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Real Time Fault Detection in Photovoltaic Systems

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Abstract:

In this paper, a method for real time monitoring and fault diagnosis in photovoltaic systems is proposed. This approach is based on a comparison between the performances of a faulty photovoltaic module, with its accurate model by quantifying the specific differential residue that will be associated with it. The electrical signature of each default will be fixed by considering the deformations induced on the I-V curves. Some faults, such as: interconnection resistance faults and different shading patterns are considered. The proposed technique can be generalized and extended to more types of faults. The fault diagnosis will be determined by fixing a normal and a fault threshold for each fault. These thresholds are calculated based on the Euclidean norm between ideal and normal measurement or between ideal and fault mode measurement. Each threshold is set in a range bounded by the minimum and maximum values of the differential residue obtained for the considered fault. The proposed approach provides identification of faults by calculating their specific threshold ranges. This method allows the instantaneous monitoring of the electrical power delivered by the photovoltaic system.

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Keywords: diagnosis; electrical signature; threshold of failure; model power; modeling

1. Introduction

Solar energy is the most abundant, inexhaustible and clean of all renewable energy resources. Interest in photovoltaic power generation has increased in recent years thanks to its advantages. This wide distribution of photovoltaic panel production was not followed by monitoring, fault detection and diagnosis functions to ensure better profitability. Numerous studies have been done on diagnosis of photovoltaic systems but just a few have been reported for describing and localizing faults in PV systems. They are not directly applicable to conventional PV systems and they require a relatively high cost in equipment.

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Fault detection methods for photovoltaic systems are numerous (electrical characterization, visual inspection, ultrasonic inspection, infrared imaging, imaging…) [1]. Some methods use appropriate equipment (thermal camera…). These visual inspection or the thermal detection methods, require visual checking with frequent visits on the PV module to monitor changes in its appearance as indicators of failures: browning, mechanical damage or occurrence of hot spots… Electrical diagnostic methods specifically uses the electronic signature of faults. They continuously monitor the PV module performance until the appearance of a fault. The deformation of the resulting output provides information on the occurrence, location and nature of default [2]. The first indication of module degradation is provided by decrease in its output power. Resulting symptoms are presented by the I-V curves of electrical characterizations of the PV module. After detection, microscopic analysis can be performed to understand causes of the degradation. These techniques allow analysis of the induced degradation and its progression.

Nomenclature

T	Cell temperature (°C)
G	Global irradiation on the array surface (W/m^2)
STC	Standard test condition of the PV cell; T_{STC} = 25°C and G_{STC} = 1000 W/m^2
PV	Photovoltaic
q	Electron charge (1.6*10^{-19} C)
K	Boltzmann constant (1.38*10^{-23} Nm/K)
I_{PV}	Light generated current of a PV module (A)
I	PV module current (A)
V	PV module voltage (V)
I_{MPP}	Maximum power point current (A)
V_{MPP}	Maximum power point voltage (V)
I_{SC}	Short-circuit current (A)
V_{OC}	Open-circuit voltage (V)
V_{T1}	Thermodynamic voltage of diode 1 (V)
V_{T2}	Thermodynamic voltage of diode 2 (V)
a, a_1, a_2	Ideality factors of the cell
I_0 /I_{01}, I_{02}	Saturation currents of cell for 1Diode model / 2Diode model (A)
$RX_{id,ft}$	Residual signals generated from the difference between X_{id} and X_{ft}
$RX_{id,nm}$	Residual signals generated from the difference between X_{id} and X_{nm}
X_{ft}	Set of the output variables (I_{mpp}, V_{mpp}, I_{sc}, V_{oc}, S_1, S_2, S_3) in faulty condition
X_{nm}	Set of the output variables (I_{mpp}, V_{mpp}, I_{sc}, V_{oc}, S_1, S_2, S_3) in normal condition
X_{id}	Set of the output variables (I_{mpp}, V_{mpp}, I_{sc}, V_{oc}, S_1, S_2, S_3) in ideal condition
N_F	Square root of the root of $RX_{id,ft}$
N_N	Square root of the root of $RX_{id,nm}$
S_1	Incremental derivative ratio between the point (0; I_{sc}) and the point (V_{mpp}; I_{mpp}) (Ω^{-1})
S_2	Incremental derivative ratio between the point (V_{mpp}; I_{mpp}) and the point (V_{oc}; 0) (Ω^{-1})
S_3	Value of the variation of the series resistance (Ω)
R_S	Series resistance of diode model (Ω)
R_P	Parallel resistance of diode model (Ω)
T_{NOCT}	Normal operating cell temperature (°C)
K_I	Temperature coefficient of short-circuit current (%/°C)
K_V	Temperature coefficient of Open-circuit voltage (mV/°C)
ΔT	Difference between actual temperature and T_{STC} (°C)
Ns	Number of cells connected in series

First, we propose to set different specific electrical signatures to several faults. Specifically in this article, we focus on partial shading fault and interconnection resistance fault.

As following method proposed in [3], we suggest to consider six variables from three major points of each I-V curve: A (I_{MPP}, V_{MPP}), B (I_{SC}, 0), C (0, V_{OC}) and three associated parameters, S_1 defines the slope between the short-circuit point and the maximum point and S_2 the slope between the maximum and the open circuit point and then S_3 expresses variation of R_S. We will therefore be able to assess the impact of the arrival of a fault on six variables across the