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Maximum Energy Output From Solar PV Array During Partially Shaded Condition

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ABSTRACT

Considering the high initial capital cost of a Solar Photovoltaic (SPV) source and its low energy conversion efficiency, it is essential to operate the SPV source at Maximum Power Point (MPP) so that maximum power can be extracted. Techniques to extract maximum power from SPV Arrays (SPVA) where some of the cells are not receiving the full insolation (partial shaded condition) has been presented in this work. Effects of reconfiguration of the array and tracking of load have been analyzed for maximum power availability. This work aims at maximizing the energy obtained from SPVA under partial shaded conditions through a more accurate SPV model, better configuration of arrays and optimized Maximum Power Point Tracking using artificial intelligence methods.

This research article represents an improved method of SPV module suitable for analysis under partial shaded conditions is developed. An insolation dependent shunt resistance Rsh has been added in the popular single diode model of the SPV module. It was experimentally found that the value of Rsh prominently depends upon insolation and its variation with temperature is very low. An empirical relation was established between Rsh and insolation by conducting a series of experiments recording the characteristic at different insolations. This model is a better representation of SPV module. A novel technique for fast display and recording of the characteristic of SPV module under forward and reverse bias conditions has also been presented

KEYWORDS Isolated hybrid power system, PV, Solar power generation

Introduction

Energy from Sun using solar photovoltaic system has negligible running cost but has high installation cost efficient utilization of the installed.

Photovoltaic cells under all conditions are therefore necessary to draw maximum electrical energy from a given installation. Issues related with efficient energy utilization of SPV system under partial shaded conditions have been presented in this article [1].

The reduction of output power in SPV modules can be attributed to many factors, but the most important are maximum power point (MPP) mismatch and shadows [4]. Shadowing effects due to tree leaves, dust or opposite house antennae in urban street canyons are common factors which lead to non negligible power losses of SPV generators. In a large SPV system occupying a wide area of land, moving clouds can also lead to shading. In building integrated SPV systems, SPV modules may be installed with different orientations to fit the building outer wall, which makes the modules receive different levels of irradiance, a situation similar to partial shading. The major power reduction due to shading effect can be addressed by judiciously reconfiguring the array and effectively tracking the MPP [2]. This work proposes the reconfiguration and maximum power point tracking issues of SPVA under partial shaded conditions.

LITERATURE REVIEW

Literature review in the following areas is presented:

(i) Modeling of SPV module under partial shaded conditions
(ii) Modeling of SPV array configurations
(iii) Reconfiguration and MPPT techniques for partial shaded SPV System
(iv) Intelligent controller for MPPT

Modeling of SPV Module under partial shaded conditions

Walker (2001) has developed a mathematical model for SPV using MATLAB M-file coding. This model is useful for finding the characteristics of SPV for different insolation and temperature [3]. However in this model the author didn't consider the shunt resistance and partial shading.

Swaleh and Green (1982) discussed the effect of shunt resistance in the partially shaded modules. Alonso-Garciaa and Ruizb (2006 a) have suggested a new model. This model comes from the study of avalanche mechanisms in SPV solar cells, and counts on physically meaningful parameters. It can be adapted to SPV cells in which reverse characteristic is dominated by avalanche mechanisms, and also to those dominated by shunt resistance or with breakdown voltages far from a safe measurement range [7]. A procedure to calculate model parameters based in piecewise fitting is also proposed.

Modeling of SPV Array Configurations

Quaschning and Hanitsch (1996) describe a well known numerical algorithms and their implementation. The numerical algorithm, which considers the mismatch in individual SPV cells and their shading levels, has been proposed by them to simulate the complex characteristics of a SPVA[9]. It requires each element (each cell of the module, bypass diode, blocking diode, etc.) to be represented by a mathematical expression.

Reconfiguration and MPPT Techniques for Partial Shaded

SPV System Velasco-Quesada et al (2009) applied a dynamical electrical array reconfiguration (EAR) strategy on the SPV generator of a grid-connected SPV system based on a plant-oriented configuration, in order to improve its energy production when the operating conditions of the solar panels are different.

Intelligent Controller for MPPT

De Medeiros Torres et al (1998) discuss the application of a neural network based controller for tracking the point of maximum power of a SPV system interconnected to the utility grid. The neural network is used to identify, in real time, the voltage for maximum output power of the system. The controller, through the information supplied by the neural network, generates a control signal that will be applied to a DC-DC (boost) converter I such a way to take the voltage of the system to a value which guarantees the operation of the SPV system at maximum power.

MODELING AND SIMULATION OF SOLAR PV ARRAY

A Solar Photovoltaic (SPV) system directly converts sunlight into electricity. The basic building device of a SPV system is a SPV cell. Many SPV cells are grouped together to form the modules. Modules are normally formed by a series connection of the SPV cells to get the required output voltage. Modules with large output currents are realized by increasing the surface area of each SPV cell or by connecting them in parallel [6]. A SPVA may be either a module or a group of modules connected in series and parallel configuration.

The output of the SPV system may directly feed the loads or may use a power electronic converter to process it. These converters may be used to serve different purposes like to regulate the variables at the load side, to control the power flow in a grid connected systems, and mainly to track the maximum power available from the source. Model of the SPV system is required to be known to study the converter and other connected system performances. For this purpose models are required to represent the SPV cells/ modules/arrays [10]. The major task of this chapter is to develop a simulation model of the SPV cell as well as the modules to reproduce the characteristics of the existing cells/modules in the lab. SOLKAR (Model No.3712/0507) cells and modules are available in the laboratory for practical testing. The manufacturer's datasheets for SOLKAR cell and module are given in Appendix A1.1 and Appendix A1.2. In order to maintain the conditions of the simulation as realistic as possible, the characteristics of these cells/ modules are represented by the equivalent model in MATLAB M-file coding.

Modeling of Practical SPV module

Practical modules/arrays are composed of several SPV cells and the observation of characteristics at the terminals of the cells/ module/array requires the additional parameters to the basic equation (Rauschenbach 1980). That is, to include the leakage current and the conductive losses of the cell, Rsh and Rse are added in the equivalent circuit. The final electrical equivalent circuit of the SPV cell consists of a current generator and a diode plus series and parallel resistances as shown in Figure 1. This is referred as standard five parameter model or single diode model of the SPV cell (Duffie and Beckman 2006).

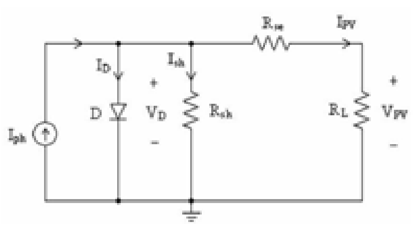

Figure 1 Electrical equivalent circuit of 5-parameter model of SPV cell

As with the connection of the cells to form the modules, a number of modules can be connected in a series string to increase the voltage level, in parallel to increase the current level or in a combination of the two. The exact configuration depends on the current and voltage requirements of the load. Matching of the interconnected modules in respect of their outputs can maximize the efficiency of the array. The conventional SPV module is constructed of several SPV cells (normally 36 cells) connected in series. In fig 1 generates the I-V characteristics of the practical SPV module with NS cells in series as shown in Figure 2. In Figure 2, three remarkable points are indicated: short circuit point (0, Isc), maximum power point (Vmp, Imp) and open circuit point (Voc, 0).

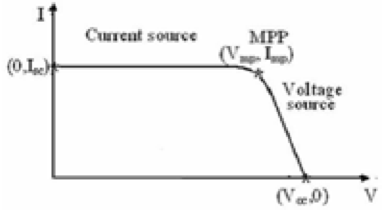

Figure 2. I-V Characteristics of practical SPV cell with remarkable points

PERFORMANCE ANALYSIS OF BASIC SPV ARRAY CONFIGURATIONS UNDER PARTIAL SHADED CONDITIONS

A number of series/parallel connected SPV modules are used to form a solar array for a desired voltage and current level. The major challenge in using a SPV source containing a number of cells in series is to deal with its non-linear internal resistance. The problem gets all the more complex when the array receives non-uniform irradiance (partially shading) [8]. In a solar array spread over vast area, it is likely that shadow may fall over some of its cells due to tree leaves falling over it, birds or bird litters on the array, shade of a neighboring construction etc. In a series connected string of cells, all the cells carry the same current. Even though a few cells under shade produce less photon current but these cells are also forced to carry the same current as the other fully illuminated cells. The shaded cells may get reverse biased, acting as loads, draining power from fully illuminated cells. If the system is not appropriately protected, hot-spot problem (Quaschning and Hanitsch 1996) can arise and in several cases, the system can be irreversibly damaged [3]. Nowadays there is an increasing trend to integrate the SPV arrays at the design level in the building itself. In such cases it is difficult to avoid partial shading of array due to neighboring buildings throughout the day in all the seasons. In conventional SPV systems, those shadows lower the overall generation power to a large degree. Hence the SPV installation cost is increased, because the number of SPV modules must be increased, and as a result, SPV power generation will be less attractive. This makes the study of partial shading of modules a key issue. Moreover it is very important to understand the characteristics of SPV under partial shaded conditions to use SPV installations effectively under all conditions.

PERFORMANCE ANALYSIS OF DERIVED SPV ARRAY CONFIGURATIONS UNDER PARTIAL SHADED CONDITIONS

The basic configurations have been discussed in the last chapter. It is understood that the common use of by-pass diodes in anti parallel with the series connected SPV modules can partially mitigate the power reduction due to partial shadow but at expenses of using more sophisticated MPPT algorithms able to disregard local power maximums that appear in the V-P curve of the SPV generator. Alternatively, the maximum available DC power can be improved if the connection of the SPV modules can be reconfigured such that panels with similar operating conditions are connected in the same series string. Moreover the parallel configuration is dominant under partial shaded conditions[5]. The well known drawback of the parallel connection of the cells, high output current, have to overcome in order to attain competitive configurations in terms of performance but also limiting the same current.

The main focus of this chapter is to analyze the various SPV array configurations and to mitigate the losses faced in SPV systems by incorporating a bypass diode. With a physical SPV module it is difficult to study the effects of partial shading since the field testing is costly, time consuming and depends heavily on the prevailing weather conditions. Moreover it is difficult to maintain the same shade under varying numbers of shaded and fully illuminated cells throughout the experiment. However it is convenient to carryout the simulation study with the help of a computer model. Hence a generalized MATLAB M-file has been developed for any required array size, configuration and shading patterns. On performing the analysis on various configurations, a new configuration has been proposed[9]. All the configurations have been analysed with bypass diodes. Comparative study of these configurations is made for different random shading patterns to determine the configuration less susceptible to power losses under non-uniform insolation. Apart from the comparative analysis a new configuration is proposed.

Conclusion

Reverse biased characteristics of a SPV cell are required to model the partial shading conditions of the SPVA. During reverse bias the shunt resistance Rsh is an important parameter affecting the behavior of the cell.

Most of the researchers have either taken Rsh as constant or have neglected it. In this thesis an empirical relation has been established through a series of experiments and the insolation dependent resistance has been added in the model to improve its accuracy. The proposed model is more accurate when applied to analyze SPV module characteristics under partial shaded conditions. The developed model can be interfaced with power electronics circuits to see the impact of shading and can be used to develop new methods to reduce the adverse effects of partial shading. The proposed electronic load method is a simple circuit for display and recording of the characteristics in field conditions.

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