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Optimization of a photovoltaic field during faulty and normal operation

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Abstract

With the increasing use of photovoltaic (PV) systems, the research studies to improve the efficiency of PV systems have gained greater interest in recent years, especially under non-uniform operating conditions and failed operation. The aim of this paper is the study, the optimization and the analysis of behavior of a photovoltaic system in normal and failed operation for one or more of any defects and any configuration of the PV system (module, string or field) trying to get close to the actual operation of photovoltaic systems.

Keywords: PV generator; Power optimization; Defects; P&O algorithms

1. Introduction

The electricity consumption of the world will increase considerably during this century (Razykov et al., 2011; Houssein et al., 2010; Pappas et al., 2012; Li and Huang, 2012). Solar energy is one of the most promising energy options with its many advantages such as free of pollution, safe, without noise, easy to install, and short construction period (Xu et al., 2011). Solar energy is a green and renewable energy source, which has been widely exploited in grid-connected systems, PV-pumps and stand-alone systems. With most system requirements, a large number of PV modules are required to be connected in series to form a PV string. This enables the overall PV array to obtain a high input voltage whilst simultaneously producing high output power (Hu et al., 2013). During operation, a PV array may subject to different kinds of faults and abnormal operating conditions such as mismatch, partial shading, electrical faults (Jahn and Mayer, 2000; Granata et al., 2009). These abnormal operations can affect the operating performance of the array downstream components such as MPPT, PV inverter, grid connection ... (Bun et al., 2011). In this paper we try to modeling the different defects and to optimize a PV field in failed operation the obtained simulation results, using the MATLAB®-SIMULINK® package are given and interpreted.

2. PV array simulation

The equivalent circuit model of the two diodes is given in Fig. 1. The model is closest to the actual behavior of the solar cell, because it takes into account the mechanism of transport of electric charges inside the cell (two diodes).

The mathematical model for the current–voltage characteristic is given by:

$$I = I_{ph} - I_{s1} \cdot \left(e^{\frac{q(V+I\cdot R_s)}{n_1\cdot K\cdot T}} - 1\right) - I_{s2} \cdot \left(e^{\frac{q(V+I\cdot R_s)}{n_2\cdot K\cdot T}} - 1\right) - \frac{V + I\cdot R_s}{R_p} \tag{1}$$

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Nomenclature

PV	photovoltaic
P&O	perturb and observe
MPPT	maximum power point tracking
I_{ph}	photocurrent produced
I_{s1}	saturation currents of first diodes
I_{s2}	saturation currents of second diodes
q	electric charge ($1.602 \cdot 10^{-19}$ C).
R_p	parallel resistance.
R_s	series resistance
K	Boltzmann constant ($1.38 \cdot 10^{-23}$ J/K).
$n_1 n_2$	factors purity of the diode.
T	absolute temperature in Kelvin
E_g	energy band of the semiconductor
P_{pv}	power of photovoltaic panel
N_s	number of series cells
N_p	number of parallel cells
V_{ce}	voltage of the PV generator
I_{ce}	current of the PV generator
S	sunshine
I_{op}	optimal current
V_{op}	optimal voltage
P_{op}	optimal power
N-C	normal conditions ($S = 1000$ W/m^2, $T = 298$ K, $R_s = 0.015\ \Omega$ and $R_p = 300\ \Omega$).
C-I	chopper and single MPPT control
S-C	choppers associates in series
P-C	choppers ranked

With:

$$I_{ph}(T) = I_{ph|(T=298)} \cdot \left(1 + (T - 298 \cdot K) \cdot (5 \cdot 10^{-4})\right) \tag{2}$$

$$I_{s1} = K_1 \cdot T^3 \cdot e^{\frac{-E_g}{K \cdot T}} \quad I_{s2} = K_2 \cdot T^3 \cdot e^{\frac{-E_g}{K \cdot T}} \tag{3}$$

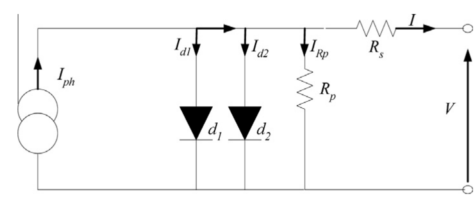

Fig. 1. PV cell equivalent circuit.

3. Constitution of a photovoltaic generator

By combining the PV cells in series or in parallel. We can constitute a PV generator for the specific targeted applications. The series–parallel cabling is used to obtain a generator with the desired characteristics, with N_s series cells and N_p parallel cells; the power available from the PV generator is given by:

$$P_{pv} = N_s \cdot V_{ce} \cdot N_p \cdot I_{ce} \tag{4}$$

With:

N_s and N_p are respectively, the number of series cells and the number of parallel cells.

V_{ce} and I_{ce} are respectively, the voltage and current of the PV generator.

The resulting characteristics by setting ($z = 1, 2, 4$ and 8) identical parallel PV cells or N_s ($z = 1, 3, 9, 18$ and 36) identical series PV cells are shown in Figs. 2 and 3 respectively.

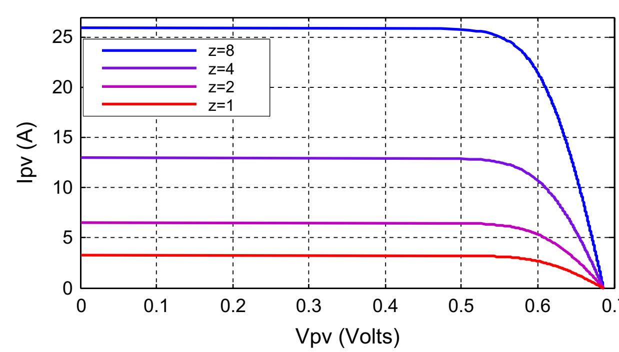

Fig. 2. Photovoltaic electrical characteristics for N_p identical cells in parallel.

4. Different configurations of a photovoltaic generator

The different basic configurations of photovoltaic generator are:

- The PV cell is the smallest element of a PV system. It is composed of semiconductor materials and directly converts light energy into electrical energy.
- The PV module is the smallest set of PV cells interconnected and completely protected against the outside environment. Generally it also contains mechanical protection to protect the PV cells operation that can be destructive. Connections can be performed in parallel or in series.
- The PV string is a set of modules connected in series to generate the desired output voltage.
- A solar PV array field is composed of N strings containing M modules per string to obtain powers of a few kilowatts, under proper tension.

5. Modeling of various defects

During operation, a PV installation may be subject to various defects and abnormal operating conditions.