading effect in one module or a group of modules will considerably affect the overall power production. This problem can be solved with a multi-tracker inverter [7]. The presence of a multi-tracker inverter is therefore justified when several parts of a PV array do not have the same electrical properties. For example, when a part of the field is likely to be subjected to shading, it is connected to an MPPT of a dedicated inverter. Similarly, when two parts of a field do not have the same orientation and inclination (for example double bridge east–west), each part can be connected to a singular MPPT. Of course, the multi-tracker is a technical solution that increases the overall cost of the installation.

1.2.2. A tracker per module

It is now clear that when there are power disparities (especially because of the shade or dust), the ideal solution would be to have an MPPT for each module [10–12]. Thus, the available power of each module would be obtained. Some manufacturers offer this option in their pack. This solution is ten times more expensive than the multi-tracker solution [7].

1.2.3. Photovoltaic array reconfiguration

This technique depends on using poles and switches for obtaining an optimal PV reconfiguration. This technique has been adopted by many authors as follows:

- The simplified form of PV array reconfiguration was started by Salameh et al. (see Refs. [13,14]). In these studies, the PV array reconfiguration has been applied to supply the required power to a DC motor coupled with a water pump.
- This approach was also employed to supply electrical cars with necessary power [15]. The real application of PV cells reconfiguration has been started by Sherif and Boutros [16]. They realized the PV reconfiguration using transistors and switches between cells.
- The PV array reconfiguration, which has been achieved by Nguyen et al. [17], has been divided into fixed and adaptive parts with switching matrix between them (Fig. 2). However, they didn't present any mathematical formula for the optimal reconfiguration.
- In Refs. [18–20], a new PV reconfiguration has been reached taking into account the mathematical formula required for

optimal solution. But with 280 possibilities of configuration for just nine PV modules, it will be difficult to determine the optimal configuration. Therefore, this solution is suitable for a small number of PV modules.

- In Ref. [8], Shams El-Dein et al. have founded an optimal PV array reconfiguration in addition to mathematical formulation, but this solution is so complicated and needs a lot of poles and

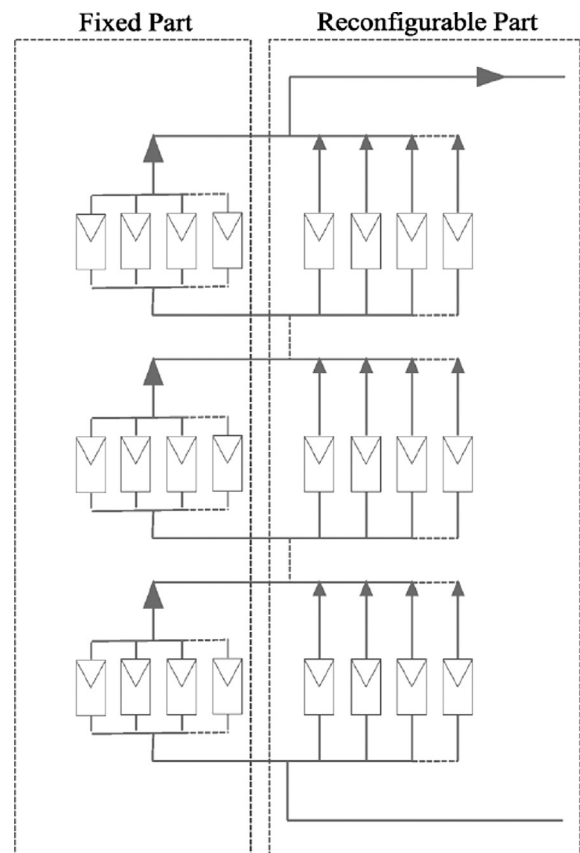


Fig. 2. Fixed and adaptive parts of PV reconfiguration proposed by Nguyen et al.

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