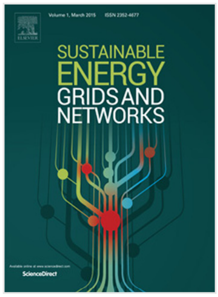

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Topology Reconfiguration for Optimization of Photovoltaic Array Output ☆

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Abstract

As more utility scale photovoltaic (PV) power plants are installed, there is a need to improve monitoring and management of PV arrays. A procedure is presented here for optimizing the electrical configuration of a PV array under a variety of operating conditions. Computer simulations and analysis with synthetic and real data are presented in this paper. The performance of the optimization system is evaluated for a variety of partial shading conditions using a SPICE circuit simulator. In general, a $4-5\%$ gain in power output is achievable by employing active switching in order to reconfigure the array's electrical configuration.

Keywords: Photovoltaic Systems, Fault Tolerant Systems, Condition Monitoring

1. Introduction

In spite of its many advantages, photovoltaic (PV) technology faces various barriers which prevent efficient utilization of this important technology. The major barrier is cost. In the United States in 2010, the average levelized cost of energy (LCOE) for PV electricity was \$211/MWh, while the LCOE of coal was only \$95/MWh [1]. PV has overcome the cost problem with conventional energy only for special cases such as very remote locations where fuel shipping costs are extremely high. The other barrier is its dependence on weather conditions, resulting in stability and reliability problems for the electrical grid. These issues suggest that any technology that would lower cost or improve reliability will increase the deployment and improve efficiency of utility scale PV power generation.

In this paper a method of optimizing the electrical configuration of a switchable PV array is presented. This system is developed as one part of a comprehensive PV monitoring system incorporating performance analysis, fault detection, and mismatch mitigation [2, 3, 4, 5, 6]. The optimization strategy results in higher power output under array mismatch conditions such as partial shading. It is shown that the optimal electrical configuration under partial shading varies depending on which modules are shaded, motivating the development of an optimization algorithm. Power increases of 4-6% are observed by switching from a base configuration to the optimal configuration.

The paper is organized as follows: in Section 1 the operation of PV arrays is described, including under partial shading conditions, and in Section 3 several approaches to the problem of maximizing output under shading conditions are described. The reconfiguration method is described in Section 4. Section 5 describes the simulations used to test the method and their results. Finally, the significance of the optimization method and its usefulness is discussed in Section 6.

2. Problem statement

This section provides an outline of the topology reconfiguration system and discusses the physics behind the operation of a PV array. The various topologies that are employed in practice and their electrical behavior is presented. The models that can be used to predict the electrical characteristics of a PV module are explained.

2.1. Electrical Behavior of a PV Module

A typical PV cell consists of a P-N junction in silicon or another semiconductor, although more exotic configurations exist [7]. Although a single cell is capable of generating significant current, it operates at an insufficient voltage for typical applications. To obtain a higher voltage, cells are connected in series and encapsulated into a PV module/panel. These modules show similar electrical behavior to individual cells, with the exception of small effects due to mismatch between cells.

Fig. 1 shows the commonly used single-diode model of a PV module. At the heart of the device is a current source I_L connected to a diode. I_L models the current generated

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